UNIVERSITY OF PATRAS

International Center for Sciences and Hellenic Values

AN INTERNATIONAL CONFERENCE

ANCIENT GREECE & CONTEMPORARY WORLD

THE INFLUENCE OF GREEK THOUGHT ON PHILOSOPHY, SCIENCE AND TECHNOLOGY

Ancient Olympia,
28-31 August 2016

Editor:
STEPHANOS A. PAIPETIS
Professor Emeritus, University of Patras

An International Conference

ANCIENT GREECE AND CONTEMPORARY WORLD

The Influence of Greek Thought
on Philosophy, Science and Technology

Ancient Olympia, 28-31 August 2016

UNIVERSITY
OF PATRAS

International Center for
Sciences and Hellenic Values

ANCIENT GREECE AND CONTEMPORARY WORLD

The Influence of Greek Thought on Philosophy, Science and Technology

Editor: STEPHANOS A. PAIPETIS
Professor Emeritus, University of Patras

Consultant on issues of Philosophy and Epistemology:
CHRISTOS KEHAGIAS,
Lecturer, University of Athens

ATHENS
MARCH 2017

An International Conference

The Influence of Greek Thought on Philosophy, Science and Technology

Editor: STEPHANOS A. PAIPETIS
Professor Emeritus, University of Patras

Consultant on issues of Philosophy and Epistemology:
CHRISTOS KEHAGIAS, Lecturer, University of Athens

Production:
Avatar | Web and Print Solutions
Vardousion 5 Galatsi 111 47, Athens. Tel .: 210 2914778,
mail: admin@avatar.gr
http://www.avatar.gr

ISBN 978-960-530-171-2

9 789605 301712

PAPERS

A. PHILOSOPHY - POLITICAL PHILOSOPHY - ART - MYTHOLOGY - THE RIDDLE OF TARTESSUS

TABLE OF CONTENTS

A5. THE RIDDLE OF TARTESSUS

B. SCIENCE AND TECHNOLOGY

B1. MEDICINE, BIOLOGY, GEOLOGY

B2. MATHEMATICS

B3. PHYSICS

B3.1 PHYSICS

B3.2 PHYSICS OF INFORMATION

B3.3 PHYSICS OF SACRED PLACES

B4. ASTRONOMY AND ASTRONOMICAL INSTRUMENTS

B5. TECHNOLOGY

PREFACE

The present volume includes the works presented at the International Conference "Ancient Greece and Contemporary World", Ancient Olympia, 28-31 August 2016. The Conference was the result of at least twenty years of effort of several colleagues at the University of Patras, coming from all areas of Letters, Science and Technology. This Conference is the fourth in a series of conferences[1] with similar scope, aiming at investigating all these that ancient Greece has still to offer to humanity. It is not an exaggeration to say that answers to many of the critical problems of the modern world may be hiding somewhere in the great achievements of civilization. A civilization that remains a timeless source of knowledge, inspiration and ideas, helpful even to face contemporary threats against life on our already heavily burdened planet.

The Conference was based on two fundamental concepts, i.e.: (a) As the individual is not able to conceive existing knowledge as a whole, they tend to artificially break down human knowledge into many isolated disciplines by adopting extreme specialization. Thus they are deprived from a holistic world view which results to substantial loss of new knowledge and, in the extreme case, they turn into technocrats (*τεχνοκράτης* = a highly knowledgeable and very productive person within a very narrow scientific or technological area who remains unaware of the potentially negative consequences of their own activities) and, (b) The ancient Greek world should not be approached by the various disciplines separately, albeit from the aspects of each one in coordination or interaction with the others, so that an integrated world-view could be produced.

The scope of the Conference included three general areas, i.e. Philosophy, Science and Technology. Distinguished scientists from the respective fields from a total of 10 countries were invited, and offered contributions of significant importance. The response to the call for papers was more than satisfactory. Out of a large number of papers submitted of papers were submitted. Eventually, a total of 58 characterized by original, high level content of knowledge were accepted for verbal presentation. These formed the final program which was organized as following: Philosophy (Political Philosophy, Art, Mythology), Science (Medicine, Biology, Geology, Mathematics, Physics, Astronomy and Astronomical Instruments and Ancient Technology. This is the sequence in which they are presented in this volume.

Due to the interdisciplinary character of the Conference, substantial effort was made toward the coordination of speakers in order to encourage communication and discussions between delegates of diverse fields. The undersigned wishes to express his satisfaction, since the said efforts were crowned by absolute success, and the discussions following each presentations were extremely interesting and fruitful.

Moreover, most important was the presence of H. E. The President of the Hellenic Republic Professor Prokopios Pavlopoulos, who, responding to a request by Professor Venetsana Kyriazopoulou, Rector of the University of Patras, accepted to place the

1. Two of them had the same title "Ancient Greece and Contemporary World", 1997 and 2002 respectively (Proceedings published by the University of Patras) and another two, titles, «Extraordinary Machines and Structures in Antiquity", 2001 and "Science and Technology in Homeric Epics" (Proceedings published in Greek by "Peri Technon", Patras and in English by Springer).

Conference under his auspices and deliver the main speech, during a magnificent Opening Ceremony, at which important personalities of the academic, political, cultural etc. communities were present. In particular, the presence of Mr. Frans Timmermans, Vice President of the European Commission, was an outstanding event.

Finally, most substantial and full of important messages related to the timeless Hellenic presence in history and to what should be the common aim of all Hellenes was the speech of Mrs. Aikaterini Panagopoulos, National Ambassador of Greece to the Council of Europe for Sports, Tolerance and Fair Play and main sponsor of the Conference. Furthermore, Mrs. Panagopoulos announced the establishment of a new research institution, title "International Centre for Sciences and Hellenic Values", whose aim shall be the realization of the goals set at the present Conference. The ambition of the Organizers is that via this research Institute, a broad national and also world cooperation will commence, which combining research and the exploitation of ancient Greek wisdom and ideals, will exhibit Timeless Greece and its contribution to humanity, providing new solutions and model cultural tools, so desperately needed in the present adverse times.

I want to express the deep appreciation of the Organizers to all those who contributed to the success of this important Conference, and firstly to Mrs. Aikaterini Panagopoulos, who, by accepting the basic principles of the Conference and by exhibiting her full trust towards the Chairman and the Organizing Committees, as well as her full support from every possible aspect, managed to turn an initially ambitious idea into tangible reality.

Sincere thanks are also due to the Rector of the University of Patras Professor Venetsana Kyriazopoulou for her multiple contribution. Professor Kyriazopoulou agreed that the University would be the main Organizer of the Conference, and submitted the request to the President of the Hellenic Republic to place the Conference under his auspices. By her physical presence at all of the relevant functions, and also by her prestige and authority she supported the Conference immensely. Equally warm thanks go to Professor Demosthenes Polyzos, Deputy Rector, for his valuable support, especially through the administrative and financial mechanisms of the Research Committee of the University of which he is in charge.

Every member of the Organizing Committees contributed its best, however, I wish to emphasize the important contribution of Professor Stavros Papamarinopoulos of the University of Patras, who, with great enthusiasm and zeal assisted substantially with the selection of invited speakers and the preparation of the technical program of the Conference.

Out of the members of the Local Organizing Committee, catalytic was the role of Mr. Georgios Panagiotopoulos, financial and administrative consultant and that of Mrs. Teta Giannarou, Public Relations and Communication Officer, with both of whom we shared what I call a "creative agony" during the preparation of the Conference. In particular, the former managed to solve lots of crucial problems with unparalleled ability and inventiveness, while the latter not only provided solutions to lots of issues beyond her main duties, but also managed to find time to contribute to one of the most interesting works presented. Finally, quite substantial was the contribution of Dr.

Christos Kehagias, distinguished philologist and Lecturer of the University of Athens as consultant of the present in issues of Philosophy, History and Language.

The list of acknowledgments could be endless, but space is limited, therefore, we close with a grateful reference to the International Olympic Academy, for their impeccable hospitality, and also to the local authorities, i.e. Mr. Georgios Georgiopoulos, Regional Deputy Governor for Eleia and also the Majors of Ancient Olympia and Elis, E. Kontzas and Ch. Christodoulopoulos respectively and to ensure them that we shall remain at their side with the great task of safekeeping the sacred places bestowed on them.

S. A. Paipetis, Professor Emeritus
Chairman of the Conference

CONFERENCE OPENING CEREMONY

MONDAY 29 AUGUST (10.30-12.30)

- Address by the Chairman of the Conference, Professor Emeritus S. A. Paipetis.
- Address by the First Vice-Chairman of the European Commission Mr. Frans Timmermans.
- Address by the Commissioner for Immigration, Internal Affairs and Citizenship Mr. Dimitris Avramopoulos.
- Address by the Rector of the University of Patras Professor Mrs. V. Kyriazopoulou.
- Address by Prof. A. Kounadis, Academy of Athens.
- Address by the National Ambassador at the Council of Europe Mrs. Aikaterini Panagopulos, announcement of the founding of the International Center for Science and Hellenic Values and commencement of signing the Founding Charter by Thymios Kotzas, Mayor of Ancient Olympia, Georgios Georgiopoulos, Deputy Secretary General of Eleia Regional Area and Christos Christodoulopoulos, Mayor of Elis, who will deliver symbolic addresses
- Speech by H.E. the President of the Hellenic Republic.
- Departure of H.E. the President of the Hellenic Republic.
- Welcome party and continuation of signing the Founding Charter.

A1. PHILOSOPHY

A1.1 From the "Atoms" of Democritus and the "Homogeneous" of Anaxagoras to the "Monads" of Leibniz

I. G. Dellis
Emeritus Professor
University of Patras

Abstract

The development of "natural philosophy" or "corpuscular philosophy" during the 16th century and especially in the 17th has its origin in the atomic theory of Democritus. Many thinkers, from P. Gassendi till Newton, Democritus theory was considered efficient and therefore they have used it.

Democritus (460-390 BC) applied two ontological principles: the "atoms" and the "empty space". Everything consists adopted atoms and empty space. There is an infinite number of atoms and of kinds of atoms differing in shape and size. Anaxagoras (5th century BC), a natural philosopher contemporary of Democritus, maintained that "everything consists of homogeneous particles" (DK, 59A1), while Wilhelm Leibnitz (1646-1716), based on Democritus' views, suggested that all prima minima are "the monads", from the accumulation of which everything consists.

In the present we will emphasize that all 17th century thinkers as well as Leibnitz replaced the Democritean term "atoms" with other terms such as corpuscular, particles without really meaning something different, just to avoid the blame of "atheism". This is justified because Democritus was considered an "atheist" because "God's Providence" and "God's Intervention" were not a prerequisite in his theory of creation and the motion of "atoms". For this reason we suggest the term "theistic individualization".

Introduction

The Democritean atomic theory is the most persuasive explanation of natural bodies and phenomena formulated during the period of pre-Socratic philosophers. All physicists believed that the minimal point of matter is the "atom" until the atomic fission and the emergence of the modern field of the "physics of particles". The omniscient philosopher from Abdera (Thrace) on the one hand is characterized as "Gelasinos", due

to his optimistic attitude toward the world and on the other hand as "Aristotle" before Aristotle, due to his involvement in many philosophical fields and numerous works just like the Stageirean philosopher whose birth 1400 years ago, we celebrate this year with conferences and various events.

Thrasilus has classified Democritus' writings into quadrilogies: a total of 13, i.e. 52 works. Unfortunately the tradition was not favorable to Democritus' writings for many reasons. One of them is a testimony that "Plato ordered them to get burnt".

From all of them, according to the classical compilation of H. DIELS – W. KRANZ, "Die Fragmente der Vorsokratiker" (The Fragments of the Pre-Socratics), 297 fragments of moral- political and conceptual content. According to research, the fragments (fragmenta) are conceded as the opinions of Democritus himself about his atomic theory. We recognize such testimonials in Aristotle's texts who perhaps knew Democritus and Simplicius' works, i.e. the commentator of Aristotle. These witness statement are the basis to compose the atomic theory of Democritus.

We will mention in brief three points of Democritean theory based on the texts used here in translation:

a) atoms – empty space,
b) atoms behavior: weight – movement and
c) Formation of bodies.
d) We derive information relating the first atoms-empty space from an Aristotle's text (DK 67a, 6). Democritus maintained that the elements (ontological principles) are two: the full and the empty called respectively "being" and "non being". "Being" is full and solid whereas "non-being" is empty and sparse. The "empty" one exists as much as the body, for this reason the "non-being" exists as much as the being. These two elements together are the material reasons of everything existing in nature. The underlying essence, that is the atoms, is one. All things are produced by **its** variations. These variations refer to the "thinning" and the "thickening" (the sparse and the thick). The differences of the atoms are: the shape, the arrangement and the position. Whatever is physical or solid is regarded as real and is equal to the full.

Another statement given by Simplicius (DK 67A, 14) mentions that Democritus and Epicurus maintained on the one hand that the origins of beings are infinite in number, undivided and apathetic atoms, since they are solid and do not have any space in-between. Descartes refuted this theory because the division, as he said, is due to the space which is in the bodies. The atoms are differentiated in empty space.

Testimonials do not agree on whether Democritus maintained that the atoms possess weight. Some ancient writers like Aetius, write that Democritus accepted that the atoms have "size and shape" and that Epicurus was the one who added the third property, "weight".

Atoms move in infinite empty space. Aristotle attributes to Democritus the omission of not defining the form of the motion of atoms. Simplicius, in his comments of the book of Aristotle "Physics" (DK68^{A}58), notices that, according to Democritus, atoms move with mutual collisions and impacts "αλληλοτυπούμενας και κρουόμενας προς

αλλήλας κινείσθαι τας ατόμους" (= He [Aristotle] is speaking of Leucippus and Democritus, for they say that the atoms are in motion because they strike against each other). The regular movement of the atoms is due to their bouncing after collision. The character of the motion thus produced is undoubtedly defined from the weight, the shape and the previous movements of the colliding atoms. The collisions between the atoms end up in their mingling ("symploke – according to Democritus) - a term used by Leibnitz as well – and we see that if the atoms match in shape or otherwise, in their dispersing, if they do not match and that is "peripalaxis". In their bouncing that is "peripalaxis" they take the one or the other direction. Baley interpreted the term "peripalaxis" in the "Greek Atomists and Epicurus" as pulse, but this interpretation is not persuasive.

The third point of the Democritean theory we are going to mention is the "formation of bodies", that is how Democritus explains that bodies and phenomena are created by atoms. Also, according to Simplicius's comments in Aristotle's work "About Uranus" (DK 68a37), we get to know that "while the atoms move they collide and intertwine in such a way that than by attaching at to each other closely without forming any homogenous substance, since it is very simplistic to think that one or more things can ever become one". The atoms, according to Democritus, stay together for a while because of their mingling and mutual containment. Some of them are uneven, others are U-shaped, others concave, others convex and others have endless differences.

Democritus thus believes that they attach to each other and stay together until a stronger force comes from the environment to shake and spread them. This is the Democritean theory based on the texts without any details. Besides, terms of Democritus theory such as «ρυσμός» (=arrangement), «περιπάλαξις» (= collision, interlocking0, «διαθιγή» (= position) have become the object of detailed study by many modern researchers such as Jonathan Burnes, W. Guthrie, A. Long, D. Sedley et al., who have studied Presocratic philosophy. There is no time of course to analyze the various views that have been put forward.

We shall now examine the "homogenous parts" of Anaxagoras according to the main thought of the title of the present. The connection of the atomic theory of Democritus with that of Anaxagoras has been accepted since old.

Pierre Bayle (1647-1506), French philosopher, in his book "Dictionary of History", considered the quiver of the ideas of Enlightenment of the 18th century throughout Europe, writes: " it is' a pity that Democritus and Anaxagoras did not know each other and that these two bright minds did not cooperate. In that case, the result would be more complete because some points of the one approach (Democritus' one, so to say) would be completed by points of Anaxagoras's approach".

Anaxagoras of Clazomenae, Ionia (500-408 BC) was a friend of Pericles. He was charged of impiety "because he called the sun a fiery mass". With Pericles's help, he escaped capital punishment. This is what is happening with any innovation because it is considered to be dangerous. He was forced to retire in Lampsacus, where he founded a School and taught. He wrote a book entitled "On Nature", as most of the pre-Socratic philosophers. According to the collection of Diels-Kranz, 22 fragments have been given us from this and many witness statements of questionable reliability in terms of the information they give. For example, the fact that Anaxagoras came to Olympia and

foretold that it would rain, as indeed happened, and for this reason he had wrapped up himself in leather. He was older than Democritus and that is why the Abdeirean (i.e. Aristotle) criticized him for his ideas "about the sun and the moon" claiming they were ancient ones and not of his own. Is seems, though, that Democritus was influenced by Anaxagoras's ideas.

We will analyze the two ontological principles of the Anaxagorean theory based on the following texts:

a)"The sperms" which according to Aristotle were also called "homogeneous parts". We point out this term in the 17th century in the texts of French philosopher P. Gassendi and of F. Bacon. The "sperms" are material elements given in nature. They are an endless number of infinitesimally small fragments as the atoms of Democritus (DL, X44) which can be classified in groups on the grounds of the same quality. Anaxagoras believes that material does not consist of four simple elements, as Empedocles taught, that is air, fire, soil and water, but of small fragments which have various manifestations. We could say that the Clazomenean theory approaches the principles of modern chemistry, which teaches that there are chemical elements each one of them having their own qualities. Anaxagoras maintained that material elements are infinite in number and smallness. He also accepted the unlimited divisibility of matter. The atomic philosophers Democritus and Leucippus vehemently rejected this idea and used "ad hoc" the term "atoms" (uncuttable or undivisible things). Birth from zero cannot occur: nihil ex nihilo non fiat. No matter how much divide matter, Anaxagoras maintains, we will never reach the infinitesimal because nature is given in intermixture. Everything consists of a part of all original sperms and we get to know it on account of the preponderance of the element that prevails «πάντων μεν εν πάσιν όντων, εκάστου δε κατά το επικρατούν εν αυτώ χαρακτηριζομένου». That is each thing contains in itself parts of other things of heterogeneous elements and is what it is only on account of the preponderance of certain homogeneous parts which constitute its character.

It is obvious that the Clazomenean sage supported that whatever exists is the intermixture of sperms of the same quality.

Based on this assumption the following question arises: Which is the cause that leads the sperms to get out of this intermixture and confusion and make aggregates arranged according to certain qualities?

Anaxagoras supported that the ordering force is Νους (Mind). His book "About Nature" started with the statement «πάντα χρήματα ην ομού είτε νους ελθών αυτά διεκόσμησεν» (Diogenes Laertius) (=All things were together, then came Mind and set them into order).

Aristotle writes in a comment in his book "About Genesis and Decay": "Anaxagoras named the homogeneous parts of beings homogeneous matter and their underlying ordering cause Νους (Mind). May be this is a reference to the first book of Genesis. I am satisfied with this hint, since my theological knowledge does not suffice for further analysis and comparison of the two texts.

At any rate, Anaxagorean Νους (Mind) was identified as God in ancient writings. Aetius writes characteristically: "Anaxagoras said God made cosmos". We will find that this idea of God creating the world is also expressed in Leibnitz's text, who writes that

God is creator and is the one who puts the "units" in order.

The Νους (Mind) of Anaxagoras enforces a definite order in the universe, "decoration". Leibnitz calls this "Pre-established harmony". The qualities of the Anaxagorean Νους (Mind) are not material «έστι γαρ (ο Νους) λεπτότατον τε πάντων χρημάτων και καθαρώτατον και γνώμην (γνώση) γε περί παντός ίσχει και ισχύει μέγιστον και τα συμμισγόμενα τε και αποκρινόμενα και διακρινόμενα πάντα έγνω νους και οποία έμελλεν έσεσθαι και οποία ην άσσα νυν μη έστι και οποία έστι πάντα διεκόσμησε». That is "Νους (Mind) is the purest thing of the finest texture and possesses all knowledge and power and intermixes and separates all these. Νους (Mind) put everything in order, defined the way they would happen (Providence) and the form of the existence of what was and is not anymore as well as of whatever exists now and all of which has decorated".

These ideas of Anaxagoras reveal a teleological assumption for the world. We do not find such ideas about Νους (God) in Democritus, as creator, Maker of Cosmos or Anticipator. The Abdeirian sage rejects these ideas. Democritean theories are characterized by scientific characteristics in modern terms. Everything happens because of a certain cause which we must find. An excerpt mentions: «ουδέν χρήμα μάτην γίνεται αλλά πάντα τε εκ λόγου τε και υπ' ανάγκης (fr.2)». That is, nothing happens in vain but there is always a reason and necessity, while in another excerpt states: "I would rather find the reason that something happens than the Persian Kingdom to be donated to me".

Now, we shall examine in short Leibnitz's ideas which seem to be something between the ones of Democritus and Anaxagoras. Diderot characterized Gottfried Wilhelm Leibnitz (1646-1716) as a thinking machine, because he dealt with many scientific areas and he produced significant work. One could confute Diderot's point of view and characterize Leibnitz as the last Homo Universalis of waning Renaissance and of the start of New Epistemology.

Leibnitz is classified along with Descartes and Spinoza as the leading exponents of rationalism in the conflict between rationalism and empiricism, which reached a climax during the 17th century. J. Locke, L. Berkley and D. Hume, on the other hand, were ardent proponents of empiricism in the same period.

Leibnitz admits in many cases that he has borrowed from and was influenced by ancient philosophy. In a letter to his friend Michael Gottfried Hansch (1683-1752) on the one hand he confesses his admiration for ancient Greek philosophy and on the other hand the eclectic method that he was going to follow. He writes among others in this letter "I consider that for philosophizing in the right way it is useful to combine Aristotle, Plato and Democritus." Leibnitz's eclecticism is affirmed by Nicholas Jolley of the University of California, known for his studies on Leibnitz's work. Leibnitz's as well as Bacon's attitude was not always consistent towards decaying Aristotelism. Leibnitz acknowledges that he had studied Aristotle's work. Bacon, the architect of "Modern Science", ardent proponent of the Democritean theory, characteristically points out "Democritus's theory about atoms is either real or useful to prove".

Bacon claimed that philosophy and religion are separate and coexist, whereas Leibnitz thought that "neither philosophy is acceptable if it does not agree with religion, nor religion is real if it disagrees with proved truths". One could discern two

phases regarding the ancient atomic theory by studying Leibnitz's attitude. He seems to flirt with Democritean and Epicurean natural philosophy in his first one according to his texts and he detaches in his second since the "units" are not material points or elements. He gave a boost to the natural philosophy in the first phase with the revival of the two basic philosophical schools of the Hellenistic period, of Epicurism on the one hand, which continues Democritus's thought, and of Stoicism on the other.

Epicurus as well as Th. Hobbes, a contemporary of Leibnitz, support that all things are material and the change is not due to divine prudence in any case. Leibnitz criticizes both Epicurus's and Hobbes's views, claiming that the soul as well as God are synthesis of extended matter. If this holds true, then God cannot be omnipotent and omniscient and consequently does not have the quality of providence and he is not just. Such ideas contrary to the climate of the time, although atheism or natural religion as ideas were widespread in his time, led Leibnitz to a metaphysical idealistic explanation of the world. Leibnitz adopted such a view despite the fact that from the end of the 16th and 17th century, the atomic theory had prevailed in the context of natural philosophy. Bacon in another discourse (Cogitationes de natura rerum) clearly declares that "Leucippus's and Democritus's atoms are more useful for natural philosophy than Aristotle's theories about nature". Bacon, though, insisted on a scientific utilitarianism with his consolidated view that the explanation of nature provides us with useful and applicable knowledge. An aspect not found in Leibnitz, who turned to metaphysical concepts for the explanation of nature although he knew of Bacon's philosophical thought.

Leibnitz knew that Gassendi and other natural 17th century philosophers maintained that God moves the atoms, in order to avoid Democritus's atheism something that Newton supported in the General Scholium of Principia. One could name this venture as "theistic individualism".

Leibnitz did not adopt theistic individualism but a completely different course, totally metaphysical, in order to explain the world. He analyses the topic we are dealing with here in his work Monadology (1714) written at the end of his life. He condensed and simplified his philosophy in the 90 numbered paragraphs of his work. In the first 30 paragraphs he analysed his theory about units or entities that for him constitute the fundamental ontological principle.

In paragraph 3 of Monadology he writes "Monads are the real atoms of nature – in one word the elements of things" and especially "they are a simple substance which enters the compound ones, simple, that is without parts". The compound consists of the aggregation of "monads". The simple substance, that is the Monad, does not have any parts whereas the compound ones have. Leibnitz, in the first 3 paragraphs of Monadology, uses three Democritean terms: "atoms", "aggregation" which is called "symplokē" according to Democritus and the term "part-less". Our ascertainment refers to the original view of Leibnitz on matter concerned because he had acknowledged "Initially agreed with the philosophers of my time like Galileo, Bacon, Gassendi, Descartes, Hobbes and Digby. All of the above, as well as I have proved in a book adopted Democritus's theory and supported that atoms are material points. All the above introduced "atheist individualism" so as not to be blamed for atheism. Leibnitz changes

course and supports that units are real spiritual, immaterial, psychical entities that constitute a system from the simplest to the most perfect ones. The "unit" is the first element of the substance and it is a "metaphysical point". It does not have extent but only tendency, "drive" and representational ability that is "mood" and "awareness" which are Aristotelean terms. Ad hoc researchers of Leibnitz regarded that the "units" may be "energy units". The units do not have "external" properties just like the atoms of Democritus but "internal". They do not receive any external influence, because, according to Leibnitz saying they do not have openings through which something can enter or exit? God's will is the one which arranged everything in harmony and defined the situations that correspond to each case.

Thus, Leibnitz ends up to pantheism reminding Plotinus's theory surpassing out of excessive zeal his contemporaries who talked about material individualism.

The initial unit is the God, the unit of units, all the other units stem from it. The representations of the "units" do not have the same energy. Only God has perfect representation. People's souls which are "units: sometimes have more or less perfect representations. The "units" do not mutually interact but are connected with each other and act in prearranged harmony which has God as the initial force. The "genesis" and the "decay" of the "units" are possible only with the direct energy of the Divine Omnipotence.

I finish now with a concluding ascertainment. Leibnitz, on the one hand immaterializes the "atoms" of Democritus and makes them "immaterial units" and on the other hand he bluntly aggrandizes the "Νους" of Anaxagoras. D' Alembert wrote because of this in his Pre-introductory speech in Diderot's Encyclopaedia: "Leibnitz's units were not capable pre helping us to explain nature".

A1.2 Aristotle Deviant?

Emm. Mikroyannakis
Professor, Univ. of Athens

Abstract

My study of the passage at *Pol.* V,10,1310b 9-10 does not open up a new path. It does, however, at a critical point discover the path, "εν ή ιτέον", the one to be taken. The insistence of all translators, scholiasts and scholars for approximately 8 centuries (since the 13th) to translate "from the demos" as "against", the tendency to bring the people and the "worthy" into conflict, eventually led to an even greater blunder (precisely so that the text and translation could agree). They led to the correction of the text. The preposition "from" (από) became "against" (επί), "from the demos" (από του δήμου) became "against the demos" (επί τον δήμον) (as in *Seven Against Thebes, Επτά επί Θήβας*). And this despite the unanimous, without exception (*ausnahmslos*), manuscript tradition.

I believe that with the change that was proposed and accepted, Aristotle is completely overlooked or overturned. Monarchy ceases to be a "correct" constitution and becomes a "deviation". Marx, of course, would have approved of such an antithesis. And Aristotle? It would certainly have been a good transhistorical background for Marx, but is, I believe, the complete opposite of the ancient philosopher's position. Aristotle supports and shows ways in which to bridge, not intensify, the antithesis between the "few" and the "many". Between the usual opposites, it is better to have the copulative conjunction "and", which coordinates, rather than the disjunctive "or", which divides. For the preferred pairing, an able intermediary is required. Aristotle is precisely the thinker who is "midway" ("μεσεύει"), the one who believes that the interests of the opposite parties is not different but "identical".

Aristotle is perhaps the most prolific and fruitful teacher in the history of mankind. He fertilizers his students even when he is misinterpreted. One of the darkest passages in his Politics, which touches upon the huge iss ue of the differentiation of monarchy (into kingship and tyranny) is the following 10 words (one line or so from Book V 10, 1310 b9-10) :

«*βασιλεία προς βοήθειαν την ΑΠΟ ΤΟΥ ΔΗΜΟΥ τοις επιεικέσι γέγονεν*».

Over a centuries-long tradition, all translators and scholars of the *Politics without exception* have, on the basis of this passage, seen the king as turning against the demos. They have translated it thus: **kingship was created so that the "worthy" would have a leader against the demos.** They forced the text giving, offering another meaning. In order to remedy this arbitrary interpretation, they even consented to the correction of the text, so as to favour the meaning, as they saw it. On Rassow's proposal, "from the demos" («*από του δήμου*») became "against the demos" («*επί τον δήμον*»). One mistake

led to another.

The crucial and definitive "correction of the correction" was offered in 1990, in my study *Παθολογία πολιτευμάτων στην αρχαιότητα* (pp. 145 ff.) (*Pathology of Constitutions in the Antiquity*). In this work, I translated and noted, among many other things, the following: «η βασιλεία γεννάται για βοήθεια του δήμου προς τους επιεικείς (τους ολίγους ευγενείς). Βοήθεια η **από του δήμου** είναι η δημοτική, η λαϊκή». (Kingship arises for the help of the demos towards the worthy. Help from the demos is of the people, popular).

Despite my insistence in 1990, the issue was not taken up by scholars. The Greek language is also to blame (Graeca non leguntur). Thus, Eckart Schuetrumpf (and Jo. Gehrke, *Aristoteles Politik*, Berlin 1996, ad l.) translates it as "das Koenigtum wurde zum Schutz der Guten gegen den Demos eingerichtet". David Keyt (Aristotle, *Politics, Books V and VI*, Oxford 1999, ad l.) insists on the traditional translation: "kingship has arisen to provide aid to the worthy against the (depredations) by the people". P.L. Simpson (*Translation of the Politics, 1997, ad l. and A Philosophical Commentary on the Politics of Aristotle*, 1998, ad l.), with whom I discussed the issue in Greece, after having made and published my correction, adopted somehow my line of thinking but did not acknowledge this, as he was obliged to. I noted this in a re-examination of the subject (*Σχέση βασιλείας και λαού, Τιμητικός τόμος Ιω. Τριανταφυλλοπούλου* (*Relations between King and People. Volume in honour of I. Triantaphillopoulos*, Athens-Komotini 2000, pp. 139-144).

Today's re-examination of the subject focuses on the scholar Hermann Rassow, or Rassovius, who proposed the correction of the passage (which was accepted) despite the unanimous version in all the codices. Who was this Rassow? In which publication or journal did he write? How did he justify his proposal? The great W. L. Newman gives a partial explanation of the thinking behind this change from his own perspective, with a vague reference to Rassow. He states simply: "All the MSS, including Γ, have *από του δήμου*, but I have not found any parallel to the use of από in the sense of 'against' with *βοήθεια*... It seems, therefore, best to read *επί τον δήμον* with Rassow Sus.[emihl] and Welldon." Newman does not give a reference and neither does Sus., nor do any of those whom I was able to find. Welldon beneath his translation, for example, simply notes: "Reading *επί τον δήμον*".

After persistent efforts on my part in the National Library of Greece, the Gennadius Library and the British School at Athens, with the help of their willing and experienced staff, I eventually found, to my great relief, the source. It is a small study in the yearbook of a Gymnasium: "Bemerkungen ueber einige Stellen der Politik des Aristoteles", Weimar 1864, pp. 3-17. It is included in a bound volume (in BSA) along with other studies. Hermann Rassow, who published it, was the school's headmaster.

In this work, Rassow makes various observations of a primarily philological nature on Aristotle's *Politics*. We come to the crucial passage in the article that concerns us (p. 16). The discussion concerns the origins of the constitution of kingship, which is being examined in juxtaposition with that of tyranny. The author, quite reasonably, considers it essential and most important that a distinction is made between these two types of constitution and the particularities of kingship and tyranny. Rassow proceeds to the line of thought that led him to defy the whole manuscript and print tradition, saying:

....*βοήθεια η από του δήμου τοις επιεικέσι* kann schechterdings nicht Anderes heissen,

als eine Huelfe, die vom Folke ausgeht und den Fornehmen gebracht wird. Wie sich daher die Herausgeber bei dem ueberlieferten Texte haben beruhigen koennen, ist mir nicht erklaerlich; denn Aristoteles will offenbar sagen, dass die Koenigsherrschaft entstanden sei, um den Vornehmen gegen das Volk Huelfe zu bringen, waehrend umgekehrt die Tyrannis sich urspruenglich gegen die Fornehmen richtet im Interesse des Demos. Mir scheint daher nichts uebrig zu bleiben, als βοήθειαν *την επί τον δήμον* zu schreiben, obwohl die codices ausnahmslos *από* bieten.

What is Rassow telling us here? It is clear that "*βοήθεια η από του δήμου τοις επιεικέσι*" can mean only one thing. It means that the help derives from the demos and goes to the "worthy"(επιεικείς). This help he believes to be impossible and incomprehensible. Since, however, this is the only meaning of the Aristotelian passage with the preposition *από*, followed by the two words *του δήμου*, and since he considers precisely this meaning to be unacceptable, Rassow wonders, turning to the publishers, how they can remain satisfied with the transmitted text. It is inexplicable to him. It is as though he is telling them that they must do something. In his mind, there is no doubt that Aristotle wanted to say that kingship was made in order to give help to the notables against the crowd. With this logic, Rassow sees no other way out than to propose *την επί τον δήμον*. This help "η από του δήμου" became "επί τον δήμον". Not only has the preposition changed but also the case of the word δήμος. The demos, instead of helping, is now under attack from the "worthy" who have the king as their leader. Every faction has its leader. Qualitatively and ethically, however, with the "correction" that was proposed, there is no difference between a tyrant and a king. And this is the great mistake made by Rassow and all those who adopted his proposal. King and tyrant are two extreme poles of political life. One makes war and the other is a peacemaker. Greek political thought embellishes the king with all the positive characteristics and blackens the tyrant with all the negative.

According to Rassow, the text had to conform to the translation and not the translation to the text.

And how peremptory and commanding is his plea to the editors. It is as though he is saying to them: How can you sleep at night when you let Aristotle not talk of the clash between the people and the "επιεικείς". In order to overcome this error, as he sees it, he introduces an aggressive preposition, **επί** (as in "Seven against Thebes", Επτά επί Θήβας), quite different from the preposition of the manuscript tradition, the από (from).

Did Rassow's appeal persuade the editors? The response was most impressive: his correction was universally accepted. From Fr. Susemihl in the 19th century (1872) until today, all have adopted it. And the *Oxoniensis* under W.D. Ross. We thus have the striking situation that, on the one hand, the entire manuscript tradition (the *ausnahmslos*), comprised codices from the medieval period until our times, even all the publications until the 19th century (up to Susemihl), contain "*από του δήμου*". Yet, on the other, the editors of the past 150 or so years, from Susemihl (1872) until today, follow the inexplicable Rassow ("επί τον δήμον"). The former have "από του δήμου", the latter "επι τον δήμον". What is so paradoxical and unacceptable about this? <u>That despite the different versions, the interpretation of both sides is the same: both insist on enmity and con-</u>

flict between the demos and the "worthy" (notables, the good, generally those capable and suitable for άρχειν).

Susemihl had in front of him a long, centuries-old tradition that insisted on the element of conflict. It would have annoyed him, I believe, and Newman and others, that the narrow grammatical interpretation did not help. He would not have felt comfortable with the difference between the text and the translation. The "από του δήμου" cannot mean, as all the translators wanted it to, *adversus*, contra, gegen, against. This is the reason, I presume, why Susemihl, Newman and their successors felt a sense of relief with Rassow's suggestion. This suggestion would have resulted in an agreement between text and translation. The desired translation imposed the solution that was proposed.

Susemihl, the formidable Aristotelian scholar of the 19th century, had, among many others, William of Moerbeke in front of him, the 13th-century scholar and Catholic bishop of Corinth in the Latin-held Peloponnese who, at the request of Thomas Aquinas, translated works of Aristotle from Greek into Latin. Moerbeke's translations are word-for-word (*verbum pro verbo*). Whenever a difficulty arose, Moerbeke left the Greek word untranslated. In his monumental edition of 1872, Susemihl cites Moerbeke's translation, which it should be noted was done in around 1260 (756 years ago) from the afterwards lost Greek MS (Γ). This translation would also have been read by Dante, who refers to Aristotle and considers him the "teacher of teachers".

Let's see how Moerbeke translated the passage that concerns us: *regnum quidem enim ad auxilium quod a populo epieikeis factum est*. In this translation, as we can see, the king did indeed come for help. It is even stated where this help came from. It came from the people. What does it not tell us? Will the demos turn to the worthy to help them or to attack them? This is difficult to answer given that the *epieikeis* (with an unclear case and no preposition, a simple transliteration of *επιεικείς*) does not allow us to understand the syntactic function of the word. Moerbeke, I would say, simply sidestepped it without insisting on clarifying the most important point.

It seems that when reading Aristotle we expect to find in him Manichean notions of a clash between good and evil or the influence of revolutionary proclamations, which Aristotle and other thinkers would have seen as unfounded. We thus rage at and sometimes flay Aristotle when he does not agree with us. The case in point is typical. Scholars believe that Aristotle cannot have anything other in mind than a conflict between fundamental political actors, the few and the many. Conflict, according to Aristotle, is produced mainly by "deviations" and not by "correct" constitutions, namely those that save. Kingship is a correct constitution, even if it is difficult for there to be a king who "matches the magnitude and dignity of the office" (Arist. *Pol.* 1313b7). For the kingship, a suitable person with "superior virtue" (1310b11) is required.

In the passage under analysis, the king undertakes the difficult task of bringing help, and not only any usual help but the great power of the demos to the "worthy". How difficult a task it is to bring the demos "to the help of the worthy" is confirmed by the fact that even scholarly research has for centuries considered it inconceivable.

The case that we are examining acquires even greater dimensions and touches upon the number one problem of historical life, that of the fundamental relationship

between the "few" and the "many", the haves and the have nots, of all social conflicts, the subject of many scholarly disciplines. Within this social conflict between the main actors of social life, two possibilities can be seen in their relations, war or peaceful cohabitation. To this huge problem Marx, for example, gives a most clear answer: The chasm must be magnified and intensified so that we be driven to confrontation, with the expected for him (but not, however, for everyone else) positive results.

How is this eternal problem presented in Aristotle? Did he see it? Did he face up to it? My opinion is that this problem concerned him throughout the *Politics*. The great philosopher and thinker offered the advice that it is in the interests of the few to satisfy the many and of the many to satisfy the few. Marx would contrast the ancient "and I will be hostile to the people" ("και τω δήμω κακόνους έσομαι") with "I will be hostile to the worthy" ("τοις επιεικέσι κακόνους έσομαι"). The more conciliatory Aristotle would, by contrast, in the place of the "κακόνους" use the "favoured" ("εύνους"). Three constitutional forms (kingdom, aristocracy, polity) can be found in Aristotle's advice and three (tyranny, oligarchy, democracy) diverge from it.

The chapter of the *Politics* on, for example, "the safety... of each political system" ("περί σωτηρίας... εκάστης πολιτείας") (V,8,1308a26-1309b32), which extends over 4,5 pages of the Oxford edition, can be summarised by two "essentials": "in democracies it is necessary to be sparing of the wealthy... while in an oligarchy there is much necessity to take care of the poor" ("δει εν μεν ταις δημοκρατίαις των ευπόρων φείδεσθαι... εν δ'ολιγαρχία των απόρων επιμέλειαν ποιείσθαι πολλήν"). "Similar" things are said and to a much greater degree (in 15 pages) in chapters 10 and 11 (1310a39-1315b10) "on monarchy" ("περί μοναρχίας"). It is enough, I think, to consider the importance that Aristotle attributes to the pairing of the constitutions: oligarchy and democracy, kingship and tyranny. Here, Aristotle analyses, using many examples, the whole pathology of the constitutions, how they decline and how they survive, to how necessary and beneficial is "το αεί τοις αντικειμένοις μορίοις εγχειρίζειν τας πράξεις και τας αρχάς (λέγω δ' αντικείσθαι τους επιεικείς τω πλήθει..." (1308b 26 ff.).It is beneficial to give the management of affairs and offices of the state to opposite factors. And the tyrant, even, pretending to be the king, i.e. his polar opposite, improves and comes to be "half virtuous and half wicked only" (1315b 9-10),one,I would say, τυραννοβασιλεύς.

In the passage under study, if we accept Rassow's correction then we are rejecting Aristotle, because we are accepting the kingship as a "deviation" and Aristotle, in this case, as a deviator.

Aristotle does not agree with the opinion of his scholars, in this instance. Aristotle, in the whole of the *Politics*, from the beginning to the end, emphasises in many and various ways that "correct" are those constitutions that have a concern and care for all the citizens. The "deviations", the wrong political systems, care for the faction. Kingship is a correct constitution. If a king becomes the leader of a faction, then he is no longer king. He becomes a tyrant.

After all this, there is no other way out than to insist on the "help from the demos"(«από του δήμου»), in other words to return to this very familiar text from the entire manuscript tradition, in the hope that it will be accepted by editorss and researchers.

In the passage that concerns us, the monarchy "becomes" an institution and the

king is (through "superior virtue") able ("πειθούς δημιουργός") to convince the people to offer its help and consent for the actions of the "επιεικείς".[1]

In conclusion, I would note that the interpretation that is so insistently given still today in one form or other of the text (**από του δήμου, επί τον δήμον**) is peculiar to Marxist thought, as it has been expressed diachronically, and that all those who accept it, consciously or otherwise, are pushing Aristotle too, the philosopher of «μεσεύειν», to appear as "deviant" and as a stepping stone to Marx. The complete opposite is true. Aristotle sees "few" and "many" as different sizes and powers, but he believes, as did Heraclitus, that, with a good constitution, the differences can be harmonised:

"εκ των διαφερόντων καλλίστη αρμονία" (Arist. *NE*,VIII 1,1155b 5).

1. This role could also be played by some other "first man". Pericles, in his Thucydidean Funeral Oration, aims, as I argue (Emm. Mikrogiannakis, Olympic Democracy, Pericles' Funeral Oration Revisited, Nikephoros 21,2008,133-157), at an "Olympian" competitive-style democracy in which the "aristoi active in the service of the polis" are based upon the many and the demos tends competitively towards exceeding itself. In such an orderly political system, where all "ευ αγωνίζονται" and for all of whom "άθλα αρετής κείται", Pericles plays an important role. What? "Κατείχε το πλήθος ελευθέρως» (Thuc. 2,65,8) and guided it. The adverb "ελευθέρως" moderates the meaning of «κατέχειν». Pericles, we would say, acted royally and convinced the demos. He manipulated it like a king.

A1.3 Equality, Magic and Tragic

Emmanuel Mikrogiannakis
Professor of Athens University

Abstract

Aristotle highlights the meaning of the participation of the demos in power, and clarifies in his Politics its extent in a εὖ κεκραμένην polity. For the demos it is sufficient, according to Solon, to have two things: αἱρεῖσθαι καὶ εὐθύνειν τὰς ἀρχάς, to elect the rulers and to monitor them (bring charges against, punish and reimburse them). Where the demos seeks continuous equality and levelling, where it hates the rise of the aristoi and fights every ἀριστίνδην (according to merit or to birth) there political life proceeds at a snail's pace or is in turmoil. Disharmony in political life occurs also when the aristoi, those who would rise on the basis of their abilities, constitute a closed circle, when they entrench themselves and do not care for the whole.

What happened at Olympia? All citizens of the Greek states are κλητοί (invited). The invitation is even made officially. It was a punishable offence to impede anyone who wished to go to Olympia to compete or be a member of a *θεωρία*, the official representation of the polis. If, for example, an Eretrian was impeded in any way by a Chalkidian, the Games would be adulterated. Victory had to be clear and indisputable. Wars indeed took place during the Olympic Games, not only abroad but between Greeks (despite the ἐκεχειρία, the truce). During the 75th Olympiad (480 BC) Xerxes was at Thermopylae during the preparations for the Games. He fired at Athens during the five days of their duration, and was defeated at Salamis during the post-celebration events. The condition of full participation, fundamental for democracy, was sought for with the ἐκεχειρία, which means "hands off" those making their way to Olympia (or to other Games or a Panhellenic sanctuary). Asylum was thus not limited to places but extended to people. The athlete or delegate was a sacred and inviolable person. He had an institutional character and divine protection.

The next stage completes the democratic aspect: all athletes compete under the same conditions, which are indisputable.

The athletes are invited to ἅμιλλα, competition, and they accept. The first part of the word hamilla is hama. Ἅμα (and ὁμῶς, ὁμοῦ) indicates not only "similarly", together, but "under the same conditions." This ensures equality and "straightforwardness". The second part of the word hamilla is the root of ἅλλομαι, σάλ-, αλ-, ιλ. Ἅμιλλα means ἅλλεσθαι (jump) together and under the same conditions. The athletes (stadium runners, double-course runners, long distance runners, and of the other competitions) start under the same conditions. Hamilla is both a condition and an action. It is momentary, and indicates motionlessness and movement together. Something like the

Discobolus of Myron, which is motionless energy or active motionlessness. This condition has a past and a future.

And all this in the present (νῦν, nunc) which is momentary, but which contains the before and after of the duration of time. It has been prepared in the past and hurls towards the future. Here, at the starting point, at this moment of ἅμιλλα (release, more specifically) is the high point of democracy. Here all are equal. For how long? Immediately after the start, in a fraction of a second, the competitors are differentiated. Equality takes a walk. Democracy is lifted. Judgement is clear at the finishing line.

The first, the second, the last are separated. Importance is attached mainly to the victor. Here, at the finishing line, aristocracy triumphs. This hamilla, this starting (this ἀπιέναι, to start the race, departure), discerns democracy and aristocracy. They are two distinct fields that should not be merged. Democracy triumphs in the first and aristocracy in the second. Competition is the tip, the edge, the watershed.

Imagine what would have happened if an attempt was made, with some kind of equaliser (accelerator or decelerator), to maintain the stand of equality.

The athletes would all reach the finishing line together. In that case, what is the contest for? It would have no meaning. Some would say: Égalité is a very good thing and we should maintain it. In athletics, however, such an action is a disaster, and would even require a tiresome effort. To sum up: Equality and Liberty are inconsistent.

Transferring this sporting image to the political sphere, we can see that wherever, after some equalising revolution and as a characteristic of it, an attempt is made to maintain equality in a violent fashion and with the rallying cry of permanent revolution, we have constant turmoil.

Equality is a wonderful concept as a starting point, a springboard (ἐφαλτήριον). The problem is how will the shift to equality come about: in a violent, revolutionary way, or institutionally, with κείμενα, along established principles?

The democratic element comes under the general political one, and it must be aware of its limits and leave room for the other, the aristocratic element.

There is only one political system (the polity, constitution strictly speaking) as the ψυχὴ (soul) of the polis. When certain of its elements were emphasised, it became autonomous and numerous forms resulted. According to Aristotle there are six main forms: three correct political systems (kingship, aristocracy and polity) and three incorrect ones, παρεκβάσεις (deviations) as he calls them (tyranny, oligarchy and democracy). Of note in this classification is the fact that the polity is the term and the name not only for each political system (πολιτεία καὶ πολίτευμα ταὐτὸν) but also for one of the six. As such, the same name is used for the general and the specific. Is this categorisation defective? It seems that Aristotle accepts the polity as the political system par excellence, which as a μίξις (mixture) ὀλιγαρχίας καὶ δημοκρατίας is the suggested political starting point. From this starting point, it is possible for us, with an upward trend (and intensification of positive elements), to pass to an aristocracy or kingship, or, with a downward trend (and intensification of negative elements) to pass to tyranny, oligarchy or a democracy of mob rule. Aristotle classifies this last type under παρεκβάσεις. Aristotle does not leave room for misinterpretation. For tyranny and democracy, his statement is categorical. According to him, even if we conceded and accepted them as

political systems and then they are the "worst" . A necessary observation. If Aristotle were today to survey the 200 or so political systems of all the world's states (which all, as a rule, bear the title of democracy), he would not find a single one that would accord with this title. The majority are mixed, but called democracies, because the people are, according to Aristophanes, εὐγοήτευτοι, easily charmed and each likes to be presented as ἄρχων and κρατῶν even when he has no power. Aristotle highlights the meaning of the participation of the demos in power, and clarifies in his Politics its extent in a εὖ κεκραμένην polity. For the demos it is sufficient, according to Solon, to have two things: αἱρεῖσθαι καὶ εὐθύνειν τὰς ἀρχάς, to elect the rulers and to monitor them (bring charges against, punish and reimburse them). Where the demos seeks continuous equality and levelling, where it hates the rise of the aristoi and fights every ἀριστίνδην (according to merit or to birth) there political life proceeds at a snail's pace or is in turmoil. Disharmony in political life occurs also when the aristoi, those who would rise on the basis of their abilities, constitute a closed circle, when they entrench themselves and do not care for the whole, but only for their group interest, and do not renew themselves.

In an εὖ κεκραμένην πολιτείαν (well mixed constitution), channels are open. Rulers and ruled proceed hand-in-hand. Each one succeeds in relation to his proven qualification (see my article: Olympic Democracy, *Nikephoros* 21, 2008,133-157).
Long wars lasting for years (such as the Peloponnesian and the Roman Civil wars) would have been avoided or curbed if the warring parties had not become stuck in the dilemma of democracy or oligarchy (a form of which is aristocracy).This dilemma is disastrous,while beneficial is the wedding of democracy and aristocracy.

Aristocracies of all types which constitute a closed circle and do not accept new elements, and certainly not those that come about through competitions, decline and are destroyed, first from within and secondly from without by those who want to enter but are excluded.

The functionality and viability of a polity depends on the extent to which it distinguishes between the two stages of, so to say, democraticity and aristocraticity. And both are taught to us by athletics in the classical (ideal) way they were expressed at Olympia.

Equality (and equalisation) is considered by many as a magic word. There can be no revolution without the slogan of equality. This ἐξισοῦν (so dominant in mathematics with systems of equations) is put forward in every example of social life.

From all that we have noted so far in reference to Olympia, it emerges that the Olympic ideal moves towards the equal. How? In the procedure of inviting all athletes, the concern that no one should be impeded and the provision of identical preconditions for all. Is absolute equality a goal? It is fully believed that the ἀγώνιοι gods of the contest supervise. They want equality, so as to award inequality. At the end of each competition, Nike will not crown all the athletes, but only one. Was the competition for equality or inequality? The athletes who went to Olympia wanted to be distinguished, to take first place . Their value, virtue, shone e.g. with the boxing contest (πύξ), just as with football (λάξ) today.

In all types of competition, equality is not a goal but a means for its accomplish-

ment. It is something intermediary, one «between». Yet, whilst it is something intermediary, and indeed very small, it is absolutely necessary and a sine qua non for every success and progress.

For every great aspiration, it is necessary for us to get over this springboard, this ἅλλεσθαι. Ἅλλομαι, ἐφαλτήριον and ἅμιλλα are words with the same root.

There can be no ἅμιλλα without equality. This is declared in the first part of the word ἅμα. The ἅμα, ὁμοῦ ἅλλεσθαι, jump, to start a contest under the same conditions and with the same aspiration, presumes and similarly declares equality. But, it needs equality only at a specific moment. Not to become stuck on it. It wants it to abandon it. It is an intermediary station. All ἅμιλλα revolves around the point of equality. Ἅμιλλα is stopping and starting. It is not a zero point, but the arrival at and departure from it. It is, one might say, a μηδενόσε and a μηδενόθεν

Of all that has been put forward, there is no doubt that the difficulty in each competition (Olympic or Football World Cup) is to secure the equality of the participants in a way that is indisputable, and so the proper conduct of the competition, so as to produce the victor and hierarchise the participants. The problem, then, is condensed into how we secure equality and how we remove ourselves from it.

It is truly admirable that the Greek language offers us the word which means in itself both the process of securing equality and overcoming it. It is an ambiguous word, bearing the two meanings of a contradiction. It means the position and the removal, i.e. two diametrically opposed things.

The word I have hinted at is ἀνισῶ (and correlates). The usual and commonly known meaning of ἀνισῶ is "I make something unequal," i.e. different (superior or inferior). In Xenophon, however (Cyropaedia 7.5.65), we read ὁ σίδηρος ἀνισοῖ τοὺς ἀσθενεῖς τοῖς ἰσχυροῖς, where ἀνισοῖ ... means that iron weapons make equally strong (i.e. they level) the weak and the strong (iron negates the difference in physical strength).

In ἀνισῶ the first part is (A) the preposition ἀνὰ or (B) the negative prefix α-. As such, ἀνισῶ in the first case means I restore equality (which has been disturbed), and in the second I disrupt the equality (which had been achieved). Thus, the same word expresses the whole process of the two stages we mentioned, the first in terms of levelling as ἀνισάζω (equalize), ἀνισασμὸς (equalization), the second in terms of hierarchising as ἀνισάκις; ἀνισοῦν gives birth to tragedy. And tragedy is ἡ εἰς τὸ ἐναντίον τῶν πραττομένων μεταβολή. It is to arrive at the opposite of that which we seek; for one to find himself 180° somewhere else, to go north and end up south. Thus, ἐπανισοῦν (for example) can be disastrous in its application, if it is imposed from outside and without accepted leadership from above. When Alcibiades approached the Persians, advised them that the only effortless way to destroy (annihilate) the Greeks was ἐπανισοῦν (neutralise them systematically) . In this case, ἐπανισοῦν took the form of reinforcing the Spartans if the Athenians were ahead, and reinforcing the Athenians if the Spartans were ahead. The equalising of the two leading belligerents in the Greek camp (equalising by reinforcing the one in the inferior position) allows the third party (the Persians) to intervene as referee and with the equalising, i.e. destructive role of extending the contest, to have the over hand. The contest, as is well known, finishes earlier if one of the warring parties comes out on top, whereas it is continued if the belligerents

are equally strong (for their own bad luck). This is the surest way of neutralising the belligerents, and the brilliant diplomacy of the Romans (divide et impera), which they applied to such a degree and extent.

What happens in this situation? The ἀνισοῦν, the making equal, is wonderful as a slogan (here with the ἀνα -). With the search for the superior, we are constantly with weapon in hand to decapitate the most eminent, following the advice: τοὺς ὑπερέχοντας στάχυας κολούειν or ἀναιρεῖν) .

The ἀνισοῦν (with ἀνα -, or α-) acts as a saviour in the political sphere if institutionalised, if political mechanisms are established so that things are led to ἅμιλλα. It is to this ἅμιλλα that our effort must be aimed: the restitution to equality and its exceeding itself in time (regaining, retrieving).

A2.1 The Typology of Regimes in the Thought of Plato and Montesquieu: A Comparative Evaluation

Nikolaos Tsiros
Assoc. Prof. Panteion University
Senior Advisor to the Legal Council of the Hellenic State

I. INTRODUCTORY REMARKS

1. Without the pioneering contribution of Plato and Montesquieu in the analysis of systems of government of the historical reality, the formation of the modern political and social science would be rather impossible. At first, Plato mentions in the H book of the *Republic* four false forms of government, that is, regimes of the historic decay and four corresponding human types. The philosopher has already described in the previous books of the *Republic* the framework of the rigid prerequisites that concern the moral political power so as to acquire the characteristics of the optimum republic. Nevertheless, even this transcendental structure of the optimum republic has to confront its innate ontological limits from the moment it enters the social process and it has to materialize inside it in an empirical way. Even though Plato does not explain precisely the historical-type procedures that lead his optimum republic to decay the fact remains that a degeneration of its principles core takes place in the long run which finally leads to its conclusive disintegration. As a consequence, the analysis of the false forms of government presupposes the ongoing degeneration of the optimum republic[1].

These four forms of the existent regimes that is the timarchy, the oligarchy, the democracy and the tyranny are connected with the downward motion of the principles in the inner part of the human soul. A certain sociology of human passions reveals the prevailing vole that the material-causal definition plays in the structure as well as the inevitable destruction of the existent political formations.

2. Many centuries later, Montesquieu undertakes in the thirteen first books of his work the *Spirit of Law*, in his turn, as a diligent reader of Plato and Aristotle to develop the well-known theory of the three forms of government and subsequently to found what in modern scientific terms is called political sociology. The transition from the ancestral political philosophy to the actual sociology is depicted through the revelation of those necessary inevitabilities which put in order whatever has happened. As a result of this targeting the Montesquian typology of forms of government[2] is inextricably interrelated with a theory of social causality: the variety of human passions, as it is reflected in the morals, customs and ideas of collective happenings, absorbed in

1. Kosmas Psychopedis (1999), *The philosopher, the politician and the tyrant* pp. 57-58.
2. Collatee Raymon Aron (1994), *The evolution of the sociological thought*, volume A΄, pp. 36-37.

just a few forms of government thus, enabling the interpretational demand of their comprehension. If and as long as the deeper reasons that define the historical happening and as a consequence the existing political formations are made clear, then the analysis will proceed to a more convincing depiction of the empirical reality of the phenomenon of power.

Montesquieu's three-part distinction – kingless regime, monarchy, despotism– merges, as it has already been properly pinpointed, two Aristotle governmental forms (aristocracy and democracy) in one (the kingless regime) and simultaneously separates and differentiates the Aristotle reign into two completely different regimes, monarchy and despotism[3]. The analysis of Montesquieu of these three regimes contains, as well as the Platonian, a corresponding typology, their gradual disintegration and finally their transition to a new governmental form. I consider that, exactly at this point, a common (relating the methodological targeting) reading of the writing of both thinker can start: every good sociology of the Political, to the extent it is interpreted radically as such (that is primarily as a sociological analysis) ought to thoroughly include as its factual material the man with his thought, speech, desires as well as his sometimes compulsive passions. Montesquieu and Plato move towards this direction, as I intend to prove later more at length.

II. FOUR COMMON ELEMENTS OF THE ANALYSIS IN PLATO'S AND MONTESQIEU'S WORKS

3. I will examine now those common points that unite, I would say in an impressive way, the thought of both thinkers. At first, both Plato and Montesquieu precede, from a methodological point of view, the modern weberian concept of reality through the formation of idealtypes. Plato is aware that the four false forms of government cannot cover on the whole the political formations of historical experience. There are always forms of government that more in an obscure way making their pragmatological and ideological clarification (554 b,d) doubtful and finally pending. Likewise, neither Montesquieu in the Spirit of Law refuses the historical possibility of the emergence of "faulty" regimes, that is, regimes that cannot be clearly defined in a definite, social form. The sociological orientation attempting to interrelate every political regime remains in both the same, though.

Only in his way can the formation of political governing within a certain historical reality be rendered in a meaningful way. This ideotypical approach of governmental forms heralds the scientific work of the modern sociologist who, first and foremost, is convinced for the actual possibility of existence of a conceptional and rational order of things. Since fate does not govern the world by itself, then a tight, deterministic analysis is forced to clarify the material and the natural causes that create certain types of political governing.

4. The second common point of the two thinkers is derived from the way of organizing and harnessing their endless material. Both appear being contrary to natu-

3. On this, Panayotis Kondylis (1994), Introduction, in Montesquieu, *The Spirit of Law*, p. 28.

ral-law, social-contract type regards, as they move steadily towards the direction of the sociological interpretation of empirical regimes. Their analysis is not trapped in useless discussions over the genealogical or conceptual creation of this or the other regime. Human society seems to precede itself, since its basic reason is not located on the pre-existence of a contract but just on a tiny, elementary social instinct. «The son is born in his father's house and does not detach: Here is the society and its reason» Montesquieu informs us in the *ninety-fourth Persian letter*[4]. Likewise, Plato uses this archetypal tensed relationship between father-son to explain, on an individual psychology level, the downward shift of human selections from the logical part of soul to the appetitive one. Firstly, he is the son of a good father who avoids the honors and the disputes in the timarchy regime context (549 c). Since the son himself is not by nature a bad man, when he socializes with the ones who scorn his father as being idle inside an ambitious town, he takes a neutral position and surrenders his soul to its combative and courageous part (550 a-c).

As it follows, the son of this brave man, while trying to immitate his father, is obliged to change dramatically his life, when he sees his father being slandered, killed or sent to exile due to his bad luck in the war. He surrenders his soul to its appetite and greedy part, becoming a slave of his desire to make profit (553b-c). Thus, oligarchy results from the inner fall of timarchy. As a matter of fact, the democratic man is the offspring of the oligarchic who, contrary to him, cannot distinguish between the necessary, and the not-necessary desires and thus he renders himself a victim of irrational and indecent desires. That is, reacting to his oligarchic father's greediness, the democratic son follows the insatiable way of the unrestrained desires and the absolute freedom (557e-558c). The tyrant spirit, leading his desires to self-goals and to the quick fatal transition to the tyrant regime from the democratic one, is inevitably developed. Subsequently, the individual who becomes victim of his unrestrained desires by nature and by his way of living, becomes a tyrant (573c).

A second conclusion of the analysis is derived here: the ideotypical "tight" relation between a father and a son who reside in the same house, tied, is the starting point as well as the elementary instinct of sociability from the one to the other type of government. So, the nearly undeclared civil war in the house functions as a first causal explanation of the decadence of the individual morals and consequently to the wider collective decadence that is gradually established in the city[5]. This danger of instability almost haunts Plato's thought. He says in the Laws that peace is a void word, since in reality all the states are in a state of undeclared war against all, as it is natural (626a). He becomes more revealing a few lines later in the same dialogue. All the citizens, he pinpoints, are in a state of war, since they are in the same situation within themselves (626d). The first cause, leading to civil war in the city, is thus inside us, in our inner battle. The kind of regime that will be shaped will be shown from its results. If the majority remain in control of themselves then, the political collectivity being formed will be prevailing and

4. Collate on the topic, Louis Althusser (2005), Montesquieu, *Politics and History,* pp. 32-33.
5. On the concept of rebellion inside the family as a political example of civil war in ancient Greece, see Giorgio Agamben (2016), *Stasis, Civil war as a political paradigm*, pp. 11-34.

self-sufficient. Additionally, if the majority become, slaves of their desires, the regime in which they will be living, will be correspondingly insufficient and enslaved. This causal interrelation of passions and regimes leads to unsteady and variable causal relations, a fact which also explains the decay of every regime of the historical experience.

5. A third common point of the two thinkers lies in their attempt to define every regime according to the morals and habits of people living in it. Plato already uses the expression "moral of the *Republic*" in his book the Republic in order to connect a regime with a certain type of human behavior (548 c, κ.ε.). Thus, the timocratic regime has the passion for distinction and ambition because of the prevalence of the spirited part of the soul in the soul, which establishes the prevailing type of the timocracy citizen (548 c). The wide version of honor as social behavior is what determines the way that citizens act in this regime. As private wealth is accumulated in the state, though, the passion for distinction and honors is subdued.

A new passion, the passion for wealth, abases the timocratic regime and leads to the transition to an oligarchy regime (550 e). The prevailing type of the greedy citizen has under control only a part of the spirited part of soul and focuses his attention to the necessary desires. His greedy tendency towards the ever-increasing wealth corrodes such a man existentially, resulting in indulgence and idleness as well as in the soul leniency. The majority of the citizens, who have yet become impoverished will not take long to rebel when they face their rulers' impotence.

The democratic society thus, emerges from the oligarchic one, to the extent that the demand for unrestricted freedom and equality becomes its focal element. That is, the cause of the formation of this regime is the passion for freedom, where anyone wants to live as one likes (557 a-b). The isonomic-democratic man gradually gets enslaved in indecent and irrational desires, as he ventures on his turbulent archipelago of his desires without being able to hierarch or distinguish between necessary and unnecessary to fulfill desires. The appetitive, downward part of the soul prevails in the consciousness, distorting the meaning of freedom and equality, from the immodesty of their application to the action. The result of this situation is the emergence of the fourth false form of government, the tyranny. The insatiable passion of the tyrant prevails in this regime in an absolute way, since his soul is attracted by this unnatural part of this desires leading him with mathematical accuracy to the existential degeneration and madness (571c-573c).

The under tyranny state consists the image and likeness of his nature, granted his authoritarian way of governing. The state is thoroughly enslaved (577c), while the total population is in a state of slavery and lack of freedom. Fear is the domineering situation in the city since everybody has to obey without protesting the orders of a tyrant unable to control even himself. The thriving as well as the decay of the states in relation with social-political behaviors and the entailing psychological mood of the citizens can be explained on the grounds of the above analyses. Plato first realizes the significance of the development of false and true consciousness to the citizens for the establishment of a functional or not regime[6]. From this point of view, it is not a mistake to allege

6. Collate on the topic, Stelios Ramfos (2015), *Kallipolis psyche. For a state of truth and justice*, p. 331.

that he first introduces the dialectic in the history of regimes, as long as he poses the specific passions that form them, in the core of an analysis that penetrates in whatever is happening in the citizens' souls. With the passion, respectively for honour, wealth, freedom or the insatiable fulfillment of any desire we are introduced to the respective ideology of each false form of government, while we also learn that the collapse of each regime is due to the degeneration or the moderation of the prevailing passion that is its domineering ideology. As follows, we comprehend that, first and foremost, the fall of a regime is due to its decaying ideological-political characteristics. This observation shows by itself the major sociological importance of the platonic analysis.

Montesquieu in the *Spirit of Laws* appears to be a loyal supporter of the platonic sociology of human passions. The three montesquian types of government, that is the democracy, the monarchy, and despotism are primarily defined in regard with two concepts the *nature* and the *principle* of government. The nature of government is defined by the number of the possessors of its prevailing power (II:I). It is attached to the general and set institutional context of a regime and its specific structure which distinguishes it from the others. So far, the analysis follows state patterns which focus on who owns the power and in what way it is practiced. Montesquieu introduces the decisive concept for the passage to a sociological aspect of regimes with the principle of government. Democracy depends on the virtue principle, monarchy on the honor principle and despotism on the fear principle. The concept of principle has to do with the eighteenth century as well as with what Montesquieu (III:I) calls "passions" that is whatever moves people to active action.

Montesquieu as Plato earlier tries to give an answer to the classical problem of the driving force of history. This type of the definition of a regime, in final analysis through its principle, can be associated with the type of definition that Marx attributes in the final analysis to the economy, definition which does not ignore the affecting significance of politics[7]. The fundamental principle of a regime is its ideology in the language of marxistic sociology. The principal point of coincidence thus, between Plato and Montesquieu is consequently, their mutual targeting on the ideological-political issue: in Plato, the human passions reflect historical experiences of development of the false and the true consciousness.

Human passions are the driving force of the acme and the decadence of regimes. Likewise, in Montesquieu, the expressed passion through the principle of each regime are considered not as moral but mainly as sociopolitical sizes. The power of principles (that is the ideology of each regime) sweeps away everything and for this reason Montesquieu, as well as Plato, explains that the corruption of each regime always starts with the corruption of its principles (VIII:I). It should be noted that the content similarities of the analysis at the partial passions-principles of each regime are important. Thus, virtue as the principle of the timocratic regime consists a qualitative criterion for the way of exercising the power in the context of a more or less moderate regime (III:III). The montesquian virtue of the democratic citizen is a politicosocial size that intensely reminds the platonic idea of the good as the cause of truth for the formation of the

7. Louis Althusseur (2005) as stated before, pp. 65-66.

optimum state. In their analysis of honor as principle Plato and Montesquieu coincide: Plato analyses the philosophical lack of the democratic man, who is constantly seeking approval and distinction without ever surrendering to the true knowledge.

Finally, the prevalence of the spirited part of soul leads this tough and arrogant man to the ignorance of the spirit of honour in favour of his private enrichment. In the same thinking pattern, Montesquieu highlights the fake, from a philosophical point of view, principle of honor of the monarchy regime. Honor is born from the desire of distinction of a certain social class, the class of the aristocrats. It is about the passion of a social class putting itself innately superior to the others. The lie is in giving the impression of ethic and value to reasons that only have to do with the futility of a class. Althusser named honor just to the point as the speech cunning of the noble class, since finally their honor has no relation with either the truth nor the ethical order of the worldly issues[8].

The principle of fear is the common ideological position for the analysis on the one hand of the platonic tyranny as well as of the montesquian despotism, on the other. Plato considers in the Republic that even the suspicion of the existence of the free spirit of some citizens is enough so as the tyrant to bring about war conflicts and even surrender these citizens to his enemies (567a). The tyrant as well a his subjects in a state under the state of tyranny are in an unfree and enslaved regime. By force, such a town is full of fear whereas cries, weeping and sighs come out by its people (578a). Fear does not need to be defined, because as Aron cleverly remarks, it is an elementary feeling and in some way sub-political[9]. Thus, the main characteristic of the montesquian analysis is that this regime does not have fundamental laws since it is not subjected to a social, political or legal structure.

Montesquieu conceives despotism as the absolute evil, as that regime where the despot decides uncompromisingly and without judging any arguments. The life of the despotic regime is entirely the life of the immediate passion. For this reason, fear is not even a compound and cultivated passion, neither a social passion since it knows no codes or laws[10]. As Montesquieu locates fear as the prevailing passion of despotism and actually in its most ideotypically enraged immediacy, he seems to be talking directly with the corresponding analysis of the platonic tyranny which locates on the face of the despotic ruler the ultimate irrationality and illegality of the desires as the cause of his miserable choices. The tyrant cultivates fear in the town, exactly because he himself cannot set under self-reflection the quality of his desires, fact which makes him kill his potential rivals out of his insecurity.

6. The fourth common point of the two thinkers emerges by interpreting their mutual demand for the materialization of a harmonious, as much as possible, unity referring especially to the function of a good regime. In Plato's *Republic*, the demand for unity presupposes the common soul dedication and the coincidence between interests and convenience. Furthermore, such a state is fair when the three kinds of vir-

8. Althusser, as stated before, pp. 88-95.
9. Aron, as stated before, p. 43
10. Althusser, as stated before, pp. 102-103.

tues that it contains, wisdom, bravery and modesty each exercise their own task. In this way, the logical part of soul, which must rule, is activated in respect with the three virtues, the appetitive part which is ruled and the spirited part of soul which assists the logical part and it gives it the power to curb the desires and passions to moderation[11] . If justice means everyone to occupy the position in the state which by nature suits him, without interfering in actions that don't suit him (433a), then the social differentiation which will create the creation of a fair is necessary. The guards-rulers, that is the philosophers are put at the top of the pyramid as the political *βουλευτικόν* which corresponds to the logical part of soul. The guards-fighters follow which correspond to the spirited part of soul. The producers follow, that is, the simple citizens who correspond to the appetitive part of soul (441c). Only the guards rulers are ruled by the good and keep safe distances from the satisfaction of partly desires. Thus, they provide the needed modesty to exercise power with moderation and subsidence having as a goal the total benefit of their state. This is the reason why Plato is critical to the democracy of his time: since democracy practically equals the equal with the unequal, since its psychological foundation is the sensuality, it loses any moderate characteristic resulting in complete disorder and unruling anarchy.

In his turn, Montesquieu himself defends a moderate regime based on the concept that no one can rule in an authoritative way and against the law. His goal is the sharing of the prevailing power in mutually balanced regulating bodies of in practice. Even though Montesquieu is widely known for his notable separation of the three forms of power (legislative, executive, judiciary) in the legal meaning of the term, in contrast modern sociological analysis has revealed with convincing arguments that his basic idea is not the separation of powers but what we would call a balance of the social powers as the term of political freedom. That is, the real work of Montesquieu is the political problem of the correlation of the powers and not the legal problem which concerns the definition of legality and of its aspects[12]. Moderation in Montesquieu's work concerns the balanced distribution of power to the certain power centers: the king, the nobles and the simple people. Let us remember, by the way, the three-part distinction of the individual soul and of its counterparts, the three social classes in Plato's work.

We can highlight now the meaning of the three part distribution of power to the corresponding three power centers of the montesquian work applying the common idea that connects the work of the two philosophers: their goal is the continuous collaboration among all the parts so as the mutual control and balance are practiced and harmonized in the body of an enlightened form of government which will self-restrict the executive power. It should be noted that Montesquieu as well as Plato reject the idea of a democracy without representatives and rules, where the poor people will have the power. This democracy is an imminent despotism where its hedonistic equalizing elements will inevitably destroy the unifying grounds of the state and will defi-

11. For the structure of the right state in Plato see Konstantinos Despotopoulos (1980), *Political Philosophy of Plato*, 2nd edition, pp. 63-101.
12. See for this issue Althusser's analysis, as stated before, pp. 113-125.

nitely establish a totalitarian regime of political lack of freedom.

III. FINAL CONCLUSIONS

7. Summarizing, the two thinkers present quite many common characteristics which must become further clear by modern sociological analysis. The ideotypical approach of regimes through their structure as social types, the anti-idealistic comprehension of the existing societies resulting in the causal interpretation of the acme and corruption of each regime, the emergence of human passions and consequently of the ideology as the driving force of the regimes and the collective action and finally, the modest targeting of both while attempting the formation of a good and functional regime, consist at least four points on which their thought crosses each other.

Regarding now the interpretation of modern regimes through the extension of desires by opposingly targeted subjects, I consider, the basic study and familiarization with work of Plato and Montesquieu is absolutely necessary.

BIBLIOGRAPHY

Agamben, Giorgio (2016), *Stasis. The civil war as a political paradigm,* Athens: Koukkida.

Althusser, Louis (2005), *Montesquieu, Politics and History,* Athens: Plethron.

Aron Raymon (1994), *The evolution of the sociological thought, volume A΄*. Athens: Gnosis.

Despotopoulos, I. Konstantinos (1980), *Political Philosophy of Plato*, 2nd edition, Athens: Papazisisis.

Kondylis Panayotis (1994), «Introduction» in Montesquieu, *The spirit of Law*, Athens: Gnosis.

Montesquieu (1994), *The Spirit of Law*, Athens: Gnosis.

Plato (1988), *Laws*, Athens: Legal Library.

Plato (2002), *Republic* (redaction N.M. Skouteropoulos), Athens: Polis.

Ramfos, Stelios (2015), *Kallipolis psyche*. For a state of truth and justice, Athens: Armos.

Psychopedis, Kosmas (1999), *The philosopher, the politician and the tyrant,* Athens: Polis.

A2.2 The Illiberal Democracy of Ancient Athens

Aristides N. Hatzis
Associate Professor of Philosophy of Law & Theory of Institutions
Department of History & Philosophy of Science, University of Athens

Abstract

Ancient Athenians introduced democracy, majoritarianism and popular sovereignty. They also introduced populism and rent-seeking. Moreover, Athenians didn't invent the rule of law. The power of demos was almost unlimited, there were no constitutional guarantees, checks and balances. The laws were subjected to the whims of the majority of citizens or judges. Most importantly, individual rights were not recognized in Athens. The concept of liberty in Ancient Athens was very different from the concept of liberty that prevailed after the Great Revolutions of the late 18th and the early 19th century which led to the contemporary liberal democracies. We will discuss these issues with reference to famous historical episodes and trials.

1. Ancient and Modern Liberty

On February 13, 1819, thirty years after the break of the French Revolution and four years after the Bourbon Restoration, Benjamin Constant, a leading liberal intellectual of the era delivered one of the most important lectures in the history of political theory.

Benjamin Constant was 52 years old at the time, a veteran liberal activist and a very respected personality in French politics and letters. He delivered his lecture at the Athénée Royal, under the title: "The Liberty of Ancients Compared with that of Moderns" (*De la liberté des Anciens comparée à celle des Modernes*). This speech remained rather obscure for almost 150 years before it was rediscovered by contemporary scholars.

In this lecture, the most important argument of Constant is very simple: Athens was a democracy but not a liberal democracy. Even though it was the best democracy of antiquity, it was not equal to the advanced democracies of the 19th century. The reason being that Athenians were quite free but not as free as an individual in a modern liberal constitutional democracy.

Let me explain first what a liberal democracy is.

Democracy is essentially a way of reaching collective decisions. The democratic way to decide collectively is the majority rule. When there is a disagreement – and in a genuine democracy there is always disagreement – the decision by a majority ensures political legitimatization because it sounds (and it is) fair. At the same time, majority rule is the decision-making process most compatible with freedom. The principle of popular sovereignty based on majority rule is called the democratic principle that it

was literally invented in ancient Athens.

However, one could ask: is it politically desirable for the majority to decide on everything? No. There is an area where individuals should be free to decide for themselves even when their decisions have an impact on society-at-large. This area is protected by individual rights. Individual rights define the area of personal freedom where the society, the majority, the government cannot intervene. What's the extent of this area? It depends on the amount of freedom society has conceded to individuals. Let's call this the liberal principle. The liberal principle was introduced by James Madison in the U.S. Constitution of 1787 and the U.S. Bill of Rights of 1789.

Consequently, in a liberal democracy there is a personal domain protected by negative rights. This domain should be shielded not only from an authoritarian government but also from a democratic majority. This domain should be under the protection of the rule of law and its most powerful institutional weapon: the Constitution. A society where people are regularly called upon to express their values, preferences and choices through voting and where an extended area of personal liberty is safeguarded by the rule of law is a liberal society. Individuals in this society are in charge of their life, they are personally autonomous. In such a society well-being is linked to individual preferences. It is not determined by society, by a majority or by a committee of experts. Well-being is achieved by the satisfaction of preferences through choices and contracts.

To understand the antithesis between the democratic and the liberal principle let's see how John Stuart Mill defends this par excellence individual right: "If all mankind minus one, were of one opinion, and only one person were of the contrary opinion, mankind would be no more justified in silencing that one person, than he, if he had the power, would be justified in silencing mankind" (On *Liberty*, 1859, II.1).

Athens was a democracy, but not a liberal democracy. Athenians discovered the majority rule but not individual rights. Furthermore, one can hardly characterize Athenian government a rule of law. Because in a rule of law, as Aristotle later defined it, law is above men, even majorities: "And the rule of the law, it is argued, is preferable to that of any individual. On the same principle, even if it be better for certain individuals to govern, they should be made only guardians and ministers of the law." (Aristot. Pol. 3.1287a). In Ancient Athens, the people, the Demos, *hoi polloi*, were politically dominant and nothing was there to restrain them. There was no Constitution, laws could be annulled or nullified by a temporary majority, there were no checks and balances. Athens was an illiberal democracy.

Let's see what is exactly the argument of Constant. According to him liberty for ancient Greeks

> *consisted in exercising collectively, but directly, several parts of the complete sovereignty; in deliberating, in the public square, over war and peace; in forming alliances with foreign governments; in voting laws, in pronouncing judgments; in examining the accounts, the acts, the stewardship of the magistrates; in calling them to appear in front of the assembled people, in accusing, condemning or absolving them. But if this was what the ancients called liberty, they admitted as compatible with this collective*

freedom the complete subjection of the individual to the authority of the community. You find among them almost none of the enjoyments which we have just seen form part of the liberty of the moderns. All private actions were submitted to a severe surveillance. No importance was given to individual independence, neither in relation to opinions, nor to labor, nor, above all, to religion. The right to choose one's own religious affiliation, a right which we regard as one of the most precious, would have seemed to the ancients a crime and a sacrilege. In the domains which seem to us the most useful, the authority of the social body interposed itself and obstructed the will of individuals. [...] *Thus among the ancients the individual, almost always sovereign in public affairs, was a slave in all his private relations. As a citizen, he decided on peace and war; as a private individual, he was constrained, watched and repressed in all his movements; as a member of the collective body, he interrogated, dismissed, condemned, beggared, exiled, or sentenced to death his magistrates and superiors; as a subject of the collective body he could himself be deprived of his status, stripped of his privileges, banished, put to death, by the discretionary will of the whole to which he belonged.*

At this point Constant makes a distinction. Ancient Athens had not the same kind of democracy with the rest of them. Athens was a special case. Athenians lived freer lives than most Greeks and their democracy had some similarities with modern liberal democracy:

There was in antiquity a republic where the enslavement of individual existence to the collective body was not as complete as I have described it. This republic was the most famous of all: you will guess that I am speaking of Athens. [...] [*O*]*f all the ancient states, Athens was the one which most resembles the modern ones.* [...] [*Athens'*] *example might be opposed to some of my assertions, but which will in fact confirm all of them. Athens, as I have already pointed out, was of all the Greek republics the most closely engaged in trade, thus it allowed to its citizens an infinitely greater individual liberty than Sparta or Rome. If I could enter into historical details, I would show you that, among the Athenians, commerce had removed several of the differences which distinguished the ancient from the modern peoples. The spirit of the Athenian merchants was similar to that of the merchants of our days.* [...] *Observe how their customs resemble our own.* [...] *In their relations with strangers, we shall see them extending the rights of citizenship to whoever would, by moving among them with his family, establish some trade or industry. Finally, we shall be struck by their excessive love of individual independence.*

Nevertheless, even though Athens had the more liberal regime in Ancient Greece, it could hardly be characterized a liberal democracy. The "complete subjection of the individual to the authority of the community" was there too:

However, as several of the other circumstances which determined the character of an-

> *cient nations existed in Athens as well; as there was a slave population and the territory was very restricted; we find there too the traces of the liberty proper to the ancients. The people made the laws, examined the behavior of the magistrates, called Pericles to account for his conduct, sentenced to death the generals who had commanded the battle of the Arginusae. Similarly, ostracism, that legal arbitrariness, extolled by all the legislators of the age; ostracism, which appears to us, and rightly so, a revolting iniquity, proves that the individual was much more subservient to the supremacy of the social body in Athens, than he is in any of the free states of Europe today.* [...] *Ostracism in Athens rested upon the assumption that society had complete authority over its members. On this assumption it could be justified.*

Apparently Constant overemphasized the importance of the institution of ostracism – and he is right: ostracism is incompatible with a liberal democracy. Did he pick ostracism because it was the most illustrative example for his case or because he lived in political exile himself so many years, ostracized by almost every authoritarian French government, the revolutionaries included? Are there any other examples of the illiberal nature of the Athenian democracy and the absence of the rule of law? More than enough. We are going to present some of them in the third section. But before that we have to briefly discuss the nature and the guiding principle of the Athenian Democracy.

2. Athenian Democracy and Popular Sovereignty

I am not going to narrate the history of the development of the democratic institutions in Athens and I am not going to describe them. The literature (older and recent) on Athenian democracy is rich and of a very high quality, given our constraints to document a kind of political organization so far, in many respects, from ours. Still, I have to clarify some issues and emphasize some characteristics of the Athenian system of government.

I will start with something that is rarely stressed when Athenian democracy is described: the concept of democracy was not developed theoretically in parallel with the institutional development of Athenian democracy. Democratic theory was embryonic in the fifth century BC. Of course we can find some ideas developed by philosophers (like Plato) and play writers (like Aeschylus) and we should not understate the importance of Pericles' Funeral Oration, one of the most important political texts in human history. However, we don't have rigorous (democratic) political theory before Aristotle.

On the other hand, the institutional development for at least 250 years (from Solon's reforms to the end of Athenian independence when Great Alexander consolidated his power in Southern Greece) was more than impressive. It was radical, innovative and complex. At the same time, it was not always consistent and based on principles. Even a century after Cleisthenes' reforms the average Athenian had a rather ambiguous idea of what Democracy meant. The lay people in Athens, but also the intellectuals, identified democracy with a set of institutions which safeguarded popular sovereignty. But for a lot of them, democracy was the equivalent of a mob rule since the uneducat-

ed farmers, laborers, small-size merchants and sailors were always the majority. A majority which was fallen prey, very often, to demagogues, opportunists and chauvinists. Despite its lack of definition, democracy was very popular in Athens. Even its enemies disguised themselves as democrats. The Thirty Tyrants' reforms were called "democratic" while the brutal authoritarian regime was executing 1,500 prominent democrats.

That is why one additional institutional development was necessary: a legal clarification of what democracy really means. This development came rather late. In 337 BC, at the eleventh hour of Athenian democracy, the Law of Eukrates identified Democracy with Popular Sovereignty for the first time in legal history:

> *If anyone should rise up against the Demos for tyranny or join in establishing the tyranny or overthrow the Demos of the Athenians or the democracy in Athens, whoever kills him who does any of these things shall be blameless.*

The original idea in this decree was the fact that the good under legal protection was not anymore (as in previous legislation against subversive activities) the vague concept of Democracy but the more politically tangible concept of Popular Sovereignty. Demos was the only source of political power and political legitimization. The decree was written up on a marble stele capped with a relief depicting Democracy crowning the seated Demos. Political symbolism was more than clear.

At the end of its life, the ancient Athenian Democracy was a genuine democracy, a political system which literally gave absolute power to the people. But it also gave to the people the right to abuse this power, absolutely.

3. Democracy Without Individual Rights

Athenian citizens had rights, but these rights were political rights, not individual rights. This means that Athenian citizens had a right to participate in politics, to vote and be elected. One could say that they had a share in the Athenian political community - of course not all the inhabitants of Attica but only a 10-12% of its total population (the free adult men of Athenian birth with a full citizen status were 30,000 in the fifth-century Athens of more than 250,000 residents).

But these rights were not owned by the citizens in the way individual rights are attached to persons today. Athenian citizens were not "individuals" (individualism had not been invented) but parts of an organic whole. The "individualistic" behavior was identified with selfishness and it was not tolerated by the political system – ostracism was the safeguard. It was also frowned upon by philosophy and poetry. Heroes of Greek mythology with alarming individualistic tendencies were accused of hubris and their end was predestined.

Individual rights could not be invented in such an environment. Aristotle has described the limits of the individual in his early social contract theory which sounds a lot like the one advocated by Thomas Hobbes, 2 millennia later. A man cannot survive as an isolated individual because he is by nature a social animal. He cannot be con-

ceived otherwise but only as a part of society. Polis is naturally prior to an individual, because an individual cannot exist apart from society. Not only because he is not self-sufficient but also because he cannot be conceived as something separate from society. And since he cannot be a god he is clearly a beast.

To use Constant's terminology: the individual was not only subservient to the supremacy of the social body – it was unnatural for him to be conceived as something separate from the social body. This was the conventional wisdom in Ancient Greece, even in the democratic Athens. Individual rights, i.e. negative rights against the political community were thus unthinkable.

4. Democracy Without the Rule of Law

The Athenian Democracy was not a constitutional democracy. Athens didn't have a constitution. So the power exercised could not be restrained. Yes, there were laws prescribing procedures. However, these procedures could have been changed rather easily if a temporary majority wished so. Retroactivity was not common but it was not alien to the Athenian legal system. The Jury system was dominant. Actually the trials in Athens were less trials by jury and more trials by a political body with 501 members. It would be difficult for any lawyer to present evidence and use rational argument to such a formidable body. The fact that there were no lawyers, but the accused had to defend themselves with some help from a speech prepared by a professional speech-writer was illustrative. Athens was a clear case of a political system ruled by men, not laws.

We don't wish to belittle the progressive nature of this political system for its era. Athenians had more safeguards to protect them against arbitrary power than any other nation on earth. In addition, they felt free and independent. But this was, in a certain degree, a mirage. There is a number of trials which can testify for this.

One of the most famous examples is the trial of the generals after the (victorious for Athens) naval battle of Arginusae. 6 of the 8 generals were prosecuted (the other two chose self-exile) because they failed to rescue the survivors of sunken triremes due to a wild storm in the area. The six generals were sentenced to death after a messy trial, a mix of political maneuvers and emotional outbursts despite the attempts of several officers to enforce the law and ensure a fair trial. They failed miserably. One of the law-abiding officers was Socrates who was an "epistates" (president of the court), the only public office he had in his life.

The failure of protecting the "rights" of the defendants in the Arginusae trial and the dodging of the law to achieve political ends led to the prosecution of Socrates himself. The real prosecutor was not Anytus but the Democratic Party itself. Anytus was a rather ill-reputed nouveau riche politician who became popular (despite his doubtful past) when he actively participated in the overthrown of the Thirty Tyrants. He epitomized a widespread resentment of the members of the Democratic Party against the criticism of Socrates to the idea of majority rule, popular sovereignty and democratic governance. Socrates critique was not necessarily dismissive of democracy. But it was clearly critical in one aspect: Socrates was an adherent of the idea of a rule of law.

For Socrates laws were not just "Covenants, without the Sword, [but only with]

Words". Socrates attested to his conviction with his teaching and his choices. In probably the most famous passage in political philosophy he explains why (Plato, *Crito* 50a-b):

> *Consider this: What if the laws and the government come and interrogate me: "Tell us, Socrates," they say; "what are you about? are you going by an act of yours to overturn us- the laws and the whole State, as far as in you lies? Do you imagine that a State can subsist and not be overthrown, in which the decisions of law have no power, but are set aside and overthrown by individuals?"*

Socrates' persecution and punishment was such a shock to his followers that led, essentially, to the birth of political philosophy. The impact of this shock is evident in Aristotle but it is also evident as far as the official proceedings of the Constitutional Convention of the U.S. Constitution of 1787.

Despite the infamous legacy of the Socrates trial, there is another trial, a political trial, which is the best example for our purposes. It is the case of the unlawful award of a golden crown to Demosthenes after a proposal of his political ally, Ctesiphon, in 330 BC. Aeschines, who was then a political opponent of Demosthenes, decided to persecute Ctesiphon (injuring Demosthenes at the same time) because the particular honor was against the law since Demosthenes was still in office and the ceremony took place in Dionysia. It is clear that Ctesiphon violated the law with his proposal. Aeschines waited for six years to find the right time for the persecution of Ctesiphon until 336 BC. In his very well organized, structured and reasoned speech (Against Ctesiphon), Aeschines demonstrated the unlawfulness of the proposal based on facts and the written law of the city. In a much cited passage he declares that the Athenian Democracy is a rule of law. He explains to the jurors why this is important (Aeschin. 3 6):

> *There are, as you know, fellow-citizens, three forms of government in the world, tyranny, oligarchy, and democracy. Tyrannies and oligarchies are administered according to the tempers of their lords, but democratic states according to their own established laws. Let no man among you forget this, but let each bear distinctly in mind that when he enters a court-room to sit as juror in a suit against an illegal motion, on that day he is to cast his vote for or against his own freedom of speech. This is why the lawgiver placed first in the jurors' oath these words, "I will vote according to the laws." For he well knew that if the laws are faithfully upheld for the state, the democracy also is preserved.*

Some scholars cite this passage as a proof that the Athenian Democracy was a rule of law after all. But this is not a description. This is an argument. An argument that Aeschines lost bitterly.

Despite his brilliant speech he couldn't persuade more than 1/5 of the jurors. All the others were mesmerized by Demosthenes' speech. Demosthenes didn't bother much with legal arguments; he didn't even offer decent counter arguments to Aeschines.

He just delivered one of the greatest political speeches in history. It is characteristic that he announces from the very beginning that his arguments will be purely political (Dem. 18.11).

> *Malicious as you are, Aeschines, you were strangely innocent when you imagined that I should turn aside from the discussion of public transactions to reply to your calumnies. I shall do nothing of the sort: I am not so infatuated. Your false and invidious charges against my political life I will examine; but later, if the jury wish to hear me, I will return to your outrageous ribaldry.*

The devastating defeat of Aeschines was also a defeat for the idea of the rule of law.

5. An Imaginary Open Society

Athens was never a rule of law. Individual rights were not recognized. It was an illiberal democracy. Benjamin Constant was right when he stressed the differences with modern democracies. Nevertheless, Athens was not just another democracy. Athenian democratic institutions were sophisticated and the atmosphere of freedom pervasive. We cannot but discern in political and legal texts, like that of Aeschines or Plato, that Athenian intellectuals longed for more. I am going to refer briefly to three texts, a tragedy, a comedy and a political speech. They share the same uncanny insight for a rule of law, for individuality and for a tolerant liberal society (respectively).

In Eumenides the goddess Athena establishes Areopagus with a declaration which is impressive because she promises one of the pillars of a rule of law: an impartial judiciary, bound only by laws (Aesch. Eum. 470-490):

I will select judges of homicide bound by oath, and I will establish this tribunal for all time. Summon your witnesses and proofs, sworn evidence to support your case; and I will return when I have chosen the best of my citizens, for them to decide this matter truly, after they take an oath that they will pronounce no judgment contrary to justice.

Aristophanes in The Acharnians introduces a character who is an Athenian citizen and decides to make a private peace with Sparta. Aristophanes wrote the play during the Peloponnesian War, while he was persecuted by Cleon, a warmongering demagogue. It is not a coincidence that when Dikaeopolis, the protagonist, decides to behave as an autonomous individual, disillusioned with the collective decision-making (at the Ecclesia), he has to confront social stigma and contempt but also hostility by his countrymen.

> **Chorus**
> *You ask that, you impudent rascal, traitor to your country; you alone amongst us all have concluded a truce, and you dare to look us in the face!*
>
> **Dicaeopolis**
> *But you do not know WHY I have treated for peace. Listen!*

Chorus
Listen to you? No, no, you are about to die, we will annihilate you with our stones.

He manages to persuade them by stressing the aggressions of the Athenian democracy (Aristoph. Ach. 496) and then, the first thing he does (after ridiculing Lamachus a war-mongering general who was considered a war hero), is to establish a private market - a market where trade is welcome even with belligerent nations!

Dicaeopolis
For my own part, I make proclamation to all Peloponnesians, Megarians and Boeotians, that to them my markets are open!

Dicaeopolis' individualistic behavior is vindicated and his fellow-citizens acknowledge it using the word "Eudaimonia" (Aristoph. Ach. 836):

Chorus
The man is truly blessed. Didn't you hear how his enterprising plan is progressing? The man will reap a bumper crop by sitting in his market.

Finally, Pericles himself, in his Funeral Oration, describes Athens as a tolerant liberal democracy in an extraordinary passage (Thuc. 2.37):

There is no exclusiveness in our public life, and in our private intercourse we are not suspicious of one another, nor angry with our neighbour if he does what he likes; we do not put on sour looks at him which, though harmless, are not pleasant.

There is no historical evidence certifying that Athens was such a society, an open society like a contemporary liberal democracy. Apparently Pericles was exaggerating or most probably Thucydides let his imagination free when he described Athenian Democracy. His insight, as well as the insights of the two poets are a living proof of a vibrant intellectual life which maybe had not been reflected in institutions and everyday life, but it inspired and it still inspires the ideas of freedom.

** The author is thankful to Yulie Foka-Kavalieraki and Nicholas Hatzis for useful comments.*

Texts:

Aeschines, *Against Ctesiphon* (translated by Charles Darwin Adams). Cambridge, MA: Harvard University Press, 1919.

Aeschylus. *Eumenides* (translated by Herbert Weir Smyth). Cambridge, MA: Harvard University Press, 1926.

Aristophnes, *Acharnians* (translated by Jeffrey Henderson). Cambridge, MA: Harvard University Press, 1992.

Aristotle, *Politics* (translated by Benjamin Jowett). New York: Colonial Press, 1899.

Demosthenes. *On the Crown* (translated by C.A. Vince and J.H. Vince). Cambridge, MA: Harvard University Press, 1926.

Eukrates, *Decree Against Tyranny* (translated by Benjamin Meritt), Esperia 21: 355-59 (1952).

Plato, *Crito* (translated by Benjamin Jowett). New York: Century, 1903.

Thucydides, *History of the Peloponnesian War* (translated by Benjamin Jowett). Oxford: Clarendon Press, 1881.

A2.3 The Mottling Between the State of the Nation and the Nation State in the Political Project of I. Capodistrias. A Case Study Analysis of I. Capodistrias World- View for the Formation of the Greek Nation

Asst. Prof. Dionysios Tsirigotis
University of Piraeus

Abstract

How Hellenism is established within history? What are the conformational factors regarding the formation and restraint of the Greek nation? What is the relationship between the Greek nation and conceptualization of nation state?
These questions revolve around the central problematics of this study, emphasizing on intersubjective factors, i.e. the notion of nation-state, national identity and historical continuity or discontinuity of the nation. By this remark, we specify our analysis in the political-strategic project of I. Kapodistrias before, during and after the Greek regeneration. It is in this manner that we attempt to demonstrate and explain the core features of the Greek governor's worldview, thinking and practice in relation with his political endeavor to organize the newly established Greek state.
A starting point here may be the intersubjective elements, on the basis of which, each collective entity decides to become autonomous and to determine its political, economic and social structure. In this context, the official discourse of I. Kapodistrias crystallizes the necessary and sufficient factors – spirit, religion, customs, historical origins, common descent – both for nation's construction as well as its preservation and political-strategic orientation.
Accordingly, national formation process is implemented and completed by an "existential decision" for the selection of intersubjective (patriotism, traditions, metaphysical world) and objective (geographical location, population, wealth-producing resources, technology) factors, so as an appropriate kosmoeikona to guarantee its survival and promote the national interest is formed. In this respect, the endless political goal of national integration – Great Idea – was formed by I. Kapodistrias as an appropriate cosmo-icon for the strategic orientation of the Greek nation. In its minor form, it could be look like I. Kapodistrias's State, while in its major portrayal corresponds to the ecumenical dimension of Hellenism as nation-cosmosystem.
In retrospect, by expanding the methodological reflection of this study to its starting point, i.e. the conceptual definition and factual operation of nation throughout the political thought wave of I. Kapodistrias, we conclude to the apparent connection between nation and state. This end is found on the anthropocentric cosmosystemic base of Greece's historical acquis as the heritage of Greek Cosmopolis (Constantinople) confirms.

The organization of humanity in collective groups, of any form and size, "sometimes sharply defined and sometimes lose",[1] derived from the perpetual necessity for survival-safety, is an axiomatic assumption of the evolution of international systems, from antiquity to nowadays[2]. Promptly, the transformation of the sociopolitical organization of collective entities into distinct communities within certain territorial limits governed by a central power, is a result of remapping the territorial status of Western Europe by the peace treaty of Westphalia (1648). This development marks the beginning of the modern international system with the ontological foundation of the nation state as a dominant form of collective sociopolitical organization[3].

Accordingly and respectively, the vital need for the formation and retention of the modern state will raise the need of ethnogenesis by developing collective identities. In this environment, the claim of collective freedom of Hellenism is arisen culminating by the national fight for regeneration pushing the European despotisms,[4] in the founding act of birth of the Modern Greek state.[5] The resolution (VI) of the Third National Assembly of Troizina (April 6, 1827), which elected the earl I. Kapodistrias "in the name of the Greek nation" as governor of the modern Greek state[6] and the defeat of the Ottoman fleet in the Battle of Navarino (October 1827) took place in the meanwhile. Seen in this light, the objective of this study is to investigate and interpret the political-strategic project of I. Kapodistrias for the realization of national integration, having as central axis the position-role of the Greek nation to add meaning and lead the national reorganization and it is reflected on the following axial questions:

How is the Hellenism established during historical diachrony?

What are the conformational constitution-retention factors of Greek nation?

What is the relationship of the Greek nation with the modernist concept of the nation state?

These questions are rotated around the central issue of this study and examined on a case by case basis with reference to the political imperative of I. Kapodistrias for the realization of national integration.

---

1. Ernest Gellner, *Nations and Nationalism*. Oxford: Basil Blackwell, 1983, p.53.
2. Robert G. Gilpin, "The richness of the tradition of political realism", *International Organization*, vol. 38, no. 2 (1984): 287-304, (especially p.290). Generally for the development of international systems, from antiquity until modernity see: Adam Watson, *The Evolution of International Society. A comparative historical analysis*, London & New York: Routledge, 1992. Barry Buzan & Richard Little, *International systems in world history. Remaking the study of international relations*. Oxford: Oxford University Press, 2000.
3. 3 John Gerard Ruggie, "Territoriality and Beyond: Problematizing Modernity in International. Relations". *International Organization*, vol. 47, no.1 (1993): 139-174. Andreas Osiander, *The States System of Europe, 1640–1990*. Oxford: Oxford University Press, 1994.
4. In the context of rational considerations of the forthcoming arrangement of Anatolian issue and the resulting formed of the balance of power in the wider perimeter of the Eastern Mediterranean and the Balkan Peninsula.
5. With the first of the three protocols of London on January 22nd / February 3rd, 1830, Greece was declared a dominant / independent state. Απόστολος Ε. Βακαλόπουλος, *Ιστορία του Νέου Ελληνισμού*, vol. 6. Athens: Herodotus, 2007, pp. 489-524. Διονύσιος Τσιριγώτης, *Νεότερη και Σύγχρονη Ελληνική Ιστορία. Διεθνείς Σχέσεις και Διπλωματία.* Athens: Piotita, 2013, p.59.
6. See, Ανδρέα Ζ. Μάμουκα, *Τα κατά την αναγέννησιν της Ελλάδος. Ήτοι, συλλογή των περί την αναγεννώμενην Ελλάδα συνταχθέντων πολιτευμάτων, νόμων και άλλων επισήμων πράξεων από του 1821 μέχρι του 1832*, vol. 8. Athens: Hliou Xristophidou typography, 1840, pp. 13-14.

I) The theoretical background of ethnogenesis

Before moving on to explore the central questions, we consider the analysis of baseline principles of ethnogenesis of collective entities important. Starting from the double question whether the nation as a sociopolitical fact and its derivatives are products of modern times or inherent from the beginning of people's organization into collective entities, with different sociopolitical forms, we will demonstrate the lack of universally accepted assumptions and the impossibility of forming a general theory around it. Its cause lies in the methodological framework of theoretical discussion developed around the determining components and the spatiotemporal origins of ethnogenesis and coincides with the different historical and sociopolitical subdivisions of the development of collective life. In particular, we can distinguish three cycles, namely the pre-modernist, modernist and postmodernist.[7] This development led to different starting points about the concept of nation, its birth and configuration resulting in methodological weakness for the formation and application of a large theory of global interpretative scope.[8] Instead, the theoretical discussion was developed around two central problematics, the modernist and traditional. The former which was shaped in contrast to the traditional pre-modernist analysis,[9] fluctuates between modernist and perpetual assumptions[10], focusing on the distinguishing characteristics which turn a group, a community or other collective entity into a nation. The first ones will develop an instrumental-rationalist vision for the nation. The nation as a means of rational self-interest is instrumentally used for the collective mobilization of society by political elites. It is the sense of belonging to a collective entity that leads to the development of national identity among its members[11] . To the contrary, the second ones analyze the nation with intersubjective descriptive criteria, demonstrating its ontological, historical and social origins.[12] The nation is recognized either as a revised version of the national communities that are inherent since ancient times, or as collective cultural identities –traditions, living and being co-formed along with national communities throughout the course of historical diachrony.

By extending the above reasoning, Anthony Smith will incorporate the subjective criterion of intersubjective determination of nation by introducing a set of common standards and values, among which is the common culture, common economy, common rights-obligations that promote developing a sense of belonging to a collective entity. However, over and beyond subjective and intersubjective factors, the fundamental formative criterion of ethnogenesis is the exercise of political sovereignty. As

7. They recognize the historical antiquity of the social organization called nation, limiting the difference between ethnicity- nationality, so that the nation and the national community are recognized as related even identical concepts.
8. Anthony D. Smith, *Nationalism and Modernism: A Critical Survey of Recent Theories of Nations and Nationalism*. London and New York: Routledge. 1998, p.221.
9. Smith, *Nationalism and Modernism*, p.146
10. Gellner, *Nations and Nationalism*, p.5-7.
11. Smith, Nationalism and Modernism p.157. A typical example is the Gellner's typology, for the delineation of the nation on the basis of cultural and voluntarist-voluntarist criteria. Gellner, *Nations and Nationalism*, p.5-7.
12. Smith, *Nationalism and Modernism*, p.159.

highlighted by Azar & Yakobson, a people is converted into a nation when it is politically dominant, collectively exercising the right of its political self-determination or self-government or when it constantly struggles for their realization.[13] This shows that the binary, cultural and voluntarist delimitation of nation and its construction reflect the partial rather than the complete picture.[14]

In contrast to the modernist version, this study is based on the gnosiology of Greek cosmosystem (pre-modernist tradition) for the description and interpretation of Hellenism as a nation-state. The historical continuity of the Greek nation, as identitarian reference, formed during the Cretomycenean period and continuously developing until nowadays[15] , proves to be axiomatic assumption of cosmosystemic gnosiology[16]. More specifically, the key to the typological distinction of alternative cosmosystems into anthropocentric and despotic is the degree of their freedom linked with the "cosmosystemic" time of individual, decrystallizing the stage of anthropological maturation as a political being.[18] In fact, Greek people are composed on anthropocentric basis as a cosmosystem[19] of small scale , demonstrating the sizeable number of Greek state societies, extending from Gibraltar to the Urals. Thus, it is the emergence of the city-state, as a fundamental sociopolitical form of collective organization, with freedom as a statute symbol, which comprised the foundational background of the Greek cosmosystem. In the Greek case, the concept of the nation coincides with the concept of genus, signifying a certain way of life which "makes freedom a statutory foundation of man. In this sense, "Hellenism constitutes the collective identity of Greek, attributed nowadays as nation".[20]

The conception of Greek nation on cosmosystemic basis, demonstrates both the methodological weakness of modernist school over analysis- interpretation of Greek national identity-consciousness and its stochastic error to give meaning-define the existence of nation on state-centric bases. For example, the assumption that the Greek national consciousness was developed in the 19th century, signified by the perpetual national objective of the Great Idea, is completely abstract and mis-

---

13. Azar Gat with Alexander Yakobson, *Nations. The Long History and Deep Roots of Political Ethnicity and Nationalism*. New York: Cambridge University Press, 2013, p.23.

14. Gellner, *Nations and Nationalism*, p.7.

15. Νίκος Γ. Σβορώνος, *Το Ελληνικό Έθνος*. Athens: Polis, 2004, p.25.

16. See, Γιώργος Κοντογιώργης, *Έθνος και «εκσυγχρονιστική» νεοτερικότητα*. Athens : Alternative publications, 2006. Γιώργος Κοντογιώργης, *Το Ελληνικό κοσμοσύστημα. Η κρατοκεντρική περίοδος της πόλης,* vol. I. Athens: Sideris, 2006. *Γιώργος Κοντογιώργης, Το Ελληνικό κοσμοσύστημα. Η περίοδος της οικουμενικής οικοδόμησης(4ος π.χ.-4ος μ.Χ. αιώνας*), vol. II. Athens: Sideris, 2014.

17. For more details on the distinction between the despotic and anthropocentric cosmosystem, see Γιώργος Κοντογιώργης, "Γνωσιολογία της δημοκρατίας και νεωτερικότητα. Το διακύβευμα της υπέρβασης του Δυτικοευρωπαϊκού Διαφωτισμού", Διάλογος, 4/2014.

18. Κοντογιώργης, *Έθνος και «εκσυγχρονιστική» νεοτερικότητα*, p.18-19.

19. The nation- cosmosystem, since it contains all of these identitarian parameters constitutes the concept of genus in comparison with the nation-state, which is identified as species, i.e. more specific manifestation of collective identity in the environment of the modern ethnocentric cosmosystem. (Κοντογιώργης, *Έθνος και «εκσυγχρονιστική» νεοτερικότητα*). It is worth noting that both Plato, Politeia E '470c, and Aristotle, Politics H.735, use the term Genus.

20. Γιώργος Κοντογιώργης, Η ελληνικότητα ως έθνος, το πανεπιστήμιο, η πολιτεία του Ρήγα. http://contogeorgis.blogspot.gr/search?q=ελληνικότητα

leading.[21] This is because the goal of national integration comes from the fall of the universal Cosmopolis -Constantinople, in 1453 and ends in the project of the Asia Minor campaign.

In other words, the ethnogenesis in Western Europe will be the vehicle for the disintegration of the autocracy, the anthropocentric formation of society and the development of a collective identity.[22] The formation of collective identity, as an anthropocentric and cultural fact, requires the development of national consciousness. While the identity "can be defined as the precise positioning of the entity in the world," providing "a reliable orientation framework" for the latter, "to move voluntarily and self-reactively and act in different situations with established goals and consistent feasibility"[23] becomes a determinant and connecting element of each collective entity for its transformation and recognition as nation. Thus, the concept of Greek national identity is established on multiple levels -at national-, "racial, at the level of the city's society, the level of cosmosystemic Greek identity, etc."[24]

A key implication of the above is the anthropocentric formation of Hellenism in terms of freedom, as a foundational background of its national status-identity, so that [the Hellenism] as a concept of genus, precede the nation-state of modernist Europe.

II) A case study analysis of Ioannis Kapodistrias' worldview about Hellenism concept

Coming back to baseline questions of study and having already described the cosmosystemic establishment of Hellenism macro-historically, we can demonstrate the conceptual definition of the Greek nation in the political imperative of I. Kapodistrias delving into the formative factors of Greek national identity.

Starting with the intersubjective- descriptive criteria, based on which a collective entity decides to be autonomous- self-determined socially, politically, economically, into a whole, I. Kapodistrias clearly describes the necessary and appropriate elements (spirit, religion, morals, historical origins) for the establishment of nation for self-preservation-survival and strategic orientation. Through its description, it the pre-existence of Hellenism as a nation and its historical continuity throughout the historical diachrony is evidenced, which is confirmed by its distinct national identity -the otherness over foreigners.

"[...] Strong Greece having this infinite power, passed four centuries of corruption and of all other misfortunes, without ever stopping to form a nation, and being subordinated to our divine legislator's sacred laws". [25]

---

21. See, Anna Triandafyllidiou and Anna Paraskevopoulou, "When is the Greek Nation? The Role of Enemies and. Minorities", *Geopolitics*, Vol. 7, No. 2 (Autumn 2002) : 75-98.
22. Παναγιώτης Κονδύλης, *Από τον 20 στον 21ο αιώνα. Τομές στην πλανητική πολιτική περί το 2000*. Athens: Themelio, 1998, pp.95-6.
23. Παναγιώτης Κονδύλης, *Ισχύς και απόφαση*. Athens: Stigmi, 1991, p.30.
24. Κοντογιώργης, *Έθνος και «εκσυγχρονιστική» νεοτερικότητα,* p.23.
25. Letter from I. Kapodistrias to the interim administration of Greece.
Geneva, 12 December 1825. Cited in *Ioannis Kapodistrias Archives*, vol. 7, Corfu, 1986, p.251. http://kapodistrias.digitalarchive.gr/aik.php.

"It will be, I hope, easy to show.

1) That the Greeks never stopped being a Nation in its full meaning.

2) That with this title they could enjoy the benefits of European culture.

3) That these benefits made them exceed their limits" [26]

Subsequently, regarding the question of what we mean by the term Greece, he decrystallizes the constituent parameters of the Greek nation, highlighting the intersubjective criteria of language and religion:

"The Greek nation consists of those people, who since the fall of Constantinople did not stop confessing their orthodox faith and speaking the language of fathers, and remained under the spiritual or secular jurisdiction of their church, wherever they lived in Turkey". [27]

Thus, thinking over the national identity, I. Kapodistrias identifies himself individually and collectively as Graikos [28] (Greek), demonstrating the constituent parameters of historical traditions of Greek national identity as genus. [29]

The second factor is indicated by reading the political imperative of I. Kapodistrias, the concept of national consciousness, result of the diversity of Hellenism against the Ottoman influence. More specifically, the nation as a collective entity requires first of all the development of society / national consciousness through the exact determination of its position in the world. Consequently, the development of national consciousness makes distinct the otherness of collective entity, "as a source of national energy, ecstatic and eteropios", established and retained through a "historical, pluralistic structure of traditions", [30] which encloses all standards and modulation levels of collective -national identity. In this light,

"The Greek people keeps everywhere - in connection with the Turks – its special character, religion, language, traditions, as well as moral superiority, which offers them their genius ". [31]

But what is the eteropia, the third element of Hellenism that according to Greek governor "maintains everywhere [...] its special character"?

To the extent that the nation is "the body of the complex [collective] personality" the formative element of diversity, is the "normal of collectivity", "a historical structure of traditions". [32] So I. Kapodistrias, was characterized by his biographer, C. Dafnis, as "the best expresser of this line, that gave meaning to the term tradition", defining as a

---

26. Letter from I. Kapodistrias to Bishop Ignatius. Geneva 12/24 April 1823. Cited in *Ioannis Kapodistrias Archives*, vol. 7, Corfu, 1986, p.230. http://kapodistrias.digitalarchive.gr/aik.php.

27. Answer of I. Kapodistrias to the questions of the British deputy minister for the Colonies, Ouillmot Orton, Paris, 3/15 October 1827. Cited in *Ioannis Kapodistrias Archives*, vol. 7, p. 286. http://kapodistrias.digitalarchive.gr/aik.php.

28. See, Βασίλειος Μυστακίδης, *Αι λέξεις Έλλην, Γραικός* (*Γραικύλος*), *Ρωμαίος* (*Γραικορρωμαίος*), *Βυζαντινός, Μωαμεθανός, Τούρκος*. Constantinople: [unknown publisher], 1920, p. 9

29. Letter from I. Kapodistrias to the president of Graikodakikis Company, St. Petersburg, May 15, 1811. Cited in Ioannis Kapodistrias Archives, Vol. 7, p.182. http://kapodistrias.digitalarchive.gr/aik.php.

30. Θεόδωρος Ζιάκας, *Έθνος και Παράδοση*. Nicosia: Aegean-Alternative publications, 1993.

31. Memorandum of I. Kapodistrias "The present situation of the Greeks." Cited in Ioannis Kapodistrias Archives, Vol. 7, p.210. http://kapodistrias.digitalarchive.gr/aik.php.

32. *Θεόδωρος Ζιάκας, Έθνος και Παράδοση. Λευκωσία: Αιγαίον-Εναλλακτικές εκδόσεις,* 1993, σ.91.

central prerequisite for the institutional establishment of the modern Greek state its consistency with tradition. The Greek tradition was reflected as an amalgam of ancient Greece, Byzantium and Greek communities of Ottoman rule. [33]

"Consulting your home traditions and consciousness, you will be able to clearly discern the interest of this truth. The fact that nothing else proves more comfortingly this truth is that it got out of this fraudulent policy, which was used by the Turks to make your fathers slaves, and all the miracles that God made to save them". [34]

Among the standards of collective life that are signified by the multiple traditions of Hellenism, I. Kapodistrias recognizes the following: the spirit of the nation, the metaphysical/religious element, the common historical origin and moral-normative principles.

"The Turks enslaved and corrupted the mortal part of Greece, [...]; but the soul, and through this, the spirit of the nation always remained free and independent [...] keeping pure principles and morals, which make up a nation through the connection of these people, I mean religion and by that, its general origin and voluntary allegiance to one and common intellectual dominance". [35]

The formation of national identity is not only the appropriate –necessary - condition for ensuring the survival of Hellenism's interest, but also the fundamental background of ultimate political purpose, namely the autonomy-independence claim of the Greek nation.

"[...] forming nation it had brave men in the mountains, to defend it, and so on the islands to emerge it in sophisticated world [...] to maintain its connection to that old Greece, whose spirit brought the light of science in Europe". [36]

The claim for national independence and consequently the imperative of national integration of Hellenism demonstrates the ultimate criterion of ethnogenesis since "certain groups have the need and mood, even by using myths, to define themselves as a nation and to act, live and die in the name of this nation". [37]

As the Greek governor mentions in the Fourth National Assembly of Argos, (July 14, 1829):

"This Nation wants to show directly to its respectable Allies and the entire world, that it wants and knows how to insist on its honest plan to restore through its struggles, its ethnic and political recovery". [38]

In conclusion, the political imperative of I. Kapodistrias was inspired by the Greek Community tradition having as fundamental background the anthropocentric freedom. The Greek governor obeyed the command of the nation by taking up the work of internal financial and political reconstruction and national reorganization.

---

33. *Γρηγόριος Δαφνής, Ιωάννης Α. Καποδίστριας. Η γένεση του ελληνικού κράτους*. Athens: Ikaros, 1976, p.563.
34. Letter from I. Kapodistrias to the temporary administration of the Greece. Geneva, December 12, 1825. Cited in, E.A. Βετάν, (επιμ.) *Επιστολαί Ι. Α. Καποδίστρια, Κυβερνήτου της Ελλάδος. Διπλωματικαί, διοικητικαί και ιδιωτικαί, γραφείσαι από 8 Απριλίου 1827 μέχρις 26 Σεπτεμβρίου 1831, μτφ. Μιχαήλ Γ. Σχινάς*, vol. 4. Athens: Constantinou Rhalli Typography, 1843, p.429.
35. Ibid p.429-30. 34
36. Ibid p.430-1.
37. Παναγιώτης Κονδύλης, *Από τον 20 στον 210 αιώνα*, p.95.
38. Cited in Mamouka, ibid, vol. IA', p.207.

"I did not come to Greece only to ask for a position, and especially the first one, but I obeyed at the election and call of nation, only to contribute, with all my power, to the recovery policy (of nation). This is and remains my goal". [39]

As part of this development, his decision to concentrate all powers in his face, was made by necessity [40] and by no means changes the fundamental, community form of the state-political organization that was formed through the constitutions of the Greek Revolution. [41] The fact that he reserved the Community system, highlighting the formation of a civil society, as an institutional factor and constituent partner of the Greek state, under the previous restoration of the overall freedom - personal, social, political, [42] starting from the right to property and universal suffrage, verifies the above reasoning.

"[...] I hope that within a few (days) the government will be able to give all landless residents of the provinces, a few acres of land. After that, people will be able to get rid of slavery that oppresses them, and be free to enjoy the right to vote and build communities, [...], based on laws". [43]

Conclusion

The present study attempted a metatheoretical analysis of the conceptual determination of the nation as a collective entity, among the many shades of modernist and traditional school of ethnogenesis. Having demonstrated the instrumental use of the nation as a means of rational self-interest by the modernist shades of modernity, we conclude to P. Kondylis' hypothesis for futility on the:

"search of pure races and nations, or creating a fixed list of objective general attributes, based on which people could be defined as nation. Whatever was occasionally mentioned as such a feature (origin, language, religion, etc.) was not always found or was not a necessary or sufficient condition for forming a nation. We cannot examine or even find out, whether the concept of people coincides with the concept of nation, which to a decisive extent is a political term"[44].

As a result of this development, we followed the epistemology of Greek cosmosys-

---

39. Letter from I. Kapodistrias to Colonel K. Raikos, commandant of Patras. Nafplio, March 20th, 1830. Cited in Βετάν, ibid, vol. 3. Athens: Constantinou Rhalli Typography, 1842, p.378.

40. Because of the need to balance - reduce the financial and political hegemony of notables. For this reason Kapodistrias will seek to ensure the right of universal suffrage, resting on private property. See. Letter from I. Kapodistrias to the Senate, Nafplio February 14th, 1830. Op. cit. 39, p. 357.

41. More specifically, the principle of local and regional Republican autonomy was maintained, since each step of city organization had independent governance system. Community "continue to carry out their duties as before" – They have the same powers as before that they exercise in accordance with "the rules". See, Γιώργος Κοντογιώργης, «Κοινοτική αυτοδιοίκηση και καποδιστριακό πολιτειακό σύστημα», στο *Ιωάννης Καποδίστριας* 1776-1831. *Ο κορυφαίος Έλληνας Ευρωπαίος*, εισαγ.- επιμ. – σχόλια, Π. Πετρίδης. Athens: Govostis, 1992, p.234.

42. For an a extensive analysis of the three freedoms see Γιώργος Κοντογιώργης, *Η Δημοκρατία ως Ελευθερία. Δημοκρατία και Αντιπροσώπευση*. Athens: Patakis, 2007, p. 26-9.

43. See, the letter from I. Kapodistrias to Baron Desaimvensan in Paris. Nafplio, September 8th 1830. Cited in Βετάν, ibid, vol. 4, p.98.

44. Κονδύλης, *Από τον 20 στον 21ο αιώνα,* p.94-5.

tem, for the analysis and interpretation of Hellenism as nation-state. The fundamental characteristic of Hellenism is the historical continuity, as genus, formed during the Cretomycenean period and it is continuously developed until nowadays. The identification of concept of genus with nation, in the Greek case, signifies a particular way of life under the statute foundation of anthropocentric freedom.

After all, the above assumption, controlled case by case in the political imperative of I. Kapodistrias, confirms the pre-existence of Hellenism as a nation and its historical continuity throughout the historical diachrony. The distinct national identity, which everywhere preserves its specific character, is imbued by collective standards – national traditions. Among them, I. Kapodistrias recognizes the spirit of the nation, the metaphysical element, the common historical origin and moral- normative principles. The creation and maintenance of Greek national identity emerges as a sufficient- necessary condition for ensuring the interest in the survival of Hellenism, but also as a fundamental basis of the autonomy-independence claim of the Greek nation.

A2.4 The ancient Athenian economy: a review

Nicholas C. Kyriazis and Emmanouil M.L. Economou*

Abstract

This article describes the way by which a radical change in the socioeconomic basis of Athenian society took place during the Classical period (508-322 BC). It is argued that the need to repel the imminent second invasion of the Persians in Greece, which eventually took place in 480 BCE., led the Athenians to adopt the "turn strategy into the sea" strategy and the implementation of a colossal construction program of 200 trireme warships that saved Athens and ancient Greece in general. It is argued that the shipbuilding program combined with the rapid development of both the "secondary sector of production" (shipyards, iron etc.) and the "tertiary" production (reliable monetary system, banking and insurance services, protection of private property and commercial contracts, setting up joint companies for profit) and accompanied by high level protection of citizens and economic agents through the law. The article concludes that the ancient Greek economy exercised in practice many modern methodological institutional tools that are related to the operation of a free market economy, as perceived in modern terms and therefore the earlier view of its "primitivism" must be rejected.

1. Introduction

The ancient Athenian Democracy, being the "prototype" of a democratic state and society, has raised during the last three centuries a lot of attention. Thousands of books and articles have been written over that period covering the historical, political, and social aspects of ancient Athens and this interest is very much alive today.

However, much less attention has been paid to economic aspects, perhaps because most authors believed that we lack sufficient information on this issue. Another reason has to do with the influential work of Moses Finley (1954, 1973, 1983) who argued that the ancient Greek economy was characterized by primitive structures and organization and it was "embedded" on social, political and religious aspects, thus it was not a market economy, as we understand the term today.

However, Finley's work has strongly revisited by many modern authors, such as

* Nicholas. C. Kyriazis is Professor, Department of Economics, University of Thessaly, Korai 43, PC: 38333, Volos Thessaly, Greece, e-mail: nkyr@ergoman.gr
Emmanouil Marios L. Economou (Ph.D) is a Research Fellow, Department of Economics, University of Thessaly, Korai 43, PC: 383 33, Volos Thessaly, Greece, e-mail: emmoikon@uth.gr (being also the corresponding author).

Cohen (1997), Shipton (1997), Amemiya, (2007), Bitros and Karayannis (2008), Halkos and Kyriazis (2010), Lyttkens (2013), Bergh and Lyttkens (2014), Economou, Kyriazis and Metaxas (2015), Kyriazis and Economou (2015) and Ober (2015) who argue that many elements of the ancient Greek economy can be interpreted with modern economic theory. This mostly applies to the *New Institutional Economic School* of though and with *Behavioural Economics*). [1]

Our hypothesis is that the extant fourth century sources contain sufficient information on the ancient Greek economy to enable us to reconstruct its major aspects and even to proceed to some first quantification of basic data. For this purpose, we use both ancient and modern authors. This paper mainly focuses on the Athenian case, since our historical data are quite enough to offer us safe conclusions. It argues that the external threat that the Athenians faced twice in 490 BCE in Marathon and during 480/79 BCE made them reconsider many aspects concerning their socio-economic organization, so as to effectively repel the imminent threat: the second Persian invasion. Then it is argued that Athens transformed from a mainly land power, into a sea power, which leads to a break of path dependence and leads into a new regime.

Within this regime, new, more efficient institutions, both political and economic emerged. Thus, the "turn to the sea strategy" led to a major transformation of the economy: the gradual abandonment of the feudal organization which was mainly based on land and agriculture and the establishment of a "secondary" and "tertiary" type of an economy, which was based on sea power, commerce (both naval and land) and a variety of very advanced economic institutions for the era. All these innovations were mutually reinforced by the establishment and the evolution of democracy being already introduced in Athens through Cleisthenes' reforms since 508 BCE and afterwards.

2. The Persian invasion and the "successful response of the Athenians" through the turning to the sea strategy"

At the beginning of the fifth century BC, Athens was still mainly an inward looking city-state, the great majority of whose inhabitants lived off agriculture. It had some trade, some commercial ships, and presumably some warships; but it certainly was not a major trading or naval power, as archeological findings of the sixth century BC, outside of Attica revealed.

During the 480's the Athenians and the rest of the Greeks were receiving more and more info concerning the Persians intentions to launch a second invasion in Greece. Athenian politics were strongly influenced by a visionary politician, Themistocles, who had no doubt concerning the true Persian intentions against Greece. Themistocles foresaw that the decisive encounter of the forthcoming war would take place at sea. Thus, Athens needed a strong fleet that had been lacking before. The problem

1. This discussion concerning the "primitivism" or the "modernism" of the ancient Greek economy goes back to the late 19th century, with the so-called Bücher-Meyer controversy. Bresson (2007: 16-52) offers a detailed analysis concerning the different methodological approaches of this controversy. He also offers arguments as to why modern economic theory can offer explanatory power concerning the description of the ancient Greek economy.

was how to finance such a fleet, of about 200 triremes. The city's revenues, consisting of public land revenues, custom duties, fines and war booty were insufficient for this major naval program.

Suddenly, as *a deus ex machina* in 483-482 BCE the Athenians found in Maroneia, in the silver-mining district of Laurion near Sounion an unprecedented rich vein of silver. The royalties reached the unheard figure of 100 talents per year (or 600.000 ancient drachmae), at a time when one drachma was a middle-class day's income. This amount was enough to pay for all regular state expenditures, with a large surplus to be distributed at a flat rate of ten drachmas to every citizen.

Themistocles intended to use this amount of money in order to finance a fleet of 200 new trireme warships, (100 each year) being capable enough to repel the Phoenician-Persian fleet. However, it had at first to convince the Athenian people in the arena of politics. His main political opponent was Aristides who was the leader of the conservative aristocratic party which was mainly supported by the wealthier landowners and possibly also by medium smallholders whose revenues came from agriculture. The aristocratic party was also supported by the richest classes: *the pentakosiomedimnoi* (those who had an income of as high as 500 bushels), *the horsemen* (Greek: *hippeis, or triakosiomedimnoi*, those rich enough to have a horse) and the *zeugitai* or diakosiomedimnoi (those possessing a pair of plough oxen).

On the other hand, Themistocles was supported by the low-income *thetes*, who till that time, had limited political rights: they could vote in the Assembly but were excluded from public office. Themistocles understood that he could convince the poorer thetes to vote in favour of his ship-building program if he could promise full political rights to them. But practically, he actually promised to find jobs for the poorer citizens.

Building 200 ships in two years was a task requiring the harnessing of a substantial labor force. Since at that time the slave population was relatively low, a major source of employment came from the citizens. It is logical to believe that the better-off citizens, such as farmers and city workers, would have weaker incentives to abandon their work in order to be employed in the construction of the fleet. Thus the people employed in the shipbuilding project came from the poorer class, the thetes (Kyriazis and Zouboulakis, 2004; Tridimas, 2013).

Themistocles also promised them that since triremes needed to be equipped by men, thetes were the most appropriate source of manning them. Triremes comprised by a crew of 200 men: 7 officers from the upper income class, including the captain (called *trierarchos*), 10 marines (called *penonautai*) possibly coming from the medium-income hoplite class, 10 sailors, 4 archers and 170 rowers (Morrison Coates and Rankov, 2000). Rowers were coming from the low income class, the thetes.

The Athenians finally decided to approve the proposal of Themistocles to build the fleet. This decision can be seen as an issue of "public choice", if we use a modern economic term: sacrifice more consumption (ten drachmas to each Athenian) in favour of the public good (defence). This is the so-called "butter for guns" choice. In retrospect it can be argued that the Athenians chose wisely since this fleet, which comprised the 2/3 of the entire Greek fleet, saved Greece, Europe and the western world, as it defeated the mighty Phoenician-Persian fleet in the Salamis naval battle (490 BCE).

In order to construct the fleet, the Athenians introduced the *trierarchy*, according to which a wealthy Athenian was charged with the running expenses of a trireme warship for one year, at the same time acting as captain of the ship. In the beginning the trierarchy fell on individual wealthy Athenians, who realised, during the course of the fourth century, the limitations of this system, both from a "justice" and practical point of view. So, on the basis of a proposal by Demosthenes, they introduced the *symmoriae* system, under which a group of wealthy Athenians was collectively responsible for each trierarchy (Kyriazis, 2009). Trierarchy proved a successful Public Private Partnership (PPP) program in the area of national defense, if we interpret it in modern economic terms.

Kyriazis and Economou (2015) characterize triremes as a "school of democracy": people from different social groups and with different life experiences had to cooperate together so as to achieve a common goal, to defend their motherland and even to die fighting in favour of their "altars and hearths" (*yper vomon kai estion*)[2]. Making a trireme warship to coordinate with the other ships of the fleet and performing difficult and venturesome maneuvers during the battle, required exceptional seamanship, courage and determination. But most importantly it needed trust and cooperation (*hamila*) between the crew. All members, from the wealthy captain to the poorer rower, depended on each other. Thus a well-run trireme worked like a well turned orchestra, in which different musical instruments playing sometimes different tunes produce one melody.

Thus seeing the repel of the Persian invasion through A. Toynbee's ([1946], 1966) spectacles, it proves not only the ability of the Athenian socio-political system to "survive" and to respond effectively to the external threat, but also that the repel led to a major socio-economic change: it transformed the economic base of the Athenian economy. In the next section the financial and economic institutions and mechanisms that the Athenian economy introduced after the "turn to the sea" are analysed.

3. The rise of commerce and the gradual transformation of the economy through the creation of a secondary and tertiary sectors of production

The necessity to repel the Persian fleet leads not only to the construction of trireme warships, but also to the creation of the proper infrastructure so as to make the construction program feasible. New production sectors arose such as: timber (for the production of ships, oars, etc.), forges, steelwork stores (for the rams of warships and special nails in order to connect the different parts of the ships etc.), paint shops, shops for ropes, and a variety of products that they were related with shipping industry such as pitch, hemp, flax, iron, as well as a major upgrade of the existing infrastructure for dockyards (*naustathmoi*), anchorages and marine installations etc.

Then, the next step followed: once the threat faded away, all this newly-made infrastructure did not become useless. The democratic spirit of innovation led the Athenians

2. Kyriazis (2014) and Kyriazis and Economou (2015) analyze how the organization of the *hoplite* (phalanx) formations and the trireme warfare forged bonds of trust, emulation and bravery between the *hoplites* and the sailors and promoted the democratic ideals

to exploit this infrastructure so as to make their city wealthier and stronger. One has to bear in mind that after the repel of the Persians, the Athenians took the lead of the Greek world together with the Spartans. The Athenians played a major role in the establishment of the so-called First Athenian Alliance (Delian League) during 478-404 BCE. Thus Athens had actually managed to integrate a large part of the East Mediterranean region into an integrated status of economic cooperation and security through its mighty fleet. Commerce in all this unified area of economic cooperation rapidly flourished.

Athenian exports comprised olive oil, Hymetus honey, wine from the agricultural sector, but more significantly, handicraft and "industrial" products, like pottery, furniture, silver plate, arts products like marble and bronze statues, iron and bronze domestic utensils, arms and jewelry (Kyriazis and Zouboulakis 2004). According to some estimates (Cohen 1997) the import of grain required 600 shiploads at 3000 medimni (120 tons) per shipload. Total trade value has been estimated to at least 13,8 million drachmae, or 2300 talents per year (Isager and Hansen 1975) a colossal sum created through economic transaction. Luxury items like ivory were also imported, as well as slaves.

Once the secondary sector of the economy was shaped and the volume of commerce started to increase, the Athenians were flexible enough to understand that they had to develop new institutional mechanisms in favour of commerce. Thus, they proceeded on a series of steps. At first, property rights and their protection were further refined during the period of democracy in Classical Athens (510 to 322 BCE). Kyriazis and Economou (2015) argue that a regime of property rights protection was gradually under development since the Homeric era and afterwards.

Property rights protection is one the most important prerequisites and axioms that safeguard the prosperity of a modern state (Hodgson, 2015a). During the Classical era property rights were further secured. In case of a violation of his property, a citizen had the right to sue the one who was responsible for the violation. The system of property rights was so advanced that citizens had the right even to sue the state itself in case they faced a state violation (Karayannis, 2007). As Cohen (1997) has persuasively shown, free Athenian women could also own property, and even could function as entrepreneurs, and as bankers.

Another major issue has to do with the introduction of a reliable coin as a means of performing efficient economic transactions. Camp and Kroll (2001), Kroll (2011) and van Alfen (2011) have thoroughly studied the Athenian coinage system and they strongly support our argumentation. The Athenian owls were introduced at about 650 BCE and during the 6th and 5th century BCE the Athenian state, through state mints introduced thousands of very reliable coins, including their subdivisions so as to make feasible every kind of transaction (of a higher or a lower value). The Athenian coins such as the famous *tetradrachm*, had an intrinsic value (as all coins in antiquity) and they were very reliable and pure concerning their silver content thus they rapidly became the universal coin for the era.[3]

3. As it also happened later, with the Greco-Macedonian *tetradrachm* after the conquests of Alexander the Great, the roman *denarius*, the Byzantine *solidus*, the Venetian *grossi*, the Great Britain's *pound sterling* and currently, the US *dollar*.

The fact that Athens and many other Greek city-states utilized reliable coins led to what it is known in modern economics, as transactional cost reduction. During 375/4 BCE Nicophon introduced his Monetary Law, which was accepted by the Assembly. Under its provisions, all "good" foreign coins (meaning of correct silver content) could circulate in the Athenian economy together with Athenian drachmas and traders, etc., could use foreign coins for their transactions without having to change them into Athenian money. This reduced transaction costs and facilitated trade and exchange. In cases of doubt about the "purity" of the contents of the foreign coins (and as a state guarantee against fraud) the office of the "tester" (called *dokimastis*) was introduced.

The "tester" was a state official with an office, a bench in the market places in Athens and the harbor of Piraeus. If one of the private contracting parties had doubts about the purity of the foreign coins, he could bring them to the "tester" who examined their purity. If found to be authentic, the transaction could proceed with state guarantee. If found impure (e.g. in the case of fraud) the coins were confiscated. The law of Nicophon again reduced transaction costs and generated, by its existence and provisions, trust (Ober, 2008, ch. 6).

In addition, according to modern economic literature, the protection of commercial agreements and contracts is pivotal so that commercial transactions become credible (Hodgson, 2015b). This is strongly related to the existence (or not) of a regime that protects property by law and under legitimate procedures backed by the state, which is the legal institutional mechanism that safeguards property rights that are related to commercial action. Edward Cohen (1973: 158-198) mentions a variety of cases of property rights that have to do with maritime law.

He argues that at some point during the fourth century BCE, special maritime courts were set up in Athens to deal with commercial cases, (*dikai emporikai*), apparently replacing an earlier system of such cases *nautodikai*. There is no doubt that the use of written contracts was a standard commercial practice. Cohen (1973: 93) also argues that in cases where trials concerning *dikai emporikai* took place, jurors (*dikastai*) were specially chosen from those with experience to handle such kind of cases. Such cases were judged within a month, so that justice was provided rapidly among litigants.

A comment must be offered as far as banking is concerned, since banking activities are strongly related with the enforcement of contracts and the protection of property. In Athens, there were a series of wealthy men who could offer various banking services to Athenian and foreign citizens. Banking services covered a wide range of economic activities, such as offering loans, safekeeping of valuables (possibly acquired as security for loans) while their merchant owners traded elsewhere, arranged the payment of merchants' creditors in their absence to their associates and acted as guarantors in favour of an economic agent.

They could also provide witnesses for business deals, keep contracts of arrangements and offer currency exchange etc. Cohen (1997) and Shipton (1997) offer various passages (Dem. Phor. 36; Dem. Ag. Tim. 49 etc.) and epigraphical evidence (IG 11^2 2741, 11. 5-6) to support this thesis. During the fourth century, the wealthiest Athenians were no longer landowners, but "enterpreneurs" (Kyriazis, 2009). Thirty bankers are known to us by name, such as Passion and Phormion (Cohen 1997). Finally, related to banking

and commercial activity, there are also attested insurance and joint-stock companies, the later established for profit reasons. These institutions made trade activity easier and safer (Plut. Solon, 31, Dem, Against Zinothemis; Cohen, 1997; Reed, 2003).

A general comment must also be made concerning the procedures of attributing justice in public courts, because they are obviously related to the enforcement of the law and property rights[4]. It is known that litigants were required to provide all the documentary evidence, such as contracts and bills to the judges. The Athenian state had laws which were inscribed on large stone blocks erected in various public areas of Athens, as in the Areopagos court and in the Acropolis.

Beginning at the end of the fifth century copies were kept in public buildings. Many would have been located at the office of the magistrate whose duties were related to a certain type of case. In the fourth century a large collection of official documents including laws were located in the *metroon*, an ancient Greek temple dedicated to a mother goddess. A special institutional body called *nomophilakes* (meaning "guardians of the laws") was responsible for the safety and protection of those written laws from forgery, loss or damage of the inscribed passages being written on them etc., and for this purpose, they had full access to the *metroon*, also known as *nomophylakion* (Sickinger, 2004: 95-86, 102-104; Lanni, 2006). This means that there was an officially established system of laws (being previously decided by the Athenian Assembly) according to which the jurors offered their verdict.

4. Conclusions

In 483/2 the Athenians found a large vein of silver in Maroneia at Lavrion mints. Themistocles, the leader of the democratic party convinced the Athenian citizens in the Assembly to "invest" their money in favour of the public good defence against more personal private consumption. In order to repel the Persians, the Greeks, and more specifically the Athenians, chose the "turn to the sea strategy" and they performed a colossal shipbuilding program, (which may be seen as of Keynesian inspiration in todays' interpretation) and they finally managed to repel the threat.

But the "turn to the sea" strategy was transformed into a process of re-shaping the Athenian economy towards a well-functioned monetized market economy with flouring institutions and highly developed secondary and tertiary sectors. The Athenian economy utilized in practice a series of institutions such as property rights protection, reliable coinage, the enforcement of contracts, an effective banking sector, insurance and prototype joint stock companies and an effective judicial system that protected all the commercial transactions.

This paper sheds more light in favour of the current academic trend who favours a major revision concerning the "backwardness" of the ancient Greek economy. The ancient Greek economy had many modern characteristics and can be interpreted by making use of many modern methodological tools that are related to economy theory.

4. Lanni (2006) provides an extensive analysis concerning the Athenian judicial system.

Bibliography

Ancient Authors

Demosthenes, "Against Timotheus", (Dem. Ag. Tim.).

Demosthenes, "For Phormion", (Dem. Phorm.).

Demosthenes, "Against Zinothemis", (Dem. Ag. Zin).

Plutarch, "Solon", (Plut. Solon).

Modern authors

Amemiya, T. (2007). *Economy and economics in ancient Greece*. London: Routledge.

Bergh, A. & Lyttkens, C.H. (2014). Measuring institutional quality in ancient Athens, *Journal of Institutional Economics*, 10(2): 279-310.

Bitros, G.C. & Karayannis, A.D. (2008). Values and institutions as determinants of entrepreneurship in ancient Athens, *Journal of Institutional Economics*, 4(2): 205-230.

Bresson, A. (2007). *L' economie de la Grèces des cites, les espaces de l' echange*, Vol. 2. Paris: Armand Colin.

Cohen, E.E. (1973). *Ancient Athenian maritime courts. Princeton*, New Jersey: Princeton University Press.

Cohen, E.E. (1997). *Athenian economy and society: a banking perspective*. Princeton University Press, Princeton.

Camp, J. & Kroll, J.H. (2001). The Agora mint and Athenian bronze coinage, *Hesperia*,70(2), 127-62.

Economou E.M.L., Kyriazis N. & Metaxas T. (2015). The institutional and economic foundations of regional proto-federations, *Economics of Governance*, 16(3): 251-271.

Finley, M.I. (1954). *The world of Odysseus*. New York: The Viking Press.

Finley, M.I. (1973). *The ancient economy*. Berkeley: University of California Press.

Finley, M.I. (1983). *Economy and society in Ancient Greece*. New York: Penguin Non Classics.

Halkos G. & Kyriazis, N. (2010). The Athenian economy in the age of *Demosthenes, European Journal of Law and Economics*, 29: 255–277.

Hodgson, G.M. (2015a). *Conceptualizing capitalism: institutions, evolution, future*. Chicago: University of Chicago Press.

Hodgson, G. M. (2015b). Much of the 'economics of property rights' devalues property and legal rights, *Journal of Institutional Economics*, 11(4): 683 – 709.

Isager, S. & Hansen, M.H. (1975). *Aspects of Athenian society in the fourth century B.C. Odense*.

Karayannis, A. (2007). Ancient Greek leadership on economics. Athens: Papazisis (in Greek)

Kroll, J.H. (2011). The reminting of Athenian silver coinage 353 B.C., *Hesperia*, 80: 229–259.

Kyriazis, N. & Zouboulakis, M. (2004). Democracy, sea power and institutional change: An economic analysis of the athenian naval law, *European Journal of Law and Economics*, 17: 117-132.

Kyriazis, N. (2009). Financing the Athenian state: Public choice in the age of Demosthenes, *European Journal of Law and Economics*, 27(2): 109-127.

Kyriazis, N. (2014). *Democracy and war. Histories from ancient Greece*. Athens: Eurasia Publications (in Greek).

Kyriazis, N. & Economou, E.M.L. (2015). *Democracy and economy. An analytical history of democracy from its birth to today*. Athens: Enalios (in Greek).

Lanni, A.M. (2006). *Law and justice in the courts of Classical Athens*. Cambridge: Cambridge University Press.

Lyttkens, C.H. (2013). *Economic analysis of institutional change in ancient Greece.Politics, taxation and rational behaviour*. Abingdon: Routledge.

Morrison, J.S. & Coates, J.F & Rankov, N.B. (2000). *The Athenian trireme*. Cambridge. Cambridge University Press.

Ober, J. (2008). *Democracy and knowledge. Innovation and learning in Classical Athens*. Princeton University Press: Princeton.

Ober, J. (2015). *The rise and the fall of Classical Greece*. Princeton: Princeton University Press.

Reed, C.M. (2003). *Maritime traders in the ancient Greek world*. Cambridge: Cambridge University Press.

Shipton, K. M. W. (1997). The private banks in fourth-century B.C. Athens: a reappraisal, *The Classical Quarterly*, 47(2): 396-422.

Sickinger, J.P. (2004). "The laws of Athens: publication, presentation, consultation", in E.M. Harris & L. Rubinstein, (eds.), *The Law and the Courts in Ancient Greece* (pp. 93-109). London: Duckworth..

Toynbee, J.A. ([1946] 1966). *A study of history*. Oxford: Oxford University Press and Dell Publishing Co.

Tridimas, G. (2013). Homo Oeconomicus in ancient Athens: silver bonanza and the choice to build a navy, *Homo Oeconomicus*, 30(4): 435–458.

van Alfen, P.G. (2011). "Hatching owls: Athenian public finance and the regulation of coin production", in F. de Callatay (ed.), *Quantifying Monetary Supplies in Greco-Roman Times* (pp. 127-149) Bari: Edipuglia.

A3.1 From Ancient Greek Architecture to Neoclassical Facades: Types and Examples of Caryatids in Athenian Buildings

Maria Leni, Archaeologist MSc, MA
General Directorate of Restoration, Museums and Technical Works, Hellenic Ministry of Culture and Sports

Abstract

Ancient architecture, particularly the principles of symmetry and harmony, influenced strongly the buildings of the Modern Greek state, since new public and private buildings were inspired by classical models.

The facades of Athenian neoclassical buildings often have sculpture or plastic decoration; in particular they are frequently decorated with caryatids. Although during the classical period caryatids supported, as an Ionic column, the weight of the entablature, the neoclassical caryatids have a more decorative use and usually do not carry heavy weight. Their size and material depend on their functionality, regarding the support they provide to different parts of the building.

Using as a distinguishing criterion the development of their bodies, the neoclassical caryatids can be classified into different types: a) Full-body caryatids used as pilasters or receive heavier weights. b) Caryatids placed, from waist down, on a broadening on top base. c) Caryatids' busts without arms on a schematic female breast base.

The different types of caryatids' form are presented in a series of examples of Athenian architecture, created by well-known or anonymous architects. The increased preference to this exterior decoration form is due to the influence of the caryatids that adorn important monuments, such as Zappeion, Hotels Bagheion and Megas Alexandros, the Benaki Museum and the Ziller-Loverdos residence.

1. INTRODUCTION:

The revival of Greek antiquity values during the Enlightenment period in Western Europe was evident in art and literature. The influence of classical aesthetics was crucial in all aspects of art; it was particularly evident in architecture, which was inspired by the detailed drawings of the 18th and early 19th century travelers in Greece and Asia Minor, depicting the architectural remains of antiquity and spreading, thus, the value of classical civilization.

Neoclassicism was born in western European urban centers, as ancient Greek thought and philosophy, logic, rationalism, the meanings brought by classical education were expressing the values that represented the rising bourgeoisie. The western European cities were built with neoclassical public buildings, which referred to the

principles of justice, respect for freedom and democracy. Similarly, private neoclassical buildings revealed the economic prosperity, culture, education and bourgeois origin of the owner.

Neoclassicism in Greece was received uniquely, as it followed the stylistic preferences of central Europe at first, but afterwards it was inspired directly by the existing classical buildings. Therefore, although neoclassicism was a rhythm introduced by the Bavarian rulers and architects, in Greece it gained an additional symbolic value [1]. The new state did not simply follow the western European artistic trends, but was also the guardian of classical civilization, which was the role model for Western Europe. The new capital, Athens, was decorated with buildings inspired by the classical edifices that stood in the historic center of the city.

For the Greeks, neoclassical architecture was, therefore, the "natural" continuation of classical art, showing the western world that the heirs of ancient art were them, the descendants of the original creators. Consequently, for Greece neoclassical architecture was simultaneously an international and a national style. The neoclassical style acquired a particular symbolism in Greece, so the international neoclassical architecture was perceived as a unique Greek style [2].

Architectural design in the developing urban centers of the new state had found its models both from western cities and from standing classical antiquities. Athens in particular, after its proclamation as the new capital, was built with public and private structures referring to classical antiquity, indicating the particular ideological orientation and giving a distinctive cultural identity.

The monuments of antiquity were powerful models, since they seem to have inspired the architects who attempted to repeat their style [3]. Doric columns appear on many facades and also at the interior of Athenian residences and commercial buildings. Often deprived of their initial function to hold the weight of the entablature, Doric columns or half columns stand as pilasters, usually having a more decorative than functional role. In the same way, Ionic columns have a similar part, decorating the facades and offering them a monumental character.

The imitation of classical creativity appears particularly in repeating certain monuments of classic architecture, which seem to have had a profound effect on the of 19th century architectural inspiration. Two characteristic monuments of classical Athens, the choragic monument of Lysicrates (335-334 BC) and the clock tower of Kyrristos (1st cent. BC), show that, probably due to their particular shape, inspired architectural design [4]. The cylindrical body with Corinthian columns of the choragic monument and the octagonal shape of the hydraulic clock tower were repeated in several buildings, many of which were demolished during the 1960s and 1970s[1]. It is worth mentioning that both monuments have inspired architects in Western Europe and the US since the 18th century, as they had become well known through travelers' designs [5].

Female sculpt ed figures are quite common on the facades of public and private

1. Typical examples were the buildings on 25-27 Filellinon and Simonides str., Evangelides' residence in Exarchia, Stournari Mansion on Vas. Sofias Avenue etc. The hotel "Prince George" on Aeolou and Stadiou str. is still standing, having a modern usage.

buildings in the Athenian center, dating from the second half of the 19th century. The caryatids' forms that enhance the monumentality of the building had already appeared in Western European capitals, mainly in public architecture. The caryatids of the Erechtheion have become the main source of inspiration, both at the interiors, as sculptor Jean Goujon's "room of the caryatids" in Louvre proves, forming a Renaissance imitation (1550) of the model, and at the facades and entrances, as shown by the caryatids of the new church of St Pancras in London, built in 1819-1822 by architects William and Henry William Inwood.

In modern Athenian architecture female sculpted figures seem to appear and be repeated in different types during the second half of the 19th century. Although they do not have a single form, they appear to be repeatedly selected by particular architects inspired both by the authentic ancient models and their Western versions. This paper will attempt to examine these female decorative forms, classify them and identify their models.

2. PURPOSE AND RESEARCH METHODOLOGY

2.1. The Purpose of research - Questions

The decoration of the facades of neoclassical or eclectic buildings has been studied by researchers. Focusing on a special feature of the facades, for example the different types of caryatids, facilitates their classification and the research for their models. This paper will attempt to separate the different types of sculpted or plastic female figures of neoclassical facades and categorize them. The goal is to examine the models effectively and search for a possible association with a specific period. It is also worth examining whether the selection of each type relates to the construction cost of the building they are decorating. Finally, the identity of the architects who frequently use types of caryatids at the facades will also be studied.

Therefore, the research questions could be summarized as follows:

- What are the different types of caryatids and during which period were they popular?
- Which edifices were the models of this architectural decoration?
- Is there a correlation between the types of caryatids and the building construction cost?
- Which architects prefer to decorate their buildings with these forms?

2.2. Research methodology - Case study

Examining the different types of caryatids on neoclassical buildings' facades in Athens, as well as their categorization and finding of their architectural model, requires sufficient study of the city's neoclassical monuments. The information used has been collected from fieldwork and bibliographical research. The buildings examined were the important ones for the purposes of this research. The method used is empirical, based on observation.

Although caryatids are common in the architecture of almost all the cities of the Modern Greek state, this study will focus on the neoclassical buildings of Athens. The geographical restriction aims at a more effective management of the sample; moreover, the research will not be affected negatively, since in Athenian architecture all types are represented.

2.3. Research problems: Terminology issues

Usually, references to sculpted or plastic female forms on the facades of neoclassical buildings use the terms "caryatids" when they appear in a full-body or nearly full-body representation. The terms "Hermai – Caryatids" [6] "Hermai" or "Hermai with bases" are used when they consist of a column with a female head [7]. However, even if they do not hold the weight of the entablature, as the caryatids of the Erechtheion or of the Treasure of Sifnos, these sculptures are different from Korai or Hermai that do not carry any weight. Even if their role is decorative and do not support of the entablature and other architectural parts, their characteristic is that they seem to carry the weight of the upper part of the building on their heads. They have the same structural role as a column. Therefore, we choose the term "caryatid" for all the types of female forms that appear to hold the entablature, regardless of the development of their body. The decisive factor is whether they appear to support, as a column, the weight of an architrave or a pediment.

3. TYPES OF CARYATIDS IN MODERN ATHENIAN BUILDINGS

The caryatids on the facades of Athenian buildings differ from each other in material and in form. The marble caryatids decorate the large scale public buildings, such as the circular atrium in Zappeion Megaron, while the smaller private buildings preferred the ceramic versions. The ceramic materials have low costs, while achieving the architect's objective, namely the presence of sculptural decoration on the facades or the interior of a building. [6] Ernst Ziller himself noted that ceramic used in modern buildings was just as solid as the marble sculptures, while he had used them in a series of monumental architectural structures, such as Psycha's, Vouros', Mela's residences and other important buildings [7].

Organizing the caryatids typology in modern buildings is based on the size of their torso. Using as a distinguishing criterion the development of their bodies, the neoclassical caryatids can be classified into different types. Full-body caryatids used as pilasters and giving a monumental character to the building are rather rare. Typical examples are the caryatids at the entrance of the National Theatre on Koumoundourou str., built by E. Ziller during the period 1891 - 1901. The perfectly frontal posture, without any movement of the feet, and their arms crossed under the breasts refer to buildings' decorations in central Europe.

The caryatids being supported, from the waist down, on a base or a "case" that broadens towards the top are more common. These female sculptures have western European models, their breast is naked and their arms are crossed beneath it, while

their garment is loosely tied on the hips.[2] Instead of legs, there caryatids have a column with a narrower base that broadens up towards the hips[2]. Well known examples are the decorations of Hotels Bagheion and Megas Alexandros in Omonia sq., designed by E. Ziller during the period 1889 - 1894. The caryatids of the vernacular house on 45 Ag. Asomaton str., created by sculptor John Karakatsanis in the early 20th century, were inspired by the same models.

Most sculptures belong to the third type: the caryatid's head is placed on a base that widens towards the top, having a schematic breast without arms. Actually, they are female busts supporting an architrave or other architectural parts. The base is usually a column having a reversed pyramid shape, often decorated with garlands and other floral ornaments. This type is common enough and adorns both private and public buildings. Characteristic are the facades of the Mela's residence, the Ziller-Loverdos' residence and the former Hotel Excelsior, all designed by E. Ziller and constructed during the period 1874 - 1910. The same type inspired architect Anastasios Metaxas at the facades of Orphanides' residence on 56 Amalias Av. and at the Benaki Museum during the decade 1900 - 1910. The type is repeated in other Athenian edifices as well, such as the building on Satovriandou and 3rd September str. and the house on 10 Pindarou str.

The chronological examination shows that the earliest examples seem to be the heads of the caryatids at Zappeion atrium, as well as the ones at Mela's residence. The architectural plans of Zappeion were originally drawn by François Boulanger, but were not materialized due to delays. The construction began in 1874 according to Theophil Hansen's modified designs, under the supervision of E. Ziller. The circular atrium is surrounded by 32 Ionic columns, while on the second floor the columns have been replaced with caryatids' heads on a base, supporting the circular architrave. The Mela's residence on Aeolou, Kratinou, Straight and Sophocles str., designed by E. Ziller, date from the same period. The caryatids' heads on the buildings seem to have affected the architectural creation.

4. CONCLUSIONS

The correlation of the caryatids' types with the construction date of the building they decorate, as well as with the architect who designed it, is going to help answer the research questions. This research of Athenian buildings is not exhaustive, but indicative of architectural trends and options of the late 19th and early 20th century. The following table therefore shows schematically these relations and helps coming to conclusions.

2. Caryatids of this type decorate a few years earlier the Muzikverein concert hall in Vienna (1867 - 1869), according to Th. Hansen's architectural designs. The room is adorned with golden caryatids in a "case" from the line of the hips, having arms crossed under their naked chest.

Name of the building / Address	Image	Type of caryatid	Construction Date	Architect
Zappeion Megaron		caryatids' bust on a column / case	1874 – 1888	F. Boulanger Th. Hansen E. Ziller
Mela's Residence, 93 Aeolou and Kratinou str.		caryatids' bust on a column / case	1874	E. Ziller
Ziller-Loverdos' Residence, 6 Mavromihali str.		caryatids' bust on a column / case	about 1882	E. Ziller
Megas Alexandros Hotel, Omonia sq.		caryatids up to the waist line	1889	E. Ziller
Bagheion Hotel Omonia sq.		caryatids up to the waist line	1890 – 1994	E. Ziller
National Theatre, 22 Ag. Konstantinou str.		full-body caryatids	1895-1901	E. Ziller
45 Ag. Asomaton str.		caryatids up to the waist line	about 1900	(sculptor I. Karakatsanis)
Orphanides' Residence, 56 Amalias Ave.		caryatids' bust on a column / case	1900	An. Metaxas

10 Pindarou		caryatids' bust on a column / case	end of 19th – beginning of 20th century	
12 Satovriandou and 3rd September str.		caryatids' bust on a column / case	end of 19th – beginning of 20th century	
Benaki Museum, Vas. Sophias and 1 Koumbari str.		caryatids' bust on a column / case	1910	An. Metaxas
Former Hotel Excelsior, 68 Panepistimiou str., Omonia sq.		caryatids' bust on a column / case	1910 – 1914	E. Ziller

The decoration of facades with sculpted or plastic female figures that support the weight of the architrave seems to have appeared in the last quarter of the 19th century and lasted until the early 20th century and the gradual predominance of the modern movement. Since there are no samples of caryatids during King Otto's period, it seems that their use in Athenian architecture did not interest the first Bavarian and Greek architects, who used in their compositions the ancient symmetry, the balanced structure and the strict morphology, highlighting elements of the Doric and Ionic style. The caryatids of the modern period give the facades a monumental character, referring to the characteristics of classical temples.

Selecting the third type, the caryatids' heads, that have a smaller size compared to the other two types, does not correlate with the building's construction costs since this type, besides the smaller constructions, often decorates large buildings with marble components and costly construction.

The introduction of caryatids in modern Athenian architecture can be attributed to the architects of central Europe. The firsts to use these types of decorative caryatids on Athenian buildings seem to be Th. Hansen and E. Ziller. The former had already used some types in Vienna. Moreover, contemporary with the Zappeion Megaron and having many similarities was the building of the Austrian Parliament with a series of full-body caryatids designed by the same architect. E. Ziller continued using these female figures and included them in many of his architectural creations. In addition, he collaborated with Dimitrios Sarris' ceramic workshop, which he supplied with caryatids' drawings and other architectural decorations. Architect An. Metaxas, who had worked with E. Ziller, continued using decorative caryatids in his large-scale projects.

Referring to the korai of the Erechtheion, as well as to the perception of the classic

past through Western Europe, neoclassical caryatids are harmonized with the archaeological sites of Attica and bridge over twenty centuries of Athenian architecture.

REFERENCES

[1] Mylonas, P. (2000). Architectural classicism in modern Greece: The historic and aesthetic significance. In *The Neoclassical Athens of Pavlos Mylonas: drawings 1941 - 1955*. Athens: Benaki Museum

[2] Bastea, E. (2008). *Athens 1834-1890: Neoclassical urban planning and Greek national consciousness. Athens: Libro*

[3] Biris, M. and Kardamitsi - Adami M. (2001). *Neoclassical architecture in Greece. Athens*: Melissa

[4] Biris, M. (1987). *Half a century of Athenian architecture 1875 - 1925*. Athens

[5] Stuart, J. & Revett, N. (1825-1830). *The antiquities of Athens: measured and delineated*, London: Priestly and Weale.

[6] Orphanoudakis, D. (1983). *Caryatids of the 19th century in Greece*. Athens: print. Tsipopoulou

[7] Ziller, E. (1977). *Pottery samples for architectural decoration and other useful projects from Dimitrios Sarris' laboratory in Athens*. Athens: Culture.

A3.2 Olympian Bodies in L. Riefenstahl's 'Olympia' Film: A Study on Memory and Identity

Katerina Zisimopoulou,
Doctorate Candidate NTUA
Architect MArch
MSc Dipl.Eng. RIBA ARB TCG

Abstract

Leni Riefenstahl's 'Olympia' film as a case study is analysed commencing from the artist and her personality, the influences that inspired her, to conclude to the work of art, the film itself. The research has emphasised on the personality and work of the German directress Leni Riefenstahl, as she has been inspired by ancient Greek myths and archetypes of beauty and virility. The influence of ancient Greek artistic thought and athletic ideals have determined the identity of the artist and consequently the work of art produced. The impact of ancient Greek concepts, myths and art on 'Olympia' film is particularly evident during the first ten minutes of the preface, known as the film's prologue. Filmmaker Riefenstahl manipulated her own persona during the interwar as the unconventional heroine of the film industry: a merged synthesis of Diotima's adaptation, depicted as a mysterious priestess dancer, (He) Leni beautiful of national-socialist Germany, and Amazon queen Penthesilea, the perfect German woman, an exceptional female athlete who prevailed men as their equal. Respectively, the narrative of 'Olympia' film was manipulated through directress Riefenstahl by the national-socialist regime to derange the scope of the 1936 Olympic Games in Berlin and exploit the ancient Greek athletic ideal Greece to spread its interwar propaganda.

Riefenstahl managed to take the full artistic credit for the success of the film; the main responsibility for the outcome as well. Nevertheless the artwork is not merely analysed as the creation of the artist, but also as an object that expresses its epoch and subsequently embodies its time's predominant ideals. The film represents these ideals in a space that expresses them. As a work of art 'Olympia' uses ancient Greek myths that embody both the artist's personality and the collective identity of its time. The prologue of the film is composed of carefully directed fragments of representations of ancient Greek architecture and art icons. The film presents them to the modern world as a new narrative representation of mythical ancient, male and female, gods, heroes and athletes and carefully selected masterpieces of Greek, Hellenistic and Roman art. The story of an imaginary Olympia is registered in the viewer's collective memory through modern cinema. The film intends to use this registry in order to link the modern and contemporary world to the ancient world, its concepts and ideals.

Parts of the prologue of 'Olympia' have been filmed on June and July 1936 in

Greece, while preparation ceremonies for the Olympic Games had been taking place. True action or staged action? Is it a documentary film or fiction? We shall investigate these questions looking into the scenes of the prologue that precede and follow the Olympic torch relay from Olympia to Berlin; these scenes constitute a politically structured imaginary ceremonially directed place for the history of art and cinema. Where were these scenes actually filmed? Why did Riefenstahl choose to shoot parts of the film in Delphi? Did she come to that decision under the influence of the Greek photographer Elli Sougioultzoglou-Seraidari (Nelly's)? The ancient Greek ideals of female body beautiful and male body virility are represented in the film in consecutive fractal extracts. Where did Riefenstahl and her crew search for the representatives of these ideals while they were in Greece?

The will in the film to intentionally transform and shape the collective memory tends to use the bodily movements as structured narratives and architectural monuments as landmark settings. Moving bodies and monumental architecture, as represented in the film, form a narration that negotiates issues of memory in time and space. This cinematic mechanism that generates collective memory, reconstructs the past taking a given present time and its needs primarily into account. Ancient Olympia in the film generates, stimulates and attributes meaning to the collective memory of the viewers as well as their modern ideology and conscience. Olympia emerges after viewing the film's prologue as an archaeological landscape landmark, but also as an imaginary place where political athletic and architectonic ideas meet. When we discuss the film and the prologue now, we analyse the historical past at the time when the film was made and we reveal the social and political necessities that generated the film, but we also discuss the social and political needs of the present time that make the specific film still pertinent. While discussing the interwar we cannot help discussing the similarities and the disparities to the present social and political situations. Exactly just as the past is shaped – when history is written and a story is narrated – with the present political needs in mind, the future could be prescribed as the continuous creative line of the narration. The questions that emerge when analysing 'Olympia' film are still as timely as they ever have been.

CORE TEXT

As the museum closed late at night
Deidamia descended from the pediment
Tired of the tourists
she took her hot bath
and spent a long time in front of the mirror
combing her golden hair.
Her beauty was
forever halted in time...
The statue and the craftsman by the Elian poet Giorgis Pavlopoulos/
Collection "Master keys" (1988), translated by the author

1. Introduction

As a young child back in the early 1980s I visited the archaeological site of Olympia every once in a while escorting along with my parents and brothers one family of friends after the other with their children. Usually they were Germans or Austrians, visiting the Peloponnesian land and the famous origin of the Olympic Games, and we all took an imaginary roadtrip with our vehicles following our motorised interpretation of Pausanias' footsteps in Helia[1] . Our group of children could not really talk to each other, as we did not speak each other's native language, but no one could stop us from playing "catch me if you can" or "hide and seek" in the open grounds of Olympia's premises. Our games never lasted long enough because parents and guards cannot always appreciate sports even at the birthplace of athletics; they like to keep it quiet and under control. I think I will never forget the awkward feeling of dirt and pine needles mixed with the sand and salt of the nearby beaches in my shoes and a sense of shame for not paying full respect to a sanctuary. Nevertheless, Olympia has always been to me a place near home, a favorite land at close distance, reachable, accessible and memorable.

1.1 The directress Leni Riefenstahl as Diotima, Heleni, Penthesilea

Since I watched the film *Olympia*, directed by Leni Riefenstahl, 1936, my own experienced land of Olympia, the actual landscape of the archeological site approached from an architectural perspective during the years of my study as an architect and the imaginary space sequences of Olympia represented in the film *Olympia's* prologue, all three spaces that fled my mind have been negotiating ever since. My personal research interests have specifically focused on this particular modern film of the interwar era, directed by a woman: ambiguous Leni Riefenstahl.

The German film directress's whole career was inspired by ancient Greek mythical heroes and timeless athletic ideals. The classical allusion projected on Riefenstahl's extravagant persona perceives the directress as a woman building her identity and professional life through the ancient Greek beauty ideal, bodily culture and athletics. In her memoirs, she evolves from an unknown actress playing "Diotima" the mysterious dancer,[2] to directress "(He)Leni beautiful" of interwar Nazi Germany, or actress and directress "Penthesileia", a female idol of aggressive perfection [1]. Director Arnold Fanck's Diotima, in Brigitte Peucker's words(...)

conjures up the Diotima of Hölderlin's Hyperion (1777-79) as well as her model, the priestess in Plato's Symposium whose role is to explain both the nature of love as well as

1. Referring to Pausaniou Hellados periegesis, Heliaka, Ekdotiki Athinon in Greek and ancient Greek. A copy of the book remained all summer long in the car and a home-recorded audio cassette tape of Helia's periegesis was frequently played along the journey to my discontent as a child.
2. Leni Riefenstahl, *Memoiren 1902-1945 Zeitgeschichte* (Frankfurt/M, Berlin: Ullstein, 1994), 158: Referring to her first meeting with Hitler and her dance in the role of Diotima in Fanck's film "the Holy Mountain" she writes "He [Hitler] enthusiastically spoke of my 'dance by the sea', and said that he had seen all the movies in which I had acted." [Translated from German by the author]

the connection between the beautiful body and the ideal. [2]

Riefenstahl's attraction to beauty and harmony translates the Platonic ideal of the beautiful and erotic into modernity and the modern art of photography and film. National Socialist Germany's political objective to manipulate the narrative of the 1936 Olympic Games in order to spread the prewar national-socialist propaganda, identified with Riefenstahl's ambitious personality perfectly. The perception of politics as art, the *"aestheticization of politics"* [3], is presented in Riefenstahl's *Olympia* film through male virility and female beauty as timeless ideal representations. These are analyzed herewith in order to study the image of ancient Greece and Olympia projecting on an artwork in the context of the cultural production of the interwar.

2. Interwar Germany and the Greek Temple

Many years after the 1936 Olympic Games, in 1997 Riefenstahl when interviewed for Spiegel by journalists Schreiber and Weingarten expresses her aversion towards reality[3]. When the journalists ask her, *"If you photograph a Greek temple and a rubbish heap is next to it, would you leave out the rubbish?"* Riefenstahl replies, *"Absolutely. Reality does not interest me."* [4] If we consider the most influential films she has ever directed, which are the Nazi party Rally film and the Olympic Games film [5], this is quite an astonishing assertion coming from the director of mainly documentaries about real events considered to be filmed 'live', while real time action was actually taking place.

Why did the journalists who interviewed Riefenstahl in 1997 ask her about an ancient Greek architectural monument and the annoying rubbish heap that ruins the perfect frame? Why was that example chosen out of many? How is it possible one of the best directors of documentary film in the world to admit being completely uninterested in reality? Is it acceptable for film to create art at any cost, even at the cost of truth?

2.1 Olympia's I Prologue, Ancient Art in Motion

The only film Riefenstahl directed that includes Greek temple scenes is Olympia, 1936 in the prologue of part 1, Celebration of the People. The only time Riefenstahl ever visited Greece for film shooting, according to her biographies and memoirs, was on July

3. The readers of her biographies can judge for themselves if the argument is valid for her life as well as her art. I have worked with the following books about Riefenstahl's life: Jürgen Trimborn, *Riefenstahl: eine deutsche Karriere* (Berlin: Aufbau-Verlag, 2002) in German, Mario Leis, *Leni Riefenstahl* (Hamburg: Reinbek, 2009) in German and Mario Leis, *Leni Riefenstahl, The Power of Will*, trans. Ioanna Avramidou, (Athens: Melani Publications, 2011), in Greek, Steven Bach, *The life and work of Leni Riefenstahl* (New York: Alfred A. Knopf, 2007) and Leni Riefenstahl, *Memoiren* 1902-1945 *Zeitgeschichte* (Frankfurt/M, Berlin: Ullstein, 1994) in German and Leni Riefenstahl, Wild Century-Autobiography, trans. Tonia Kowalenko (Athens: Terzo Books, 1996) in Greek. However there are also other: *Leni Riefenstahl, the Seduction of a Genius* by Rainer Rother, *A Portrait of Leni Riefenstahl* by Audrey Salkeld, *Leni Riefenstahl* by Renata Berg-Pan, *Leni Riefenstahl. Schauspielerin, Regisseurin und Fotografin* by Charles Ford, *The Films of Leni Riefenstahl* by David B. Hinton, *Leni Riefenstahl and Olympia* by Cooper C Graham amongst others.

1936 during the filming of Olympia for less than a week.[4] *Olympia's* prologue represents the birth of mankind, the myth of genesis. According to Dr. Stephanie Grote

> *The Fest der Völker begins with shots of the peoples of ancient Greece, the 'birthplace' of the Olympic Games. Classical ruins, Doric columns, ancient temple sites, and images of the statues of Greek deities as silent witnesses of past times.* [6]

The analysis of the film's prologue in scenes shows a sequence of Greek temple images for approximately 194 seconds from 1'06" to 4'20", which diagrammatically could be described as an imaginary tour for a few seconds through Olympia, the Erechtheion (supposedly filmed at dawn, camera facing East, but most probably filmed when the sun sets and then its motion was reversed), Olympia again and Delphi, the Parthenon, Propylaia, Erechtheion again from a different angle to include the Caryatides' porch, a Doric temple that might have been the Parthenon or Sounio to end the scene with the exquisite Pendelikon marble portrait of Alexander the Great from the Acropolis Museum under the Dorian columns of the Parthenon. Three minutes and fourteen seconds are enough to connect Riefenstahl to the Greek temple in the collective memory for ever.

The narrative of the Olympic Games is connected to the Greek land of Olympia; the film could be characterized as a modern epic documentary linking Germany to ancient Greece with the Olympic torch relay and ceremonies.

Seeking answers in the film sequence and backstage story itself, letting the artwork speak for itself and the creator, I believe that it is worth the effort to analyze Riefenstahl's and the era's relationship to the timeless ancient Greek archetypes, the mythical heroes and heroines, the classical body ideal cultural heritage, no matter how appalling the national-socialist political ideas interwoven in the film may rightfully be to our contemporary culture. Robert Taylor in *The Word in Stone* cites Hitler in order to describe the regime's rules of stylistic imitation for art and architecture: *"it is better to imitate something good, than to produce something new but bad."*[7] This takes us back to Winkelmann's famous argument:

The only way for us to become great or, if this be possible, inimitable, is to imitate the ancients. What someone once said of Homer – that to understand him well means to admire him – is also true for the art works of the ancients, especially the Greeks. [8]

For the purposes of this analysis and through the lens of the formalist approach of an aesthetic distance, *Olympia* and especially the film's prologue reverts Winkelmann's hermeneutic "Kunstmythologie" method, i.e. *"his method of interpreting an-*

---

4. According to my research at the open Greek Press archives in the Library of the Greek Parliament, Riefenstahl came to Greece on Saturday, July 18, 1936 and left to return to Berlin probably on the 23rd. She personally supervised the shooting of the Olympic torch lighting in Olympia, which took place on Monday, July 20, 1936, and part of the flame relay in Greece. The newspaper Kathimerini, on the issue of 19.07.1936, published a front-page interview of Leni Riefenstahl, titled "Leni Riefenstahl in Athens." However her crew arrived in Greece much earlier, most probably in June or May, in order to make the necessary preparations and begin with the shooting of the film on various locations, including archaeological sites and museums. Finally Riefenstahl might have visited close relatives who live in Salonica and Chalkidiki later in life, though this visit has not received wide publicity.

cient mythological imagery, which in the nineteenth century was referred to as Kunstmythologie."[9] Nikolaus Himmelmann in his book *Reading Greek art / essays by Nikolaus Himmelmann* describes the winkelmannian method of interpreting ancient art imagery through myths. In the film *Olympia* we will analyze how directress Leni Riefenstahl creates ravishing moving images as modern art through timeless myths.

3. The Male Sculptured Body, Herculean power

The transition from the myth of birth to the superhuman athletes of mankind in Olympia's film prologue is achieved through the resurrection of the famous statue of the Discobolus (discus-thrower) created by the ancient sculptor Myron of Eleutherae. The statue filmed for Olympia is a Roman marble copy of the original ancient Greek bronze, known as the Lancelotti Discobolus, and is represented from a fixed viewpoint for approximately four seconds before it enlivens to a real athlete, German decathlete Erwin Huber. The athlete comes to life; marble becomes flesh, then he gradually begins to move and eventually throws the disc. The scene was shot most probably in September 1936 in Curonian Spit, the land that separates the Curonian Lagoon from the Baltic Sea coast, near the Latvian border, as the Getty images and the Hulton Archive attest. The mise-en-scene included a glass-glazed wooden frame where the outline of the statue's selected viewpoint was literary drawn in full scale in order to ensure that the human body of the athlete would assume the exact same position, within the border of the camera's frame. Co-director of the film's prologues, cinematographer Willy Zielke must have used great quantities of smoke powder and plenty of vaseline for the statue and the athletes to create the mystic atmosphere of the prologue [10].

Riefenstahl's enliven Discobolus was not the first attempt to regenerate modern art on ancient artwork paragons. Greek photographer Nelly, or Elli Souyioultzoglou-Seraidari, had photographed her Discobolus in Delphi in the late 1920s[5] most probably during the Delphic Festivals' revival organized by Eva Palmer-Sikelianos and Angelos Sikelianos . Archaeologist Dimitris Damaskos in his paper *The uses of Antiquity in photographs by Nelly: imported modernism and home-grown ancestor worship in inter-war Greece* discusses Nelly's influence on Riefenstahl's Olympia and Irene Boudouri implies that the two of them might have met in Greece during the shooting of Olympia [11], though this has been not been confirmed yet.

Andrew Stewart in Art, *Desire and the Body in Ancient Greece remarks clearly that "the Greek male body was of course the rule"* [12]. The social gender structure in ancient Greece consists of a climax to climb, a goal to achieve and a trophy to conquer. Stewart quotes Simonides of Ceos (verses mentioned also in Plato's dialogue *Protagoras*) *"it is difficult to become* (*a*) *truly excellent* (*man*)*, four-squared in hand and foot and mind,*

5. Referring to the two photographs that the Benaki Museum Photographic Archives have catalogued with the codes N_1821 a, N_1821 b and label them as "Athlete, Delphic Festival" when published in the book Nteny Euthymiou-Tsekoura, Klimentini Vounelaki, Irene Boudouri, *Nelly's: Body and Dance* collective work (Athens, Kalamata: Agras Publications, Ammos Publications, Benaki Museum, Kalamata International Dance Centre, 1997), 102-103, not defining if the photograph was taken on the first Delphic Festival in 1927 or the second in 1929-30.

formed without blemish." Riefenstahl and Olympia promote this perfect image as the immaculate objective and sanctifies the constant struggle to reach the goal of personal perfection in body and mind. In Susan Bordo's words

(…) even the most shallow representations (…) discloses a moral ideology one, in fact, seemingly close to the aristocratic Greek ideal described by Foucault in The Use of Pleasure. The central element of that ideal (…) is "an agonistic relation with the self" aimed (…) at a "virile" mastery of desire through constant "spiritual combat. [13]

Athletics in *Olympia* map the way for the spirit of all to fight for excellence. However the female mythical iconic idols exemplified in the film to glorify beauty differ significantly from the male ones, though they do operate complimentary in order to successfully produce their effect for desire to reach perfection under a leading guidance.

4. The Female Body Beautiful Dance, erotic grace

Stewart quotes Roland Barthes to remark that *"the signs that try to pass as 'natural'* (…) *in reality have the most intense ideological burden, because they attempt to foist culture as nature"* [14], in order to describe the processes through which the Greeks and we ourselves look at the artwork. In *Olympia's* prologue the female bodies take their lead from the male ones in a ceremonial choreography that represents the lighting of the Olympic torch. Following the discus-, spear- and sphere-thrower athletes, nude female dancers perform ball, rope, ribbon and hoop gymnastics exercises in a natural landscape under the windy cloudy sky, in front of trees and reflecting waters. Then they form a group of three and perform expressive dance choreography under a foggy sky that debilitates a central light, maybe the sun, before they are covered with flames of fire.[6] Wind flora water light sun and fire: nature integrates with the female naked bodies only to verify the relegation of the latter as part of the domain of nature.

The female bodies of *Olympia's* prologue are filmed purposefully different than the male bodies. Stephanie Grote draws vividly the lines of the comparison:

The transition to the naked female bodies in the following scene is accompanied and highlighted by the change of rhythm in music. Resembling pagan incantation rituals, the movements of the dancers are harmonious, graceful, shallow and localised; they are in harmony with nature, along with images of swaying grasses on the beach. Riefenstahl reinforced the gender issue using perspective. While the camera captures even when partially the gymnastic exercises of the filmed women in horizontal plan view, Riefenstahl contrasts this impression with the consistently low view of the male athletes. (…) This representation suggests strength, fighting spirit, space conquest and force of nature - almost divine attributes. [15]

The female bodies that represent female erotic grace in O*lympia's* prologue are moving under the forces of nature. Moreover the faces of the female temple dancers are hardly recognizable. They remain obscure under the chosen light, wind and smoke conditions, filmed from an angle that hinders definite identification. The objective of the directress behind this choice is to transmit a sense of passive docility to the female

6. Starting from minute 8'37" and ending at 11'02".

body, which is rendered submissive: the female dancers surrender willingly their personal identity to the harmonious geometry of the exercise and the totality of nature. The resemblances of the images of the nude female temple dancers in *Olympia's* prologue to Nelly's photographs of Mary Wigman's expressive dancers are striking. The natural landscape backdrop, the female bodies captured in graceful dancing motion, the tripartite complex of Riefenstahl's temple dancers performing geometric repetitive gestures refer to the Delphic Festival's chorus lines as represented in Nelly's photographs, imitating ancient Greek pottery images and terracotta dancing figurines[7] that influenced both Wigman's and Palmer's choreographies.

This ceremony in the view of Stewart's argument takes us to Laura Mulvey and *Visual Pleasure and Narrative Cinema*. Mulvey argues that *"pleasure in looking has been split between active/male and passive/female"* [16]. In the line of Mulvay's scopophilic argument, *Olympia* prologue's nude women dancers *"are simultaneously looked at and displayed, with their appearance coded for strong visual and erotic impact"*. They somehow interrupt the diegetic process of the prologue to symbolize nature in the story; they intervene between the first men athletes active competing and the torch relay, and *"freeze the flow of action in moments of erotic contemplation"*. Hence women viewers of the female beautiful figures in *Olympia's* prologue are exposed to the passive docility of the women performing fragmental rhythmic gymnastics exercises as symbolic dancers to be watched performing out of context.

5. Conclusion, Olympian bodies and the collective memory

Riefenstahl was a creator of beauty in art and also a modern emancipated woman. She directed *Olympia* manipulating beauty, in a way that transcends binaries and dilemmas. Her directing speaks of a female consciousness and identity which is not to be unambiguously defined by such dualist axes as subject/object and spectacle/spectator. It is not so easy with Riefenstahl's work to separate action and spectacle in Mulvay's active/male and passive/female split; Riefenstahl has placed her definite personal erotic gaze upon the male athletes she films. Male bodies are indeed treated as spectacle in Olympia, as well as the paragons for men to imitate. However modern women, like ancient Kallipateira [17], can place their gaze on the male protagonist, since they are not banned out of the modern Olympics or their film, but preferably not get emancipated through the process: they would much rather identify with the women dancers "as (passive) raw material for the (active) gaze of man (...), [as] demanded by the ideology of the patriarchal order" [18]. There is a

7. See for instance the ancient Greek terracotta dancing girl, ~ 350 B.C. exhibited at the British Museum, the "Furious Maenad, carrying a thyrsus and a leopard, with a snake rolled up over her head", ancient Greek Attic white-ground kylix 490–480 BC from Vulci, exhibited at the Staatliche Antikensammlungen Munich Germany, the ancient Greek terracotta statuette of a dancing maenad, 3rd century BC, from Taranto, exhibited at the Metropolitan Museum of Art, New York. Nelly had also photographed ancient Greek sculpture of dancers for the quarterly edition 'En Grece, In Greece, In Griechenland', Ministry of Press & Tourism, 1935-6. See also Dimitris Damaskos, "The uses of Antiquity in photographs by Nelly" in *A Singular Antiquity, Archaeology and Hellenic identity in twentieth-century Greece, Mouseio Benaki, 3rd Supplement*, 321-335 and especially 330, figure 25.

profound distinction between male athletes and female dancers in Olympia's prologue, a distinction not to be discharged without circumspection: athletes aim to win, while dancers aim to entertain. So the split between active/male and passive/female representation in Olympia remains valid in content, even if the scopophilic gaze is playfully interchangeable between male and female viewers.

Riefenstahl in *Olympia* treats male and female bodies differently, but still spectacularly, in accordance to what Brigitte Peucker in her book *The Material Image: Art And the Real in Film* characterizes as *"anti-Eisensteinian principle of accretion"*. Riefenstahl's editing style according to Peucker is based on an organic theory of art whose governing structure is wholeness. As in a kaleidoscope, patterns (...) change but yet in some sense remain constant: in substituting for narrative, movement and editing merely replace one form of spectacle with another. [19]

Olympia film, edited as spectacle after spectacle in a kaleidoscopic manner, produces a modern artwork based on timeless ancient Greek models of male and female archetype bodies. The structure of the prologue reveals the impact of classical antiquity on modern narratives in art and culture. Nudity in the case of Riefenstahl's athletes and dancers vividly exposes the plasticity of the body in controlled stylized serial motion, aiming to emulate the aesthetic effect created by ancient Greek sculpture and the material texture smoothness of marble. Stewart turns to John Berger's remark that *"nudity is a form of dress"* [20] to discuss the naked body in ancient Greek art. In *Olympia's* prologue the naked body becomes an object of gaze in order to transform to a nude representation and a dress of marbled plasticity in stylized motion.

The will in the film to intentionally transform and shape the collective memory tends to use bodily movements as structured narratives and architectural monuments as landmark settings. Moving bodies and monumental architecture, as represented in the film, form a narration that negotiates issues of memory in time and space. This cinematic mechanism that generates collective memory, reconstructs the past taking a given present time primarily into account. Ancient Olympia in the film generates, stimulates and attributes meaning to the collective memory of the viewers as well as their modern ideology and conscience. Olympia emerges after viewing the film's prologue as an archaeological landscape landmark, but also as an imaginary place where political athletic and architectonic ideas meet. When we discuss the film and the prologue now, we analyse the historical past at the time when the film was made and we reveal the social and political necessities that generated the film, but we also discuss the social and political needs of the present time that make the specific film still pertinent. While discussing the interwar we cannot help discussing the similarities and the disparities to the present social and political situations. Exactly just as the past is shaped – when history is written and a story is narrated – with the present political needs in mind, the future could be prescribed as the continuous creative line of the narration. The questions that emerge when analysing *Olympia* are still as timely as they ever have been.

Katerina Zisimopoulou, Doctorate Candidate NTUA
Architect MArch UCLA MSc Dipl.Eng. NTUA, RIBA ARB TCG

REFERENCES

[1] About Riefenstahl (Heleni and Penthesilea) and an analysis of the classical allusion projected in her persona see pages 3-6 in https://lekythos.library.ucy.ac.cy/bitstream/handle/10797/6210/ISSEIproceedings-Katerina%20Zisimopoulou.pdf?sequence=1

[2] Brigitte Peucker, *The Material Image: Art and the Real in Film* (Stanford, California: Stanford University Press, 2007), 57.

[3] About *the aestheticizing of political life* see Walter Benjamin, "The Work of Art in the Age of Its Technological Reproducibility" in *The Work of Art in the Age of Its Technological Reproducibility and Other Writings on Media*, ed. Michael W. Jennings, Brigid Doherty and Thomas Y. Levin, trans. Edmund Jephcott, Rodney Livingstone, Howard Eiland, and Others (Cambridge, Massachusetts London, England: The Belknap Press of Harvard University Press, 2008), chapter XIX, 41-42. *"More than any other art, the art of politics is far removed from the dry theories of the desktop"* writes Joseph Goebbels in his article "Will and Way" or in German "Wille und Weg (later the title became "Unser Wille und Weg"), 1 (1931), 2-5. See also the article found at http://research.calvin.edu/german-propaganda-archive/wille.htm [last visited May 2016].

[4] Mathias Schreiber and Susanne Weingarten, *Realität interessiert mich nicht*, published in Der Spiegel 34 (1997) from http://www.spiegel.de/spiegel/print/d-8761533.html [last visited March 2013]. Translation of the interview extract (*Realität interessiert mich nicht*, 205) from German into English by Narraway Guinevere, "Control and Consumption: Photographs of Leni Riefenstahl" *in Riefenstahl Screened: An Anthology of New Criticism*, ed. Neil Christian Pages, Mary Rhiel and Ingeborg Majer-O'Sickey (New York, London: Continuum, 2008), 228, note 73.

[5] *Triumph of Will* 1935 is the best of the three Nazi party rallies films, the other two are Sieg des Glaubens 1933 [Victory of Faith] and Tag der Freiheit - Unsere Wehrmacht 1935 [Freedom Day - Our Armed Forces]. The exact titles of the XI Olympiad two-part film are *Olympia* (Part 1) *Fest der Völker* [Celebration of the People] and (Part 2) Fest *der Schönheit* 1938 [Celebration of Beauty]. "Triumph of the Will and Olympiad are undoubtedly superb films (they may be the two greatest documentaries ever made)..." Susan Sontag, "Fascinating Fascism" in *Movies and Methods: An Anthology*, ed. Bill Nichols (Berkeley & Los Angeles, California – London, England: University of California Press, 1985), 42. See also "Riefenstahl's position in film history's pantheon has been secured by her two masterpieces, Triumph of Will and Olympia." Ruby Rich, *Chick Flicks: Theories and Memories of the Feminist Film Movement* (Durham, North Carolina: Duke University Press, 2004), 41.

[6] Stefanie Grote, *'Objekt' Mensch. Körper als Ikon und Ideologem in den cineastischen Werken Leni Riefenstahls. Ästhetisierter Despotismus oder die Reziprozität von Auftragskunst und Politik im Dritten Reich* (Eingereicht von Stefanie Grote an der Kulturwissenschaftlichen), (Fakultät der Europa-Universität Viadrina Frankfurt (Oder), 2004), 194 [only on the internet at https://opus4.kobv.de/opus4-euv/files/4/grote.stefanie.pdf, last downloaded May 2016].

[7] Robert R. Taylor, *The word in stone: the role of architecture in the national socialist ideology* (Berkeley, Los Angeles, London: University of California Press, 1974), 39, note 106 [quoting Adolf Hitler, Hier Spricht Das Neue Deutschland - Heft 7 - Adolf Hitler - Die Deutsche Kunst (1934, 19 S., Scan, Fraktur), 11 found at https://archive.org/details/Hier-

spricht-das-neue-Deutschland-Heft-7, last visited May 2016].

[8] Johann Winckelmann, "Reflections on the Imitation of Greek Works in Painting and Sculpture" in *The Art of Art History: A Critical Anthology*: A Critical Anthology, ed. Donald Preziosi (Oxford: Oxford University Press, 1998), 31.

[9] Nikolaus Himmelmann, "Reading Greek art / essays by Nikolaus Himmelmann" (New Jersey: Princeton University Press, 1998), 217. See also note 6, 233.

[10] See for instance Brigitte Peucker, *The Material Image: Art and the Real in Film*, 60.

[11] Dimitris Damaskos, "The uses of Antiquity in photographs by Nelly" in *A Singular Antiquity, Archaeology and Hellenic identity in twentieth-century Greece, Mouseio Benaki, 3rd Supplement*, ed. Dimitris Damaskos & Dimitris Plantzos (Athens: Benaki Museum, 2008), 321-336. Damaskos discusses Riefenstahl's relationship to Nelly in pages 332-333 and Nelly's photographs of the Diskobolos (Discus-thrower) in pages 326-327. Regarding Riefenstahl meeting with Nelly see also Irene Boudouri, *Nelly's: Photographic Approaches of Greek Art in Antiquities, Greece 1925-1939, NELLY'S* (Athens: Melissa & Benaki Museum, 2003), 27, note 95. Further research I have undertaken, in the Benaki Museum Photographic Archives and Nelly's archive, has not confirmed the allegation of Riefenstahl and Nelly having met in Athens in 1936.

[12] Andrew Stewart, *Art, Desire and the Body in Ancient Greece*, trans. Anastasios Nikolopoulos, ed. Dimos Koyvidis (Athens: Alexandreia, 2003) in Greek, 44.

[13] Susan Bordo, *Unbearable Weight, Feminism, Western Culture, and the Body* (Berkeley Los Angeles London: University of California Press, 1993), 198.

[14] Andrew Stewart, *Art, Desire and the Body in Ancient Greece*, 46.

[15] Stefanie Grote, *'Objekt' Mensch.*, 197 [translation from German by the writer].

[16] Laura Mulvey, "Visual Pleasure and Narrative Cinema" in *Film Theory and Criticism: Introductory Readings*, eds. Leo Braudy and Marshall Cohen (New York: Oxford University Press, 1999), 837.

[17] Kallipateira was the woman who successfully violated the ban on women's presence at Olympia in ancient times. See for instance David C. Young, *A Brief History of the Olympic Games* (Oxford, Malden, Carlton: Blackwell Publishing, 2004), 107, 120. Also Gergia Emm. Chatzi, *The archaeological museum of Olympia* (Athens: Olkos, 2008) found at http://www.latsis-foundation.org/ell/electronic-library/the-museum-cycle/to-arxaiologiko-mouseio-olybias and especially *"The unknown artist uniquely depicts the mixed feelings of attraction and repulsion in the expression of the beautiful Lapith woman",* 233.

[18] Laura Mulvey, *Visual Pleasure and Narrative Cinema*, 843.

[19] Brigitte Peucker, *The Material Image: Art and the Real in Film*, 49.

[20] Quote from John Berger, *Ways of Seeing* (London: British Broadcasting Corporation and Penguin Books, 1972), 54. See also Andrew Stewart, *Art, Desire and the Body in Ancient Greece*, 71.

A4. MYTHOLOGY

A4.1 The Moleia of Nestani (Arcadia, Pelopon-nese); The Most Ancient Ceremony Dedicated to the Water and the Environment: A Geo-Mythological Approach

Ilias D. Mariolakos
Dr. rer. nat., Emeritus Professor of Geology National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Department of Dynamic, Tectonic & Applied Geology, mariolakos@geol.uoa.gr

Abstract

It is mentioned that in Mantineia basin (Arcadia, Peloponnesus, Greece [1]), during the late prehistoric times, the ceremony of Moleia took place, at the wider area of Nestani village. This was a war ceremony, in memory of the murder of the Homeric hero Arethoos Korynitis by the king of Tegea, Lykourgos. Moleia were celebrated throughout Arcadia. Arethoos was honoured in the hypostasis of Ippios Poseidon, as god of the sea and waters and protector of the flora, while Lykourgos in the hypostasis of Lykaios Zeus, god of the atmosphere, who destroys the flora by heat.

The Arcadic plateau, while it represents a hydrologically closed system, hydrogeologically, is an open one. Because of the intense karstifiation, there is a large number of great sinkholes and caves. In almost all the basins of the Arcadic plateau, the Minyans, an ancient Pelasgian phylum, had constructed various great land reclamation works [2], some of them were drainage works and others small or greater dams that aimed at the collection of water in reservoirs. Land reclamation and geo-hydraulic works were planned and constructed by the Minyans since the first half of the 4th millennium B.P. They had drained the Kopais lake and, most probably because of that, dominated politically, as well as economically, the greater area of Boeotia [3].

Arethoos was a Minyan [4]. It is likely that the furry of Lykourgos versus Arethoos was related to water shortage issues, that were not settled by the Minyans, and Arethoos was considered responsible.

Regardless of the above mentioned causes, that are hypothetical, Moleia must be the most ancient ceremony for the water and the environment.

1. Introduction

In Arcadia three different physico-geographical systems can be distinguished [5]: (i) the mountainous area, which comprises almost the whole of the central part of Peloponnesus, (ii) the lowland area and (iii) the coastal area of the Argolic Gulf.

The lowland area includes the Megalopoli basin, the Arcadic plateau and the Stymfalia and Feneos basins.

The Arcadic plateau, part of which is the Tripolis plateau (Fig.1), does not constitute a uniform lowland area, but it is rather a series of basins with the common characteristic the absence of surface runoff. Specifically, the Tripolis plateau is a closed hydrological system that has not turned into a permanent lake (or lakes) but only periodically. The runoff water that ends up to the plateau from the surrounding mountains, usually drains through numerous sinkholes. Consequently, although the Tripolis plateau is a closed hydrological system, *it behaves as an open system from a hydrogeological point of view.*

The geological and tectonic structure of the Arcadic plateau are complex, with an even more complex evolution, that continues until today, since it constitutes an *active seismotectonic structure*.

The special physical and geological characteristics [5] of the plateau are the following:

i) The great extend of carbonate rocks (limestones and dolomites) and

ii) the extensive kartsification, that is the intense dissolution of carbonates that leads to the creation of all kinds of karstic formations, such as dolines, sinkholes, caves etc. The great number of sinkholes and caves is located both on the margins of the carbonate rocks, as well as at the bottom of the basins that is covered by clastic sediments of small thickness. The Arcadic plateau consists of a number of poljes.

Fig.1. 3D representation of the wider area of the Tripolis plateau, showing the location of the different sinkhole systems.

On the other hand, Arcadia is not as known for its geological and tectonic structure, as for its contribution to the cultural evolution of Greeks, since the ancient prehistory of the people later known as Arcadians, is lost in the greater depths of the human prehistory.

Arcadia is essentially the cradle of the Greek Mythology [6], [7]. Numerous Gods of the ancient Greeks were born here, among those Poseidon on the Alission mt., Zeus on Lykaion mt., Pan on Mainalo mt., Hermes in Kyllini and possibly more [8].

There are no great Gods or other deities that have not lived part of their lives in this broader area of Pelopennesus, such as Rea and Cronus along with Atlas from the Titans, Giants, as well as the Gods Artemis and Appolo, Hera and Demeter, Aphrodite and Dionysus, Asklepios and many others.

Local heroes, descendants of Pelasgus, Lykaon and Arcas, were the founders of different settlements. Some of these settlements evolved to important cities along the long history of the inhabitants of this area, others did not. It is noteworthy that many of the names of locations, rivers, mountains, cities and villages have stayed the same, until nowadays, even though many of these changed in the meantime, because of the historic and social circumstances of the last 1200 years, when Slavic, Albanian and western European phyla conquered the area, for a short or a longer time, without being able to destroy the local cultural heritage.

Taking into account all the above-mentioned about the Gods and the local heroes, it is not an exaggeration to say that, possibly, there is no other area in the world where so many Gods and heroes were born or acted.

Because of this long prehistoric and historic route, many ceremonies and festivities are mentioned to take place here. Some of these are celebrated even today, within a Christian context, after the ban of all celebration dedicated to the Gods of the ancient Greeks. One of these celebrations, almost forgotten today, is the Moleia.

2. Moleia

It is believed that *Moleia* [1] was a war-related celebration in memory of the murder of the Homeric hero *Arethoos* (*or Arethus*) *Korynitis* by *Lykourgos*, king of Tegea, son of *Aleus*.

Moleia was celebrated all over Arcadia and both the two heroes – opponents, *Arethoos* and Lykourgos were honoured. Arethoos was honoured in the hypostasis of *Ippios Poseidon*, while *Lykourgos* in the hypostasis of *Lykaios Zeus*. The *Mantineian Ippios Poseidon*, being the God of water, springs and protector of the flora, disputes with *Lykaios Zeus*, who is in charge of the atmosphere and consequently destroys the plants with heat. It is said that this myth symbolizes the "war" between rain and drought, or between wetness and dryness, and the struggle of the inhabitants of the Arcadic plateau to cultivate an arid land. It is noteworthy that *Arethoos Korynitis* [4] originated from the city of *Arni in Boeotia*, the Mycenaean acropolis located near the modern village of *Kastro* in Kopais. At that time, all the area of Kopais was inhabited by a Pelasgian phylum, the *Minyans*, and the main city was Orchomenos. The Minyans, as proved by their constructions, had great technical – geological and hydraulic knowledge and had

managed to drain the Kopais lake with the construction of great anti-flooding and land reclamation works [3].

As it was mentioned, *Poseidon* and *Zeus*, were born in Arcadia. Zeus was born at the top of Lykaion Mt. and Poseidon at the slopes of a hill named *Alision Mt.*, near the plane of the modern-day village of *Milia*, which is part of Mantineia.

The ceremony of Moleia took place at the site where it is said that Lykourgos killed the Minyan Arethoos Korinytis. This site was named *Molyhio* or *Phyzon* [1]. Its exact location is unknown, but it is at the broader area of Nestani village (Fig.2). *Nestani* is built on the western slopes of Artemision Mt., at the southern hilly margins of a basin, known as *Argon Field*, which is one of the independent basins of the Arcadic plateau.

Others believe that the Moleia were celebrated at a site of Nestani known as *Panigysristra*.

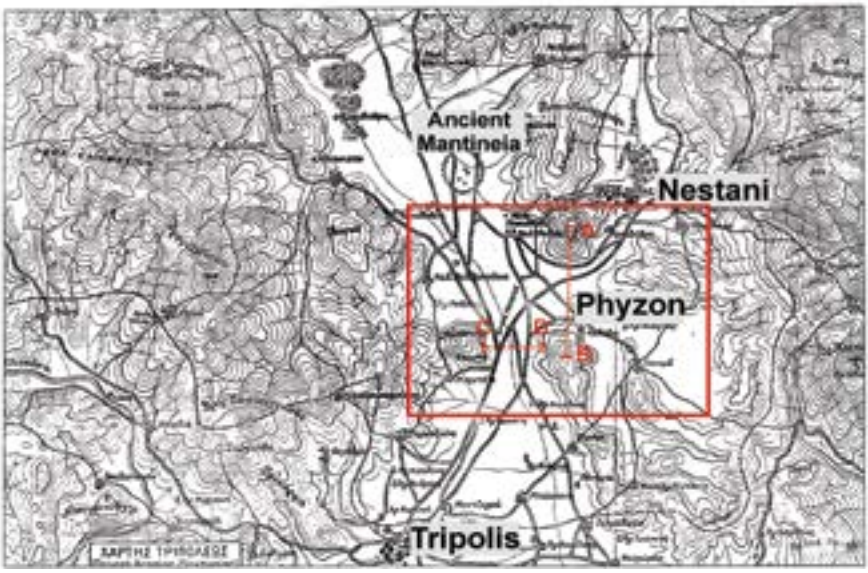


Fig.2. Schematic map showing the possible location of Molyhio (Phyzon) (A – B). C-D: Dam site [2].

3. Moleia and climatic changes

Some may wonder what kind of celebration *Moleia* was. I think that, in order to understand the symbolism of Moleia, one should connect it to the *geoenvironment* of the area and especially to the climate of that time and mainly the mean air temperature and the precipitation, as well as the climatic changes of that prehistoric – mythological time, as these are accepted today [9].

This is very important because Mantineia and the Argon Field, as well as the other planes such as *Taka, Kandyla, Stymphalia* and others, were often flooded then, as they are today. This happens because, as it is already mentioned, they are closed hydrological systems.

Consequently, flooding created problems in winter and, on the other hand, drought created problems in the summer. This antithesis appears to be symbolised by the physical and geological dimension of Poseidon who, being the God of waters and of the Earth's interior, regulated the drainage, and that of Zeus who dominated the atmosphere, i.e. the precipitation, the sunshine and the high temperatures that caused droughts. So, for the dry periods Zeus was responsible. That is why, in several sites of the Eastern Greece, there were sanctuaries dedicated to "Omvrios" Zeus (omvros = rain), as for example on the eastern slopes of Mt. Hymmetus, (eastern Attica).

4. Possible reasons of the dispute

What is the reason for the fury of Lykourgos, an Arcadian, against a Minyan, Arethoos? Moreover, why a Minyan was in Mantineia and what was the reason of the disagreement between Lykourgos of Tegea and Arethoos and not between Lykourgos and an inhabitant of Mantineia, especially an inhabitant of Nestani? Why the murder took place in the area of Nestani (according to the myth) and not in Mantineia? Could it be that Arethoos was considered responsible for the drought?

The answers to the above-mentioned questions are, obviously, not given by any ancient author. I believe that the answers are related to the physical and geographical conditions that prevailed in the broader area of Mantineia during the Mycenean Times and the economic and technical activities of the Minyans. The Tegean Lykourgos lived just before the Trojan War. The period of his struggle with Arethoos seems to coincide with the 2nd Little Ice Age, the maximum of which dates around 1200 B.C., according to Shore (in [10]). This was probably a dry period for the area, since it is known that the decrease of temperature is connected to a decrease in precipitation.

At the time, Mantineia and Tegea should have been allies. It is noteworthy that, later, Tegea formed an alliance with the Lakedaemonians, while Mantineia allied with the Argeans and the Athenians. So the murder of Arethoos should not be related to political disagreement.

All these lead to the conclusion that the Moleia must have been related to the land reclamation activities of the Minyans in Arcadia. As it is proven by the detailed studies of Jogst Knauss [2], the Minyans constructed low dams in the basin of Taka lake, in Mantineia and in the basin of Kaphyes. These geotechnical works aimed at water collection, as well as the protection against flooding. In Mantineia, the Minyans constructed a dam at a site east of *Skopi* village, where, according to Knauss [2], in the reservoir that was formed, 15 million cubic meters of water could be retained. This great work put an end to the flooding of the Mantinean plain and allowed the construction of the city of Mantineia, while still securing water for the summer months, when the temperatures are high.

It seems that for some reasons, possibly technical ones, the quantity of the water in the reservoir was not enough to secure the water supply during an extended drought period, and Arethoos was held responsible for the technical shortcomings of the dam. So, it is possible that the reason of the dispute between Lykourgos and Arethoos, which lead to the murder of the latter, was the water shortage. This viewpoint seems all the more

possible, since within the inundation area there are several sinkholes, one of which is the well known *Kanatas sinkhole*, located west of the small church of St. Nikolaos.

So, it seems that Arethoos was the representative of the "constructors" and was responsible for the maintenance and the smooth operation of the dam.

5. Conclusions

Regardless of the causes of the dispute, Moleia is the most ancient ceremony dedicated to the water, from the Mycenaean Period although drought periods are mentioned from even older times.

6. References

[1] Fougeres, G., 1898: Mantineè et l' Arcadie Orientale, 44, 576 p., Taf.9.

[2] Knauss, J., 1991: Mykenische Talsperren in Arkadien und Böotien. In: Historische Talsperren 2, 19-40, Verlag Konrad Wittwer. Stuttgard.

[3] Knauss, J., 1984: Die Wasserbauten der Minyer in der Kopais - Die aelteste Flussregulierung Europas (Kopais 1). Wasserbau und Wasserwirtschaft, Nr. 50. Technische Universitaet Muenchen.

[4] Homer: The Iliad (H, 137).

[5] Philippson, A., 1892: Der Peloponnes.- Berlin.

[6] Hesiod: Theogony.

[7] Kakridis, J., 1986: Greek Mythology. Ekdotiki Athinon, v. 4 (in greek).

[8] Pausanias: Ellados Periigisis - Arkadika. Ekdotiki Athinon.

[9] Milankowitch, M., 1941: Kanon der Erdbestrahlung und seine Anwendung auf dem Eiszeitenproblem.- Royal Serbian Sciences, Spec. Publ. 132, Section of Mathematical and Natural Sciences, 33, 633 p., Belgrade.

[10] Schwarzbach, M., 1974: Das Klima der Vorzeit: Eine Einfuhrung in die Palaoklimatologie.- Ferd. Enke Verlag, Stuttgart.

A4.2 The Way Back of the Argonauts According to *Argonautica Orphica*

Kalachanis, K., Preka-Papadema, P., Kostikas, I., Theodossiou, E., Manimanis, V.N., Panou, E.
Department of Astrophysics-Astronomy and Mechanics, School of Physics, National and Kapodistrian University of Athens

Abstract

According to the unknown author of *Argonautica Orphica*, the return of the Argonauts begins with the murder of Absyrtus. The Argonauts sailed the Phasis River upstream, reaching Lake Maeotis. After ten days of wandering, Argo reached the Riphean Mountains, where the sources of Danube are, and then the Argonauts, passing through a narrow channel, made their way to the Ocean, called "Cronian Sea". There they met the Cimmerians and, bypassing the island of Ierne, they went far from the shore, in the open Atlantic Ocean, as it is explicitly called in the text. After a 15-day travel, they reached Aeaea, the island of Circe, then Tartessus, and then they approached the Pillars of Heracles. Their subsequent course was inside the Mediterranean Sea: They sailed by Sardinia, the Ausonian (Italian) islands, the shores of the Tyrrhenian Sea, and through the Lilybaeum strait to Sicily, where they met Charybdis and then the Sirens. After that, they arrived at Corcyra (Corfu), where the Phaecians (Phaiacians) lived. Leaving Corcyra, they were carried by the winds towards Africa, they reached Crete and then Anaphe. Finally, by rowing, they passed by Cape Maleia and arrived at Iolcos.

In the present study, we examine the feasibility of such a voyage and identify certain problematic points in the description of the voyage.

1. Introduction

The Greek epic poem *Argonautica*, narrated in the name of Orpheus, describe the expedition of the Minyans from Iolcos (at the foot of the mountain Pelion, Greece) to Colchis (on the banks of Phasis River, today Rioni River, Georgia) in order to retrieve the "Golden Fleece". The title of the text, "Argonautica", originates from the name of their ship, Argo. This was a sailing ship that could also travel by using the force of 50 rowers (v. 278-306, *πεντήκοντ' ἐρέτησιν*). From the heroes who participated in the expedition, it appears that it took place one or two generations before the Trojan War.

The *Argonautica Orphica* were transmitted orally until the age of the Peisistratids, when they were recorded by a commission headed by Onomacritus (c. 530-480 BCE), as reported by Clement (*Stromat.* I, 21, 131). Herodotus (VII 6) informs us that Onomac-

ritus was accused for reshuffling the Orphic texts.

In the present study we follow and analyze the voyage of Argo's return based exclusively on the Orphic text.

2. From Colchis to the Riphean Mountains

After getting the Golden Fleece, and after Absyrtus was murdered by Medea, the Argonauts sailed from Colchis and, because of the night and a miscalculation, they moved towards the interior of the country (the feet of Caucasus) and not towards the estuary of Phasis River in Euxeinos (the Black Sea) (Fig. 1). When the dawn came, they found themselves on an island between the rivers Phasis and Saraggis, which reaches the Maeotis "lake" (the Sea of Azov). After rowing for two days, they reached the passage of Boos (Strait of Kerch).

However, in order for the Argonauts to reach the Sea of Azov from the Rioni River, the probably followed another river that has its estuary in that Sea, such as Hypanis (Kuban), which has its source near Mount Elbrus in Caucasus (5642 m). However, Kuban and Rioni are far from connected to each other, since they are more than 100 km apart (Fig. 1). It is hard to believe that they followed a route from Rioni through the rivers Tskhenistskali, Kheledula, Kasleti, Nenskra and Dalari to reach Kuban (Fig. 1): In order to follow this demanding route, one has to climb up to an altitude of about 2,000 m. Of course, the topography of the region could change during the intervening centuries.

After they reached Maeotis, the Argonauts sailed through the Strait of Kerch from north to south in order to reach the Black Sea. For nine days, they sailed parallel to its northwestern coastline, something attested by the description of the tribes they met. On the tenth day, they reached the Riphean Mountains and then, going through a narrow pass, they found themselves in the Ocean, called by the Hyperboreans "Cronian" and "Dead" Sea.

The Riphean Mountains have been variously identified as the Ural Mountains or the Alps in Switzerland. In *Argonautica Orphica* it is mentioned that they are near the Alps (v. 1123-1126). Since the Alps are next to the Southeastern Black Forest, where are located the uppermost sources of Danube, a river that flows into the Black Sea[1,2], the text supports the view that the Argonauts went up the whole Danube and then the Rhine, either directly or through tributaries, as the two rivers approach each other as close as 30 km (Fig. 2). Thus, they reached the "Cronian Sea" near modern Rotterdam (the Netherlands), where the mouth of Rhine used to be (*Ὁ μὲν γὰρ ὑπὸ ταῖς ἄρκτοις πᾶς μὲν ἀρκτικὸς καὶ βόρειος λέγεται, ἤδη δὲ αὐτοῦ τὸ μὲν ἀνατολικώτερον Σκυθικὸς ὠκεανὸς, τὸ δὲ δυτικώτερον Γερμανικός τε καὶ Βρεττανικὸς καλεῖται· ὁ δὲ αὐτὸς οὗτος σύμπας καὶ Κρόνιον πέλαγος καὶ Πεπηγὼς καὶ Νεκρὸς ἐπωνομάζεται.*)[3].

Figure 1: Upper: The itinerary from Phasis to Maeotis through the Western Caucasus. Highlighted is the distance between the rivers Phasis and Hypanis. Lower: Detail of the distance between Phasis and Hypanis that equals 60.7 km; it includes flows of smaller rivers (see text). With green dot is highlighted Mount Elbrus (5642 m).

However, the following questions arise naturally:

1) How did they climb the steep slopes of Caucasus? By rowing against the fast current? Even if the topography was different back then, with more small rivers present, the feat remains almost impossible.
2) How did they achieve to do such a difficult travel within no more than 50 hours? What's more, the Kuban River (Hypanis) is not mentioned in the text. Instead of it, the Saraggis river is named, a river that other ancient sources place in Vaktria (Polyaenus, *Strategems*, I, 1, 3, 2) or in India (Arrian, *Indica*, 4, 8, 2).
3) Why among the Black Sea tribes are mentioned the Hyperboreans, who they used to reside a place beyond the Riphean Mountains (Clement, Stromat. I 15), the Nomads (Numidians), who lived in north Africa (Appian, *Historia Rom., Preamble*, 3, 4), and the Caspians, who lived on the shores of the Caspian Sea (Stephen of Byzantium, *Ethnica*, 365, 3)?
4) The Riphean Mountains are described as being near the Atlantic Ocean; the exact path of the Argonauts is not mentioned.

Figure 2: The itinerary from Danube to the Riphean Mountains and the Black Forest, and then, through the Rhine, to the Atlantic Ocean (Cronian Sea). The Dreisam River (arrowed) lies between Danube and the Rhine; the distance between the two major rivers is approximately 30 km.

3. In the "Cronian Sea" – the route to Circe

The reference in the text that the ship was directed to the *"right-hand part of the shore"* means a northern direction. This is confirmed by the description that *"the sea was sleeping under the Helike and the last waters of Tethys"*. Helike was a name given to any of the two Ursa constellations (Ursa Minor and Ursa Major), both signifying the northern direction; Tethys is the wife of Oceanus, whose "last waters" were at its northern edges. The Argonauts, because of lack of wind, pulled their ship to the pebbles of the beach, moving *"swiftly"* northwards along the shore for 5 days. Of course, it would be more reasonable to move towards the southwest, in order to pass through the English Channel and return to the Mediterranean Sea through Gibraltar; however, a noticeable ocean current dominates the Channel, which is directed towards the northeast (Fig. 3).

Figure 3: The itinerary of the Argonauts according to Argonautica Orphica (*thick blue line*) *and their direction* (*black arrows on the blue line*). *The other arrows indicate the direction of the ocean currents.*

On their sixth day in the ocean, they reached the Macrobians, who live in *"meadowy"* places, the Cimmerians, the "Acheron River" near a *"rough prominent turn and a shore protected from the wind"*, a region characterized as "cold". They also reached the *"low"* (flat) Hermionia with its many *"pastures"*. These descriptions fit to the region of the Netherlands, the northern shore of Germany and the Jutland peninsula (Denmark). The speed of a walking person is 4 to 5 km/hour[4]. If the Argonauts moved during both daytime and nighttime, then in 6 days they could travel a distance of ~ 600 km, i.e. the distance Rotterdam-Esbjerg (Fig. 4a). The coastal area of Ho Bugt near Esbjerg, with its several sand dunes, which forms an extended lagoon, could fit the description that "the waters of 'Acheron' (the Varde stream/river?) have a silvery but also golden color", as the yellow color can originate from the erosion of the dunes. Additionally, we note that, while the ship was previously being pulled upon pebbles, it is written that in this region *"the vast waters of the Ocean hum over the sand"*. The dark nature of the region of the Cimmerians is not attributed to the long winter nights of the far northern regions, but rather to the fact that the region is located between high mountains, so that direct sunlight does not find a way to reach the ground (v. 1120-1126).

In this region the Argonauts experienced a change in weather, as the calm turned into a strong wind, so they prepared to sail. As for the currents, here we meet the Norwegian Current (Fig. 3), that comes from the west and in this region turns to the north, in its way to Norway. The Argonauts circumnavigate the island of Ierne (Ireland or pos-

sibly the British Isles), pushed from behind by *"a black storm with thunders that bellied the sail and the boat run fast"*. As the author had previously alluded to the direction of the wind, the "push from the back" means that they go west, or west-northwest if we add the effect of the Norwegian Current. In this way they managed to pass from the north of the British Islands (Fig. 3).

Turning then to the south, obviously aided by favorable winds, they passed Ireland from the west, at a distance of about 200 km; so they were in the open sea and for 12 days they did not see any land. In Figure 3 the route traced, at a calculated speed of 6 to 7 km/h, corresponds to approximately 2000 km. Note that the average speed of ancient ships 4-6 calculated knots/h (7,4 - 11,1 km/h)[5].

They would follow the southern route of the ocean current of Canary Islands and be led to Gibraltar (Fig. 3). However, they saw "from very far away" an island with a *"great cloud forming a circle around it"*. Indeed, the southernmost tip of that route (Fig. 3) is a few tens of km from Madeira, so that it could be barely visible, mostly thanks to the orographic clouds that covered the peaks of its mountains (1861 m being the altitude of the highest peak, Pico Ruivo), a way to locate land well-known to sailors.

The identification of the specific island, known as the "Island of Demeter", the goddess of agriculture, was a sign that they had overshot Gibraltar, so they had to change their route. Argo turned to the left (east) in an attempt to reach Gibraltar, however they already were on the wide Canary Current, a surface ocean current that flows southwest about as far as Senegal. Thus, their effort fails and they make landfall in northwest Africa, several hundreds of km far of Gibraltar. Even today in navigation is difficult to track down this passage[6].

They arrived at a peninsula (*cherson*, v. 1208), and not an island in the modern sense of the word, where Circe resided. Indeed, it seems that Argo reached the Essaouira of Western Morocco (near the foot of mount Atlas) three days after they passed from Madeira (Figs. 3 and 4b). The distance of approximately 700 km is covered within this time span at a speed of 9 to 10 km/h, i.e. the speed of 6 to 7 km/h added to the speed of the Canary Current of 1 km/h. As it can be seen in Figure 4b, the Mogador Island is merely 1.5 km (less than a mile) from the small peninsula of Essaouira. Thousands of years ago, this island was probably united with the mainland. Thus, the appearance of the then-peninsula would resemble a long "island".

Argo moored near a rocky area and some crew members disembarked in order to explore this "endless land". However, Circe appears almost immediately, coming from the opposite direction and not allowing them to walk further.

The determining expression *"Λυκαῖον ποτί χέρσον"* (v. 1206, Leipzig edition 1764), from the root lyc = light, reminds of the "Mountain of the Sun" mentioned by Ptolemy in his Geography (IV, 1, 3, 1); this topographic feature corresponds to the coordinates of Essaouira (310 30′ 47′′ N , 90 46′ 41′′ W). Besides, Circe was daughter of Helios, the Greek sun-god, while in the same region the Greeks placed the residence of Eos (*Odyssey* XII, 1-5), the personification of the dawn and sister of both Helios and Selene (the Moon goddess).

The "island" of Circe is described by Homer as (*Odyssey* X) forested, and Essaouira is near the foot of the Atlas Mountains. The ship of Odysseus (Ulysses) approached to

a deep harbor, as indeed is the natural harbor formed there, since the Mogador island combined with the edge of the peninsula forms a safe mooring place. Nearby there was a river, near which Odysseus killed a tall deer. Indeed, there is the river Qued Ksob, only about 2 km far from Essaouira; moreover, in the region still lives a subspecies of red deer, the "Barbary stag" (*Cervus elaphus barbarus* or Atlas deer). Finally, in the residence of Circe lived wolves and lions, and in the Atlas region lives the African golden wolf (*Canis anthus*) and the Barbary lion (*Panthera leo* - Atlas lion). Consequently, the Essaouira peninsula fits the Homeric description of Circe's "island" in multiple ways.

However, there are some problems:

1) The Cimmerians are described as living both on the shore of the Atlantic Ocean and amidst the tall mountains of Central Europe. It is mentioned that sunlight is obscured in the early morning by the Riphean Mountain, in the noon hours by Phlegra, and during the last hour before sunset by the Alps. Yet, the Alps are to the east and the Riphean Mountain (the Black Forest) lies to the west; hence, the east-west orientation reported in the text is exactly the opposite from the one generally accepted (!).

2) During the period the source texts for *Argonautica Orphica* were written, the Cimmerians were located to the north of the Black Sea and Maeotis (Hecataeus of Miletus, *Fragmenta* 195, 5-6; Polybius, *Histories* IV, 39, 3, 1; Herodotus IV, 12, 4). However, in the *Argonautica* there is absolutely no mention about Cimmerians in that region during the Mycenaean period. It seems that this ethnic group appeared in the region much later. What was the relation of the Black Sea's Cimmerians with the Cimmerians mentioned in the *Argonautica Orphica* and in the Odyssey?

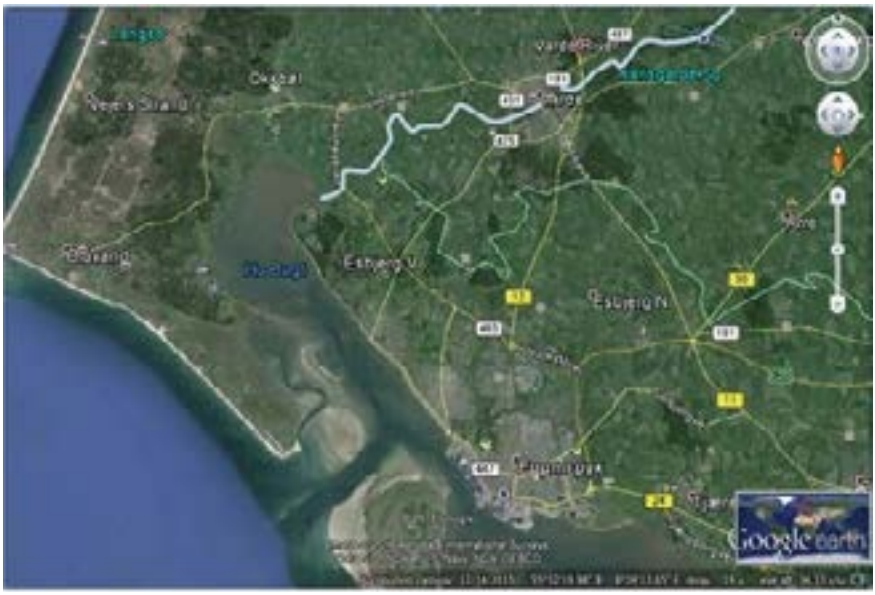


Figure 4: a) The Esbjerg region of the Jutland peninsula (Denmark); the Ho Bugt coastal area with its dunes and the Varde River are marked (light blue line). b) The Essaouira city and peninsula in Morocco; the Qued Ksob River is indicated in the lower left (light blue line). It is also noted that the mountains near Essaouira are the foot of Atlas Mountains.

4. The voyage in the Mediterranean Sea

The Argonauts then departed and sailed towards the "mouth" of Tartessus (*"ανά στόμα Ταρτησσοίο ικόμεθα"*), approaching the Pillars of Heracles (Strait of Gibraltar). According to the Liddell-Scott-Jones *Lexicon*, the syntax of the preposition *ana* with accusative case denotes a motion from a lower to an upper part. The "mouth" of Tartessus (a city on the Atlantic coast of Spain) is given as an allusion for the Pillars of Heracles, from where they entered the Mediterranean Sea. After they passed from Sardinia, the Ausonian islands and the Tyrrhenian shores (Italy), they reached the Lilybeum Strait; this is the strait between Sicily and northern Africa, named after the city of Lilybeum (today's Marsala), i.e. the "city that looks towards Libya". In this region (Campi Flegrei Mar Sicilia) there are many volcanoes under the sea and volcanic islands (Fig. 3), where the Argonauts met Charybdis.

A wave of hot water came up from the bottom of the sea and flowed around the ship's bow, while in the form of a boiling wave fell at the edge of the sail. The boat was immobilized and then it started to rotate over a "cavity on the sea", while it risked going down and being stuck to the muddy seabed. This description fits perfectly a sea whirlpool caused by the eruption of a submarine volcano[7].

After this incident, Argo reached a nearby protruding *"skopelos"*. This word, according to the Liddell-Scott-Jones *Lexicon*, denotes a tall rock or peak, a precipitous shore

or promontory. The sea under it is pressed through openings, causing the waves to make a humming noise. On the top of this rock sit the Sirens, who emit a "ligyre" voice. According to the above dictionary, this Greek word means a clear, whistling, acute and intense sound.

The Argonauts left the oars and Argo headed towards the Sirens, who were sitting on a *"προβλήτα κολωνόν"*, that is a protruding "hill" and not a precipitous rock (*"πέτρη απορρώξ"*), as mentioned just a few verses prior. This description reminds the emergence of a volcanic islet as the result of an eruption of a submarine volcano. The "acute and intense sound" that accompanies the volcanic eruption as a result of turbulent flows and friction by the hot gases as they accelerate upwards after they leave the crater together with fragments of magma, ash and other solidified particles, could indeed be paralleled to the "voice" of the Sirens. The sounds produced by volcanoes are very strong and can cause loss of hearing and even material damages[8] (http://volcano.oregonstate.edu/volcano-sounds-during-eruptions). One could imagine that, because of the deafening sound the Argonauts left the oars to close their ears with their hands, while Orpheus is presented as covering the sound by playing his phorminx.

Then, from another, "snow-covered" (*νιφόεντα*) rock, the Sirens emitted a terrible sigh and committed suicide by falling to the sea from the edge of the precipitous rock, being immediately transformed to small rocks. The odd description of the second rock as "snow-covered" denotes presumably the white constituents of volcanic matter, such as perlite and pumice, that covered it. The "Sirens" fell on the sea like discs (*"δίσκευσαν"*), in other words they fell while rotating, just like discs thrown by a discus thrower. This description aptly conveys the motion of volcanic bombs, i.e. pieces of viscous molten rock ejected during a volcanic eruption. If they were human bodies, the text would speak of a vertical fall, because of their weight. The fall of volcanic bombs creates volcanic stones.

Hence, it is reasonable to suggest that both the Charybdis and the Sirens as mentioned in the *Argonautica Orphica* are actually metaphors of a submarine volcanic eruption to the south of Sicily. On the other side, the Sirens, the Scylla and Charybdis mentioned in the Odyssey are located closer to the island of Circe (XII 165-167). Odysseus, unlike the Argonauts, meets first the Sirens and later on the Scylla-Charybdis pair. And, if we stick to the mythical chronological order, it is impossible for the same Sirens to appear in both works, since the ones in *Argonautica* were transformed into rocks decades before Odysseus met his Sirens as sweetly-singing women in a meadow of a larger island (XII 37-45, 165-170). Moreover, Scylla is not mentioned in the Argonautica, while the description of Charybdis is markedly different; the Homeric Charybdis draws the sea water three times per day, reminding the tidal cycle with a strong tidal bore[9].

5. The voyage in the Greek seas

When the Argonauts left Sicily, they crossed the Gulf of Taranto and continued eastward to Corfu, the Homeric island of the Phaeacians. They avoided the dangerous Libyan Sea (Fig. 3). However, at the same time arrived to Corfu the Colchian fleet. It seems

that they waited for the Argonauts to the south of the island, for if they were in the north they would have intercepted them before they could reach Corfu. Maybe they had settled in the Paxoi islands.

After an agreement they reached with the Colchians, the Argonauts sailed south, towards the Ambracian Gulf. Unfortunately, the strong wind pushed them across the Mediterranean, to the African Gulf of Sidra. From there, they reached Crete, where the metallic giant Talos did not allow them to disembark. They struggled with the waves of the Sea of Crete, trying to reach the "Melantian Rocks."

According to Scylax of Caryanda (*Periplus,* 113, 1), these Rocks were between Mykonos and Icaria, not far from Delos. This is compatible with the following myth: Paean (Apollo) threw an arrow to point to the Argonauts as a shelter from the storm a new island, at the center of the ancient Sporades Islands (the modern Cyclades). Because that island "*ανεφάνη*" (reappeared) out of the darkness and the tempest, it was named Anafi. Anafi lies to the south of Mykonos and then probably the Melantian Rocks are the two rocky islets (nowadays known as Pacheia and Makra) just to the south of Anafi (Apollonius Rhodius: *Argonautica*, transl. *Peter Green*, p. 307).

The Argonauts arrived finally at Cape Maleas of Peloponnese, where Orpheus disembarked and climbed to the Tainaron hill, where there was an entrance to Hades. The other Argonauts continued their voyage to Iolcos.

However, the following issues arise:

1) The Argonauts met in Corfu the King Alcinous and his wife Arete, whom Odysseus met there decades later along with their daughter Nausicaa. This is an event incompatible with the time that elapsed between the Argonautics and the voyage of Odysseus.

2) In the *Odyssey* there is no mention of the word Kerkyra/Corcyra (Corfu), while the inhabitants of "Scheria", which is not characterized as an island, are called Phaeacians. Besides, Strabo in his *Geographica* (I, 2, 18- 14) suggests that Scheria and Ogygia are located in the Atlantic Ocean.

3) The Phaeacians of *Odyssey* were not indigenous to Scheria, but they had moved there from Hypereia (a place near the region where the Cyclopes lived, i.e. either in Sicily or on the adjacent shore of the northern Africa). The darker-skinned inhabitants of northern Africa would be aptly called "phaeacians", since in ancient Greek phaeos means "dark-colored"; similarly, the dark-skinned inhabitants of eastern Africa were called "Aethiopes", i.e. "burned faces".

6. Conclusions

By studying the text of *Argonautica Orphica*, we conclude that the described itinerary is feasible. The Minyans knew the route through the rivers Danube and Rhine, which allowed the communication between the Black Sea and the "Cronian Sea". It also seems that they knew the ocean currents of the Atlantic and used them for their voyages. By following the route described, we identify Madeira as the "Island of Demeter" and Essaouira, in today's Morocco, as the "island" of Circe.

We point out the inaccuracy of "transferring" the mountains of Central Europe to

the shores of North Atlantic, and with an opposite orientation, an utterly unjustified mistake for a chresmologue and scholar such as Onomacritus.

By comparing *AO* with the Odyssey, we notice different adventures appearing under the same name (Charybdis and Sirens, Cimmerians, Phaeacians, etc.). If Onomacritus actually modified *AO*, we propose as topic for further study whether a part of our points of observations can be his modifications, and what was his purpose in doing so.

References

[1] Stephan von Byzanz (1849): *Ethnika*. Ed. A. Meineke. Berlin: Reimer. 650, 3.

[2] Aeschylus (1959): *Fragmenta* . Ed. H.J. Mette. Berlin: Akad. ¬Verlag. 32, play B, 330, 2.

[3] Anonymus (1861): *Geographiae Expositio*, ed. K. Müller, vol. 2. Paris: Didot. 45, 8.

[4] Browning, R. C., Baker, E.A., Herron, J.A. and Kram, R. (2006): "Effects of obesity and sex on the energetic cost and preferred speed of walking". *Journal of Applied Physiology* 100 (2): 390–398.

[5] Casson, L. (1951). "Speed under sail of ancient ships". *Transactions of the American Philological Association* Vol. 82, pp.136-148.

[5] Carracedo, J.C., Torrado, F.P., González, A.R., Soler, V., Turiel, J.L., Troll, V., Wiesmaier, S. (2012): "The 2011 submarine volcanic eruption in El Hierro (Canaryc Islands)", *Geology Today*, vol. 28, issue 2, pp. 53–58.

[6] Petrides, Z. (1994). *Odyssey, a naval epic of Ancient Greeks in America*, Athens {selfedited, in Greek}.

[7] Carracedo, J.C. Torrado, F.P. González, A.R. Soler, V. Turiel, J.L. Troll, V. Wiesmaier, S. (2012). The 2011 submarine volcanic eruption in El Hierro (Canary Islands), *Geology Today*, Vol 28, Issue 2, pp 53–58.

[8] Wendel, J. (2016): "Sound waves help scientists track volcanic eruptions", *Eos*, 97.

[9] Chanson, H. (2011): *Tidal Bores, Aegir, Eagre, Mascaret, Pororoca. Theory and Observations*. World Scientific, Singapore.

A4.3 The Orphic Cosmogonic Theory: Dialectics of All

Maria Sideri
writer- independent researcher

Summary

The ancient Greece, a paradigm for the modern world, is best defined by the Orphic Cosmology- Ontology, a science of a dialectic methodology.

Some of its axioms are:

- The preontologic spheroid Principle "EN" (One), immaterial, contained the Chronos-point. Psyche (Soul).
- The "EN" releases two dynamic Laws, prerequisites of the "ΓΙΓΝΕΣΘΑΙ" (evolution process): The Principle "ΥΛΗ- ΓΗ" (Matter- Earth), Cause of division, and the Principle "ΥΔΩΡ" (water) Cause of synthesis.
- The interaction of the two Principles generates the infinite Chronos (Time), active force of Reality's foundation.
- The Chronos transforms inside him the "Matter- Earth" into potential matter-Chaos and the "Water"- Ether, into pure matter-energy.
- Mutually penetrated, Ether and Chaos provoke a strong gravitational activity, causing the first material creation of forms: the cone (vortex) "ΙΛΙΓΞ" (Iligx-whirlpool) corresponding to the "black holes".
- The mixture of chaotic "roots"- Ether, <u>inside the Iligx, strikes the background field of "ΠΝΕΥΜΑ" (Spirit).</u>
- The Spirit, is drawn into the mixture recomposing the elements and forcing the Iligx to eject its <u>positively charged</u> content, which is now transformed to an expanding sphere raising to the Ether and pumping spin from the Chaos.
- That is the Orphic "ΩΟΝ" (Egg), the real Space. The Ether inside the ''ΩΟΝ'' is stabilized as a common membrane- fifth element, adapted to every tendency/ state of the matter, carrying the released in Space energies.
- Inside the full of radiation "ΩΟΝ", is formed a hot core of Ether- Spirit, of matter. As this hot core is growing, the "ΩΟΝ" is overheated beyond its resistance's limits, is fissured spawning flaming Light and Spirit merging to the World of Ideas and every enlightened value between the "EN" and the reconstituted "ΩΟΝ", drawing now from its offspring the fundamental existential conditions.

Introduction

What preceded the Physical World? What interferred as a procedure of the space-time, the multiverse Universe's Genesis? Which were the first steps and which the various transitions that led to its actual, relatively, stable state?

What could one say about the causes and Laws that provoked its Creation? Were these reasons and foundations nothing but random, or on the contrary, conscious and above any experimental approach?

What is the deep nature of matter, force and energy?

With these, -among others- questions, deals the introductive part of the Greek Orphic Theology, better known as Cosmogony. It does so, in an integral, continuous, open and complete way, (complete and at the same time aware of its incompleteness), through the path of the widely praised dialectic processing.[i]

The purpose of the following document is to superficially expose the Orphic Cosmogony's main theses, as they are composed into Otto Kern's "FRAGMENTA ORPHICORUM" collection- especially those found in the Greek edition's first volume.

Other philosophers' words (Orphic or not) will also be quoted in order to reinforce and denote the continuity, on common grounds, of the entire Greek cosmologic philosophy, starting from its first specified source.

However, as it is widely admitted, Orpheus was not literally the first theologian: he couldn't have been inspired this truly astonishingly wise theory, whilst living in a world of ignorance. What he in fact did, was to interpret, complete and spread his theory beyond the boundaries of the royal/ prelatic mysteries, in which he took part as a member of the prime-royal class.

<u>The "En" (One). The First Conceivable Duality</u>

"Let's realize that the En is the Primal Principle"[ii]
The Orphic theology according to Hieronymus and Hellanicus indicates: "in the beginning there were Hydor (water) and Yle (matter) - or their mixture called "Ylis" (mud), from which earth was coagulated; and these he establishes as the first two principles, water and earth, the latter as capable of dispersion, and the former as providing coherence and connection for material elements. The single Principle before the two, however, he leaves unexpressed, his very silence being an intimation of its ineffable nature" [iii].

The Orphic Cosmogony begins by referring to the highest first scale of Cosmogony, the one that "future followers of Orpheus" (Hesiod, Homer etc.) never mention. That being said, there are many those amongst them who consider it as the absolute basis, using various names to define it. It is called "Unutterable Principle", "the looking like unity", "Intelligible Intellect" (the first).

On Pelasgian inscriptions the word means amongst others: 1) "It", 2) One, overlord /master, 3) divinity. As for the imposed silence, it doesn't prove the rejection of the En (One) itself, but of public narrations about it. It was an ordinance equivalent of the sacred "unspoken" and the legislated secrecy surrounding the ancient Greek mysteries.

The "ineffable and unconceivable" of the first causes [iv] is originally named "En /

One" in the Orphic Sacred Words. For instance: "...the Gods exist permanently within the En"[v] , and "the primordial principle, called "En" and "entirely good" by theologians, after which follows the mystic dualism, superior of all ontological systems[vi].

-In Greek consideration, the notion of absence is absent; zero, emptiness and everything related to narrow, self-referential systems is rejected. Therefore, despite all theoretical restrictions, a lot has been in fact said about the En and its properties. It is proclaimed perfect.

All theologians and natural philosophers believe, without exception, that the First Cause is unequivocally unborn, self-existent [vii]

This perfection is exalted especially via Beauty (Kallos), which is attributed to the En as its basic sort quality:

"And so Orpheus said that Phanes can be conceived by our intellect. So, as Beauty pre-existed of Fhanes in the first supreme beings as relevance and continuity, he called him Beauteous God. Because he was the first to be confined with secret ineffable beauty"[viii].

Shape consists of the aesthetic manifestation of the content as well as of one of the categorial of form through which the being is identified.

The ideal form of the Sphere is defined by the conception of the otherwise, inconceivable En. "The sphere is the shape corresponding to the Creator God, as it pre-exists in his primitive principles within the secret cosmos" [ix].

The Sphere is considered as emblazonment of the highest of values such as: Justice, Truth (Parmenides), Friendship (Empedocles), but also as the Perfect Being.

According to the authentic Orphic theology, the En corresponds partially to the Parmenidian vision as unchangeable content/ substance, wherever, and as long as, no alterations and events occur.

Before we proceed, it is important to keep in mind the following rule: "we should not isolate any conceivable part from the rest, but accept that their union is unbreakable"[x].

Any arbitrary distinction can be realized for the sake of practical approaches and only after the first conceivable duality has emanated from the Unexpressed Principle, which is the starting point of the evolution process (Gignesthae).

The En is not empty. However its mass should be considered null without any properties of the active matter.

Its texture is presented as follows: "The primal principle fills in everything, the Intellect Worlds and Beings, with divine light".

The Light revealed by Chronos (time) ..... consists of the purest face of the inconceivable principles' World..... the Sun offers the world the light as a manifestation of the Truth, revealing at the same time the inconceivable Worlds ...[xi]

Light, the main expression of energies, is also the dominant element of the spheroid En. We know [xii]that gravitational forces attract not only bodies with mass but energy as well, with light positively curved deflection being a perfect example.

One Orphic thesis is the fact that the En's content is filled by different/dissimilar forces:

"So, this otherness is not without substance either, but it is understood that it exists

within the En.... Originated from the En it advances and divides itself into material unities [xiii]

The pre-existing difference manifests itself when the En opens, as contrast of divisible and continuous force, pre-signifying the genesis of real matter-energy. The distant origin of "our" similar systems is implied by the immaterial nature of gravity (amongst others), as undetectable, zero mass waves, moving at the speed of light. This is a reminder that anything concrete corresponds to a partly transmuted abstract: "Nature loves to hide" as said Heraclitus or "beings are nothing but force" (Plato).

According to Aristotle, we distinguish three evolutionary phases of the homologous with substance and matter being: "potential", "energetic", "perfected". Substance (Ousia) is not subject to the usual birth and decline/degeneration process. It is defined as that, which was a priori possible to become. Due to its supremacy compared to the phenomena, when the substance is being studied, it leads, through subtraction, to the final analysis of the latter. The last and beyond time result is their substance, the predominant cause.

These three phases of the being,- "potential", "energetic", "perfected"- can be associated in a restrictive way, with the current characterizations of matter ("potential", "real") and in a wider approach with " energy" and so forth. The force is the substance of movement and change, in other words of energy.

Putting aside philosophers such as Democritus, Anaximander or Anaxagoras and their sayings about size, mass or transitions of matter, we arrive at the modern discovery of wave-particles without mass: photons and gravitons. Therefore, the orphic axiom according to which some material principle dominates the En s content is confirmed into the physical world as well. This principle is called Nyx (Night).

The ancient Greek thinking rejects both the notions of null and "space less". The En exists in a familiar environment, which proves that despite its indestructible nature, it is not literally "unborn"/ without beginning. Whenever we deal with ontology in a positive way of thinking, all sorts of distinctions are vanished through the dialectic enantiodromia: "interaction between opposite tendencies" (Democritus). For instance it is mentioned: "Indeed, we conclude that the pre-universal place and the colorless, shapeless and unapproachable substance, and every transcendent width.... includes all the intellectual entities as well the Principle of the eternal all, the En".[xiv]

The description of a width containing the En itself fits to Nyx (Night).

"Orpheus said that dark Nyx that possesses everything... meaning that Nyx precedes everything else". Therefore, the En's environment resembles to Nyx. It is possible that whatever gave birth to the En remained intact as its environment, and whatever was received into the sphere was transmuted according to the defined space's conditions.

Nyx (Night) and Yle (Matter)

The first referred differentiation of Nyx takes place when (infinite) part of her (infinite) "quantity" derives from the En as Matter-Earth or as Hylis (mud). Since the first Intellectual Duality has an intensively metaphysical character, to understand the

properties of Nyx, it is important to relate her to Chaos, with which it seems to have a correlation to the Aether.
The main attributes of these two Principles are the same:

"Chaos is a field of potential birth of forms...it has no boundaries, no bottom... dense darkness..... is there... that is why Orpheus concludes that matter (Chaos is "potential" matter) was produced by the First of Intellectual Beings that is the Nyx. Because there, abundant darkness and lack of limits rule... these characteristics are more evident in Nyx than in her derivative states[xv].

Chaos is also interpreted allegorically as "Pelagos (=open sea)", connotation of "width"; in addition, agitations attributed today to negative curvatures, are also indicated.

Nyx is an affirmative Principle: it has the power/will to be dark; Chaos has neither this ability nor the opposite, according to the following part of the previous quotation.

Nyx corresponds to the definitions of substance and movement as prime "eternity", self-existence.

Chaos is not exactly a "substance", it's "shapeless". As an absolute denial, it anticipates its homologous absolute thesis (Aether), to become subsistence.

Modern physics may be able to arrive at a "representation/image" of the Night, equivalent to dark matter, dark energy, particles-carriers of interaction etc. In philosophical terms, it can be defined as "Reason of matter", according to Aristotle, and its antecedent, "Number" (Arithmos) ; because Number – as power of harmony is called "proanousios"[ ]. So, Reason and Number are not substances (by superiority).

Moreover, Nyx in the content of the En, has the position of Cognition. Cognition is equivalent to reasonable Mind. Philosophers refer as Mind to any absolute causal subsistence, super-divine or divine, and also the En (from the word Noa: in Dorian Dialect=Source).

The Intelligible Mind is called '' Metis". A cross sectioned sphere presents three basic components: a core, a perimeter and the space between them. Considering them distinguished within the En, we name the core "Mind" (source of emission of every conception), the space between we name "Nyx" and the perimeter "Logos". The term "logos" means amongst others "collect" and "cradle".

Nyx evaluates the Mind's suggestions and forwards them to Logos, where they gather. Philosophers described material universe based on the model and the structure of the En. For instance: Leucippus and Democritus believe that the world is surrounded by a ''stretched tunic...." The interaction of the Unexpressed Principle's three "places" is a discontinuous procedure. Anaxagoras estimations about the Mind's pushing and mechanical activity within the world, is very close to that hypothesis.

Manifestation of Noesis (Intellect)

"After the intelligible and indivisible unity, it became necessary to distinguish all those that appeared apart from the En. This distinction was made by "Arithmos" (Number)..... Intelligible's female precedes them all.....[xvii].

Plato repeats Orpheus words: "The concise divination of Nyx is the centre of each

true science…"[xviii].The simple pre-existing difference is also expressed through "abstract" values, such as "The Hours of Nyx….. The first foresees and foretells –a characteristic of Science. The second is called Sophrosyne (Wisdom). The third brings Justice into our world….."[xix].

The words mentioned above show the main property of Nyx: She is Intellect. Later on she will express herself as Metis- feminine part of the First-born God, Zeus' embodiment, Titanis, Cosmic consciousness, human inventiveness….

Nyx is also genuine in the world, as invisible nature-Eimarmeni: "Eimarmeni is the substance binding all beings, or Logos according to whom the world evolves"[xx]

The pair '' Matter-Earth/ Water", the first "clear distinction", attracts the Soul, '' Anagae" (Necessity), Persuasion (Spirit) and Logos.

The transcendent soul is simple: pure will, the absolute "wille" of Schopenhauer. This duality corresponds to urge and capability of life, conditions that activate all Laws.

Whilst the soul and the spirit nest mostly within matter, water relates by nature to Logos- Shape. Their interaction gives birth to Chronos (Time), born before space.

The distinction between space and "something else" containing matter is mentioned in the Orphic words: "(Chaos)…. Is not a place but a huge chasm…"[xxi].

Chronos before space is called 1)"Un-ageing" and 2)"Hercules".

1) Unattached to real matter. Chronos-point pre-existed within the En. The aforementioned discontinuity in there, places him in the centre of the Sphere.
2) "Hercules" because he wants and acts to satisfy the Soul's and Matter's will.

The Orphic Cosmogony concludes that: the "spinning" Anangae- Necessity and the "whole" Adrastia (means inevitable, another name of Nemesis) are considered of the same origin as Chronos. Necessity shows a restrained but intense motional activity: "All mighty Necessity binds the En with strong ties"[xxii], and :"….. this Cosmos in its origin was generated as a compound, from the combination of Anangae-Necessity and Nous- Mind. And in as much as Mind was controlling Necessity by persuading her to conduct to the best end the most part of the things coming into existence, thus and thereby it came about, through Necessity yielding to intelligent persuasion …..[xxiii].

Necessity holds the" spindle", stretched, through which the spheres spin [xxvi]. Adrastia seems immobile, overstretched, and tangent to all points of the sphere: a repulsive/ expansive force, opposite to Necessity, identical to Spirit/Persuasion.

Chronos-point reveals the Soul within the intact En: "beginning and cause of every movement" (Plato).

Chronos- Chaos- Aether

Out of the interpenetration of Matter-Earth and Water came Chronos. They released Aether, equivalent to Water, and Chaos, equivalent to Matter. So, the Second Intellectual Trinity is formed: the duality Aether-Chaos, and the unit Chronos. The expulsion of the pair's biggest part from Chronos creates the conditions of space, by nature a continuum of Chronos.

Aether and Chaos are not superior to the various transcendent ontological systems. Their components consist of the foundations of worlds, that is to say, of future onto-

logical systems: "shaped substance".

Chronos is allegorically described as "waving snake", with heads of Taurus (chthonic powers), and of Lions (solar celestial powers) on the sides, wigs on the shoulders and "face of God", illustrating a push forward and the tendency towards the future that now begins to show.

Water and Matter remain unexpressed within Chronos. Aether's movement defines Chronos as a continuous, rhythmical, High-frequency flow of power dynamic and kinetic. The temporality of Chaos, on the contrary, reveals disorder and instability.

The current description of the negative curvature static field of vacuum resemble to the Chaos: "The first one guarantees the completion of beings, whereas Chaos is the beginning of continuous evolution. The one is the root of everything; the other has no beginning and no end"[xxv].

Therefore, the ''Roots'' is not the minimum sizes, proportionate to "subatomic particles" and the question of their further division. They are, however, attributed to the cognitive of Nature and Soul tetractys, which is structured. According Aristotle: "soul, is the first integrality (entelechy)"). Plato also in Timaeus refers to the structural elements of soul.

Aether is called, amongst others, "wet Aether"[xxvi], "Perfect element of Cosmos" (Orphic Hymn to Aether).

Desirable results will be achieved by the intensified interaction between Aether and Chaos, always attached to Chronos. Aether is the bearer of roots of"Gignesthae" (evolution process), the fourth unit of the one Law/Logos."

''The universal Law expands infinitely within the vast Aether and the fully shed light of Sun" and Aether "sunk into matter"[xxvii].

Under free conditions, Aether moves in waves. (Spiral "River", according to the dragon-Chronos model). Into positively curved space, it is considered as a stretched membrane that covers the Universe internally like a ''hymen", and externally as a "shining" tunic, according to the example of Adrasteia.[xxviii]. But his lack of motion within a restless environment derives from his divine nature. He is extremely sensitive to every impulse, movement or any other behavior of matter and energy, where he adapts regulatory. Therefore, his immobilization is a primal or ultimate state.

Aether should not be identified with "any other" form of matter or energy, nor with fire or light. He is everywhere, dense or thin. Aether is identified with Zeus, as a substance, thanks to his "sticky-attractive property. Zeus is transformed to Eros when he creates according to Pherecydes. In the world of Gignesthai it is obvious that he is Eros unstoppable, in contrast with his calmness in the Conceivable World [xxix].

He acts as a pair with Spirit (Metis), so his compositions are not random but viable-dynamic. So, Zeus asks Nyx-Noesis:

"...Your Higness...tell me how to hold the will of the gods with my hands?

-''...take all that revolves within Aether..."[xxx].

Plato in Timaeus after the description of the other four platonic solids says:

"...God projected into the Universe a fifth structure". In "Epinomis" he clarifies: "The elements are five...Fire…Water...Air...Earth… and the fifth is Aether"[xxxi]

Aether adapts to every condition/impulse of matter, while he bares energies logi-

cally by place and quality. Pure, he corresponds to the material form "plasma": thunder, northern lights, the "soup of subatomic particles in the Universe", even melting rocks and minerals.

Aether, although he is correlated with the Higgs field, he is by no means a laboratory production. He is in absolute interdependence with Chronos, but within the world, as god, he acts "non in tempore, sed cum tempore" (Augustine).

Space-time cannot "repeal" the substance or the conscience which, according to Hegel, "falls" inside "our" time. The universal noesis (mind) might be included in Gödel's theorem, within the true suggestions that it predicts.

Modern physics reminds of the Orphic Cosmology: Weinberg assumes the existence of one Super-Universe and many "universes". N. Prantzos assumes a "bubble" from another universe that fertilized our own universe.

Genesis of Universal World (Oon/Egg)

The First Principles denying their principii essenti state, advanced to principia fiendi state, aiming at the accomplishment of a princicium cognoscendi Whole.

"Orpheus says that the universe was actually born, in the following way: the ancient matter was animated and inside it was merging another substance… that repeated millions of imperfect mixtures, smashing themselves into that disorder. But at some point, all this infinite "pelagos" started spinning like a whirlpool and mixing all substances as if they were in a funnel….. that whirlpool containing everything, attracted the Spirit which added logic to the content. Just like liquids form bubbles, a spheroid body was formed moving upwards. It looked like an egg and its speed kept it flying. It is clarified that the Oon (egg) was revolving.

So, the space where all physical worlds' universes would be formed was created. The whole procedure is described in details on fragment 3[xxxii].However, it is interesting to mention:

1) Thermal forces and their role in the shape and distinction of material qualities, and
2) The distinction but also the strong relation between pure Aether and his absolute next, Air, as of common substance, bearer of spirit.

The world of Ideas/The Light

a) At first, the Oon is full of free, cold radiation. However, gradually, a hyperthermic core of Aether and positive matter, pervaded by Spirit, is being formed.
b) While the core expands, it increases in heat so that, at some point, it exceeds the tolerance of the defined space. Therefore, the sphere cracks and the exceeding heat is released. Burning light and Spirit form a new world existing in between the Intellectual World and the Perceivable world. That is the World of intelligible beings and especially the World of light; a light similar to the solar one but diffused all over that world and of total homeostatic temperature.

c) It is defined that the Oon's core, consists of the birthplace/the womb of the First- born God, Fanes (light), Metis (Noesis-Mind), Erikepeos (Eros, Life), who brings into being the "Aforementioned Light, that traversed Aether"(~ Cosmic rays)[xxxiii].

His body is the source of the Ancestral Light -the common root essence of beings-, whose transformations are the source/origin of the energetic equilibrium and positive evolution of all, as well as matter itself.

The perceivable universes' Suns, are material manifestations of Fanes, who is the progeny and mate of Nyx (Night)-Noesis (Cognition) and primeval matter.

As for the light, the ultimate condition of existence, brought forth by Aether, it's the proof of the ideal origin of things that we should aspire to and defend.

Perhaps this is the most essential influence that the modern world should receive from Ancient Greece.

Notes

i. THEOLOGY (SCIENCE). The first philosophy about the Being. Aristotle's Metaphysics 10.7.7

ii. THE ORPHIC THEORY- ORPHICORUM FRAGMENTA coll. Otto Kern. Extract 51 Translation and Comments by Maria SIDERI. Ed. PYRINOS KOSMOS- Athens Greece. In the following notes the references to the extracts of this book will be noted only by their number.

iii. Extract 1

iv. Extract 27

v. Kern introduction page 98 Greek ed.

vi. Extract 51

vii. Aristotle's "About Heaven" C1

viii. Extract 20

ix. Extract 18

x. Extract 20

xi. Extract 32

xii. M.Plank

xiii. Extract 43

xiv. Extract 34

xv. Extract 13

xvi. Extract 112 (proanoussios means a being existing before the oussia)

xvii. Extract 42

xviii. Extract 47

xix. Extract 43

xx. Zenon Kitieus Physicq 172 (Stoicorum fragm. Coll Ioannes Ab Arnim Ed. prima Stutgard)

xxi. Extract 13

xxii. Parmenides extract 298. The Presocratic Philosophers. G.S.Kirk- J.E. Raven-M. Schofield Gr ed. MIET

xxiii. Plato Timaeus 48

xxiv. Extract 1

xxv. Extract 13

xxvi. Extract 13

xxvii. Empedocles 413, 372 Presocratic Philosophers MIET as above.

xxviii. See Theory of membranes. Also Huygens.

xxix. Extract 31

xxx. Extract 109

xxxi. Epinomis 981c, 982a

xxxii. Extract 3

xxxiii. Extract 12

A4.4 Deciphering Theseus' Myth

Dr. Socrates Christodoularis
DO. DC.ND. DAc. FICA

Abstract

The well-known myth of Theseus accounts for a lot of achievements of the hero performed against the bandits Periphetes or Korynitis, Sciron, Sinis, Procrustes and Kerkyon. However, the labors committed correspond to the ways of healing applied by the modern science of osteopathy.

1. Theseus: Hero and King

Theseus[1] was born in Troezen[2] of Argolis was the son of princess Aethra and Aegeus or Poseidon. He was one of the first Kings of Athens and is considered a descendant of Erechteus. According to the legend, Aegeus placed his sandals and sword under a huge stone and ordered that if the child to be born would be a boy, he should lift the stone, get his fathers' bequest and secretly come and meet him in Athens. Theseus as a teenager began his journey to Athens and achieved feats similar to those of Hercules. He did away with bandits, sending them to the underworld. He arrived in Athens through the Sacred Way and was saved from death when Medea, then married to Aegeus, tried to poison him. Theseus was recognized by his father, chased away Medea and her children and passed part of his kingdom to Theseus.

As a King, Theseus continued his labors by incorporating villages and towns of Attica into the state of Athena, and naming her "Athens" in plural. It is not clear when and where he died but there is a story saying that he was pushed off a cliff by a contestant king. The temple of Thesseion[3] is alleged to house his bones when they were deposited there in 473 BC.

The myth of Theseus

Theseus, traveling from Troezen to Athens[4] met the first robber at Epidaurus, the giant

1. Ragavi P. Alexander, Dictionary of Greek Archaeology, Anastatiki Edition Institute Book-A. Kardamitsa, Athens 1996 sel.386 on.
2. Kerenyi K., Translation Dimitris Stathopoulos, The Mythology of the Greeks, Editor[1] "Hestia" John. D. Kollaros & Co; AE, Twelfth Edition, June 2006, pp. 458.
3. Kerenyi K., Translation Dimitris Stathopoulos, The Mythology of the Greeks, Publisher[1] "Hestia" John. D. Kollaros & Co; SA, Twelfth Edition, June 2006, pp. 489.
4. Paul Decharme, Translation Alexander M. Karalis, Mythology of Ancient Greece, Publisher Dimiourgia Ap. A. Harisis, Athens 1996 pp.624.

Periphetes or Corynitis, who by "swinging" a clave (bat)[5] killed travellers passing by. Theseus killed Periphetes and retained the club, which was Theseus' emblem thereafter.

At Kechreai, one of the two harbors of Corinth, where the road turns towards the Isthmus, there was Sinis, another dangerous man, who passed strangers through a horrific ordeal. Sinis was called Pityokamptis, i.e. tree-bender, since he bent Pitis (pine trees) trees to the ground. Travellers not strong enough to prevent the springing up of the trees were flung in the air and crashed to the ground. Theseus triumphed again by defeating Sinis the Pine-bender.

At Megara Theseus killed Sciron who robbed travellers and threw them over the precipice down to the sea. The rocks were steep and the Megarians recounted a story about a sea turtle, an animal of Hades, which shredded up and devoured people. They also recount that Sciron sat on one of these rocks and forced passersby to wash his feet. While the travellers tried this, Skiron would kick them down the sea to be eaten by the turtle. The rocks, till today are named Skironides Stones.[6]

The Megarians believed that Skiron was not a robber but a punisher of thieves and a friend of the righteous Kychreus, father-in-law of Aeacus. Skiron was also believed to be a God of the Underworld.

Another feat of Theseus performed on his way to Athens was to confront Procrustes who stretched and hammered passersby, like the blacksmith hammers and stretches heated iron. Others recount that the deadly workshop was on the Korydallos Mountain range, where the road to Athens led through the Sacred Way from Eleusis. They even say that a bed was sculptured on one of the rocks and if the bed was too long, he stretched them to fit by dismembering them. If, on the other hand they were taller than the bed, he would chop off the protruding parts.

According to an old story, Theseus upon arrival to Eleusis, met Cercyon, i.e. the one with a tail, a wrestler. The Cercyon forced travelers to wrestle with him and killed them in the process. On the road connecting Megara with Eleusis, local gentry showed the place where Cercyon performed his deadly event. Theseus lifted him up and threw him forcefully to the ground smashing his bones. It is said that Theseus was the first to discover the art of wrestling and that he defeated Cercyon with his dexterity rather by sheer strength.

Deciphering the myth

Many years of studies and observations, but mainly a long standing application and implementations in osteopathy in the treatment of patients as an osteopath, have led the author to the conclusion that the above feats of Theseus are related to treatments methods of Hippocratic medicine.

The first "bandit" whom our Hero meets is Periphetes or Corynitis. He uses the

5. Skarlatou D. Byzantine, Greek Dictionary, Ed. Andrew Koromila, Athens 1852, pp.745.
6. Kerenyi K., Translation Dimitris Stathopoulos, Mythology Greek, Editor of "HOB" John. D. Collar & Co. Inc., Twelfth Edition, June 2006, p. 462.

clave or bat or knocker as a lever or as a hammering tool. Today the lever method is used to break down or soften up chronic contractions or spasms involved in the displacement or lesions of the vertebrae. These lesions intervene by pressing or even "throttling" exiting nerve roots, thereby reducing the neural capacity, strength, i.e. the current which ought to be directed to the diseased part of the body.

Today, apart from the Asculapian lever (the corina or clave of Corynitis) being used as a lever, it is also used for rhythmic knocking on trigger points, with due caution. Initially the rhythmic knock (percussion) was in use. Then the little hammering rejuvenator (activator method) was invented. Recently the use of the "knocker/anvil" method was reinstated, although sparingly applied due to the intense reaction of the body. My observations have shown that the results are extremely positive.

The next "robber" *en route* is Sinis the Pityocamptis: Today we use the inverse gravity jolting machine in order to reduce a dislocated hip. Thus, with a sudden tug of the leg, the necessary reduction is obtained.

The third "thief" is Skiron, who after a therapeutic care to the travelers, he ordered them to wash his or their feet, i.e. to make them lean forward. Nowadays we ask our patients to bend forward so as to verify any positive or negative results of our treatment. If Skiron failed, he threw them over the cliff into the sea, where they were eaten by a gigantic turtle. But "turtle" is the name of a bowl at the mining company in Lavrion which has the shape of a boat. Could we exclude the probability of the bundling off, of travelers within this turtle shaped tub and sending them to their destination by sea? After paying a robbing ransom of course.

The fourth "thief" is the still notorious Procrustis or Polypimon reported to have invented the first traction table. Today traction is being used when the muscles of the lumbar region are so tight or so painful that the normal muscle relaxants do not contribute to the mobilization or reduction of the vertebrae. Hippocrates had a reduction or traction table, as described clearly in his book "Mochlikos."

Our treatment consists of a type of kinesiotherapy where we exert all our strength to restore quickly the malfunctioning of the body structure, particularly in difficult cases. Since some patients are classified as rather sedentary types, their joints are stiff and seize up suddenly when lifting heavy loads or perform violent movements. This resembles to the Greek "free for all" wrestling. In this way, to the eyes of the uninitiated, we may associate to the wrestler Cercyon, who killed his opponents, while wrestling with them.

Theseus, the offspring of King Aegeus, with the Greek mitochondrion, an acquisition from his mother Aethra, **12** is urged to organize this regime into the Scientific Therapeutic Hippocratic Medicine.

My conclusion is that Theseus killed or distanced those who in an uncontrolled way monopolized medical care on the Trizoene-Athens route and possibly selected all who were dealing with medical care within a controlled area, so that their knowledge would possibly evolve and contribute in founding the Scientific Hippocratic Medicine.

Bibliography

1) D. Apostolidis Panos, Dictionary of Hippocratic words, Gavrielides Publications, Athens 1997.

2) Hippocrates Surgical, Translate-introduction-comments Dimitrios Lypourlis, Editions Zitros 2001.

3) Ragavi P. Alexander, Dictionary of Greek Archaeology, Inhibitory Edition, Institute of Book-A. Kardamitsa, Athens 1996.

4) Skarlatos D. of Byzantius, Greek Dictionary, Edition: Andrew Koromila, Athens 1852.

5) Stageiritis Athanasius, Ogygia or Archaeology, Vol 1, Publisher "Eleutheri Skepsis" 6th Edition, Athens 2011.

6) Triantafyllides Constantinos, Genetic History of the Greeks, the DNA of the Greeks 2nd Edition, Kyriakidis.

7) Decharme Paul, Translation Alexander M. Karalis, Mythology of Ancient Greece Publisher "Dimiourgia" Ap. A. Harisis, Athens 1996.

8) Haldeman Scott, D.C., Ph.D., M.D., Modern Developments in the Principles and Practice of Chiropractic, Appleton-Century-Crofts /New York, USA 1980.

9) Kerenyi K., Translation Dimitris Stathopoulos, Mythology of the Greeks, Publisher "Hestia" John. D. Kollaros & SIA, Twelfth Edition, June 2006.

10) Strang V. Virgil, D.C., H.C.D. (Hon.), Essential Principles of Chiropractic, Palmer College of Chiropractic, Davenport, Second Printing 1985

A5. THE RIDDLE OF TARTESSUS

A5.1 Paleo-Geography of the Gulf of Cadiz in SW Iberia during the Second Millennium BCE

Antonio Rodríguez-Ramírez[1] and Juan J. R. Villarías-Robles[2]

Abstract

A remarkable feature of the geomorphological processes at work on the coasts of the Gulf of Cadiz in SW Iberia is the estuarine mouths of a number of large-flowing rivers: Guadiana, Piedras, Tinto-Odiel, Guadalete, and Guadalquivir. These mouths exhibit sandy barriers and marshlands. Over the most recent millennia, these five estuaries have been conditioned by fluvial-marine dynamics, climate change, neo-tectonics, and anthropogenic activity. The systems of sandy littoral barriers and marshlands have built up during phases of progradation and aggradation, interrupted at intervals in the course of the Holocene by erosional phases of "Extreme wave events" or EWEs (storm surges or tsunamis) and subsidence. A multidisciplinary study from a number of cores drilled in the Guadalquivir paleo-estuary has made it possible to identify evidence of as many as three EWEs in the area in the 2nd millennium BCE: A (~2000 cal yr BCE), B (~1550 cal yr BCE), and C (~1150 cal yr BCE). Evidence of these three events has been recognized elsewhere along the Iberian coasts of the Gulf of Cadiz. The three events caused significant geographical changes which may have affected human settlements established in the area during the Neolithic and Copper Age periods, as well as during the subsequent Middle Bronze Age. They may have affected, for instance, the site where the city of Cadiz now stands. In the Middle Bronze Age, which EWE C probably terminated, the present-day peninsula of Cadiz was divided into at least three islands, one of them being "Erýtheia," mentioned by Greek geographer and ethnologist Strabo of Amasia around AD 1 in connection with the legend of Geryon or Geryones, king of Tartessus. This legend is intertwined with that of Bronze Age Greek hero Heracles. A

1. Universidad de Huelva, Departamento de Geodinámica y Paleontología, Facultad de Ciencias Experimentales, Campus de El Carmen, Avenida de las Fuerzas Armadas S/N, 21071 Huelva, Spain. E-mail address: arodri@uhu.es.

2. CSIC, Instituto de Lengua, Literatura y Antropología del Centro de Ciencias Humanas y Sociales (IL-LA-CCHS), Calle Albasanz 26-28, 28037 Madrid, Spain & Department of Anthropology, The University of Chicago, 1126 East 59th Street, 60637 Chicago, IL. USA. E-mail address: juanjose.villarias@cchs.csic.es.

large temple dedicated to this character (*the Herákleion*) on one of the islands, arguably Erýtheia, made Cadiz famous in Antiquity. Strabo also mentions a settlement by the name of "Port of Menestheus" as well as an oracle by the name of "Oracle of Menestheus" upon the shores of the Gulf of Cadiz. In all likelihood, this "Menestheus" was the same as the Athenian leader Menestheus who fought in the Trojan War, according to Homer in *The Iliad*.

We would like to start by thanking professors Papamarinopoulos and Paipetis for allowing us to present in this magnificent, though appropriate, scenario such as Olympia the results thus far of the Hinojos Project in Spain with respect to the geomorphological evolution of the coasts of south-west Iberia in the 2nd millennium BCE. These results are relevant to any discussion regarding contact and knowledge of that area by Greeks of the Bronze Age, as echoed in the writings of later authors such as Homer, Stesichorus of Himera, Strabo of Amasia and, perhaps, even Plato, the philosopher.

The Hinojos Project started in 2005. It began as a small project with an aim that was simple: testing on the ground the basic tenet of a hypothesis that had been published, in somewhat different versions, in 2003 and 2004 by the German scholars Werner Wickboldt (Wöstmann 2003a, 2003b) and Rainer W. Kühne (2004). These researchers had analysed images of the IRS satellite of the lower Guadalquivir River basin and were able to identify in them a number of large geometric outlines that appeared to be the marks of man-made structures—specifically, elements of a large archaeological site from Antiquity and perhaps even earlier: from Prehistory. This site could be that of the pre-Roman city of Tartessus or that of the political and religious core of Atlantis as described by Plato in his dialogues *Timaeus* and *Critias*; or perhaps both—provided that both names, "Tartessus" and "Atlantis," belonged in different, yet parallel traditions about the same place. The outlines identified by Wickboldt and Kühne showed at least two rectangles within two circles. These features stood in the Marsh of Hinojos within the Guadalquivir paleo-estuary; hence the name of our project: "Hinojos Project."

The Wickboldt-Kühne hypothesis soon reached the popular media as well as academic circles. This quick, wide diffusion of the hypothesis was due in part to the internet, but also in part to its scientific significance. In order to fully grasp this significance, we must first comprehend the geomorphological and archaeological contexts that the hypothesis touched on.

We can anticipate, however, that, as it turned out—i. e., as the development of the Hinojos Project would establish—, Wickboldt and Kühne were right in proposing evidence of early cultural development in the marshes of Doñana; yet this development has nothing to do with the geometric outlines that they identified, but rather with remains that lie buried in the ground and, therefore, cannot be detected by satellite images or aerial photographs. We have discovered—or rather confirmed—what colleagues before us, and before Wickboldt and Kühne, intimated: namely, that southwest Iberia is a key area for understanding much of the rise of civilization in Western Europe.

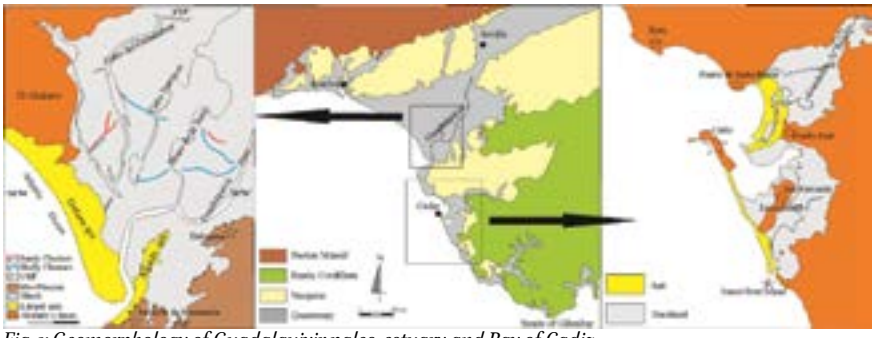


Fig. 1: Geomorphology of Guadalquivir paleo-estuary and Bay of Cadiz.

1. Geomorphological features of the Gulf of Cadiz

The Iberian side of the coast of the Gulf of Cadiz comprehends a number of large embayments, formed by marine flooding of river valleys in an advanced state of sediment infilling, while the interfluves exhibit pronounced headlands. The morphology and processes involved are mainly linked to tidal regime, wave action, coastal-drift currents, fluvial dynamics, climate change, and anthropogenic activity. The estuaries include spitbars and marshlands, which are the end product of a complex process of land formation that started some 5,000 years ago, upon the highest stand of the Atlantic Ocean following the last Ice Age.

The Guadalquivir paleo-estuary is the largest of such embayments. Much of it makes up Doñana National Park, a well-known UNESCOMAB Biosphere Reserve. The remaining area comprehends the Guadalquivir River itself, other rivers that converge into the marshland, and two spitbars or sandy coastal barriers—known as "Doñana" and "Algaida"—that separate the marshland from the Ocean (Fig 1). These two spitbars are largely covered by active dunes.

Other large-flowing rivers in Southwestern Iberia that empty into the Ocean are Guadiana, Piedras, Tinto-Odiel, and Guadalete, the latter flowing into the Bay of Cadiz, which includes the Valdelagrana spit and a number of rocky isles (Fig. 1).

The littoral barriers and the marshlands built up during phases of progradation, interrupted at intervals by erosional phases of "Extreme wave events" or EWEs (i. e., storm surges or tsunamis), as well as subsidence of the ground (Rodríguez-Ramírez et al., 2014). Progradation develops in periods of slightly low-stand or stability of the marine level, which result in the formation of spits and extensive tidal plains.

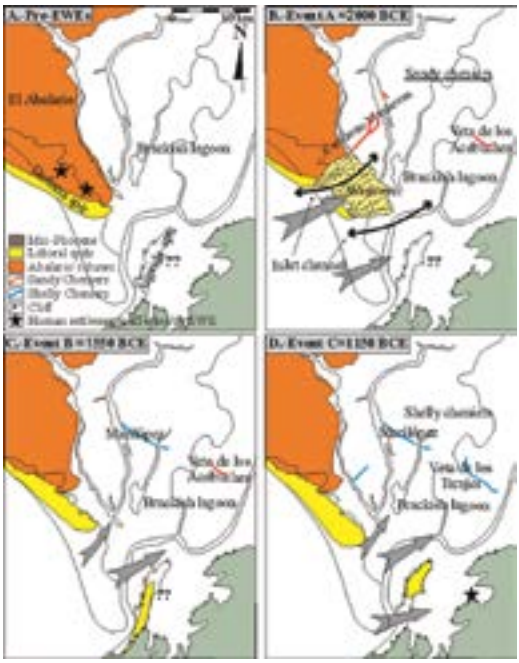


Fig. 2: Geomorphological effects of EWEs A, B, and C in the Guadalquivir Paleo-estuary in the 2nd millennium BCE (Rodríguez-Ramírez et al. 2015).

2. EWEs during the second millennium BCE in the coast of the Gulf of Cadiz and effects over human settlements

Our multidisciplinary study in the Guadalquivir paleo-estuary has made it possible to identify as many as three EWEs and their facies in the 2nd millennium BCE (A: ~2000 BCE, B: ~1550 BCE, and C: ~1150 BCE) (Rodríguez-Ramírez et al., 2015). These events, which caused strong erosion of the coast, including destruction of the sandy barriers, brought about significant geographical changes that must have affected human settlements established in the area during the Neolithic and Copper Age periods, and during the Middle Bronze Age.

Evidence of the first EWE has also been identified on the littoral of Barbate, some 50 km south-west of the city of Cadiz (Koster and Reicherter 2014). The second EWE can be correlated with an earthquake that has been suggested for south-west Portugal c. 1600 BCE (Vizcaíno *et al.* 2006). Evidence of the third EWE has been recognized in the Tinto-Odiel estuary (Morales et al. 2008) as well as in the Guadalete estuary (Lario *et al.* 1995, Dabrio et al. 1999, Luque *et al.* 2001).

Interestingly, the period that followed the marine transgression of EWE A was one of production of alluvial soils that left types of pollen and other by-products of human activity in the Paleo-estuary, specifically cereal agriculture and pastoralism. So did the alluvial soils of the period following EWE C, c. 1150 BCE. This biological evidence suggests that during long time spans in the 2nd and the 1st millennium BCE, much of the Paleo-estuary was above sea level - as it is at present - and sustained a human pop-

ulation of some form, the material remains of which lie buried in the ground and are, therefore, hidden from view.

Our study has confirmed the importance of the role played by neo-tectonics in the rapid geomorphological transformations occurred in the Paleo-estuary in the Holocene, especially during the marine transgression of the EWEs. In effect, the Paleo-estuary is criss-crossed by a number of SW-NE fault alignments. The most conspicuous of them is the Torre Carbonero-Marilópez Fault (TCMF), which divides the Paleo-estuary by about halves (Rodríguez-Ramírez *et al.*, 2014). South of the TCMF fault, we have discovered that the Paleo-estuary experienced a marked subsidence from about 2000 BCE (the date of the first event) up to the first centuries of the Christian era (Rodríguez-Ramírez *et al.*, 2014). This subsidence proceeded through a series of sedimentary sequences of retrogradation and aggradation within a context of relative sea-level rise. From the first centuries of the Christian era up to the present, the subsidence has remained relatively dormant, with progradation of the littoral systems and infilling of the marshland progressing within a context of sea-level stability (Rodríguez-Ramírez *et al.*, 2014).

Upon the marine transgression of each of the three events, the regular low-energy dynamics of the Ocean and the rivers resumed. Within a few centuries of EWE C, progradation of the Doñana coastal barrier all but isolated the erstwhile wide estuary of the Guadalquivir from the Ocean, generating a coastal lagoon as a result.

3. The archaeological context: An area peopled since at least the Neolithic Period

Archaeological evidence suggests that the coasts and hinterlands of the Gulf of Cadiz have been settled by human communities since at least the Neolithic period, which started in the area in the 6th millennium BCE, if not earlier. These communities had to be affected by the marine episodes.

Episode A explains the wide dispersion of artefacts from the Neolithic and the Copper Age found in the marshland since the 1920s, as well as the hiatus that has been identified at the sites of San Bartolomé de Almonte and Lebrija which mark the end of the Neolithic-Copper Age occupation. The magnitude of the event may have been strongly conditioned by the intense subsidence of much of the ground of the Paleo-estuary at the same time (Rodríguez-Ramírez *et al.*, 2014).

Episode B, c. 1550 BCE, looks like it had lesser paleo-geographic effects in the Paleo-estuary, possibly because the epicentre may have been in south-west Portugal rather than in the Gulf of Cadiz.

Episode C, c. 1150 BCE, may have had the same magnitude as Episode A, as it also covered an extensive geographical area and catastrophically affected the Middle Bronze Age settlement of Marsh of Rajaldabas, near the present-day mouth of the Guadalquivir River. It may explain, too, the second hiatus registered at the nearby site of Lebrija, as well as a hiatus registered about the same time at other sites of the Spanish South-west. The event severely eroded the Doñana spit and turned the Algaida spit into an island. In the Bay of Cadiz, the effects must have been devastating, as the EWE

significantly eroded the rocky isles and caused the system of sandy barriers associated with them to move toward the mainland. The cultural effect overall in south-west Iberia may have been the end of the Middle Bronze Age, like the overall cultural effect of Event A may have been the end of the Neolithic-Copper Age Tradition. The Middle Bronze Age in South-west Iberia was the period of possible trade or other form of contact with Mycenean Greece and other cultural formations in the East Mediterranean Sea, as substantiated by the finds of Mycenean and Hittite pottery in the Guadalquivir River basin and suggested by the stories that Greek mythology places in south-west Iberia.

Following the subsequent geomorphic and cultural interruption caused in the region by Event C, the final phase of the Late Bronze Age and the subsequent Early Iron Age are well represented, in terms of both number of sites and cultural deposits generated in them. Such final phase of the Late Bronze Age and the subsequent Early Iron Age are the archaeological correlates of the historical kingdom of Tartessus, which may have started around the year 900 BCE, if not earlier.

In the 1920s, Anglo-French archaeologist George E. Bonsor and German linguist Adolf Schulten conducted excavations at the site of Cerro del Trigo—near the mouth of the Guadalquivir River, where Roman remains had been unearthed—in an attempt to find and dig out evidence of the lost city of Tartessus. Like scholars before him, and like Wickboldt and Kühne after him, Schulten believed that the city of Tartessus was the same as the political and religious nucleus of Atlantis which Plato described.

Both names, "Tartessus" and "Atlantis," may indeed refer to the same place or area in different, but contemporary oral and literary traditions in Antiquity. The city of Tartessus was the capital of a kingdom in south-west Iberia, also called "Tartessus," that, according to Herodotus, traded regularly with Ionian Greece in the 7th and 6th century BCE, mostly through the city-state of Phocaea. These trade relations soon combined with a political and military alliance between the two powers in the western Mediterranean Sea that rivalled the alliance there between Phoenicians, Carthaginians, and Etruscans.

A king of Tartessus from older times, Geryon or Geryones, stands prominently in Greek mythology in connection with the story of "the labours" of demigod Heracles. In the best known version of this story, King Geryon is portrayed as a mighty, super-human figure who ruled in the far west of the known world. His large body was equipped with three trunks and three heads above the waist. Furthermore, he had with him a vicious two-headed watchdog, Orthrus. King Geryon owned a large herd of red cattle which Eurystheus, then paramount king of Greece, wanted Heracles to steal for him. Heracles deferred to Eurystheus's authority and set out for the western end of the Mediterranean Sea, where he opened a sea channel to take the king of Tartessus by surprise—today's Gibraltar Straights—and landed on an island called "Erýtheia," where he confronted Geryon. Heracles killed him and his watchdog, stole the herd of cattle, and returned to Greece by marching across the Pyrenees and along the northern Mediterranean coast.

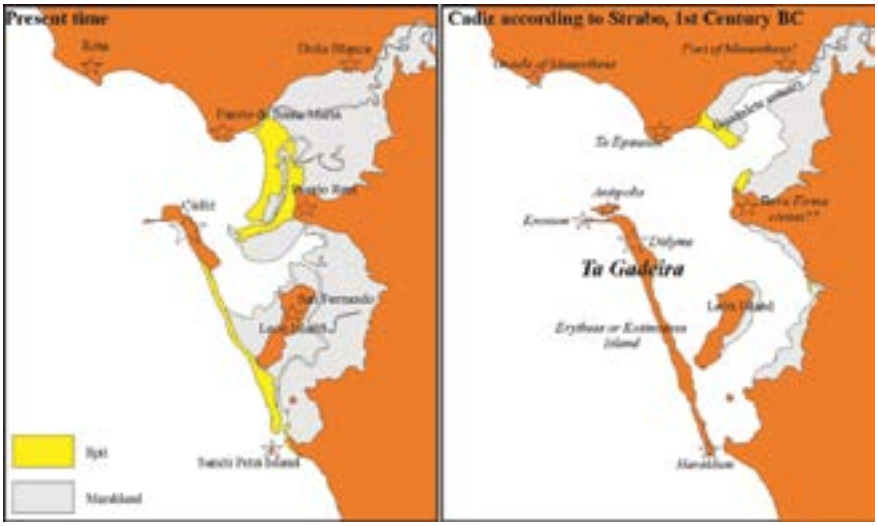


Fig. 3: The islands and bay of Cadiz and their vicinity in present time and according to Strabo of Amasia. Geomorphological data partially referred to in Alonso et al. (2015) *and Dabrio et al.* (2000)

According to 7th-century BCE poet Stesichorus of Himera, as quoted by Strabo in his *Geographiká*, Geryon had been born in a cave near the mouths of the Tartessus River and across from the island called "Erýtheia," where he would meet Heracles and die. Strabo, then quoting Pherecydes of Athens (who lived in the 5th century BCE), wrote that "Erýtheia" was the long island—some 18 km long—that at Strabo's time housed the multi-sited city community (polis) of Cadiz, to which he referred, appropriately, as *"Ta Gádeira,"* literally "The Cadizes" (see Fig. 3).

Close by the city community, at the north-western end of the island, stood a temple for the worship of Cronus: "The Krónion." Greek mythology represents this character (Roman Saturn) as the king of the Titans, who had ruled mankind during its golden age, before the time of the Gods. North of the island of Erýtheia lay a smaller island, where "the anti-polis" of the city community stood. A third island lay between Erýtheia and the mainland, in the Bay of Cadiz: the present-day island of Leon.

There were settlers from the city somewhere on the mainland as well. In addition, a few decades before Strabo's time a new port, "Tò Epíneion," had been built on the other side of the Bay, in all likelihood where Puerto de Santa María now stands. Timaeus of Tauromenium, who wrote in the 3rd century BCE, referred to the 100-stadium island as "Kotinoussa" because of the many olive trees that one could see on it. Strabo also mentions, in the Guadalete paleo-estuary, one "Port of Menestheus," after the leader of the Athenians in the Trojan War as told by Homer—arguably a former port of the city. Elsewhere on the littoral of the Bay sat one "Oracle of Menestheus": Strabo's narrative suggests it was at or near the present-day town of Rota, where apparently Roman and pre-Roman remains of a temple or a shrine turned up in the 17th and again in the 19th century (De San Cecilio 1669: 497-504, Sociedad Geográfica de Madrid 1878).

According to Flavius Philostratus the Athenian, who wrote in the 3rd century AD, Menestheus was the object of a cult among the citizens of Cadiz.

The Heracles of Greek mythology is commonly associated with a character in Near Eastern mythology known as "Melkart," who was the object of an agricultural cycle-related cult in the Phoenician city-state of Tyre from the 10th century BCE onward. Near Eastern mythology represents him as a former divine king of this city-state who had been responsible for daring commercial expeditions and colonization in the Mediterranean Sea (García-Bellido 1963). Strabo suggests that the city of Cadiz was founded a few years after the end of the Trojan War by Tyrian explorers who were searching the far west of the known world for the trail of Heracles's—i. e., Melkart's—exploits. The element in King Geryon's story of Heracles's opening up the Gibraltar Straights for his "labour" of stealing the cattle of the king of Tartessus may be interpreted as meaning that Heracles was thought to have been the first among Easterners in the Mediterranean Basin to open the sea route for trading with Tartessus, or the first to set the terms to the Tartessian authorities for such trading, or both. Upon reaching the long island of Cadiz—Strabo also wrote—, the Tyrian explorers founded the city of Cadiz at its farthest end while erecting a temple for Heracles, known as "Herákleion," at the nearest end.

The Book of Kings, in the Old Testament, makes reference to a faraway country across the Mediterranean Sea called "Tarshish," to which the joint trade fleets of King Solomon of Israel and King Hiram of Tyre would sail out in search of "gold and silver, ivory, apes, and baboons." Many a scholar—including Schulten and many others before him—has pointed out that this "Tarshish" was nothing but the Old Hebrew name for the land, river, kingdom, and city that Herodotus, Strabo, and other ancient Greeks called "Tartessus."

Plato, who wrote in the 4th century BCE, mentioned no kingdom or city of Tartessus, let alone the land of Tarshish. The reference to Atlantis—Plato wrote—came originally from Solon of Athens, who had lived in the first half of the 6th century BCE. Solon heard the Atlantis story to the priests of Sais, then the city capital of Egypt, on the occasion of a visit that he paid there. It is not impossible, though, that those priests were referring to Tartessus, or to south-west Iberia, with a different name.

Schulten and Bonsor were quite familiar with these and other pieces of information from Antiquity about Tartessus, Tarshish, and Atlantis. Nevertheless, they failed in their archaeological pursuit at the site of Cerro del Trigo. Elsewhere in the paleo-estuary, however, at a number of separate locations, they run into isolated artefacts—especially, ground axes—that represent the first evidence of the cultural development that took place in south-west Iberia in the Neolithic period and the Copper Age which ended c. 2000 BCE, likely because of EWE A. In addition, the geologist in their team, Otto Jessen, managed to produce the first map of the geomorphological composition of south-west Spain. He also found the first evidence of subsidence of the ground in Doñana.

Thereafter, beginning from the 1950s, archaeological projects at sites in and out of the Guadalquivir paleo-estuary, but still within south-west Iberia, such as San Bartolomé or Lebrija, yielded interruptions in the occupational record that can be ex-

plained by either EWE A or EWE C, or by both.

The significance of Wickboldt's and Kühne's hypothesis in 2003 and 2004 lay with vindicating the old search for the city of Tartessus inside the Paleo-estuary, which Schulten and Bonsor had begun. It lay, too, with bringing back to life the older hypothesis that the story of Atlantis could have a basis in historical fact.

These were reasons enough for starting the Hinojos Project.

References

Alonso, C., Gracia, F.J., Rodríguez-Polo, S., and Martín-Puertas, C., 2015. El registro de eventos energéticos marinos en la bahía de Cádiz durante épocas históricas. *Cuaternario y Geomorfología* 29 (1–2), pp. 95–117.

Dabrio, C. J., Goy, J. L., and Zazo, C., 1999. The record of the tsunami produced by the 1755 Lisbon earthquake in Valdelagrana spit (Gulf of Cadiz, southern Spain). *Geogaceta* 23, pp. 31-34.

De San Cecilio, P., 1669. *Annales de la Orden de Descalzos de Nuestra Señora de la Merced, Redempción de Cautivos Christianos, Parte Primera.* Barcelona: Dionisio Hidalgo.

García-Bellido, A., 1963. Hercvles Gaditanvs. *Archivo Español de Arqueología* 36, nº 107, pp. 70-153.

Koster, B., and Reicherter, K., 2014. Sedimentological and geophysical properties of a ca. 4000 year-old tsunami deposit in southern Spain. *Sedimentary Geology* 314, pp. 1-16.

Kühne, R. W., 2004. A Location for "Atlantis"? *Antiquity* 78, nº 300, http://antiquity.ac.uk/ProjGall/kuhne

Lario, J., Zazo, C., Dabrio, C. J., Somoza, L., Goy, J. L., Bardají, T., and Borja, F., 1995. Record of recent Holocene sediment input on Spit Bars and Deltas of South Spain. *Journal of Coastal Research* 17, pp. 241-245.

Luque, L., Lario, J., Zazo, C., Goy, J. L., Dabrio, C. J., Silva, P. G., 2001. Tsunami deposits as palaeoseismic indicators: Examples from the Spanish coast. *Acta Geologica Hispanica* 36, pp. 197-211.

Morales, J. A., Borrego, J., San Miguel, E. G., López-González, N., and Carro, B., 2008. Sedimentary record of recent tsunamis in the Huelva estuary (southwestern Spain). *Quaternary Science Reviews* 27, pp. 734-746.

Rodríguez-Ramírez, A., Flores-Hurtado, E., Contreras, C., Villarías-Robles, J.J.R., Jiménez- Moreno, G., Pérez-Asensio, J.N., López-Sáez, J.A., Celestino-Pérez, S., Cerrillo-Cuenca, E., and León, Á., 2014. The role of neotectonics in the sedimentary infilling and geomorphological evolution of the Guadalquivir estuary (Gulf of Cadiz, SW Spain) during the Holocene. *Geomorphology* 219, pp. 126–140.

Rodríguez-Ramírez, A., Pérez-Asensio, J.N., Santos, A., Jiménez-Moreno, G., Villarías- Robles, J.J.R., Mayoral, E., Celestino-Pérez, S., Cerrillo-Cuenca, E., López-Sáez, J.A., Ángel León, Á., and Contreras, C., 2015. Atlantic extreme wave events during the last four millennia in the Guadalquivir estuary, SW Spain. *Quaternary Research* 83, pp. 24–40.

Sociedad Geográfica de Madrid, 1878. Antigüedades de Andalucía. *Boletín de la Sociedad Geográfica de Madrid 5* (año III), nº 9, pp. 13-14.

Vizcaíno, A., Gràcia, E., Pallàs, R., García-Orellana, J., Escutia, C., Casas, D., Willmott, V., Diez, S.,

Asioli, A., and Dañobeitia, J.J., 2006. Sedimentology, physical properties and ages of mass-transport deposits associated to the Marquês de Pombal Fault, Southwest Portuguese Margin. *Norwegian Journal of Geology* 86, pp. 177-186.

Wöstmann, F., 2003a. Atlantis lag in Südwest-Spanien. *Braunschweiger Zeitung*, 10 January 2003.

Wöstmann, F., 2003b. Forscher meldet: Atlantis gefunden. *Braunschweiger Zeitung*, 19 February 2003.

A5.2 The Representation of the peopled Kingdom of Tartessus by the Ancient Greeks Revisited: New Evidence for a Forgotten Cause

Juan J. R. Villarías-Robles[1] and Antonio Rodríguez-Ramírez[2]

Abstract

Results in the recent studies of the geomorphological evolution of the coastlines of Iberia in the Gulf of Cadiz in the Middle and Late Holocene add up to archaeological evidence accumulated since the 1980s in support of a renewed case for the representation of the pre-Roman kingdom of Tartessus in the writings of a number of Greek and Roman authors of Antiquity. Herodotus, for instance, made reference to this Iberian kingdom in connection with Ionian navigation, trade, and settlement in the western Mediterranean Sea in the 7th and 6th centuries BCE. The accumulated evidence ought to make researchers revise the paradigm for studying Tartessus that has prevailed in the literature since the 1960s. Launched in the wake of a number of sustained archaeological excavations and spectacular finds in the Spanish regions of Andalusia and Estremadura in the late 1950s and early 1960s, this paradigm has two defining characteristics: (1) the resort to archaeology as the practically exclusive source for Tartessus, to the detriment of the narratives from Antiquity, and (2) the concept of this ancient kingdom as a derivative culture in the long history of relations that natives of southern Iberia maintained with Phoenician traders and colonists.

In our previous presentation we mentioned evidence of at least three high-energy events or EWEs in the Gulf of Cadiz in the 2nd millennium BCE that significantly altered the otherwise gradual, uniformitarian geomorphological evolution of the coasts of the Gulf. The coasts of the Gulf that are most relevant for our presentation now are those of the Guadalquivir and Guadalete estuaries. Around 1150 BCE, Event "C" was cataclysmic enough to bring to an abrupt end the Middle Bronze Age in at least both estuaries. In the Guadalquivir estuary, the rapid changes in the landscape included a new rupture of the Doñana spit and a rupture as well in that of Algaida that transformed this second coastal barrier into an island. In the Guadalete estuary, the event must have eroded the Valdelagrana spit and altered much of the sub-aerial extension

1. CSIC, Instituto de Lengua, Literatura y Antropología del Centro de Ciencias Humanas y Sociales (IL-LA-CCHS), Calle Albasanz 26-28, 28037 Madrid, Spain & Department of Anthropology, The University of Chicago, 1126 East 59th Street, 60637 Chicago, IL. USA. E-mail address: juanjose.villarias@cchs.csic.es.
2.Universidad de Huelva, Departamento de Geodinámica y Paleontología, Facultad de Ciencias Experimentales, Campus de El Carmen, Avenida de las Fuerzas Armadas S/N, 21071 Huelva, Spain. E-mail address: arodri@dgeo.uhu.es.

of the three islands of Cadiz, moving eastward the sandy formations (beaches and dunes) that are associated with rocky ledges.

Following the violent marine transgression in both estuaries, however, the low-energy geomorphological forces at work in the Gulf since the end of the last Ice Age resumed their action. In the Guadalquivir estuary, the Doñana spitbar started to grow again; this time more toward the south-east than before. In the process, the erstwhile wide estuary became ever more confined vis-à-vis the Atlantic Ocean, which in a few centuries would result in the formation of a coastal lagoon. The island of Algaida, by contrast, would take longer to become a spit again: as much as 1,500 years, up to the Roman imperial period, when the mouth of the Guadalquivir River would approximate its present form and the coastal lagoon would turn into the present-day marshes of Doñana National Park. Because of the magnitude of the Doñana spit, future EWEs hitting the area would affect the sea front far more than would the inner sectors of the estuary.

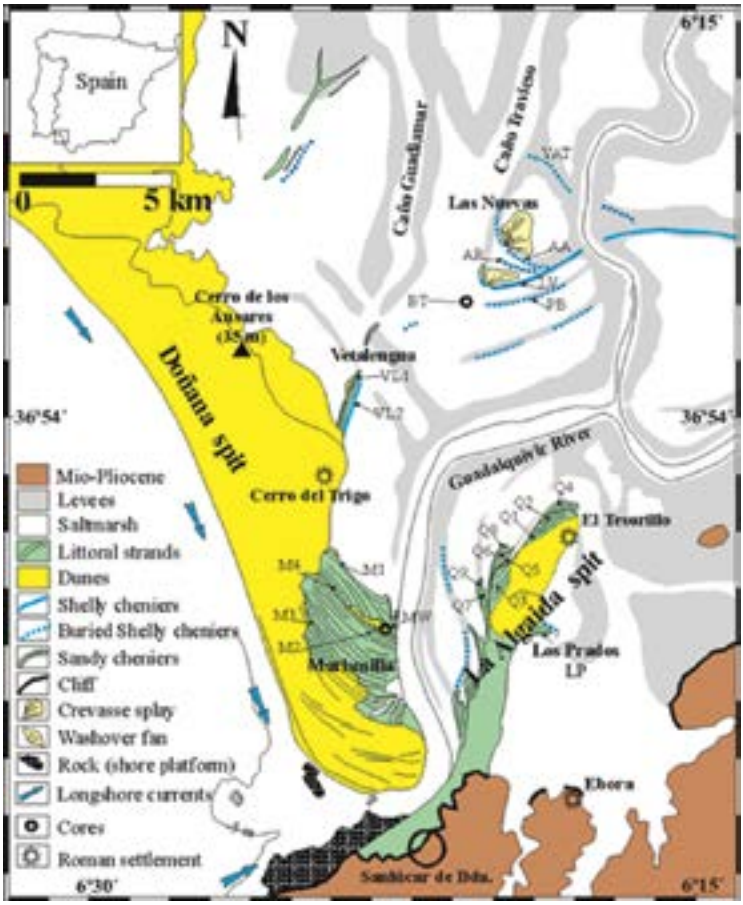


Fig. 1: Chenier systems in the Guadalquivir paleo-estuary

The development of chenier systems in the larger Guadalquivir paleo-estuary is consistent with this evolution. Cheniers are relict beach ridges of sandy and shelly deposits with a littoral strand morphology that overlie the clayey infilling of the marshland in the Paleo-estuary. They signal the location of ancient shorelines and are evidence of changes in paleo-environmental conditions, specifically changes in the sediment supply, the river discharge, the sea level, and the frequency of storms. South of the Paleo-estuary, near the present-day mouth of the Guadalquivir River, there are sandy chenier systems that are 50 to 100 m wide and 2.00 to 2.25 m high above sea level. They consist of overlapped strands associated with the two ancient paleo-mouths and inlet channels that the estuary had up to the Roman Imperial Period. The western paleo-mouth, defined by the littoral strands of Vetalengua, was flanked on the right side of the estuary by the Doñana spit and on the left side by the Algaida spit. The eastern paleo-mouth, defined by the littoral strands of Los Prados, was flanked on the right side by the Algaida spit and on the left side by the hills of Sanlúcar de Barrameda.

The existence of the two paleo-mouths is confirmed by the testimony of Greek and Roman authors who described the area. One of them was Strabo of Amasia, in the first years of the Christian era. He wrote that the Guadalquivir River, known as "Baetis" in Roman times, emptied itself into the Atlantic Ocean by means of two outlets. Some fifty years later, Pomponius Mela of Tingentera, a native to southern Iberia, wrote that the River reached the Ocean in the form of two large streams which flowed from a large lake that stood not far from the Ocean. The erstwhile spit of Algaida, therefore, would have been an isle in at least Roman times, lying between the two mouths. By way of both, the fluvial current as well as the tidal flows would put the Ocean in connection with the coastal lagoon that Mela mentioned.

In the Guadalete estuary, also following the marine transgression of Event C, the Valdelagrana spit resumed progradation toward the south, which would make the Bay of Cadiz as well as the Guadalete estuary itself ever smaller (Alonso *et al.* 2015). The sandy formations in the southern half of the island of Erýtheia, because of the marine dynamics and the EWEs themselves, would tend to move eastward, approaching the island of Leon. This erosive process has been recognized elsewhere on the outer front of the Bay of Cadiz, especially from the Roman period onward (Gracia *et al.* 1999). Such post-cataclysmic paleo-geography would be the setting, we submit, for the founding of a Phoenician colony on the islands of Cadiz sometime after the end of the Trojan War which Strabo also wrote about. Explorers from the city-state of Tyre in search of the trade routes opened in the Bronze Age by the hero Melkart (likely, the Greek Heracles) established a settlement at one end of the island of Erýtheia while erecting a temple for the cult of Melkart at the other end. Strabo also mentions, in the Bay of Cadiz or in the Guadalete paleo-estuary, one "Port of Menestheus," after the Athenian leader in the Trojan War mentioned by Homer. We think it was an erstwhile port of the city that might correspond with the archaeological site of Doña Blanca, where remains of a Phoenician settlement in the 8th century BCE have been found (Ruiz-Mata and Pérez 1995). Elsewhere on the littoral of the Bay, Strabo places one "Oracle of Menestheus." Judging by the structure of his narrative, we believe this oracle was at or near the present-day town of Rota, where apparently Roman and pre-Roman remains of a temple

or a shrine turned up in the 17th and again in the 19th century (De San Cecilio 1669: 497-504, Sociedad Geográfica de Madrid 1878).

1. The issue of Avienus's Ora maritima

With respect to the coasts of south-west Spain as well as the islands of Cadiz, we submit that our reconstructed paleo-geography for the same period following the geomorphic effects of Event C fits the scenario described in another well-known source for the study of southern Iberia in Antiquity, particularly as regards the pre-Roman kingdom of Tartessus. This additional source is the poem *Ora maritima*, by Roman author R. F. Avienus. The credibility of this source, however, has been seriously doubted by many a specialist for some fifty years now. The poem dates from the 4th century AD, but contains references to the sea coasts of the Iberian Peninsula that are much older. Avienus himself mentions many or most of the authors whose works he read and inspired him to write the poem. At least some of these authors - such as Himilco, the Carthaginian explorer; Euctemon, the Athenian geographer; and Herodotus, the Ionian historian and ethnologist - lived no less than seven hundred years before he did. Furthermore, the poem belongs in an intellectual context of revivalism of pre-Christian advancements in philosophy, science, and the arts (Mangas and Plácido 1994: 17-18, 26).

One of his unnamed sources for the poem appears to be an old description of a coastal course, like in a portolan chart or rutter (*periplous*), or a number thereof, to help mariners navigate from the islands *Sacra* and *Albionum*, in the North Atlantic, down to the "Pillars of Heracles", which flanked the Straits of Gibraltar, and from there on to the Greek colony of Marseilles along the coasts of southern and eastern Iberia. Avienus cited this ancient rutter at large; in many of his verses, even *verbatim*—to such an extent that *Ora maritima* became famous right after it was argued for the first time, by the Danish scholar G. Schöning, late in the 18th century, that the poem had an old portolan chart embedded in it. The chart contains a clear reference to the realm of Tartessus, indicates the western and eastern boundaries of this realm, and provides directions as to where exactly the city capital was located. This city - the unnamed author wrote - sat on an isle, "the isle of Cartare," which was within a large river, also called "Tartessus." The isle was near the mouth of the River and could be seen from the sea. The River surrounded the isle after flowing through a lake called *Lake Ligustinus*. The eastern branch projected three channels into the hinterland further east and then joined the western branch south of the isle through a "two two-fold" outlet—apparently a sequential bifurcation within a small delta. The joined course of the River then emptied into the Ocean.

Despite this detailed information, the remains of the city of Tartessus were never found; not even in the Roman period. One reason is that the geographical scenario described in the rutter matches no landscape known in southern Iberia today. Another reason is that its author makes reference to additional places and features that are mentioned in no other narrative for ancient Iberia, which makes identification an apparently unsolvable problem.

There is, for instance, the city of *Herbi*, located somewhere between the mouth of

the Guadiana River and the mouth of the Tartessus River. Avienus commented that this city no longer existed in his time, as it had been destroyed in "past times of wars" - in probable reference to the conflicts and disturbances of the 2nd century AD in southern Iberia.

Beyond the mouth of the Tartessus River, Avienus cited the rutter to remark that the prospective mariner, in his way to the Straits of Gibraltar, could make out in the horizon a feature known as *Gerontis Arx* ("King Geryon's citadel"), which received the waters of "a wide river" (*flumen amplum*) that flowed into the sea nearby. Across from *Gerontis Arx* was *Fani Prominens* ("The Cape of the Shrine or of the Temple"). *Gerontis Arx* and *Fani Prominens* flanked the entrance to *Sinus tartessius* ("The Gulf of Tartessus"). In addition, *Gerontis Arx* stood by or was located in the walled city (*oppidum*) of "Gadir," arguably the core settlement of the Phoenician colony of Cadiz.

A channel (*interfluum*) five stadia wide (some 900 m) separated the walled settlement and *Gerontis Arx* from the island of "Erythia," which must be the same as the 100-stadium island of "Erýtheia" mentioned by Strabo in connection with the story of King Geryon. To the west of this long island stood another island, "consecrated to Venus Marina," which included a subterranean temple and an oracle.

Suffice these examples to argue that the very rareness of the content of *Ora maritima* - an unfamiliar geography and a sequence of singular names for places and features - support the authenticity of the chart as much as they evince its lack of credibility. Indeed, the rare names might well be pointed to in contending that they reflect the description of at least two commercial sea routes in a remote past. One was from the city of Tartessus to the islands *Sacra* and *Albionum*, in the North Atlantic, and back, so as to procure lead and tin. The other sea route would connect the city of Tartessus to the Ionian colony of Marseilles and beyond in the Mediterranean Sea.

So interpreted, the rare information contained in *Ora maritima* can then be dated, as in effect it has been (Cf. Mangas and Plácido 1994: 23), to the time of the close relations (political as well as commercial) that Ionians - particularly Ionians of the city of Phocaea, through the colony of Marseilles - kept with the kingdom of Tartessus in the 7th and 6th centuries BCE. More specifically, the information appears to date to the first half of the 6th century BCE, as it mentions the colony of Marseilles, founded c. 600 BCE, but fails to mention the colony of Ampuries, which was founded by people from Marseilles c. 550 BCE.

The relations between the kingdom of Tartessus and the Ionians of Phocaea became close to the point - wrote Herodotus - that the Tartessian king, Arganthonios, offered the city of Phocaea assistance with which to resist the expansion of the Persian Empire. Fierce commercial competition, however, might have existed between the Ionians, on the one side, and the Phoenicians and Carthaginians on the other for the Iberian and the northern Atlantic trade.

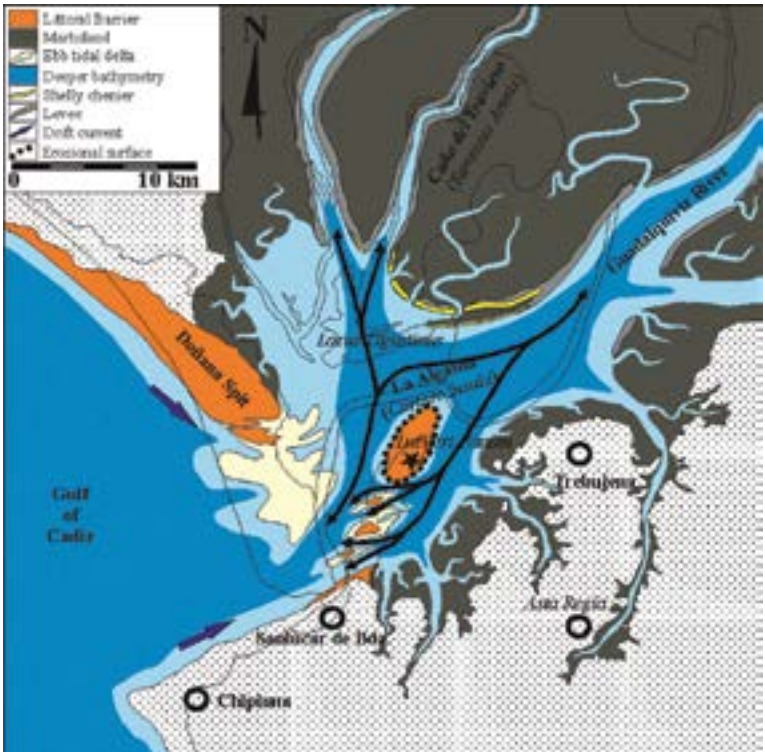


Fig. 2: Paleogeography of the mouth of the Guadalquivir River in the Tartessian period as inferred from geomorphological evidence from the Guadalquivir paleo-estuary.

2. Interpretation in the light of the geomorphological evidence from the Guadalquivir and Guadalete paleo-estuaries

Our reconstruction of the geomorphological evolution in the Guadalquivir and Guadalete paleo-estuaries in the course of the Middle and Late Holocene invites us to suggest that the isle that the spit of Algaida was from c. 1150 BCE to Roman imperial times was "The isle of Cartare" mentioned in *Ora maritima* as the isle where the city of Tartessus stood. If so, then the Tartessus River was the present-day Guadiamar River, which flowed across the Guadalquivir paleo-estuary through today's relict "Travieso" channel. *Lacus ligustinus* was, therefore, the coastal lagoon that progradation of the Doñana spitbar had formed.

Archaeological remains from the Tartessian period have been found at the present-day spit of Algaida. These remains, however, have been interpreted as those of a Carthaginian shrine (Blanco-Freijeiro and Corzo-Sánchez 1983). The spit of Algaida does have been pointed to as the location for the city of Tartessus by other researchers (Barbadillo-Delgado 1951, Menanteau in Palacios 1981); yet they lacked the geomorphological evidence presented here.

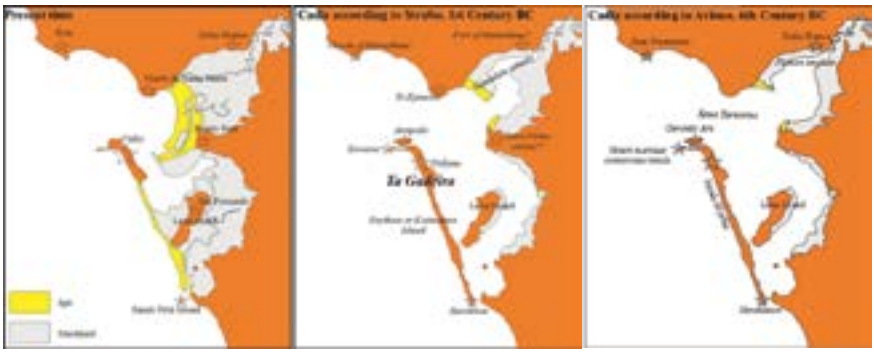


Fig. 3: The islands and bay of Cadiz and their vicinity as described in Strabo's Geographiká and Avienus's Ora maritima. Geomorphological data partially referred to in Alonso et al. (2015) *and Dabrio et al.* (2000)

To continue with the direction of the rutter: *Arx Gerontis*, "King Geryon's citadel," we believe stood on the isle which geophysical tests run in downtown Cadiz have revealed that lay north of an outlet of the Bay though the present-day beach of La Caleta. This isle would later hold the core of the first Phoenician settlement, referred to as *Gadir* in *Ora maritima*. It is the same isle that still later in the 1st millennium BCE, wrote Strabo, would hold the "the anti-polis" of the multi-sited city community of *Ta Gádeira*. The "polis" counterpart sat across the 5-stadia wide outlet of the Bay though the beach of La Caleta, on the long island of Erýtheia, where according to Greek mythology King Geryon had confronted Heracles and died.

Opposite *Arx Gerontis*, on the other side of the entrance to the Bay, stood *Fani Prominens*, "The Cape of the Shrine or Temple." Opposite the northernmost end of the Cadiz peninsula today, on the other side of the entrance to the Bay, stands the town of Rota, where, as remarked earlier, Roman and pre-Roman remains of a temple were found in the 17th and 19th centuries and where, to judge from Strabo's directions, "Oracle of Menestheus" may have stood. It is then tempting to surmise that the shrine or temple on a cape across *Arx Gerontis* was the "Oracle of Menestheus" mentioned by Strabo for the coast line of the province of Cadiz where Rota now stands. *Sinus tartessius*, "The Gulf of Tartessus," therefore, would be the Bay of Cadiz and the Guadalete paleo-estuary. *Flumen amplum* would be the Guadalete River.

Finally, the island consecrated to Venus Marina may have been the present-day island - and peninsula, depending on the tidal cycle - of San Sebastián, where, according to Strabo, a temple for the worship of Cronus once stood. Cronus (Roman Saturn) and Aphrodite (Roman Venus) were connected in Greek mythology.

3. The fall of the Schulten Paradigm

For more than a century, up to the 1960s, the rutter embedded in *Ora maritima* was considered geographical information of the utmost importance for doing research on Tartessus. It was the fundamental evidence, for instance, to which Schulten and

Bonsor pointed in the 1920s to announce their hypothesis that the remains of the city of Tartessus lay buried at the site of Cerro del Trigo, on the spitbar of Doñana. This hypothesis was the archetypal product of a paradigm for the study of Tartesus that can be called here, for the sake of argument, "The Schulten paradigm," even though it far antedates Schulten, as it can be traced as far back as The Renaissance and the rise at the time of modern Classical scholarship.

The defining characteristic of this paradigm was methodological: practitioners placed trust upon the comparative analysis and interpretation of all references to Tartessus, whether direct or indirect, contained in the writings preserved from Antiquity. Avienus's *Ora maritima*, Strabo's *Geographiká*, Herodotus's *History* were such writings; yet so were the references in the Old Testament to "the land of Tarshish" (out to which the merchant ships of ancient Israel as well as Tyre would sail) and the references to this same land in the cuneiform texts of Assyria. Information from archaeological projects, or from projects from other scientific disciplines, such as geology, was viewed as supplementary to the information provided by these writings.

In the 1960s, however, this time-honored paradigm was abandoned—and with it the credibility of all those sources from Antiquity, including Avienus' *Ora maritima*. Instead, a different paradigm was adopted, which can be called here "The Xeres Paradigm," after an important meeting of experts on the subject of Tartessus that took place in the city of Xeres, southern Spain, in September, 1968. Although the reasons for the paradigm change were many, few of them, if any, could justify it. It had two defining characteristics: (1) the resort to archaeology as the practically exclusive source for Tartessus, to the detriment of the narratives from Antiquity, and (2) the concept of this ancient kingdom as a derivative culture in the long history of relations that natives of southern Iberia maintained with Phoenician traders and colonists.

Since the 1990s, however, new data and new intellectual conditions are increasingly bringing about a renovated interest in those narratives. The new data that are most significant are the ever larger amounts of Greek pottery shards and other types of evidence that add up to remains known for decades which date to periods covered by the written sources, the Middle and Late Bronze Age included. The most spectacular developments have taken place in the city of Huelva and in the city of Cadiz. The references in the Old Testament to "the land of Tarshish" understood as the realm of Tartessus have been re-vindicated as well from the field of Biblical Studies (Cf. Koch 2003).

The new intellectual conditions are those of an increasing impatience with the limitations of the Xeres paradigm, which in the face of the fresh archaeological evidence presses its supporters to answer questions about the less material aspects of culture related to this evidence that the paradigm was ill set to pose in the first place; e. g., aspects of social and political organization and economic interaction patterns, precisely the topics that the written sources most inform about.

This new context favoring a renewed interest in the written sources of Antiquity should extend, sooner or later, to Avienus's *Ora maritima*, too.

References

Alonso, C., Gracia, F. J., Rodríguez-Polo, S., and Martín-Puertas, C., 2015. El registro de eventos energéticos marinos en la bahía de Cádiz durante épocas históricas. *Cuaternario y Geomorfología* 29 (1–2), pp. 95–117.

Barbadillo-Delgado, P., 1951. *Alrededor de Tartessos: Los descubrimientos de La Algaida*. Sanlúcar de Barrameda: Ayuntamiento de Sanlúcar de Barrameda.

Blanco Freijeiro, A., and Corzo-Sánchez, R., 1983. Monte Algaida: Un santuario púnico en la desembocadura del Guadalquivir. *Historia 16* nº 87, pp. 123-128.

Dabrio, C. J., Zazo, C., Goy, J. L., Sierro, F. J. Borja, F., Lario, J., González, J. A., and Flores, J. A., 2000. Depositional history of estuarine infill during the last postglacial transgression (Gulf of Ca¬diz, Southern Spain). *Marine Geology* 162, pp. 381-404.

De San Cecilio, P., 1669. *Annales de la Orden de Descalzos de Nuestra Señora de la Merced, Redempción de Cautivos Christianos, Parte Primera*. Barcelona: Dionisio Hidalgo.

Gracia, F. J., Alonso, C., Gallardo, M., Giles, F., Benavente, J., and López-Aguayo, F., Evolución eustática postflandriense en las marismas del Sur de la Bahía de Cádiz. *Geogaceta* 27, pp. 71-74.

Koch, M., 2003.] *Tarshish e Hispania: Estudios histórico-geográficos y etimológicos sobre la colonización fenicia de la Península Ibérica*. M. Prieto Vilas, transl. Madrid: Centro de Estudios Fenicios y Púnicos.

Mangas, J., and Plácido, D., 1994. Introducción. In J. Mangas & D. Plácido (eds.), *Testimonia Hispaniae Antiqua I: Avieno, Ora maritima, Descriptio orbis terrae, Phaenomena*, pp. 19-30. Madrid: Ediciones Historia 2000.

Palacios, J., 1981. Aquí estaba Tartessos. *Gaceta ilustrada* 1278, pp. 28-39. Barcelona.

Ruiz-Mata, D., and Pérez, C. J., 1995. *El poblado fenicio del Castillo de Doña Blanca* (*El Puerto de Santa María, Cádiz*). El Puerto de Santa María: Ayuntamiento de El Puerto de Santa María.

Sociedad Geográfica de Madrid, 1878. Antigüedades de Andalucía. *Boletín de la Sociedad Geográfica de Madrid 5* (año III), nº 9, pp. 13-14.

PAPERS

B. SCIENCE AND TECHNOLOGY

B1. MEDICINE, BIOLOGY, GEOLOGY

B1.1 Spiritual Pulse and the Medical Care of the Ancient Olympiads (5th - 4th cent. BC)

Christos Lolas, M.D., Ph.Dsop.
Evangelismos Hospital, Athens

Abstract

In this presentation some remarks are made about the basic philosophy, the heart and the spiritual pulse of the ancient Olympiads and then mainly about the medical care during the games (during the 5th and 4th century BC). The medical care and services provided at the modern Olympic Games are a very important part of their organization. Medical services must be comprehensive, satisfactory and have such a degree of readiness as to be able to respond at any moment to any medical problem from a simple sprain to open heart surgery, and to deal with severe injuries or burns from whatever cause. Did medical services exist at the ancient Olympic Games and what were they? Were they sufficient? Did they cover the contests? Unfortunately, we have only limited medical evidence or records for the type of care provided during the ancient Olympic Games. One may assume that medical services were approached with the same attention and seriousness which the organizers of the Olympic Games organized everything else. To answer these questions, ancient medicine and mainly Homeric and Hippocratic medicine, will be discussed by reviving an ancient Olympiad and the facilities of the city of Elis, the city that prepared and organized the Olympic Games.

Introduction

Today the development and implementation of the Olympic Health Services is a major organization field on a grand scale and is a vital part of hosting a successful Olympic Games. The question to be answered now is: What were the health services and the medical care during the Ancient Olympiads? Were they sufficient? Did they satisfy the needs of the contest?

Materials and Methodology

Since the 1st modern Olympiad, the Games constituted a unique international event in which the entire world participated expressing the positive and negative aspects of the society as it was at any particular time. The Olympics today is a most powerful and useful tool that we have to facilitate globalization of mankind.

The basic philosophy of this paper, the heart and the spiritual pulse of the ancient Olympic Games of the 4th and 5th century BC, and in particular the associated medical care, are discussed. An ancient Olympiad and the facilities of the city of Elis – the city that prepared and organized the Olympic Games – and a detailed program of the Olympic contest including health risks to the athletes, the spectators and generally to everyone in Olympia are described and discussed.

The ancient Greeks believed that the seat of the mind was within the heart creating a spiritual pulse which guided their way of acting and thinking. The notion of right and wrong derived from their feelings, which also created characteristics such as courtesy, deep faith, sensibility, tenderness and purity expressed as Arête, the ultimate virtue.

The 4th and 5th century BC during which 50 Olympiads took place from a total 293 Olympiads, was the most important period, the Classical period, of Ancient Greece. It was the time of Pericles and the teachings of the greatest philosophers such as Socrates, Plato, Aristotle and their successors. It was the time when the Parthenon was built, glorious battles took place, and when Alexander the Great expanded the Greek civilization to the East.

During that time, Hippocrates, the father of Medical Science, founded his school, the principles of which are still taught throughout the entire world today.

Imagine listening to a conversation between physicians in Olympia at this ancient time discussing some medical conditions. We would hear them use the following terms: *arthritis, hypothalamus, crisis, tetanus, asthma, dysentery, anthrax, dysplasia, cardiac arrhythmia, osteomyelitis,* etc. We would hear these same words today from a Greek or foreign doctor talking about the same subjects. They would use the same terminology which is now international medical terminology. These few words demonstrate the influence of ancient Greek Medicine on the development and formation of modern medicine.

Let us see where and how an ancient Olympiad was organized, prepared and staged.

The city of Elis was located in the Peloponnese northwest of Olympia. The Elians were responsible for the care of the facilities in the sanctuary of Olympia, as well as the preparation, and the organization of the Olympic Games. This was not a simple task. Most delegations arrived by sea in the small harbor of Pheia close to the estuary of the Alphaeus River. Most roads to Olympia were not easily traveled and the conditions were hard. It took weeks for a Macedonian delegation to reach Olympia by sea.

In the city of Elis, instead of the usual administration buildings that existed in all Greek cities, and apart from the temples and sanctuaries, the buildings were related to the organization and realization of the Olympic Games. These buildings consisted of two large gymnasiums, a wrestling ring for the athletes to warm-up, and the Hellino-

dikion, the judges building. Hygiene facilities – baths and showers were available for the athletes as well.

Once the one-month preparation in Elis was completed, usually two days before the Olympic Games, a large procession of the whole Olympic Family would start off to Olympia. The journey to Olympia lasted two days and covered a distance of 58 km. The sanctuary of Olympia was located in one of the most beautiful areas of Greece in the valley of the Alphaeus River and its tributary Kladeus.

In order to imagine medicine and its clinical application during the Olympic Games of the classical period of Greece, it is necessary to know a little about ancient medicine. From the beginning, of all the Olympic gods, Apollo and his son, Asclepius, remained the principle gods in charge of illnesses. Asclepius was the most important and famous personification of these gods. His family members were Padalirious and Mahaon, the two physicians mentioned by Homer.

Hygeia, the goddess of health, Panacea, the goddess who treated every disease, Telesphoros, the god of convalescence, Ipioi, his wife, the goddess who relieved pain and two other daughters, Iaso and Aceso, the goddesses of healing.

The god and all the members of his family and their successors practiced their healing abilities in the Asclepia. These were religious healing sanctuaries, places of worship dedicated to the god Asclepius, where patients were treated and healed. The famous Asclepeion of Epidaurus was a complex dedicated to Asclepius with many impressive buildings, among them, the theater and the stadium.

The serenity and beauty of the environment as well as the reputation of the god Asclepius in successfully treating serious cases made the patient psychologically prepared and susceptible to the treatment offered.

Medicine of that time was a mixture of experience and rudimentary rules of hygiene, diet and the use of herbs by which healers in the Avaton, guided by divine forces, cured diseases sometimes using even magic.

In ancient times, only the gods had the right to take human life. Here, Apollo and Artemis killed the sons and daughters of Niovis with their bows and arrows and the word "toxic" is derived from the Greek word "toxo" meaning "bow".

It was the time for Homeric medicine. Homer refers to several operations and describes 47 cases of injuries. Most of his heroes had some medical knowledge which they applied to their compatriots when wounded in battle. Towards end of this period, however, philosopher-scientists pioneered a movement that began to provide explanations based on natural law. The age during which warrior-heroes, practical doctors and gymnasts passed on health knowledge led to a time when the world view of scientists developed logical theories and healing methods and led eventually to the period of Hippocratic medicine in the 4th century.

But the most famous physician of all times was Hippocrates of Kos who created the first school of Medicine. Together with his students, he wrote many books and treatises on medical subjects. These works are contained in the volumes of the *Hippocratic Corpus*.

The famous code of Hippocrates was based on careful observation and logical approach and evaluation of all data collected. Hippocrates recommended that nothing

be overlooked and the patient be assessed as a whole. The doctor should think very carefully before reaching a decision and should use all his senses – vision, hearing, taste, touch and smell, without any prejudice.

The patient's overall condition should be evaluated and not only the symptoms. Hippocrates recommended that the patient's country of origin be taken into account as well as the climate, dietary habits, age, speech, manners, movements, thoughts, sleeping patterns and the type of dreams the patient had. The information should be gathered and assessed honorably and honestly. The doctor is under the obligation to inform the patient of his/her problem and prognosis.

The famous Hippocratic Oath binds the physician to safeguard the highest human and professional duties. He promises the gods to respect patient's life by refraining from administering poison, procuring means of abortions, or performing castrations. The physician promised to lead a simple and honorable life and to practice medicine honorably as well as to maintain silence and discretion and to safeguard medical confidence.

There were many cases of athletes trying to win at any cost using illegal means such as fraud and performance enhancing substances. Hallucinogenic mushrooms and naturally derived stimulants were widely used to overcome fatigue or injuries. Anti-doping policy, again, has its roots in ancient Greece. Athletes using illegal means to win were forced to be exposed in common view while building very expensive copper statues of Zeus. These statues were named Zanes. Doping, unfortunately still remains a major and unresolved problem in modern Olympics among other problems such as excessive commercialism and gigantic athletic events.

Conclusion

It must be concluded that medicine practiced at the Ancient Olympic Games during the 4th and 5th century BC was a mixture of Homeric medicine, that of the philosopher-scientists, which culminated in the medicine of Hippocrates. It should be understood that Hippocratic medicine did not guarantee patient's recovery. On the contrary, good diet, and healthy lifestyle, good physical condition, patient's age and the seriousness of his illness must have been the most important factors in recovery rather than any intervention and action of the physician in those remote times.

But isn't this also often the case nowadays? Even with modern medicine and its more radical and scientific methods, the patient's outcome is still largely based on the patient's natural resistance and life-style factors.

Bibliography (Limited)

Adkins L., Adkins R. *Handbook to Life in Ancient Greece*. New York. Oxford: Oxford University Press, 1997.

Drees L., *Olympic Gods, Artists and Athletes*. New Your, Washington: Frederick Publishers, 1967.

Lolas Ch., *The Olympics – Medical Care*. Olysseas Publication, Athens, 2008.

Lolas Ch., *Medical Care at the Ancient Olympic Games*. Odysseas Publication, Athens, 2003

Majano G., *The Healing Hand, Man and Wound in the Ancient World*. London, England: Cambridge, Massachusetts, Harvard University Press, 1975.

Vrionis S., *The Medical Unity of the Mediterranean World in Antiquity and the Middle Ages*. University of Crete Press, 1991.

B1.2 The Contribution of Ancient Greece to Neuroscience

George Paxinos
NHMRC Senior Principal Research Fellow and Scientia Professor of Medical Sciences, Neuroscience Research Australia, and The University of New South Wales, Sydney, Australia

Abstract

The present work initially refers to historic clues relating the contribution of Greek to neuroscience and subsequently to the big questions: a) what the mind is, if it is needed to invoke the term soul in order to study the human behavior and if there is free will, and b) if the brain is able to solve the problem of the environment that it created on its own. Some of the points mentioned have already been presented in the introductory speech of the author in the Academy of Athens.

1.Introduction

According to an Aesop's fable, a fox enters an actor's house and looking about various things it drags up a mask, a marvelous imitation of a human head. It puts its leg on it and says: *"What a wonderful head! Nerveless, it has no value because it has no brain at all?"*

We cannot infer without a particular study that the brain creates the mind and is the centre of intellect, motion, senses and feelings. Egyptians were mindlessly throwing away the brain, despite the care they showed for life after death, sending there in this way brainless generations of Pharaohs. (Doty, 2007)Some pre-Socratean philosophers rejected the supernatural causes and the mythical interpretations about the natural world and the nature of the soul. These philosophers replaced myth with reality and exiled the gods and magic.

Some writers consider Alkmaeon (Pythagoras's student, about 500 BC) of Croton (today's South Italy's Crotone) as the first one who associated brain with intellect.

This thought was possibly transferred to Kos where Hippocrates was working. Hippocrates (460-377 B.) expressed a tremendously modern approach which could be taught today in any University: People should know that pleasure, delight, sadness, pain and tears come from the brain.

Plato also supported the prevalence of the brain. In the tripartite division of psyche, the "Logical", the immortal soul, inhabits the brain. The "Spirited" soul inhabits the heart. The part of the soul that deals with hunger "Appetitive" inhabits the area under the diaphragm. That is Plato considered the most important of these souls living in the brain.

Aristotle (384-322 BC), possibly the greatest scientist of all antiquity, missed the

target by saying *"All souls inhabit the heart. Brain just reduces the blood temperature".*

Herophilos of Chalcedon studied medicine in Kos 65 years after Hippocrates's death. He is deemed to be the first anatomist. There are no written records of his texts but there are references to him in others' works, such as Galenus. Herophilos attributed the strongest part of the soul to the ventriculars of the brain (Dobson, 1925, Acar et al, 2005).

Galenus (130-200 AD) admirer of Hipporcates and Herophilos and doctor of Marcus Aurelius, brought the intellect or the soul back to the brain and rejected as unreasonable Aristotle's view that the function of the brain is to cool the blood.

Galenus also said that the folds of the brain have nothing to do with intellect since *"the donkey's brain has a lot of folds".*

The heart-centered view of Aristotle and the brain-centered one of Galenus competed with each other until Shakespeare's era. In the Merchant of Venice Porcia asks *"Tell me where is fancy bred, or in the heart or in the head?"*

2. Brain, mind, soul and free will

Today there is no doubt where love is located. When one receives heart transplant, one does not fall in love with the wife of the late donator.

Brain is the location of love and not only. And, today, from this place, where some of these ideas originated 2,500 years ago, I would recommend to issue a news bulletin, urging people not to exchange photos with hearts on St. Valentine's day but with something much more correct.

The greatest cartographer of the cortex of the human brain was von Economo (1876-1931), born in Romania by Greek parents and flourished in Austria. He described the cerebral stupor and the post-cerebral Parkinsonism. He was given the Award of Positive Studies of the Academy of Athens and was offered the Chair of Neurology and Psychiatry, but he never wanted to come back to Greece (*personal communication with L. Triarhou*, 2012).

Von Economo and Koskinas described 107 areas of the cortex of human brain (*Economo and Koskinas, in Triarhou*, 2007). Brodmann (1909), whose map is still used, describes only 50. Unfortunately, the much better map of Economo and Koskinas is not used.

After such a struggle to find the location of the psyche, psychology loses its soul in 1930. According to Hebb (1958), the mind is the composition of the energy of brain neurons. That is, there is no phantom in the machine (human organism).

If the relationship between brain and behavior is 1 to 1 (that is totally corresponding) we do not need to invoke the soul in order to study the behavior.

According to Paul Broca (as von Bonim mentions, 1950) there is a group of functions in the human mind and a group of folds in the brain and the data that science has collected so far allow to say … that the big areas of the mind correspond to the big areas of the brain.

What does science know about the relation between mind and brain? When there is damage in one lobe of the brain, there is equivalent damage in human behavior. In

Alzheimer, the degeneration of the brain brings about catastrophic behavior changes. The mind is the energy of brain and bears the same damage as the brain.

The above thoughts as congruent with Hippocrates's thoughts.

According to many neuroscientists, there is no need to invoke the existence of soul so as to study behavior. The question is if there is any free will.

Many neuroscientists (e.g. Skinner) believe that behavior is the result of only two factors over which we have no choice.

a) Of our genetic disposition (we do not choose our parents)

b) Of our environment (we do not choose the society we are born in, neither a mother smoking during pregnancy).

Since we can choose neither of these two factors, many neuroscientists and neurophilosophers have come to the conclusion that no free will exist. It is somewhat easier to show that there is no free will in the emotional part.

I will conjure up Michalis Kakoyannis who shows us with his lyrics that it is impossible for a man to get out of his head a certain love. *"Love that you became a double-edged knife. Once you gave me joy only... But now you drown the joy in tears..."*

Are we then slaves of the past? Behavior changes with the influence of the environment and the psychologists have exactly this goal: To change the behavior e.g. of smokers and drag-addicts and free them from addiction. It is not the person who decides to change his/her behavior because of his/her free will. It is the environment which conveys this change.

What do we win by believing that there is no free will? We lose the feeling of hatred. You can neither hate a crocodile for eating your hand nor wish to take revenge on it. No one is responsible for the evil he/she has commited this, we come to Jesus' words *"Love your enemies' or at least not hate them"*. Jesus' teaching opposes the Christian thought about the after-death revenge, punishment, tyranny and hell (Sam Harris, 2012).

In case you have not been convinced that the brain is an important organ, just look at what an artist wrote, George Bernard Shaw (Human and Superhuman, Act III):

DON JUAN: I did so purely for the sake of alliteration, Ana; and I shall make no further allusion to them. And now, since we are, with the exception, agreed so far, will you not agree with me further that Life has not measured the success of its attempts at godhead by the beauty or bodily perfection of the result, since in both these respects the birds, as our friend Aristophanes long ago pointed out, are so extraordinarily superior, with their power of flight and their lovely plumage, and, may I add, the touching poetry of their loves and nestings, that it is inconceivable that Life, having once produced them, should, if love and beauty were her object, start off on another line and labor at the clumsy elephant and the hideous ape, whose grandchildren we are?

THE DEVIL: You conclude, then, that Life was driving at clumsiness and ugliness?

DON JUAN: No, perverse devil that you are, a thousand times no. Life was driving at brains – at its darling object: an organ by which it can attain not only self-consciousness but self-understanding.

I have many concerns about the brain capacities that I will mention later.

Susan Blakemore (1999) says: *"our brain is three times bigger than that of our closer species in comparison with the size of our bodies. This huge organ is dangerous and painful to give birth about the 20% of the energy of the body when it is calm, although it only has the 2% of the total body weight. There must be a reason for all this evolutionary expenditure".*

What distinguishes brain differ from other organs? It has a body map. It has a map of the outside world. It has a map of our experiences. It is the only organ which has all these three qualities (Rakic, 1999).

Some statistics about the brain: the brain has 1.000 nuclei, 2.000 major interconnections, 200 important enzymes and expresses 20.000 genes. The brain of all mammals as well as of all birds is like this.

The difference in the human brain is that it has 87 billion neurons, much more than one could expect of the size of the mammal we are. In a similar way that the giraffe has a tall neck, we have a big brain. We do not have the biggest brain. Whales have a brain ten times bigger than ours, they have a much bigger body though. Besides, we have many cells of primates, small and many, probably very efficient. Whales are not primates and do not have such neurons.

3. Brain and environmental crisis

Today we face an imminent environmental crisis and the question is if we will act like the Athenians and the Spartans towards the forthcoming war.

The fuel industry places a sarcophagus of carbon dioxide (CO_2) above us. The companies have a lot of money to persuade many that there are doubts among scientists about if the overheating of the planet is man-made. As Naomi Oreskes and Eric Conway mention in their book *Merchants of Doubt* (2011), the companies are the merchants of doubt.

The companies of fuel mining will be destroyed if they are not allowed to make use of their stock, if they are allowed, on the other hand, they will destroy the atmosphere. They have much more money than they need to organize attacks against the scientists and misinform people, so as not to block their business model which will induce the 3-6° Celsius rise of temperature before the end of the century.

I think one of our biggest problems is the lack of self-awareness.

Who are we?

We are at a loss concerning nature. We do not know why we are here, without a free will, having Paleolithic feelings with remnants of the brain of serpents and with a dreadful technology putting at risk ourselves and all ot her life forms.

It has been said that we use only 10% of our brain. This is a sophism and it is possibly conducive to the hubris (arrogance) that we possess immense spiritual reserve. We lack self-awareness and think that, if need be, we will manage to cool our overheated planet with geo-mechanical methods.

Since the time that Narcissus saw his reflection on the river and fell for it, there has not been a human organ becoming the object of such admiration and surely with such

insufficient reason.In fact, our brain is a limited organ which sets boundaries in our intellect, emotions and motives.

4. General conclusion: has our brain the right size?

If our brain was "smaller" than it is (less smart and less capable of speech), it could not have invented science and technology which today threaten our lives. For example, the other primates do not threaten either themselves or us. If our brain were "bigger" than it is, may could possibly understand the problem and perhaps solve it. Thus, I come to the conclusion: the human brain does not have the right size.

Bibliography

Acar, F, Sait, N, Guvencer, M, Ture, U and Arda, MN, *Herophilus of Chalcedon : A pioneer in Neuroscience, Neurosurgery*, 56: 861-867, 2005.

Blakemore, S, *Meme, Myself, I*, New Scientist, March 13, 1999.

Brodmann, K, *Vegleichende Lokalisationslehre der Grosshirnde*, Barth, Leipzig. 1909.

Dobson, JF, *Herophilus of Alexandria*, Proc R Soc Med, 18:19-32, 1925.

Dobson, R, *Alkmain's discovery that brain creates mind : a revolution in human knowledge comparable to that of Copernicus and of Darwin*, Neuroscience 147, 2007 : 561-568.

Harris, S, *The delusion of free will. Festival of Dangerous Ideas* 2012, Sydney Opera House.

Harris, DO, *A Textbook of Psychology*, Saunders, Philadelphia, 1958.

Rakic, PT, *Great Issues for Medicine in the Twenty-First Century*, Ann.N.Y.Acad. Sciences, vol.882, p.66, 1999.

Von Bonin, G., *Essay on the Cerebral Cortex*, Thomas, Springfield, 1950.

Von Economo, C and Koskinas, G., N, *Atlas of Cytoarchitectonics of the Adult Human Cerebral Cortex*, Translated revised and edited with an Introduction and additional appendix material by L C Triarhou, Karger, Basel, 2007.

B1.3 The Genetic Origin of the Greeks

Constantinos Triantaphyllidis
Emeritus Professor of Genetics and Human Genetics
Faculty of Biology, Aristotle University of Thessaloniki

Abstract

The recent fascinating developments in the DNA analysis have allowed Genetics to assist History, Archaeology, Linguistics and other sciences in answering the question of the origin of the Greeks, both Ancient and Modern.

The population genetics data support the model of first appearance of the anatomically modern human (*Homo sapiens*) only in Africa about 200,000 years ago. From Africa humans moved to the Middle East and from there arrived in the area of Modern Greece 53.000 years ago. The oldest evidence of humans in Europe was discovered in Kleisoura and Franchthi caves, in Argolis. From Greece hunter-gatherers spread throughout Europe. During the last Ice-Age human presence were limited to four refugia in Southern Europe. One of these was the Balkan regugium, out of which, after the ice melted, humans with a distinct genetic make-up re-expanded into Central Europe. Approximately 12,500 years ago inhabitants of the *Fertile Crescent* in the Middle East developed agriculture and animal husbandry. The dissemination of the innovative agricultural technology by settlers into Greece then followed. The main starting point of Neolithic agricultural populations groups arriving in Greece/Europe is believed to be Western Anatolia, mainly by a maritime route, and to a lesser extent also a terrestrial route through the Bosporus strait. Archaeogenetic studies indicate that the Aegean Neolithic population can be considered the biological root for all early European farmers and their colonization routes, and furthermore help trace their expansion routes.

The genetic data indicate that the genetic heritage of Greeks was created by four main independent migratory population waves corresponding to: a) The early colonization of Greece by pioneer hunter-gatherer Homo sapiens from Africa through the Middle East during the ***Middle Palaeolithic Era***. b) The population movements from Northern/Central Europe to the warm Balkan glacial refuge of Southern Europe during the ***last glacial*** and the subsequent ***postglacial re-population*** of deserted areas of Central and Northern Europe from the Balkan glacier refuge. c) The ***Neolithic demographic*** *diffusion* of farmers from the Near East and their arrival into Greece approximately 10,000 years ago, and d) the migrations mainly from Greece to the rest of Europe, and vice versa, since the ***Bronze Age***. So, it seems that, to a great extent, the genetic heritage of the present inhabitants of Greece had already been formed in that distant prehistoric *Bronze Age* period and it is therefore the descendants of these people who inhabited the area of Greece as early as 2,000 BC who will be characterized

as Greeks.

Genetic results prove the existence of the genetic signature of the ancient Greeks in all their colonies, the close relationship with the inhabitants of Southern Italy and finally the genetic continuity of the population living in the geographical area of Greece. On the other hand, it refutes theories such as the Indo-European incursion from the North/Caspian area that "hellenized" Greece or the descent of Cretans from Egypt.

Ultimately, the genetic evidence supports the view that was expressed by the prominent archaeologist Sir Colin Renfrew: *"The Greek culture, Greek beliefs and probably the Greek language developed here, within the land which we know as Greece today that in that sense the Greeks were autochthonous and were ever in the process of becoming".*

1. Introduction

The DNA molecule contains the genetic information that determines our biological development. Thus, the components of a human being (individual) are "constructed" according to the plan that is stored in DNA. Therefore similarities between organisms are due to the similarities in their genetic (DNA) material.

DNA replication has excellent fidelity. Therefore DNA is passed unchanged from generation to generation, unless a biological error occurs during duplication, e.g. a *mutation*, which under certain conditions can be inherited (passed) to offspring. Thus, each of us carries DNA in our cells, which was inherited from our parents. By the same mechanism our parents inherited their own DNA from their own parents and so on until we arrive at our ancestors from the past. For this simple reason the DNA of modern humans can be a credible witness to events in the human history that happened dozens, even hundreds or thousands of years ago.

2. The colonization of Greece and Europe by anatomically modern humans

Anatomically modern humans (*Homo sapiens*) originated in Africa at least 200,000 years ago (**Fig. 1**). Hunters-gatherer population groups left Africa from today's Ethiopia by crossing the Red Sea at the Bab-el-Mandeb Strait and spread into the Arabian Peninsula (modern Yemen), during a mild and wet climate interval at least 100,000 years ago. From the Arabian Peninsula, anatomically modern humans moved to the Near East, where there were already populations of the *Homo neanderthalensis* species. Individuals of both species lived, met and interbred in the Near East, albeit rarely, during the Paleolithic era. The two species also probably interbred in Europe. However, the majority (> 97%) of the genetic heritage of anatomically modern humans living outside Africa, and therefore of Greeks and the other Europeans has originated in Africa.

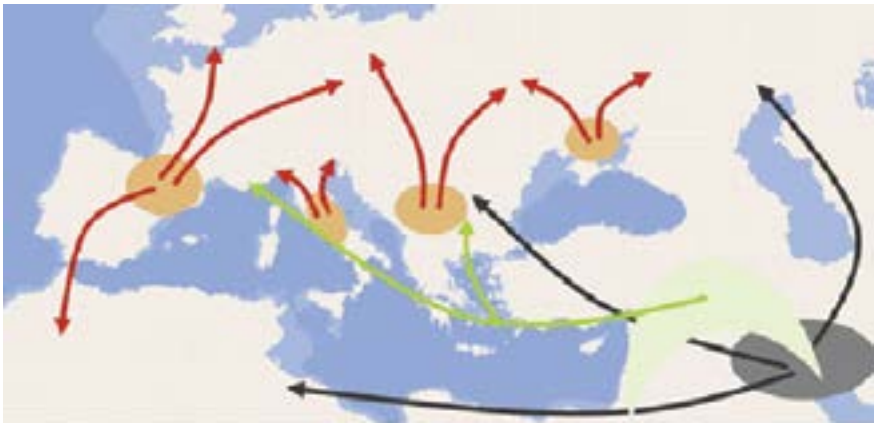


Fig. 1. *Schematic map of Eurasia showing the major migration events that may have influenced the gene pool and genetic diversity of modern-day Europeans. The Eurasian ancestral population originated from an African population before at least 100,000 years.* ***Black arrows****. They symbolize the initial expansion of hunter-gatherers from the Middle East and their settlement in Europe during the Middle Palaeolithic era around 53,000 years ago.* ***Red arrows****. During the last glaciation period (25,000-19,000 years ago) the populations of Northern and Central Europe retreated into four glacial refugia (Franco - Cantabrian, Italian and Balkan Peninsulas as well as that of the Northern coast of the Caspian Sea). After the end of the last Ice Age, these refugia were the starting points for the subsequent recolonization of Europe.* ***Green arrows****. The movement of Neolithic farmers approximately 12,500 years ago from the Fertile Crescent of the Near East west over Cyprus and the Aegean Islands and into Southeastern Europe (mainly Greece and Bulgaria) and their expansion to the rest of Europe following different paths*[8].

Anatomically modern humans arrived in Greece at least 53,000 years ago (**Fig. 1**). These human population groups developed the *Uluzzian culture* in the Ermionida province (Kleisoura and Franchthi caves) in the eastern part of Argolida prefecture (southern Greece), as well as in the region of Puglia in SE Italy.

During the *Middle Palaeolithic era*, the first hunter-gatherer population groups that arrived in Greece from the Near East were carriers on the matrilineal clade of mitochondrial haplogroup R, and mainly of the genealogical clades of the mitochondrial haplogroup U, and, on the patrilineal clade, carriers of the Y- chromosome haplogroups R and IJ. These population groups of hunters - gatherers spread the *Aurignacian culture*.

The first expansion wave of hunter-gatherers from the Near East into Europe was followed by a second expansion wave (32,000-22,000 years ago) during the *Late Palaeolithic era*. They were carriers of the matrilineal haplogroup H and they developed the *Gravettian culture*, which was established throughout Europe. Almost at the same period, the Y-chromosome haplogroup IJ-429 evolved into haplogroup J in the Near East and approximately 30,000 years ago haplogroup I was created in the Balkan Peninsula. Carriers of this Y-haplogroup spread from the Balkans to the whole of Europe carrying the *Gravettian culture*.

3. Population movements from 23,000 BC to the Mesolithic era

During the peak of the last glacial period (25,000-19,000 years ago) the Paleolithic hunter-gatherers with *Aurignacian* or *Gravettian culture* could not withstand the Northern European cold weather and retreated to the south until they arrived and settled in four warm shelters, those of the Franco-Cantabrian, the Italian and the Balkan peninsula and the Northern coast of the Caspian Sea (**Fig. 1**).

After the gradual global climate re-warming (19,000-13,500 years ago) the second stage of recolonization of Central and Northern Europe with hunter-gatherers from all the glacier shelters followed (**Fig. 1**). From the Balkan shelter populations who were carriers of mitochondrial haplogroups I, U5b1, U4, H1, H3 and V spread into Central and Northern Europe. Similarly, men from the Balkan shelter, with genetic make-up of the Y-chromosome haplogroup I, repopulated Central and Northern Europe as far as the Scandinavian Peninsula, as well as part of Eastern Europe.

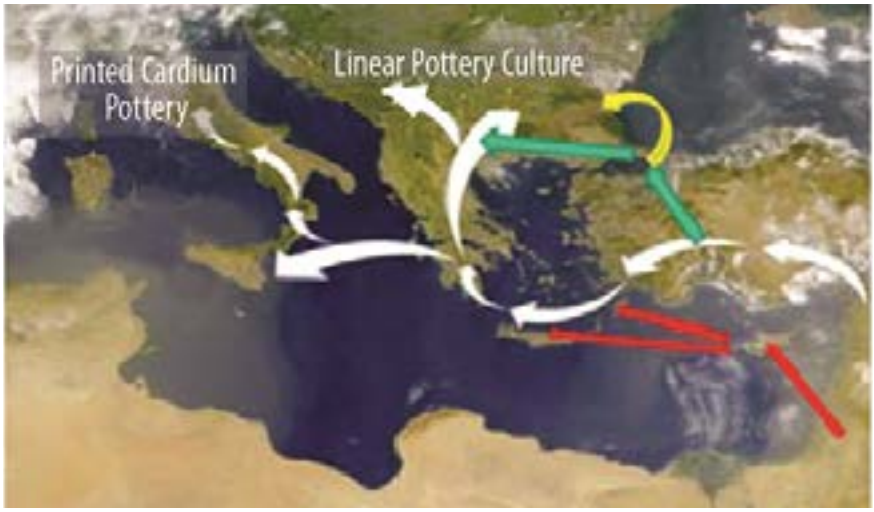


Fig. 2. *Possible routes of expansion of Neolithic farmers from the Near East into Greece and Europe. The Neolithic farmers from the Near East traveled mostly by sea to reach Greece/Europe. a) The main maritime route connecting Western Anatolia via the Aegean islands (Dodecanese/Lesvos/Chios) – Cyclades Islands – to the Peloponnesus, mainland Greece and to the rest of Europe is symbolized by* **white arrows**. *Two further alternative maritime routes have been also suggested: b) Levantine – Cyprus – Aegean islands – mainland Greece and rest of Europe* (**red arrows**). *c) Northern Anatolia – Danube River and rest of central Europe* (**yellow arrows**). *A possible land route* (**green arrows**) *is also indicated on the map: Northwestern Anatolia - Dardanelles and Bosporus strait - Thrace - Macedonia - Southern Balkans and on to the rest of Europe*[15].

4. Population movements during the Neolithic Era

Approximately 12.500 years ago, the hunter-gatherers of the Fertile Crescent developed the cultivation of cereals, the domestication of wild animals and animal husbandry.

The transition from the hunter-gatherer way of life to the agricultural way of life, at the beginning of the *Neolithic* era is considered the most important cultural and technological innovation in the history of anatomically modern humans. Generally speaking there are two possible migratory routes (**Fig. 1** and **2**) that the pioneer Neolithic population groups could have followed into Greece and Europe: (i) over land through the Dardanelles and (ii) across the sea over the Aegean islands. The main starting point of the Neolithic settlers arriving in Greece/Europe is believed to be the Western Anatolia coast, although to a lesser extent Neolithic people may have also used the maritime route starting at the Levantine coast, as well as the terrestrial route to Thrace. Next, the expansion of the Neolithic population groups, of agricultural technology and of ceramic artifacts from Greece to the rest of Europe followed two major routes, the *Mediterranean route* towards Italy and the *Continental route* through the Balkans (Axios and Danube valleys) towards Central Europe.

Based on the available genetic data it is concluded that during the Neolithic era population groups of farmers arrived in the Greek geographical territory carrying characteristic patrilineal and matrilineal haplogroups. Individuals/carriers e.g. of the patrilineal lineage G2, and the E-V13 lived on the Aegean islands 7,000 years ago. The existence of these sub-haplogroups in the inhabitants of Southern Italy and the French Provence probably reflects the maritime colonization of these areas by the ancient Greeks during the *Neolithic era*, but mainly during the *Iron Age*.

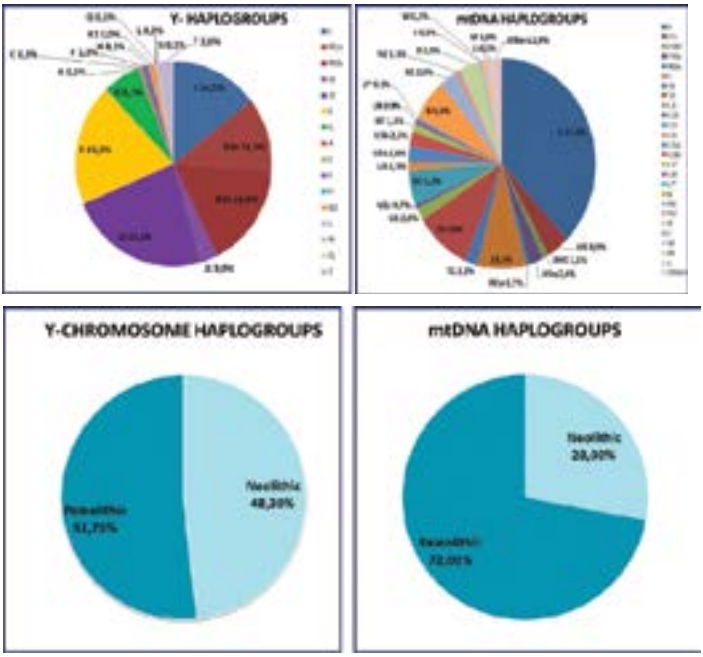


Fig. 3. ***Top.*** *Y-chromosome* (***left***) *and mitochondrial haplogroups* (***right***) *of Greek people. Bottom. The percentage of Y chromosome haplogroups* (***left***) *and mitochondrial haplogroups* (***right***) *representing Paleolithic and Neolithic origins of present day Greeks*[11].

The spread of carriers of haplogroup G from Thessaly into Sicily, SW France and the Iberian Peninsula has been associated with the *printed-cadmium pottery culture* from 5,000 BC to 1,500 BC **(Fig. 2)**. Additionally, this haplogroup has been found in archaic human remains from Central Europe with *linear pottery culture* (*LBK*). Consequently, the archaeogenetic studies support the view that Neolithic populations carrying this lineage played an important role in the expansion of agriculture from Greece into Central Europe.

Percentages of haplogroups in Greeks. The major paternal lineages, i.e. Y- chromosome, and maternal, i.e. mitochondrial, haplogroups, found in the Greek population are presented in **Fig. 3**: The DNA studies revealed that the majority (> 95%) of the Greeks are descendants of people who were carriers of 8-10 matrilineal and patrilineal haplogroups.

The inhabitants of Greece are characterized by a high prevalence of mitochondrial (matherlinear) H-haplogroup, which is the predominant haplogroup in the Europeans. Haplogroups L, which is characteristic of the African population, is very rare among Greeks. In the patrilineal make-up of Greeks, the highest frequencies were observed for the R and the J2 and E haplogroups that denote Palaeolithic and Neolithic descent, respectively.

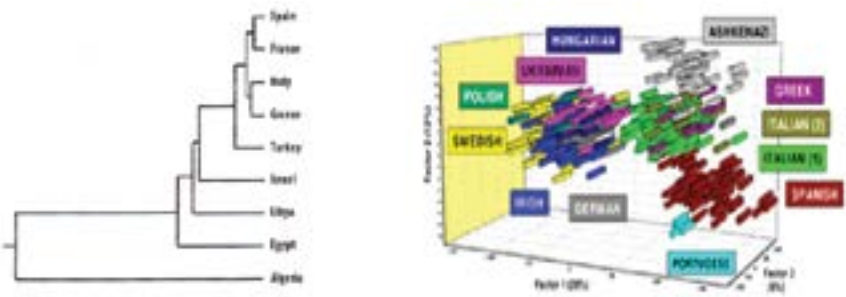


Fig. 4. ***Left.*** *Phylogenetic tree showing the genetic relationships among the inhabitants of nine Mediterranean countries*[10]. ***Right.*** *Using thousands of single nucleotide polymorphisms in Americans hailing from 11 different European countries allowed grouping them into two main population groups, representing European ancestry from northern and southern parts of the Continent. The sample population marked Italy 2 are Americans of Italian origin, while the sample labeled Italy 1 are native Italians*[9].

5. The position of the Greeks on the Mediterranean genetic map

The geostrategic position of Greece at a crossroads between three continents has provoked huge interest for anthropological and genetic studies. In addition, the populations of the Mediterranean countries are quite diverse consisting of people of different nationality, language and religion. Hence, it was worthwhile to explore the genetic relationships between Greeks and other Mediterranean people, as well as the genetic relationship among the inhabitants of the Mediterranean countries. For that purpose, data were collected for the genetic heritage of the inhabitants of 9 Mediterranean countries (**Fig. 4**) for genetic variants (alleles) associated with *classical genetic markers*[10].

From the graph (**Fig. 4, Left**), which represents the genetic relationship among nine Mediterranean populations, it is concluded that: a) The smallest genetic distances (or the greatest genetic affinity) occur between French - Spaniards and Greeks - Italians. b) The greatest genetic distances were determined between the Algerians and the inhabitants of the other eight Mediterranean countries. Moreover, the populations of the North Mediterranean countries were clustered together in one genetic group, while this was not the case for the inhabitants of North Africa. Thus, one could argue that the Greeks seem to be genetically closer first with the Italians, next with the French and Spaniards and last with the Turks. Similarly, based on thousands *single nucleotide polymorphism markers* (*SNPs*) it has been documented (**Fig. 4, right**) that the Greeks exhibit the highest genetic affinity first with the Italians and then with the Spaniards[9].

6. Genetic and archaeological evidence concerning the Minoan civilization

In the beginning of the twentieth century the British archaeologist Sir Arthur John Evans discovered relics of a *Bronze Age* culture on Crete, which he named *Minoan civilization*[9]. Evans attempted to provide a plausible explanation for the origin of the people who developed such an advanced civilization. Based on the apparent similarities between the archaeological findings of the Minoan period and those of Egypt and Libya he suggested as founders of the *Minoan civilization* descendants of refugees derived from the culturally advanced Delta region of Egypt. Evans' hypothesis is still in force today. Of course, both Evans himself[3], and modern archaeologists later questioned this version of events. It has been suggested that the Minoans were descended from *Bronze Age* settlers coming to Crete from neighboring regions, either from the Middle East, or Anatolia or the Cyclades Island or finally that the development of Minoan *civilization* was indigenous, created from descendants of the original Paleolithic or Neolithic settlers of Crete. The final answer to this archaeological issue was given by molecular genetic analysis of ancient DNA in Minoan remains[4].

None of the archaic Minoan samples from Crete carried mtDNA sequences of the L haplogroup that characterize African populations. Furthermore, the statistical comparisons of the mtDNA variants illustrated the great *genetic distance* (i.e. absence of genetic similarities) between the Minoans and the Egyptian, Libyan and other African populations. This interesting study instead demonstrates that the Minoan gene pool's strongest genetic relationships are with modern and ancient (*Neolithic and Bronze age*) South Eastern European populations. In fact, the highest genetic similarity of the Minoans' DNA is observed with modern Greeks and especially with the current inhabitants of the Lassithi prefecture, as well as those of the Chios, Euboea, Argolida and Laconia regions. These results, according to the authors, refute or at least raise convincing doubts about the correctness of Evans's initial theory[2,3], that the founders of the *Minoan civilization* were of North African (Egyptian or Libyan) origin. Based on the archaeological and genetic evidences it was suggested that the Minoan civilization was native, i.e. created by the Cretans, and therefore was European.

7. Conclusions regarding the study of the genetic heritage of the Greeks

The genetic studies on the structure of the present inhabitants of Greece with various genetic markers have revealed that the Greek population is *pammictic*, which means that marriages are made randomly and there is no substantial stratification into subpopulations. In addition, the inhabitants have *higher rates of genetic variation* than the people of central, northern and western Europe. This indicates that various population groups – from the *Middle Paleolithic Era* until relatively recently – moved from the Greek geographical area to western and central Europe and that the area of Greece is at the core of the *Biological history of Europe's populations*.

Interestingly, despite the proximity or even cohabitation of the Greeks with different people, the Greek population does not exhibit significant recent admixture with other neighboring populations. Thus although the island of Crete is close enough to accept African genetic penetration, the genetic heritage of the Minoans had a higher rate of affinity with Neolithic, ancient and current European populations. This result indicates that the *Minoan civilization* has a European – and not an Egyptian origin. Similarly, the Greek refugee population that originated from Asia Minor, and now resides in Greece, shows greater genetic similarity to the population of mainland Greece, that to the Turkish population. In a broader context, despite four centuries of Ottoman rule, Greeks and Turks have different genetic heritages, since apparently there has been no significant admixture between Greeks and people of Mongolian origin.

All the previous genetic data[11] suggests that the genetic heritage of Greeks was created by four main independent migratory population waves corresponding to: a) The early colonization of Greece by pioneer hunter-gatherer *Homo sapiens* from Africa through the Near East during the *Middle Palaeolithic Era* before at least 50,000 years, b) The population movements from northern/central Europe to the warm Balkan glacial refuge of Southern Europe during the *last glacial* (25,000-19,000 years ago) and the subsequent *postglacial re-population* of deserted areas of central and northern Europe from the Balkan glacier refuge between 19,000 and 13,500 years ago, c) *the Neolithic demographic diffusion* of farmers from the Near East and their arrival into Greece approximately 10,000 years ago, and d) the migrations mainly from Greece to the rest of Europe, and vice versa, since the *Bronze Age* (approximately 3.500 years ago).

Hence, to a great extent, the genetic heritage of the present inhabitants of Greece had already been formed in that distant prehistoric *Bronze Age* period. It is therefore the descendants of the people who inhabited the area of Greece certainly as early as the 3rd millennium BCE and perhaps even earlier who will be expressing themselves in Greek since the *Mycenaean Era* at least and characterize themselves as *Hellenes*/ Greeks at the end of *Bronze Age*.

The genetic data show that the distribution of the genetic markers coincides perfectly with the geographical distribution of the ancient Greeks in the Eurasian region at the first half of the 1st millennium BCE. This includes southern mainland Italy and Sicily, areas situated to the north of the present Greek borders, covering the southern part of Albania, fYROM and Bulgaria and a part of Asia Minor at latitudes projecting up to the city of Trabzon on the Black Sea. Similarly, research projects on the genetic

structure of the Italians show a template that reproduces almost faithfully the Greek colonization in antiquity. The perseverance of close genetic affinity between modern Greeks and the current inhabitants of various areas of Italy that had been colonized by the ancient Greeks is convincing evidence for their common ancestry from ancient Greeks.

These patterns of affinity that reflect the dispersion of the Ancient Greeks are repeated in the results of the investigation of the genetic heritage of Eurasian peoples and demonstrate the durability of the DNA signature of the Greeks. Thus, one could plausibly argue that the genetic investigations document, albeit indirectly, the genetic continuity of the Greeks in space and time.

Roughly three quarters of the genetic background of modern Greeks' DNA sequences signal the genetic fingerprint of human hunter-gatherers who lived in the Greek geographical area as early as the *Middle Paleolithic/Mesolithic periods* and about one quarter DNA sequences that represent farmers who entered into what is today Greece during the *Neolithic Era*. The admixture of these population groups basically constitutes the genetic background of the current Greeks.

The relatively low level of admixture with other human population groups that has been detected in the DNA of the modern Greeks may be indicative of genetic isolation due to natural barriers or to cultural, religious and linguistic characteristics of the Greeks. Of course, the genetic data in no way should be interpreted as reflecting any form of "purity" of the genetic heritage of the Greeks. Additionally, whether a person is Greek cannot be determined using genetic analysis.

Ultimately, the genetic evidence supports the reports of ancient writers about the indigenous origin of the Greeks. The Athenian rhetorician Isocrates (436 BCE - 338 BCE) said in his 4th Panegyricus (verses 23 to 24, 380 BCE) that he addressed to the Athenians: *"Our city is recognized as the oldest, the largest and most famous in the world. Therefore, being so glorious since the beginning of history, it should be further honored for continuity. Because we who dwell in this city, have not driven others hence, neither have we found it deserted, nor have we gathered here scattered by different peoples. Our origin is so good and genuine, so that in the very land on which we were born, in this we have lived without interruption (forever), because we are indigenous in this place. So we can call the city with the same name one gives to their closest relatives».*

The same view was expressed recently by the prominent archaeologist Sir Colin Renfrew[6,7]: *"The Greek culture, Greek beliefs and probably the Greek language developed here, within the land which we know as Greece today, that in that sense the Greeks were autochthonous and were ever in the process of becoming".*

8. References

1. **Boric D. and Price T.D.** (2013). *PNAS USA* **110**: 3298-3303.
2. **Evans, A.J.** (1921). *The Palace of Minos at Knossos*. Volume I. London: MacMillan and Co.
3. **Evans A.J.** (1925). *The early Nilotic, Libyan and Egyptian relations with Minoan Crete*. The Huxley Memorial Lecture for 1925. J. Royal Anthr. Inst. **55**, 1925, 199-228.
4. **Hughey J., Paschou P.,** *et al.* (2013). *Nature Commun*. **4**: 1861.
5. **Paschou P., Drimeas P.,** *et al.* (2014). *PNAS USA* **111**: 9211-9216.
6. **Renfrew C.** (1993). *II. Who were the Greeks? A problem of ethnicity.* Stanford University, April 31, The Tanner Lectures on Human Values.
7. **Renfrew C.** (1996). *"Ever in Process of Becoming': The Autochthony of the Greeks,"* In J. A. Koumoulides (ed.), The Good Idea: Democracy in Ancient Greece.
8. **Renfrew C.** (2010). *Curr. Biol.* **20**: R162-R165.
9. **Seldin M.F., Shigeta R.,** *et al.* (2006). *PLoS Genet* **2**: e143.
10. **Triantaphyllidis C., Kouvatsi A.,** *et al.* (1986). *Hum. Hered.* **36**: 218-221.
11. **Triantaphyllidis C** (2016). The genetic origins of the Greeks. Kyriakidis Editions, Thessaloniki (Greece), pp. 248.

B1.4 The Natural Environment and Its Significance

Petros Themelis
Univ. of Athens, GR

The time that separates us from the past is composed of an unbreakable chain of archaeological and historical layers. It is not a chasm that has to be bridged because it cuts swiftly through cultural continuity, but it is the solid ground of the process in which the present is rooted.[1] In consequence, the past does not die unconditionally, but continues to exist and to act down through the generations, constituting a cultural and humanistic force of the highest significance. History appears as a genetic evolutionary function; as "change within time," according to Aristotle, it refers principally to mankind, in its activity and its fate. Natural elements also exist within it, for instance the geographical location as residence, battlefield and workplace, along with land roads and sea lanes, rivers, floods, earthquakes, volcanic activity, and plagues - the natural environment in general. Man as a natural being finds himself in the bosom of natural reality and at the same time lives in a particular historical period with a specific cultural and intellectual horizon.[2] Geographical conditions, the natural environment, and the climate, affect and to a great degree determine the ways of life and of thinking, the beliefs, and the aesthetic values of local communities. The human-geographical fixations of the late Semni Karouzou, director of the National Archaeological Museum, come to mind. As soon as she met you, she would ask "where do you come from?" and draw her conclusions according to your place of origin, whether from mountain-dwelling, islander, farming, or nomadic herder parents from Peloponnesus, Thessaly, Macedonia, or Asia Minor.

Historical geography has as its aim the reconstruction of the lost historical location (natural and man-made) which framed it and set its limitations on human action, affecting the course of events.[3] Geography constitutes the core prerequisite for understanding historical events and is justly recognized today as a factor in the renewal and rebirth of historical research and its enrichment with new material, mainly from the area of archaeology. Through its vital contributions to current work in the applied sciences and archaeometry (dating of archaeological finds using scientific methods), archaeological research has the power to bring new material remains to light and to illuminate aspects of the past, with its main goal to approximate the natural and man-made environment more closely. The archaeologists' pickaxes reveal monuments that throw light on unfamiliar aspects of historical events in antiquity, confirming or

1. H.G. Gadamer, *Truth and Method* (New York 1975).
2. K.D. Georgoulis, *Φιλοσοφία της Ιστορίας* (Athens 1993).
3. G. Steinhauer, *Historical Geography of the Ancient World, Greece-Rome* (Athens 2009).

changing established views.

Except for the gradual rise in the sea level that has changed details of the coastlines, it has been held that the contours of the Mediterranean are still those which people living around twenty-five hundred years ago saw. Geologically, it is new and therefore unstable. A fair number of volcanoes are active and earthquakes are relatively frequent. The forests of pine, oak, beech, and chestnut trees were more numerous and denser, according to certain studies. Since the Archaic period, they have been losing ground to cultivated land and expanses of maquis. According to the palaeozoologist Günter Nobis, who studied the numerous animal bones from the excavations at Ancient Messene, the mountains around the city were in antiquity home to many animals, including brown bears, red deer, jackals, foxes, and wild pigs. Even today, there are many wild pigs as a result of human intervention, but because of the lack of woodlands they invade cultivated areas and cause damage.

The Greek philosophy of nature as developed at Miletus in Asia Minor and later on in other Greek cities was a pioneering intellectual creation. All the concepts that make up the system of philosophy and physics were born then – the concepts of matter, of force, of number, of motion, of becoming, of being, of space and time, the idea of the atom as well as the method of empirical physics that would triumph later on. The ancient Greeks saw the element of life everywhere in nature. The theory of Animaxander, a student of Thales, concerning the origin of species is startling—that they initially evolved from the seas, then on dry land, and adapted to the natural environment—contains ideas which Darwin would introduce into biology more than two millennia later.

Interest in the alteration and destruction of the natural environment, especially in beleaguered Attica, has its roots in classical antiquity. Plato took a lively interest in the natural environment. With great sensitivity he describes the landscape around the banks of the river Ilissus, which Socrates especially loved. The most reverend Archbishop of Pergamon Ioannis mistakenly attributed Western man's arrogance and responsibility for today's ecological crisis to Platonism[4]. The understanding of nature was a basic aim of Western thought, but it should not be identified with that of controlling nature. The sophist Critias, in Plato's dialogue of the same name, describes the deforestation and stripping away of the land of Attica: (quote) "...what there is now compared with the way it was then, is like a sick man, with all the fat, soft earth washed away and only the land's bare bones remaining. But at that time the land was intact, and for mountains it had high earth-covered hills, and instead of the "rocklands," as they are now called, it held plains full of rich soil, and it had much woodland in its mountains, of which there are visible proofs even today, for some mountains which now have food only for bees, they had trees not very long ago, and the beams from the trees felled there for roofing the largest buildings, are still sound... It was moreover enriched by the water each year from Zeus, which was not lost, as it is now, by running off the thin earth into the sea. Rather, it had much soil that received the water and stored it up; by drawing off the water from the heights down into the hollows, it provided all the various districts

4. "THE KATHIMERINH", (Athens daily, 30 July 2006, 24 [http://news.kathimerini.gr/4dcgi/w_articles_ell_2_30/07/2006_192534].

with abundant running water from springs and streams..." (Plat. *Criti*. 111b-d).

By the Ilissus, according to mythology, Orethyia, daughter of King Erechtheus, was once playing with her friends when Boreas, the North Wind, seized her by force and made her his wife. Plato (*Phaedr*. 229b-c) mentions an altar of Boreas near the ford going toward the sanctuary of Artemis Agrotera. After a long conversation with Lysias at his house near the sanctuary of Olympian Zeus, Phaedrus came outside the walls of Athens to study a manuscript in a quiet place, cool and shady since midday was approaching and the heat was unbearable. The area of the Ilissus was an ideal spot for study and contemplation in the summer. On the way, Phaedrus met Socrates. They walked barefoot through the riverbed, which at that time of the summer had little water, but it was cool and clear. They sat down on the opposite bank, beneath the shade of a "tall and spreading" plane tree beside the river's "delightful and transparent" waters (*Phaedr*. 230b), on the grass of the verdant slope of a little hill, with the cicadas singing ceaselessly around them while the leaves of the trees rustled as the wind's cool breath touched them. Complementing this paradisiacal landscape beside the banks of the Ilissus was a most agreeable little spring with cold water and a big shady willow tree that perfumed the air with its blossoms. There was also a sanctuary of the Nymphs and Acheloos there nearby, with terracotta dedications, as well as one of Pan.

How can I describe the complete disappearance of the Ilissus River today, and its transformation into a sewer running under the pavement of Vasileus Konstantinos Ave. Kallirhoe, and Ilissus streets? How can I render the current plight of the one-time landscape along the Ilissus that Plato described so gracefully? What can I say about the shabby remnants of the temple of Agrotera and the modern buildings that surround it? The odors that dominate the area nowadays certainly have nothing to do with sweet-smelling willows. The constant roar of automobiles does not remind you at all of the unbroken song of the cicadas and the rustling of leaves. The paradise of the landscape along the Ilissus has been turned into a hell.

For ancient Messene it should be stressed that the city kept its size and Hippodamian urban plan down to the end of the fourth century A.D. The 9.5 kilometer long walls, surrounding an area of 290 hectares, enclose open space larger than the built-up area that included the mountainous bulk of Ithome for woodcutting, quarrying, and grazing, as well as flat expanses to the south, west, and east of the city's center for cultivation, in fields with fruit trees, olives, vineyards, and domesticated animals. The image that the urban landscape presented, the wider area of the walled city in antiquity, did not differ essentially from the present look of the archaeological park, with its magnificent ancient buildings of a political and cultic character looming among the modern olive groves, vineyards, and fields of fruit and vegetables.

Zeno, the founder of Stoicism, saw the population of the inhabited world (*the oikoumene*) as one people, citizens of a single city and living under a single set of laws. Human beings could be happy only when they learned to live according to the law of order inherent in nature. Many of Zeno's ideas, together with those of his successors Cleanthes and Chrysippus, derive from Pythagoras and Plato, but the notion of the unity of mankind may well have been inspired by Alexander the Great's achievement. The location of Zeno's school, the stoa (colonnaded portico), was a typical secular urban building.

Epicurus' choice of setting and location for his school was equally significant: he bought a garden far away from the center of the city. There, he practiced a philosophy based on an understanding of nature first developed by the fifth-century atomists Leucippus and Democritus. The chance movement, collision, and conjunction of tiny particles had brought the material world into being, and it is constantly changing as atoms separate and come together again in different patterns. Each human being is merely a collection of particles that break apart at death, an individual with no responsibilities. Since people have no future existence after death to live for, they should trust their own desires, seeking peace and happiness in satisfying them without giving in to excess. This is best done in a garden, remote from the pressures of the city where society constantly imposes its demands.

We live today in a global village, a "global ethnoscape," (the oikoumene of Zeno) to use Arjun Appadurai's neologism, and the distribution of "common images" for the world, chiefly by means of the mass media, speaks in favor of a "common view" about culture and natural environment[5]. The challenge which humanity today is called to confront is to understand that the planet constitutes a totality and to devise strategies that will avert the rapid destruction of the environment and at the same time its economic collapse, to develop a plan for the sustainability of our culture and a course towards a more hopeful future. In other words, we should build a world "where the basic needs of all the Earth's people are satisfied, and a world that will allow us to think of ourselves as civilized," as Lester R. Brown stresses in his 2011 book *World on the Edge: How to Prevent Environmental and Economic Collapse.*[6]

In 1972, Costas Carras founded the Hellenic Society for the Protection of Environment and Cultural Heritage (*Elliniki Etairia*), an interdisciplinary non-governmental organization (NGO), roughly thirty years before Lester Brown founded his own Earth Policy Institute. The foundation of the *Elliniki Etairia* was sparked by Athens' environmental pollution and the destruction of a great part of its architectural heritage with an eye to easy profit, using the real-estate swap (*antiparochi*) as a tool and the flawed legal protection of certain traditional settlements as an excuse. Costas Carras' book containing published texts written between 2000 and 2008[7] is extremely topical today - even prophetic, I would say - articulating the agonies and the struggles of a time when Greek society began, admittedly after a considerable delay, to turn its interest towards the environment and the need to protect it. Three streams, to use Carras' apt expression, united to create the broad river of the ecological movement: love for nature, re-

5. A. Appadurai, "Global Ethnoscape: Notes and Queries for a Transnational Anthropology," in R. G. Fox (ed.), *Recapturing Anthropology: Workin g in the Present* (Santa Fe 1991), 191-210. [= A. Appadurai, *Modernity at Large: Cultural Dimensions of Globalization* (St. Paul, Minn. 1996), 44-65].

6. Translation into Greek by Christos Foundoulis, *Ο πλανήτης μας στα όριά του ή πώς θα αποτρέψουμε την περιβαλλοντική και την οικονομική κατάρρευση* (Athens 2011). In 2001 Brown founded the *Earth Policy Institute*, a non-governmental interdisciplinary research organization based in Washington DC whose aim is to offer a plan for the viability of our civilization and a road map for us to get out of the crisis.

7. *Unfinished Landscape: Will and Opposition in the Struggle for Sustainability* (*Ημιτελές Τοπίο: Βούληση και Αντίθεση στον Αγώνα για την Αειφορία*), Athens 2011. The book was presented by the astrophysicist Nikolaos Zerefos, the constitutional expert Nikos Alevizatos, the writer Apostolos Doxiadis, and the actress Lydia Koniordou.

spect for architectural heritage, and concern for public health. Following the book's four main sections is a powerful epilogue that analyzes the current dramatic collapse of the Greek (and by extension the Western) social, economic, and management model, as well as the catastrophic consequences of this collapse for the environment and the survival of the world's inhabitants.

The disruption of the environment's fragile equilibrium, with the monstrous growth of the man-made environment at the expense of the natural world, is not just a Greek or European problem. It is global and threatens the planet Earth's very survival. If you insist on proclaiming the value of the cultural heritage, if it matters to you and you fight passionately to protect the environment and censure those who break the law and cause destruction, then it is certain that these same wrongdoers will pursue you by illegal means to ruin your image and to vilify you as corrupt and immoral. When you spend years fighting about issues that affect certain interests, you frequently cause trouble and become a target. Nonetheless, we all carry an existential burden of moral values and truths about mankind which we can approach within nature, tradition, and life.

The past does not die, as I argued above, but continues to exist and to act down through the generations, constituting a cultural and humanistic force of the highest significance. Archaeologists, as sensitized citizens and researchers, practice their discipline on behalf of the community, cultivating the relationship the past has with the present.

The material remains of the past and the natural environment become perceptible to our senses, send out messages, and constitute a part of reality not only of the past but also of the present; they are connected with individual and social situations. The relationship we have with the material remains of our civilization and the natural world is experiential, not only for specialized researchers but also for every inhabitant. The ancient stones that come to the surface during excavation are not mute: they speak, revealing their secrets to everyone who approaches them with interest, sensitivity, and love. Freud is known to have admired archaeologists; he admitted that he followed the methods used by excavators in his own practice of psychoanalysis in order to bring the deepest layers of the subconscious to the surface.

Archaeological excavation and working outdoors have the benefit of providing you with the joy and excitement of immediate physical contact with human beings of the past through the material remains of their culture as well as their bones, which have been preserved in burials. Whether surrounded by their books or outdoors under the hot sun, archaeologists dig, looking for relevant truths in the depths of the human past. Their task is to study the process by which human societies perceived the material world, nature, and their environment, and evolved from small groups of hunter-gatherers to cultivators of the soil and to the city-dwellers of the contemporary consumer world. They collect all the evidence from their direct contact with the material remains that they bring to light, and using it as their basis proceed to a reconstruction of the past and of the ancient environment, and to an understanding of human beings as creators. This contact is not passive, but an interactive joint activity of the mind and the senses which has changed with the passage of time, developing rapidly from the time of the Renaissance down to the present postmodern perspective and the virtual

world of computers and the Internet.

To understand the environment, material culture, and works of art is to practice a sort of translation. The meaning depends on the context and the position of the translator (the interpreter, so to speak) in relation to the context. No translation, to be sure, can be so perfect or exhaustive as to claim an absolute degree of identity with the original. The reason why the past is shaped within the social present is rooted in contemporary ideologies. Interpretations and reproductions of the past are affected by the social beliefs and ideological positions of those who propose them. Historians, archaeologists, sociologists, and researchers in the applied sciences, as responsive scholars, are obliged to assimilate the subjective element as much as possible and to underline the social and political connectedness of the past, both natural and man-made, with the present.

There are invisible dimensions of an internal emotional character which are not expressed directly in the scholarly writing of researchers who are engaged in the study of the remains of the past. These material remains have a natural status and send out manifold messages that have historical, social, political, and existential dimensions.

Unfortunately, it is impossible to incorporate the testimony of the senses which participate in the daily toil of revealing the material remains of the past directly into your scholarly presentation. The whole complex of experiences of the present excavation remains inescapably beyond the text that describes your contact with the past as a natural and man-made environment: the excitement of your first encounter with the find, the special feeling when you first recognize an inscription, or when you touch the skulls in the burial you have just opened. Only the sketches and photographs that you take capture the moments, express the process, depict things in their original locations before they are removed for storage, conservation, recording, and publication. Experiences are not photographed, to be sure, but they are indelibly impressed upon you, making an essential contribution to the reconstruction of the past and to the search for its human creators.

In the wasteland of barbarism in which we live, human creativity, innovation, and imagination are the things that count. "We are fortunate that the course of the universe led to the creation not only of life, but also of civilization and the arts."[8] Research and creation are an oasis.

The protection of natural beauty, of natural and historic features, and of wildlife and monuments is a matter of the survival of the human race. A sine qua non is moreover the cultivation of human beings in ways and by means which prompt them to preserve intact all the goods already mentioned so that the generations to come can enjoy them too.[9] The elitist version of ecological and cultural imperialism, in contrast, has this strategy: "save the flora and the fauna/*the animals and the plants, keep the people away."

Let us proceed to the foundation of more national parks at the very least. What

---

8. Ilya Prigogine 1994 (*La Fin des certitudes*, Translation into English *The end of certainty* [1997]).
9. John G. Mitchell, "Threatened Sanctuaries: The state of U.S. Parks," *National Geographic* (October 2006), 56-61 [http://ngm.nationalgeographic.com/2006/10/national-parks/mitchell-text].

David Quammen has written about national parks is just as valid for archaeological parks[10]. The national park enjoys the special advantage of being a precious expanse of the natural world.

What, indeed, is responsible for the recent vigorous activity of publishing organizations vis-à-vis the depiction of wild flora and fauna, of nature's treasures, of the traditional elements of our culture? I think it is owed to the fact that we are anxious and feel remorse and responsibility for the destruction of the environment that is occurring around us every day, and for the gradual destruction of the very planet Earth that created and continues to nurture us. We are eager to record the last moment, to immortalize (though photographically) what has survived intact not only in our own country, but also all over the world, to make it more widely known.

Knowledge by itself is nevertheless not enough - even if it leads to self-knowledge and love for the monuments of nature and of mankind - if knowledge does not serve to spur the immediate taking of measures for protecting and preserving these treasures. The danger of their extinction is unfortunately at the gates, and it is we ourselves who are responsible for it because most of us are unaware of their value and indifferent to the natural environment. Of course, the State is to blame as well, because it has invested very little in education and in the promotion of those elements that define the character of our civilization - in antiquity, the early modern period, and at the present - as well as of our natural environment. Nature and the monuments cannot take it any longer. We must take immediate measures because in a little while we will not have anything beyond photo albums by socially conscious publishers to remind us of the paradise that has been destroyed.

In the case of Greece, the now-downgraded Ministry of Culture, which is usually completely given over to mere words, should finally commit itself to deeds in order to show itself the first in its class. Let it be staffed, let it be equipped, let it obtain a specific, accountable annual budget, and let it take up the protection of the environment together with the promotion and protection of monuments. The Archaeological Service could be integrated into a "Ministry of Cultural Heritage, Research, Technology, and the Environment." This new ministry for research and technology would as a unified body respond most fully to the problems involved in protecting the potential of monuments and of the natural environment.

---

10. "A national park is, in more cases than not, a wildly ambivalent act of collective purpose: dreamy yet provident, selfish yet sacrificial, local yet global in significance. Unlike a national anthem or a national flag, a national park exists in the concrete dimensions of geography, biology, and economics—and in the dimension of symbolism as well. It has living denizens and physical boundaries. It has benefits and costs. It has friends, and sometimes it has enemies. It has an aura of sacred permanence as a place that society has chosen to set aside and protect forevermore." David Quammen, "An Endangered Idea," *National Geographic* 17.4 (2006), 26-31 [http://ngm.nationalgeographic.com/2006/10/world-parks/quammen-text/2].

B1.5 A Geomythological Approach of Acheloos River and Echinades Islands (Western Greece)

Mariolakos I[1]., Fountoulis I[†]., Bantekas I[2]., Theocharis D[2]., Kapourani E.[2]

Abstract

Although many consider the Greek Mythology as a figment of imagination of the imaginative Greeks, we believe that the Greek Mythology is the encrypted, most ancient history of the inhabitants of the Aegean and Circum-Aegean region, as well as that of the neighboring areas. In reality, it's their struggle for survival in a Geoenvironment that started to change drastically 18,000 BP. These changes, which lasted for about 12,000 years, have led to dramatic consequences not only to their living needs, but also to his social and psychological needs, have been depicted in many mythological narrations.

The myth relating Echinades islands to Acheloos river is one of many that absolutely coincide with the physical and geological evolution of the broader area of the western Greek mainland since 18,000 BP.

The majority of rivers were considered as Gods by the ancient Greeks, children of the Titans Oceanus and Tethys. Acheloos was one of the most famous rivers in antiquity and was honored as a god. But because some Nymphes who lived in its banks offered sacrifices to other gods and did not honor him, he *"dragged the place of the Nymphes to the sea"* (Ovid. Metamorph. VIII 576) and formed the Echinades Islands. Later on, some of them, turned once again in land, because of Acheloos river deposits (Her., B. 10). Nowadays the small islands of Echinades are located in front of the Acheloos Delta at the south-western point of the continental Greece, near the Ionian coasts. From a geographical point of view are distinguished in northern and southern Echinades.
For the physical-geological interpretation of the myth, the following have been taken into account:

i) The actual configuration of the Acheloos Delta which started to form after the Holocene Climatic Optimum (~6,000-4,000 BP)
ii) The Upper Acheloos river (aprox. upstream Kastraki village) which was gradually shaped during the last 6 Ma years, whereas partwise even earlier.
iii) The glacial-eustatic movements during the last 18,000 years (last glaciations' peak).

1. *Dr. rer. nat.*, Emeritus Professor of Geology, National and Kapodistrian University of Athens, Department of Geology and Geoenvironment, Section of Dynamic, Tectonic & Applied Geology, mariolakos@geol.uoa.gr
2. National and Kapodistrian University of Athens, Department of Geology and Geoenvironment, Section of Dynamic, Tectonic & Applied Geology

The geomythological analysis of the relationship between Acheloos river and Echinades islands has shown the following:

i) Absolute coincidence of the myth with the physical-geological evolution of the Delta area during the last 18,000 years.
ii) The Greek Mythology is not a figment of imagination of the imaginative Greeks.
iii) Some descriptions in the Greek Mythology referring to physical and geological conditions are much older than the Neolithic period, as the modern geological dating shows.

1. Introduction

Geomythology, is the branch of Geology that aims to find out the relationship between the various ancient people's myths and the geological environment in which their civilizations were developed.

We consider the Greek Mythology as the encrypted, most ancient history of the inhabitants of the Aegean, Circum-Aegean region, as well as that of neighboring areas, and not as a figment of imagination of the imaginative Greeks.

The older mythology describes the struggle of the inhabitants for survival in a geoenvironment that started to change drastically 18,000 years Before Present (BP). That means that the Greek mythology has a geoenvironmental dimension. A great part of the Greek Mythology is directly connected to the physical-geological evolution of the Aegean and Circum-Aegean area.

The myth relating Echinades islands to Acheloos river, is one of many that absolutely coincide with the physical and geological evolution of the broader area of the western Greek mainland.

From a geographical point of view, Echinades islands are distinguished in northern and southern. The southern Echinades islands are located in front of the estuaries and the northern Echinades to the north of the Delta of Acheloos River (Fig. 1).

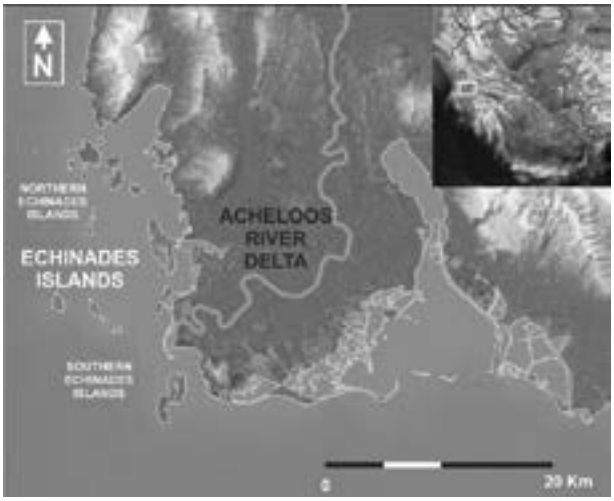


Fig. 1: *Lower Acheloos. The Delta of Acheloos river and Echinades islands. The southern Echinades are located in front of the estuaries, whereas the northern Echinades are located north of the Delta.*

2. ACHELOOS RIVER

The majority of rivers, were considered as Gods by the ancient Greeks, children of the Titans Oceanus and Tethys (Hesiod – Theogeny). According to a particular mythological version, Acheloos is the first river-God born (Fig. 2, Table I).

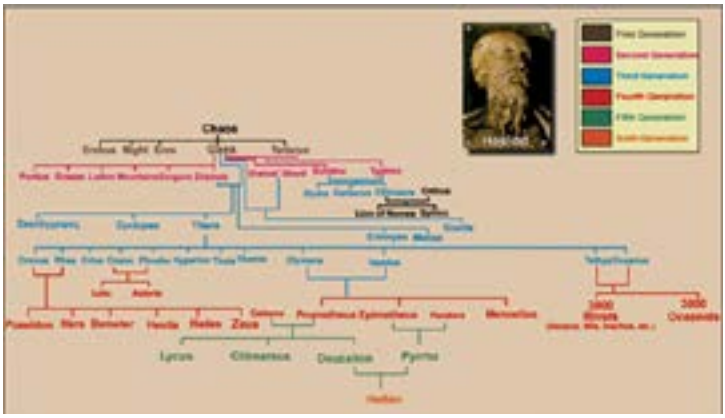


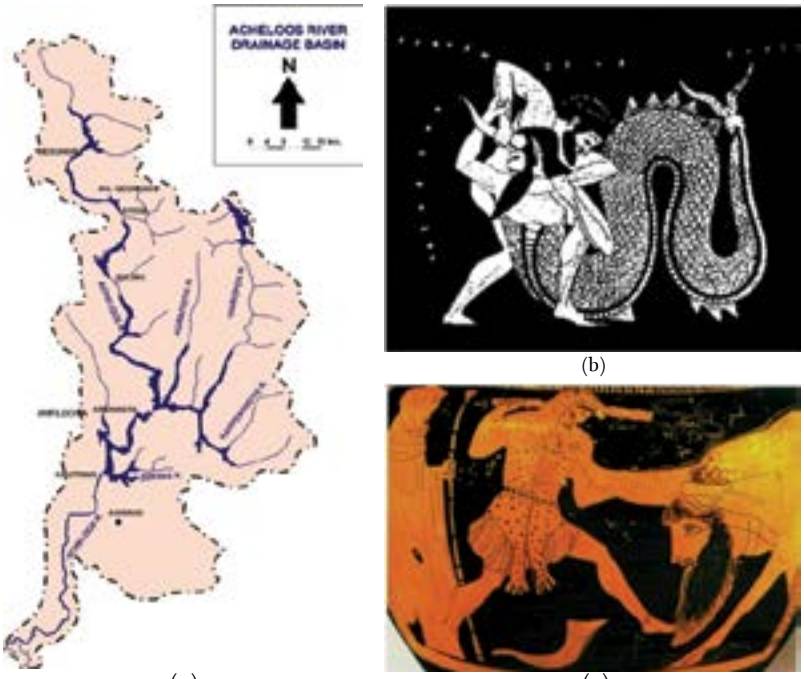
Fig. 2: *According to Hesiod – Theogeny, about 3,000 River-Deities are the children of Oceanus and Tethys.*

Table I: River-Deities.

Acheloos	Nessos	Kaikos
Nile	Rhodios	Saggarios
Alpheios	Aliakmon	Ladon
Eridanos	Eptaporos	Parthenios
Strymon	Granikos	Evinos
Meander	Asopos	Ardiskos
Istros = ***Danube***	Simoeis	Scamandros
Phasis	Peneios	& 3000 others
Rissos	Ermos	

Strabo mentions that Acheloos River, mainly in the Delta area, during the Mycenaean Period, was the boundary between the neighboring states of Aetolians and the Acarnanians. Because of the continuous changes of the riverbed, there were constant boundary problems between the two. These problems were the major reason why Hercules was called to "tackle" the issue. This intervention is imprinted in the great myth of the struggle between Hercules and the river-god Acheloos, in order to win the heart of Deianira, daughter of Oeneus, the king of Calydona (Fig. 3b, c). Since this myth refers to the Mycenaean Period, it is related to the most recent Delta, the one created after the Holocene Climatic Optimum. The myth of the river-god Achelloos and Echinades is clearly older and is related to the older river Delta, the one created during the last glacial period until 18,000 years B.P., i.e. until the great climatic change begun, because of the all the well-known reasons.

The Acheloos River Delta is one of the most important deltaic areas in Greece, due to: i) Its great geological and mainly sedimentological interest, ii) its Archeological and Mythological interest.



(a) (b) (c)

Fig. 3: *Acheloos river drainage basin* (*a*)*, and the struggle between Hercules and Acheloos* (*b & c*).

Through the historical time Acheloos (Αχελώος) river had many different names:

- *1st name*: *Thoas* (*Θόας*). That's why *Echinades* are called by Homer (O, 299) *"Thoai"* (*Θόαι*). *«νήσοισιν θοήσιν»*.
- 2nd name: *Axenos* (Άξενος)
- 3rd name: *Thestios* (Θέστιος)
- 4th name: *Acheloos* (Αχελώος)

The first two names are related to physical and geological characteristics of the river, whereas the third and the fourth are linked to the tragedies of two local heroes - kings.

1. The name *"Thoas"* is obviously related to the great flow rates of the river which, in many places "froths" and appears white, hence the present-day name *Aspropotamos* ("white river"). This characteristic is mainly linked to the upper part of the river. Possibly, this name was valid (from a physico-geographical point of view) till the time that the river started to form a Delta.
2. The second name is *"Axenos"*. The word *"Axenos"* is used to describe someone or something that is inhospitable to man. That means that the river and the fluvial areas i.e. the Delta, was constantly forcing man to re-arrange the land used for cultivation, water supply and irrigation. The word "Axenos" is related

to humans, contrary to the previous one (Thoas) that is clearly related to physico-geographical features. Consequently, this name was given by the people who lived there, but before they were organized to evolved communities. This must have happened after the Climatic Optimum of the Holocene, most likely shortly after the start of the Delta formation. When the inhabitants of the area were organized in evolved social groups creating settlements, leaders such as Thestios and Acheloos, arose.

3. *Thestios*, son of the god *Ares* and *Peisidiki* was the *King of Aetolia*. Being in Sikyon for a long time, when he returned, he found his son, *Kalydon*, resting in bed with his mother. Thestios then, believing that his wife had committed adultery, killed his own son. When he realized what he had done, he threw himself *in Axenos river* and drowned. Since then, for a certain time period, the river was named *Thestios*.
4. *Acheloos*: This name was also given to the river for a similar reason. Acheloos, son of *Oceanus* and *nymph Naias*, mated with *Kleitoria*. However, he did not know that she was his offspring. He was then devastated and threw himself in Thestios river, which since then, has been named *Acheloos*.

3. THE MYTH OF ECHINADES ISLANDS

According to Mythology, Echinades isl. were *Naiad Nymphs* (=nymphs of the flowing waters) and they lived on both sides of the riverbed of the old Acheloos river and its tributaries, which crossed the old Delta, i.e. the one that was created during the glacial period until the 18,000 years B.P.

Once, the nymphs offered sacrifices to the Gods on the river banks, but they forgot to honour the river-God Acheloos. Worth to note that the course of the old flow route is totally different from that of the present day and that this old course is unknown, as nowadays it is overflooded by the waters of the Ionian Sea, because of the eustatic movements.

The river-God Acheloos was then outraged and "dragged" the site of the Nymphs to the sea (*Ovidius, Metamorph., VIII*, 576), overflooding the banks, thus forming the Echinades islands, named after the prophet Echinos.

> *"...I can refer to Acheloos separetely, which after crossing Acarnania and reaching the sea, has already turned half of the Echinades islands to land with its deposits..."*
>
> Herodotus (B.10).

4. THE INTERPRETATION OF THE MYTH

For the physical-geological interpretation of the myth, the following have been taken into account:

1. The upper Acheloos river (approximately upstream of Kastraki village and Kastraki dam) was gradually shaped during the last 6 Ma, whereas part-wise even earlier.
2. During the last glaciation "maximum" (18,000 BP), as the sea-level was about 125 – 150 m below the actual sea-level, a large Delta was created. It extended

from the village of Kastraki as far as the depth between -125 and -150 m. of the bottom of the Ionian Sea, west of the fron of the present-day Acheloos Delta.

3. The sea-level rise, because of the glacial-eustatic movements during the last 18,000 years.
4. The actual configuration of the Acheloos Delta started to form after the Holocene Climatic Optimum, i.e. between approximately 6,000 and 4,000 years before present (4000 – 2000 B.C.).

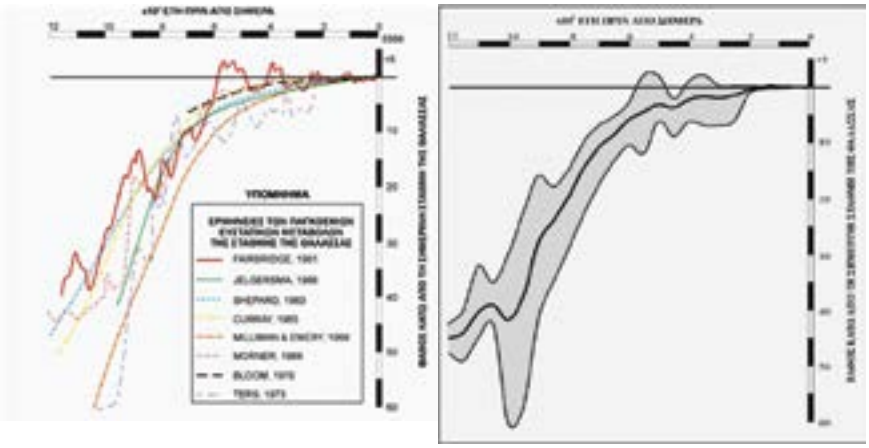


Fig. 4: *The curve of the global sea level changes due to climatic-eustatic movements, after various researchers. The bold line represents the mean curve and the gray area represents the width between minimum and maximum values. The occurring differences probably caused on regional geological factors.* (*Mariolakos I. & Theocharis D., 2003*)

Table II

Time Period Before Present	Approximate global sea-level corresponding the actual s.l.	
7.500 – 6.800 B.P.	≈	-10 m.
9.000 – 6.800 B.P.	≈	-15 m.
9.400 – 7.300 B.P.	≈	-20 m.
9.800 – 7.700 B.P.	≈	-25 m.
10.200 – 8.200 B.P.	≈	-30 m.
11.300 – 8.500 B.P.	≈	-35 m.
10.000 – 9.000 B.P.	≈	-40 m.
11.400 – 10.000 B.P.	≈	-45 m.
12.200 – 11.400 B.P.	≈	-49 m.
13.000 – 12.200 B.P.	≈	-52 m.
13.500 – 13.000 B.P.	≈	-57m.
13.800 – 13.500 B.P.	≈	-61 m.
14.000 – 13.800 B.P.	≈	-67 m.
14.700 – 14.000 B.P.	≈	-73 m.
15.000 – 14.700 B.P.	≈	-94 m.
16.000 – 15.000 B.P.	≈	-100 m.
18.000 – 16.000 B.P.	≈	-115 m
18.000 B.P.	≈	-125 / -150 m.

Taking all the above into account, that is the data of Table II, the sea-level changes as they are depicted in Fig. 4, as well as the present day sea bathymetry, a series of palaeogeographical maps of the mainland coasts, and those of the Ionian Islands Kephalonia & Zakynthos have been constructed (Fig. 5 & Fig. 6). The vertical land movements due to the tectonic activity, that surely took place during the last 18000 years, are not included in the map-constructing calculations.

From this series of the palaeogeographical maps we present here only six, for some special time periods.

According to the palaeogeographical maps, the present day Echinades islands, during the Upper Paleolithic, were hills.

The first series depicts the coastal configuration of the Ionian Sea that is located between the Ionian Islands and the Peloponnesus in the time period 18000 - 6000B.P., that is the crucial period when the sea-level was at its level (-125 m.) as at this time it is considered the global temperature reached its lowest level. The second map series presents in greater detail the evolution of the area in front of the actual Acheloos Delta, where the islands of Echinades are located, during the same time period.

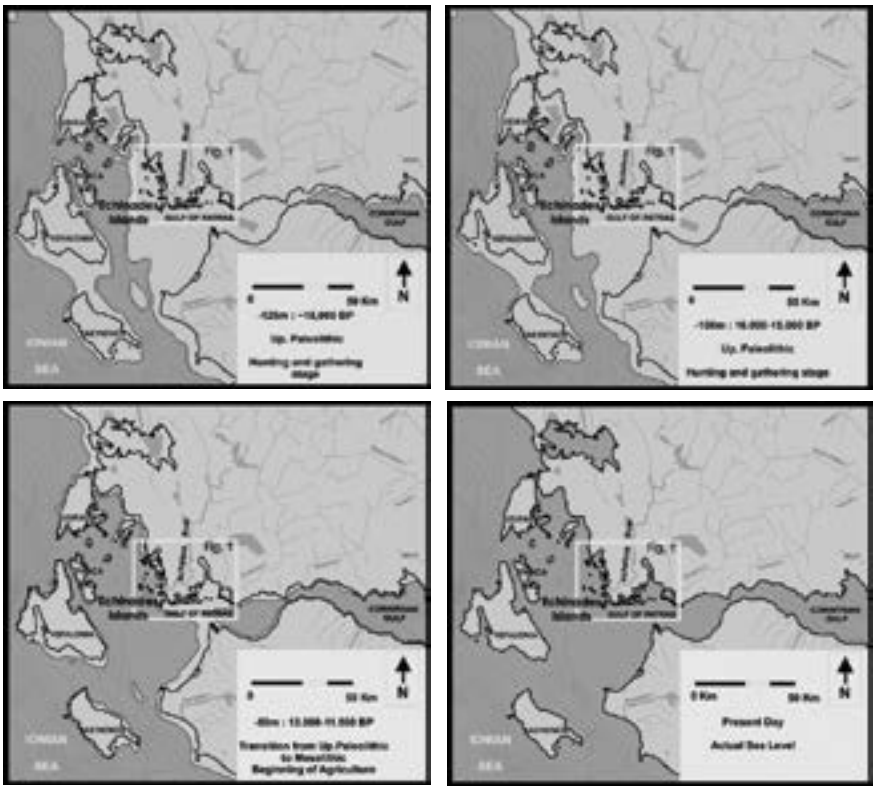


Fig. 5: *Palaeogeographical maps of the western Greek mainland coasts, and the Ionian Islands.*

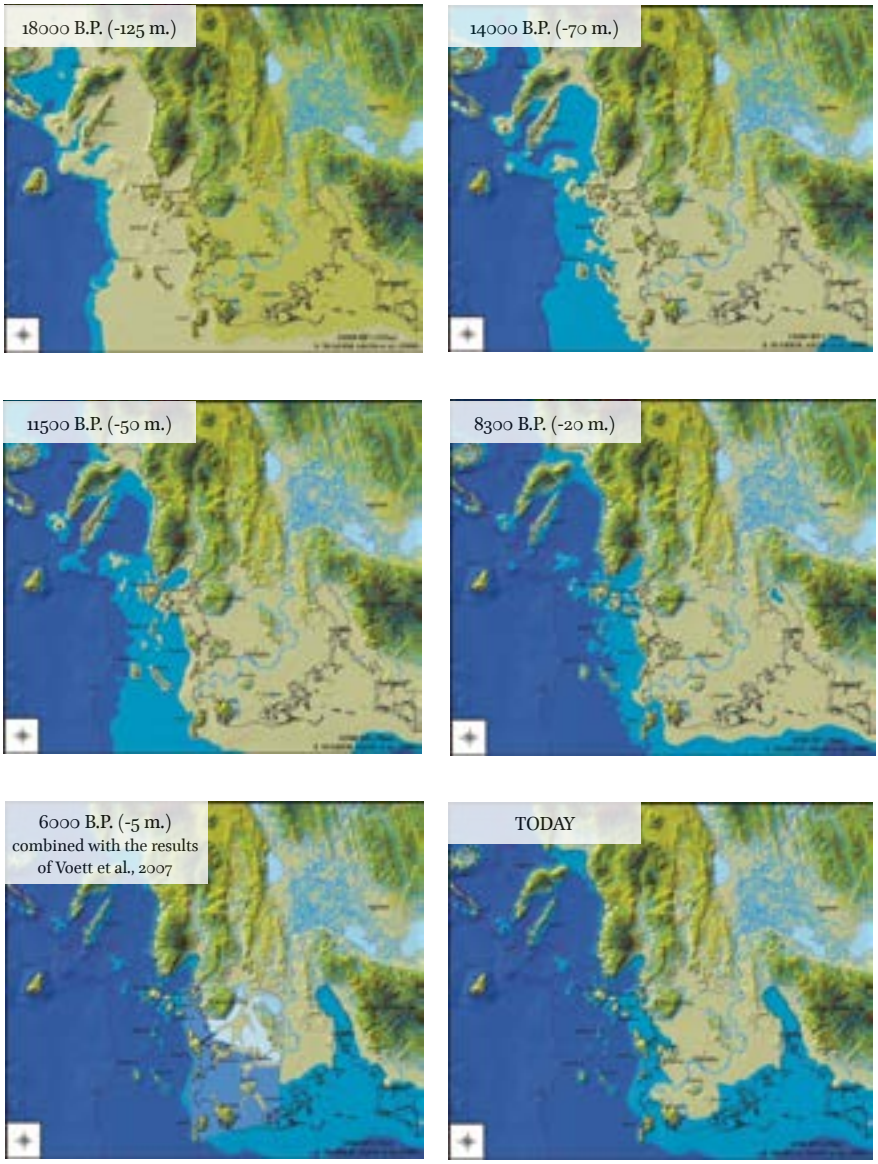


Fig. 6: *DEM* (*Digital Elevation Model*). *The coastal evolution of the Acheloos Delta greater area during the time period between 18,000 and today. The map of the 6000 B.P. stage incorporates the results of Voett at al., 2007*

Besides **Herodotus** (B.10), **Thucydides** (2.102) writes: "...Most of the Ehinades isl. are located just opposite of the Oeniades, very close to the estuaries of Acheloos river.

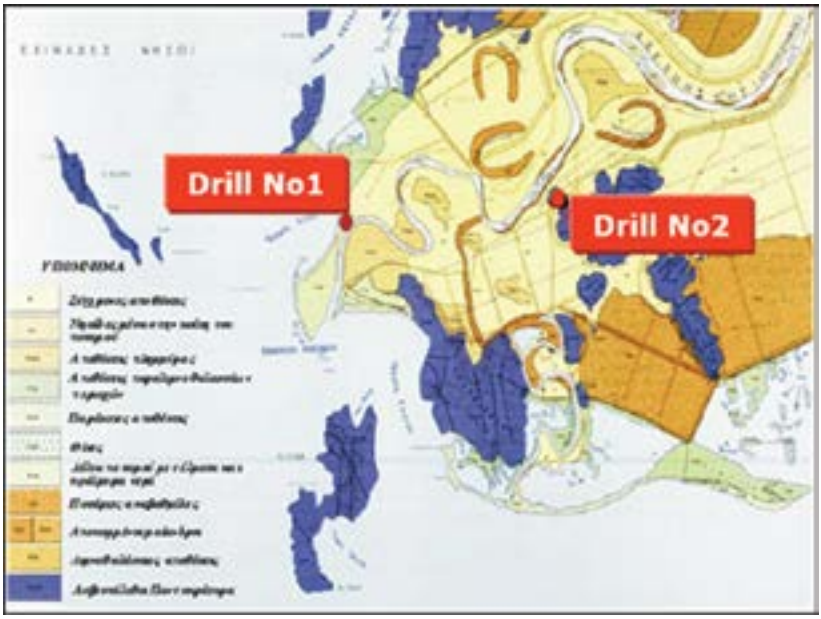
There, the great river constantly carries sediments, so some of the islands are con-

nected to the land. There is hope that, not in short time, the same thing will happen to the rest…".

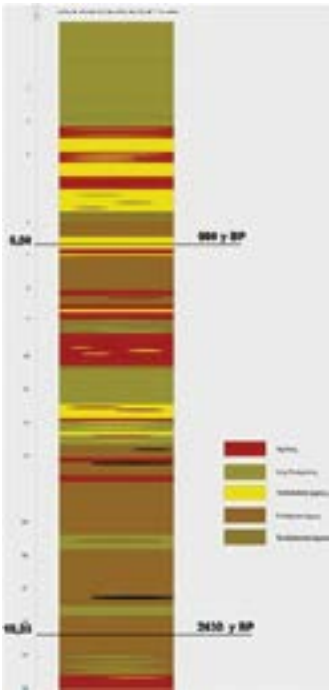
If we wish to find out whether the great historian (5th century. BCE) is right or not, we have to take into account the results of the studies of Piper & Panagos, (1981) (Fig. 7) , and Voett et al., (2004, 2007) (Fig.8). As it is depicted in Fig. 9, the sedimentation rate is very high in some areas of the Delta.

Fig. 7: *Map of the Acheloos river Delta. The dotted area represents the sediments deposited by the river during the last 6000 years* (*Piper & Panagos,1981*).

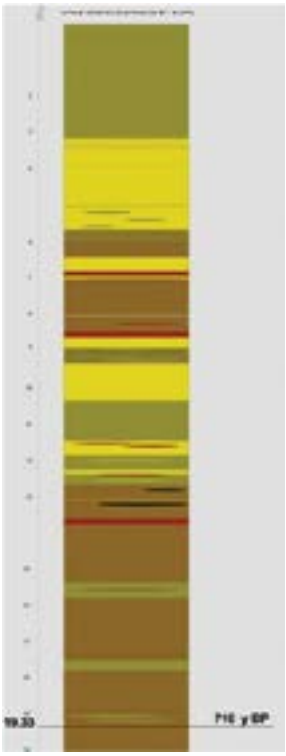
Fig. 8: *The evolution of the Lower Acheloos River Delta during the last 5400 years, that is since the Climatic Optimum of the Holocene, when the sea surface reached its highest level* (*after Voëtt et al., 2004*).



(a)



(b)



(c)

Fig. 9: *The location of the 2 shallow sampling drillings on the Acheloos Delta area geological map (a), and the resulting drill logs (b &c). It is evident that during the last 2430 the sediment thickness exceeds 18m. (b), whereas in the case of drill 2, the sediments deposited during the last 710 years exceed 19 m.(c) (Mariolakos I. et al., 2008).*

The results of the previously mentioned studies (sedimentological, palaeogeographical) in the greater area of the Acheloos River Delta, prove the fact that Thucydides was right.

Fig. 10: *The shoreline evolution of western Greece and the Ionian Islands in different time periods, beginning from the last glacial maximum until nowadays. The shoreline displacement was caused by the eustatic-climatic movements.*

5. CONCLUSIONS & QUESTIONS

The detailed palaeo-geographic analysis of the shoreline displacement caused by the great climatic change that took place about 18000 years and ended 6000 years ago (Fig. 10) and the accompanying climatic-eustatic movements, combined to the geomythological analysis of the relationship between Acheloos river and Ehinades islands, has shown the following:

i. An absolute coincidence of the myth with the physical-geological evolution of the Delta area during the last 18,000 years. Of course, it was not the River-God Acheloos the one who dragged the Echinades nymphs to the sea, but rather the sea-level rise that caused the flooding of the older river-banks and the surrounding area. This sea-level rise turned the older hill into islands. Consequently, from a geomythological point of view, the myth coincides with the physical and geological processes of the last 18000 years, and mainly with those that took place between 18000 and 6000 B.P.

ii. The Greek Mythology is very old since its descriptions are referring to physical and geological conditions that are much older than the Neolithic period.

iii. In the case of Echinades islands, the Greek Mythology describes geological events which should have happened at least 14,000 (?) years ago!

iv. Since the physical and geological evolution of the area is verified by the myth, *the Greek Mythology could not be a figment of the imagination of the imaginative ancient Greeks*, as in this case, the myth describes the palaeogeographic evolution of the shorelines displacement, caused by the glacial-eustatic movements.

If the conclusions are correct, some basic questions have to arise:

i. Who has communicated this very old geological – palaeogeographical processes, which should have taken place before the Neolithic period?
ii. In which language the Pro-Hellenes have informed the Hellenes and communicated with them, when the latter, as a branch of the Indo-Europeans, arrived to Greece sometime between 5,000-4,000 B.P. (2,000 BCE) and, according to the linguists, is the oral tradition of the same age?

Consequently, the myth of Echinades Islands is one more evidence that the Indo-European theory of language origin cannot be correct.

REFERENCES

Diodorus Siculus. Bibliotheca Historica, 4,35:2

Duff D. (1993). Holme's Principles of Physical Geology. *Chapman & Hall*, 791 p.

Emiliani C. (1971). The last interglacial: paleotemperatures and chronology. *Science*, **171**, pp. 637-642.

Goudie A. (1992.: Environmental Change. Contemporary Problems in Geography. *Claredon Press*, 329 p., Oxford.

Herodotus. Historiae, B (Euterpi), 10.

Homer. The Iliad, Odyssey

Kraft J. C., Belknap D. F., & Demarest J. M. (1985). Geological studies of coastal change applied to archaeological settings. In: Rapp G., Gifford J.A. (Eds.), Archaeological Geology. Yale University Press.

Leontaris S. N. (1968). Geomorphologische Forschungen uber das Becken der Aetoloakarnanischen Seen. Ann. Geol. Pays Hell., XIX/A: pg. 541-620.

MacKillop J. (1998). Oxford Dictionary of Celtic Mythology. *Oxford University Press*, London.

Mariolakos I. (2006): Geomythology. In J. Birx (Ed.) *Encyclopedia of Anthropology,* vol. *3*, pp. 1066-1071, Sage Publications, New York.

Mariolakos I., Fountoulis I., Theocharis D. (2001). Water Supply Needs in Aetoloakarnania Prefecture." Vol. XXXIV/5, p. 1835-1842, Proceedings of the 10th Congress of the Geological Society of Greece, Athens, 2001

Mariolakos I. & Theocharis D. (2003). Asopos river and the creation of Aegina and Salamis island (Saronic Gulf, Greece). A geomythological approach. The Mediterranean World Environment and History. (pg: 305-311). Elsevier SAS, Elsevier, 2002.

Mariolakos I., Mariolako s D., Fountoulis I., Tziovara A., Champilomati A., Anagnostou Ch., & Sakellariou D., (2004). Shallow sampling drillings in the Acheloos delta area: preliminary results and radiocarbon dating. 10th Congress of the Geological Society of Greece, April 15-17, 2004, Thessaloniki. (Abstracts: pg. 496-497)

Mörner N.-A. (1976). Eustasy and geoid changes. Journal of Geology, **84**, pp. 123-152.

Mörner N.-A. and Lind B.G. (2010). A Mediterranean Trading Centre in Southeast Sweden. In *S.P. Paraminopoulos* (*Ed.*), The Atlantis Hypothesis—Commentary 2008, pp. 685-699.

Mörner, N.-A., & Lind, B. G. (2013). The Bronze Age in SE Sweden - Evidence of Long-Distance Travel and Advanced Sun cult. Journal of Geography and Geology, 5(1), pp. 78-91.

Ovidius. Metamorphoses, VIII 576.

Philippson A. (1956). Die Griechischen Landschaften, Band II. Das westliche Mittelgriechenland. Die Landschaft Aetolien (der atolische Pindos) und Akarnanien. s. 299-417, Frankfurt.

Piper D. J. W. & Panagos A. G., (1981). Growth Patterns of the Acheloos and Evinos Deltas, Western Greece.

Strabo. Geographica, 1, 3:8.

Voett A. (2007). Relative sea level changes and regional tectonic evolution of seven coastal areas in NW Greece since the Mid-Holocene. *Quaternary Science Reviews*, Volume 26, Issue 7-8, p. 894-919, Elsevier.

Voett A., Brückner H., Schriever A., Handl M., Besonen M. & Van der Borg K. (2004). "Holocene coastal evolution around the ancient seaport of Oiniadai, Acheloos alluvial plain, NW *Greece*". *In* Schernewski, G., Dolch, T. (Eds), *Geographie der Meere und Küsten. Coastline Reports*, vol. **1**, pp. 43-53, Rostock-Warnemunde.

B2. MATHEMATICS

B2.1 The Zahariou Conjecture and Plato's Hidden Theorem on the Distribution of Primes

Antonios Ioannis Vardulakis
Professor Emeritus, Department of Mathematics
Aristotle University of Thessaloniki

Abstract.

The story behind a conjecture by the late professor Andreas Zachariou of the Department of Mathematics of the University of Athens that a passage in Book 5, 737e, 738 of Plato's dialogue "The Laws" is in fact a "hidden" theorem concerning the *arrangement of prime numbers* is revisited and two independent proofs of this remarkable result are given. More study reveals a remarkable relation of this passage in Plato's dialogue with the Riemann Hypothesis !

1. Introduction

I will try to remind you what prime numbers are and a few things about what ancient Greeks said about them.

A. A few things about Plato's dialogue "The Laws" and what Plato says there in a particular passage (in a cryptic way) about prime numbers and why and how this passage constitutes a mathematical Theorem regarding the arrangement of prime numbers among the natural numbers.

B. A few things about what Great Mathematicians in the last 300 years have said about prime numbers ((Euler- Legendre- Gauss Hadamard-de la Vallee Pousin-Riemann, Hardy, Littlewood and others).

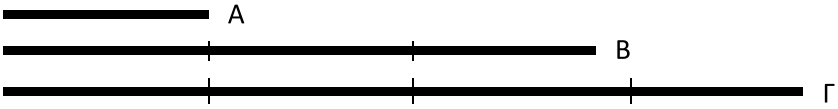
C. The remarkable relation, I believe, between the passage in Plato's dialogue "The Laws" and the Riemann Hypothesis.

Plato: "The Laws" - "NOMOI". The Laws is Plato's last and longest dialogue. It is gener-

ally agreed that Plato wrote this dialogue as an old man, having failed, in his effort in Syracuse on the island of Sicily to guide a tyrant's rule, instead having been thrown in prison.

"Prime numbers" are natural numbers which are divisible by 1 and themselves. The rest of natural numbers are called "composite". Euclid from Alexandria (300 B.C.), with a very elegant proof, proved that, prime numbers are infinite. Nowadays we perceive the natural numbers, prime or composite, as abstract objects, (Platonic ideas) which we symbolize with ideograms like: 1 2 3 4 5 6 7 8 9 ...

Ancient Greeks perceived the natural numbers as ratios of line segments whose length was a multiple of a unit line segment. Where we speak about "divisibility" Euclid writes in the "Elements" about line segments that are "measured". He views for example the line segment A "measuring" (dividing) segment B three (3) times and segment Γ four (4) times. So the numbers 3 or 4 are the result of the measurements of segments B or Γ by segment A.

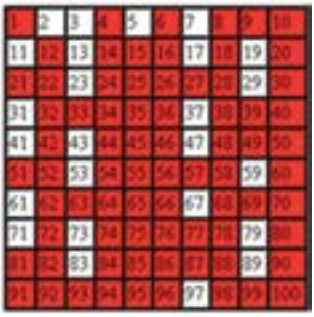


Ancient Greeks did not have the notion of "INFINITY ". Today, even school kids perceive, (or think that they perceive) the idea of a line of "infinite length". The Ancient Greeks where more punctilious and more rationalists than us, nowadays. That is why Euclid could not have written the phrase: «there is an infinity of prime numbers". That is why he wrote: "Οἱ πρῶτοι ἀριθμοὶ πλείους εἰσὶ παντὸς τοῦ προτεθέντος πλήθους πρώτων ἀριθμῶν" (Prime numbers are more of any predetermined multitude of prime numbers).

Euclid «The Elements» Book IX, Proposition 20. The oldest extant manuscript and printed editions of Euclid's Elements, in Greek (888 AD). Clay Mathematics Institute Historical Archive.

Θεώρημα . Οἱ πρῶτοι ἀριθμοὶ πλείους εἰσὶ παντὸς τοῦ προτεθέντος πλήθους πρώτων ἀριθμῶν. **(Theorem**. Prime numbers are more of any predetermined number of prime numbers.

The sieve of Eratasthenis from Kyrini (Lybia) (Λιβύη) 276 B.C. - 194 A.D. Nobody knows how the prime numbers are arranged among the natural numbers. During the last 2.500 years mathematicians tried to give an answer to the question if there is a rule according to which prime numbers are distributed among the natural number. Although up to now the efforts to give an answer to the above question have not been successful these efforts lead to many fundamental mathematical results with many practical applications.



Prime numbers are for arithmetic what are for Physics the atoms of the matter. They are the building blocks with which all other natural numbers are formed. Prime numbers are matched and identified by that excruciating mystery that the human knowledge is trying to unravel. Given a prime number how can we predict when we will obtain the NEXT prime number ? We wonder whether there is a mathematical formula that produces prime numbers. Where is the mould that produces these God made (?) numbers. From the days of ancient Greece up to our time, mathematicians are trying to give answers to these questions and unravel this old puzzle. The solution of the "**prime number problem**" (if ever achieved) it will herald a revolution in the world of MATHEMATICS. The solving of the mystery will have Cosmo genic effects on science, and not only.

The fundamental theorem of Arithmetic. The proof was given by Euclid of Alexandria at about 300 B.C. One of the most important theorems of NUMBER THEORY. According to it every natural number, greater that unity, can be factored in a unique way as a product of **prime numbers**, e.g.

The Goldbach conjecture. Christian Goldbach (1690-1794) was born in Königsberg,

$$4773 = 3 \times 37 \times 43$$
$$6111 = 3 \times 3 \times 7 \times 97$$
$$23244 = 2 \times 2 \times 3 \times 13 \times 149$$

Prussia but passed most of his life in Russia as secretary of the Imperial Academy of Sciences in St Petersburg.

On the 7th July 1742 Goldbach in a letter addressed to Euler, one of the greater mathematicians of all time, formulated the conjecture that every **even number** can be written as the **sum of two prime numbers** , e.g.

4=2+2	10=3+7=5+5	16=3+13=5+11	22=3+19=5+17=11+11
6=3+3	12=5+7	18=5+13=7+11	24=5+19=7+17=11+13
8=3+5	14=3+11=7+7	20=3+17=7+13	26=3+23=7+19=13+13

Up to today the conjecture has been verified for all even numbers up to 400.000.000.000.000 but nobody had succeeded to give a proof that the conjecture is valid for ALL even numbers.

The publishing company Faber and Faber, publisher of the book of Apostolos Doxiadis, "*Uncle Peter and the Goldbach Conjecture*" offers 1.000.000 pound sterling to whoever gives a valid proof of the Goldbach conjecture.

Let us now look very briefly at the Platonic dialogue "*The Laws*". Unlike most of **Plato's** dialogues, **Socrates** does not appear in the ***"Laws".*** This is fitting because the dialogue takes place on the **island of Crete**, and Socrates never appears outside of **Athens** in **Plato's** writings, except in the ***Phaedrus***, where he is just outside the city's walls. In the ***"Laws"*** instead of **Socrates** we have the **Athenian Stranger** (in Greek, "Xenos" - Ξένος) and two other old men, an ordinary **Spartan citizen** (Megillos) and a **Cretan politician and lawgiver** (Kleinias) from **Knossos.** The **Athenian Stranger**, who is much like **Socrates** but whose name is never given, joins the other two on their religious pilgrimage to the "Idaion Anron". The entire dialogue takes place during this journey, which mimics the action of Minos, who is said by the Cretans to have made their ancient laws, who walked this path every nine years in order to receive instruction from Zeus on lawgiving.

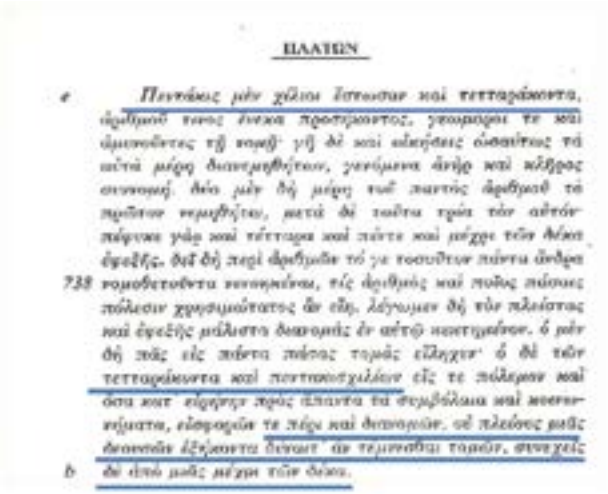
Mythology-Geography-Etymology. Μυθολογία-Γεωγραφία-Ετυμολογία

Plato's dialogue takes place at the Island of Crete during a journey by the three friends to a place of pilgrimage at the cave of Zeus, at 1530 meters, on the Mount of Ida named "Idaion Andron" (Ιδαίον Άντρον) (Cave of Mount Ida (Ίδη). According to the Greek Mythology, Zeus, the father of all Gods, was born by Rea who sheltered her newly born child in the cave to save it from her husband Kronos = Χρόνος = (Time) (Saturn) who used to eat his children. Despite all that Kronos =Xronos = Time, still to this day, consumes the rest of us – ("its children").

2. Back to Plato's "Laws"

In Book 5, 737e, 738 of Plato's "Laws" it is stated that the number of citizens of an ideal City State should be 5040 because this number its divisible by a total of 59 numbers and in particular by all integers from 1 up to 10.

The page in Plato's "Laws" where the number 5040 and its remarkable properties are first mentioned



ΠΛΑΤΩΝ

e Πεντάκις μὲν χίλιοι ἑπτακισμυριοι καὶ τετταράκοντα,
ἀριθμοῦ τινος ἕνεκα προστιμωντος, γεωμοροι τε καὶ
ἀμυνοῦντες τῇ νομῇ· γῆ δὲ καὶ οἰκήσεις ὁσαύτως τὰ
αὐτὰ μέρη διανεμηθήτων, γενόμενα ἄνδρ καὶ κλῆρος
συνωμοῖ. δύο μὲν δὴ μέρη τοῦ παντὸς ἀριθμοῦ τὸ
πρῶτον νεμηθήτω, μετὰ δὲ ταῦτα τρία τὸν αὐτὸν
πάλιν γὰρ καὶ τέτταρα καὶ πέντε καὶ μέχρι τῶν δέκα
ἑφεξῆς. θιῦ δὴ περὶ ἀριθμῶν τό γε τοιοῦτον πάντα ἄνδρα
738 νομοθετοῦντα νοεῖν χρεών, τίς ἀριθμὸς καὶ ποῖος πάσαις
πόλεσιν χρησιμώτατος ἂν εἴη. λέγωμεν δὴ τὸν πλείστας
καὶ ἑφεξῆς μάλιστα διαιρουμένς ἐν αὑτῷ κεκτημένον. ὁ μὲν
δὴ πᾶς εἰς πάντα πάντας τομὰς εἴληχεν· ὁ δὲ τῶν
τετταράκοντα καὶ πεντακοσχιλίων εἴς τε πόλεμον καὶ
ὅσα κατ' εἰρήνην πρὸς ἅπαντα τὰ συμβόλαια καὶ κοινω-
νήματα, εἰσφορῶν τε πέρι καὶ διανομῶν, οὐ πλείους μιᾶς
δεκάδος ἐξήκοντα δίνωσι· ἃν τεμνόμενος τυγχάν, συνεχεῖς
b δὲ εἰσὶ μιᾶς μέχρι τῶν δώδεκα.

An English translation of the part of book 5 of Plato's Laws where the number 5040 is mentioned:

"[737e] Let us assume that there are--as a suitable number--5040 men, to be land-holders and to defend their plots;2 and let the land and houses be likewise divided into the same number of parts--the man and his allotment forming together one division. man who is making laws must understand at least thus much,-- [First, let the whole number be divided into two; next into three; then follow in natural order four and five, and so on up to ten. Regarding numbers, every 738a] what number and what kind of number will be most useful for all States. Let us choose that which contains the most numerous and most consecutive sub-divisions. Number as a whole comprises every division for all purposes; whereas the number 5040, for purposes of war, and in peace for all purposes connected with contributions and distributions, will admit of division [738b] into no more than 59 sections, these being consecutive from one up to ten.

3. The Zahariou conjecture.

Professor Zahariou observed that:

$5040 = 1\times2\times3\times4\times5\times6\times7 = 7!$

(the exclamation mark after the number 7 signifies the shown product of the first seven numbers and mathematicians call the symbol 7! "Seven factorial".

10 =11-1

7 and 11 are **successive** prime numbers

And finally, according to Plato:
[738a] Regarding numbers, every 738a] what number and what kind of number will be most useful for all States. Let us choose that which contains the most numerous and most consecutive sub-divisions. Number as a whole comprises every division for all purposes; whereas the number 5040, for purposes of war, and in peace for all purposes connected with contributions and distributions, will admit of division [738b] into no more than 59 sections, these being consecutive from one up to ten..

So that he could conjecture that in the above passage by Plato is stating, in a cryptic way, a Theorem which can be stated as follows:

Plato's theorem for the distribution of prime numbers. If P and Q are successive prime numbers $(\text{with } 3 < P < Q)$ then $P! = 1 \times 2 \times 3 \times \cdots \times P$ is divisible by every integer $r \leq Q - 1$.

From the "Laws" and or for the successive prime numbers: $P = 7$ and $Q = 11$ the number $P! = 7! = 1 \times 2 \times 3 \times 4 \times 5 \times 6 \times 7 = 5040$ is divisible by all natural numbers from 1 to $Q - 1 = 11 - 1 = 10$ i.e. 5040 is divisible (exactly with no remainder) by the numbers: 1,2,3,4,5,6,7.8,9,10 .

The Proof of the Theorem. Although until 2003 the conjecture had been tested to be true for very big successive primes, to our knowledge, up to the summer of 2003, no proof of the Theorem was available.

The first proof was given by Peter Shiu of the University of Loughborough in 2004 after the conjecture was mentioned to him my colegue and friend Professor C. Pugh of the same University.

The second proof was given by a Greek young Medicine undergraduate, Georgios Velisaris, in 2007.

Corollay (Plato's sieve for the primes) If $p_1 = 2,\ p_2 = 3,\ p_3 = 5,\ p_4 = 7, \ldots$ is the sequence of prime numbers and according to Plato's theorem for $k \geq 4$ for the two successive primes p_{k-1} and p_k, it holds that $p_{k-1}!$ is divisible by all natural numbers: 1,2,3,... up to $p_k - 1$ but not p_k, it follows that p_k is the least non divisor of $p_{k-1}!$

So, for $k \geq 4$, knowledge of a prime p_{k-1} allows us to compute the next successive prime p_k by the following algorithm:

· Compute $p_{k-1}!$

· For $j = 1, 2, 3, \ldots$ examine if $\dfrac{p_{k-1}!}{p_{k-1} + j}$ is an integer. The first $j = 1, 2, 3, \ldots$

for which $\dfrac{p_{k-1}!}{p_{k-1}+j}$ **is not** an integer gives the next prime p_k as: $p_k = p_{k-1} + j$.

3. Plato's theorem and its relation to the Rimann Hypothesis !

For every natural number n let $\pi(n)$ the multitude of **prime numbers that are less than or equal n**, e.g.for $n=10$, $\pi(10)=4$ because there are 4 **primes** i.e, $(2,3,5 \text{ and } 7)$, that are less than or equal to 10.

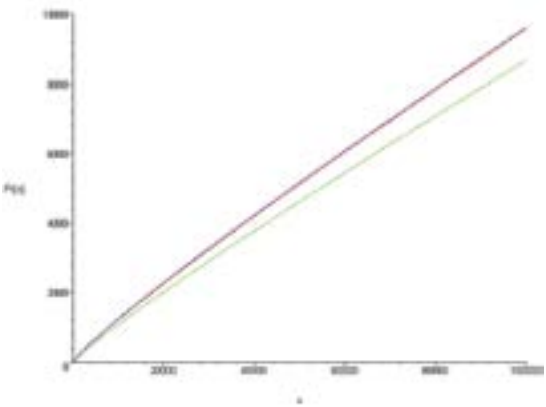
The problem of prime numbers (posed originally by Gauss and Legendre)
Can we find an approximation of $\pi(n)$?

In 1792 the young **Gauss** (15 years old) proposed the rough estimate:

$\pi(n)$ is approximately equal to $Li(n)=\int_2^n \frac{1}{\log t}dt$ $(Li = \text{logarithmic integral})$

In 1798 Legendre gave a (better) approximation

$\pi(n)$ is approximately equal to $\dfrac{n}{\log n - 1.08366}$



$\pi(n)$ the multitude of prime umbers that are less than or qual to n

Approximation according to $\frac{n}{\log n}$ (Legendre, Hadamard, de la Valle-Pousin)

Approximtion according to $Li(n)=\int_2^n \frac{1}{\log t}dt$ (Gauss)

The Riemann hypothesis and the Platonic number 5040

In 1851 Tchebycheff showed that if the limit $\lim_{n\to\infty} \frac{p(n)}{n/\log n}$ exists, then it must be equal to 1.

But he could not show that the limit existed. The proof that $\lim_{n\to\infty} \frac{p(n)}{n/\log n}$ was given independently in 1896 by Hadamard and de la Vallee Pusin. In 1859 Bernhard Riemann opened a new epoch in Mathematics by publishing an eight page paper with the title: "Ueber die Anzahl der primzahlen unter einergegebenen Grosse"

(About the number of prime numbers that are less than a given size).

In this paper **Riemann** describes a method to prove the **Prime number theorem**. **Riemann's** method of proof relieson the ZETA funcion:

$$\zeta(s)=\sum_{k=1}^{\infty}\frac{1}{k^s}=\frac{1}{1^s}+\frac{1}{2^s}+\frac{1}{3^s}+\ldots$$

Where $s=x+iy$ complex number. The function $\zeta(s)$ was originaly defined by **Euler** (1707-1783) for $s=n$ integer number. **Euler** had proven the remarcable identity :

$$\zeta(n)=\frac{1}{1^n}+\frac{1}{2^n}+\frac{1}{3^n}+\ldots=\left(\frac{2^n}{2^n-1}\right)\left(\frac{3^n}{3^n-1}\right)\left(\frac{5^n}{5^n-1}\right)\ldots=\prod_{p=prime}\left(\frac{p^n}{p^n-1}\right)$$

where the product is defined for all **PRIME NUMBERS** ! and associates the natural numbers 1,2,3,4,5,6,7,... with the **PRIME NUMBERS** 2,3,5,7,...

This work Riemann contains probably the most **famous and important** unsolved mathematical problem the socalled **Riemann Hypothesis** which states that **all complex zeros of the ZETA function :** $\zeta(s)$ **are located on the "critical line"** $\mathrm{Re}(s)=\frac{1}{2}$.
In 1915 **Hardy** proved that $\zeta(s)$ has an infinity of zeros on the **critical line** $\mathrm{Re}(s)=\frac{1}{2}$.The **Riemann** hypothesis remains an open problem for**150** years. The **Clay** Institute for Mathematics give a reword of **1.000.000** U.S. Dollars for the first correct proof of the **Riemann hypothesis**. In 1901 Koch shoed that if the **Riemann** hypothesis **is true**, then $\pi(n)=Li(n)+$ an error term of the order of $n^{\frac{1}{2}\log n}$.

If $\sigma(n)=\sum_{d|n} d$ is the **"sum of the divisors of a natural number n"** (e.g. for $n=10$, $\sigma(10)=1+2+5+10=18$) and γ is the" **Euler - Mascheroni constant"**

$$\gamma=\lim_{n\to\infty}\left[\left(\sum_{k=1}^{n}\frac{1}{k}\right)-\log(n)\right]=0.57721566\ldots$$

then $n=5040$ is the **greater known natural numberfor which the inequality** : $\sigma(n)>e^{\gamma}n(\log\log n)$ **holds true**.

The fact that $n=5040$ is the **largest known natural number** for which the inequality: $\sigma(n)>e^{\gamma}n(\log\log n)$ **holds true**, allows us to formulate the conjecture that:

$$\sigma(n)<e^{\gamma}n(\log\log n)\quad\forall n>5040$$

Robin's theorem .

In 1984 **Guy Robin** in a paper with the title: "Grandes Valeurs de la fonction somme des diviseurs et hypothèse de Riemann." *J. Math. PuresAppl.* **63**, 187 – 213 prved that

$$\sigma(n)<e^{\gamma}n(\log\log n)\quad\forall n>5040$$

if and only if the Riemann hypothesis is true !!!!

http://blogs.msdn.com/devdev/archive/2007/07/16/robin-s-theorem.aspx

Therefore theoreticaly, the Riemann hypothesis could be prooved wrong if someone could find a number a positive integer $n > 5040$ such that: n e n loglogn . Sinse most Mathematicians believe that the Riemann hypothesis hods true, it is more plausable that

$$\sigma(n) < e^{\gamma}(n \log\log n) \quad \forall n > 5040$$

is true, and a proof of this inequality could earn you 1.000.000 $.

4. Plato and Riemann

We see that through Robin's Theorem which states that:
"The Riemann Hypothesis is true if and only if

$$\sigma(n) < e^{\gamma} n(\log\log n) \quad \forall n > 5040$$

the Platonic number 5040 is related with the truth or not of one of the most importan and ununshetred hypothesis in the history of Mathematics.
Whatever else, I believe that this fact is something very remarkble!

5. References

[1] Plato, The Laws, 4th Century BC.

[2] A.I.G. Vardulakis and C. Puch, Plato's hidden theorem on the distribution of primes. The Mathematical Intelligencer, Vol. 30. No. 3, August 2008.

B2.2 The Rate of Change in Euclidean Geometry, Newtoni-an Mechanics and Fractional Calculus

George Dassios
Professor Emeritus
University of Patras and FORTH/ICE-HT, Greece

Abstract
Centuries before Euclid, the idea of the rate of change of a quantity was used in the form of the local tangent to a plane curve. On the other hand, the same idea re-appeared initially in the calculations of Torricelli and then in the generic form of fluxions by Newton in the framework of velocity. And the main question is the following: What is the reason for this, more than 20 centuries delay, in understanding that the concepts of tangent and velocity are two different aspects of the same idea, that of the rate of change ? Two possible answers to this philosophical question will be reported. Furthermore, a discussion of the rate of change as measured by using fractional derivatives will be presented.

1. THE CONCEPT OF THE TANGENT

The concept of the tangent to a curve provides a local approximation of the curve by a linear segment. The direction of the tangent to a curve determines the rate at which the values of the function that defines the curve increase or decrease. In other words it determines whether the curves 'goes up' or 'goes down' as well as the amount to this variation. We refer to this variation as the derivative of the curve at one of its points and it is obvious that this tangent exists only when it can be defined in a unique way. Consequently, we have to accept that the concept of the derivative has an age that maybe approaches to three millennia, since we come across this concept in the Babylonians, the Egyptians as well as in China, many centuries before it settles in the Elements of Euclid [1,3].

2. THE CONCEPT OF VELOCITY IN CLASSICAL MECHANICS

Almost 19 centuries after Euclid the concept of the derivative re-appeared, in a purified way, within a completely different frame work, that of the velocity.

Already from the middle of 17th century Torricelli used the concept of velocity in connection with the rate at which a barrel, filled with some fluid, loses its contain through a little hole, as well as the rate of change of the hydrostatic pressure in the interior of the barrel. However, the person that established mathematically the concept of

the derivative, in the second half of the 17th century, was Newton. As we know, the concept of the rate of change in the work of Newton is not restricted only in the concept of the velocity but it appears over the whole spectrum of the 17th century Physics [4].

In any case, the introduction of the *Method of Fluxions* that is todays Infinitesimal Calculus, by Newton was not restrictive even in the number of successive repetitions of the rate of change upon the variation of the same quantity.

Every contemporary book on Infinitesimal Calculus contains the tangent and the velocity as the first two examples of the concept of the derivative. Therefore, it is obvious to ask the following question: *Why it took more than two thousand years for the human mind to understand that the definitions of the tangent and the velocity have the same conceptual basis?* In what follows we will provide two possible answers to this question that are based on ideological obsession and on neurophysiological differences of our censors.

3. THE POSSIBLE REASONS FOR THE DIFFERENTIATION

As it is well known, from the period of Antiquity until the late Renaissance it was believed that it was not possible to compare, or even to associate, unlike quantities. The *measurement* was always a *comparison* between similar quantities. It was possible to compare length with length, a quantity of a given material with a corresponding quantity of the same material, and so on. This way, it was simple as well as permissible to compare the *height variation* of a curve use the *height variation* of a line. Both quantities were lengths, therefore quantities that are allowed to be compared. Who could violate the laws of Nature as they have been stated by all ancient philosophers and especially Aristotele?

Hence, the human race had to wait for twenty centuries, until the appearance of Newton, in order to compare space with time and measure the spatial variation as a function of the temporal variation, that is to define the velocity as it is known today.

Even more than this *revolutionary* idea of comparing quantities of different kind, we should re-examine how time was perceived by the man before the dawn of the scientific discovery. What exactly was the mechanism that turns daytime to nighttime and back to daytime again, ages the animals, develops the plans, ages the humans and offer the possibility of memory to logical beings? [3, 5, 8, 9].

Consequently, it was not just the ideological trapping of the prohibition to compare unlike quantities, it was also the fact that, in as far as the velocity is concerned, time was an incomprehensible quantity. This observation gives us the opportunity for a dipper philosophical thinking of the concept of time. Today, we know that time is not different than space; at least as far as the independence of different quantities that specify the concept of dimension is concerned. But what exactly prevented us to recognize this particular fact for so many centuries?

Let us look first at the analytic definition of the derivative. The calculation of the limit of the fraction of differences

$$\frac{f(x)-f(x_0)}{x-x_0}$$

as, $x \to x_0$,demands not only the value of the function at the point x_0 but also, all the values of f in an arbitrary small interval that contains the point x_0 in its interior. This demand assumes that we are equipped with the neurophysiological censor that provides a perception of what we exactly understand by neighborhood of a point, what exactly means a left interval and a right interval of the point x_0 . As far as the spatial dimensions are concerned, this censor is provided by our eyes, through which we have the ability to *see* neighborhoods of points.

On the other hand, when we refer to the derivative as the velocity, the role of the neighborhood belongs to the dimension of time, for which however we *do not* have a censor that can *see* a neighborhood of time. We *feel* the time as an instantaneous reality, as a transitive boundary that transfers us from to the future to the past, as an uninterrupted flow of instantaneous facts. We can not *see* temporal intervals, and therefore, we have a great difficulty to combine the values of the function of a *visible* spatial interval with the values of the function on an *invisible* temporal interval.

All we have to do in order to understand the inability to perceive an interval of time is to consider the way that time was perceived during the antiquity. This difficulty is exactly what forced Newton to define a homogeneous time that 'runs' continuously from minus infinity to plus infinitely along which all physical phenomena unfold. In some way Newton introduced time as an invisible dimension independent from every other geometrical (spatial) dimension. Today, with the cataclysmic temporal intervals in which we are spending our lives, as well as the multilateral technology of measuring and recording time, we do not have any difficulty to understand the concept of time interval, and hence the concept of velocity as the rate of change of space in terms of time. However, a few centuries ago things were not as today and it took the genius of Newton to free us from the inexplicable experience of the time flow. Newton's reference of the derivative as a flow (fluxion) suggested exactly the continuous flow of this invisible dimension of time.

4. THE FRACTIONAL RATE OF CHANGE

When L' Hospital learned about the concept of the derivative in the form

$$\frac{df(x)}{dx}$$

as it was symbolized by Leibnitz, sent a letter to Leibnitz dated 30 September 1695 asking him what happens when the order of differentiation is not an integer, for example when the order is equal to ½. Leibnitz replied with the following prophetic comment: *It leads to a paradox, from which one day useful consequences will be drawn.*

The history of Fractional Calculus is long and interesting but it does not belong to the present analysis. The most widely used, among many others, definition of the fractional derivative and the fractional integral is the one introduced by Riemann and Liouville [2,6,7]. According to this definition, the integral of order $\alpha > 0$, of the continuous function f , is defined by the formula

$$ {}_cD_x^{-a} f(x) = \frac{1}{\Gamma(a)} \int_c^x (x-\tau)^{a-1} f(\tau)\, d\tau $$

where Γ is the well known Gamma Function and *c* is a constant determining the interval [*c, x*] over which the history of f is specified. The integral is a singular function at the upper limit of integration when 0 < α < 1, but the integral exists as an improper integral.

On the other hand, the derivative of order α > 0 of f is defined by the formula

$$ {}_cD_x^{a} f(x) = \frac{d^{m+1}}{dx^{m+1}} \frac{1}{\Gamma(m+1-a)} \int_c^x (x-\tau)^{m-a} f(\tau)\, d\tau $$

where m = [α]. When α is not a positive integer, the point is again a singularity of the integrand because -1 < *m* - α < 0. Therefore, we observe that in order to define the derivative of none positive integer order *a* we first integrate up to the first next to *a* integer [*a*]+1, and then we differentiate [*a*]+1 times. This way the fractional integration of order *m* + 1 - α will be subtracted as a fraction of the integral order derivation. As a consequence, we see that the fractional differentiation is defined via a fractional integration.

The important characteristic of the above definition of the derivative is that the derivative is defined through a global process and not through a local process as the convential differentiation. That is the fractional derivative at the point depends on all the values of the function in the interval [*c, x*].

Using the Riemann-Liouville definition of the fractional derivative we obtain

$$ \begin{aligned} {}_0D_x^{a} x &= \frac{d}{dx} \frac{1}{\Gamma(1-a)} \int_0^x (x-\tau)^{-a} \tau\, d\tau \\ &= \frac{1}{\Gamma(1-a)} \frac{d}{dx} \frac{x^{2-a}}{(1-a)(2-a)} \\ &= \frac{x^{1-a}}{(1-a)\Gamma(1-a)} \\ &= \frac{x^{1-a}}{\Gamma(2-a)} \end{aligned} $$

and in particular, for α = ½, we arrive at

$$ {}_0D_x^{1/2} x = \frac{x^{1/2}}{\Gamma(3/2)} = \frac{2\sqrt{x}}{\sqrt{\pi}} $$

which is exactly the answer that L' Hospital was waiting to receive from Leibnitz, 321 years ago.

Consequently, apart from the constant factor 1/Γ (2 - α), the α - derivative of the function χ decreases proportionally to the exponent of χ by the order of differentiation α ∈ (0,1).

It is obvious that

$$ \lim_{a \to 0} {}_0D_x^{a} x = x $$

and

$$\lim_{a\to 1} {}_0D_x^a x = 1$$

In every case, the global definition of fractional derivative makes even more strange the problem of temporal dependence, since it replaces the arbitrary small neighborhood, needed to calculate the derivative, with a full specified interval.

Because of the interpretation of the independent variable as time, we can claim that the process of calculating the fractional rate of change incorporates the essence of memory.

In the following paragraph we introduce a local definition of the fractional derivative, that is a definition which does not involve memory.

5. A LOCAL DEFINITION OF THE DERIVATIVE

It is possible to define the fractional derivative on a *local basis* if we build on the following idea. The conventional definition of the derivative at the point demands the existence of the limit

$$\frac{f(x)-f(x_0)}{x-x_0}$$

as. $x \to x_0$ But what exactly this ratio represents?

It is obvious that this ratio measures the variation of the function f between the points χ and χ_0 using as a unit of measurement the corresponding variation of the identity function $id(\chi) = \chi$. The identity, being a linear function, has the characteristic property that it is a homogeneous unit of measurement. However, nobody prohibits us to use a non-homogeneous unit of measuring functional variations. For example, we could measure the variation of the function $f(x) = x$ using as a unit the variation of the function $\sqrt{x}$. This way we would have

$$\lim_{x\to x_0} \frac{x-x_0}{\sqrt{x}-\sqrt{x_0}} = \lim_{x\to x_0} \frac{\left(\sqrt{x}-\sqrt{x_0}\right)\left(\sqrt{x}+\sqrt{x_0}\right)}{\sqrt{x}-\sqrt{x_0}} = 2\sqrt{x_0}$$

This result, although differs from the corresponding Riemann-Liouville derivative of order ½ by a multiplicative constant, it has a local character. Along this line, we can define the general fractional derivative of order α, with $0<\alpha<1$, of α differentiable function f by the formula

$$D^a f(x)\Big|_{x_0} = \lim_{x\to x_0} \frac{f(x)-f(x_0)}{x^a - x_0^a} = \lim_{x\to x_0} \frac{f(x)-f(x_0)}{x-x_0} \lim_{x\to x_0} \frac{x-x_0}{x^a - x_0^a} = f'(x_0)\frac{1}{ax_0^{a-1}}$$

and therefore

$$D^a f(x) = \frac{x^{1-a}}{a} f'(x)$$

In the case where $\alpha>0$, with $m=[a]$, where α is not an integer, we define the α- order derivate of f as the α-$[\alpha]$ order derivative of the classical derivative $f^{(m)}$. That is

$$D^a f(x) = D^{a-m} f^{(m)}(x) = \frac{x^{m+1-a}}{a-m} f^{(m+1)}(x)$$

where now $0<\alpha-[\alpha]<1$. We observe that for $0<\alpha<1$

$$\lim_{a\to 1} D^a f(x) = \left(\lim_{a\to 1} \frac{x^{1-a}}{a}\right) f'(x) = f'(x)$$

but as $\alpha \to 0$ the expression for $D^a f(x)$ becomes infinite. This is due to the fact that for $\alpha=0$ the unit of measuring functional variation degenerates to the constant function equal to 1

$$\lim_{x\to 0+} x^a = 1$$

which, as a constant function, does not have any variation.

Consequently, the fact that the derivative becomes infinite because of wrong choice of the unit of measurement.

6. CONCLUSIONS

The rate of change in the form of the tangent of a curve is known for almost three thousand years. This is due to the fact that, in the definition of the tangent we compare two quantities of the same kind, in our case these two quantities are two lengths, for which we have a global visual perception of the neighborhood of any point. On the other end, for the definition of the velocity we have to compare two quantities of different kind, that is length and time, and the difficulty comes partially from the fact of our luck of familiarity to compare quantities of different kind. However, it is most probable that this difficulty is due the fact that while definition of the derivative demands the knowledge of a neighborhood of a point, in the case of time the man is not equipped with a sensor that provides a synchronous perception of a temporal neighborhood.

It is possible to extend the definition of functional variation from integral numbers to order of any real number, and this can be achieved in many different ways, both global, where we need the values of the function in a whole preassigned interval, and local, where only the values of the function in an arbitrary small interval are necessary. In the cases of the definitions with a global character the value of the rate of change preserves a *memory* of the values of the function in a full interval.

Finally, we should mention that the use of different units of measuring functional variation could be very useful when we deal with a particular problem that has incorporated a related behavior. The first researcher that utilized this idea was Abel who, in 1823, solved the following integral equation.

$$f(x)=\int_a^x \frac{u(t)}{\sqrt{x-t}}\,dt$$

Using fractional calculus of order ½. Specifically, Abel wrote this equation in the form

$$f(x)=\Gamma(1/2)\frac{1}{\Gamma(1/2)}\int_0^x (x-t)^{-1/2}u(t)\,dt=\sqrt{\pi}D_x^{-1/2}u(x)$$

where $\Gamma(1/2)=\sqrt{\pi}$, from which he arrived at the solution

$$u(x)=\frac{1}{\sqrt{\pi}}\,{}_0D_x^{1/2}f(x)=\frac{1}{\sqrt{\pi}}\frac{d}{dx}\frac{1}{\Gamma(1/2)}\int_0^x (x-t)^{-1/2}f(t)\,dt$$

$$=\frac{1}{\pi}\frac{d}{dx}\int_0^x (x-t)^{-1/2}f(t)\,dt$$

Hence, we see that the choice of measuring the rate of change via the function x^a, $0<\alpha<1$, can dictate a unique choice for solving a particular problem.

BIBLIOGRAPHY

1. Hart,W. (editor) *The Philosophy of Mathematics*. Oxford Readings in Philosophy. Oxford (1998).
2. Kilbas, A., Srivastava, H. and Trujillo, J. *Theory and Applications of Fractional Differential Equations*. North-Holland Amsterdam (2006).
3. Lockwood, M. *The Labyrinth of Time*. Oxford University Press. Oxford (2005).
4. Newton, I. *Newton's Principia. The Mathematical Principles of Natural Philosophy*. Published by Daniel Adee. New York (1846).
5. Novikov, I. *The River of Time*. Cambridge University Press. Cambridge (2004).
6. Oldham, K. and Spanier, J. *The Fractional Calculus*. Academic Press. New York (1974).
7. Podlubny, I. *Fractional Differential Equations*. Academic Press. Boston (1999).
8. Tasic, V. *Mathematics and the Roots of Postmodern Thought*. Oxford University Press. Oxford (2001).
9. Whitrow, G. *The Natural Philosophy of Time*. Oxford Science Publications. Clarenton Press. Oxford (1984).

B2.3 The Concept of Symmetry in Classical Antiquity and Modern Applications of Spherical Symmetry in Multispace

Athanase Cotsiolis and Nikos Labropoulos
University of Patras, Greece
In memory of Professor Thierry Aubin (*1942 -- 2009*)

Abstract

This is an examination of the concept of symmetry in classical Greece where it had a great variety of applications in nature, science and art. In particular, great figures such Plato, Aristotle, Pythagoras-Pythagoreans, Archimedes, Democritus etc., by referring to the symmetry of forms, mention the sphere as expressing the absolute harmony in space and respectively the circle on the plane.

As suitable applications, the present work proposes:

1. The isoperimetric inequalities of Plato's School.
2. The generalization of isoperimetric inequalities in Euclidean multispace and their equivalence to the optimal inequalities of Sobolev και Nash type.
3. The application of optimal inequalities in the solution of nonlinear partial differential equations in geometry, mathematical physics, economy etc. problems.

1. On symmetry

In the present work, the concept of symmetry is investigated. The etymology of the word stems from the ancient Greek word *«συμμετρικός»* (*symmetric=συν+μέτρον, i.e. plus+measure*) meaning *'with a measure'*, *'by rule'*, *'by calculation'*, *'by measurement'*. In this context, the word *'symmetry'* was considered in Ancient Greeks as synonymous to the harmony of proportions, a purely mathematical notion. Also, it is proved that symmetry has a huge field of applications in art and science and quite often appears in nature. In addition, it has a deeply philosophical and mathematical significance.

There are two ways of approaching symmetry:

First, symmetry is associated with the regularity of a form or an object. It is basically the harmonious proportion of the parts of a whole, the harmonious order or the periodic repetition of particular characteristics. In this sense, symmetry is not limited to objects in space, but develops into a general notion expressing order, beauty and perfection. Second, symmetry is a mathematical concept perfectly accurate. Hermann Weyl (1885-1955) in his work *"Symmetry"* [1] states that:

'All forms of symmetry lead to the general idea which is the basis of all special Symmetry forms, namely the idea of unchanged-invariant of a data formation with respect to a group of automorphism transformations'.

2. Symmetry in ancient Greece

In the classical antiquity the concept of symmetry appears in art quite often. Sculptors and architects perceived it as beauty and harmony. Parthenon and in particular its eastern front is the perfect example. Parthenon, to its tiniest details, exhibits perfectly harmonious (golden) rations, making its magnificence monumental. Parthenon's perfect ratios were achieved by the use of the gold rectangles (580-496 BC Pythagoras golden section). We remind that Pythagoras and his school [2] had as a basic principle:

'Everything is number'

The conclusion that the main harmonic intervals correspond to simple numerical ratios led the Pythagoreans to discover, with leaps of unsurpassed courage, that in the root of phenomena of the natural world lies the harmony of mathematical concepts, the *`music of the spheres'* as they called it, heaven's harmony, which is not noticeable but conceivable [3].

The gold rectangulars, the main tools of ancient architecture, were predominantly used by Phidias.

Photo 1

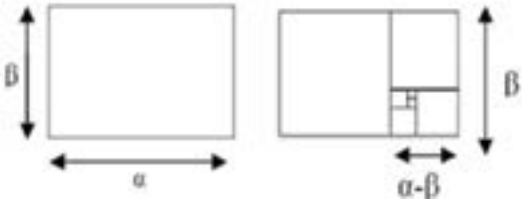


Figure 1

Therefore, the golden number, i.e. the ratio of the longer to the shorter side of the golden rectangle, also called the *beauty constant*, is symbolized by the Greek letter φ in honor of Phidias. Thus $\varphi = \frac{\alpha}{\beta}$.

Moreover, according to the definition of Euclid (*def.3, Elements, book vi* [4]):

""Ἄκρον καὶ μέσον λόγον εὐθεῖα τετμῆσθαι λέγεται, ὅταν ᾖ ὡς ἡ ὅλη πρὸς τὸ μεῖζον τμῆμα, οὕτως τὸ μεῖζον πρὸς τὸ ἔλαττον,"(=A straight line is said to be divided into edge and middle ratio, when the ratio of the whole line to the longest part of it is equal to the ratio of the longer part to the shorter).

Obviously, Euclid refers to the line segment. In particular, the line segment is said to be divided into end and middle ratio when the ratio of the line segment to the length of the larger part is equal to the ratio of the larger part of the length to the smallest.

Therefore, applies that $\frac{\alpha}{\beta} = \frac{\beta}{\alpha - \beta}$, thus $\alpha^2 - \alpha\beta = \beta^2$, thus $\varphi^2 - \varphi = 1$, solution of which is $\varphi = \frac{1+\sqrt{5}}{2} = 1{,}618033989...$

Polyclitus (sculptor, 5th cent. BC) was the first to refer to symmetry as a concept of mathematical dimension with excellent application in art. The famous phrase,

> *"Η χρήση πάρα πολλών αριθμών σχεδόν πάντα προκαλεί ακρίβεια στην γλυπτική"*(=*nearly always the use of very many numbers causes precision in sculpture*).

is attributed to him. His work *"The spear bearer"*, a statue representing an athlete holding a spear (*see Figure 6*), also known as "The Rule", since, due to its perfect proportions, was used as a model by other sculptors.

Photo 2

As a philosophical/ moral concept, symmetry appears in Plato's Republic, *486d-487a* [5]:

> *«Ἀλλ' οὐ μὴν τό γε τῆς ἀμούσου τε καὶ ἀσχήμονος φύσεως ἄλλοσέ ποι ἂν φαῖμεν ἕλκειν ἢ εἰς ἀμετρίαν. Τί μήν; Ἀλήθειαν δ' ἀμετρίᾳ ἡγῇ συγγενῆ εἶναι ἢ ἐμμετρίᾳ; Ἐμμετρίᾳ. Ἔμμετρον ἄρα καὶ εὔχαριν ζητῶμεν πρὸς τοῖς ἄλλοις διάνοιαν φύσει, ἣν ἐπὶ τὴν τοῦ ὄντος ἰδέαν ἑκάστου τὸ αὐτοφυὲς εὐάγωγον παρέξει » .*

> *"But where else we could say that an unmusical and shapeless nature leads? Naturally to asymmetry. Of course, where else? However, do you think the truth has more to do with symmetry or asymmetry? By symmetry. Therefore, we should seek an intellect endowed by nature so that he considers symmetry and grace to be essential and that his inherent predisposition would easily lead to the actual being".*

Also, Aristotle in the `Nicomachean Ethics' [6] uses symmetry as a moral entity that encases beauty:
«μετριότης γὰρ καὶ συμμετρία κάλλος δήπου καὶ ἀρετὴ πανταχοῦ συμβαίνει ..., "(=Measure and symmetry are beauty and virtue all over the world).

In the same work the famous dictum, `medium modulus' can be found.

Much later Galen of Pergamon (129-216 AD), shares the same views in his work 'On constitutions' [7] maintaining that:

"σύμμετρον όπερ εκατέρου των άκρων απέχει", i.e. that state of mind that is equidistant from the ends.

Furthermore, Plato in *`Timaeus'* (*vii-34A*) [8, 9], referring to the mathematical dimension of symmetry, states that: *The body of the world was created by four elements connected with ties of geometric proportions.*

In fact, he correlates the four basic elements with four regular polyhedrons, ie. fire with tetrahedron, earth with cube, air with octahedron and water with icosahedron. In turn, the four Platonic solids can be further broken down into simpler geometric forms (which, however, cannot be further analyzed) constructing the perceptible universe.

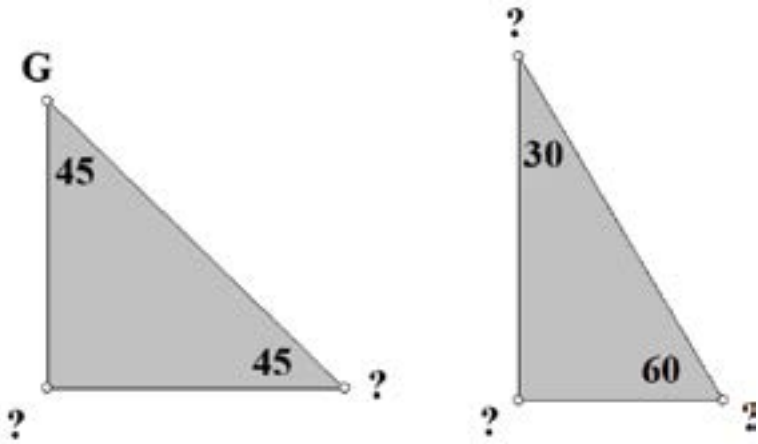


Figure 2

Figure 3

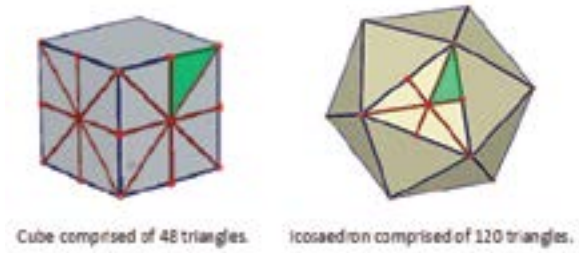


Figure 4

According to Plato, these triangles are of two kinds: a) rectangular and isosceles or half blocks according to the Pythagoreans and b) orthogonal whose hypotenuse is twice the one of their vertical sides.

Furthermore, in *'Epinomis'* [10], Plato attaches spherical form to the celestial bodies, considering it to be perfect, and introduces the dodecahedron - which he called ether- to be the fifth regular polyhedron, in which he observes the whole universe. For this reason, in *Timaeus 55c* [8], Plato refers to dodecaedron as the structure of god. In this, ether in is the 'fifth essence' and symbolizes heaven. The word generated by the Greek verb 'etho' which means: kindle, burn [11], (Figure 5).

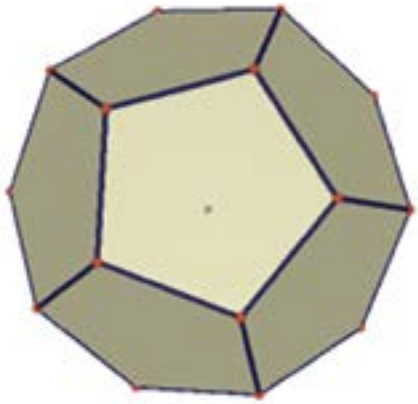


Figure 5

So, Plato, in *Timaeus*, by giving the mathematical dimension of symmetry, in an attempt to interpret the world by mathematizing nature says:

'The body of the world has the shape of a sphere which is the most uniform and symmetrical shape.'

Subsequently, Euclid proved that these five regular polyhedra are the only ones fitting within a sphere while every regular polyhedron accepts a sphere within it.

At this point, one should note that the individual materialists Leucippus and Democritus believed that the structural components of the universe can have innumerable symmetrical forms or may have an irregular shape. For them, atoms are eternaly existing, irrespective of any ultimate intervention, therefore, they claimed that the worlds-generating elements are atoms and void, calling them respectively as *'being'* and *'non-being'*. These two are the material causes of all things. Their shapes may have any form and their number and sizes are infinite.

In contrast, for Plato, atoms are not material bodies, but geometrical forms existing in the real world of mathematics and are finite. Considering them as purely mathematical entities, they are free from the notion of material, and the four solid can be transformed into each other, exchanging some of their triangles, without creating any gap.

Aristotle in his work *`On sky'* [12] considers the sphericity of celestial bodies as the form of perfect symmetry. In this work, he gave the celestial bodies spherical shape because anything else would diminish their perfection:

"ὅτι μὲν οὖν ὁμοίως γε πανταχόθεν ἀπὸ τῶν ἐσχάτων φερομένων πρὸς ἓν μέσον ἀναγκαῖον ὅμοιον γίγνεσθαι πάντῃ τὸν ὄγκον, φανερόν· ἴσου γὰρ πάντῃ προστιθεμένου ἴσον ἀνάγκη ἀπέχειν τοῦ μέσου τὸ ἔσχατον· [297a25-29] τοῦτο δὲ τὸ σχῆμα σφαίρας ἐστίν.

Meaning:

"When, an equal amount from everywhere, is added to the body necessarily every part of the body region will be separated from its center in the same way as with any other part, and this shape corresponds exactly to the sphere."

Finally, Archimedes in his two-volume work *`On Sphere and Cylinder'* [13], containing a total of 60 propositions, was the first to develop a formula calculating the surface area and the volume of the sphere. Both cases are formulated dramatically in a conclusion of Propositions 33 and 34 of Book I: *"The cylinder with a base equal to a maximum circle of the sphere and a height equal to a diameter of the sphere has a total surface* (*a side surface along with the two bases*) *exactly equal to 3/2 of the surface of the sphere and a volume exactly equal to 3/2 of the volume of the sphere"*

From which the formulae for the surface area E and the volume V of sphere of radius r are derived

$$E = 4\pi r^2 \quad \text{and} \quad V = \frac{4\pi r^3}{3}$$

It was mentioned that, as the absolute symmetry, the philosophers of classical antiquity define: 1) on the plane to be the circle denoted by (in which an infinite number of regular polygons fit), and 2) in the space to be the sphere denoted by (in which only

five regular polyhedral fit).

Among the problems studied, the isoperimetric problem of Plato's School is included,

(1) **on the plane:**"Out of all closed plane curves with given length L, find the one maximizing the area of the surface it includes," i.e. the isoperimetric inequality holds: and this inequality turns to equality if and only if the closed curve becomes a circle,

(2) **in space:** Zenodorus Geometer (200-140 BC) formulated the following proposition: "From all geometric bodies with given surface area, the sphere is the body that includes maximum volume."

3. A MODERN APPLICATION OF SHERICAL SYMMETRY IN MULTISPACE

Two thousand years later, in 1852, the Swiss mathematician Ludwig Schlafli [14] in his "Theorie der vielfachen Kontinuität", demonstrated that, apart from the five Platonic solids there are exactly six regular multispace (whice is the generalization of polyhedra) in four dimensions entered in hypersphere S^3. He also showed that there are exactly three polytopes (the generalization of multispace) on 5 or larger dimensions, entered in hypersphere S^4 or S^5 respectively etc ...

The isoperimetric inequality in the high dimensions states as follows:
For every subset Ω of the n-dimensional Euclidian space holds:

$$|\Omega|^{\frac{n-1}{n}} \leq K(n,1)|\partial\Omega|$$

where $K(n,1)^{-1} = n^{1-\frac{1}{n}}\omega_{n-1}^{\frac{1}{n}}$, $|\Omega|$ and $|\partial\Omega|$ are the n- dimensional Lebesque measure of Ω and the $(n-1)$- dimensional measure of its boundary respectively, while ω_{n-1} is the volume of the unit ball in R^{n-1}.

Federer, Fleming and Rishel in their articles [15] and [16] proved that in the high dimensions the isoperimetric inequality is equivalent to the following optimal Sobolev

$$\left(\int_{i^n} |u|^{\frac{n}{n-1}} dx\right)^{\frac{n-1}{n}} \leq K(n,1)\int_{i^n} |\nabla u| dx$$

In this second part of this article, we present the most interesting aspects of some Sobolev-type inequalities, i.e. Sobolev inequalities and Nash inequalities. More precisely, we are focusing our interest in the special case of the standard unit sphere $^{n-1}$ of , from the geometrical point of view. By developing particular geometrical properties of the sphere, we can calculate the precise values of the best constants in the presented Sobolev-type inequalities. This result of this analysis represents an improvement over the classic analysis and allows us to prove the existence of solutions for elliptic differential equations of scalar curvature of the generalized type with supercritical exponents.

Consider the sphere $S^n \subset R^{n+1}$, of dimension $n \geq 3$ and radius 1, i.e.

$$S^n = \left\{ x \in \mathbb{R}^{n+1},\ n \geq 3 : |x| = 1 \right\}$$

Let

$$\mathbb{R}^{n+1} = \mathbb{R}^k \times \mathbb{R}^m = \left\{ (x, y) : x \in \mathbb{R}^k,\ y \in \mathbb{R}^m \right\}$$

where $k+m = n + 1$, $k \geq m \geq 2$.

Let, also, $x = (x^1, x^2, ..., x^k) \in {}^k$ and $y = (x^{k+1}, x^{k+2}, ..., x^{n+1}) \in {}^m$ where $S^n = \left\{ (x, y) \in \mathbb{R}^{n+1} : |x|^2 + |y|^2 = 1 \right\}$

It is well known that S^n enjoys a lot of symmetries, namely, the compact Lie group $O(n + 1)$acts isometrically on S^n. Let now $G = O(k) \times O(m)$. Then G is a compact subgroup of $O(n+1)$. For $g = (g_1, g_2) \in G$, where $g_1 \in O(k)$ and $g_2 \in O(m)$, the action of G on S^n is defined by $g(x, y) = g_1 x, g_2 y$ and if $P(x, y) \in S^n$ since $|x|^2 + |y|^2 = 1$, its orbit under the action of G, is

$$O_P = S^{k-1}(|x|) \times S^{m-1}(|y|) = S^{k-1}(|x|) \times S^{m-1}\left(\sqrt{1 - |x|^2}\right)$$

Let $H_1^p(S^n), p > 1$ be the standard Sobolev space consisting of functions in $L^p(S^n)$ with gradient in $L^p(S^n)$. Denote $C_G^\infty(S^n)$ the subspace of $C_G^\infty(S^n)$ consisted of all G-invariant functions under the action of the group G, and $H_{1,G}^p(S^n)$ the space of all G-invariant functions of $H_{1,G}^p(S^n)$.

We should be recall that the general form of the Sobolev inequality [17] is

$$\left(\int_{\mathbb{R}^n} |u|^{\frac{np}{n-p}} dx \right)^{\frac{n-p}{np}} \leq K(n, p) \left(\int_{\mathbb{R}^n} |\nabla f|^p dx \right)^{\frac{1}{p}}, \qquad (1)$$

The value of the best constant $K(n, p)$ for $1 < p < n$ in (4) together with external functions, in the Sobolev embedding for the whole Euclidian space under the Euclidean metric [19], defined by:

$$\frac{1}{K(n, p)} = \inf_{\substack{u \in L^{p^*}(\mathbb{R}^n) \setminus \{0\} \\ \nabla u \in L^p(\mathbb{R}^n)}} \frac{\int_{\mathbb{R}^n} |\nabla u|^p dx}{\left(\int_{\mathbb{R}^n} |u|^{p^*} dx \right)^{\frac{p}{p^*}}}$$

was explicitly computed by Aubin [18] and Talenti [19] to be equal to:

$$K(n,p)=\frac{p-1}{n-p}\left(\frac{n-p}{n(p-1)}\right)^{\frac{1}{p}}\left[\frac{\tilde{A}(n+1)}{\grave{u}_{n-1}\tilde{A}\left(\frac{n}{p}\right)\tilde{A}\left(n+1-\frac{n}{p}\right)}\right]^{\frac{1}{n}}$$

where Γ is the gamma function.

In this paper, concerning to the Sobolev inequalities, we will consider functions in the space $H^p_{1,G}(\mathbb{S}^n)$,and regarding to the integer k there are two possibilities:
$k>2$ or $\varkappa=2$.

(i). Suppose now that $k>2$. Due to the Lemma of Ding [20] the embeddings $H^p_{1,G}(\mathbb{S}^n)\subset L^q(\mathbb{S}^n)$ is compact for any $q<p^*=\frac{pk}{k-p}$, but the embeddings $H^p_{1,G}(\mathbb{S}^n)\subset L^{p^*}(\mathbb{S}^n)$ is only continuous. So, there exist constants A,B such that for all $\phi\in H^p_{1,G}(\mathbb{S}^n)$ the following inequality holds:

$$\left(\int_{\mathbb{S}^n}|\phi|^{p^*}\,dV\right)^{\frac{p}{p^*}}\le A\int_{\mathbb{S}^n}|\nabla\phi|^p\,dV+B\int_{\mathbb{S}^n}|\phi|^p\,dV \qquad (2)$$

Concerning the inequality (2), we are interested in the value of the first best possible constant A , i.e.

$$\mathcal{A}=inf\left\{A\in\mathbb{j}\ :\exists\ B\in\mathbb{j}\quad s.t.\ (2)\ is\ true\ for\ all\ \phi\in H^p_{1,G}(\mathbb{S}^n)\right\}$$

In our case we are interested for functions defined not in the whole $H^p_1(\mathbb{S}^n)$ but in its subspace $H^p_{1,G}(\mathbb{S}^n)$ and our primary goal is to solve nonlinear elliptic equations on S^n, $n\ge 3$ with supercritical exponent (critical of supercritical). In aim to solve our first equation all results we need proved by Aubin and Cotsiolis in [21], and firstly, we need the following theorem:

Theorem 3.1

For all $\phi\in H^2_{1,G}(\mathbb{S}^n),\ n\ge 3,\ k+m=n+1,\ k\ge m\ge 2$, and $q>\frac{2n}{n-2}$, *the following inequality holds:*

$$\left(\int_{\mathbb{S}^n}|\phi|^q\,dV\right)^{\frac{2}{q}}\le A(n,k)\int_{\mathbb{S}^n}|\nabla\phi|^2\,dV+B\int_{\mathbb{S}^n}\phi^2dV \qquad (3)$$

where $A(n,k)=2\left[k(k-2)\right]^{-\frac{1}{2}}\left(\omega_k\omega_{n-k}\right)^{-\frac{1}{k}}$.

Moreover, A (n.k) is the optimal constant for this inequality.

Consider now on $S^n, n \geq 3$ the following nonlinear differential equation

$$\Delta\phi + a(x)\phi = f(x)\phi^{q-1}, \ \phi > 0 \qquad (4)$$

where Δ is the Laplace-Beltrami operator: $\Delta\phi = -\nabla^i \nabla_i \phi$, α and f are two G-invariant functions and $q = \dfrac{2k}{k-2}$.

Since $k < n$, $q > \dfrac{2n}{n-2}$, and for $p > \dfrac{2n}{n-2}$ the equation (4) is supercritical. In the case where is critical of the supercritical, which means that for any $p > q = \dfrac{2k}{k-2}$ the equation (4) accepts only the trivial solution i.e. the solution $u = 0$.

Thus, if $2 < p < q = \dfrac{2k}{k-2}$, by using standard variation methods (i.e. see in [22])., we can solve the following equation

$$\Delta\phi + a(x)\phi = f(x)\phi^{p-1}, \ \phi > 0 \qquad (5)$$

Concerning the supercritical case, firstly, due to Theorem 3.1 we can solve the equation (5), and in the consequence solve the equation (4). Meanwhile, we will give some useful notatio

For $2 < p < q$ define the functional

Suppose that the operator $\Delta + \alpha$ is coercive, i.e. there exists a real number $\lambda > 0$, such that, for $\phi \in H^2_{1,G}(\mathbb{S}^n)$ all,

$$I_p(\phi) \geq \int_{\mathbb{S}^n} \phi^2 \, dV$$

and we set $\mu_p = inf\, I_p(\phi)$, $\phi \in \mathcal{A}_p$, where

$$\mathcal{A}_p = \left\{ \phi \in H^2_{1,G}(\mathbb{S}^n), \ \phi \geq 0 : \int_{\mathbb{S}^n} f(x)\, dx \phi^p = 1 \right\}$$

Firstly, by the standard variation method, (i.e. see in [22]), we prove that there exists a function $\varphi \in C^\infty$ strictly positive which satisfies the equation

$$\Delta\phi_p + a(x)\phi_p = \mu_p f(x)\phi_p^{p-1}, \ \phi > 0 \qquad (6)$$

Secondly, letting $p \to q$, due to the Remark 1 in [23] and Theorem 1 in [22] we obtain the following theorem holds:

Theorem 3.2

Let α and f be two C^∞ (S^n), n > 3, G- invariant functions with $\sup_{x\in S^n} f(x) > 0$, *(i.e. f is somewhere positive),* $q = \frac{2k}{k-2}$ *and the operator Δ + α is coercive on S^n. Then the equation (9) accepts a C^∞ solution, strictly positive if*

$$\mu_q < \frac{1}{4}(\omega_k \omega_{n-k})^{\frac{2}{k}} k(k-2)\left(\sup_{x\in S^n} f(x)\right)^{-\frac{2}{q}}$$

(ii). Suppose now that $\varkappa = 2$, and then $n = 3$. In this case for all $p \geq 1$ the embedding $H^2_{1,G}(S^3) \subset L^p(S^3)$ is compact, but $H^2_{1,G}(S^3) \not\subset L^\infty(S^3)$. However, in S^3 when $q=\infty$ for all $\phi \in H^2_{1,G}(S^3)$, $e^\phi \in L^1(S^3)$ and in this case the following theorem holds:

Theorem 3.3

For all $\phi \in H^2_{1,G}(S^3)$ *the function e^ϕ is integrable and for any real* $\nu > \frac{1}{32\pi^2}$ *there exists a constant C_ν such that for all* $\phi \in H^2_{1,G}(S^3)$ *the following inequality holds:*

$$\int_{S^3} e^\phi dV \leq C_\nu \exp\left(\nu \|\nabla\phi\|_2^2 + \frac{1}{\omega_3}\int_{S^3} \phi dV\right) \qquad (7)$$

Moreover, $\frac{1}{32\pi^2}$ *is the optimal constant for this inequality.*

The precise value of the best constant ν in inequality (7) appears in results of the existence of nontrivial solutions of the following exponential elliptic equation:

$\Delta\varphi + \alpha(x) = f(x)\, e^\varphi$

where α and *f* are two C^∞ (S^3), *G*-invariant functions. In particular the following theorem holds:

Theorem 3.4

Let α and f be two C^∞, G-invariant functions on S^3 with $\sup_{x\in S^3} f(x) > 0$, *(i.e. f is somewhere positive). Then the equation (11) accepts a C^∞ solution, strictly positive if*

$$0 < \int_{S^3} a(x)\, dV < 16\pi^2$$

Nash inequalities

The Nash inequality in the case of the whole the Euclidean space was introduced in 1958 by Nash [24].

It should be noted that the results of Nash used in Optimization Theory and due to the great contribution of the Theory in Economics, awarded to Nash the Nobel Prize in Economics.

The Nash inequality was used to prove the Holder regularity of solutions of divergence form uniformly elliptic equations and states as follows:

We say that the Nash inequality is valid on R^n if there exists a constant A such that for all functions $u \in H_1^2\left(R^3\right),\ n \geq 3$ holds:

$$\left(\int_{i^n} u^2 dx\right)^{1+\frac{2}{n}} \leq A \int_{i^n} |\nabla u|^2 dx \left(\int_{i^n} |u| dx\right)^{\frac{4}{n}} \qquad (9)$$

Let $A_0(n)$ be the best constant in Nash's inequality (9) above for the Euclidean space.

That is

$$A_0(n)^{-1} = inf\left\{\frac{\int_{i^n} |\nabla u|^2\, dx \left(\int_{i^n} |u|\, x\right)^{\frac{4}{n}}}{\left(\int_{i^n} u^2 dx\right)^{1+\frac{2}{n}}} : u \in C_0^\infty\left(i^n\right),\ u \not\equiv 0\right\}$$

This best constant has been computed by Carlen and Loss in [25], together with the characterization of the extremals for the corresponding optimal inequality, as

$$A_0(n) = \frac{(n+2)^{\frac{n+2}{n}}}{2^{\frac{2}{n}} n \lambda_{1,n} \left|\mathcal{B}^n\right|^{\frac{2}{n}}}$$

where $\left|\mathcal{B}^n\right|$ denotes the Euclidian volume of the unit ball $\mathcal{B}^n$ in R^n and $\lambda_{1,n}$ is the first Neumann eigenvalue for the Laplacian for radial functions in the $\mathcal{B}^n$ unit ball.

We say that the L^1-Nash inequality holds on $\mathbb{S}^n,\ n \geq 3$, if there exist two positive real numbers A and B such that for all $\phi \in H_1^2\left(\mathbb{S}^n\right)$

We define the best constants for this inequality an analogous way as in the Sobolev inequality, i.e.:

$$\mathcal{A} = inf\left\{A > 0 : \exists\ B > 0\ \ s.t.\ (10)\ is\ true\ \ for\ all\ \ \phi \in H_1^2\left(\mathbb{S}^n\right)\right\}$$

And

$$\mathcal{B} = inf\left\{B > 0 : \exists\ A > 0\ \ s.t.\ (10)\ is\ true\ \ for\ all\ \ \phi \in H_1^2\left(\mathbb{S}^n\right)\right\}$$

For all $\phi \in H_1^2\left(\mathbb{S}^n\right)$, consider now the L^2- Nash inequality

$$\left(\int_{\mathbb{S}^n} \varphi^2 dV\right)^{1+\frac{2}{n}} \leq \left(A \int_{\mathbb{S}^n} |\nabla \varphi|^2 dV + B \int_{\mathbb{S}^n} \varphi^2 dV\right)\left(\int_{\mathbb{S}^n} |\varphi| dV\right)^{\frac{4}{n}} \qquad (11)$$

and define its two best constants $A^2(n)$ and $B^2(n)$ in the same way as in the previews case.

In this paper, we are focusing our interest in the special case of the standard unit sphere S^n o R^{n+1}.We study both Nash's inequalities L^2 and L^2 firstly in the general case and secondly in the presence of symmetries. More precisely:

In the general case, i.e. for functions belonging i $H^2_{1,G}(\mathbb{S}^n)$, we answer the problem of finding both best constants in the L^2-Nash inequality in S^n and we prove the non-existence of extremal functions. Subsequently, we, also, find both the best constants in the L^2-Nash inequality in S^n and we prove the existence of extremal functions.

In the presence of symmetries, i.e. for functions belonging i $H^2_{1,G}(\mathbb{S}^n)$, we study the problem of the best constants in the L^1-Nash inequality in S^n, $n \geq 3$, where the data are G-invariant under the action of the group $G = O(k)$, $K+m = n+1$, $k \geq m \geq 2$, we find the best constants, and we prove the existence of extremal functions in this inequality.

All results presented in this part of the paper, concerning the Nash inequalities, have been proved by Cotsiolis and Labropoulos in [26].

For the problem of finding the best constants of the Nash inequalities in the sphere, in the general case, we have the following two theorems:

Theorem 3.5 (L^1-Nash inequality).

For any $\varepsilon > 0$ and for all $\varphi \in H^2_1(\mathbb{S}^n)$ the following inequality holds

$$\left(\int_{\mathbb{S}^n} \varphi^2 dV\right)^{1+\frac{2}{n}} \leq A_0(n,\varepsilon)\int_{\mathbb{S}^n} |\nabla\varphi|^2 dV \left(\int_{\mathbb{S}^n} |\varphi| dV\right)^{\frac{4}{n}} + \omega_n^{-1-\frac{2}{n}}\left(\int_{\mathbb{S}^n} |\varphi| dV\right)^{2+\frac{4}{n}}, \quad (12)$$

where $A_0(n,\varepsilon) = A_0(n) + \varepsilon$ and ω_n denotes the volume of the standard unit sphere S^n of R^{n+1}.

Moreover, $A^0(n)$ and $\omega_n^{-1-\frac{2}{n}}$ are the optimal constants for this inequality.

Corollary 3.1

The inequality of Theorem 3.5 is false if $e = 0$ and there do not exist extremal functions.

Theorem 3.6 (L^2-Nash inequality).

For all $\varphi \in H^2_1(\mathbb{S}^n)$, $n \geq 3$ the following inequality holds

$$\left(\int_{\mathbb{S}^n} \varphi^2 dV\right)^{1+\frac{2}{n}} \leq \left(A_0(n)\int_{\mathbb{S}^n} |\nabla\varphi|^2 dV + \omega_n^{-\frac{2}{n}}\int_{\mathbb{S}^n} \varphi^2 dV\right)\left(\int_{\mathbb{S}^n} |\varphi| dV\right)^{\frac{4}{n}} \quad (13)$$

Moreover, $A^{o}(n)$ *and* $\omega_n^{-\frac{2}{n}}$ *are the optimal constants for this inequality.*

In addition, there exists an extremal function $\varphi_0 \in H_1^2\left(\mathbb{S}^n\right)$, $\varphi_0 \not\equiv 0$, *for this inequality, namely, a function such that*

$$\left(\int_{\mathbb{S}^n} \varphi_0^2 dV\right)^{1+\frac{2}{n}} = \left(A_0(n)\int_{\mathbb{S}^n} |\nabla \varphi_0|^2 dV + \omega_n^{-\frac{2}{n}}\int_{\mathbb{S}^n} \varphi_0^2 dV\right)\left(\int_{\mathbb{S}^n} |\varphi_0| dV\right)^{\frac{4}{n}} \quad (14)$$

Concerning the best constants for the L^2 Nash inequality in the sphere, in the presence of symmetries, we have the following theorem:

Theorem 3.7

For all $\phi \in H_{1,G}^2\left(\mathbb{S}^n\right)$, $n \geq 3$, $k + m = n + 1$, $k \geq m \geq 2$ *the following inequality holds*

$$\left(\int_{\mathbb{S}^n} \phi^2 dV\right)^{1+\frac{2}{k}} \leq \left(A_0(n)\omega_{n-k}^{-\frac{2}{k}}\int_{\mathbb{S}^n} |\nabla \phi|^2 dV + \omega_n^{-\frac{2}{k}}\int_{\mathbb{S}^n} \phi^2 dV\right)\left(\int_{\mathbb{S}^n} |\phi| dV\right)^{\frac{4}{k}} \quad (15)$$

Moreover, $A_0(n)\omega_{n-k}^{-\frac{2}{k}}$ *and* $\omega_n^{-\frac{2}{k}}$ *are the optimal constants for this inequality.*

Acknowledgment:

The creative contribution of Mrs Teta Giannarou to the first part of the present work and to the whole of its presentation is gratefully acknowledged.

References

[1] W. Herman, Symmetry: Princeton University Press, 1952. (Greek version title: W. Herman, Symmetry Trochalia).

[2] Diogenes Laertius: Pythagoras - Pythagoras, Publisher Loeb, 1988.

[3] D. Christodoulou, Speech, Quantum Magazine Vol. 3, Issue 5, 1996.

[4] Euclid's elements of geometry, The Greek text of J.L. Heiberg (1883– 1885) from Euclidis Elementa, edidit et Latine interpretatus est I.L. Heiberg, in aedibus B.G. Teubneri, 1883–1885 edited, and provided with a modern English translation, by Richard Fitzpatrick.

[5] Plato: Politeia Editions Zaharopoulos, 1973.

[6] Aristotle: Nicomachean Ethics, Publications Classical Library, 1993.

[7] Galen of Pergamon: About constitutions, Publishing Cactus, 2000.

[8] Plato: Timaeus (or on nature), Publications Zaharopoulos, 1993.

[9] K. Dortsios and S. Amarantidis: Cosmology Plato through the Timaeus, The Column of Mathematics 2011.

[10] Plato: Law i-Epinomis. Publishing Cactus, 1994.

[11] H. G. Liddel and R. Scott: Great Dictionary of the Greek Language, 2007.

[12] Aristotle: On the sky, Anthology of Ancient Greek Secretariat, 2012.

[13] E. Howar: Dijksterhuis E.J., Archimedes, New York, Humanities Press, 1957. (Greek version Title: Great Moments of mathematics I. Until 1650. Howar, Eves, Archimedes About Sphere and Cylinder, Trochalia).

[14] L. Schläfli. Gesammelte mathematische Abhandlungen. Band I. Verlag Birkhäuser, Basel, 1950.

[15] H. Federer and W. H. Fleming: Normal and integral currents, Ann. of Math. 72, 458-520, (1960).

[16] W. H. Fleming and R. Rishel: An integral formula for total gradient variation, Arch. Math., 11 218-222, (1960).

[17] S. L. Sobolev: On a theorem in functional analysis, Amer. Math. Soc. Trans. (2) 34, (1963), 39-68; translated from Mat. Sb. (N.S.) 4, (46) 471-497, (1938).

[18] Th. Aubin: Problemes isoprimetriques et espaces de Sobolev, J. Diff. Geom., 11, 573-598, (1976).

[19] G. Talenti: Best constant in Sobolev inequality, Ann. Mat. Pura Appl. (4), 110 353-372, (1976).

[20] W. Ding: On a Conformally Invariant Elliptic Equation 0 . Commun. Math. Phys. 107, 331-335, (1986).

[21] Th. Aubin and A. Cotsiolis: Equations elliptiques non lineaires sur dans le cas supercritique. Bull. Sci.Math. 123, 33-45, (1999).

[22] Th. Aubin: Some non-linear problems in Riemannian Geometry. Springer, Berlin (1998).

[23] A. Cotsiolis and D. Iliopoulos: Equations elliptiques non lineaires a croissance de Sobolev sur-critique. Bulletin Sci. Math. 119, 419-431, (1995).

[24] J. Nash: Continuity of solutions of parabolic and elliptic equations, American Journal of Mathematics, 80, 931-954, (1958).

[25] E. A. Carlen and M. Loss: Sharp constant in Nash's inequality, International Mathematics Research Notices, 7 213-215, (1993).

[26] A. Cotsiolis and N. Labropoulos: Sharp Nash Inequalities on the unit sphere: The Influence of symmetries, Nonlinear Analysis 75 612–624, (2012).

B3. PHYSICS

B3.11 Aristotle's Physics on Free Falling Bodies

Georgios H. Vatistas
Concordia University, Montreal Canada
vatistas@encs.concordia.ca

Abstract

A lot has been written on the old question of how solid bodies fall under the action of gravity. Aristotle maintained that (i) heavier bodies descend faster than the lighter ones, and (ii) in a denser fluid, a body will fall slower that in a lighter fluid. Here, the general free fall problem is formulated using Newton's second law including the pertinent hydrodynamic forces. The resulting equation is first solved analytically with a constant drag coefficient and then verified numerically for the case where the coefficient varies with the velocity (Reynolds number). It is shown that, if indeed tests were performed by dropping spherical objects (one 200 pounds cannon ball and the other musket ½ pound ball), from 200 cubits as claimed in *Dialogues Concerning Two New Sciences*, the experimenter would have come to the conclusion that the heavy ball reached the ground first, followed by the lighter ball having a noticeable separation distance between them. It is also shown that the legendary *reduction ad absurdum* (*διά τῆς εἰς ἄτοπον ἀπαγωγής*) thought experiment, as structured in *Two New Sciences*, to disprove the Aristotelian physics, *vis–à–vis* the free fall of solid objects in fluid media, is not valid.

1. Introduction

In 2002 a forensic study on the dynamics of floating bodies in oceanic whirlpools [1] revealed that the descent due to gravity of larger mass bodies towards the vortex center, was faster than those of smaller mass. The last was found to be in accord with the observations of a Norwegian fisherman, while inside the vortex, described by Edgar Allan Poe (1841) in his short story "A Descent into a Maelström" [2]. This is also in agreement with Aristotle's teachings but contrary to what was claimed in *"Two New Sciences"*(*TNS* henceforth).
Aristotle, discussing the motion of solids in free fall within fluids made the following

two famous assertions:

"We see the same weight or body moving faster than another for two reasons":

"... either because there is a difference in what it moves through, as between water, air, and earth, or" [3][1]

"because, other things being equal, the moving body differs from the other owing to excess of weight or of lightness" [3][1].

Furthermore, he also commented on the shape of the body:

"The shape of bodies ... will account for their moving faster or slower" [4][2]

The above assertions were devised to prove that void does not exist:

In a vacuum where the density is zero, a body must fall with an unbounded velocity, which is not possible [3][1]

Therefore,

"From what has been said it is evident, then, that void does not exist" [3][1].

In a recent revealing article Rovelli [5] shows that "... Aristotelian physics is a correct and non-intuitive approximation of Newtonian physics in the suitable domain (motion in fluids), in the same technical sense in which Newton theory is an approximation of Einstein's theory ". Based on present day knowledge he shows that Aristotle's "factual statements are all correct,... Hard to claim this is not based on good observation" [5].

In this study, based on Newtonian mechanics, including current knowledge in fluid mechanics, we evaluate the statements concerning the separation distance of the cannon and musket balls, as appeared in the TNS [6] p. 62. Furthermore, it is shown that the usage of *reduction ad absurdum* method [6] p. 63, to disprove Aristotle's claims on free fall, reported in the *TNS* is unsuitable for motions in fluid media, and hence misleading.

2. Mathematical Formulation and Validation

The equation that describes mathematically the motion of a solid object, falling freely in a motionless fluid is:

$$\left(m + m_{add}\right)\frac{dV}{dt} = \left(B - mg\right) \quad \frac{1}{2}\rho_f \, C_D \, A\left|V\right|V, \tag{1}$$

where

$$C_D = fn\left(\mathrm{Re}\right), \;\; \mathrm{Re} = \rho_f \, L\left|V\right|/m \tag{2}$$

The coordinate system is shown in Fig. 1. The different variables in the above equation represent the: mass of the body m (kg), added or virtual mass m_{add}(kg), velocity of the

1. 215^a 25
2. 313^a 14

moving particle V (m/s), time t (s), buoyancy $B = \rho_f g \forall$ (N), density of the fluid ρ_f (kg/m^3), volume displaced by the solid $\forall$ (m^3), gravitational acceleration g(m/s2), weight of the body $W = m\,g$ (N), drag D = 1/2 $\rho_f C_D A|V|V$(N), drag coefficient (dimensionless), projected area of the body A (m^2), Reynolds number Re = $\rho_f V L/\mu$ (dimensionless), characteristic length of the problem L (m), and dynamic viscosity of the fluid μ (kg/ms).

The acceleration of a free-falling spherical body with diameter d is given by:

$$\frac{dV}{dt} = -\frac{2(1-\frac{\rho_f}{\rho_b})}{2+\frac{\rho_f}{\rho_b}} g + \frac{3}{2}\left(\frac{\rho_f}{\rho_b}\right)\frac{C_p}{(2+\frac{\rho_f}{\rho_b})\,d} V^2 \quad (3)$$

Where ρ_b (kg/m^3) is the density of the body, and the drag coefficient for a sphere is given by [7]

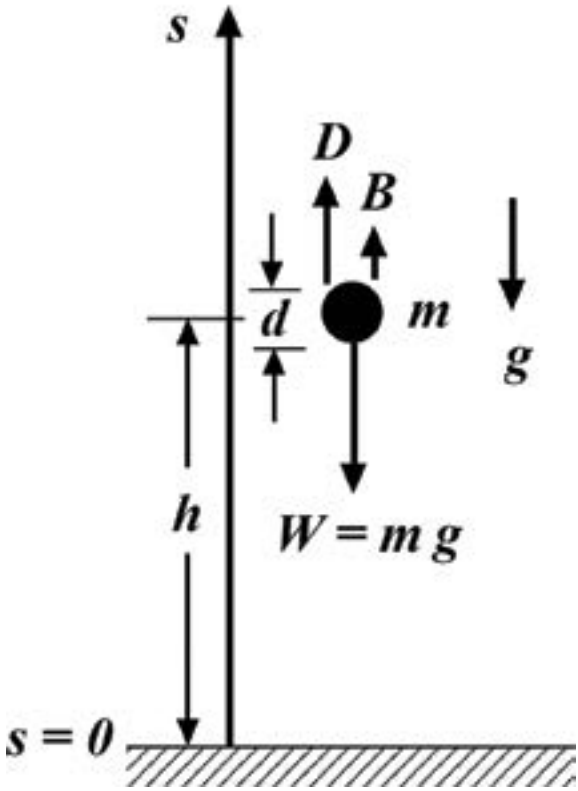


Figure 1: Schematic of the problem

$$C_D = \frac{24}{\mathrm{Re}} + \frac{6}{1+\sqrt{\mathrm{Re}}} + 0.4$$

Since we will be dealing with heavy solid objects say steel (ρ_b = 8,050 kg/m^3) falling in air (ρ_f = 1.22 kg/m^3) ρ_f/ρ_b << 1 (~ 0.0001), Eq. 2 simplifies into:

$$\frac{dV}{dt} = -g + \frac{K}{m_b} V^2 \qquad (5)$$

where $K = 1/2\, \rho_f C_D A$.
The above equation was solved first analytically assuming a constant K (C_D is equal to its asymptotic value 0.4, Re → ∞), and then numerically employing the Runge-Kutta 4th order method with a variable C_D given by Eq. (4).

Integration of Eq. (4) with constant C_D, along with the initial condition t=0, V=0 yields the velocity of the object [8],

$$V = -\sqrt{\frac{gm}{K}}\, tanh\left(\sqrt{\frac{gK}{m}}\, t\right) \qquad (6)$$

As time increases the velocity tends to a constant value, known as terminal velocity given by $V_T = -\sqrt{g\, m/K}$.

Integration of (Eq. 6), along with the initial condition t=0, s=h (s (m) is the vertical coordinate, and h (m) is the initial height see Fig. 1) gives the position of the body s for any t after release [8],

$$s = h - \frac{m}{K}\, ln\left\{\cosh\left(\sqrt{\frac{gK}{m}}\, t\right)\right\} \qquad (7)$$

The flight time $t_F(s)$, or the time that the object is airborne can be found setting s=0 and solving Eq. (7) for t:

$$t_F = \frac{arccosh\,\{exp\,(\frac{hK}{m})\}}{\sqrt{\frac{gK}{m}}} \qquad (8)$$

The velocity and the position of a steel ball having a diameter of 0.2 m, falling in air as a function of time were obtained analytically using Eqs. (6) & (7) assuming a C_D = 0.4, and numerically via the 4th order Runge-Kutta method with a variable C_D. The results between the two were found to be very close. For example, the flight time t_F = 63.2s was calculated from Eq. (8) with C_D= 0.4. For a variable C_D, t_F was found to be 62.8 s. The difference between the two time values is only 0.6%. Therefore, in the discussion that follows, the analytical solutions for V and s, given by Eqs. (6) & (7) respectively, will be utilized, in lieu of those obtained numerically.

The outcome of a real case of free fall is shown in Fig. 2. In 1942 a team of researchers, from the Medical School of Northwestern University studied the physiological effects on humans during delayed parachute jumps. The results of their investigations were published in the School's *Quarterly Bulleting* [9]. Their observations along with the theoretically obtained position as a function of time (Eq. (7)) show a good correlation amongst the two, thus attesting to the efficacy of the theory in describing the real phenomenon reasonably well.

From Fig. 3 we see that there are two phases in the free fall of solid objects from rest. In phase I the velocity increases with time while the body experiences a gradually diminishing acceleration. In phase II the acceleration of the object is almost zero, which implies that the velocity is constant and equal to the terminal velocity, obtained from Eq. (6) letting $t \to \infty$. The demarcation between the two phases is designated here by the time required for the acceleration to reduce to 1% of its original value (or to 0.01g).

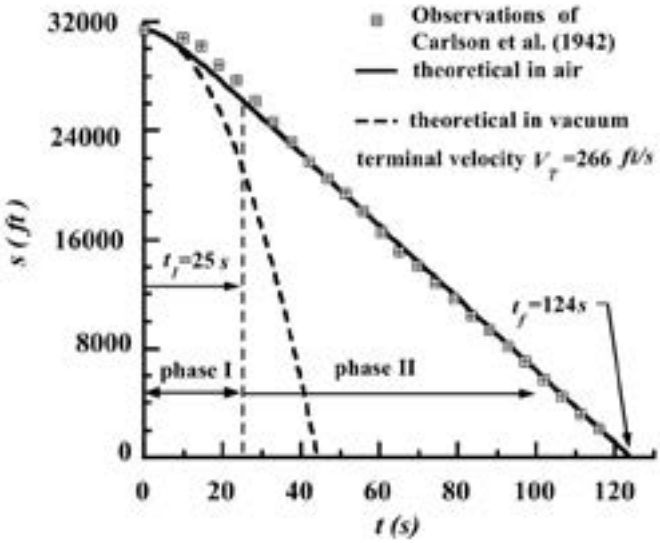


Figure 2: Altitude versus time of the delayed parachute jumps by Carlson et al. [9]. *In the presence of atmospheric air, the jumpers attained a terminal velocity of 265.7 ft/s and would have reached the ground after 123.9 s, while in vacuum they would have reached a terminal velocity of 1422 ft/s and their flight time would have been 44.2 s.*

3. 216[a]

4. Since the details of aerodynamic drag were known back then, Aristotle most probably by shape meant geometric and not hydrodynamic.

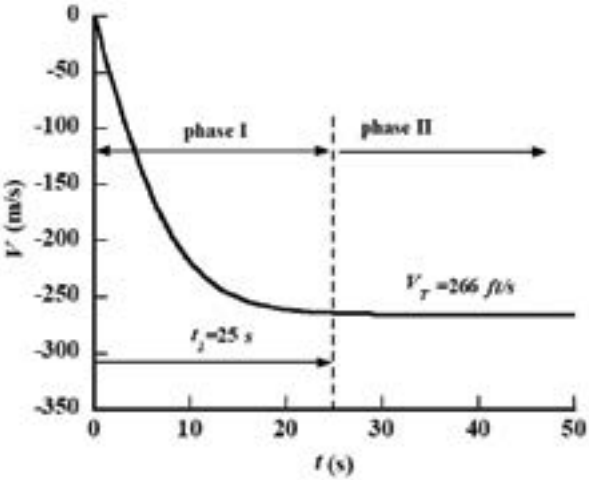


Figure 3: Velocity of descend versus time of the parachute jumper.

3. Analysis of the results

The study of free falling bodies in fluid media dates back to the times of Aristotle (384–322 BC). His theory remained intact until John Philoponus (490 - 570 AD) and after Galileo Galilei (1564 - 1642 AD) expressed objections.

Subsequent to many years of advances in physics, it is now clear from Eq. (1) (as well as tests in vacuum) that in absence of a fluid, the acceleration of any free falling body given by,

$$\frac{dV}{dt} = - g$$

is uniform, and that it does not depend on its mass or shape. Hence, in vacuum, objects will take equal times to cover the same distance irrespective of their weights or shapes. The last corollary is not applicable to Aristotle's theory, which is related to the motion of solid objects descending in fluid media.

Based on the present analytical approach let us now evaluate the claim, which appeared in *"Dialogs Concerning Two New Sciences":*

> *"Sagredo. But I, Simplicio, who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as such as a span ahead of a musket ball weighing only half a pound, provided both are dropped from a height of 200 cubits." p. 62* [6].

The position and flight time of the 200 and 0.5 pounds objects that correspond to

cannon and musket balls respectively calculated from Eqs. (7) & (8) are shown in Fig. 4. Although the two do not have the same aerodynamic form ($C_D A$), it is clear that the heavier object reaches the ground earlier that the lighter, as claimed by Aristotle[4]. It is true that the flight times of the cannon and musket balls are very close, $t_F = 4.33_s$ and 4.41_s correspondingly. However, their separation distance l_s (defined as the difference in height between the large and small objects when the large hits the ground, is 3 m (or 12 diameters of the cannon ball). This distance, is visually noticeable, and thus hardly "... a span ahead of a musket ball" p. 62 [6]. The previous is more evident if a musket and a wooden ball of the same diameter. In this case the separation distance would have been 24 m (or 96 diameters of the cannon ball). This experiment would have been more appropriate because all other things, including $C_D A$ are the same for both balls and only the weight is different[5] .

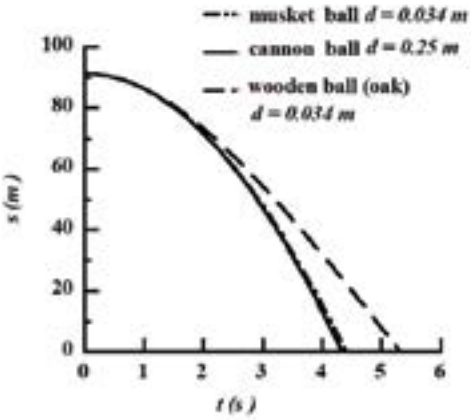


Figure 4: *Position of three different spherical objects in free fall (in air); cannon (steel), musket (steel), and made out of wood (oak ρ_s = 740 kg/m³). All three were dropped from a height of 200 cubits or 91.44m.*

In another section of *TNS*, the objection to Aristotle's statement, that the velocity of descent of a solid body is analogous to its weight are interpreted by the author as follows: "Aristotle says that "an iron ball of one hundred pounds falling from a height of one hundred cubits reaches the ground before a one-pound ball has fallen a single cubit". I say that they arrive at the same time" p. 64 [6].

Using Eq. (8) we find that the flight time of the large and small balls are 3.06 and 3.08 seconds respectively. From Eq. (7) we calculate that at the time of impact of the large ball, the separation distance between the two objects is 0.57 *m* (or 3 large sphere diameters), and the velocity ratio (V_{100lb} / V_{1lb}) at the time of impact of the large ball is 1.02. Note that both spheres have not yet reached their terminal velocities. Taking into

5. "...other things being equal" [3][1], after all in order to determine the influence of an independent variable on a dependent, one should vary the first and keep the remaining independent variables constant.

account the difficulties associated with accuracy of the experiment (like for example dropping the balls ate the same time), it is very possible that the two balls would have been perceived to be moving "with the same speed ..." p. 64 [6]. Is this then the experiment (where the effects of aerodynamic resistance are unnoticeable[6]) that led to the conclusion that all bodies fall at the same rate?[7] Although the last is a possibility, it cannot be answered without a good dose of speculation.

It is not known whether when Aristotle refers to "faster or slower" he is in fact speaking of terminal velocities. However, it is instructive to see if there is a possible connection of terminal velocity to his statements (i) & (ii). In terms of the terminal velocity Eq. (6) as was mentioned in [5] is:

$$V_T^2 = \frac{gm}{K} = \beta \frac{W}{\rho} \tag{9}$$

Where the term $\beta = 2/C_D A$ is the proportionality constant. The only difference between the previous, and the mathematical interpretation of Aristotle's thesis, is that the velocity squared (not the velocity alone) is directly proportional to the weight of the body, and inversely proportional to the density of the fluid medium. Rovelly [5] in this instance isolated V_T on the left by taking the square root of the right hand side of Eq. (9). Of course it would have been not possible for Aristotle to infer that the velocity must be to the second power without advanced measuring techniques and instruments.

Another erroneous conclusion in the old theory is associated with the ambitious extrapolation made by Aristotle to show that a diminishing fluid density will render the velocity unbounded (which is unreal), and thus mistakenly justify why void should not exist. Newtonian mechanics and detailed aerodynamic principles were not available at that time in order for him to realize that he was in fact dividing needlessly by zero.

The inherent contradiction of the Aristotelian dogma was allegedly established in *TNS* by the following "brilliant thought experiment" [11], *reductio ad absurdum*:

Salviati. If then we take two bodies whose natural speeds are different, it is clear that on uniting the two, the more rapid one will be partly retarded by the slower, and the slower will be somewhat hastened by the swifter. Do you not agree with me in this opinion?

Simplicio. You are unquestionably right.

Salviati. But if this is true, and if a large stone moves with a speed of, say, eight while a smaller moves with a speed of four, then when they are united, the system will move with a speed less than eight; but the two stones when tied together make a stone larger than that which before moved with a speed of eight. Hence the heavier body moves with less speed than the lighter; an effect which is contrary to your supposition. Thus you see how, from your assumption that the heavier body moves more rapidly than the lighter one, I infer that the heavier body moves more slowly.

Simplicio. I am all at sea because it appears to me that the smaller stone when added

6. Considering the experimental error.

7. It is interesting to note in passing that one hundred cubits is very close to the height of the 7th floor of the leaning campanile of Pisa.

to the larger increases its weight and by adding weight I do not see how it can fail to increase its speed or, at least, not to diminish it.

Salviati. Here again you are in error, Simplicio, because it is not true that the smaller stone adds weight to the larger [6], *p. 63.*

The proof would have been valid if Aristotle had claimed that in vacuum heavier bodies descent faster than light ones. Since he did not believe in the existence of a void his claims were relevant to the natural motion of solids in fluid media (as clearly stated in his book of Physics"). The system that consists of spherically shaped solids with different weights shown in Fig. 5 (as presented in Brown [12]), is not an appropriate paradigm to illustrate the absurdity of fall in a fluid medium, because α, β, and $\alpha+\beta$ do not posses identical hydrodynamic shapes.

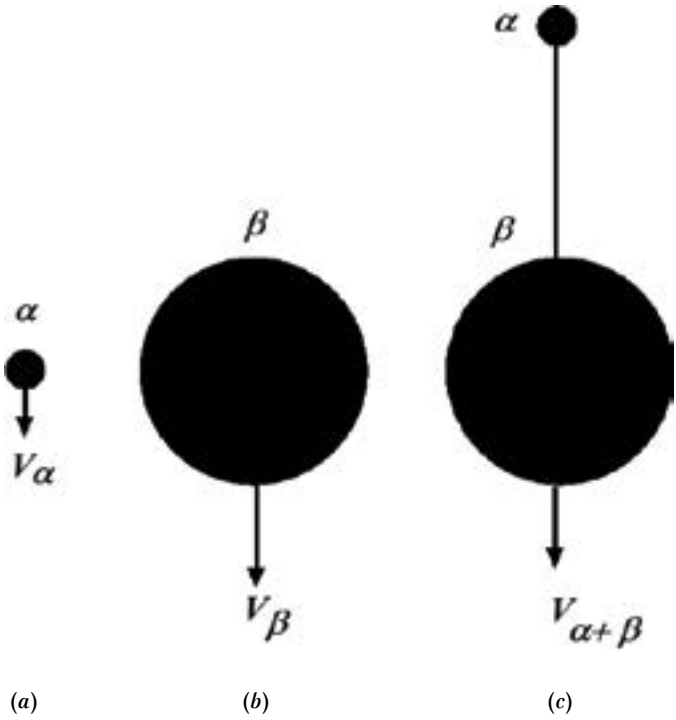


Figure 5: *(a) Small sphere α, (b) Sphere β larger than α, and (c) α and β, tied together.*

Let us restructure the *reductio* in such a way that the requirements of Aristotle's teachings (complemented with modern knowledge in dynamics and fluid mechanics) are taken into consideration.

Hypothesis: Two solid spheres 1 and 2 with the same hydrodynamic shape ($C_d A$) but different weights $W_1 > W_2$, when dropped from rest, in tranquil atmospheric air simultaneously, and from the same altitude (h), will hit the ground at the same time ($t_{f1} = t_{f2}$).

Analysis: For brevity let us take the already considered musket and wooden balls (musket ball $W_1 = 1.62\,N$ & wooden ball $W_2 = 0.15\,N$). From Eq. (8) we find that $T_{f1} = 4.41\ s$ while t_{f2}=5.31 s, or $t_{f1} < t_{f2}$, which contradicts the initial proposition.

Outcome: Hence, the hypothesis is not valid.

4. Conclusions

The problem of free fall of solid bodies was formulated using the conservation of momentum including the relevant aerodynamic effects. The derived equation was solved analytically and numerically. It was shown that if the experimenter in the *Two New Sciences*, performed indeed the mentioned (200 and 0.5 pounds balls) test, then he would have come to the conclusion that the heavy cannon ball reached the ground first followed by the lighter musket ball with a distinguishable separation distance. Based on modern knowledge in dynamics and fluid mechanics, we also found that the method applied in the previous monograph, to disprove the Aristotelian dogma is not appropriate.

Acknowledgement: I would like to than Mr. Georgios Panagiotakakos for his contribution in the numerical verification phase of the study.

References

1. Vatistas, G. H. (2002) “Floating Body Dynamics Inside Whirlpools as Described in Mythology and Literature”, 2nd World Congress, Ancient Greece and the Modern World, University of Patras, Ancient Olympia, July 12-17, Greece, 2002. http://users.encs.concordia.ca/~vatistas/OlymbiaPaper.pdf

2. Poe, E. A. "A Descent into a Maelström", First published in Carpenter's Penny book, under the title "In a Maelström", 1841, also Mabbott T. O. (Editor) "Collected works of Edgar Allan Poe II ", Belknap, Cambridge, MA, pp. 574-597, 1978.

3. Aristotle, “Physics,” in The Works of Aristotle, Volume 1, pp. 257–355. The University of Chicago, 1990.

4. Aristotle, “On the Heavens,” in The Works of Aristotle, Volume 1, pp. 357–405. The University of Chicago, 1990.

5. Rovelli, C. “Aristotle’s Physics: a Physicist’s Look”, arXiv:1312.4057v2 [physics.hist-ph] 18 Aug 2014.

6. Galileo G. “Dialogues Concerning Two New Sciences”, translated by Henry Crew and Alfonso de Salvio, Dover Publications Inc, New York, 1954.

7. White, F. M. “Viscous Fluid Flow”, 2nd Edition, McGraw-Hill, Inc., 1991.

8. Davis H. T *Introduction to Nonlinear Differential and Integral Equations*, Dover Publications Inc., New York, 1960.

9. Carlson, A. J., Ivy, A. C., Krasno, L. R., & Andrews, A. H. "The Physiology of Free-Fall Through the Air: Delayed Parachute Jumps", Quarterly Bulletin, Northwestern University Medical School p. 254, 1942. (Also in [8]).

10. Palmieri, P. " 'Spuntar lo scoglio piuù duro': did Galileo ever think the most beautiful thought experiment in the history of science?" Stud. Hist. Phil. Sci. 36, 223–240, 2005.

11. Brown, J. R. "Thought experiments", In W. H. Newton-Smith (Ed.), A companion to the philosophy of science. Oxford: Blackwell Publishers, 2000.

12. Brown, J. R. "Why Thought Experiments Transcend Empiricism ", Chapter 1, in "Contemporary Debates in Philosophy of Science", Edited by Christopher Hitchcock, Blackwell Publishing Ltd, 2004.

B3.12 Aristotelian Aether and Modern Physics

Konstantinos Kalachanis
University of Athens

Abstract

Since the Pre-Socratic period of ancient Greek philosophy it was widely accepted that the Universe consists of the four elements (fire, air, earth, water). However, in the Aristotelian philosophy a fifth element, the ether, is referred to, whose nature is considered as superior compared to the other elements. This theory, although abandoned by the Byzantines, came to prominence during the 17th and 18th century by Descartes, Newton and Huygens, acquiring a completely different content, being connected with light. The ether is no longer seen as the material that fills the Universe, but it is a means through which light is propagated (as a wave), as with the air and the sound. Even the Michelson-Morley experiment which is supposed to have proved that no ether exists, should not be related to the Aristotelian concept of this substance.

Introduction

The hypothesis of the existence of ether was examined not only by ancient Greek but was also studied in the Physics field. The philosopher who dealt extensively with this theory was Aristotle, arguing that ether is a material that fills the space beyond the Moon. In this paper the Aristotelian view on ether which is considered as a superior body in relation to the four elements will be examined. Then we will examine the concepts expressed in the 17th century which establish ether as light carrier, the Michelson-Morley experiment that rejects this assumption, and the objections of Silvertooth on this experiment. Finally, the role of ether in modern Physics will be presented and in particular the possibility that the theory of ether can be related to contemporary theories referring to the presence of a substance that fills the Universe.

1. The Aristotelian ether

Aristotle argues about the meaning of the ether, that previous philosophers had supported the existence of a first body beyond the known elements (fire, air, water, earth), ether, which is also called *ἀνωτάτω τόπον* (highest region). Also the term ether (*αιθήρ* in Greek) according to Aristotle derives from the words *θεῖν ἀεί* which means that ether is strongly related with the notion of motion and particularly of eternal motion, a view also supported by Plato in his dialogue *Cratylus* (410b, 6). Moreover Aristotle criticizes Anaxagoras for having considered the ether as a fire [1].

The reference of Aristotle to the highest region clearly refers to the main feature of his cosmology, which lies in the Universe split into two zones, the sublunar and the celestial region that lies beyond the Moon. This highest region (*ὁ περί τᾶς ἄνω φορᾶς*) is full of ether [2]. Instead the sublunar region is divided into four concentric spheres and identified each one of the four elements (fire, air, water, earth). Earth is the heaviest element and due to this attribute is found in the center (figure 1) [3].

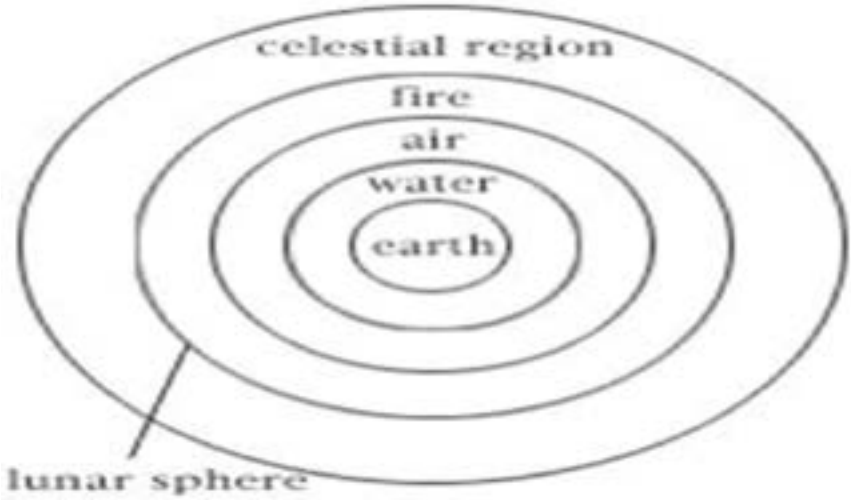


Figure 1: *the division of the Universe according to Aristotle* (*Source: what-when-how.com*)

Aristotle in order to strengthen his argument for a different construction of the sky relative to the Earth, referred to the issue of the motion of physical bodies. Specifically, Aristotle considered that there is another law that governs the rotation of celestial bodies different from the one prevailing on Earth and which causes the circular motion. A direct consequence of this move is that the heavenly bodies do not have a final resting point where movement will end, but instead they move circularly and end up into 'being' (ὄν). Hence, the Aristotelian commentators and particularly John Philoponus (490-570) calls the ether as σῶμα κυκλοφορητικόν (circulating body) [4]. This property of circular motion was given by Aristotle in the ether within the context that all natural bodies have a natural movement that has a beginning. Therefore, the motion of the physical body has an end where motion is stopped and the body relaxes [5].

The yield by Aristotle to ether of characteristics superior to the four elements is not an original teaching, since it reflects the argument expressed by Plato, who pointed out that the ether is the cleanest part of the air [6]. In fact, according to a commentary on Plato's dialogue Timaeus by neo-Platonic Proclus (412-487), the founder of the Academy has connected the four elements with the four solids (earth-cube, air-octahedron, water-icosahedron, fire-tetrahedron), yielding the pentagonal dodecahedron to the fifth element with which God formed the sky [7].

It is obvious that Aristotle attaches to Ether characteristics that differentiate it from the other four elements and also highlight its superior nature. Also considers ether as the substance of celestial bodies.

2. The luminiferous ether

The concept of ether in Byzantium was not accepted as inherently opposed to the basic parameter of the Christian teaching that God is the only cause of creation of the Universe and of its motions. Within this framework, Philoponus claims that the cause of motion of the sky is God. [8] Moreover, a Christian thinker could not accept the existence of an element which has divine attributes and is not affected by genesis and corruption while being outside the material world [9]. In addition to this, according to the Aristotelian notion ether is *first* in relation to the other elements and also the cause of creation, having the characteristics of a principle [10].

Following the rejection of the ether theory in Byzantium, the next that spoke on this issue were the medieval alchemists who referred to the ether as the material which pervades the entire creation, from plants and animals to the sky. Moreover in the 17th century, Descartes came up with the idea (Rene Descartes, 1596-1650) that the world is a machine that works due to the motion of matter. Furthermore, he spoke against the idea of a remote power, since the transmission must be a means of mediating, which should explain the transmission of light from the Sun to the planets. [11] This led to the acceptance of the existence of a thin material that permeates the heavenly bodies, and is also the reason that causes the turbulent motion from which the planetary orbits originate. This function of the ether is sufficient according to Descartes to explain natural phenomena such as gravity, while explaining the propagation of light, acting as its means of propagation [12]. In 1690, however, Christian Huygens (1629-1695) published his *Treatise on Light* (*Traite de la lumiere*), where he claimed that such sound waves propagate through the air, and light waves should respectively have a propagation medium. But the key point of Huygens's theory was undoubtedly the case of the wave nature of light, which finally was confirmed in the 19th century thanks to Hertz's experiments and Maxwell's equations that unified electricity and magnetism. Huygens claimed that if we observe the Sun and the stars, then the existence of the ethereal matter is necessary [13]. Opposed to the wave nature of light Newton[1] (Isaac Newton, 1643-1727) was, who –after having accepted the particle nature of light- does not exclude the possibility of interaction of the particles with a material such as ether [14].

It is evident that these scientists did not consider ether just as the material that"fills" the universe and also creates the heavenly bodies, but treated it as a light transmission medium. So they actually speak of luminiferous ether, which is present throughout the area, with the bright waves being vibrations of this material [15]. In addition, the ether should: 1) not affect the motion of solid objects (eg planets). 2) The laws of electromagnetism would take their simplest form in a reference system which

1. Today we know the phenomenon of wave-particle duality, where the fundamental entities of nature have wave and particle behavior.

is stationary with relation to ether, so it will be an absolute reference frame [16]. It is easily understood that the definition of ether as a light transmission medium is no way associated with the corresponding Aristotelian theory.

3. The experiments of Michelson-Morley and Silvertooth

In order to substantiate the hypothesis of the existence of the ether, Michelson and Morley performed in 1887 the homonymous experiment using an interferometer[2] (figure 2).

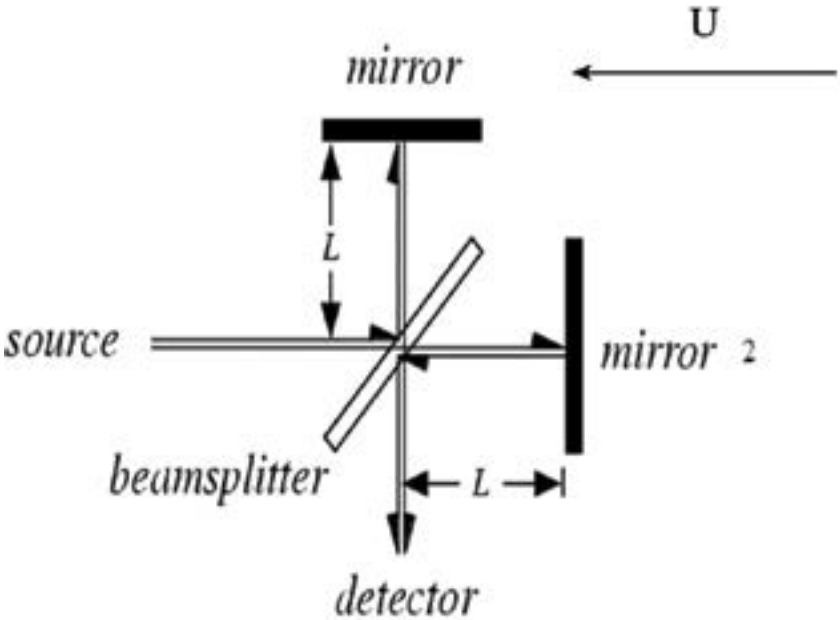


Figure 2: *the interferometer of Michelson and Morley scienceworld.wolfram.com*

A monochromatic beam of light from a single source is divided into two parts by a semi-silvered mirror (beamsplitter) with a 45° angle. The split beam after encountering two mirrors (mirror and mirror 2) is reflected and returns to the mirror, from which it results to the detector. The detector receives information from both mirrors, of which impinges half of each beam, thereby creating interference fringes. The flux of the radiation recorded by the observer will be a function of the ratio of the two phases of the rays that were in phase before their separation. In case of change of the distance travelled by each beam, then the phase will change and will be recorded by the observ-

2. Michelson, A. A.& Morley, E.W. (1887). "On the Relative Motion of the Earth and Luminiferous Aether" *American Journal of Science*, No 223.

er. Moreover, the motion of the Earth through the ether (which is strongly aligned with one of the two arms of the device) will be equivalent to the case of the ether flow (U) in the opposite direction. In this case the speed of light which is approaching the mirror 2 measured by the reference system (Earth) will be c - u under the rule of Galilean velocity-addition and when removed after reflection should be c + u. During the experiment no change in the fringe pattern was recorded, and no change in the speed of light. Yet even in experiments conducted in other laboratories, no change of the interference fringes was ever detected [17]. The fact that no difference was observed in the speed of light means that ether should not be considered as a means of propagation of light.

The impact of the experiment in the development of Physics was decisive, and led Einstein to the formulation of the two basic postulates of the Special Theory of Relativity (STR):

1) The speed of light in vacuum is always c = 299.792.458 m / s, in all inertial reference systems.

2) The laws of physics are the same in all inertial reference systems. Consequently, in any measurement of the speed of light no change will be observed.

According to STR there is a universal, absolute and mathematical time and space, as it was known in Newtonian physics. In this case the time intervals measured are a function of the speed of the observer's motion. Phenomena such as time dilation, have been observed in STR during which a moving clock is slower than a clock that stands still. Therefore speed changes the perception of time for each observer [18]. Apart from the time dilation in STR contraction of the length is also observed, by which the length of a moving object (with a speed close to the speed of light) is smaller than its proper length which occurs only in the direction of motion [19].

In 1987 E.W. Silvertooth constructed a standing wave interferometer through which he attempted to measure the Earth's motion through the ether. His criticism on the experiment of Michelson-Morley was about their measurement of the speed of light without being referred to the motion of the observer. Silvertooth took into account this parameter while using a more modern version of the Sagnac experiment[3]. Specifically he carried out an experiment claiming that there may be standing waves of different wavelengths measured by rays that move in opposite directions along the same route. Instead of rotating the entire device and recording displacement of the standing wave, he rotated only the detector while using a sensor that measures the distance between the standing wave nodes. Calculating th distance between standing waves Silvertooth argued that on a given day of the experiment a motion 378 m/s of Earth to the constellation of Leo was recorded.[20] Although the results of the experiment have been questioned, however, the contribution to the study of the ether is acceptable.

It is remarkable that although Einstein had initially rejected the ether hypothesis, however, he admitted that the ether is compatible with the General Theory of Relativity. Otherwise, we would have to assume that empty space has no physical properties

3. O French physicist Georges Sagnac (1869-1928) found that two identical light waves, which are at the periphery of a circular experimental set, return the emission point covering the same distances at the same times. But if we rotate the device, then the waves return to the launch point having traveled different distances at different times. Accordingly is recorded a phase difference between two light waves.

[20]. However, in such a case we have a material that fills the seemingly empty space.

From the above it is obvious that according to the results of the Michelson-Morley experiment ether hypothesis as a light transmission medium is rejected. But this fact has contributed to the formulation of STR, expanding human knowledge beyond the limits of Newtonian Mechanics. Nevertheless, the perception cultivated on the ether has absolutely no relation to what was claimed by Aristotle. Instead, the aspect of ether highlighted by Einstein is much closer to that of Aristotle.

4. Is there a place for ether in modern Physics?

Although the theory of luminipherous ether has been abandoned in Physics, however, the question of its existence remains open for the following reasons: a) The Aristotelian concept of the ether as a material of construction of the heavenly bodies should be sufficiently explained. b) The ether is a key argument in favor of the absence of vacuum. However, since ancient times there have been suggestions (Leucippus, Democritus) which attribute creative properties in the vacuum which has not the meaning of “nothing” [21].

The formulation of a theoretical model based on the Aristotelian theory, should have as a basic parameter the fact that the ether "fills" the Universe. A case of a material that fills the Universe is the cosmic background radiation (CBR) which was discovered by the astronomers Penzias and Wilson. This radiation is the "echo" of the Big Bang, thus confirming the hypothesis of G. Gamov on the "trail" which had left the Big Bang (Figure 3).

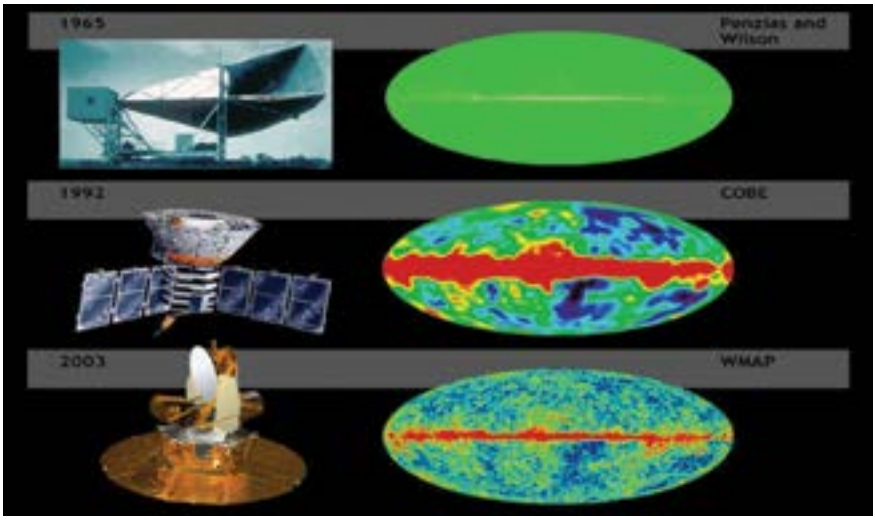


Figure 3: *In the picture one can see the detail in the recording of the cosmic background radiation by Penzias & Wilson, and by the COBE and WMAP satellites. The Milky Way corresponds to the strip in the middle.*

The blackbody radiation measured by both astronomers had a temperature of 2.73 K emerging from the whole Universe and is also isotropic. This isotropy contrasts with observational data showing that at large scales and distances in the Universe there are big "walls" consisting of galactic superclusters, and large gaps between them. This radiation could be potentially used as a reference system for our local movement (movement of the Earth around the Sun, movement of the sun in the Milky Way and of our galaxy relative to the galaxies of the Local Group). In relation to the motion of our neighboring galaxy, an increase in temperature in one direction has been recorded, while reducing the opposite. In such a case, however, the CBR despite running the Universe, cannot be related to the ether as light transmission operator [22]. But it is a material that spreads throughout the Universe, just like ether, but with the difference that it is merely a result of the Big Bang and not a "first body", that causes the creation of everything.

Apart from the CBR, the observational data from the Universe, demonstrate that indeed there is a material that "fills" the space and is not perceived by our senses. In particular, the matter of the Universe we perceive is only 5% while 68% is attributed to dark energy which led to the expansion of the universe. Finally 27% of the matter of the Universe is dark matter, which owes its name to the fact that it does not interact with electromagnetic radiation.

But since dark matter is invisible, astronomers have resorted to other means of "tracking" it. Specifically they used: a) supernova type 1a as waxes standards. b) the accelerated expansion of the Universe 3) effects of the gravitational lens to calculate the mass of galaxy clusters, reaching the conclusion that there is much more matter in the Universe than we can observe. This fact led to the conclusion that galaxies are not dissolved despite their fast rotation. So astronomers yielded this phenomenon in the dark matter surrounding galaxies and detected by the gravitational pull. There are also observational data supporting this view gathered by Fritz Zwicky (1898-1974) from the galaxies of the Virgo cluster, which showed that the mass of galaxies is not sufficient to maintain coherence. Therefore there must be an invisible mass that secures the flock cohesion (Figure 3) [23].

Dark matter is assumed to consist of [24]: 1) diffuse gas that does not radiate, but absorbs light from quasars. 2) Very hot gases that emit not in the visible spectrum, but in X-rays. 3) Compact dark objects such as black holes and dead stars. Possibly even part of the galaxy's mass consists of baryonic matter object which is called MACHO (Massive Astrophysical Compacte Halo Objects-Great Mass compact astrophysical objects). These objects do not emit light and are difficult to identify. According to another view, dark matter consists of hypothetical exotic matter (massive neutrinos, gravitons) called WIMPS (Weakly Interacting Massive Particles-weakly interacting massive particles). Particularly so, neutrinos created in the Big Bang, fill our galaxy and their observation is only possible through specialized detectors.

So dark matter shares a common property with ether because it fills the Universe. Obviously this characteristic that is attributed to the ether is of great importance in modern Physics.

Epilogue

From the above it is obvious that the Michelson-Morley experiment, which was based on the ether hypothesis as a medium of light propagation, is not associated with the Aristotelian doctrine of ether, which is considered by the philosopher as the material forming the stars and the sky. Therefore that consideration of the ether is not related to the Aristotelian conception. However, scientists have shown that in the Universe apart from the observable matter exists and a non-directly observable material that fills the space and is called dark matter. Thus, the Aristotelian theory of ether as a material that fills the universe has common points with modern scientific discoveries.

References

1. Aristotle, *De caelo*, 270b, 20-23.
2. Aristotle, *Meteorologica*, 339b, 16-18.
3. Aristotle, *Περί Ουρανού*, 308b, κ.ε.
4. Ibid 279b, 3 and Philoponus, *Contra Proclum*. 520.
5. *Αυτόθι*, 301a, 20-21 and 304b, 14. See also Kalachanis, (2011).
6. Plato, *Timaeus*, 58d, 2.
7. Proclus, *On Timaeus*, II, 45, 17-22. See also Spyridis, (2015).
8. Philoponus, *De opficio* 28, 20 - 29, 9.
9. Φιλόπονος, *D. Gen and Cor.* 67, 17.
10. Philoponus, *De opficio*. 9, 2.
11. Whittaker, (1910), pp.5-6.
12. Cushing (2003), pp. 239 κ.ε.
13. Krauss, (2006), pp. 51-53. and Kalachanis (2015).
14. Hall & Hall (eds) pp.189-191.
15. Kalachanis, (2015), p.122.
16. Serway et al. (2007), pp. 5-10.
17. Kalachanis, (2015), pp.123-125.
18. Aristotle, *Phys*. 223 b, 12 and Kalachanis et al. (2013).
19. Serway et al. (2007), pp.12-18.
20. Kostro, (1994), p. 200. See also Bitsakis, (2014), pp. 72-73.
20. Βλ. Silvertooth, (1987) and (1983)
21. See also Kalachanis, (2012).
22. See also. Kalachanis, (2015).
23. Danezis & Theodosssiou, (1999), vol. B΄ p. 206.
24. Krauss, (2005), pp.118-119.

Bibliography

Aristotle, (1956). *De Caelo*, ed. P. Moraux, Les Belles Lettres, Paris.

Aristotle, (1919). *Meteorologica*, ed. F.H. Fobes Harvard University Press, Cambridge.

Cushing, T. (2003). *Philosophical concepts in physics, the historical relation between philosophy and scientific theories*, Cambridge University Press, New York, (trans. in Greek M. Orphanou, S. Giannelis, ed. K. Skordoulis), Athens, Leader Books.

Hall, R. E. and Hall, M.B. (eds), (1978). *Unpublished Scientific Papers of Isaac Newton*, Syndics of Cambridge University Press, Melbourne, Australia.

Theodossiou, E. & Danezis, M. (1999). *The Universe that I loved-Introduction into Astrophysics*, Athens, Diavlos Publications [in Greek].

Kalachanis, K. (2011). *On the Paradigm and the icon in the work of John Philoponus*, Phd Dissertation, Dept of Philosophy-Pedagogics-Physchology, Dept. of Philosophy, University of Athens, Greece [in Greek].

Kalachanis, K. (2012). "Cosmological views of the Atomic Phillosophers", *Physics News*, Hellenic Physicists Society issue 3, July pp.13-16 [in Greek].

Kalachanis, K. (2015). "From ether to dark matter" *Socrates, International Scientific Review of Ancient Greek Philosophy*, vol. 1 International Scientific Association of Ancient Greek Philosophy, pp.121-130 [in Greek].

Kostro, L. (1994). "The physical meaning of Albert Einstein's Relativistic Ether Concept" *Proceedings of International Conference of Fundamental Physics, Olympia, Greece*, Springer Publ. New York, pp. 193-202.

Krauss, L. (2005). *Quintessence* (trans. in Greek Th. Grammenos), Athens, Travlos Publications, [in Greek].

Bitsakis, E. (2014). *Time and Space, an ongoing research* Athens, Agra Publications [in Greek].

Philoponus, J. (1899). *Contra Procli de aeternitate mundi*, ed. H. Rabe, Leipzig Teubner.

Philoponus, J. (1897). *De opficio mundi*, ed. W. Reichardt, Leipzig: Teubner.

Philoponus, J. (1897). *In Aristotelis libros de generatione et corruptione* ed. H. Vitelli, CAG 14.2. Berlin, Reimer.

Plato, (1968). *Timaeus*, ed. J. Burnet, Oxford: Clarendon Press.

Proclus (1906). *On Plato's Timaeus* ed. E.Diehl, Leipzig, Teubner.

Spyridis, Ch. (2015). "The Pythagorean orthogonal triangle" *Proceedings of the 3rd Scientific Conference Philosophy and Cosmology*, Piraeus, Aegeis Publications.

Silvertooth, E.W., (1987). "Experimental Detection of the Ether", *Speculations in Science and Technology*, Vol.10, No.1, p. 3.

Silvertooth E. W and. Jacobs S. F. (1983). "Standing wave sensor" *Applied Optics* Vol. 22, Issue 9, pp. 1274-1275.

Whittaker, E.T. (1910). *Theories of Aether and Electricity*, Longmans, Green and Co, Dublin.

B3.13 'ΚΑΙ Ο ΚΥΚΕΩΝ ΔΙΙΣΤΑΤΑΙ' K. G. Beltsios World-Structure Formation and Matter According to the Presocratics

Konstantinos G. Beltsios
University of Ioannina, Greece

Abstract

Presocratics sought explanations for the spatial differentiation exhibited by the immediately perceived world (and, possibly, by Cosmos as well); in the general case they accepted as a starting point the existence of matter that was homogeneous (at least above a certain size scale), while 'phase' separation or 'phase' transition processes followed. Other considered processes include the action of membranes, sedimentation, drying and more. Versions involving transmutations reflect Pre-Parmenidean confusion between phases and elements. Some of the views in consideration share features with certain current cosmology/cosmogony views while several are more interesting as suggestions for structure formation processes in our *immediately* accessible world. Here we emphasize pertinent background fundamentals, then briefly consider possible guidance from analogs and conclude by discussing interesting aspects of some cosmogony examples. Presocratics offer material [1] often competing with 19th c. views and not necessarily exhausted today.

1. Introduction

Presocratic natural philosophers, many of them Ionians (from Ionia, Samos and colonies, including Abdera and Elea), are active during the 6th and 5th c. BC in the often threatened periphery of the Greek world. Their views about nature are largely qualitative, with the exception of the number-guided views of the Pythagoreans and isolated examples, such as an obscure 'reaction' equation of Heraclitus (B31A) and some equally puzzling ratios in Anaximander (A21-22) and Empedocles (B36). Culmination achieved upon inspired consideration of key claims of the Heraclitus–Parmenides dipole by Anaxagoras, Empedocles & Democritus; some of the ideas of the latter compare well with 1800+ AD qualitative views about natural phenomena.

The title of this presentation incorporates part of Heraclitean B125: 'ὁ κυκεὼν διίσταται κινούμενος'. Kykeōn is a multiphase ritual drink; a cosmological hint is possible. Dissociation refers to separation at a large scale while kykeōn is already heterogeneous at a smaller scale. The often suggested correction '*μὴ* κινούμενος' might not be necessary if a reference to a 'δὲ ἵσταται κινούμενος' form is implied (ἵσταται = remains [mixed]) [2] and/or because certain modes of stirring can cause separation (instead of mixing); yet, Heraclitus competes mainly with recent key poets.

2. Fundamentals I: In place of Thermodynamics

Thermodynamics begins its life at around 1850. Key thermodynamic concepts include heat and temperature, energy and work, enthalpy and entropy and thermal, mechanical and species equilibria. While the basic thermodynamic framework is absent (and in particular there is nothing closely related to entropy and/or the *Second law*), some Presocratics did perceive some related concepts.

The First law is about energy conservation and conversions of its forms. But energy, in its post-1850 technical sense, is a difficult to perceive concept while its occasional comparison with Heraclitean fire is arbitrary. Less impressive but safer conclusions arise from Post-Parmenidean consideration of *matter* conservation on a species basis; then fire (somewhat close to modern Heat), assumed to be of material character, is conserved and this idea shares features with the conservation of Caloric, a view that was popular from ca 1780 to ca 1850 and was eventually overthrown by the 1st law. On the other hand, inferior pertinent views (ranging from the protoalchemical transmutations to changes attributed to the transfer of phlogiston) prevailed between the 4th c. BC and the late 18th c. AD. As regards conversion, Heraclitus suggests (B90) that there is an equivalent of fire (hence of Heat) for all things; however pertinent conversions have the form of matter transmutations under *ordinary* conditions and, hence, this is closer to alchemy than to 'modern science'.

Heat & Temperature. The difference between heat and temperature was not well understood before Joseph Black in the 1750s while the related concepts of hot and cold continued to confuse able thinkers for decades and the general public up to now; yet, Democritus theorized that cold matter is simply a less warm one and there is no objective coldness opposite to hotness.

Enthalpic interactions, attractions & repulsions. Empedocles suggests that a special material pair of active agents affects mixing: Love favors full mixing and Strife favors full separation of the four elements, while comparable impacts of the two agents lead to a rich world-structure. The two agents in consideration (vaguely comparable to a Yin-Yang pair) change position within the passive matter of the world and the organization of the latter varies periodically (but quite slowly). If we prefer to emphasize the *material* character of the two agents we might, for example, compare Love to some universal glue; yet, essentially, the two agents act as a pair of *forces*, an attractive (/non-discriminating) and a repulsive (/discriminating) one. The thermodynamics of mixing/separation require consideration of composite free energy functions (which include entropy terms etc); however the work of Empedocles does *not* provide a realistic ground for pertinent comparisons. On the other hand, attractions and repulsions relate more directly to enthalpic interactions; while an enthalpy-based criterion for mixing and separation is an imprecise one, it suffices to note that it was supported vigorously by Berthelot, a leading chemist of the second half of the 19th c.

As regards Democritus, it is occasionally suggested that he admitted atomic attractions and repulsions from a distance; however, if nothing else, his theory about magnetism should have been less awkward than that in A165. Certainly, Democritus describes same as tending to group with same etc (B164, A128) with a somewhat awk-

ward inclusion of *animate* examples; yet, there is a response-based rather than an interaction-based atomic explanation: when processes such as shaking, spinning etc contribute to relocation, same atoms respond in the same way and different atoms respond in different ways; hence, same end up at comparable locations (i.e. 'together') and different at different places. The atomists sought a minimalistic framework of hypotheses and believed in an inherently mechanical universe where attractions and repulsions were large-scale possible perceptions with no genuine atomic-scale counterparts.

Equilibria. The idea of a pressure balance is a near natural one in the case of fluid phases but we will consider briefly a different case of a *mechanical stability/equilibrium* idea. Anaximander argued (A26, A11) that while there is motion in the Universe, Earth equilibrates at the equidistant center (see also 28B8.43-44). Related symmetry arguments are occasionally encountered in the physics of the 20th c.; e.g. in a polymer melt the forces that can affect the equilibrium chain shape are equal and opposite and, hence, the equilibrium chain shape is the *unperturbed* Gaussian one. As regards *species equilibria* it is instructive to consider the atomistic model of life sustained by *soul* atoms (*see* also below). The atmosphere exerts a pressure to the body but the concentration of the soul atoms of a living body does not diminish as air also supplies soul atoms (67A28); life persists as long as the particular atom balance is preserved. This is not unlike equilibrium for a particular *species*, as a result of equal chemical potentials of this species in two phases, a gaseous (air) and a condensed one (body), in contact. Further, a simple adjustment of the same idea (with fire instead of soul atoms) can allow for the description of a *thermal equilibrium* between two bodies (or two phases etc) without a need to refer directly to something like temperature; however, no pertinent Presocratic hint survives. Finally, an accidental but exciting outcome of the Anaxagoras handling of matter conservation should be noted: in modern multicomponent *equilibrium phase diagrams* each phase contains [at least minute] amounts of all components and this, in view of 59B11, can be described as the 'rule of Anaxagoras'.

3. Fundamentals II: Arranging and rearranging matter

Motion & Atomism. For 5th c. BC atomists atoms and void are equally real and the latter facilitates motion/rearrangement; void and its distribution within masses were used to explain fluidity, the possibility of one material being denser but softer than another and more. Weight might be directional and depending on the location within a cosmic vortex while there is no weight outside vortices. Possibly the first atomists felt that as regards the experienced gravity effect, revolution (within a vortex) is a more fundamental cause of motion (beyond the inherent one of atoms) than, say, some magic-like action at a distance. Atoms in (or: *small* particles within) fluids follow crooked paths. As regards straight-path motion we might borrow from Post-Aristotelian atomists (Epicurus and Lucretius, DRN 2.230-2.239): in addition to the, supposedly inherent, irregular motion of small entities, it is possible that large particles move with equal velocities when they follow parallel paths within vacuum, while the larger particles move faster in straight paths when within a fluid medium. This is a fully correct blend, though,

admittedly, it is not necessarily representative of *Presocratic* atomists as the Post-Aristotelian atomists adopt a modified set of assumptions for the description of particle motion. Finally, a charming description of pertinent to random walk is provided not by an Atomist but by Parmenides (B 6.5-9); yet it is not correct that random walk 'leads nowhere', as Parmenides appears to suggest.

Non-condensable matter. Post-Parmenidean Presocratics assume special forms of matter capable of performing unusual functions. The Mind of Anaxagoras, the Love & Strife Pair of Empedocles and the fire & soul atoms of Democritus are key examples; overall they resemble somewhat the quasi-Imponderable forms of matter often considered in more recent physics.

Let us briefly consider the fire and soul atoms of the Atomists (67A28); the traditional coldness/soul (ψῦχος/ψυχή) Greek connection is rejected; there is no genuine coldness and soul resembles fire. These atoms are round and mobile, lend mobility to matter, sustain life and their smooth round surface prevents the formation of a condensed phase (as for atomists bonding is mechanical only); on the other hand, for the Caloric of ca. 1800 non-condensation is a result of self repulsion of its units, while mingling of its parts with those of ordinary matter occurs via attractions.

Ordered matter. Crystallography type ideas are encountered in Democritus. The atoms (found in condensed matter) differ as regards form, type of [interatomic] contact and orientation (67A6). According for Empedocles (A87, B91), mixing is not possible if the pores are not commensurate; Empedoclean matter is not discrete and, possibly, pores define a scale below which there is no mingling of elements. Of further interest is the Empedoclean reference to the composition of e.g. bone (fire/water/earth = 4/2/2 parts, B96) and flesh & blood (fire/water/earth/air = 1/1/1/1 parts, B98). But why is there a reference to 4/2/2 and not to 2/1/1 parts? It might be that the locations of the elements fitted together (B107) to form bones relate to the 8 corners of a cube, while a 1/1/1/1 composition might be related to the corners of a tetrahedron; this might be another crystallography-related Presocratic idea, this time with Pythagorean overtones.

4. Analogs

As regards Presocratics and experiment the modern view is often a concealed unsafe extrapolation of Plato's attitude to Pre-Platonic times. However some of the 5th c. BC conclusions can be best explained as a result of combination of theoretical inspiration and qualitative observations, including those involving analogs (a quite useful yet 'often misleading' [3] tool).

Tigner [4] considers a possible Empedoclean study of an analog. 31B100 and 59A68-69 are examples of the few surviving actual references to experimental observations. B9 of Anaxagoras hints at a qualitative extrapolation of observations as regards separation depending on the swiftness of revolution.

In the case of Democritus, who apparently envisioned a mechanical universe with some fractal features (e.g. motes move like atoms, 67A28, and a human resembles a small world, 68B34), it makes sense to probe the world at the most convenient scale;

here the study of analogs might have included particles (e.g. pebbles, seeds, sand) of different sizes and shapes subjected to shaking (in open containers), dropping (in fluids), mixing (e.g. pebbles with sand for the study the non-additivity of volume; the same with water and ashes, as in 67A19), sieving, swirling (68B164) and spinning (with fluids within conical vessels of different sizes; a side-outcome might have been the empirical, according to Archimedes, Democritean determination of the expression for the volume of a cone). It is also possible that Democritus was interested in the potential temporal fractality of the world as there are reports of weather forecast in the meromēnia manner (e.g. Pliny, NH, XVIII, 231).

5. World-structure formation views

According to Aristotle (Physics, 187a12), some Presocratic physikoi explain material diversity as a result of transformations induced e.g. by force-fields and having the form of transitions (e.g. as in Anaximenes) or separations (e.g. as in Empedocles). Presocratics also consider diverse Unit Operations (membrane-based separations, sedimentation, drying and more). Some *Pre*-Parmenidean transformations are essentially transmutations because of confusion of physical-chemical changes with elemental changes; the latter confusion ceases after Parmenides but reappears with Plato and Aristotle. Finally, Presocratic cosmogony considerations are supplemented by biological imagery (e.g. elements as roots, nuclei-seeds, secretion, growth, death of worlds, bark-like layers, biological-like membranes etc). Examples follow.

Anaximander. The 'Boundless' in eternal motion generates (A9-10, B1) of pairs of opposites (hot/cold and dry/wet); if the opposites pre-exist in a [homogeneous] *mixture* the idea is close to modern phase separation (in Anaximander as "*substance*' separation'), though especially in the case of the hot/cold pair the described process is not one permitted by thermodynamics. Alternatively, the 'Boundless' is a *simple* 'substance' that yields pairs of opposites upon splitting in various ways (compare e.g. with: Sphere * N+S Hemisphere or W+E Hemisphere). Between Parmenides and Plato, a simple substance cannot convert to another substance or pair of substances etc and, more or less, only the *mixture*-based process is permitted; however a Post-Parmenidean issue was not necessarily a subject of Pre-Parmenidean concerns. Further, biological processes might have provided inspiration, at least in part, as an attained differentiated structure was compared to a tree trunk and its bark (A10). Finally, additional processes, such as condensation of 'air' (confused with water vapor) and Earth's drying, lead eventually to the formation of the structure of this world.

Anaximenes. Anaximenes emphasizes phase transitions as a result of change of density (a modern physics echo is a, based on difference of densities, 'order' parameter for isotropic phases). The following is a possible sequence of main phase transitions (confused with transmutations, as phases are confused with substances), via rarefaction or condensation steps (A5):

fire ↔ air ↔ wind ↔ cloud ↔ water ↔ earth ↔ stones

As regards cosmogony (A6, A7), Anaximenes considers air in motion as a starting point, while transitions and additional processes lead to the formation of the universe;

the aforementioned sequence is not followed everywhere as, e.g., Earth forms directly from air. We might also note that winter in Ionia offers the chance to observe that ice is less dense than liquid water; hence, Anaximenes, who did relate cold to 'compressed' matter and hot to 'slack' matter (B1), should have been aware of this density inversion; it is even possible that the same inversion contributed to the earlier view of Thales that water-derived Earth floats on liquid water (B14). However, antiquity was also aware of rock-crystal (SiO_2 single crystal), which was viewed as a 'very frozen' and, hence, denser etc form of ice; thus, the scheme of Anaximenes was '*eventually*' followed.

Heraclitus. Fragment B31A describes a puzzling sequence, apparently first a transmutation-type transformation of fire to sea and subsequently a separation-type of step; the details, including the literal meaning of the term 'tropai', are strongly debated while confusion is enhanced when related fragments [B31B, B36, B76] are also taken into account. However, there is no guarantee that the nature-related Heraclitean oracular sayings reflect *self*-consistent 'physics' views. At the same time, Heraclitus is strongly interested in sound patterns and that for the consonants of B31A is '123/421/124[...] 12342', where 1-4 = π-τ, while in the intervening part there is an echo from the repetition of two words. Then, the puzzling 'prēstēr' (a phenomenon and not an element) might appear in B31A partly because of its consonant pattern (so that B31A starts and ends with the same, 12342, sequence); in brief, it should not be overlooked that 'prēstēr' makes B31A *sound* good. In any case, 'neither god nor human created this 'cosmos'' (B30); this statement might be related to the idea that the [changing] arrangements of world parts follow natural patterns/laws and do not reflect, e.g., the caprices of Greek gods.

Atomists. For given conditions, particular atomic processes will occur necessarily/'by necessity', especially according to the Presocratic atomists, for whom 'necessity' (67B2, 68A66) might be an umbrella for deterministic (yet, often, still unknown) natural laws (+ spontaneous cosmic vortices); these atomists accept neither genuine chance nor purpose. In an atomistic cosmogony a vortex suddenly forms and atoms are sorted out (like with like); rotation supposedly is of such type that larger particles/atoms remain near the vortex axis while finer atoms move towards the periphery (though in reality the opposite is also possible under certain whirling conditions; yet, in any case (from an atomistic perspective), the smaller atoms can cross the layers of the larger atoms as long as rotation persists). These thinkers also suggest that certain (such as hook-shaped (67A23)) types of atoms entangle and form a spherical membrane which acts as an atomic/molecular sieve etc but also provides a first spatial definition of what, following additional processes, will become our earth-centered spherical world. The cosmogony and world views of these Atomists (e.g. 67A1, 67A10, 67A22, 67A24, 68A1) are in part conservative ones (e.g. according to Democritus earth is more or less flat, as in Anaximenes, 13A20; this is one of the hints for a possible unknown Milesian 'bridge' between Anaximenes and Leucippus) and in part provocative ones and comparable to recent views (68A40, 68A82): the Universe includes many worlds (some possibly populated; see also 70A6), worlds form, collide and disappear etc.

References

[1] H. Diels & W. Kranz, Die Fragmente der Vorsokratiker, 6th Ed., Berlin, 1952

[2] M. McKenzie, Amer. J. Philology, 107, 542, 1986

[3] P.-G. de Gennes, private communication, March 26, 2007

[4] S.S. Tigner, Isis, 65, 432, 1974

B3.14 The Big Bang Theory According to Hesiod's Theogony

Ioannis Karadimitropoulos

Abstract

The creation of the universe has always fascinated civilisations including the Hellenic one. The small amount of ancient Hellenic literature that has been preserved is enough to initiate our comprehension into our ancestors' way of thinking. Mystic Hesiod, in his epic poem Theogony, describes in a few verses the facts concerning the creation of the universe.

Astrophysicists consider that our universe has been created as a result of the Big Bang of a highly condensed and over-warmed singularity. Since then the universe is ever expanding.

By making use of a **mystical** approach and **spiritual** analysis it is possible to relate the modern theories on astrophysics to verses 116-128 of Hesiod's Theogony. Hesiod presents his knowledge to his contemporaries as well as to future generations in a "**philotis**" (friendly) manner. Hesiod himself notes that he wrote Theogony under the divine direction and narration of Muses, the daughters of Zeus, father of all Gods and Humans.

1. Introduction

Out of all the scientific theories concerning the creation of universe, a widely accepted one amongst astrophysicists is known as the Big Bang theory[1]. In his epic poem **Theogony**, Hesiod presents poetically the creation of universe. The similarities between astrophysics and Theogony, concerning the events that took place during the Big Bang, exceed the limits of simple coincidence and challenge us to be open minded.

The description of universe's creation in Theogony starts in verse 116. Verses 1 to 115 describe firstly, the sacred rite of aquatic purification of Muses, secondly, the hymning of Gods and finally, upon Zeus' request, the initiation of Hesiod into the Apollonian arts of **music** and **poetry** so that, being divinely inspired, to hymn and narrate both the past and the future.

Hesiod is considered on the one hand, the **second most important epic poet** of antiquity and on the other hand to have derived his topics from **imagination** as well as **experience**. Not even Homer has escaped the characterisation of being a falsehood narrator, despite the fact that archaeology and other sciences prove his poems' narrations truthful.

---

1. *Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extragalactiques, 1927, Georges Lemaître, Catholic Priest, Astronomer and Physist at University of Leuven. "The universe in a nutshell, Stephen Hawking. Έκδ. Κάτοπτρον, 2001, σελ.23",*

2. The true meaning of the word "Myth"

The deliberation that Hesiod refers to non-real events directs us to place special emphasis on the difference, in both meaning and notion, of the words "μῦθος-[mythos] (myth)" and "παρα-μύθιον-[para-mythion] (fairy tale)". Modern science and common opinion consider both words as synonymous to narration of facts that are either non true or born by the author's imagination. On the contrary, the lexicon of Liddle & Scott distinguishes the meanings of these words and interprets παραμύθιον ([paramythion]-**fairy tale**): as exhortation, consoling or hortatory stories and **Μῦθος** ([mythos]-**myth**): **whatever is narrated** verbally, including **history**, regardless of being **true** or **false**.

By not understanding the correct meaning of the word **myth** one yields to misconception, misunderstanding and rejection of preserved truths such as the **Trojan War**, the **Minoans** and **Mycenaean** civilizations.

The truth exists in the core of every myth. Considering the words **myth** and **para-myth** as having identical meanings, one frames an unreasoning reason (παρά-λογον λόγον), a misjudged judgement (παρα-φρονούσης φρονήσεως), a misconceived conception (παρα-νοοῦντος νοῦ) and a counterfeiter (παρα-χαράκτου) of truth.

3. Fundamentals of the Big Bang Theory

The **Big Bang theory** accepts that the universe has a starting point[2] that is considered to have taken place 13.7 milion years ago. Before that start **there was no space, mass, time, energy. During the beginning** there was a **very high density** and **high temperature stage**, a **singularity**[3] that **exploded** or, according to others, **expanded**[4], unrolling the universe. The explosion's or expansion's products started **staving off** each other and since then universe is ever expanding[5]. Evidence of the Big Bang is considered to be the existence, in the visible universe, of huge quantities of the "**light elements**" **hydrogen** and **helium** as well as the discovery of **Cosmic Microwave Background radiation** which is thought to be the **remnant** of the **singularity's heat**. That discovery earned astrophysicists **Arno Perzias** and **Robert Wilson**[7] a quarter each of the 1978 **Nobel Prize**. As far as the creation of space is concerned, **Stephen Hawcking** with **George Ellis**[8] and **Roger Penrose**[9] extended the General Relativity theory and in years 1968 and 1979 published their works claiming that the singularity did not appear in space but **rather space began** inside the singularity.

---

2. *The universe in a nutshell, Stephen Hawking. Katoptron, 2001, pg.35, 41, 79*
3. *The universe in a nutshell, Stephen Hawking. Katoptron, 2001, pg.23*
4. *site Stephen Hawking http://www.hawking.org.uk/the-origin-of-the-universe.html, and http://www.big-bang-theory.com/*
5. *See footnotes 1 καὶ 2, pgs.23, 92*
6. *See footnote 4*
7. *site https://www.nobelprize.org/nobel_prizes/physics/laureates/1978/*
8. ***The Cosmic Black-Body Radiation and the Existence of Singularities in our Universe**, Steven W. Hawking, George F.R. Ellis, Astrophysical Journal, vol. 152, (1968) pp. 25-36, Definition of singularity sct. II. The nature of the singularity sct. vi.*
9. ***The Singularities of Gravitational Collapse and Cosmology**, Steven W. Hawking, Roger Penrose, Proceedings of the Royal Society of London, series A, 314 (1970) pp. 529-548. ἱστότοπος http://rspa.royalsocietypublishing.org/*

The view that space was created within the singularity **rather** opposes the Aristotelian logic of "**cause** and **effect**", which induces that the singularity, regardless of its smallness, occupies an infinitesimal but still some space.

Until future scientific announcements prove otherwise, astrophysics reserves its opinion and replies "**I do not know**"[10] to the following questions: what is the origin of the singularity? What is its nature? Why was it created? Where was it created?

Furthermore, science developed the concept of the **necessary** and **sufficient** condition in order to achieve a specific result.

For an explosion to take place, the "**necessary**" condition consists of the coexistence of a) space within which the explosion will take place, b) **mass** to be exploded and c) **catalyst** to trigger the process of the explosion, while the "**sufficient**" condition consists of the existence of the appropriate state of affairs like **mass density, pressure** and **temperature.**

4. Interpretation of Theogony's verses

Hesiod, without violating the Aristotelian logic of "**cause-effect**" describes **not only** the **necessary** and **sufficient** conditions for an explosion to take place, **but also** the results of the explosion till nowadays.

4.1 Necessary condition for the Big Bang

The **necessary** condition for the **Big Bang** is described in Theogony as follows:

coming into being of space:	First of all Chaos came into being. But then Gaia broad-chested, always the unshakable seat of all and Eros, the most beautiful among the immortal gods, dismemberer for all Gods and humans	Theog. v. 116
coming into being of mass		Theog. v. 117
coming into being of catalyst		Theog. v. 120
		Theog. v. 121

Hesiod chooses the words and presents the facts in a way that cannot be considered as coincidence, as presented below.

4.1.1 First of all Chaos came into being

Hesiod selects the word "**primary**" (πρώτιστα-[prootista]) and not "**in the beginning**" (ἐν ἀρχῇ-[en archee]) as used by other texts referring to cosmogony. The word "ἀρχὴ-[archee]" etymologically is originated by the verb «ἄρχω-[archoo]» (to rule, to govern) and is interpreted as "ἔναρξις-[enarxis]" (starting). Usual uses of the word "archee (beginning)" are found in mathematics like "we **define** point **A** as the **beginning**... of a line segment, of a circle's periphery, as well as in daily expressions like:

10. *site http://www.big-bang-theory.com/*

"**beginning** of a street, time period, conversation etc." Furthermore, St. Basil, the father of Christian Orthodox religion writes[11]:

*Because by nature, the **beginning extends** itself both sides, ...*

And in the next paragraph:

There was a stage older than the one of the universe's creation
that was appropriate to the supernatural powers, the ones beyond time,
the eternal, the non-visible.

Therefore, both the usual use and the theological meanings of the word "beginning (ἀρχὴ-[archee])" cannot and do not indicate the moment the universe began.

The word "**primarily** (πρώτιστα-[**prootista**])" is the superlative form of the word "πρῶτος-[prootos] (first)" and expresses the ultimate first. In that sense, this is the only word that can accurately mark the moment universe began. At the same time, the word indicates that nothing existed before that moment.

Remarkable is also the meaning of the word "γένετ'[ο] ({geneto[o]}-took place)" that etymologically comes from the verb "γίγνομαι ([gignomai]-become)" and is interpreted as "be born" for humans (passive voice), "be produced" for things (middle & passive voice) and "coming into being" for happenings (active voice).

It is concluded therefore that, since **Chaos is** not human nor a **thing** has **neither** been born **nor** produced. **Chaos came into being** primarily. The lexicon of Liddell-Scott presents the nature of Chaos as "**the first state of universe**", as **infinite** space, **infinite** area, in general as **infinite**. The word **Chaos** etymologically comes from the verb "χάσκω ([chaskoo]-gape), χαίνω ([chainoo]-yawn)". Therefore, **Chaos** is the **gap** and consequently the space.

Hesiod characterizes Chaos as "Ζοφερὸν ([zoferon]-dusky)":
dwell the Titans on the other side of **pitch-dark Chaos.**[12] Theog. v. 814

4.1.2 Immediately after Gaia broad-chested

Immediately after Chaos, the broad-chested Gaia came into being, the mass, the "singularity". Orpheus uses numerous epithets in the hymn "**To Gee every seed's fumigation**[13]", like **Goddess, mother, all-nurturing, bringing fulfilment, destroyer of all, promoting growth, yielding fruits, bursting good time...** Instead of using one of them,

---

11. *"Speech on the six days", speach a, unite II, para 4*
12. *Theogony, A. Athanassakis, Johns Hopkins University Press, Baltimore, 1983*
sites https://msu.edu/~tyrrell/theogon.pdf and http://www.sacred-texts.com/cla/hesiod/theogony.htm. All translation in English language of Theogony's verses, included in this work, are inspired by the above documents. However, modifications have been introduced by the author of this work in order to much the author's point of view.
13. *The Mystical Hymns of Orpheus, Tomas Taylor, London, MDCCCXCVI (1896)*

Hesiod chooses the epithet "**broad-chested**". **Why?** There are various possible interpretations for this. We adopt the following view.

The chest protects the two main organs of life that is: **lungs** and **heart**. Consequently, the **broad- chested Gaia encompasses** and **protects universe's generative organs**. Being generative Gaia is by nature:

*Gaia broad-chested, **always** the **unshakable seat of** all*	*Theog. v.. 117*
*the **immortals** who hold the peaks of snowy Olympus,*	*Theog. v. 118*
*and dark Tartaros in the recesses of the **wide-wayed chtoon**,*	*Theog. v. 119*

4.1.3 After Eros came into being... dismemberer

After **Chaos** and **Gaia** follows the genesis of the **catalyst**, the "λυσιμελὴς-[lysimelis] dismember" Eroos who is not the archer son of Aphrodite and Hares.

According to Liddell-Scott, "λυσιμελὴς-(lysimelis)" is epithet of **Hypnos** and is translated as "dismemberer". At that moment of the creation, only Chaos and Gaia were in existence. Therefore, Eroos could only act as dismemberer to them.

4.1.4 Completion of the necessary condition for the explosion

The first system has been formed. Chaos, Gaia and Eros are present. According to thermodynamics, the created system contains specific energy that depends only on its state and not on the way the system arrived to that state. The energy situation of that system is described in verse 700.

divine **ineffable heat (Καῦμα** [kavma]) occupied Chaos	*Theog. v.* 700
Καῦμα: burning heat (Liddell-Scott).	

4.2 Gaia, chthoon: two distinct amongst them entities

Gaia broad-chested, **chthoon** wide-wayed. It is worth noting Hesiod's way of writing the words "**Γαῖα**-Gaia" (24 repetitions), "**γαῖα**-gaia" (27 repetitions), "**Γῆ-Gee**" (once), "**γῆ-gee**" (8 repetitions) and "**χθὼν**-chthoon" (18 repetitions).

The use of majuscule and miniscule in writing the words does not indicate any mistake or omission. We strongly oppose to the conventional science that considers those words as synonyms. We keep our own point of view for the meaning of the word "Γῆ-Gee", the analysis of which is beyond the objectives of this presentation.

Hesiod places the humans on chthoon:

Oath who, for most **men on chthoon**....	Theog. v.231
From then on, for the immortals the tribes of **men on chthoon**	Theog.v.556
to the ash trees for **mortal men** *who dwell* **on chthoon**	Theog. v.564

Gaia and **chthoon** are two **distinct entities** and the wide-wayed chthoon is **always** seating **stably** on broad-chested **Gaia**.

5. The sufficient condition for the explosion

The rod-map towards the **sufficient** condition for the explosion is described in Theogony as follows:

action of **Chaos** genesis of **Erebus** and **dark Night**
From **Chaos** came into being **Erebus** and **dark Night**· *Theog. v. 123*

action of **Erebus** and **Night** genesis of **Ether** and **Day**
From **Night** came into being **Ether** and **Day**, *Theog. v. 124*

in which way did genesis happened? mixture in philotis.
after she was mixed in **philotis** with **Erebus**. *Theog. v. 125*

Of utmost importance is the understanding of the meaning of the word "φιλότης-philotees" (friendship, love, affection according to Liddle & Scott) as figure of speech. Systematically, Hellenes as well as foreign scholars and translators of Theogony attribute the word **philotis** as **erotic act** in the 25 out of the 26 repetitions of the word. The only potential exception is the verse:

Then she bore **Deceit** and **Philotis** Theog. v. 224

The lexicon of Liddell-Scott gives to the word **philotis** the notion of erotic act only "... in erotic relationship between man and woman..."

Instead, we interpret **Philotis** and mainly "**mixture in philotis**" as the "**sufficient** condition" for achieving a specific result. This connection between the concepts of "**philotis**" and "**sufficient condition**" is firstly, not in line with the dominating view concerning the word "philotis" and secondly, not given by the lexicon. However, our interpretation is strongly in line with the concept of **metaphor** of the Hellenic language's figures of speech.

Barren translations would lead to paralogous syllogisms. For instance:

- "the situation is **pregnant** and risks to explode [κατάστασις **ἐγκυμονοῦσα** κινδύνους]" = situation that has been in ~~sexual intercourse~~!
- "this is **born** by the imagination [**ἀποκύημα** φαντασίας]" = imagination that has been in ~~sexual intercourse~~!

Barren translation implies annulation of the figures of speech of the language, and especially of poesy. One would then wonder what would be point in analysing poems!

5.1 Thermodynamics – mixture in philotis

Thermodynamics provide an excellent example of "**mixture in philotis**" (as shown in figure 1).

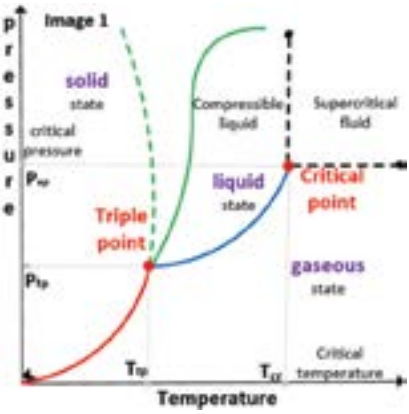


Figure 1: typical phase diagram[14]. The solid green line applies to most substances; the dotted green line depicts the anomalous behaviour of water.

Target: Stable coexistence of water's phases: **solid, liquid** and **gas.**
Necessary: existence of the three phases.
Sufficient: mixture in **philotis** of **pressure** and **temperature** yields to the **triple point** where the three phases coexist **in stability.**

- Beyond that point **solid, liquid** and **gas** phases stop coexisting.
- **Pressure** and **temperature do mix but not in philotis** for the defined target.

5.2 Action of Chaos

The wheel of creation starts moving. The **sufficient** condition for the explosion begins to be formed. In the presence of **dismemberer Eroos, Chaos** acts first and brings **Erebus** and **dark Night** into existence. Erebus is not characterised by any epithet whereas **Night** is characterised as "**dark**-μέλαινα-[melaina]", "**gloomy** (δνοφερὴ-[dnoferee])" and "**Erebus**-like (ἐρεβεννὴ-[erevennee])"

from **gloomy Night** and those whom salty Pontos bore.	*theog. v. 107*
From **Chaos** were born **Erebos** and **dark Night**·	*theog. v. 123*
without having slept with any of the Gods the **Erebus-like Night**	*theog. v. 213*
"**Γῆ-Gee**" is also characterised as **gloomy** while **Gaia** is not. of **gloomy** night and murky Tartaros	*theog. v. 807*

5.3 Action of Erebus and Night being mixed in philotiti

Initially, the Night moves from the **gloomy** and **erebus-like** states towards the **dark** one (see figure 2).

The wheel of production keeps moving. **Erebus**, in the presence of dismemberer **Eroos**, is mixed in **philotis** with **Night** and brings **Ether** and **Day** into existence, entities that are hymned by Orpheus as well.

14. sites https://el.wikipedia.org/wiki/Κρίσιμο_σημείο_(θερμοδυναμική) and https://en.wikipedia.org/wiki/Triple_point

Figure 2: the road map towards the completion of the sufficient condition

From **Erebus** (absolute blackness) we gradually arrive to the **Day** (absolute light).

Day is the **light** that is the production of heat, and ultimately is the **sufficient** condition for the explosion.

The **then** universe is **on fire!** The **necessary** and **sufficient** condition for the explosion is met. **Necessary** and **sufficient coexist**. **Necessary: Chaos, Gaia, Eroos. Sufficient**: the **ineffable heat** of **Chaos**, the genesis of **Day**.

6 The big bang takes place

The Big Bang is described in Theogony as follows:

> **Gaia** first brought into existence the **e q u a l to herself** starry **Uranus** *Theog. v. 126*

> Verse 127 describes the scientifically proven ever expansion of Uranus
> **Starry Uranus**, so that he covers everything, *Θεογ. στ. 127*

Only one entity, **Gaia**, brings into being the equal to herself **starry Uranus** whose mission is to cover everything. Therefore:

Gaia = **starry Uranus**

In that equation one can see the principle of **energy conservation**, that science named thousands of years later as "**first law of thermodynamics**".
An idea about the noise of the explosion is given in verse 703.

> Such a loud (**δοῦπος** [doupos]) sound would arise (**ὀρώρει** [oroorei]), *Θεογ. στ. 703*

Liddel-Scott: **δοῦπος**-[doupos]: any dead, heavy sound, thudding. **ὀρώρει**-[oroorei]: from the verb ὄρνυμι-[ornymi] = make to arise, call forth.

Hesiod in Theogony describes the first and later entities that came into being by Gaia. Within the **starry Uranus** the **life-death** circle never stopped existing. Astrophysicists know that the circle of **creation-death** of stars still goes on and therefore **Gaia** continues **acting** in the presence of dismemberer **Eroos. Jan Pierre Vernant** in his book «**L'univers, les dieux, les hommes**» explains why the castration of **Uranus** signals the **liberation** of natural forces, the **beginning** of **movement** and therefore of **time** as well as the **eternal bearing** of children via the birth of Aphrodite.

The inexorable **Χρόνος** [time] (**Κρόνος** [Saturn]) keeps on eating his own children.

6.1 Graphics showing the Big Bang according to Hesiod (image 3)

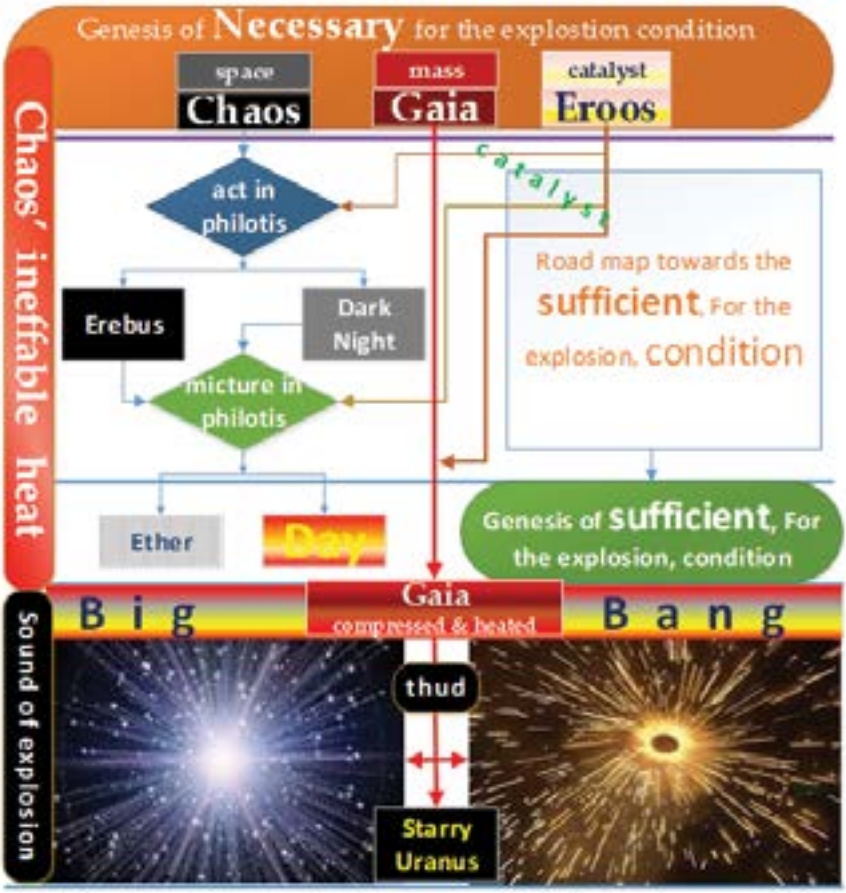


Figure 3: The road map to Big Bang according to Hesiod

7. Source of knowledge of the shepherd Hesiod

The aforementioned are described by a shepherd. Indeed, it is oxymoron *on one hand* the **social class** and *on the other hand* the **accomplishments** as well as the **geographical knowledge** of **Hesiod** in an era when even the trip from one village to the next was considered as **living abroad**!

The shepherd has profound knowledge, while avoiding paradoxes and preposterous descriptions in his verses concerning the creation of universe. He does not violate the "cause-effect" principle, and describes the genesis of the **necessary** and **sufficient** condition for the Big Bang.

> To the reasonable question: **whence this knowledge**? The reply is given by Hesiod himself. **Inspired by the Muses of Helicon**! Theog. v. 32

8 The dilemma

Having said that, we are in front of the following dilemma: Should we **believe** and consider **Hesiod** as **divinely inspired** or should we **reject** him as being an **uneducated, fanciful** and **untruthful** shepherd? To this dilemma responds the position of the father of Christianity Chrysostom which is presented below in a **philotis** modified version. We copy from the prologue of the Old Testament, pg 7, Panagiotis Tzelatis, publ. Paraskevas Leonis, 1892:

> *If one of the simplest human beings that is non-initiated into the **Theogony** (~~orthodox theology~~), does not understand the meaning of a topic while reading, he should blame himself for not being able to understand the truth **Muses** (~~God~~) spoke. The reason of the reader's misunderstanding is his own imperfection, and not the fact that **Muses** ($_{God}$) spoke unclearly or incompletely; be initiated (~~lead away~~)! The complete **Theogony** (~~holy bible~~), given its divine origin, is speaking the truth.*

9 Etymology of Uranus

We strongly believe the mission of Uranus (Οὐρανὸς) "*to cover everything*" allows us to consider that etymologically Οὐρανὸς is formed by the prefix "ουρ- [our-]" (far away) and the verb "ἄνω-[anoo]" (going through, move towards the end).

Indeed, Uranus is very far, going through everything, as he moves towards the end of the infinite universe. Uranus extends beyond the limits of human vision and technology and probably extends even further beyond human imagination. Uranus expands; who knows the space and time limits for the expansion **to cover everything**.

10 Conclusion – Hesiod the mystic

Hesiod enjoys the glory of **being the second poet of antiquity** but at the same time is considered an unworthy fanciful.

According to our point of view, Hesiod is an important, knowledgeable and initiated figure for his era. He modified his knowledge with **philotis** to present it to his contemporaries as well as to future generations.

Hesiod's description cannot be simple coincidences or products of the ever unrestrained and creative imagination of Hellenes. Hesiod does not derive the topics from his imagination. Being initiated and with divine order, he describes in Theogony the creation of the Universe as viewed by the modern Big Bang Theory.

Unfortunately for the mankind, the knowledge of Hellenes sages did not profit from a scientific continuity and remained unknown for centuries. It has been abused unmercifully even by those that have suckled on Hellenic literature. Knowledge has

been teared into pieces. The student of Livanios and later father of Christianity, St. Basileios, writes[15]:

> ***Hellenes philosophers have said too much about nature**, and **none** of their words **stayed steady** and **stable** since a second philosopher has always turned against the opinion of the first one. Therefore there is no need for us to judge their work. It is enough that one was rejecting the opinion of the other.*

The few preserved documents of our ancestors are full of knowledge. The giants of human intellectuality continuously contribute knowledge that can address the concerns of humankind. The Socratian midwifery allows filtering the literature of our ancestors in order to dig out and understand the unearthly truths!

11 Epilogue

The acceptance or rejection Hesiod's assertion concerning his "divine word" lies upon the judgment and degree of initiation of each one of us.

The presented connection of Theogony's verses to the data of modern astrophysics is not **divinely inspired** but the result of **thoughtful study**.
Other opinions are possible and welcome.

In conclusion we cannot imagine:

- Chthoon and Uranus mixing in hostility.
- Chthoon not desiring the rain, not being "pregnant" by it, not rain-producing.
- Chthoon's uterus producing nourishment in the absence of Uranus' rain.

Bibliography:

1. Theogony by Hesiod, original ancient text
2. Theogony by Hesiod, Stavros and Aggelos Vlachos
3. Theogony by Hesiod, site https://msu.edu/~tyrrell/theogon.pdf
4. Theogony by Hesiod, site http://www.sacred-texts.com/cla/hesiod/theogony.htm
5. The universe in a nutshell, Stephen Hawking, publication Katoptron, 2001
6. The Cosmic Black-Body Radiation and the Existence of Singularities in our Universe, Steven W. Hawking, George F.R. Ellis, Astrophysical Journal, 152, (1968) pp. 25-36.
7. The Singularities of Gravitational Collapse and Cosmology, Steven W. Hawking, Roger Penrose, Proceedings of the Royal Society of London, series A, 314 (1970) pp. 529-548. Web site http://rspa.royalsocietypublishing.org/

15. *Ὁμιλία εἰς τὴν ἑξαήμερον, ὁμ. Α', παρ.ΙΙ, γραμμὴ 2, Μέγας Βασίλειος*

8. L'univers, les dieux, les hommes, Jan Pierre Vernant, Paris, 1999

9. Les Origines de la pensée grecque, Jan Pierre Vernant, Paris, 1962

10. Mythe et religion en Grèce ancienne, Jan Pierre Vernant, Paris, 1990

11. Speech to the six days of creation, Vasilios father of Christianity.

12. Against Greeks, Athanasios father of Christianity.

13. Old Testament according to 70, 1892, chapter Genesis.

14. Apollonius Tyaneus, Filostratos

15. The Orphic Hymns, Ἰωάννου Πασσᾶ, ἐκδ. Ἥλιος,

16. The Orphic Hymns, Supreme Council of Ethinkoi Hellenes, 2001, Dr. Andreas Tsolomitis, Aegean University.

17. The Orphic Hymns, by Thomas Taylor, London, MDCCCXCVI (1896)

18. Web site «Ancient Hellenic Language and Literature» www.greek-language.gr

19. Web site Lexigram www.lexigram.gr

20. Web site LSJ: THESAURUS LINGUAE GRAECAE The Online Liddell-Scott-Jones Greek-English Lexicon http://stephanus.tlg.uci.edu/lsj/#eid=1&context=lsj

21. Web site lexicon Liddell & Scott Koonstantinidou, Aegian University, Section of Mathematics, prof. Andreas Papasalouros, Antoonios Tsolomytees, web site http://myria.math.aegean.gr/lds/web/

22. Web site Stephen Hawking http://www.hawking.org.uk/publications.html

23. Web site Stephen Hawking http://www.hawking.org.uk/lectures.html

24. Web site Stephen Hawking http://www.hawking.org.uk/the-origin-of-the-universe.html

25. Web site Stephen Hawking, A brief history of time, http://www.hawking.org.uk/the-beginning-of-time.html

26. Web site NASA https://www.nasa.gov/

27. Web site NASA http://science.nasa.gov/astrophysics/focus-areas/what-powered-the-big-bang/

28. Web site http://www.big-bang-theory.com/

29. Web site https://el.wikipedia.org/wiki/Κρίσιμο_σημεῖο_(θερμοδυναμικὴ) καὶ https://en.wikipedia.org/wiki/Triple_point

B3.2 PHYSICS OF INFORMATION

B3.21 Live and Death from a Modern Physics and Ancient Greek Philosophy Standpoint

Nina Sotina

*PhD in Physics, Senior Researcher, Lomonosov Moscow State University, Moscow, Russia 448 Neptune Avenue, Apt.12E, Brooklyn, NY, USA, 11224**

Abstract

Unlike a regular chemical environment, one of the attribute of the chemistry of living things is that the molecular systems in the living substance are in the state of continuous irreversible interaction. This interaction does not exhibit any molecular chaos! On the contrary, the biomolecules act as the well-tuned mechanisms. From the physics point of view, a molecule is a quantum system. According to modern physics, quantum system behavior should be governed by the probabilistic laws of quantum mechanics. Schrödinger was the one who pointed out that Quantum Mechanics in its present day form is unable to describe a behavior of living matter.

In the opinion of the author of the present work the incompleteness of description of a living nature by probabilistic laws is an argument in favor of the deterministic (causal) interpretation of quantum formalisms. As is known, the causal interpretation agrees with quantum formalism only if "nonlocal hidden variables" (like a special type of a field) are taken into consideration. The author has proven that under deterministic approach some spatial structures accompany any quantum object (atoms, molecules, biomolecules) in a physical vacuum. Obvioslly, the structures that are accompanying living biomolecule's system must differ from structures which are accomponing non-living quantum systems.

In this regard, it is interesting to consider the experiments by Romanian biochemist Eugene Macovschi (1906-1985). According to Macovschi, living cells consist of two qualitatively different forms of matter: a special form of structured matter ("biostructure") and coexisting molecular matter, chemicals. He guessed that the biostructure is an entity carrying the control function in living cells, and that this control is irreducible to electric and electromagnetic interactions. Eugene Macovschi re-evaluated the results of some experiments that were explained by their authors on the basis of the molecular theory. The starting point for Macovschi and his coworkers was the fol-

lowing observation: after being exposed to 200 ATMs hydrostatic pressure, the living plant tissues released a certain amount of water and still remained alive. In the case of a dead tissue the situation was quite different: after exposing to 200 ATMs a dead tissue released all the water it contained. Then, Macovschi postulated that life depends on the biostructure integrity and that it can stand rather high hydrostatic pressures without breakdown, i.e. without releasing all the water it comprises. The killing of the residue leaded to the biostructure breakdown and to the release of the biostructured water it contained.

The idea that a living organism is not just a material substance, that is accumulation of molecules, but also some non-molecular structure in the physical vacuum goes back to the mists of time. In works of Greek philosophers, we can find the idea of a soul, as a substance composed of a fine kind of matter which person loses in death. In Homeric poems, soul was solely associated with human life, and not with other living things. Empedocles and Pythagoras went further suggesting that not only humans and animals have soul, but plants as well. Epicurus suggested that it is necessary to introduce a new substance for description of the soul. Greek philosophers had also different opinions on what happened to the soul after it leaved the body. According to Plato "it is destroyed and dissolved on the day the man dies". Stoics also believed the soul was mortal, but that it outlives the body.

Introduction

Achieving an understanding of Life and Death has been a long-cherished goal of humanity. At some point we all will pass to the "afterlife", eternal oblivion, but it is not clear from a biophysics standpoint *what* will go to "afterlife". After all, the molecules and atoms that make up living matter will remain! But yet, there is still a sense that there is some sort of unity of a living organism which controls these molecules and atoms inside the cell, and the cells themselves. It is that *unity* that get destroyed when a living organism dies.

To distinguish the living from the dead a concept of 'soul' was introduced in ancient Greek philosophy. Empedocles, Pythagoras, Epicurus and Plato proposed different ideas about the structure of the soul and what happens to it after death. Most of them believed that it consisted of a fine kind of matter that dissolved after the soul leaves the body. Epicurus even suggested that it is necessary to introduce a new substance (which he believed to be composed of atoms) to describe the soul. Empedocles and Pythagoras went further suggesting that not only humans and animals loose the soul at the moment of death, but plants as well.

Many centuries passed since then but science still cannot claim much progress in understanding of life and death. According to contemporary biophysics a human organism is composed of cells, which in turn are mainly composed of biomolecules, and the biomolecules are composed of elementary particles. The space between elementary particles is filled with a special kind of medium – the physical vacuum. From the point of view of the dominant physics theories the physical vacuum must have a uniform density of energy everywhere.

From the molecular physics standpoint life is a continuous irreversible interaction of biomolecules, and emotions are associated with hormones produced in our body. The difference between living things and inanimate clumps of carbon atoms is seen in the better capability of the latter to be much better at capturing energy from their environment and dissipating that energy as heat. We can see that the modern scientific view on a human being is much poorer than that of ancient Greeks. In the modern physics there is no place for feelings, thoughts or the soul.

In the recent time, however, a new direction, quantum biology emerged, which studies the role that quantum mechanics plays in biological systems. (Until now, the systems were considered to be too complex to be explained using quantum mechanics). In order to understand the human mind, many began to turn to the concepts of quantum nonlocality. However, quantum mechanics in its present form is ill-suited for description of the processes occurring in the living organism, because biomolecules demonstrate a high degree of determinism, which disagrees with the concept of a molecule as a quantum system that is governed by probabilistic laws of quantum mechanics.

The author of this paper believes that a big step in understanding of a living organism behavior and what happens with it at the moment of death can be made if we go beyond the molecular level in the investigations, into the deep of matter. In this case, however, it is necessary to discard the model of immovable and homogeneous physical vacuum. Introduction of a "vacuum substance" as a material medium would bring back the idea of existence of *hidden variable*, which would allow to give the causal (deterministic) description of quantum theory. D. Bohm and Louis De Broglie were the most famous proponents of the causal (deterministic) interpretation of the quantum mechanics. Not all the Bohm's assumptions were correct, however, the deterministic approach he used led to very interesting results. This approach gave a strong mathematical base with which to suggest that some spatial structures (quasi-particles) are formed in the physical vacuum associated with an atom. Obviously, the more complex a quantum object (atom – molecule – biomolecule) is the the more complex is the structure accomponing it in the physical vacuum. It is reasonable to suggest, that the structure accompanying a living biomolecule's system must differ from structures accomponing non-living quantum systems. In our opinion the structure is the entity which controls chemical processes in a living organism. These ideas are in agreement with the results of the experiments conducted by Eugene Macovschi. These experiments will be discussed in details in Chapter 4.

1. Biomolecules and Quantum mechanics

According to modern physics a molecule is a quantum system, and, therefore, its behaviour should be goverened by the probabilistic laws of quantum mechanics. However, in living organisms, the biomolecules demonstrate a high degree of determinism. Schrödinger was the one who pointed out that Quantum Mechanics in its present day form is unable to describe a behavior of molecules of living matter [1]. He wrote: *"a single group of atoms existing only in one copy produces orderly events, marvelously tuned in with each other and with the environment according to most subtle laws... we are here*

obviously faced with events whose regular and lawful unfolding is guided by a 'mechanism' entirely different from the 'probability mechanism' of physics."

Let us demonstrate on the example of a microscopic organization, such as a virus, that living organism or/ and *pre*-cellular *life* forms show tremendous stability of the biomolecular system which disagrees with the concept of a molecule as a quantum object. Note, that viruses are generally not considered to be true living organisms because they do not use any external energy (food, radiation), do not have a program of death, and cannot reproduce without getting inside some living cell. The viruses that infect bacteria are known as *bacteriophages*. Bacteriophage T2 looks like a tadpole (Fig.1) [2].

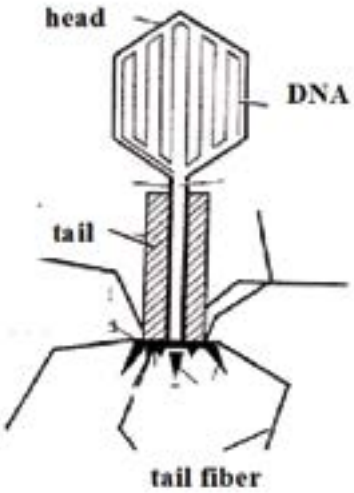


Fig.1

A "head" (a protective protein shell) contains DNA (some types of bacteriophages contain RNA only). A "tail" is a protein tube. By six legs (tail fibers), the phage attaches to the surface of the much larger bacterium *Escherichia coli*. Once attached, the bacteriophage injects DNA into the bacterium. The DNA instructs the bacterium to produce masses of new viruses.

The following is an approximate list of the bacteriophage's functions.

a) Detecting (done at a range of several phage's own lengths) and turning the tail towards the bacterium;

b) Attaching to the surface of the bacteria and penetrating it with the tail;

c) Injecting genetic material into the bacterium. (The injection is accompanied by the contraction of phage's "head", and the simultaneous cooperative shift of its protein subunits with respect to each other occur, which makes the tail become shorter and thicker. The tail of the phage can be visualized as a "molecular syringe").

From the physics standpoint, the "intelligent" behavior of the bacteriophage must be caused by some physical phenomenon of interaction. Thus most of researchers suggest that:

a) detecting and turning towards the bacterium is done by electrostatic forces. [Note, that this is not very convincing because the abilities of electrostatic forces are limited (there are only two sighs of a charge + and –), at the same time the variety of phages in the micro world is enormous and every phage parasite on its own type of bacteria].

b) attaching to the surface of a bacterium occurs due to Van der Waals forces.

c) injecting of genetic material, partially occur due to the pressure difference (DNA is packed tightly inside the protein shell of a phage; as a result of that, DNA has elastic energy and exert pressure on the walls of the protein shell). Interaction of DNA and protein, which is explained to be due to the formation of the special correlations of electric charges, also plays an important role in the process [3].

However, the above reasoning alone cannot explain the coherence and a high degree of determinism of biomolecules behavior. Thus, if assume that the interaction between DNA and protein is due to the complex correlations of electric charges alone, then how to explain the stability observed in the functioning of a bacteriophage at the temperature around 300K? The heat fluctuations should have caused disorder in the complex mechanism.

Besides that, according to the theory of molecular quantum systems it is possible to tell only with a certain probability whether a chemical reaction or change of a molecule configuration is to occur. Even if we assume that an error in every reaction and every change of configuration occurs with a small probability, these errors must accumulate overtime since molecular systems in the living substance are in the state of continuous irreversible interaction. In real life, on the contrary, we observe surprising stability of a behavior of living organisms. For example, the "molecular syringe" of any bacteriophage T2 always works in the same manner and the same processes repeat over from generation to generation.

Thus, it is impossible to calculate the behavior of a biomolecule even theoretically using the methods of the quantum mechanics alone without bringing some heuristic models. And it is not only because of the complexity of a problem. The question is much deeper: the question is about incompleteness in the description of physical reality by quantum mechanics (so-called problem of "hidden variables" which would allow a quantum system to be consistent with the deterministic theory).

2. The deterministic (causal) interpretation of quantum formalism.

While the mathematical formalism of quantum mechanics describes many experiments for non-living matter well there are heated discussions among scientists about its physical interpretation. The various interpretations offer different approaches to the issues that arise, which include *the wave function collapse, paradoxes such as EPR*, and etc. It is important to emphasize, that at present time there is no physical inter-

pretation of quantum formalism that would not have contradictions within it or with accepted ideas and theories. The proponents of the Copenhagen interpretation, for example, are having difficulty explaining results of experiments with the essentially quantum effects (e.g., teleportation of polarization of the photon).

Failure of quantum mechanics in its present day form to describe behavior of living matter is an argument in favor of the search for the deterministic interpretation of quantum formalisms. This interpretation centers about the existence of "hidden variables". The concept of "hidden variables", which uniquely characterize the given state of a quantum system, was first suggested by Einstein, Podolsky, and Rosen (*the EPR paradoxe*, 1935). In 1964, however, John S. Bell advanced his famous inequalities. It followed from the violation thereof in quantum theory that any theory of "hidden variables" agreeing with quantum formalism, must be "nonlocal" only. "Nonlocality" means two possibilities: either existence of a physical field which allows for interactions to attain speeds greater than the speed of light, or propagation of "signals" of the changes of a particle's quantum state with an infinite speed (to avoid introduction of long-distance forces some physicists began to talk about non-separability of quantum mechanics, that is about existence of some type of an information "link" between remote quantum objects).

The most famous proponents of the causal (deterministic) interpretation of the quantum theory, and, consequently, the existence of "nonlocal hidden variables" were D.Bohm [4] and Louis DeBroglie. Some of the Bohm's assumptions appeared to be incorrect, however, the deterministic approach he used led to very interesting results.

Quantum Mechanics, as known, explains a large number of experiments. Since, the Schrödinger equation is the main postulate of quantum mechanics, we should preserve it, if we are to develop a new approach; possibly by giving a different interpretation to the Schrödinger equation. The author of the present work proved that the Schrödinger equation can derived from the deterministic laws of classical mechanics [5, 6]. Under the deterministic approach the Schrödinger equation is a necessary condition of a stable motion of electrons in an atom. Besides that this approach gives a strong mathematical base with which to suggest that some spatial structures (quasi-particles) are formed in the physical vacuum associated with the motion of electrons. These structures are responsible for stabilization of the election's motion in an atom.

Up to now we did not introduce any hypothesis regarding the nature of "nonlocal hidden variables". If we make an assumption that "hidden variables" are associated with some kind of a field that is created by a medium similar in properties to He-3, then we can be more specific about the form of the structures. Indeed, in superfluid He-3 structures like homogeneous precessing domains are observed, where all spins of the fluid particles precess with the same frequency and phase. If we assume, that in the material substance (the superfluid vacuum) such domain (the quasi-particle) accomponies electron's motion in a hydrogen atom, then it can be demonstrated that the frequencies of precession of the quasi-particle's spin are the natural frequencies of the atom (calculated from the Rydberg's formula).

Obviously, the more complex a quantum object (atom – molecule – biomolecule) is the the more complex is the structure accomponing it in the physical vacuum. It is

reasonable to suggest, that the structure accompanying a living biomolecule's system must differ from structures accomponing non-living quantum systems. These structures hold information and energy necessary to control biochemical processes.

3. Macovschi' concept of a biostructure.

The idea that a living organism is not just a material substance, that is accumulation of molecules, but also some non-molecular (intangible) structure in the physical vacuum goes back to the mists of time. Romanian biochemist Eugene Macovschi (1906-1985) was the first who made an attempt to approach this idea scientifically. According to Macovschi, living cells consist of two qualitatively different, though interacting, forms of matter: a special form of structured matter ("biostructure") and coexisting molecular matter, chemicals. He guessed that the biostructure is an entity carrying the control function in living cells, and that this control is irreducible to electric and electromagnetic interactions. Eugene Macovschi re-evaluated the results of some experiments that were explained by their authors on the basis of the molecular theory [7, 8].

The starting point for Macovschi and his coworkers was the following observation: after being exposed to 200 ATMs hydrostatic pressure, the living plant tissues released a certain amount of water and still remained alive. In the case of a dead tissue the situation was quite different: after exposing to 200 ATMs a dead tissue released all the water it contained. Then, Macovschi postulated that life depends on the biostructure integrity and that it can stand rather high hydrostatic pressures without breakdown, i.e. without releasing all the water it comprises. The killing of the residue leaded to the biostructure breakdown and to the release of the biostructured water it contained.

According to the present molecular concept, water occurs in both living and dead tissues under only two main states: free and bound. Of course, water in the vicinity of the solid surfaces, free ions, macromolecules, and so on of the cell exhibit properties different from ordinary water. Once the biological water is released from the biological system it immediately regains the properties of ordinary water. According to contemporary biochemistry, the living matter and the dead one consist of the same substances and are not qualitatively different. It follows from this experiment, however, that two forms of matter, living and dead, are fundamentally different.

Note that Macovschi's ideas of biological structures stand out from all other explanations of organism behavior. At the same time some scientists tried to explain mysterious phenomena in biology by introducing a new kind of physical field (*the biofield*), which was presented in living organisms only. Note that the term "the biological field" was introduced by A. Gurvitsch at the beginning of the 20th century. According to Gurvitsch the nature of "the biological field" lies within electromagnic phenomena. However, later on there were papers by other authors that considered biofield, as a new type of field, having non electromagnetic nature [9].

By the term "physical field" Gurvich and his followers understood an agent that transmits action from one object to another, where both objects were composed of molecular matter. In physics, a field is a quantity that has a value in each point in space that is a field in most cases has a property of continuity. A spatial structure, on

the other hand, is a system composed of elements (items) of arbitrary nature and has a definite shape (Macovschi viewed the biostructure as a sponge). Here lies a significant difference between structures and the physical field.

The examples of simplest non-living structures are various formations of iron filings under the action of a magnet. The elements of the structure in this case are the iron fillings and the coherent behavior of distant elements is controlled by magnetic field.

It is important to note that in order for biostructures to be stable and at the same time dynamic there must exist some kind of interaction among non-molecular elements of a biostructure which controls the coherent behavior of the distant elements. Thus, to understand biostructures it is important to go beyond the molecular level in the investigations, into finer level of matter.

Despite the Macovschi' concept of a biostructure and a number of conundrums encountered by biophysicists, modern biology continues to develop solely within boundaries of molecular concept which does not provide a satisfactory understanding of the specifics of a living matter. The main reason for that is the theory of relativity which prevents the further development of the concept of biostructure. Indeed, if spatial structures existed in physical vacuum then it would be possible to link a coordinate system with them, and it would be possible to introduce an "absolute motion" of objects with respect to vacuum which contradicts the first postulate of special relativity – the postulate of relativity.

4. 'Soul' as a material substance in works of ancient Greek philosophers.

As discussed above, according to Macovschi all living organisms consist of two forms of matter: a molecular form and a coexisting specific form of matter ("biostructure"). His experiments demonstrate that the biostructure is destroyed at the moment of death. It is interesting to note that Macovski and his followers supposed that in living matter there are various levels of matter organization (molecular level, basic biostructural level, and other more complicated biostructural levels).

The idea of a biostructure overlaps with notion of 'soul' in ancient Greece. In Homeric poems a soul is something that person loses in death. In Iliad, Achilles says that he is continuously risking his soul. In Homeric poems, the soul was solely associated with human life, and not with other living things. Empedocles and Pythagoras, on the other hand, believed that not only humans and animals have a soul, but plants as well, and therefore, a dead plant was missing something that the living one had.

Some Greek philosophers, Heraclitus for example, viewed the soul as being composed of a fine kind of matter. The material nature of the soul helped to understand the effect of the soul on the body. The difference between the soul and the body was viewed as merely the difference in properties of the matter they were composed of. In attempt to understand the structure of the soul, Epicurus, who was advocating for the material nature of the soul, suggested that it is necessary to introduce a new kind of substance (composed of atoms) to describe the soul. He also believed that this substance is responsible for sense perception.

What happens to the soul after death? Whether it is a continued existence of a per-

son or it simply dissolves at the moment of death? These were the questions that concerned many ancient Greek thinkers. For example, Pythagoreans referred to a "soul" as being a quasi-person that continued to exist after death. On the other hand, Epicurus believed that the soul decomposes at death into atoms. In Plato's *Phaedo* we can find a similar view "...They think that after it [soul] has left the body it no longer exists anywhere, but that it is destroyed and dissolved on the day the man dies" [10]. According to Stoics, the soul is also mortal, but outlives the body. Socrates presented a different view, according to him even though the soul is composed of a finer matter than the body it is less subjected to destruction.

We can see that without having sufficient experimental evidences, Greek philosophers intuitively came very close to the concept of a fine matter that exists in living organisms along with the rough, what we call the molecular, part of the organism. The further development of physics, especially the model of the physical vacuum, probably, will shed light on what controls the behavior of the living organism and what happens to it at the moment of death.

Acknowledgments.

I would like to thank Nadia Lvov for her help in the preparation of the article and for valuable comments.

References

1. E.Schrödinger, What is Life? Cambridge (1944).
2. http://nauka.relis.ru/16/0109/16109098.htmB
3. D.E.Smith, S.J.Tans, S.B.Smith, S.Grimes, D.L.Anderson, C. Bustamante, "The Bacteriophag 29 portal motor can package DNA against a large internal force", *Nature*, 413, 748-752 (2001).
4. D.Bohm, *Phys. Rev.*, 85 (2), 166 (1952).
5. N. Sotina, *Physics Essays*, 27, 321 (2014).
6. N. Sotina, "*The hidden variables in quantum mechanics. The precession of the electron's spin in an atom, Proceedings of Natural Philosophy Alliance*, vol.11, 113-122 (2015)
7. E. Macovschi, *Rev. Roum. Biochim.*, 19, 177-186 (1982)
8. G. Drochioiu, "Eugene Macovschi's concept of biosructure and its current development", LIVE and MIND, in search of the physical basis, Trafford publishing, Canada, Editor S.Savva, 43-60 (2006).
9. S. Savva: "Biofield control system of the organism", LIVE and MIND in search of the physical basis, Trafford publishing, Canada, Editor S.Savva, 3-24 (2006).
10. Lorenz, Hendrik, "Ancient Theories of Soul", *The Stanford Encyclopedia of Philosophy* (Summer 2009 Edition), Edward N. Zalta (ed.) URL= http://plato.stanford.edu/archives/sum2009/entries/ancient-soul/.

B3.22 Informational Properties of Water

Nina B. Sotina[1]
PhD in Physics, Lomonosov Moscow University
448 Neptune Ave., Apt.12E, Brooklyn,NY , USA, 11224 &

Nadezhda Lvov
Division of Mathematics and Physics,
Essex County College, Newark, NJ, USA

Abstract

Water is an essential substance for all living beings on Earth. According to Aristotle, water is one of the four basic elements of the Universe. Although people have studied properties of water since ancient times, some of its properties still remain mystery. In the present work we address the ability of water to transmit, receive and retain complex biological information (the property which is used in homeopathy). But the most puzzling, probably, are the sacral properties, which manifest themselves in divination or blessing using water. We describe experiments which demonstrate that some of the amazing and sacral properties attributed to water are not solely a creation of human imagination.

The first experiment conducted by J.Benveniste demonstrated that biological information can be imprinted on water [1, 2]. We believe that the theory of G. Preparata of *coherence domains* is the most suitable for the explanation of such experiments [3, 4]. Using the quantum electrodynamics approach Preparata proved that coherence domains are formed in liquid water. (In such domain, all molecules are in a coherent state).

Another series of experiments conducted by H. Hu and M.Wu [5] shows that molecules of water that were in contact continue to influence each other even after being separated. The pH value and the temperature of water in one of the reservoirs was non-locally affected through manipulating the water in the other reservoir. This experiment is manifestation of *quantum entanglement* in macroscopic systems. Even though quantum mechanics formalism is widely used to explain the above experiments, the quantum physics, however, is not well understood. Note that at present time there is no physics interpretation of quantum formalism that would not have contradictions within it or with accepted ideas and theories. From our point of view, the next step in the understanding of these phenomena can be made if "nonlocal hidden variables", which reflect the motion of the superfluid physical vacuum (like He-3), are introduced in quantum mechanics. Under such approach, the molecules as well the coherence

* PhD in Physics, Lomonosov Moscow University

domains would be structures in the physical vacuum [6, 7].

The J.Benveniste's experiment as well as the experiments by H. Hu and M. Wu demonatrate that certain rituals involving water have roots in real phenomena. Ancient Greeks, for example, had vessels which contained "holy water" that was used for blessings people during ceremonies. The possibility of remote connection between objects that have previously been in contact gives grounds to the contagious magic. Recall, that some of the ancient rituals were based on the belief that things which have once been in contact with each other continue to act on each other at a distance after the physical contact has been severed. Homer left us a description of a rite where Greek worriers under the walls of Troy covered the body of Patroclus with hair cut from their heads.

Introduction.

The importance of water for living organisms is well known. According to a Greek philosopher Fales (around 625-547 BC) a "wet element", or water, is the most basic element of all multiform of nature. Fales claimed that everything emerges from water and goes back to water.

Although people have studied properties of water for centuries, some of its properties still remain a mystery. For example the ability of water to receive and retain a complex biological information. This property of water in particular is used in preparation of homeopathic remedies. However, the most puzzling are the sacral properties, which manifest themselves in water divination or blessing using water. Thus, in ancient Greece the spring near temple of Demeter was used to predict the major event. Ancient Greeks had special vessels with *holy water* that they used to bless people during ceremonies. Not explained or confirmed by official science, all the properties of water listed above can be combined under a common term "the informational properties of water". We will consider below two unique experiments that demonstrate that the sacral properties of water are not solely a creation of human imagination.

The first is an experiment conducted by a French scientist J.Benveniste, in which he showed the ability of water to retain memory of a substance previously dissolved in it, even after multiple dilutions [1, 2]. Another is a series of experiments conducted by H.Hu and M.Wu [3, 4], that demonstrate the property of water to retain a connection between its parts after they were separted. The very possibility of the distant connection between objects that were previously in contact gives some grounds to contagions magic and shows that it has roots in real physics phenomena.

1. "Water memory".

In 1988 a French immunologist Jacques Benveniste published a series of experiments in Nature [1, 2] in which he demonstrated that water retains the memory of the substance diluted in it even when, after multiple dilutions, none of the molecules of the original substance remained. His work provided a scientific explanation of the concept of homeopathy.

Benveniste studied the reaction of the human white blood cells, basophiles, to the solution containing anti-immunoglobulin E (aIgE). According to conventional science, the dilution of a substance should result in the decrease of the reaction. However, Benveniste observed a different result: after multiple dilutions of aIgE antibodies accompanied by a violent shaking (the principle used in preparation of homeopathic remedies) the human basophiles still reacted to the solution, even when dilution was so high (1 to 10^{60}) that only molecules of water and no molecules of antibodies remained. Benveniste suggested that water carries the memory of the substance that was dissolved in it, the concept that later became known as "water memory" .

Benveniste experiments were not accepted by the scientific community, because not all laboratories could replicate his results. His controversial discovery, however, stimulated further study of the unique water properties. Thus, an independent research group conducted experiments in which the action of the highly diluted solution was terminated by the alternating magnetic field of certain frequencies; this was not observed for the solutions which contained the actual molecules of the substance. This effect was not taken into consideration when Benveniste's experiment was replicated and could have been a factor of the failure to obtain the original result (for example the electromagnetic radiation emitted by some of the devices could have affected the solution).

Later, in 2002 L. Rey studied emission of ultra-high dilutions of lithium chloride and sodium chloride . The solutions were irradiated by X- and γ-rays at 77K, then progressively rewarmed to room temperature. The experiments showed that emitted light of the ultra-high dilutions was the same as of the original salts dissolved initially [8]

The quantum electrodynamics approach to water theory seems to us the most interesting and well justified of all other approaches proposed by various scientific groups. The Italian physicist G.Preparata discovered that water organizes itself in *Coherence Domains*. In such a domain, all molecules are in a coherent state described by the same wave function. The diameter of the coherent domain (which organizes itself into a spherical shape) is tenth of a micrometer, and at a temperature of +20C the volume of all domains can reach up to 40% of the volume of water. One domain contains about 1 million molecules. Within a domain, the quantum energy level is lower compared to the energy level of the rest, non-coherent water, which provided stability of the domain to the energy fluctuations. The viscosity of the water within the domain is about one order of magnitude less than the viscosity of non-coherent water. Due to this amazing properties of the domains all chemical reactions should occur much faster within the domains, than in the non-coherent component of water.

In 2010 a research group in Troitsk city in Russia, under supervision of Mikail Zhadin conducted a series of interesting experiments. They studied the optical properties of water subjected to radiation. The samples of water were taken from three different sources: distilled water, sink water and spring water from a *holy* place. They found that each type of water contained different amount of coherent domains. The group also found that *holy water* contained more coherent domains than other types and, therefore, must have higher memory capability.

In the further study of water memory, J. Beneveniste demonstrated experimentally that the biochemical information can be transmitted to water via electromagnetic

signal. A different group of scientist observed that solutions containing pathogenic bacteria's and viruses' DNA emit low frequency electromagnetic radiation. We think that shaking the solution at the preparation of each dilution apparently contributes to this radiation.

Note, that the coherent domains must have their natural frequencies. The mechanism by which the low-frequency electromagnetic radiation acts on the coherent domain, and "infect" them with their frequencies is unclear. And the problem is not solely in the complexity of the quantum electrodynamics problem, but also in the fact that the very quantum physics formalism with its accepted probabilistic interpretation is not well understood. At present time there is no physical interpretation of quantum formalism that would not have contradictions within it or with accepted ideas and theories.

2. Experiments by H.Hu and M.Wu.

The experiments conducted at Stony Brook [4] can be considered as another confirmation of the existence of the coherent domains in water. H.Hu and M.Wu found that if samples of water are taken from the same reservoir, and then separated into two remote reservoirs, the water's pH value, its temperature and even the water's gravity in one reservoir can be non-locally affected through manipulating of the water in the other remote reservoir. The original water reservoir (made of plastic) was exposed to microwave radiation in a 1500W microwave for 2 min or audio-frequency radiations of a 20W magnetic coil for 30 min and then water was divided into two smaller volumes. The researchers used the macro-quantum entanglement to explain this unique quality of water. Strictly speaking water is considered to be a non-quantum system, therefore, the explanation of this phenomenon through quantum entanglement goes beyond the bounds of modern theory. However, if we accept the existence of the coherent domains in water a different explanation can be given. The domains are macroscopic quantum systems (such as, for example, domains in superfluid), and if some of domains were originally in the same quantum state then quantum correlations can exist between the domains after water were divided into two containers. The initial microwave or audio-frequency irradiation of the water sample probably set some of the domains in the same quantum state, maybe via resonance.

These specific properties of quantum systems, such as quantum correlations, have no analogue in classical physics, and, therefore, their manifestations seem supernatural. From our point of view, the next step in the understanding of these phenomena can be made if "nonlocal hidden variables", which would reflect the motion of the superfluid physical vacuum (like He- 3), are introduced in quantum mechanics. Under such approach, the molecules as well the coherence domains would be structures in the physical vacuum [6, 7].

3. Macroscopic quantum correlations and magic.

The J.Benveniste's experiements, as well as the experiments by H. Hu and M. Wu demonstrate that rituals involving water, for example blessing using water, have roots

in a real physics phenomenon.

H. Hu's and M. Wu's experiments on macroscopic quantum correlation give grounds to the contagious magic. Many ancient rituals involve a belief that it is possible to harm a person remotely through his hair or nails and even through a trace left by him on the ground. For example, one of the Phythogorean's rules forbade piercing of the human trace with a knife or a nail.

Many rituals assume the existence of 'communication' between alive and dead human beings. In ancient Greece a strand of hair was used to attract the soul of someone who was deceased. Homer left us a description of a rite where Greek worriers under the walls of Troy covered the body of Patroclus with hair cut from their heads *"In front fared the men in chariots, and thereafter followed a cloud of footmen, a host past counting and in the midst his comrades bare Patroclus. And as with a garment they wholly covered the corpse with their hair that they shore off and cast thereon;"* [Hom. Il. 23.93]

There is another paragraph where Achilles put a strand of hair in his dead friend's hand:*"He* [*Achilles*] *took his stand apart from the fire and shore off a golden lock, the rich growth whereof he had nursed for the river Spercheüs, and his heart mightily moved, he spake, with a look over the wine-dark sea:'Spercheüs, to no purpose did my father Peleus vow to thee that when I had come home thither to my dear native land, I would shear my haor to thee and offer a holy hecatomb...So vowed that old man, but thou didst not fulfill for him his desire. Now, therefore, seeing I go not home to my dear native land, I would fain give unto the warrior Patroclus this lock to fare with him.' He spake and set the lock in the hands of his dear comrade"* [Hom. Il. 23.138].

In another poem Homer tells how Orestes put a lock of his hair on a tomb of his father Agamemnon, the King of Mycene.

One could argue that these rituals do not involve quantum systems described by a common wave function, and, therefore, they should be considered solely a creation of human imagination. However, if we assume that physical vacuum is similar in its properties to superfulid He-3 these ritual can have a scientific explanation. In such a vacuum not only molecules, biomalecules but the organism as whole is a single quantum system. And the concept of a soul acquires a quite scientific meaning.

References

1. Benveniste, J. (1988) "Dr Jacques Benveniste replies", News and views, Nature, 334:291.
2. http://hubpages.com/hub/Homeopathy-and-The-Memory-of-Water-with-Benveniste
3. Giuliano Preparata , QED coherence in condensed matter, World Scientific Publishing, Singapore, New Jersey,London Hong Kong (1995)
4. E. Del Giudice & Giuliano Preparata, "**Coherent dynamics in water as a possible explanation of biological membranes**",*Joirnal of Biological Physics*, 20,105-116 (1995)
5. Hu, H. & Wu, M. (2007). Evidence of Non-local Chemical, Thermal and Gravitational Effects. *Progress in Physics*, vol.. 2, 17-24.
6. N. Sotina, *Physics Essays*, 27, 321 (2014)
7. N. Sotina, The "hidden variables" in quantum mechanics. The precession of the electron's spin in an atom, *Proceedings of Natural Philosophy Alliance*, vol.11, 113-122 (2015)
8. L. Rey, Thermoluminescence of ultra-high dilutions of lithium chloride and sodium chloride, Physica A , 323, 2003, pp. 67-74]

B3.3 PHYSICS OF SACRED PLACES

B3.31 Vibrations and Natural Phenomena at Ancient Sites Affecting Brain Activity: How to Study the Mind at Archaeological Sites

prof.agg. Paolo Debertolis
Department of Medical Sciences - University of Trieste Chair of Dental Archaeology Coordinator of project SB Research Group Trieste, Italy*

Daniele Gullà
Forensic researcher Project SB Research Group Bologna – Italy*

Abstract

From a number of research studies and experience, it was observed that some ancient archaeological sites of religious significance have a specific affect on brain waves. The resonant frequencies found at these sites were tested on a group of volunteers in the laboratory of the University of Trieste. Audiometric tests conducted at the Otorhinolaryngology Clinic were used and the response was measured using EEG. Similar tests on the same group were repeated at an ancient hypogeum in Italy. Whilst the frequencies were played, we found there was a prevalence of the frontal or occipital (posterior) areas with no particular cerebral hemisphere (left of right) dominating the other. Throughout the experiment some areas of the brain had a split of waves, but only in those volunteers who regularly practiced meditation or prayer. Each volunteer had a different sensitivity to each of the tones played, as each exhibited a strong response to a subjective and personal tone. In the same hypogeum we applied some innovative methods of research to better understand this altered state of mind induced from the vibrations present in the location with very interesting results.

I. INTRODUCTION

Archaeoacoustics is a complementary discipline to archaeology that involves the study of ancient sites through an interdisciplinary approach. We used new forensic methodologies and a medical-anthropologic approach to extend archaeoacoustical analysis to examine the relationship between the human body and archaeological sites. Re-

search in collaboration with the Head and Neck Department and the Clinical Neurophysiological Unit at the University of Trieste (Italy) was conducted, to assess the effects of resonance phenomena on the human body [5,9]. The idea that there could be a connection between brain activity and ancient "sacred" sites was first proposed in the international literature by Princeton Engineering Anomalies Research Group (PEAR), University of Princeton, NY under the directorship of Robert Jahn. In 1996 PEAR published a paper titled "Acoustical Resonances of Assorted Ancient Structures" [10]. In it they studied six Neolithic temples in England and Ireland and found an acoustic resonance of around 110Hz, frequencies that commonly fall within the male vocal range. They also found that the dominant standing-wave patterns of such frequencies, form the principle of radial or longitudinal harmonics with little azimuthal or vertical variations. PEAR's conclusion showed that the ancient structures possessed resonant acoustical properties that may have contributed to their functional purposes.

On the basis of PEAR's findings, a research group from UCLA (USA) directed by Cook, published a paper in 2008 analyzing ancient architectural acoustic resonance patterns and regional brain activity"[1]. In it the authors looked at the effect and correlation of the frequencies found by PEAR at English and Irish temples on brain activity using electroencephalography (EEG). In their pilot project, 30 healthy adults listened to tones of 90, 100, 110, 120, and 130 Hz whilst brain activity was monitored using EEG. In particular they found that the pattern of asymmetric activity over the prefrontal cortex shifted from one of higher activation on the left side at most frequencies to right-sided dominance at 110 Hz. These findings are compatible with relative deactivation of language centres along with a shift in prefrontal activity that could relate to emotional processing. These results suggested that the acoustic properties of ancient structures may influence human brain function and that a wider study of these interactions should be undertaken. From these results Cook hypothesised that the resonance of the chamber cavities might have been intended to support human ritual chanting. There was the possibility that tones at these frequencies might specifically affect regional brain activity" [1].

SB research group tried to repeat this experiment on a group of 10 volunteers who underwent examination by EEG while listening to tones between 90Hz and 120Hz[5,10], similar to the resonant sounds found at some Neolithic structures in Europe (England, Ireland, Italy, Malta, Turkey) as in the study by Ian Cook at the University of California (UCLA, 2008).

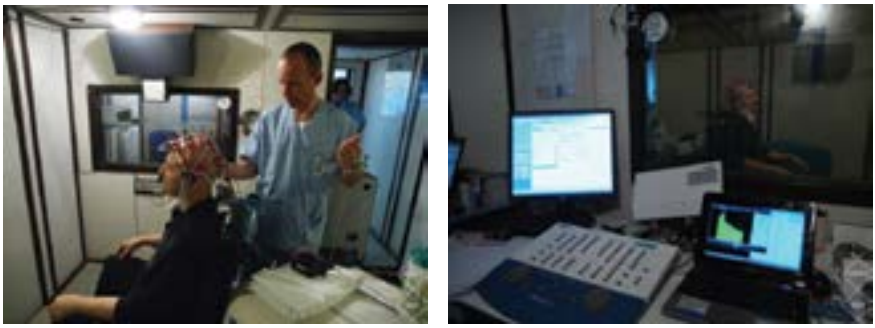


Fig. 1 – The absorbing sound room and the devices during EEG research.

In the second instance, we searched another approach to volunteers by an imaging system able to value the emotional state of subjects during tones based on information on the integral parameters of head mobility obtained using a video analysis called TRV (Variable Resonance Imaging Camera) technology, which provides quantitative information of the periodic movements of any part of the body of imaged volunteer [3,6].

The TRV image analyzer system is used to monitor vibrations in normal or altered physiological states. In a little square on the computer screen the image of the subject is shown using a spectrum of false colours, with a graph corresponding to the initial position. Any emotional state of examined subject produce a different vibration of the body not visible to a naked eye, but visible to TRV camera. The coordination of human movement depends on the emotional and physiological state of mind affected by various factors increasing or decreasing his stress conditions.

This system was developed by the secret services to test the emotional state of terrorist suspects under police interrogation. Furthermore this special technology is used by airport security staff to evaluate the emotional/stress condition of passengers. Any subject planning a terrorist attack who is in a stressful condition, can be immediately identified by the red/orange colour painted on computer monitor by dedicated software around the subject taken by security video camera. We are the first research group who used this new technology for other purpose than security [9].

This last method of research is at work but we have preliminary results which confirm EEG results.

II. EEG RESEARCH RESULTS

All of our 10 volunteers, 4 male and 6 female, were subjected to a "comfortable" volume of sound whilst in the absorbing sound room (see Fig. 1). This is used for audiometric tests at the Otorhinolaryngology Clinic and has has been modified with suitable software and hardware. This type of room was also protected by a Faraday cage to shield from any possible external electromagnetic interference that could affect the results. After two minutes of silence to evaluate the resting brain rhythm, the volunteers were subjected to the tones of 90, 95, 100, 105, 110, 115, 120Hz arranged in a random way for one minute each. At the end of every cycle they listened to a mantra of the same frequency for a period of two minutes. Skilled technicians examined the EEGs to verify the data collected. They found there was a prevalence of frontal areas or occipital (posterior) areas with no predominance of one cerebral hemisphere (left of right) over the other during playing. Each volunteer had a different sensitivity to all the tones without one tone prevailing (i.e. 110Hz), with each exhibiting a strong response to a subjective and personal tone (i.e. 90Hz or 105Hz or 120Hz) [5].

In the results obtained by Cook, Pajot and Leuchter the activity in the left temporal region was found to be significantly lower, closer to 110 Hz than other frequencies. Additionally, the pattern of asymmetric activity over the prefrontal cortex shifted from one of higher activity on the left at most frequencies to right-sided dominance at 110 Hz [1].

Our results showed that each volunteer has their own individual activation frequency that can be significantly different than 110Hz, but always within the range of

90-120Hz.

Further, those volunteers with a frontal lobe prevalence during the toning received ideas and thoughts similar to what happens during meditation, whilst hose with an occipital lobe prevalence during the toning predominantly visualized images.

This could explain why some ancient sites feature a number of chambers each tuned to different resonant frequencies instead of just one at 110 Hz. We proposed that other frequencies are equally capable of activating emotional processing as 110 Hz. Achieving this emotional state was an important component of ancient rites so that a real sense of mystical elevation could be achieved. It is also possible some areas of the brain are affected without the sound actually passing through the ear.

As a result of this study, the volunteer protocol was modified to introduce a series of questions for each volunteer after they were exposed to the tones (*Have you seen any mages? Have you interesting thoughts during the sounds? Did some frequencies disturb you?*). Volunteers will also be invited to raise their arm if they received some sensations during a tone (left arm for images, right arm for thoughts) and a little pause (20 sec) will be inserted between each tone[5].

During this study, we observed that the exposure to these frequencies during meditation or prayer can create a brain activity response which differs depending on whether or not the volunteers are trained in meditation techniques. This lengthy research has yet to be concluded, but initial results indicate that the aspect of brain waves measured by EEG are totally different[9].

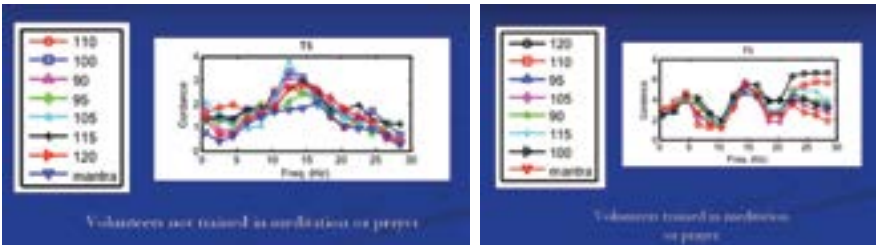


Fig. 2 – The EEG cordance aspect of different tones in the volunteers.
***Left**: the aspect in T5 electrode in a not trained volunteer in meditation or prayer.*
***Right**: the same electrode in a trained volunteer*

In particular we can observe two or more peaks of brain wave frequency in some areas during the emission of tones between 70-140Hz, something that is not usually possible under normal conditions. Usually, (but not with a pathology), such frequencies are found, during sleep, or another frequency, when we are awake, it is not ordinarily possible therefore for two frequencies to be experienced contemporary, (i.e. to be asleep and awake at the same time). However these results showed this is possible if the volunteer is trained in meditation or prayer techniques and is exposed to particular tones. This creates an oneiric experience (one of visions or ideas) with total consciousness but without the use of chemical substances [9].

In the research at work we examined the same group of volunteers in the underground

structure of Cividale del Friuli hypogeum, a very ancient structure connected with a Great Mother's cult and located in North Italy, using a portable EEG device (see Fig.3). The volunteers were subjected to the resonance frequencies present, theoretically making a comparative assessment with our laboratory study. The structure was stimulated in the different chambers by a Irish (or shamanic) with the brains behaviour drum recorded by the EEG. In Cividale del Friuli hypogeum there are two chambers each with a different resonant frequency. The other 4 chambers have been modified over the centuries, which makes it impossible to say with any certainty if they too had a different or a similar range of resonance. Also Jahn and his collaborators found different frequencies of resonance in different temples in England and Ireland, often in different chambers within the same temple[10]. Such frequencies create strong emotions in people, making these places ideal for ritual purposes.

Fig 3 - The underground structure of Cividale del Friuli hypogeum during EEG research. The stimulation of the resonance was obtained by a shamanic drum.

III. TRV CAMERA RESULTS

TRV technology (Variable Resonance Imaging Camera) is something we have been working with over the last three years [3,6]. The TRV system's camera has a common CCD backlit, with a three MegaPixel sensor. The protective anti-aliasing filter was removed to extend its vision beyond visible light into the infrared (IR) and ultraviolet (UV) range. It has a system of rotating LEDs from infrared to visible light which generates ultraviolet light and synchronises it to the lights rotation at will from 1 Hz to 10 KHz. The lens is a 25 mm quartz-fluorite with passband from 200nm to 1800nm. It is connected to a PC, but videos can also be saved to internal flash memory (see Fig. 4).

We utilised a TRV camera and software derived by Russian technology, the same used at Sochi Winter Olympic Games in 2014 (known as the Defender System X in Japan and Merlin Camera in Italy) which analysed almost 2,500,000 people before they entered the venues. It was deemed a real success, because no terrorist attack occurred.

Fig. 4 – The digital camera of TRV system used in Cividale del Friuli hypogeum.

The TRV cameras software makes clear immediately the emotional state of the volunteer, in fact human vibrations from 1Hz to 10Hz are pointed out by the colour and extension (Fig.5).

Fig. 5 - Images converted to a scale of pseudo colours in relation to the frequency in Hz of the human body.

We used this method in the archaeoacoustic field in Italy at the site of Alatri[6] and in Cividale del Friuli hypogeum[2,3,4]. At the second site, we found a natural vibration of geological origin coming from underground which could affect the mind. We found this using a traditional archaeoacoustic method (digital recorders and ultra-sensitive microphones). Normally low frequencies can affect the mind because they are close to natural brain wave frequencies. We must also remember that brain activity is not only electric in nature, but also magnetic, therefore magnetic fields that merge with geological vibrations can modify the state of mind.

For example in Cividale del Friuli (Italy) hypogeum, the TRV system recorded perfectly the transition to an altered state of consciousness of the volunteer, which occurred when the entire chamber began to vibrate at the same frequency as the subjects during chanting. Initially this was captured by the camera and software as a transition to one color, until the image of the person in the foreground totally disappeared, indicative that the frequencies moved from a broad range to a narrower range [6].

In Cividale del Friuli hypogeum this altered state of consciousness was achieved by simply repeating a mantra for approximately eight minutes, as documented by an audio recording which was taken at the same time. Ultimately the male voice or percussion instruments tuned to the right resonance frequency, confirm by TRV camera that a "*mystical*" state can be reached after a few minutes by those who are subjected to the resonance phenomenon inside the hypogeum chambers [6].

Fig. 6 – A volunteer in Cividale del Friuli hypogeum. The blue band around the body indicates the very low frequency of the body which means a very deep state of relaxation of the mind (between 1-2Hz).

Fig. 7 – Using the TRV camera it is possible to value the stress condition of everyone. This child is on the top of Alatri acropolis and the vibrations coming from below make the subject relaxed. She looks to be in a medium state of relaxation as opposed to meditation (4-5Hz).

This method confirms that sound at particular frequencies, within the 70-140 Hz range, can change the state of mind moving the human brain into different level of consciousness. Further, this method expresses the concept that people trained to meditation and prayer can take full advantage from these temples resonances.

IV. CONCLUSIONS

Our research demonstrates the real effect of resonance at ancient temples, on the human body. Archaeaoacosutics is an interesting method to analyse ancient sites to re-discover a forgotten technique that effects the emotional sphere of human consciousness.

In six years of research using new technologies, we are along way from any definitive conclusions. Despite amazing results we need to study more deeply the relationship between ancient sites and people who spend some time within them. We understood that ancient civilizations did not build their temples everywhere, but in particular locations where natural physical phenomena were able to modify the state of conscience of the people during a ritual. New technologies combined with more established methods such as EEG, showed this in our studies. We can say through our technologies and methods ancient populations have a good knowledge of the brain, empiric for sure, but effective.

But we have to underline that only trained people can take advantage from being in these temples in the presence of right tones. Both methods evidenced this. So we can conclude that these temples look as if they were only for "initiated" people or priests, like the historical sources wrote.

We can further conclude imaging technologies open new roads for better understanding this aspect by researchers within the archaeoacoustic field. Archaeoacoustics should therefore not only consider analyzing the acoustic properties of the site, but also all the associated physical phenomena that is not perceived by the ears, which could potentially influence a population and their perception of a particular site as being sacred. Using such technologies, we observed a change of emotional state in various volunteers after they remained for some time at a particular site, es-

pecially from audible vibrations, (as a chant or a drum) or in particular in connection with the resonance phenomenon or non audible sounds (eg natural infrasounds). It appears that mechanical vibrations are only one aspect of the possibility to affect the human mind, because also magnetic fields can have a similar effect. Without studying the relationship between the environment and the human mind, the study of archaeoacoustics appears to be somewhat limited. In our research we demonstrated that some physical phenomena (vibrations, magnetic fields) present at such sites, can influence brain activity [7]. To analyze altered states of consciousness at particular locations, we suggest to use musical instruments or the voice re-creating the original ancient environmental situation to stimulate the resonance whilst volunteers were monitored using electroencelography (EEG)[5,9] and TRV camera[3,6,9]. We also have to consider we cannot use both methods in the same moment, because one interferes with the other for electric and magnetic reason. But it is also necessary to have an archaeological analysis of the site, because archaeoacoustics without an archaeological perspective is only acoustic.

ACKNOWLEDGMENT

We are grateful to the Department of Medical Sciences of the University of Trieste (Italy) for supporting our research and in particular to the Director, Professor Roberto Di Lenarda.

REFERENCES

[1] Cook, I. A.; Pajot, S. K.; Leuchter, A. F., "Ancient Architectural Acoustic Resonance Patterns and Regional Brain Activity", Time and Mind, Volume 1, Number 1, March 2008 , pp. 95-104 (10).

[2] P. Debertolis, N. Bisconti: "Archaeoacoustics analysis and ceremonial customs in an ancient hypogeum", Sociology Study, Vol.3 no.10, October 2013, pp. 803-814.

[3] P. Debertolis, Gullà D, Richeldi F, "Archaeoacoustic analysis of an ancient hypogeum using new TRV camera (Variable Resonance Camera) technology", Proceedings of the "2nd International Virtual Conference on Advanced Scientific Results" (SCIECONF 2014), Žilina (Slovakia) June, 9 - 13, 2014, pp. 323-329.

[4] P. Debertolis, N. Bisconti: "Archaeoacoustics analysis of an ancient hypogeum in Italy", Proceedings of the Conference "Archaeacoustics: The Archaeology of Sound", Malta, February 19-22, 2014, pp. 131-139.

[5] P. Debertolis, G. Tirelli, F. Monti: "Systems of acoustic resonance in ancient sites and related brain activity". Proceedings of Conference "Archaeoacoustics: The Archaeology of Sound", Malta, February 19-22, 2014, pp. 59-65.

[6] P. Debertolis, D. Gullà: "Archaeoacoustic analysis of the ancient town of Alatri in Italy", British Journal of Interdisciplinary sciece, September, Vol. 2, (3), 2015, pp. 1-29.

[7] P. Debertolis, M. Zivic: "Archaeoacoustic analysis of Cybele's temple, Roman Imperial Palace of Felix Romuliana, Serbia", Journal of Anthropology and Archaeology, Vol. 3 (2), 2015, pp. 1-19.

[8] P. Debertolis, D. Gullà: “Anthropological analysis of human body emissions using new photographic technologies. A study confirming ancient perceptions in Art History”, of the “3rd International Virtual Conference on Advanced Scientific Results” (SCIECONF 2015), Žilina (Slovakia) May, 25-29, 2015, pp. 162-168.

[9] P. Debertolis, D. Gullà: “New Technologies of Analysis in Archaeoacoustics ”, Proceedings of Conference "Archaeoacoustics II: The Archaeology of Sound", Istanbul (Turkey), Oct 30-31 Nov 1, 2015, pp. 33-50.

[10] R.G. Jahn, P. Devereux, M. Ibison: "Acoustical Resonances of Assorted Ancient Structures," J. Acoust. Am Soc Vol.99 No.2, February 1996 pp.649-658.

---

* Note. Super Brain Research Group (SBRG) is an international and interdisciplinary project team of research (Italian, Croatian and Finish members) on archaeo-acoustic of ancient sites and temple in Europe (Official web site: http.//www.sbresearchgoup.eu).

B3.32 Archaeoacoustics In Ancient Civilizations: How to Approach this New Complementary Discipline to Archaeology

prof. agg. Paolo Debertolis
Department of Medical Sciences - University of Trieste Chair of Dental Archaeology Coordinator of project SB Research Group Trieste, Italy*
paolo.debertolis@sbresearchgroup.eu

Nina Earl, BSc
Scientific assistant Project SB Research Group London – United Kingdom*

Abstract

Archaeoacoustics is a relatively new approach to analyze any archaeological sites that has interesting acoustic characteristics. It can be used to demonstrate sound occurrences believed to have been incorporated into the design by the architects of certain structures. Another aspect of archaeoacoustic research can understand how such structures affect brain activity, useful during rites where an altered state of mind intensifies the experience. Natural phenomena can also influence the psychological state for example by inducing mystical states. We have demonstrated ancient civilizations had some knowledge of this phenomena, through understanding the significance specific locations were choosen for buildings such as temples. Using digital recording equipment, it is now possible to record non-audible sound frequency bands. These bands have a direct effect on the human body and mind without a person being aware of the existence of their accompanying mechanical vibrations. The hypothesis of SB research group is that at some archaeological sites, exists a measurable natural audio or electromagnetic phenomena that enhance its mystical properties. Following this line of research, interesting archaeoacoustic effects have been discovered at a number of sacred sites from Malta to Turkey and Serbia to Italy. Incorporating a neurophysiological approach, is adding weight to this hypothesis.

I. ARCHAEOACOUSTICS

Archaeoacoustics is a complementary approach to archaeology, it is a new perspective to analyze archaeological sites which sometimes have interesting sound characteristics [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16]. It can demonstrate sound occurrences planned by the builders of some structures Natural sound phenomena were used in several civilizations to create impressive rites, with some ancient structures designed in a such a way as to

directly influence the mind through the vibrations they produced towards a particular state of consciousness [7,16,17,18]. This point of view of ancient sites has had more expansion in the nineties and our research group has followed this road since 2010 investigating a large group of "sacred" sites in Europe and Asia (England, Bosnia, Serbia, Slovenia, Italy, Portugal, Malta and Turkey) publishing our conclusion. Using modern digital recording techniques it is now possible to record very clearly non audible sound frequency bands such as ultrasound or infrasound, which are able to modify the brain activity. It is also possible to make visible and display magnetic fields affecting the mind; using UV Imaging, photography and special software to show the micro-movement of air crossed by magnetic forces [8,13,16]. We discovered that the most part of really sites from Gobekli Tepe in Turkey to Tarxien Temples in Malta, from Alatri Acropolis in Italy to Felix Romuliana Palace in Serbia are all placed over sources of natural low frequencies or magnetic fields which affect human brain activity. We also reproduced the band of vibrations found by other authors in some sacred sites in UK and Ireland in the laboratory and in one sacred site in Italy, confirming that these vibration interfere with human mind in various ways [7,16]. Sometime these bands of sounds have a direct effect on the human body without a person being aware of the associated mechanical vibrations. So after the analysis of about thirty ancient sites the hypothesis of our research group was confirmed and became a thesis. This is: in some archaeological sites considered sacred for thousands of years, there are measurable natural audio phenomena (or magnetic field) that make the place somewhat more mystical than others. How between 11.600 and 2,000 years ago the builders of the temples were able to find the right location for their temples without the use of the measuring devices we have today? We cannot know this for the most ancient civilizations without a written source, but we know that ancient Romans had this knowledge because we have historical records speaking about this. These techniques were used to find the optimal location for military camps, public buildings or spas, being careful to avoid any potential negative impact on health [15]. It is believed that the empirical knowledge handed down to the Romans from the Etruscans, resulted in the Romans holding their soothsayers and in particular a category of priests, called the augurs in high esteem [12].

II. INFRASOUNDS, AUDIBLE LOW FREQUENCIES, ULTRASOUNDS AND MAGNETIC FIELDS

There are a lot of scientific papers that evidence mechanical vibrations have a positive or negative influence on our health and there are several predominant sources of naturally occurring ultrasounds, very low frequency and infrasound found in the environment. Depending on age and gender, humans can perceive sounds in the range of 20Hz to 20 kHz, in some cases sounds above 14-18 kHz are not audible to the human ear. Frequencies above 20 kHz are considered ultrasound whilst frequencies below 20 Hz are considered infrasound. Careful measurements have shown that hearing does not abruptly stop at 20 Hz but the ear is capable of registering infrasound if the sound pressure is sufficient.

Low frequency sound has a relatively long wavelength and low material absorption

rate, hence it has the ability to travel vast distances. These properties make it possible to achieve a profound effect on vast tracts of acoustic space with the production of high sound pressure level acoustic waves. Low frequency sound is non directional sound in its propagation and therefore has the effect of enveloping the individual without any discernable localized source.

Any severe and artificial extreme imposed on the sonic environment has a profoundly destabilizing effect on the individual, indeed infrasound has been used in the context of wars and nowadays there are currently several organizations conducting research in the area of acoustic weapons. However, natural low vibrations with an absence of high pressure can have a positive influence on human health and some people can perceive very low-frequency sounds as a sensation rather than a sound. Infrasound may also cause feelings of awe or fear in humans. Given it is not consciously perceived, it may make people feel that odd or supernatural events are taking place [2]. So it is possible to hypothesize that where there are a lot of natural low vibrations present, ancient populations considered these sites to be "sacred".

Fig. 1 – A subwoofer emitting 18Hz at low volume was positioned close to an incubator where some human cardiac cells were growing. After few minutes all the cells were died. This can express that some "not lethal" weapons are not devoid of serious effects to human body.

In our experience in laboratory research we are conducting on human cardiac cells in collaboration with University of Udine (Italy) we have been able to kill these cells in few minutes after an exposure to 18 Hz (Fig. 1). We realized that the vibrations destroyed the cytoskeleton of human cells by interfering with their quantum vibration. This research is currently ongoing, but it shows how some low vibrations can be dangerous for human health and also used as a weapon.

The same argument could be applied to natural ultrasounds. The upper frequency limit in humans of approximately 20.000Hz is due to limitations of the middle ear, which acts as a low-pass filter. However, if ultrasound is fed directly into the human skull and reaches the cochlea through bone conduction, without passing through the middle ear, it is then possible to also hear these frequencies [2]. Because in humans the upper limit pitch of hearing tends to decrease with age, children are able to hear some high frequencies sounds that older adults cannot. Ultrasounds are well known and used in the medical field. Ultrasonography is a diagnostic medical imaging technique used to visualize many internal organs with real time tomographic images. Ultrasound is used for healing inflamed tissue and for therapeutic applications or in dentistry for

cleaning tartar from teeth. Although the long term effects of exposure to ultrasound at strong intensity are still unknown, currently the medical profession considers the benefits to patients outweigh the risks. In contrast to medical applications ultrasound has been studied as a basis for sonic weapons, due to its direct effect on the human body and nervous system. Applications have been developed that include riot control through the disorientation of attackers and lethal levels of ultrasound that can be used like a gun. In fact high frequencies can readily be absorbed by materials and as they are highly directional they have been incorporated in the design of acoustic weapons. It is probable that natural emissions of ultrasounds were heard by very young people of ancient civilizations as a supernatural sound, but in the rest of the population these were felt only as a good or bad sensation relative to the perceptible frequencies in a particular location along with the mystic aspect of the site.

For a long time neurology has been studying brain magnetic activity deriving from electro-activity of the brain with good success. For example the MEG (magnetoencephalography) allow the recording of cerebral electromagnetic activities with excellent temporal resolution. These tools have also considerably progressed in spatial resolution and now constitute real methods of Electric and Magnetic Source Imaging (a). Nowadays this method contributes to the presurgical evaluation of pharmacoresistant partial epilepsies[19].

In recent years the electromagnetic theories of consciousness propose that consciousness can be understood as an electromagnetic phenomenon. Electromagnetic field theories (or "EM field theories") of consciousness propose that consciousness results when a brain produces an electromagnetic field with specific characteristics. Neurophysiological observations made by Freeman over several decades contribute to the idea that brains are essentially non-equilibrium systems which do not come to a steady state even for a fraction of second. Brains constantly change, using dynamical patterns of activation in their operation to present memories, concepts, and actions. These considerations suggest that the brain's integrative functions are the result of competition of complementary tendencies of cooperative integration and autonomous fragmentation among many distributed areas. The interplay of these two tendencies (autonomy and integration) constitutes the metastable regime of brain functioning, whereas local (autonomous) and global (integrated) processes coexist as a complementary pair, not as conflicting principles[20].

A natural magnetic field can affect brain activity in the same way. This is not the place to discuss problems associated with artificial magnetic fields emitted by modern technology, but research carried out at different sites using modern technology, has confirmed that various locations have a strong natural magnetic field which directly affects brain activity. Ancient populations were more sensitive than our civilization, and by using empirical methods they realized that some sites had somehow changing their consciousness and creating an altered state of mind [16,21].

III. HOW TO MOVE INTO ARCHAEOACOUSTICS?

For recording **sounds** we use two types of dynamic high-end microphones extended in

the ultrasound field together principally with a digital portable recorder with a maximum sampling rate of 192 kHz (Tascam DR-680 of TEAC Group), but we controlled the result with other digital recorders (Tascam DR-100 and Marantz PMD661) with less technical characteristics.

At the same time as recording in the air we used professional studio microphones with a wide dynamic range and a flat response at different frequencies (Sennheiser MKH 8020, response Frequency 10Hz - 60.000 Hz) along with shielded cables (Mogami Gold Edition XLR) and gold-plated connectors.

Fig. 2 – The set-up used for recording sounds: the recorder Tascam DR-680 and Sennheiser MKH 8020 microphones in Enclosure D of Göbekli Tepe ancient site (South-East Anatolia).

For recording in water we used ultrasensitive omnidirectional microphones also used by sea biologists (Aquarian H2a-XLR Hydrophone, frequency response from 10Hz to 100Hz) with shielded water proof cable from factory. This type of microphone has a wide bandwidth typically used to hear whale song up to several kilometers away. In this case the sound is transmitted very quickly in water, with the body of water acting as a reflector capable of capturing every vibration many meters away.

Fig. 3 *– The Aquarian H2a-XLR Hydrophone.*

Fig. 4 *– Two microphones Hydrophones were placed in the main well of the Medieval Abbey of San Salvatore which is at the foot of Mount Amiata in Tuscany (Italy). Mount Amiata is an extinct volcano, but some activity remains underground; at the time of the Etruscans who were greatly impressed by the vibrations, considering it as the voice of God and therefore led them to consider these locations sacred.*

For recording ultrasounds we use a Pettersson D1000X Bat detector and Bat sound software, Pettersson Elektronik, Uppsala University. It is the best source for recording ultrasounds from every source. Originally built for recording ultrasounds from bats, this device is very useful for recording natural ultrasounds up to 400.000Hz.

Fig. 5 – The Pettersson D1000X Bat detector from Swedish firm Pettersson Elektronik.

Fig. 6 – The Pettersson D1000X device was used for detecting the emission of ultrasounds from the granite of the megaliths in Portela de Mogos (Portugal) when hit by the sun. It is also possible that in ancient times the population living without the presence of noise pollution of modern civilization could possibly have felt this vibration; without the distraction from various machine tools or transportation, without the noise of loud music and living in perfect harmony and connection with nature.

Before recording we use a spectrum analyzer (Spectran NF-3010 from the German factory Aaronia AG) for searching electromagnetic phenomena present around us which could have had a negative influence on our results.

1. Any new camera can be modified in this way, however Nikon, Sony and Olympus cameras can only be modified by a private technician automatically invalidating the warranty of the firm, and the camera can lose characteristics necessary for scientific use.

Fig. 7 - Spectran NF-3010 from the German factory Aaronia AG.

Praat program version 4.2.1 from the University of Toronto and Audacity open-source program version 2.0.2, both for Windows were used to analyze the various recorded tracks.

We also use a geologic device for confirming what we find by microphones in infrasound range. It is GeoBox SR04S3 Datasheet from Italian firm SARA. The digital sensor SR04 GeoBox is a high-performance instrument especially suitable for acquiring signals for seismological and geophysical surveys such as the Horizontal/Vertical Spectral Ratio - HVSR. The SR04 GeoBox is designed especially for recording ambient seismic noise, but it can also record earthquakes and artificial vibrations. Compact, reliable and simple, it is fully functional within minutes after deployment.

Fig. 8 – Left: GeoBox SR04S3. Right: the device connected with the computer at work.

To make visible the shape of the **magnetic field**, UV photography and a vector program for PC (PIV – Particle Image Velocimetry) was used. This consisted of a modified Canon EOS 1100D digital camera, with its anti-aliasing filter removed The camera used was modified in Canon's Italian factory ([1]). In the ultraviolet band (UV) the absorption of

lenses of normal optics (lenses without calcium fluoride and quartz for forensic use) is very strong, usually a normal optic is unable to allow electromagnetic waves below 320-350nm to pass through, but it is sufficient for analyzing the UVA band (400-315nm) where it is possible to perceive the movement and the behaviour of dust suspended in the air, and gas flows as a water steam which orientate itself as a dipole in the magnetic field [14].

Particle Image Velocimetry (PIV) by Dantec Dynamics from Denmark is the software used to analyze this movement in the UV video and photographs taken. PIV is used in industry as an intuitive measurement technique to measure two or three components of velocity in a variety of flows. The application of PIV in research and industry is widespread, due to its ease of use and accurate data representation. As easy and intuitive as PIV is, it involves many cross-disciplinary challenges, from classical optics and imaging to the use of dedicated state-of-the-art digital electronics and lasers. The principle of PIV working is very simple: two consecutive shots illuminate a slice or volume of a flow field with particles suspended in the flow. The scattered light from the particles is recorded in two consecutive images on one or several digital cameras. The images are sub-divided into smaller areas for calculating the mean particle displacement between two corresponding sub-areas. The particle displacement is calculated using cross-correlation or Least Squares Matching techniques. Since the time between the shots is known, the particle velocity can be determined. Taking into account the magnification of the optical setup, the absolute velocity field can be derived. The velocities calculated from an image pair are an instantaneous snapshot of the flow viewed by the cameras. PIV results are an accurate representation of the flow presented to the user and viewers in an easy to understand and visual manner. The presentation is aided by advanced soft-ware post-processing. Dantec Dynamics is the leading provider of laser optical measurement systems and sensors for fluid flow characterization and materials testing.

IV. RESULTS OF OUR METHODS

It's not possible to summarize all the results found during from six years of research. However, the thesis SB research group (SBRG*) proposes is that natural phenomena in the audible, infrasonic or ultrasonic sound bands, and electromagnetic or geodynamic phenomena may be closely connected to particular aspects of spirituality. These characteristics appear to have ultimately influenced the choice of construction of a particular temple in a certain location. It was observed that when a natural phenomenon was found, the archaeological site was ancient and important and had a church or temple present long before the arrival of medieval churches. Non significant data was also collected from chapels and medieval sites of religious importance, that also appeared to offer mystical properties, but without any such physical or mechanical. On the contrary, many locations built between the Neolithic Age to the Fall of Roman Empire have some interesting phenomena suggested by the archaeology without their being any significant archaeoacoustical features. Was this knowledge perhaps lost in the Middle Ages?

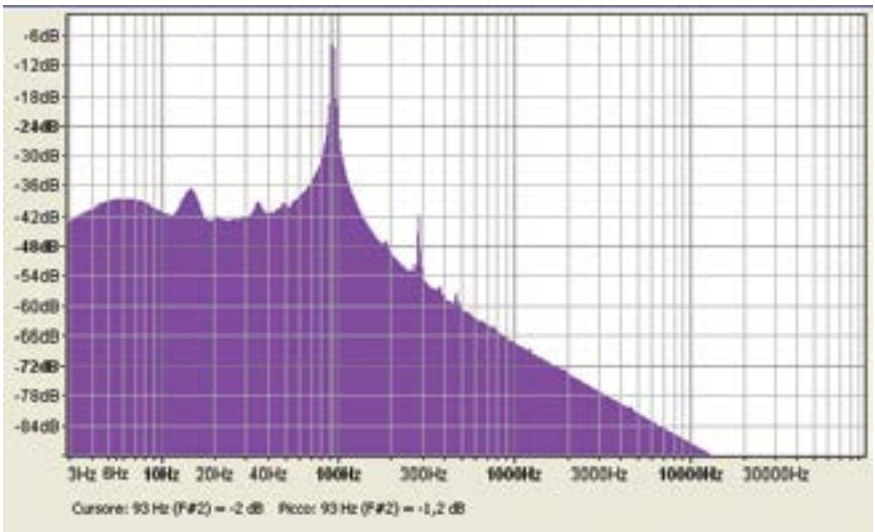


Fig. 9 – The typical aspect of resonance found in a niche of a subterranean shrine located in Sogmatar (Turkey). The temple was built with this purpose because the peek is located in the range 70-130 Hz of a male voice and affecting brain activity.

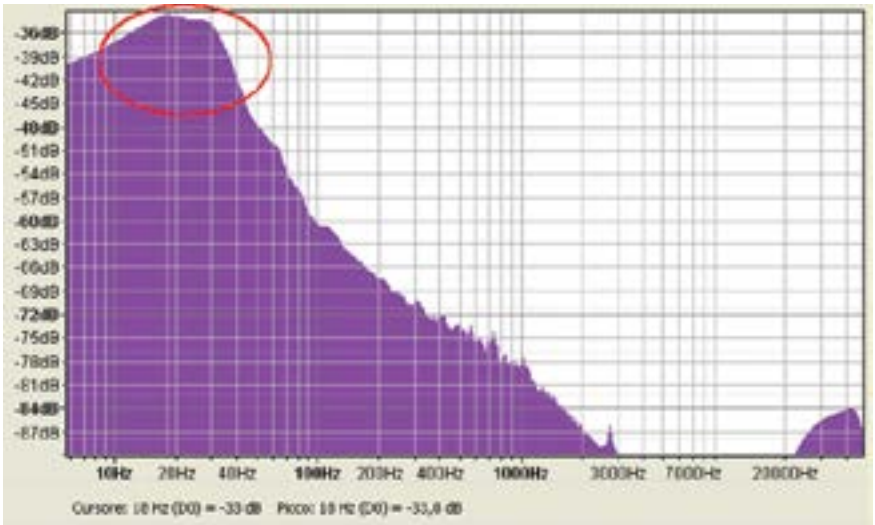


Fig. 10 – Graph of the recordings made in the Temple of Cybele (III century AD) located in the imperial Roman palace Felix Romuliana in Serbia. There is a strong peak of low frequencies and infrasounds inside the "fossa sanguinis" of the temple. These low frequencies and infrasounds would certainly have contributed to a general atmosphere of excitement and/or fear in those participating in any rituals inside this temple.

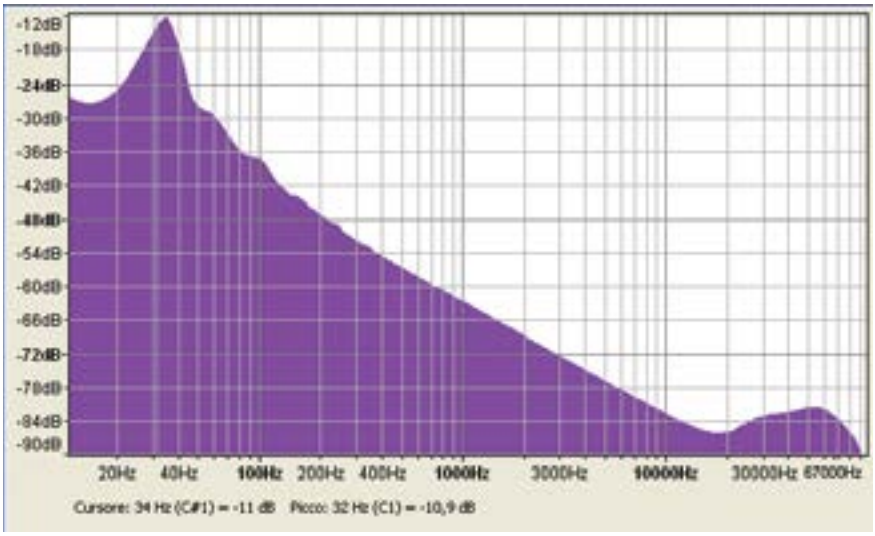


Fig . 11- The peek of frequency found in the Neolithic Xaghra Circle in the island of Gozo (Malta). In this case the peek is at 34Hz.

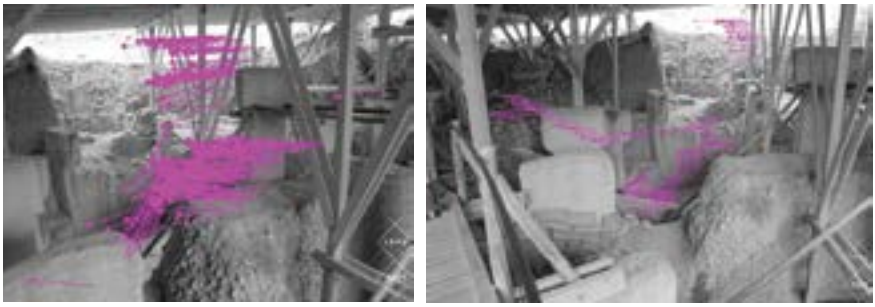


Fig. 12 – The aspect of a magnetic field found in Enclosure D of Göbekli Tepe ancient site (South-East Anatolia). The image is taken by UV camera and elaborated by PIV software.

V. CONCLUSIONS

The low frequencies, infrasounds, ultrasounds, magnetic field found in several ancient sacred sites explain very clearly the sensation of mysticism which some people perceive in these places and how it is very easy for those practising meditation at these sites to apply their techniques. We can suppose that these frequencies are probably comming from geological faults or from the movement of underground water. These

* Note. Super Brain Research Group (SBRG) is an international and interdisciplinary project team of research (Italian, Croatian and Finish members) on archaeo-acoustic of ancient sites and temple in Europe (Official web site: http.//www.sbresearchgoup.eu).

sacred sites were where wisdom, culture and attention was common, helped by this good natural enviroment. Because infrasounds and low frequencies are not directional, for our protocol we needed to capture these sounds using professional microphones with a flat response on all frequencies and a deep response in all frequencies. In either case, researching ultrasounds or low frequencies, it is very important to use well shielded cables with gold-platted connectors to avoid picking up radio waves from other sources.

Living our modern lives in urban towns and cities, we are exposed to a lot of bad mechanic vibrations with a high volume which in most cases is very detrimental for health. In contrast, in their absence ancient people would have been more attuned to natural vibrations. They understood the best locations to go to so they could make contact with God through their prayers, leading them to build their temples in these locations.

In conclusion as our experience demonstrates, archaeoacoustics appears to be an interesting new method for reanalyzing ancient sites using different study parameters. This reaffirms the aura of legends that pervades these places, and modern technology is now able to give greater clarity to the origin of many interesting phenomena.

ACKNOWLEDGMENT

We are grateful to Department of Medical Sciences of the University of Trieste (Italy) for supporting in our research and in particular to the Director, Professor Roberto Di Lenarda.

REFERENCES

[1] P. Debertolis, H.A. Savolainen: "The phenomenon of resonance in the Labyrinth of Ravne (Bosnia-Herzegovina). Results of testing "Proceedings of ARSA Conference (Advanced Research in Scientific Areas), Bratislava (Slovakia), December, 3-7, 2012, pp. 1133-1136.

[2] P. Debertolis, N. Bisconti: "Archaeoacoustics in ancient sites" Proceedings of the "1st International Virtual Conference on Advanced Scientific Results" (SCIECONF 2013), Zilina (Slovakia) June, 10-14, 2013, pp. 306-310.

[3] P. Debertolis, N. Bisconti: "Archaeoacoustics analysis and ceremonial customs in an ancient hypogeum", Sociology Study, Vol.3 no.10, October 2013, pp. 803-814.

[4] P. Debertolis, S. Mizdrak, H. Savolainen: "The Research for an Archaeoacoustics Standard", Proceedings of the 2nd Conference ARSA (Advanced Research in Scientific Areas), Bratislava (Slovakia), December, 3-7, 2013, pp. 305 -310.

[5] P. Debertolis, Gullà D, Richeldi F, "Archaeoacoustic analysis of an ancient hypogeum using new TRV camera (Variable Resonance Camera) technology", Proceedings of the "2nd International Virtual Conference on Advanced Scientific Results" (SCIECONF 2014), Žilina (Slovakia) June, 9 - 13, 2014, pp. 323-329.

[6] P. Debertolis, N. Bisconti: "Archaeoacoustics analysis of an ancient hypogeum in Italy", Proceedings of the Conference "Archaeacoustics: The Archaeology of Sound", Malta, February 19-22, 2014, pp. 131-139.

[7] P. Debertolis, G. Tirelli, F. Monti: "Systems of acoustic resonance in ancient sites and related brain activity". Proceedings of Conference "Archaeoacoustics: The Archaeology of Sound", Malta, February 19-22, 2014, pp. 59-65.

[8] P. Debertolis, N. Earl, "Forensic Imaging in Anthropology", Proceedings of The 2nd Human And Social Sciences at the Common Conference (HASSACC), Žilina (Slovakia), November, 17 – 21, 2014, pp. 206-212.

[9] P. Debertolis, A. Tentov, D. Nicolic, G. Marianovic, H. Savolainen, N. Earl: "Archaeoacoustic analysis of the ancient site of Kanda (Macedonia)". Proceedings of the 3rd Conference ARSA (Advanced Research in Scientific Areas), Zilina (Slovakia), December, 1-5, 2014, pp. 237-251.

[10] P. Debertolis, F. Coimbra, L. Eneix: "Archaeoacoustic Analysis of the Ħal Saflieni Hypogeum in Malta", Journal of Anthropology and Archaeology, Vol. 3 (1), 2015, pp. 59-79.

[11] P. Debertolis, D. Gullà: "Archaeoacoustic analysis of the ancient town of Alatri in Italy", British Journal of Interdisciplinary sciece, September, Vol. 2, (3), 2015, pp. 1-29.

[12] P. Debertolis, M. Zivic: "Archaeoacoustic analysis of Cybele's temple, Roman Imperial Palace of Felix Romuliana, Serbia", Journal of Anthropology and Archaeology, Vol. 3 (2), 2015, pp. 1-19.

[13] P. Debertolis, D. Gullà: "Anthropological analysis of human body emissions using new photographic technologies. A study confirming ancient perceptions in Art History", of the "3rd International Virtual Conference on Advanced Scientific Results" (SCIECONF 2015), Zilina (Slovakia) May, 25-29, 2015, pp. 162-168.

[14] P. Debertolis, D. Nicolic, G. Marianovic, H. Savolainen, Earl N., N. Ristevski: "Archaeoacoustic analysis of Kanda Hill in Macedonia. Study of the peculiar EM phenomena and audio frequency vibrations ", Proceedings of the 4th Conference ARSA (Advanced Research in Scientific Areas), Zilina (Slovakia), November 9-13, 2015, pp.169-177.

[15] P. Debertolis, L. Eneix, D. Gullà: "Preliminary Archaeoacoustic Analysis of a Temple in the Ancient Site of Sogmatar in South-East Turkey", Proceedings of Conference "Archaeoacoustics II: The Archaeology of Sound", Istanbul (Turkey), Oct 30-31 Nov 1, 2015, pp.137-148.

[16] P. Debertolis, D. Gullà: "New Technologies of Analysis in Archaeoacoustics ", Proceedings of Conference "Archaeoacoustics II: The Archaeology of Sound", Istanbul (Turkey), Oct 30-31 Nov 1, 2015, pp. 33-50.

[17] R.G. Jahn, P. Devereux, M. Ibison: "Acoustical Resonances of Assorted Ancient Structures," J. Acoust. Am Soc Vol.99 No.2, February 1996 pp.649-658.

[18] Cook, I. A.; Pajot, S. K.; Leuchter, A. F., "Ancient Architectural Acoustic Resonance Patterns and Regional Brain Activity", Time and Mind, Volume 1, Number 1, March 2008 ,

pp. 95-104 (10).

[19] M. Gavaret, J.M.Badier, P. Chauvel: "High-resolution EEG (HR-EEG) and magnetoencephalography (MEG)", Neurochirurgie, 2008 May, 54(3), pp.185-90.

[20] A. A. Fingelkurts, A. A. Fingelkurts, C. F.H. Neves: "Phenomenological architecture of a mind and operational architectonics of the brain: the unified metastablecontinuum", New Mathematics and Natural Computation, 2009, V. 5. No 1, pp. 221–244.

[21] T. Saunders: "Health hazards and electromagnetic fields". Complement Ther Nurs Midwifery, n.9, 2003, pp. 191–197.

** Note. Super Brain Research Group (SBRG) is an international and interdisciplinary project team of research (Italian, Croatian and Finish members) on archaeo-acoustic of ancient sites and temple in Europe (Official web site: http.//www.sbresearchgoup.eu).*

B4. ASTRONOMY AND ASTRONOMICAL INSTRUMENTS

B4.1 Ancient Greece and Origins of the Heliocentric Theory

Milan S. Dimitrijević[1], Efstratios Theodossiou[2], Aris Dacanalis[2], Petros Z. Mantarakis[3]
[1]*Astronomical Observatory of Belgrade, Serbia*
[2]*University of Athens, Athens, Greece*
[3]*Las Vegas, Nevada, 89130, USA*

Abstract

Since early antiquity, the important question of philosophy and astronomy was, what occupies the center of the known world. According to the geocentric system, in accordance with the anthropocentric view, the Earth lies at the center of the world. For centuries this was the dominant theory, supported by the majority of philosophers and astronomers. However, the Ancient Greek world was also the cradle of the opposite view, the heliocentric theory of Aristarchus of Samos (c.310 -230 BC), which is generally credited to be the first to postulate a non-geocentric system. But, centuries before him, seeds of the heliocentric theory can be traced back to the Orphic Hymns and to the teachings of Anaximander and the Pythagoreans.

Here, the evolution of the heliocentric theory of Antiquity will be analyzed and discussed from the first mention of it in the Orphic Hymns. The theory was further advanced by the Pythagoreans, especially the "pyrocentric" system with a central fire, of Philolaus of Croton. Also contributing to the heliocentric theory were the views and ideas of Icetas, Ecphantus, Heraclides of Pontos, Anaximander, Seleucus of Seleucia, and finaly of Aristarchus of Samos. Unfortunately, the heliocentric theory did not prevail over the geocentric view, which gained wide recognition due to the weight of Aristotle's support, and later on due to the theories of the great astronomer Claudius Ptolemy (2nd century AD).

1. INTRODUCTION

For centuries, the geocentric system placed Earth at the center of the world, in accordance with the prevailing anthropocentric views. But long before Copernicus, in ancient Greece, Aristarchus of Samos (c.310-230 BC) formulated the heliocentric theory.

And before that, came the seeds of theories that it is not Earth at the unique center of rotation of all heavenly bodies, starting with the Orphic Hymns and progressing to the teachings of Anaximander and the Pythagoreans and their followers. To a large degree, due to the authority of Aristotle and of the great astronomer Claudius Ptolemy (2nd cent. AD), the heliocentric theory was not widely accepted until the so called Copernican revolution, and even then, opponents were numerous.

In this contribution, we will present the ancient Greek development of the ideas that led the heliocentric theory of great Aristarchus, reformulated again in the 16th century by Copernicus.

2. ORPHIC HYMNS

As pointed out by the Greek astronomer Constantinos Chassapis [1], and Maria Papathanassiou [2, 3], the first indications of views, not in accordance with the geocentric Universe, the first seeds of the heliocentrism could be found in the ancient teachings of Orpheus, considered to be the basis of the first mystic Greek religion, e.g. the Orphic Hymns, consisting of 87 hexametric poems, consisting of 1200 verses in total, under the title "*Hymns of Orpheus to Musaeus*".

These hymns, containing a variety of astronomical information (not always obvious in the poetic language), and interesting cosmological ideas, provided inspiration for many Greek philosophers and writers.

In the Orphic Hymns [4, 5], "*chaos*", born from the cosmic egg, is what we would now call space. "Gaia" is not the planet but the earth-mother and "Eros" (love), is the creational force. Heaven, revolving around the Earth, is the ruler of the world:

> *Great Heav'n* [*Ouranos*], *whose mighty frame no respite knows... Hear, world ruler,...,*
> *forever whirling as a sphere around this earth*
> [*III. TO HEAVEN: The Fumigation from Frankincense, verse 1*]

As stressed in [1-3], the suggestion that the first seed of the heliocentric system is present in the Orphic Hymns in the following verses:

> *Hear golden Titan! Glowing like gold, you who strides above, oh heavenly light...*
> *...you who combines the epochs ...You are the world ruler...*
> *With your golden lyre, draw on the harmonious path of the world...*
> *...* [*you*] *who wanders through fire and moves around in a circle*
> [*VIII. TO THE SUN, verse 2*]

Namely, the phrase "[you who attracts] *draw on the harmonious path of the world*" could be an idea of the harmonious movement of the planets around the Sun. If one takes into account that the planets are in the meaning of the term world, as its part, then the "golden" Sun may represent the attractive center of their "harmonious paths" around him.

Moreover, in hymn 34 "To Apollo" is stated:

> *Loxias, the pure! ... You mixed in equal parts winter and summer...*
> [XXXIV. TO APOLO, verse 6,... and 20]

In fact, the Sun - "Loxias" (meaning "tilted") mixed the parts of the year so that it is divided into two equal parts, summer and winter. This detail has drawn attention of the astronomical community, since it can help to the dating of Orphic Hymns. If we take this statement literarily, and determine when in the past the duration of summer and winter was the same, we could assume, of course without further solid evidence, that the Orphic Hymns might originate near 1841 BC or 1366 BC [1,6].

In Hymn 84 (To Hestia) there is also an excerpt contributing to the heliocentric aspect, denying to the Earth the central position in Universe:

> *You who occupies the center of the home of the greatest and eternal fire.*
> [LXXXIV. TO HESTIA, verse 2]

In addition, a fragment in *Orphicorum Fragmenta* [5], concerns the rotation of Earth, stating that the round Earth rotates in equal times around its axis (Fr. 247 v. 24-26, pp. 261-262 [5]). Consequently, it appears that in the Orphic hymns all the elements of a heliocentric system can be found – a central sun, revolving celestial objects and a rotating Earth. Therefore, one may assume that the seeds of heliocentric view can be traced in the Orphic Hymns.

3. ANAXIMANDER

The first ancient Greek philosopher to talk in about the motion of the Earth around the center of the world, which may have been the Sun, was most likely the student and friend of Thales, Anaximander (c. 610 – 546 BC). He thought of the Earth as a drum-like cylinder, rotating separately from heaven, and revolving around the center of the Universe. It is also important that Anaximander assumed that even be the Sun might lie at the center.

The views of Anaximander are described for example by Theon of Smyrna (70-135 BC), who lived in the era of Emperor Hadrian, in his work "*Expositio rerum mathematicarum ad legendum Platonem utilium*" [7].

Some of Anaximander's views were accepted by later Greek naturalists and philosophers like Empedocles of Agrigentum (490-430 B.C.), Parmenides of Elea (early 5th century BC), Aristarchus of Samos, Cleomedes (2nd or 3rd century BC) and several of the Pythagoreans.

4. THE PYTHAGOREANS

The next important contribution to the development of the heliocentric view was by

the Pythagoreans. Pythagoras' school of philosophy and mathematics was founded in Croton, Calabria (southern Italy) in c.540 BC. The students of Pythagoras were trained in astronomy, but by a rather mystical approach. Pythagoreans believed in mystical relations between numbers and different phenomena and also that planetary spheres create harmonious sounds (the "music and harmony of the spheres"). They believed that this, constantly created harmony is an eternal expression of divine harmony.

The School of Pythagoras, was in fact a brotherhood, organized in the way of the Orphic religious communities, with various degrees of initiation. It made an essential contribution to geometry, music, arithmetic and astronomy, all very important for the evolution of scientific thought. With the help of geometry and the harmony of sounds and numbers, they formulated the notion of perfection of the Universe, and described it as: "Cosmos", which comes from either "*cosmo*" - "to orderly arrange", or from "*cosmema*" - "jewel" (ornament). According to the doxographer Aetius: "*Pythagoras was the first to name the place of all things Cosmos, due to its orderly nature*" [Aetius, De Vestutis Placitis, II, 1, 1 (D. 327, 8)]

According to Pythagoras, the Earth was spherical and immobile, *without being supported by anything*, in the center of the Cosmos, which was spherical as well. Also, D. Kotsakis stated that "Pythagoras was the first who taught that the apparent motion of the Sun on the celestial sphere from the east to the west, could be analyzed in two distinct motions: One daily from East to West, parallel to the equator, and one yearly from West to East on the ecliptic" ([9], p. 28).

It is of interest that in the 6th century BC, some followers of Pythagoras (Philolaus of Croton, Heraclides of Pontus, Ecphantus of Syracuse and others), believed that the Earth is not at the center of Universe and formulated a "pyrocentric" theory. Namely, they believed that the element of fire was the "first principle" of the Universe, which, after the Creation, has been accumulated at the center.

Teachings and views of Pythagoras and his students, their mysticism, as well as their aristocratic political tendencies, in addition to their innovative theories, caused the violent reaction of their adversaries in Croton. The leader of revolt was Cylon, who had been sent away from the school for failing to conform with its principles. When the followers were gathered together, he made an assault, and many of them were killed or exiled: "*Cylon of Croton... and those allied with him, hunted* (*killed*) *the Pythagoreans down to the man*." ([10] (V.P.) 248-249 ff.

Philolaos, along with some other Pythagoreans like Lysias and Archippus, survived the revolt of Cylon. According to some accounts Philolaus' teacher was Pythagoras, but according to other sources his teacher was Lyssias.

4.1 The theories of Philolaus of Croton

Pythagorean Philolaus of Croton (c. 480 - 385 BC), spread the ideas of his master, by organizing and writing a synopsis of his philosophy. According to him, Cosmos is unique and its existence started from the centre, where fire was accumulated. Around the Centre revolved "Antichthon", (or Counter-earth – a hypothetical invisible Earth), the Earth, the Moon, the Sun, the five planets known at the time (Mercury, Venus, Mars, Ju-

piter and Saturn), and the sphere of the fixed stars. So, the number of heavenly bodies revolving around the central fire is ten, a sacred number for Pythagoreans. Some speculate that Antichthon was introduced just to raise the number of the celestial bodies to the sacred number ten.

Concerning the cosmological views of Philolaus, the doxographer Aetius ([8] I 3, 10), informs us (citing Theophrastus): *Philolaus believes that there is fire around the center of the Universe, which he calls "hestia of all" and "house of Zeus", "mother of the Gods", "altar, constraint and measure of nature". There is another fire which dwells in the outer region of the Universe. The center, he says, came first by nature, and around it dance ten heavenly bodies: The sphere of fixed stars, then the five planets, then the Sun, then the Moon, followed by the Earth and Antichthon, and after all these the fire of "hestia", which lies around the center. The outer region, which surrounds the whole Universe, is a place where the elements are in their pure state, unmixed, and that place he calls "Olympus". All that lies beneath Olympus, namely the part where the five planets along with the Sun and the Moon lie, he calls "cosmos", while the area beneath those, the sublunar space ...he calls "heaven". Wisdom is related to the order which holds in the heavenly bodies, while virtue is relevant with the disorder of the things which are subject to birth. The first is perfect while the second is imperfect* ([8] II 7, 7 (D. 336, probably excerpt of Theophrastus in Posidonius).

In another passage Aetius writes: *The Pythagorean Philolaus places the fire in the center* (*for it is the Universe's focal point*), *secondly he places the Antichthon, then, our habitat, the Earth, comes third, placed opposite* [*to the Antictchon*] *and moving in a circle, that being the reason for the beings of Antichthon being invisible to the beings of the Earth. The ruling power of the Universe lies in the central fire, which God placed, like a keel, to base the foundation of the sphere that makes up the world*". ([8] III 11, 3 (D. 337 of Theophrastus)).

We can see that, according to Philolaus, all what is in "Olympus" and "Cosmos" never changes, while in the areas below the Moon, everything born, ages, and dies eventually. The Earth and all other planets revolve around central fire Hestia, in the same direction but distances and speeds are different. The Sun shines not by its own light, but by the fire obtained from Hestia, which is invisible since it always shines to the antipodes of the Earth.

We can see that Philolaus, disputing the central role of Earth in the Universe, and introducing the idea of "central fire", certainly set the basis for Aristarchus' heliocentric theory, even without the Sun in the center. Professor Stavros Plakides (1983-1990) assumed that Philolaus, refrained from placing the Sun at the center of the Cosmos, fearing for his life, after experiencing the violence in Croton.

Aetius, also informs us, that concerning the motion of the Earth, the view of Philolaus is: *Others believe that the Earth is immobile. Philolaus on the contrary, believes that the earth is moving in a circle around the fire, tracing a tilted circle, just like the Sun and the Moon does* ([8] III, 13, 1. 2. (D 378)). So, Philolaus is not in accordance with his teacher, and states that the Earth is not immobile in the center of the Universe, but revolves around the "Central Fire".

It is interesting that, according to Diogenes Laertius, Plato bought a copy of the

work of Philolaus for a very high price: *Some authorities, amongst them Satyrus, say that he wrote to Dion in Sicily instructing him to purchase three Pythagorean books from Philolaus for 100 mnae* ([12], III 9).

Plutarch inform us that Plato studied carefully the work of Philolaus, and, in his late years, was persuaded that the Earth is indeed revolving around the Sun: *As Theophrastus informs us, Plato, near the end of his days had regrets for his older opinion, by which he unfittingly placed the Earth at the center of the Universe* ([13] *Platonicae Quaestiones* H1 915, vol. XIII_1, 76-78). Probably due to the study of Philolaus, there is another change in the views of Plato: "*In Republic he identifies the celestial equator with the ecliptic, an idea different from that expressed in Timaeus*" [14].

The world-view described by Philolaus was indeed revolutionary for the scientific thought of the 5th century BC. As cited in [9], the Italian astronomer Giovanni Schiaparelli (1835-1910), wrote the following, concerning the system proposed by Philolaus: *The system of Philolaus was not a fruit of some restless imagination, but came through the torque and pull of one who sets the outcomes of observation in accordance with a predetermined principle, which exists above the nature of things...Appreciating this, and combining it to the fundamental theorems of the Pythagorean Philosophy, the system of Philolaus naturally appears as one the most wonderful creations of human genius. His critics are incapable of appreciating the power of necessary research, in order to unify the ideas of the roundness of the Earth, its levitation in space, and its motion. Indeed, without these ideas, there would have been no Copernicus, neither Kepler or Galileo and Newton* ([9], p. 30).

4.2 The views of Icetas, Ecphantus and Heraclides of Pontus

It should be mentioned that not only Philolaus, but also other Pythagoreans, like Icetas and Ecphantus of Syracuse and Heraclides of Pontus (c. 5th century BC), developed new ideas.

So, Icetas of Syracuse taught that Heaven, Sun, Moon and the stars were immobile, and that only the Earth is moving. Cicero describes his views in the following way: *As Theophrastus says, Icetas of Syracuse was of the opinion that the heaven, the Sun, the moon and the stars* (*i.e. the planets*) *and all that is high above are immobile, and nothing in the world is moving, apart from the Earth. But as it rotates around its axis with the greatest possible speed, its motion causes all these phenomena to appear, which would have appeared were the Earth immobile and heaven rotated instead of it* ([15] II, xxxix, 123).

It appears that this theory was accepted and by Ecphantus and Heraclides. They believed that the Earth rotates in space, "just like a wheel around its axis".

Hippolytus writes that the Pythagorean Ecphantus believed that the Earth spins around its axis with an eastern direction, but does not change its place in space. ([16] *Ref.* I 15 (D. 566W. 28)). This is also mentioned by doxographer Aetius, who states also that Heraclides agrees with Ecphantus. ([8] III, 13, 3 (D. 378)).

Heraclides of Pontus (c. 390 – 310 BC), a student of Plato, lived and died in Heracleia Pontica (a city on the coast of Bithynia in Asia Minor). He also believed in the rotation of the Earth around its axis and considered that the Sun might even be the center of rotation of Mercury and Venus.

5. ARISTARCHUS OF SAMOS

After the Pythagoreans, the great astronomer Aristarchus of Samos (310-230 BC), developed the heliocentric theory. This is mentioned by Archimedes ([17] I 4-6 (3, 180-182), manuscript 2, Cod. Laurent. Gr. 28) and Plutarch ([18] II, 24 (7, 355a)). Aristarchus' hypothesis was so original, that he was accused of atheism. In order to avoid consequences, Aristarchus escaped from Alexandria, with the help of his teacher Straton of Lampsacus ([8] book 7, 313b, 16-17).

Unfortunately, the heliocentric theory of Aristrachus was not accepted, and the geocentric system of Claudius Ptolemy (2nd century AD), reigned for centuries, supported by Aristotle, the indisputable authority during the Dark Ages.

6. HELIOCENTRISM AFTER ARISTARCHUS

A follower of Aristarchus, who supported a heliocentric theory of his own, was Seleucus of Seleucia on Tigris in Mesopotamia (c. 190 BC - active around 150 BC). All of the original work of Seleucus has been lost, but fragments are found in the works of Plutarch, Strabo, Aetius and Hippolytus. So, Hippolytus writes about his views that the Earth is moving around the Sun, and that the Moon influences its axial rotation and revolution ([16] Book C, 897C, 14-16), mentioning also his belief that the Cosmos was infinite ([16] Book B, 886C, 6). Seleucus also correctly explained that the Moon is responsible for tides.

A strong supporter of the heliocentric theory was Emperor Julian of Byzantium (336-363 AD), who studied carefully the works of Greek philosophers and astronomers, and believed that "*world order was influenced by a heavenly and divine hierarchy, in which everything originated from One God, the illuminating Sun*" [14]. *In his book Hymn to King Helios dedicated to Sallust, he writes: For that the planets dance about him as their king, at certain intervals, fired in relation to him, and revolve in a circle in perfect accord, making certain halts, and pursuing their orbit to and fro, as those who are learned in the study of the spheres call their visible motions; and that the light of the moon waxes and wanes varying in proportion to its distance from the Sun is, I think, clear to all* ([19] 135b, 1-6). Therefore, Julian believed that all planets revolved around the Sun in circular orbits at constant distances. Obviously, even during the 4th century AD, the theory of Aristarchus hadn't been forgotten.

7. CONCLUSION

Besides the seeds of heliocentric theory found in the Orphic Hymns, such "heretical" views evolved in the thoughts of Anaximander, Pythagorean philosophers Philolaus, Icetas, Ecphantus, Heraclides, until the father of the heliocentric theory Aristarchus of Samos, who placed the Sun in its right position in the Pythagorean "central fire".

The heliocentric theory was not accepted due to the influence of the great astronomer Claudius Ptolemy and his geocentric model, supported by the authority of Aristotle, but from time to time, philosophers like Seleucus from Seleucia and Emperor Julian supported heliocentrism.

It was only in the 16th century when the great Polish astronomer Mikolaj Kopernik (Nicolaus Copernicus 1473-1543 AD), placed again the Sun in the center of the Solar system. The predecessor of the so called "Copernican revolution" was the heliocentric theory of Aristarchus of Samos and the evolution of such views from the seeds in Orphic hymns to the Pythagoreans and their followers.

References

[1] Chassapis Constantinos, *The Greek Astronomy of the 2nd millennium BC according the Orphic Hymns*. PhD. Thesis, University of Athens [self-edited], Athens 1967 [in Greek].

[2] Papathanassiou Maria, Cosmological and cosmogonical aspects in Greece during the 2nd millennium BC, PhD. Thesis, University of Athens [self-edited], Athens 1978 [in Greek].

[3] Papathanassiou Maria, Aristarchus the Samian, *Mathematical Review* 20, Editions of the Hellenic Mathematical Society, 1980, p. 91-120 [in Greek].

[4] *Orphic Hymns*, Ed. Ideotheatro, Athens [in Greek, sine anno].

[5] *Orphicorum Fragmenta*. Ed. O. Kern, Weidmann 1922.

[6] Papathanassiou Maria, Primordial astronomical learning. *Eleftherotypia-Historica*, Athens, January 2, 2003, p. 6-12 [in Greek].

[7] Theon of Smyrna, *Mathematics useful for understanding Plato* or Pythagorean Arithmetic, Music, Astronomy, Spiritual Disciplines. Trans. by Christos Toulis, Wizards Bookshelf, 1979.

[8] Aetius, *Placitorum Compositione* (*De Vetustis Placitis*). Vol. IV 9, 8. in Diels Hermann: *Doxographi Graeci*. Berolini. Apud Walter De Gruyter et Socios, Editio Quarta, 1879 (reprinted 1965).

[9] Cotsakis Demetrios, *The pioneers of Science and the creation of the World*. Ed. Zoe, Athens 1976.

[10] Iamblichus, *De vita Pythagorica* (V.P.) *Life of Pythagoras*, with the English translation by Thomas Taylor in 1881, J. M. Watkins, 1965, p. 248-249ff.

[11] Plakides Stavros, The Geocentric and the Heliocentric Theory. *Parnassos* 16, Athens 1974 [in Greek].

[12] Diogenes Laertius, 1925. *Lives of Eminent Philosophers*, vol. II, IX 34-35, pp. 3, 441-445. Heinemann, London. The Loeb Classical Library; English translation by R.D. Hicks, revised and reprint 1959.

[13] Plutarch Chaeronensis: 1841, *Platonicae Quaestiones, Scripta Moralia*, Graece et Latine, Tomus Secundus, Parisiis, Editore Ambrosio Firmin Didot MDCCCXLI, H1 915, vol. XIII1, 76-78.

[14] E. Theodossiou, A. Dacanalis, M. S. Dimitrijević, P. Mantarakis, 2009, Heliocentric system from the Orphic hymns and the Pythagoreans to Emperor Julian. *Bulgarian Astronomical Journal*, 11, 123-138.

[15] Cicero, *Academica Priora*, with an English Translation by H. Rackham, M.A. The Loeb Classical Library. London. William Heinemann LtD. Cambridge, Massachussetes, Harvard

University Press. MCMLXI (First printed 1933, reprinted 1951, 1956 και 1961). πρ. 11, 12, 3.

[16] Hippolytus, *A Refutation of All Heresies: Refutationis Omnium Haeresium* (*Filosofoumena*). Patrologia Greca (P.G.) 16, In Origenes, Liber VII, 404-405, 339. Typographi Brepols Editores Pontificii, Parisiis 1857-1866.

[17] Archimedes, *Arenarius in Opera Omnia*, Bibliotheca Scriptorum Graecorum et Romanorum Teubneriana. Ed. I. L. Heiberg, vol. II corrigenda Adiecit E. S. Stamatis. Stutgardiae in Aedibus MCMLXXII.

[18] Plutarch Chaeronsis, *Scripta Moralia*. Graece et Latine. Tomus Secundus. De placitis Philosophorum Libri quinque. Parisiis. Editore Ambrosio Firmin Didot MDCCCXLI.

[19] *The works of Emperor Julian. The Orations of Julian, IV. Hymn to king Helios dedicated to Sallust*. The Loeb Classical Library. Trans. By Wilmer Cave Wright, Ph.D., William Heinemann Ltd. Cambridge, Massachusetts, Harvard University Press MCMLIV (First printed 19123, reprinted 1930, 1954).

B4.2 The Astronomical Eras of Taurus, Aries and Pisces and their Correlation with Ancient Greek Sculpture

Efstratios Theodosiou
Associate Professor-University of Athens
President of the Hellenic Physicist Society

Abstract

The apparent motion of the Sun on the ecliptic is characterized by four basic points, two for the equinoxes and another two for the solstices. From the zodiac constellations that characterize them, we calculate the various "astronomical or stellar eras". In this presentation I propose the hypothesis that the worship of the protohellenic goddess Hera is reduced before the Bronze Age and must have been widespread all over the Greek peninsula. In the meantime it was known the worship of the sacred bull not only in Greece but also in the other great civilizations of the northern temperate zones of our planet, which probably indicates the effective start of the cultural life of Humanity in the astronomical era of Taurus (4500-2000 BC). Note that the first letter of the alphabet (alpha) is symbolized the sacred bull of the corresponding astronomical era. Besides, it is always attractive, according to evolutionary theories, the idea that the worship of the animals –as more primitive– it was preceded the belief in anthropomorphic gods. In this way, it developed the faith that a god can be directly identified with the animal that it was sacrificed for his sake. In that manner the people or the whole race considered that the god himself was sacrificed. However no animal worship has been recorded and it was rather unknown in ancient Greece; but in many ancient myths appear the worship of a zoomorphic god that is a god who was transformed into an animal. Essentially, I prorose that the astronomical eras or phases are reflected in sculpture and on many statues in the corresponding period. Therefore in my work, I propose that the "Moschophoros statue" (calf-bearer) of the Athenian Parthenon –currently housed in the New Acropolis Museum in Athens, Greece– suggests the astronomical era of Taurus, while the stone "Kriophoros" (the ram-bearer) from the temple of Apollo at Kourion in Cyprus, as well as the dozens of other "Kriophoros" statues respectively, suggest the astronomical era of Aries, which came after the era of Taurus because of the precession of equinoxes. Finally, the ΙΧΘΥΣ (ICHTYS = FISH) on the entrance floor of the Metropolitan House of Kalymnos, suggests both Jesus Christ (ΙΧΘΥΣ = Jesus Christ God Son Saviour) and the corresponding astronomical era of Pisces.

Introduction

The modern astronomers and other scholar researchers studying ancient texts con-

clude that it is very possible the initial and limited nomenclature of the constellations comes from the time of the Sumerians. However, their general conclusion is that all of the things regarding sky have been systematised and organized by the ancient Greeks the last four centuries before Christ. Accordingly, it is a Greek achievement the final configuration of the nomenclature of the constellations in the northern hemisphere that has nothing in common with the solar worship of Ra in ancient Egypt or the so-called stellar theology of Mesopotamia.

Note however that the specific configuration of the constellations of the zodiac zone was a dynamic process, which has evolved through many millennia. Here arises a very important question: "Did the constellations formed and named according to their figures, or in this process other factors played a significant role"?

At this point the expert's opinions are divided. Some researchers argue –first of all Al - Soufi (903-986 AD)– that the figures of the constellations formed and their name, but I think that this occurs only in the constellation Scorpius. Other researchers argue the opposite. They think that ancient astronomers (and very good observers of the sky) wanted not only to consolidate some star groups, but also to use the constellations as "celestial signs". This was achieved when the constellations associated with the mythology and history of ancient peoples, with their gods and their legendary heroes. In this way, through the constellations, emerged the wonderful Greek mythology of the sky that survives in our times all over the World.

Why the zodiac zone created?

It is an indisputable fact that the zodiac zone originally created to mark the annual apparent path of the Sun on the ecliptic – the maximum circle of the celestial sphere that defines the average Earth's orbital plane around the Sun. The great ancient astronomers justified its name as ecliptic, instead of "by means of zodiac signs", from the fact that sometimes an eclipse occurs when the Moon (during the synods) is located on the zodiac circle.

Actually, the twelve zodiac constellations originally signaled the Sun's path. These constellations must be twelve because of the sanctity of the number 12, as the product of the holy numbers three and four ($3 \times 4 = 12$) and additionally by the fact that the Sun travels approximately 30° per month on the celestial sphere during its apparent annual path. In that manner: $30° \times 12 = 360°$, ie a full circle. Thanks to their long-term and systematic observations, the ancient astronomers combined the image of the starry night sky with the corresponding periods of the tropical year. By correlating the position of the Sun (when it was at the zenith, that is the upper height relative to the horizon of the observer) with the corresponding period of the day and night or the azimuth (A) of the East or the West – ie the angle between these points as for as the North or South on the horizon– the ancient astronomers identified four main points of the apparent annual path of the Sun on the ecliptic. These are the two equatorial points (equinoxes) –March 21 (γ) and 22 September (γ′)– and the two solstices – June 22 (E) and 22 December (E′) respectively. The discovery of these four basic positions of the Sun on the ecliptic was very important, since these positions signaled the beginning

and the succession of the four seasons of the year.

This was a very important event for that long period of time. In this way, they ancient people accurately knew the beginning of each season and of course the tillage time, sowing, harvesting or hunting and all these only from the apparent movement of the Sun across the stars and constellations.

Table I
The four basic zodiac constellations from 6000 BC until 4500 AD

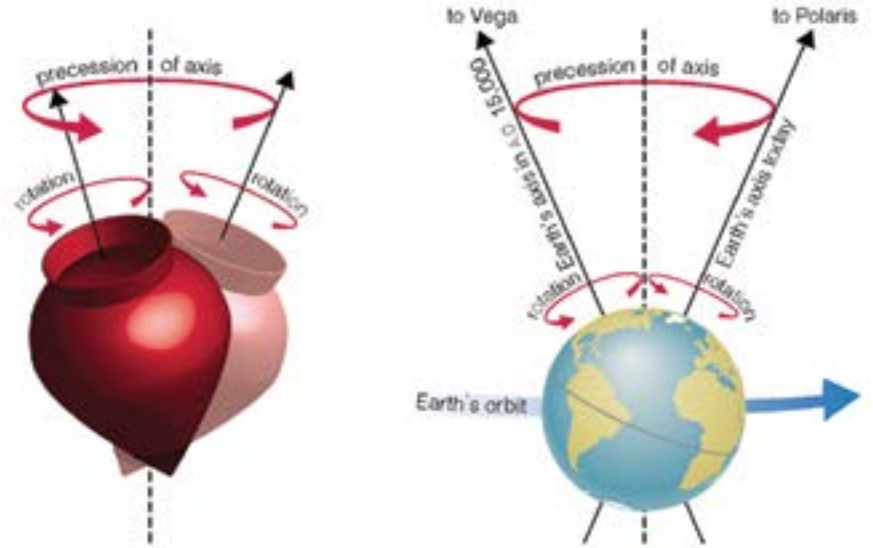
Seasons:	Spring	Summer	Autumn	Winter
6000 until 4500 BC	Gemini	Virgin	Sagittarius	Pishes
4500 until 2000 BC	Taurus	Leo	Scorpio	Aquarius
2000 BC until 1 AD	Aries	Cancer	Libra	Capricornus
1 AD until 1950 AD	Pishes	Gemini	Virgin	Sagittarius
1950 until 4500 AD	Aquarius	Taurus	Leo	Scorpio

Positions of the constellations and seasons

Hence, four particular star groups initially created, that is four major constellations, showing each one of them four basic points, which alternated every 2.100 years. It is quite known the movement of the Earth's axis –which is corresponding to the top's mechanical movement– which has as a result the precession of the equinoxes. That is, a slow, but continuous shift to the West of the points where the celestial equator intersects the ecliptic. So, every year the γ, γ′ (equatorial points) and consequently the E, E′ (solstices) shift 50′′,2526 daily or 1 ° approximately every 72 years. That is every 2,100 years the zodiac constellations which determine these four main positions of the Sun's motion are changing. Of course every 25,800 years each constellation –making a full circle– returns to its original position.

The group of four constellations takes its name from the constellation which is in the spring equator point (γ), the corresponding time. However, since the classification of the constellations became the first millennium before Christ, when Aries was on the vernal equinox, even today –although we are in the era of Pisces and we are going to the era of Aquarius– we call the (γ), internationally for historical purposes, the first point of Aries and we write (γ), the third letter of Greek alphabet, which essentially represents to the horns of Aries (♈). Probably, about the same time, the name of the zodiac constellation which determined the autumnal equinox was changed, which until then was called Che-lai Scorpius (the claws of Scorpius). This constellation renamed as Libra to indicate the balance ie the equal time of night and day (the dark and the corresponding light parts of the day), during the autumnal equinox. For this reason from that period Libra is the only "zodiac sign", which as inanimate object (thing) does not belong to the animal kingdom, including thence eleven zodiac constellations. At the time of Hipparchus (2nd century before Christ), the constellation of Aries was in the first twelfth (0°-30°) of the zodiac zone (that is constellation and sign were identical), while today it is in the last (330°-

360°). Consequently, because of the precession of the equinoxes, exists a continuous shift of the zodiac constellations relative to the corresponding twelfths.



The precession of the equinoxes

In 2000 B.C. the zodiac constellations coincided with the corresponding twelfths or houses. The spring equatorial point (γ) was in Aries' constellation, which was named "Princeps signorum coelestium" (Chief of the heavenly signs) or "Princeps zodiaci" (Chief of the zodia) or "Ductor exercitus zodiaci" (Leader of the zodiac army). Nowadays the constellation Pisces is the leader of the heavenly army (Leader of the celestial host).

Let's note also, as we can see in Table I, that at the dawn of history (4000-2000 BC) Taurus was the zodiac constellation, which corresponded to the vernal equinox. For this reason the people of that time used Taurus –the primary symbol of male fertility– to illustrate the spring. The priests generally used Taurus as a dynamic symbol of their religion. This is also seen in the decoration of ancient Minoan and Asian –especially Persian– temples.

Additionally, the *Old Testament* refers to the "golden calf" built by Aaron, when Moses was missing in the God-trodden Mount Sinai, with the corresponding symbolism. Meanwhile, the Leo constellation, which at the era of Taurus symbolized summer solstice and the beginning of summer, the same period appears in the Lion Gate in Mycenae and at the sculpted triple pillar of the palace Apantana in Persepolis in a combination with Taurus.

The quartet of that group filled out the constellations of Scorpius and Aquarius. The scorpion as a symbol is familiar both in ancient Babylonian and the corresponding Egyptian sources. Scholars of the astral sky say that the zodiac constellation Scorpius "embroiders" the Sun throwing him in the water area of Aquarius. The constellation of Aquarius probably symbolized the winter rains and the flooding of the Tigris and Eu-

phrates rivers in Mesopotamia. This waterway constellation surrounds the Sun during its winter descent to the underworld (a widespread belief in the myths of the ancient civilizations of Mesopotamia).

It is also known, that the constellation of Taurus refers to the oldest tablets in cuneiform of the Sumerians as the Bull of the great god Anu –the owner of the sky– and the constellation of Aquarius corresponded to the god Enki – the great god of waters. Similarly, Ninib, the great god of the Babylonians, identified with the constellation of Taurus and the god Nergal with the constellation of Leo. Besides, it is characteristic, during the respective eras, the Greek statues of Moschophoros and Kriophoros, which show precisely and simultaneously alluding to the succession of the sign of Taurus from the sign of Aries at the spring equatorial point (γ).

Well, we consider significant that in the Mesopotamian region there are no records to indicate the respective constellations of Aries or Cancer, instead of them, it is referred the constellation of Capricorn, the symbol of god Ea or the Babylonian god Suhumarshu, the great god of the oceans, corresponding to the Sumerian god Enki. In Mul-apin Tablets (7th century BC) there are lists of 36 stars, referred to as the stars of the gods Ea, Anu and Enlil respectively.

Cancer (crab) as a symbol of summer, according to astronomers and scholars, indicates, allegorically, the change in the Sun's orbit. The Sun, as it passes by the summer solstice, stops its upward path towards the north and begins its downhill course to the south (southern hemisphere) just as a crab that turns back and forth.

In the group of Pisces belongs the "double" signs, e.g.: Pisces, Gemini, Virgo and Sagittarius. Schematically, the Pisces are two and two are similarly the Gemini –Castor and Pollux– which as a spring zodiac in 6000 BC for Neolithic men was the source of the new life and the symbol of the spring revival of nature. Virgo represents the goddess Mother Earth, the World Mother (Ge - meter = Demeter).

Therefore the constellation Virgo represents the goddess Demeter, the Earth Mother and goddess of agriculture, but also honors and her daughter, Persephone. Then, duplication and for this sign. This zodiac constellation symbolizes fertility, as the Virgin - goddess depicted in the stellar maps keeping an ear. For this reason Spica (ear) also called the brightest star of the constellation.

Sagittarius represents the hunter centaur Chiron, with his dual nature of half man and half horse; on this fact lies its classification as a double sign. Sagittarius throws with his arch (in the group of the Neolithic period) the Sun, forcing him to start its descent to the underworld (southern hemisphere) falling in aquatic constellation of Pisces.

Around 2000 BC, when the Babylonians supported their time measurement system, the vernal equinox occurred when the Sun was approaching the direction of the constellation of Aries. However, the precession of the Earth's axis will result, as we have already mentioned, the precession of the equinoxes. For this reason, the vernal equinox moves "back" along the zodiac symbols, with the rate of approximately one sign every 2100 years. Two thousand years, then, after the period, when the Babylonians determined the vernal equinox in the sign of Aries, this has been undertaken when the Sun was approaching the sign of Pisces. This fact approximately coincided with the birth of Jesus Christ, and is very probable that one of the first symbols of Christianity is the ΙΧΘΥΣ (PISCES = Fish).

It is obvious, that approximately 2100 years after the birth of Christ, the vernal equinox will occur when the Sun will be approaching the zodiac sign that is the "House" of Aquarius and not the constellation. This is the fact which characterizes our era as the "New Age of Aquarius", as we often hear on the radio and on TV or we read in newspapers and magazines. This, according to many researchers, has been held since 1950. Essentially, however, the Sun of vernal equinox will be entered in the constellation of Aquarius in 2700 AD.

Conclusions

Certainly, from all the mentioned above, there is some relationship between time and the mythology of the sky's constellations. Apart from the wonderful Greek mythology, it appears that the configuration of the constellations' nomenclature of the northern sky there was a dynamic process that evolved through the centuries.

The apparent path of the Sun on the ecliptic characterized by four characteristics points, two by two to the equinoxes and solstices. From the zodiac constellations which characterize them we calculate the various "astronomical eras". In this presentation we argue that the astronomical eras of Taurus, Aries and Pisces associated with ancient sculpture. For example, the only sculpture of Moschoforos from the Athenian Parthenon indicates the era of Taurus. Similarly the stone Krioforos in the temple of Apollo at Kourion in Cyprus, as well as dozens of other similar statues or statuettes of Hermes Krioforos match the era of Aries.

The Moschoforos from the Athenian Parthenon (left picture), now in the New Acropolis Museum of Athens, indicates the era of Taurus. The stone Krioforos (right picture) from the temple of Apollo at Kourion (Cyprus), now in the Metropolitan Museum of New York, corresponds to the era of Aries

Subsequently, Christianity succeeded the National religion. But the new religion prevailed to Greeks, a world that was accustomed to seeing the images of the gods on the coins, on the statues, on the mosaics and on the decorations of the floors and the walls. It was therefore inevitable that the believers seek depictions of the human portrait of Jesus Christ. Thus, in early Christian art, one of the oldest Christian allegorical depictions of Jesus was that figure in which Jesus Christ is represented as the Good Shepherd, according to the parable of the lost sheep and the relevant passage in the Gospel of John: "I am the good Shepherd; the good Shepherd lays down his life for the sheep" (John, 10, 11). For this reason the first Christians liked to depict Jesus Christ as shepherd, bearing on his shoulders the black (lost) sheep. This resulted to appear in the catacombs, as in the Catacomb of St. Sebastian in Rome (225 AD), the primordial form of Jesus Christ, as the "Good Shepherd", which, as we can see in the picture below, refers rather to the golden solar Greek god Apollo or to the Persian Mithra. That is, Hermes Krioforos transformed in Jesus Good Shepherd, who holds on his shoulders the black sheep, which sometimes carries a halo of glory in order to separate, in that manner, from the other twelve sheep, depicting Jesus' 12 apostles.

The Good Shepherd. Early Christian art. Marble, height 92 cm. No. 28590 - Pius Christian Museum (Rome, 225 AD). The work originally belonged to the Collection Mariotti and joined the collections of the Vatican in the 19th century. The lower part of the garment and legs have been added by maintainers.

In fact, the themes include representation of the Good Shepherd Jesus in every expression, as we have already seen, has its beginning at the Greek bucolic art and tradition, originally of the Moschophoros and then of the Krioforos god. The image of the Good Shepherd with a lamb on his shoulders has been widely used in the various variants, from which the above statue is the most famous and most beautiful. Of course, as a simple bucolic form, the statue symbolizes the human toil. However, in this case the young shepherd is not the portrait of Jesus Christ. Probably symbolizes "the psychopompos Hermes" who leads the dead to the underworld; for this reason this issue is encountered very often in sarcophagi.

Initially Christians depicted Jesus Christ to bear on his shoulders the black sheep, and then they depicted him among "logical" sheep, which heard his voice –his sermon– and followed him.

Well, after these representations of Jesus influenced by the Ethnics, in the side by side picture of the 3rd century from the Catacomb of Domitilla in Rome, Jesus Christ be-

gins to have his Christian characteristics of Jesus Good Shepherd. Namely, Jesus Christ appears to have the lamb on his shoulders, but also with other lambs around him, a picture that is quite different from both Hermes Krioforos and the blonde solar god.

As the time goes by, the form of Jesus Christ finalized. The figure of Jesus was no longer depicted as Apollo, Orpheus or Mithra and started giving the impression of a bearded man with long hair, just as Jesus depicted in the basement of Aurelian in Rome (mid-3rd century). Possibly, the 4th century depiction of Jesus in the Catacomb of Comodilla (south of Rome), is the portrait whish presents Jesus like a real teacher of his time and in the area where he taught. Long wavy hair, long beard, big eyes and a big nose. In the same figure exist the Greek letters A and ω (omega), that is the first letter (beginning) and the last letter (end) of the Greek alphabet, with their symbolic character.

The depiction of Jesus in the Catacomb of Comodilla (4th century).

Finally, the PISCES from the mosaic floor in front of the entrance of the Metropolitan House in the Greek island of Kalymnos suggests and implies not only Jesus Christ (Jesus Christ God Son Saviour) but in addition the era of Pisces.

ΙΧΘΥΣ in front of the entrance of the Metropolitan House of Kalymnos.

References-Bibliography

1. Allen, R.H.: "Star Names: Their Lore and Meaning". Dover Publications, 1963 (republication of the work first published as: Star Names and their Meanings, by G.E. Stechert in 1899).
2. Gurshtein, A.: "When the Zodiac climbed into the sky". *Sky and Telescope*, October 1995, pp. 28-33.
3. Theodossiou E., Mantarakis P. and Dimitrijevic M.S. The era Of Aries and Kriophoros Statues. *Astronomical and Astrophysical Transactions*, issue 4, vol. 27, Cambridge Scientific Publicers, December 2012.
4. Θεοδοσίου, Ε. και Δανέζη, Ε.: «Τα άστρα και οι μύθοι τους - Εισαγωγή στην Ουρανογραφία». Εκδόσεις Δίαυλος, Αθήνα 1991. (Theodossiou, E. and Danezis, E., "Stars and their Myths – Introduction to Uranography". Diavlos Publications, Athens, 1991).
5. Θεοδοσίου, Ε. και Δανέζη, Ε.: «Μετρώντας τον άχρονο χρόνο - Ο χρόνος στην Αστρονομία». Εκδόσεις Δίαυλος, Αθήνα 1994. (Theodossiou, E. and Danezis, E., "Measuring Timeless Time – Time in Astronomy". Diavlos Publications, Athens, 1994).
6. Θεοδοσίου, Ε. και Δανέζη, Ε.: «Η Οδύσσεια των ημερολογίων». Τόμος Β΄. Αστρονομία και παράδοση (Μετάπτωση). Εκδόσεις Δίαυλος, Αθήνα 1995. (Theodossiou, E. and Danezis, E., "The Odyssey of the Calendars – Astronomy and Tradition". Diavlos Publications, Athens, 1995).

B4.3 Are the Geographical Descriptions of Plutarch Correct? A Geomythological Approach

Ilias D. Mariolakos[1]
Dr.rer.nat., Emer. Professor of Geology
National & Kapodistrian University of Athens

Abstract

Towards the end of the first century AD, Plutarch described the voyage of the hero Hercules to the exile place of Cronus, during the Mycenaean era. The description starts from Britain towards the West, to Ogygia Island and from there to three other islands located west of Ogygia. The people of Hercules travelled further to the west, to a great continental land.

Based on the detailed descriptions of Plutarch's text *De facie*, Ogygia coincides with an Iceland. The three islands westwards should be Greenland, Baffin Island and New Foundland. The great mainland westwards should be the east coast of Canada.

1. Introduction

Plutarch, who lived between 50 and 120 AD, was one of the most prolific ancient writers, known internationally for his two series, i.e. *Lives* and *Moralia*. In the *Moralia* series, he develops various issues of morality, philosophy, history, religion and science. In two of his works, i.e. *De facie quae in orbe lunae apparet* (*De facie*) and *De defectu oraculorum* (*De def. or.*), he includes numerous geographical information that allow the modern geographer to realize the following:

- That the geographical knowledge of the Minoans and the Mycenaeans were extending as far as the North Atlantic.
- That the description of their observations regarding the sediment transport in glaciated areas are confirmed through modern oceanographic research.

2. Plutarch's text

The English translation of Plutarch's text we are going to analyze from a geographical point of view is the following:

1. Email: mariolakos@geol.uoa.gr,
National and Kapodistrian University of Athens, Faculty of Geology and Geoenvironment, Department of Dynamic, Tectonic & Applied Geology, Panepistimioupoli, Zografou, GR 157 84, ATHENS, Greece

De facie, 26[2]
26. Almost before I had finished, Sulla broke in. "Hold on, Lamprias," he said, "and put to the wicket of your discourse lest you unwittingly run the myth aground, as it were, and confound my drama, which has a different setting and a different disposition. Well, I am but the actor of the piece, but first I shall say that its author began for our sake - if there be no objection. Well, I am but the actor of the piece, but first I shall say that its author began for our sake - if there be no objection - with a quotation from Homer:
[3]*'*[1] *An Isle, Ogygia, lies far out at sea, a run of five days off from Britain as you sail westward* [2] *and three other islands equally distant from it and from one another lie out from it in the general direction of the summer sunset.* [3] *In one of these, according to the tale told by the natives, Cronus is confined by Zeus, and the antique Briareus, holding watch and ward over those islands and the sea that they call the Cronian main,' has been settled close beside him.* [4] *The great mainland, by which the great ocean is encircled, while not so far from the other islands, is about five thousand stades from Ogygia, the voyage being made by oar, for the main is slow to traverse and muddy as a result of the multitude of streams.* [5] *The streams are discharged by the great land-mass and produce alluvial deposits, thus giving density and earthiness to the sea, which has been thought actually to be congealed. '*[6] *On the coast of the mainland Greeks dwell about a gulf which is not smaller than the Maeotis and the mouth of the Caspian sea.' These people consider and call themselves continentals and the inhabitants of this land islanders because the sea flows around it on all sides;* [7] *and they believe that 'with the peoples of Cronus there mingled at a later time those who arrived in the train of Heracles and were left behind by him and that these latter so to speak rekindled again to a strong, high flame the Hellenic spark there which was already being quenched and overcome by the tongue, the laws, and the manners of the barbarians. Therefore Heracles has the highest honors and Cronos the second.* [8] *Now when they have put to sea the several voyagers meet with various fortunes as one might expect; but those who survive the voyage first put in at the outlying islands, which are inhabited by Greeks, 'and see the sun pass out of sight for less than an hour over a period of thirty days...*

In the next stage we will try to follow, step by step, the text and by using a modern school geographic Atlas, to locate the places referred by Plutarch.

3. The step by step analysis

[1] *'An Isle, Ogygia, lies far out at sea, a run of five days off from Britain as you sail westward...'*

Based on the first words of Sulla, who interrupts Lamprias, the distance between

2. Translation found at:
http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Plutarch/Moralia/The_Face_in_the_Moon*/D.html, which reproduces a portion of the text published in Vol. XII of the Loeb Classical Library edition, 1957.
3. The numbering refers to the order of the text analysis, and is followed throughout the text.

Britain and the island Ogygia, can be estimated, if we take into account that a ship, similar to those of the Mycenaean era, e.g. the ships depicted on the frescos of Thera, could travel with a velocity of 4 to 5 miles per hour, under favorable conditions.

Consequently, the distance estimation for a 5 day travel is:

5 days x 24 hours = 120 hours x 4 m/h = 480 miles ≈ 800 km

According to these calculations, there is only one island at this distance, Iceland. Consequently, Isle Ogygia of Plutarch should be Iceland.

> [2] *'three other islands equidistant from it and from one another lie out from it in the general direction of the summer sunset'*

If Ogygia is Iceland, then the 3 islands located to the west, must be: Greenland, New Foundland and Baffin Isle. But their distances are not equal among all these islands.

The distance is equal to that between Britain and Ogygia (Iceland) only between Iceland and Greenland, but not between Iceland and Baffin Isle.

> [3] *'In one of these, according to the tale told by the natives, Cronus is confined by Zeus, and the antique Briareus, holding watch and ward over those islands and the sea that they call the Cronian main, has been settled close beside him'.*

According to this passage, the Cronus confinement place should be Greenland, or Baffin Isle or New Foundland.

Plutarch is also speaking about the "Cronian Main". Which is the Cronian main (Sea) and who first mentioned this part of the Atlantic Ocean?

The first who have mentioned the Cronian Main were the Argonauts.[4]

> [4] *'The great mainland, by which the great ocean is encircled, while not so far from the other islands, is about five thousand stades from Ogygia, the voyage being made by oar, for the main is slow to traverse and muddy as a result of the multitude of streams'*

If we take into account the geographic Atlas, it is clear that:

a) not far from the aforementioned islands a great mainland exists, that is North America, and
b) this mainland encircles a great ocean, in this case, Northwestern Atlantic.

4. Orphics, *Argonautica* 1083-1084.

Figure 1 – The locations of the islands mentioned by Plutarch located west of Britain.

> [5] *The streams are discharged by the great land-mass and produce alluvial deposits, thus giving density and earthiness to the sea, which has been thought actually to be congealed*

In Fig.2 the present and the palaeo-geomorphology of the area between the St. Lawrence Gulf and the Atlantic is depicted.

In Fig.3, small icebergs transporting clastic sediments in the estuary area of St. Lawrence during springtime of 2007.

Worth to notice that the shorelines of St. Lawrence Gulf should have been changed since the 6th millennium B.P. (Before Present), because of the glacial – isostatic vertical movements only, and not because of the glacial eustatic movements.

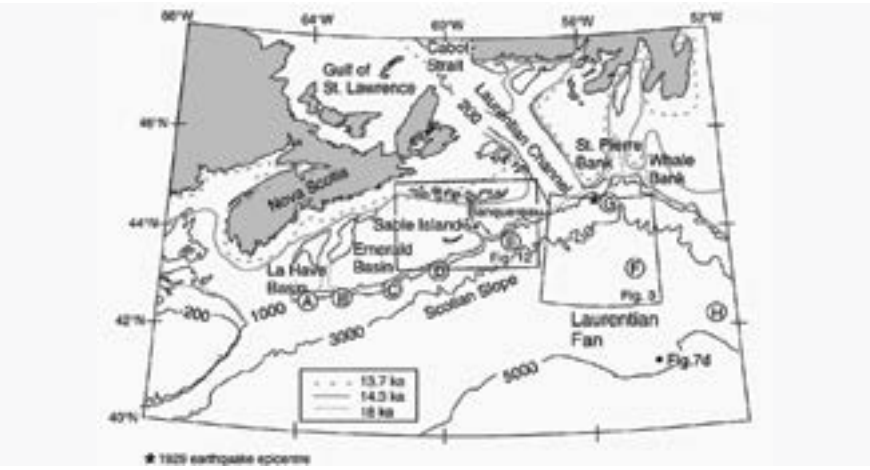


Figure 2 –Present-day geomorphology and palaeo-geomorphology of the area between St. Lawrence Gulf and the Atlantic Ocean (*Piper et al., 2007*).

Figure 3 – Small icebergs transporting clastic sediment. Location: Estuary St. Lawrence, 2007, Marais de la Pointe-aux-Ipinettes, Parc National. (*Photo from Urs Neumeier, University of Quebec at Rimouski, 2009*).

> [6] *On the coast of the mainland Greeks dwell about a gulf which is not smaller than the Maeotis and lies on the same line as the mouth of the Caspian Sea. These people consider and call themselves continentals and the inhabitants of this land islanders because the sea flows around it on all sides.*

In this passage, Plutarch clearly says that Greeks dwelled on the coasts of the mainland. This means that they did not do well everywhere, but only on the coasts of a Gulf, the size of which was around the same as that of the Maeotis Sea, that is the present day Azov Sea (southern coast of the Black Sea, Euxenean Pontus).

This Gulf of the mainland, where Greeks dwelled, is located on the same line as the mouth of the Caspian Sea. If we draw a line parallel to the latitude of the mouth of the Caspian Sea (Fig.1, line A-B) towards the west, we see that the Gulf of the great mainland, where the prehistoric Greeks dwelled is the present-day St. Lawrence Gulf.

> [7] *....and they believe that with the peoples of Cronus there mingled at a later time those who arrived in the train of Heracles and were left behind by him and that these latter so to speak rekindled again to a strong, high flame the Hellenic spark there which was already being quenched and overcome by the tongue, the laws, and the manners of the barbarians. Therefore Heracles has the highest honors and Cronus the second.*

From this passage, the following is clear that:

a) Cronus didn't go there alone, but with "people".
b) Long time after Cronus, the Mycenaean Hercules with his people arrived at the same place.

> [8]*...Now when they have put to sea the several voyagers meet with various fortunes as one might expect; but those who survive the voyage first put in at the outlying islands,*

which are inhabited by Greeks, and see the sun pass out of sight for less than an hour over a period of thirty days...

It is well known that at all places north of the Arctic Circle, that is the parallel of the 66½° North, the sun is not "passing out of sight" at least for one day during summer. These places are the northern parts of Iceland, Greenland, Baffin Island, the Island Southampton at the entrance of the Hudson Bay and others. Worth noticing is that the island of New Foundland must be excluded, as it is located further south.

4. When did all these happen...?

Two main people are mentioned in the passage of Plutarch text. The first is Titan Cronus, the second one is Hercules. These two didn't go there alone, but they were followed by many other people of Greek origin. It is obvious they were not slaves, but free men.

The question is when all this happened, as the time span between these two people is great. Concerning Mycenean Hercules, we know that he lived during the 13th century BC.

As far as it concerns the arrival time of Cronus to his exile place, based on the archaeological findings of Mycenaean and Meso-helladic period, from the SE Sweden (Mörner & Lind, 2013), we can indirectly conclude that it should be around the first half of the 2nd millennium BC. Maybe a little earlier, but certainly not before the 4th millennium BC, as the Gulf Stream regime had not been established before then, and the climatic conditions were unfavorable in these areas.

5. The criticism of Plutarch's text

From the time of Plutarch (1st - 2nd cent. AD) until the 16th cent. AD, nobody has written about this text. Apparently, nobody knew its existence!

During the 16th century AD, this geographical introduction aroused wildest speculation. Apparently, Ch. Columbus (15th cent. AD) knew nothing about the Great Continent when he discovered his Indies!

·*Johannes Kepler (1571 – 1630)*[5]

The first to be engaged was the famous astronomer Johannes Kepler (1571 – 1630), who tried to identify the islands mentioned by Plutarch. As he writes in his "Opera Omnia", he was convinced that the trans-Atlantic continent, mentioned by Plutarch, was America.

5. *J. Kepler (1593): Somnium sive Astronomia Lunaris, p.5.*

· *A. von Humboldt (1836),*
Approximately 200 years after J. Kepler, *A. von Humboldt* ,comes to the conclusion that the geographical frame of the Sullas narration in the Plutarch's text "de facie in orbe lunae" *has nothing to do with the geographic truth*.

In other words, according to A. v. Humboldt: There is no island west of Britain and consequently no island of Ogygia, that is Iceland, doesn't exist. The three islands west of Iceland, that is Greenland, Baffin Isle etc., do not exist either.

After A. v. Humboldt, this is the geographic truth. This negative position of A. v. Humboldt is astonishing, and at the same time inconceivable.

· *W. Christ (1898)*[7]
Around 60 years after A. v. Humboldt, W. Christ (1898), could assert that Plutarch's continent was "obviously America", but after W. Christ, sailors who arrived at the North American coast, were not the prehistoric Greeks, but some others who lived in the first century AD. In other words, W. Christ doesn't accept that all these happened during prehistoric time, but during the late Roman period.

· *G. Mair (1909),*[8] *although he ac*cepts the transatlantic continent, he argued that:

i. The source of his knowledge is reports of some Carthaginian seafarers,
ii. The seafarers had penetrated the Gulf of Mexico and not the St. Lawrence Gulf
iii. The island of Cronus is Scandinavia and
iv. the whole description of the geography derives from the voyages of Pytheas of Marsillia.

Some Remarks on Mair's aspects
Concerning the points of view of G. Mair, we would like to say that all his arguments are in total disagreement with the text of Plutarch, since:

i. The Gulf of Mexico is not located in the same line, that is the same latitude, as the entrance of the Caspian Sea.
ii. The size of the Gulf of Mexico, which is around 1.6 million km^2, is not the same as that of the Maeotis Sea (present-day Azov Sea), which is 39,000 km^2 only.
iii. The size of Saint Lawrence Gulf is around 236,000 km^2, whereas that of the Azov Sea is in the present days 39,000 km^2 only, but during those old times, because of the more favorable climatic conditions (Holocene Climatic Optimum), the size should be much greater. It is worth mentioning that these favorable conditions continued until the end of the Mycenaean era (≈ 1000 BC)

Concerning Maeotis Lake, it is of note to state that its size has changed many times during the Holocene. Consequently, the size given by Herodotus (D.86) is too large,

6. *A. von Humboldt (1836): "Kritische Untersuchung über die historischen Entwicklung der geographischen Kenntnisse von der Neuen Welt"* (1836), *pp. 174-185.*
7. *W. Christ (1898), "Geschichte der griechischen Literatur bis auf die Zeit Justinianus".*
8. *G. Mair (1909), "Pytheas' Tanais und die Insel des Kronos in Plutarchs Schrift Das Gesicht im Monde".*

whereas Strabo (B.V.23) says that its perimeter was 9,000 stadiums. This aspect is partly correct, as the size of Maeotis Lake does not remain stable, as it depends on the climatic conditions of the Central and North Europe, and mainly those from the drainage basins (i) of the river Volga, known as Ras or Ros by the ancient Greeks, which flows to the Caspian Sea, (ii) of the rivers Don (Tanais) and Dneiper (Vorysthenis), Dniester (Tyris) and Danube (Istros), which flow into the Black Sea.

Recent research has shown that during the Minoan and Mycenaean era, the climatic conditions were more favorable compared to the present day. This means that the mean temperature, the precipitation and the yields of the rivers were higher and consequently the size of the Azov Sea should be greater during these ancient times compared to the period of Herodotus[9] and that of Strabo.[10]

We must also keep in mind that in older times, that is during the first climatic optimum, around the 14th millennium B.P., the Caspian Sea and the Azov Sea together with the Euxeinean Pontus formed a single lake, which Tchepalyga[11] called "Neo-Euxeinean Lake".

iv. The island of Cronus could not have been located in Scandinavia sinceQ
a. Scandinavia is not an island and
b. the latter is found east of Ogygia (Iceland) and not west, as referred to in Plutarch's text.
v. Plutarch's description concerning northern geography could not derive from accounts of the voyages of Pytheas, as the famous seafarer of Marsilla never referred to:
a. a trans-Atlantic continent,
b. to a gulf lying on the same line (i.e. the same latitude) to the entrance of the Caspian Sea,
c. Nowhere is referring to Greeks who lived off the coastal areas etc., etc.

W. Schmidt and O. Stahlin (1920) who, in the 6th edition of W. Christ's work[12] suppress this note of Christ, but they put a question mark in the phrase: "...aus dem Festland jenseits des Atlantischen Ozeans (Amerika?)"

Why have they put this question mark (?) at the end, although they knew that it didn't exist in the original text?

Furthermore, many other famous scholars have criticized paragraphs 941a – 942c of Plutarch's script of "De facie in orbe lunae".

Among them the most famous are the following:

- *H. von Arnim*[13] (1921) writes that the content of Chapter 26 is a fantastic travel romance, whereas
- *W. Hamilton*[14] (1934) believes that Plutarch described a myth similar to those of other writers e.g. Hecateus of Miletus (circa 550 BC –476 BC) or Theopompus (circa 380 BC – 315 BC).

9. Herodotus (5th cent. B.C.), *Melpomene*, D86.
10. Strabo (1st cent. B.C.), *Geographica*, Z.C310,5.
11. *Tchepalyga (2003) 460.*
12. *"Geschichte der griechischen Literatur", Dritte Auflage*, zweiter Teil, Erste Hälfte, 1920, p.498).
13. *H. von Arnim, Plutarch über Dämonen und Mystik, pp. 37-47.*
14. *W.Hamilton, 1934, The myth in Plutarch's De facie (940F-945D), pp. 24-30.*

- Other writers believe that Plutarch's text of chapter 26 is a direct imitation of Plato's story of Atlantis.

It is reasonable that this travel, in this ancient time, e.g. around 4,500 years ago, is difficult to conceive and consequently to accept. But before we deny it, we have to take into account the archaeological findings at the SE Sweden.

6. Archaeological Findings at SE Sweden

After N.-A. Mörner & B. Lind[15] (2013), at about 1750 BC, the onset of the Bronze Age in Scandinavia, at the same time three things happened: (i) Bronze from the Mediterranean appeared in Scandinavia. (ii) Amber from the Baltic started to appear in masses in Mycenaean graves and (iii) pictures of huge ships started to be cut into the bedrock and bronze objects in Scandinavia.

Based on the above-mentioned, they concluded that Minoan and Mycenaean people arrived in the Vitemölla – Kivik area (SE Sweden) in big ships trading amber for bronze. In addition to the above conclusions, we have to take into account the following:

i. That the Argonauts arrived to the land of the Hyperboreans crossing the whole Eastern Europe – using the great rivers!
ii. That the Hyperboreans worshiped God Apollo.
iii. That God Apollo, also known as Sun-God stayed 6 months in the Hyperborea and 6 months in Greece – in Delphi.
iv. That the Hyperboreans sent every year presents to Delos island for God Apollo.
v. And many others…

There is no doubt that long distance traveling and trading started before the Mycenaean period.

7. What did the Prehistoric Greeks (Minoan & Myceneans) know…

Conclusively, based mainly on the text of Plutarch *De facie* and on the Argonautics of the Orphics, it could be concluded that the Prehistoric Greeks (Minoans and Myceneans) should have known – for sure – at least the following:

i. The British Islands and Ierna, that is Ireland.
ii. The island Iceland as Ogygia and its distance from the British Islands.
iii. The three islands, west of Iceland, e.g. Greenland, Baffin island and Newfoundland.
iv. The "Cronian Sea (Main)". This name was given by the Hyperboreans.
v. The great mainland beyond these three islands, e.g. at least the area around Gulf of St. Lawrence.
vi. St. Lawrence Gulf and its latitude compared to that of the entrance of the Caspian Sea.
vii. That the length of the daylight differs from place to place.

---

15. *N.-A. Mörner & B. Lind, 2013, The Bronze Age in SE Sweden. Evidence of Long-Distance Travel and Advanced Sun Cult. Journal of Geography and Geology; vol. 5, No. 1, pp.78-91*

viii. They knew how to measure great land surfaces, such as the Maeotis Lake (Azov Sea) and St. Lawrence Gulf.
ix. The Hyperboreans, that is all people around the Baltic Sea (Sarmatian Sea).
x. How to define the latitude of different places and many others.

8. Conclusive Remarks

If we take into account:
i. The previous data, comments etc.
ii. That the text of Plutarch is authentic.

There is no doubt that all geographic data described by Plutarch in *De facie* are correct.

Bibliography

Bridgman T.P. (2005): *Hyperboreans. Myth and History in Celtic-Hellenic Contacts. Studies in Classics*. Ed. by D. Obbink and A. Dyck. A Routledge Series. N. York: Routledge.

Bruneau P. & Ducat J. (1965): *Guide de Délos*. Paris: Ecole Française d' Athènes.

Christ W. v. (1898): *Geschichte der griechischen Literatur bis auf die Zeit Justinianus*.

Cunliff B. (2001): *The Extraordinary Voyage of Pytheas the Greek*. Penguin Books Ltd., p. 183.

Diodorus Siculus (90-30 BC): *Bibliotheca historica, Book 2a*, "The Greeks", Kaktos ed., Athens: (publ. 1997).

Döpp S. (1996): „Die Tränen von Phaethons Schwestern wurden zu Bernstein: Die Phaethon – Mythos in Ovids „Metamorphosen"", in: Ganzelewski M. and Slotta R. (ed.), *Bernstein Tränen der Götter*. Bochum, 1996, 1-10.

Ebner E. (1906): *Geographische Hinweise und Anklänge in Plutarchs Schrift "De Facie in Orbe Lunae*„ Münich.

Graves R. (1955): *The Greek Myths*. 2 vols Penguin books, London

Hamilton W. (1934): „The myth in Plutarch's De facie (940F-945D)", Class. Quart., 24, 24-30.

Hecataeus of Miletus (6th cent. BC): *Collective Works. Fragments, Testimonials*, "The Greeks", Kaktos ed.. Athens (publ. 2001).

Herodotus: *The Histories, Book IV* (*Melpomene*, "The Greeks", Kaktos ed., Athens (publ. 1994).

Hesiod: *Theogony*, "The Greeks", Kaktos ed., Athens, 1992 (*in Greek*):

Hesiod: *Works and Days*, "The Greeks", Kaktos ed., Athens, 1992 (*in Greek*):

Humboldt A. v. (1836): *Kritische Untersuchungen über die historische Entwicklung der geographischen Kenntnisse von der Neuen Welt und die Fortschritte der nautischen Astronomie in dem 15ten und 16ten Jahrhundert*, Berlin

Jewell R.L. (2008): „Ancient Mines of Kitchi-Gummi. Cypriot/Minoan Traders in North America", Jewel Histories, Fairfield, PA.

Kepler J. (1593): „Somnium sive Astronomia Lunaris“, in: Theatrum *Orbis Terrarum Abrahami Ortelii*, p.5, Antwerp.

Marcian of Heraclea (4th cent.A.D): *Periplus* (*Transl. D.G. Koutroubas*): Nea Thesis, Athens.

Mair G. (1909): *Pytheas' Tanais und die Insel des Kronos in Plutarchs Schrift "Das Gesicht im Monde"*. Jahresbericht des K. K. Staats-Gymnasiums in Marburg A/D.

Mariolakos I. (2004): „Geomythology“, in: Birx J. H. (ed.), *Encyclopedia of Anthropology*, 3, 1066-1071, New York, SAGE Publ.

Mariolakos, I. (2001): „The Geoenvironmental Dimension of the Greek Mythology“, *Bulletin of the Geological Society of Greece*, XXXXIV/6, (Proceedings of the 9th International Congress, Athens, September 2001), 2065-2086.

Maury M. F. (1855): *The Physical Geography of the Sea*. New York, Harper & Brothers, Publishers. 287pp. Available online at: http://books.google.gr/books?id=Z5jN3Ypo0jgC&printsec=frontcover&dq=physical+geography+of+the+sea&cd=3#v=onepage&q=&f=false (Accessed 29.1.2015).

Mertz H. (1964): *The Wine Dark Sea: Homer's Heroic Epic of the North Atlantic*, (Greek translation by Zairis), NEA THESIS publ., 1995.

Mörner N.-A. & Lind B.G. (2013): „The Bronze Age in SE Sweden. Evidence of Long-Distance Travel and Advanced Sun Cult“, *Journal of Geography and Geology*, 5/1, 78-91, Published by Canadian Center of Science and Education.

Orphics: *Argonautica*, Ed. KAKTOS "THE GREEKS", Athens 1992 (in greek):

Plato: *Kritias*.

Plato: *Timaeus*, "The Greeks", Kaktos ed., Athens 1992 (*in greek*):

Plato: *Critias*, "The Greeks", Kaktos ed., Athens 1992 (*in greek*):

Plutarch: *Moralia, Concerning the Face which appears in the Orb of the Moon*, "The Greeks", Kaktos ed., Athens, 1996 (*in greek*):

Plutarch: *Moralia, Concerning the Face which appears in the Orb of the Moon*. Available online at: http://mikrosapoplous.gr/anc_texts/texts_plut.html (Greek text) (Accessed 29.1.2015), and http://penelope.uchicago.edu/Thayer/E/Roman/Texts/Plutarch/Moralia/The_Face_in_the_Moon*/D.html) (English text) (Accessed 29.1.2015).

Orphics Aegonautica.

Picard C. & Replat J. (1924): „Recherches sur la topographie du Hérion Délien“, *Bull.Corr..Hell.*, 48, 217-263.

Picard C. & Replat J. (1942): „L' Artémission délien et les deux tombeaux des vierges hyperboréennes“, *Bull.Corr..Hell.*, XLVIII.

Tchepalyga A. (2003): „Late glacial great flood in the Black Sea and Caspian Sea“, *Geol. Soc. Am., Abstracts of the Session No. 178: "Noah's Flood" and the Late Quaternary Geological and Archaeological History of the Black Sea and Adjacent Basins"*, (September 2003), Geological Society of America Abstracts with Programs, 35/6, 460.

B4.4 The Sphere of Archimedes: A Precursor to the Antikythera Mechanism

Michael T. Wright, M.A., M.Sc., F.S.A. (UK)

Abstract

The author's reconstruction of the Antikythera Mechanism, with a principal display showing the places in the Zodiac of the Sun, the Moon and the five planets known in antiquity, is now supported by the reading of inscriptions found on the original fragments. In search of evidence for comparable ancient instruments, we consider the literary evidence for a planetarium instrument supposedly devised by Archimedes. The earliest and most explicit account was written by the Roman author Marcus Tullius Cicero; and a close examination of the passage leads us to conclude that the fabled instrument was a celestial globe, mounted so that it might be rotated about its polar axis in imitation of the diurnal motion and fitted with internal gearing to drive pointers indicating, as in the Antikythera Mechanism, the places of the Sun, Moon and planets. The author has developed a reconstruction, and has demonstrated its practicability by building a working instrument that corresponds both to Cicero's description and to those of some later writers. Even Cicero's account dates from long after the death of Archimedes, and it is possible that the customary attribution to Archimedes is false, but the author argues that it is plausible. Finally, comparison of our Sphere with the Antikythera Mechanism prompts discussion of some features of the latter instrument's design.

1. Introduction

There persists throughout later antiquity a literary tradition referring to instruments modelling the apparent motions of the Sun, Moon and planets [1]. Our growing certainty that the Antikythera Mechanism bore such a display prompts us to consider these reports seriously, as reflecting actual material culture [2, 3]. Conversely, exploration of what lies behind the literary references may amplify our understanding of the Antikythera Mechanism and the milieu in which it was created.

The several ancient authors clearly record, or imagine, a number of distinct instruments; and most associate them, either directly or obliquely, with Archimedes. This association certainly cannot be taken literally in all cases. Perhaps Archimedes devised an early instrument of this type, so that any similar device came to be regarded as "Archimedean"; or his name, as a byword for ingenuity, simply became attached to a genre that may, in reality, have been a later introduction.

Whatever the truth about its association with Archimedes, there emerges from

several sources a fairly clear picture of one particular form of instrument which was, therefore, probably quite widely known: a celestial globe with pointers for the places of the Sun, Moon and planets; and it is of such an instrument that I present a conjectural reconstruction.

It hardly matters for our purpose whether Archimedes really was the originator of this genre of instrument, but I will show that it is possible that such devices may have existed as early as his lifetime. If so then he – a mathematician with great mechanical flair [4], whose father seems to have been an astronomer[1] and who was clearly aware of developments in the field [6] – might very well have been among the first to devise one.

2. Literary evidence

For brevity,[2] I present just one literary passage, taken from the *De Re Publica* of Cicero, written between 54 and 51 B.C. [7].[3] In it Cicero describes an instrument supposedly made or designed by Archimedes and taken by the victorious Roman general at the fall of Syracuse. In spite of Cicero's clear statement of its provenance, it seems likely that the instrument that he describes was not really made by (or for) Archimedes himself. Cicero does not tell us that he has seen this historic artefact, and in view of the time that had elapsed since the sack of Syracuse and the death of Archimedes in 212 B.C. it seems unlikely that so intricate an instrument would have survived to his day, complete and workable; yet Cicero seems to describe an instrument that he has actually seen. He may substitute a description of a later instrument known to him, such as the one of which he tells us elsewhere, made by (or for) the Stoic philospher Posidonius with whom he had studied in Rhodes [8]. It is very likely that Cicero either saw this instrument then or received a written account of it later; evidence of his continuing correspondence with Posidonius exists [9]. Whatever the origin of the instrument described here, Cicero's account is of the greatest interest in that it is the earliest, and fullest, description of any such "Archimedean instrument" that we have. My own translation obviously follows quite closely the several published versions,[4] but it does contain some significant original points.

Cicero, *De Re Publica*, I, 21–22

Then Philus spoke as follows:

"I have nothing original to offer you, but I do recall what occurred when the same phenomenon was being discussed by C. Sulpicius Gallus – a very learned man, as you know – when he happened to be at the home of M. Marcellus who had been consul with him. He asked to have brought out the globe which the grandfather of M. Mar-

1. In *The Sand-Reckoner*, [5] p.223, we read: ... *I follow most of the earlier astronomers*. ... *Pheidias my father* ...

2. The prescribed maximum length of this paper precludes the presentation both of further evidence and of extended and detailed discussion, which will be published elsewhere.

3.See the Introduction by Keyes, ref. 7.

4. *e.g.*: the translation by Keyes, ref 7.

cellus had carried off when Syracuse was taken (although he had taken home nothing else of the great quantity of booty from the very well-favoured and very splendid city). Although I had often heard this globe spoken of on account of the fame of Archimedes, I was not much impressed by its appearance; for there was another, also made by Archimedes, more beautiful and better known to the public, which the same Marcellus had placed in the temple of Virtue.

"But then, when Gallus began to explain, most learnedly, the working of this one, I concluded that there had been more genius in the old Sicilian than human nature seemed able to bear. Gallus began by telling us that the other kind of globe, completely solid, was an ancient invention; the first had been turned by Thales of Miletus, but the same [sort of] instrument had subsequently been marked with the fixed stars by Eudoxus of Cnidus (a disciple of Plato, it was said); and many years later Aratus – having no knowledge of astronomy but some poetic talent – had taken the whole design and arrangement from Eudoxus and published it in verse. "However, [Gallus continued,] this kind of globe included the motions of the Sun and Moon and those five so-called moving stars – *planets*, we might say – which could not be included in the older solid globe. The contrivance of Archimedes that effected this was wonderful: he had so devised it that a single rotation would generate non-uniform, anomalous movements in the many different indications.

"When Gallus set this globe in motion, it occurred that the Moon caught up with [or: passed under] the Sun after just as many turns in that bronze instrument as [it would take] days in the heaven itself, wherefore that very same eclipse of the Sun would take place in the globe, and then the Moon would pass into that cone which represented the shadow of the Earth, when the Sun … from the place …" [*there follows a long lacuna in the text*]

3 Interpretation

Cicero describes a geocentric instrument in which indicators of the places or motions of the Sun, Moon and planets are moved by mechanism in a reasonably realistic way. He calls it *sphaera*, which I interpret literally as *globe*;[5] his comparison of its appearance with that of the other instrument, which is clearly a simple celestial globe, indicates that the mechanical instrument is indeed of the same form; but it is hollow and contains mechanism. Cicero states explicitly that the instrument exhibits the *non-uniform, anomalous* motions of the planets.

Such a mechanised celestial globe would naturally be pivoted about an axis corresponding to its celestial pole so that, when set … in motion (probably directly, by hand), its rotation would represent the diurnal motion. For this to be possible, the arbor on which it rotates must be fitted to a stand. Much ancient iconography shows (simple) celestial globes resting in rings, set on the top of tripods. A more convenient form for our purpose is the box-base shown in a mosaic from Pompeii that is thought

5. There are those, most recently Allen et al. [10], p.8, who assert that *sphaera* (Greek σφαίρα) may mean any representation of the "cosmic sphere" – the universe – whatever its configuration; but there is no reason to consider such a forced interpretation here, where the straightforward one is unproblematic.

to date from the early 1st century B.C.,[6] although probably it too illustrates a simple celestial globe which may merely rest in the base. For our mechanised globe, an arbor is set in the box-base at an angle to the horizontal equal to the observer's latitude. The globe, fitted on to it, lies with just half of it projecting above the flat upper face of the base so that this plane represents the observer's horizon, and the instrument may be used to show the risings and settings of celestial bodies.[7] See figures 1 & 2.

Fig. 1: The "Sphere of Archimedes": the pointers track round the Ecliptic which corresponds to the joint between the hemispheres.

Fig. 2: The "Sphere of Archimedes": the pointers rotate about the Ecliptic pole. A display of the phase of the Moon is seen at their boss.

6. Naples, Museo Archeologico Nazionale, inv. 124545.
7. A feature noted by the author Lactantius, writing between 303 and 311 A.D. and describing an instrument, also attributed to Archimedes, otherwise apparently very similar to that described by Cicero: [11], 5,18.

It is probable that, as in the Antikythera Mechanism, only motions in longitude of the Sun, Moon and planets were shown, the small motions in latitude (of all but the Sun) being ignored. For each body there is a pointer, of which the tip must move round the Ecliptic, visible in figure 1 as the joint between the hemispheres. The pointers must therefore rotate about the Ecliptic Pole, which lies oblique to the Celestial Pole and gyrates about it with the diurnal motion, and it follows that the pointers are mounted on the globe itself and are driven by mechanism within it, figure 2. All the pointers are worked by *a single rotation… when* [the globe is] *set … in motion*; that is, when the globe is rotated on its arbor. We must now consider what motions the pointers should exhibit, and how this may be achieved.

4. Astronomical considerations

Cicero tells us that the mechanism generate[s] *non-uniform, anomalous movements in the many different indications*. The most interesting thing about planetary motion is the occurrence of "anomalous" retrograde episodes, and in this passage Cicero makes it clear that they were modelled in some way. Certainly, an instrument that showed only the mean motions of the planets would lack conviction; it would be highly unrealistic, and dull. The pointers for Mercury and Venus, for example, would simply go round together with that for the Sun.

Kinematic planetary theory, comprising some scheme that might have served as the basis for the design of such a mechanical instrument, is generally agreed to be a Greek innovation [12]. The first such theory that we know of is the system of homocentric spheres devised by Eudoxus and later elaborated by Callippus and by Aristotle, but it is hard to imagine that a mechanical model based on this system could have been built in antiquity: it presents difficulty, both in transmitting motion to all the rotating spherical shells and in bringing indications of the planets' positions to the outside where they may be seen. At the most, in my opinion, one might construct a model for a single planet, "inside out" so as to allow the resultant motion to be observed. As a basis for a planetarium showing all the planets, it is simply too complicated.

This scheme was superseded by the simpler, and ultimately more successful, *eccentric* and *epicyclic* theories: alternative and equivalent descriptions of a single-anomaly model in which two circular motions are compounded. In contrast to the homocentric spheres of Eudoxus, either of these planar theories can readily be modelled in mechanism. This is precisely what we believe was done in the Antikythera Mechanism which, as recent epigraphic work confirms, included a concentric display showing the motion in celestial longitude of the Sun, Moon and planets [13].

5. Historical considerations

The level of achievement illustrated by the Antikythera Mechanism leaves us in no doubt that instruments such as we are now discussing could have been designed and built in *late* Hellenistic times. Merely as regards practical skill, the work could have been done much earlier. However, before outlining a reconstruction that conforms

with all the points drawn from Cicero's description, we will consider the plausibility of the implied suggestion that such an instrument might have been designed in the time of Archimedes. There are two main points to be addressed: the availability of a planetary theory that might be mechanised; and the availabilty of a suitable repertoire of mechanical ensembles with which to do it.

The origin of eccentric and epicyclic kinematic theory is often attributed to Apollonius of Perga, on the ground that Ptolemy cites a lemma of Apollonius in which he investigates the conditions under which these theories generate retrograde motion [14]. It seems reasonable, however, pace Neugebauer [6], to suggest that either theory may predate his work on it.[8] Apollonius was a younger contemporary of Archimedes [15]; we may, then, envisage the possiblity that these theories were known to Archimedes.

Either of these kinematic theories may most obviously be modelled by the use of toothed gearing for the transmission of rotary motion; and in fact no satisfactory alternative was available to the Hellenistic mechanic. In many Hellenistic devices rotary motion was transmitted using "spool-and-string" connections [16], but such an arrangement would be impracticable here because very many turns of the cord would have to be wound on to the faster-turning spool where very widely differing rates of rotation have to be accommodated. Unfortunately, though, clear evidence for the early introduction of toothed gearing is wanting. It is widely agreed that it was probably known in the third century B.C. [17], but the evidence for its use in the time of Archimedes is not strong.

We may summarize the position thus: if Archimedes really did make such an instrument as Cicero describes, then he must both have known of a suitable single-anomaly planetary theory (such as epicyclic theory) and have understood the use of toothed gearing; but if it could be shown that either resource were not available to him, then the persistent ancient tradition that attributed this genre of instrument to him must have been mistaken.

On the other hand, let us consider how his attributes support this tradition. As a mathematician, Archimedes was accustomed to think about mathematical problems in a mechanical way; as an engineer, he is said to have been a versatile and successful designer of advanced machines; his father was an astronomer and he himself kept abreast of developments in the field; moreover, he is said to have written a treatise on the making of "spheres" [5]. If we could show that he both knew a kinematic theory capable of being modelled and was familiar with the use of toothed gearing, then we should have no difficulty in accepting the tradition as true.

I will repeat here, however, that the question as to whether Archimedes was the author of any planetarium instrument, as the literary tradition insists, is not my present concern. Rather, my point is that the same literary tradition shows clearly that by the time of Cicero – by the middle of the first century B.C. – such instruments were well

8. Neugebauer [6], p. 262 ff., delivers himself of the opinion: "It seems clear that these models for planetary motions were actually invented by Apollonius ..."; but in the following pages he appears to withdraw from this position.

enough known that an author might introduce one into his narrative without turning far aside from his theme to explain it. Moreover, by then the genre seems to have been sufficiently well established for people to have accepted the great, and already ancient, Archimedes as its originator. My present purpose is to explore the artefactual reality that, I suggest, lay behind this tradition.

6. Mechanical design

Evidence from the inscriptions on the Antikythera Mechanism supports all the significant features of my reconstruction of its front dial display: not only was there a concentric display showing the longitudes of the Sun, Moon and planets [13], but the planets' retrograde episodes were modelled [18].

In the Antikythera Mechanism, both the Zodiac dial and the mechanism driving the pointers are fixed to the frame of the instrument. In the reconstructed mechanical globe, both the Zodiac on the surface of the globe and the mechanism within it revolve with the globe. In both cases the Zodiac and the mechanism driving the pointers are stationary with respect to one another. It follows that, whatever planetary mechanism was lost from the Antikythera Mechanism, or whatever reconstruction of it we may devise, just the same mechanism will serve for the present instrument, so long as it can be fitted within the globe and a way can be found to drive it. I will show how both may be done.

According to my reconstruction of the Antikythera Mechanism, single-anomaly epicyclic theory is modelled directly [2]. An alternative scheme that can achieve a very similar effect was subsequently put forward, almost simultaneously, by two sets of authors [3, 19]. This scheme is more compact and uses fewer wheels, but its design is conceptually less straightforward and limits the accuracy of the period-relations modelled because they can be realized only by simple gear-pairs, and not by compound trains. No further reconstruction of the internal mechanism has yet been offered; and, of these alternatives, mine is the only one which can satisfy the evidence that accurate, high-numbered period-relations compound were employed in the Antikythera Mechanism [18], which can be modelled only by the use of compound gear trains [20].

For the present reconstruction, however, I was under no constraint to employ compound gear-trains or to realize particularly good period-relations; in simply illustrating the feasibilty of the reconstruction, it did not matter which scheme I chose. In the event I modelled the scheme described by the other authors, partly because it results in the simplest possible assembly that can model single-anomaly theory, with retrograde episodes for the planets; but also because, whereas my scheme had been built and tried exhaustively, this alternative scheme had not been adequately tried in practice before being offered as a serious option for the Antikythera Mechanism. Its realization in the present instrument is seen in figure 3.

Fig. 3: *The "Sphere of Archimedes": the upper hemisphere is removed to reveal the internal mechanism in place.*

In the globe, as in the Antikythera Mechanism, a wheel to which the Sun pointer is connected is driven directly, and the planetary assemblies take motion from it. This is a logical arrangement because the apparent motion of the Sun is one of the two motions compounded in deriving the resultant apparent motion of each of the planets. In fact this "Sun Wheel" is a very large one, and the planetary assemblies are mounted on it. Again as in the Antikythera Mechanism, the Moon pointer is driven through a step-up train from a smaller gear under the Sun Wheel that rotates with it.

The globe rotates about the Celestial Pole, but the tips of all the pointers must trace round the Ecliptic. Therefore the Sun Wheel, with all the associated mechanism for working the pointers, is aligned to the Ecliptic Pole which is oblique to the axis of rotation of the globe.

The globe is made in two halves that meet at the Ecliptic. The internal mechanism is built on a circular frame-plate which rests on a wooden ring turned to fit the lower hemisphere, and the upper hemisphere, dropped on like a dish-cover, holds it in place.

The motion of the internal mechanism is derived as follows. The fixed arbor on which the globe turns bears a stationary wheel at its upper end near the centre of the globe. A second wheel, on an arbor pivoted within the globe that lies parallel to the fixed arbor, runs round it. This second arbor reaches up to the edge of the Mean Sun wheel where a pallet (a single gear-tooth) projecting from it engages the teeth of the wheel, so transmitting motion to it. These components are seen in figure 4. When the globe is rotated by hand the internal mechanism is made to rotate intermittently but at the correct mean rate. The obliquity of the engagement of the pallet with the wheel-teeth causes no difficulty.

Fig. 4: *The "Sphere of Archimedes": the planetary mechanism is removed to show the driving gear beneath it.*

The output is taken from the internal mechanism by a set of six concentric pipes surrounding a central arbor (figure 3), all emerging from the North Ecliptic Pole of the globe (figure 2). To these are fitted the seven pointers for the Sun, Moon and planets, each of which reaches down to the Ecliptic (figure 1). The output to the Moon pointer is conveniently brought out through the central arbor and that for the Sun pointer through the first pipe adjacent to it, so that these are the two outermost pointers, lying one immediately above the other. Consequently it is possible to arrange a display of the phase of the Moon,[9] worked – as in the Antikythera Mechanism – by the relative motion of the two pointers [21]; only, instead of the elaborate rotating-globe device of the Mechanism, here I have adopted the simplest possible arrangement, with a part-silvered, part-blackened disc seen through an aperture (figure 2).

7. Conclusion

Ancient descriptions of a planetarium instrument attributed to Archimedes, the earliest and clearest of which is given by Cicero, are compatible with the reconstruction presented here. This fairly simple device is based on the design of the yet more ancient plain celestial globe, with the addition of internal mechanism working pointers for the Sun, Moon and planets which is similar to that which we would restore to the Antikythera Mechanism. The latter instrument may now be seen as a device in the same genre, but more abstract in its principal display than a "sphere", and with the addition of further subsidiary displays yielding other information.

9. A feature noted by Lactantius [11].

8. References

1. M.G. Edmunds, "The Antikythera mechanism and the mechanical universe", *Contemporary Physics* Vol.55 no.4 (2014), pp.263–285.
2. M.T. Wright, "In the Steps of the Master Mechanic", Proceedings of Conference *Η Αρχαία Ελλάδα και ο Σύγχρονος Κόσμος*, University of Patras (2003), pp.86–97.
3. T. Freeth and A. Jones, "The Cosmos in the Antikythera Mechanism", *ISAW Papers 4* (2012): http://dlib.nyu.edu/awdl/isaw/isaw-papers/4/
4. D.L. Simms, "Archimedes the Engineer", *History of Technology* Vol.17 (1995) pp.45–111.
5. T.L. Heath, *The Works of Archimedes*, Cambridge (1897).
6. O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Springer (1975).
7. Cicero, *De Re Publica, De Legibus*, ed. & trans. C.W. Keyes, Loeb Classical Library vol. 213.
8. Cicero, *De Natura Deorum*, II, xxxiv-xxxv.
9. Cicero, *Letters to Atticus*, 21 (II.1).
10. "The Inscriptions of the Antikythera Mechanism: General Preface ...", *Almagest* Vol.7 no.1 (2016), pp.4–35.
11. Lactantius, *Divinarum Institutionem* Book II (De Origine Erroris).
12. G.J. Toomer, "Ptolemy and his Greek Predecessors" in ed. C. Walker, *Astronomy before the Telescope*, British Museum Press, London (1996) pp.68–91.
13. Y. Bitsakis & A. Jones, "The Inscriptions of the Antikythera Mechanism: The Back Cover Inscription", *Almagest* Vol.7 no.1 (2016), pp.216–248.
14. G.J. Toomer, *Ptolemy's Almagest*, Duckworth (1984), XII 1.
15. T.L. Heath, *Apollonius, Treatise on Conic Sections*, Cambridge (1896).
16. D. Kalligeropoulos, *Αυτοματοποιητική Ήρωνα του Αλεξανδριού*, Athens (1996).
17. Th.P. Tassios, "Prerequisites for the Antikythera Mechanism to be produced in the 2nd century BC", The Antikythera Shipwreck (museum catalogue with introductory essays), National Archaeological Museum, Athens (2012), pp.249–255.
18. M. Anastasiou *et al.*, "The Inscriptions of the Antikythera Mechanism: The Front Cover Inscription", *Almagest* Vol.7 no.1 (2016), pp.251–297.
19. C.C. Carman, A. Thorndike & J. Evans, "On the pin-and-slot device of the Antikythera Mechanism, with a new application to the superior planets", *Journal of the History of Astronomy*, xliii (2012), pp.1–24.
20. M.T. Wright, "The Antikythera Mechanism: compound gear-trains for planetary indications", *Almagest* Vol.4 no.2 (2013), pp.4–31.
21. M.T. Wright, "The Antikythera Mechanism and the Early History of the Moon-Phase Display", *Antiquarian Horology* Vol.29 no.3 (2006), pp.319–329.

B4.5 Astronomical Phenomena and the Dating of Troy's Fall

Papamarinopoulos S. ([1]), Preka-Padema P. ([2]), Mitropetros P. ([3])
Antonopoulos P. ([4]), Mitropetrou E, ([1]), Saranditis G. ([5])
([1]) *University of Patras,* ([2]) *University of Athens,* ([3])*Keratsini, Piraeus,* ([4]) *InterMediaKT - Interactive Media Knowledge Transfer, Patras,* ([5]) *Athens, Greece*

Abstract

A Homeric description for a gradual darkening, at noon during a warm summer day, which started with Sarpedon's death and was maximized after Patroclus' death, along with simultaneous observations of Sun and Moon, indicate a partial solar eclipse. The latter, together with the planet Venus appearance in the eastern horizon before sunrise mentioned by Homer, helped us to date the solar eclipse. It helped dating Patroclus' death, approximately two months before Troy's fall. We *combined* astronomical and seasonal data of both epics, in Iliad and in the Odyssey, in order to trace the correct solar eclipse in NASA's catalogue utilizing the Starry Night program for the time span 1400-1130 BC. We concluded that the solar eclipse of the 6th June 1218 BC, observable in Troy at noon, with obscuration of the solar disc by more than 75%, was the cause of a gradual darkening, as precisely described in the Iliad. It *occurred after ten years of war and before* the other solar eclipse mentioned in the Odyssey.

1. Introduction

One of the problems of the archaeological research which remains unanswered up today is the Homeric issue. The 'archaeologist's spade' has discovered nine layers in relation to Troy, illustrating the prehistoric city's existence since 3000 BC.

The Trojan War's historicity still remains an unsolved problem, although it has been discovered a city in the Troad indicated with layer VI and VII and their sub layers corresponding to the late Mycenaean B epoch within the peak of the Mycenaean culture. The datings of these layers converge on the one hand towards the middle of the 13th and on the other to the beginning of the 12th century BC. Mountjoy [1,2], for instance, suggests that 1300 BC corresponds to layer VIh and 1210 BC to the layer VIIa respectively, (see analytically Papamarinopoulos et al, 2012)[3]. But the reports from the ancient Greek literature converge in the same time span as Herodotus [4] (1250 BC), Dicaearchus[5] (1212 BC), Sosivious[6] (1171 BC), the Parion Chronicle (1208 BC), Eratosthenes who in accordance with Clemes of Alexandria (in his work Stromateis) suggests the datings 1184 or 1228 or 1288 BC respectively (see analytically Papamarinopoulos et al, 2012) [3]. It is known that astronomy helps the dating of different events

because the described celestial phenomena, in ancient Greek texts, can be dated with modern methods. In the Homeric Epics there are indeed reports suggesting astronomical phenomena (Theodosiou et al., 2011) [9]. Between these reports, there is a solar eclipse in the Odyssey mentioned by Heracleitos from Pontos during the killing of the suitors (*Ομηρικά Προβλήματα, εἰς ἅ περί θεῶν Ὅμηρος ἠλληγόρησεν*, (75, 1, 1 – 9,3)). Schoch initially in 1926 [10] and later Baikouzis and Magnasco (2008) [11], based on the former's suggestions, indicated that the ancient total eclipse of the 16th of April 1178 BC was the one described in the Odyssey.

However, Papamarinopoulos et al. (2012) [3] indicated that in accordance with Homer's descriptions, Odysseus' return was in the autumn. The same researchers located the Homeric solar eclipse on the 30th of October 1207 BC. But Henriksson (2012) [12] mentioned a solar eclipse described in the Iliad. He said that it was the total eclipse of the 11th of June 1312 BC (Gregorian calendar). He also suggested that Troy was the Wilusa which is mentioned by the Hittites in their archives. He assumed that the Achaeans attacked Troy in 1315 BC, when King of the Hittites was Muwatalli II *doubting about the ten years of the Trojan War*. He mentions a letter called 'the Alaksandu treaty' associated between Muwztalli II and the King of Wilusa Alaksandu, equating the latter with Paris-Alexandros, son of Priam, King of Troy. But, in that letter, Alaksandu is Kukuni's successor and not of Priam or even Laomedon, both Kings of Troy, as son and father, with one generation difference. In accordance with Henriksson (2012) [12] hypothesis, Troy's fall took place in 1312 BC. Consequently in 1315 BC (in which Muwatalli II became King, in accordance with him, three years before Troy's fall King of Troy was Priam and not Paris-Alexandros. In addition Paris never became King of Troy. He was killed by Philoktitis after Hector's death (Apollodorus (1921) [13], John Malalas (2006) [14], Cedrenus (1889)[15], Howatson (1996) [16]).In accordance with the Iliad, Priam's house was succeeded by Aeneias' house (Il.Y, 306-308).

After all of the above remarks, we analyzed the Homeric text extensively and we determined a partial solar eclipse and not a total one.

Taking into account NASA's catalogue of the eclipses we found the solar eclipse on the 6th of June 1218 BC (Papamarinopoulos et al, 2014)[17], with 75% coverage of the sun's disk, visible in the Troad, occurred exactly one *'decade of war'* before the Odyssey's solar eclipse in accordance with the calculations by Papamarinopoulos et al (2012) [3]. We note that in antiquity the different prehistoric and historic city-states within the Greek territory did not have a common calendar as we have today. Consequently the common measurement of time for the warriors in Troy was, 'how many war years they were fighting'. Because no battles were conducted in winter, a 'year of war' lasts from the spring or summer of that war year up to the next corresponding season.

With this assumption and in agreement with the above mentioned solar eclipse, *the first year* of war was within the time span 1227-1226 BC and the tenth year of war was within the time span 1218-1217 BC. Odysseus left his homeland between 1227 and 1226 BC and returned between 1208 and 1207 BC, in other words within the twentieth year, as repeatedly mentioned in the Odyssey.

2. Homeric descriptions related to the solar eclipse

In the Iliad, information is given about a migratory bird in the Troad a heron (IL.10.274-276) which denotes that the events described take place during advanced spring or summer. This observation is supported by the extensive heat (for instance Il.10.572-575, Il.11.621-622, IL642-643, IL.l1.811-812 etc.). It is noted that the summer solstice in 12th-13th centuries BC was displaced on the 4th of July, due to the phenomenon of the equinoxes' precession. The night which preceded Patroclus' death is described as *dark* (*Il.8.500-511, Il.10. 297, Il.10.394, Il.10.468 and Il.10.275-277*). *This fits with a moonless night or a New Moon phase*. It is known that the Sun, the Moon and the Earth are in line, with the Moon to be between the two other bodies. The solar eclipse occurs only during the phase of a New Moon, when Sun, Moon and Earth are in alignment. Then Moon's disk covers Sun's disk, as observed by an Earth observer. During a solar eclipse, the shadow of moon's disk, as the Moon is illuminated by the Sun, falls on Earth. The shadow's width projected on Earth is about 250 km. Observers in the regions within this shadowy width, experience total solar eclipse (complete covering of Sun's disk). The adjacent regions observe partial solar eclipse.

3. Description of a solar eclipse in the Iliad

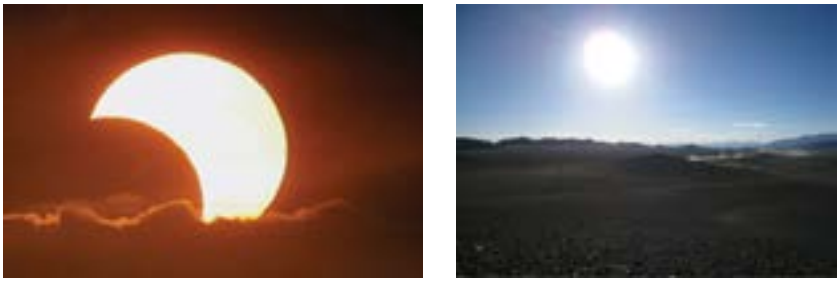
Homer in parallel with the battle's description during the 4th day offers the information of a gradual darkening within the middle of the day (IL.11.84-90) which starts with Sarpedon's death (Il.16.567-568) and it evolves during Patroclus' death (IL.L.269-270). Although he describes a '*νύκτα ολοήν-destructive night*' which became *later 'ηέρα πολλήν-much darker*' since Zeus spread it in the battlefield, the visibility continues to exist because the battle was in progress regularly.

But the clear indication for a solar eclipse's occurrence becomes during the description of the scene in which Achaeans and Trojans fight vigorously around dead Patroclus (IL.366-376):

> *So they fought like blazing fire, nor would you say that the sun or moon still remained intact, for with darkness were shrouded in the fight all the chief men who stood around the slain son of Menoetius. But the rest of the Trojans and the well-greaved Achaeans fought unimpeded under clear air, and over them was spread the piercing brightness of the sun, and on all the earth and the mountains was no cloud seen; and they fought resting themselves at times, avoiding one another's shafts laden with groans, and standing far apart. But those in the middle suffered woes because of the darkness and the war'.*

It could be very reasonable if the poet was describing only the Sun's presence during a very warm noon, with complete sunshine. Of course one can observe slightly the Moon too within a daily light, but not under intensive solar light in a summer's noon as it is described in the Homeric text. The Homeric scene fits with a partial solar eclipse where the two bodies, Sun and Moon, appear side by side in the sky (Figure 1 (a).

The phenomenon is not felt, by the warriors round dead Patroclus, because it was covered by the darkness of the battle (*'ηέρι μάχης'*), consequently by means of a synecdoche, the mayhem, the dense dust of the mist of the battle shrouded the warriors and not a 'remarkable darkness' during day light itself. In contradiction with the rest of the army which round of this team were fighting in accordance with the Homeric text. All the rest were fighting in clear air and under the piercing light of the Sun. It is known that during a solar eclipse the remaining segment of the solar disk in the sky has very sharp light and it is forbidden for people to observe it through naked eyes. In contradiction during this phenomenon, although on the ground there was darkness and the sky was cloudless, as the Homeric text described, there was enough visibility for the battle to continue. Fig. 1(b) illustrates a pretty similar case, in comparison with the Homeric text's described scene, captured in today's reality.



(a) (b)

Figure 1. (*a*) *A partial solar eclipse: The moon's disk covers partially the Sun's disk. In this concept the two bodies appear close to each other.*
http://www.sbs.com.au/news/sites/sbs.com.au.news/files/styles/full/public/images/s/i/site_1_rand_1898710893_solar_eclipse_l_2207_ap.jpg?itok=CMYhevXM&mtime=1398665530). (*b*) *An astronomical observation in which intensive solar light is emitted from the remaining uncovered part of sun's disk, whereas darkness prevails on the ground allowing limited visibility.* (*Gobi-Altai desert, Mongolia, 1-8-2008 K.Gazeas, Sector of Astrophysics, University of Athens*).

As the solar eclipse reaches its maximum phase a red cloud-'*πορφυρή νεφέλη*' comes from the sky and sits on the ground covering all of the army (Il.16.545-555). An unusual natural phenomenon of a red mist occurred and it was divinized by the poet in the presence of goddess Athena as it was natural in that remote period in antiquity.

This particular mist reduces further the already reduced visibility by the preexisting dust of the battle and the advancing solar eclipse to its maximum by covering Sun's disk by the Moon. Under these conditions Ajax shouts that he cannot see anything in the battle (Il.16.644-651).

Zeus 'responded' immediately (Il.18.649-650). The lack of visibility lasted only a few minutes as the maximum phase of the solar eclipse lasted. The Homeric text is clear with the coexistence of the two phenomena that of the solar eclipse and that of the red dust since Zeus dispersed darkness and removed the red mist (*'αυτίκα ηέρα*

μεν σκέδασεν και άπωσεν ομίχλην'). Then the Sun *re*-shone (*'ηέλιος δ' επέλαμψε'*). The phenomenon had finished sufficiently before the Sun set as the Homeric text describes (Il.18.241). But the poet gives an additional astronomical element. Three days later, in the dawn, when the fire burnt Patroclus' body, Venus (*'Εωσφόρος'*) appeared in the eastern horizon (Il.23.225-227). As it is known Lucifer-(*'Εωσφόρος'*) was called the planet Venus, much later by Plato too. Today we call this planet *Morning 'Star'* when it appears *before* Sunrise and *Evening 'Star'* when it appears *after* Sunset.

4. Searching for the solar eclipse

We already knew a solar eclipse's existence in the Odyssey. If the Homeric text was correct then one more solar eclipse should have existed within the Iliad, *ten years ahead*, of the other in the Odyssey. Consequently we search for two solar eclipses visible in Troy and Ithaca respectively together with the following additional data. Troy's eclipse occurred in the summer, at noon when Venus was visible in the East, three days after the eclipse, (Papamarinopoulos et al, 2014) [17]. Ithaca's eclipse occurred in the autumn, at noon and Venus was visible in the East five days before the eclipse, (Papamarinopoulos et al, 2012)[3]. Taking into account NASA's list of eclipses of Espenak and Meurs (2006)[18] and the software's Starry Night capacity, we searched all the time span 1400-1130 BC in order to locate a pair of eclipses which should satisfy all the Homeric text's requirements.

Indeed, there is *only one such pair of solar* eclipses with the following dates:

- Troy 6th of June 1218 BC (time-span of the phenomenon 14.10-17.07 LT with maximum in 15.45 LT)
- Ithaka 30th October 1207 BC (time span of the phenomenon 14.31-17.23 LT with maximum in 16.03 LT)

In both cases, the Sun disk's cover is large, at least 75%. The described heat and the heron's presence fit very well with June's beginning, one month before the summer solstice. For the Odyssey's eclipse there is complete analysis in another paper within this current volume. In connection with *Venus*, it was indeed visible in the East in both cases.

- For Troy: On the 9th of June of 1218 BC, rose in 3.12 LT, when the Sun rose in 4.48 LT.
- For Ithaca: On the 25th of October of 1207 BC rose in 5.13 LT, when the Sun rose in 6.50 LT.

Fig. 2 shows the solar eclipse's position above Troy in the celestial sphere in 15.45 LT. The eclipse is realized in the southwest within the Gemini's constellation region between planets Mercury (Ερμής) and Venus (Αφροδίτη).

Figure 2. The celestial sky above Troy on 6th June 1218 BC during the solar eclipse (15.45LT). Map constructed with the use of the program Starry Night, (Papamarinopoulos et al, 2014) [17]. It marks the position and the time's occurrence of Patroclus' death in the sky.

5. The astronomical phenomenon and the solar deity.

The eclipses' position, as it appears in Fig. 2, seems to have boundaries between the constellations Ursus Major and Orion, while sideways has the constellations of Taurus and the known 'clouds' of Pleiades and Hyades. But these exact constellations are pictured in Achilles' *new* shield, constructed again by *Hephaestus* (Il.18. 483-489), as Herinksson (2012) [12] and Papamarinopoulos et al (2014)[17] have reported.

In other words, Achilles 'bears' on his shield, the '*position and the time of the solar eclipse's occurrence in the sky' which marked his best friend's death*. In addition Achilles' description with the new panoply constructed by Hephaestus is a poetic symbolism of the natural phenomenon (Il.19.370-380). Achilles is described like '*Ηλέκτωρ* (*Elector*) *Υπερίων', in other words like the shining Sun, in terms of brightness. He is behind his shield, called* (*'μήνης'*) *in other words the Moon*. The word moon originates from the Greek word μήνης. And he is covered by his shield exactly as the Moon covers the shining Sun during the solar eclipse. Furthermore, if we study Patroclus' death (I.16.788-790) and his last words (Il.16.844-850), it is clear that the solar eclipse is 'connected' with the hero's death in accordance with the religious concepts of that era.

> *'For now, Hector, boast mightily; for to you have Zeus, the son of Cronos, and Apollo granted victory, they who vanquished me with ease, for they themselves took the armor from my shoulders...But it was destructive Fate and the son of Leto who slew me, and of men Euphorbus, while you are the third in my slaying.'*

Because indeed, as the text says, Phoebus-Apollo, the solar deity approached Patroclus from behind and 'removed' his panoply. It is clarified that Patroclus did not see Phoebus-Apollo because he was 'wrapped in darkness when he approached him' (*'ηέρι γαρ πολλή κεκαλυμμένος αντεβόλησε'*). In other words the solar deity was covered in darkness in correspondence with the *solar disk's darkening* during the eclipse.

6. Conclusions

Out of ten years of Trojan War, the epic poet has chosen to describe only *the facts of seven days* associated with the day Patroclus died under the shadow of a solar eclipse, two months before the fall of Troy. The dramatic events of Toy's fall in connection with Trojan Horse (Δούρειος Ίππος) or Achilles's death, the basic hero of the Achaeans, are not described in the Iliad. Hector's death, the basic hero of the Trojans is presented as the consequence of Patroclus' death. It seems that the "divine intervention", in the form of a solar eclipse, distinguished Patroclus' death from other important events. The warriors kept in their memories intensively the memory of such an event and naturally they transmitted it to others when they returned to their cities. It was therefore logical consequence that the popular muse made it a poem.

But Homer by mentioning two solar eclipses in the Iliad and in the Odyssey, respectively, and by combining them with Venus' appearance, and by offering also other descriptions which we have mentioned extensively in our papers, seems to denote to readers of his text who might know Astronomy the way to date the events. In addition Athanasios Stageiritis in his treatise "Ogygia the Archaeology" connects the dating with Astronomy emphasizing by writing "because the true and real history of the century became allegoric mythology and there stayed. And as allegory history is discovered being confused and disturbed. Due to lack of dating which are the nerves of history, it was lost due to lack of texts and due to ignorance in Astronomy and due to lack of order of time and its definition."

Fortunately, today's knowledge in Astronomy and the development of technology are good enough to complete the dating's vacuum if within the ancient texts exact astronomical information are saved as it is with the Homeric Epics.

Bibliography

[1] Mountzoy P. A. (1999a), The description of Troy VIh, *Studia Troica*, 9, 253-294.

[2] Mountzoy P. A. (1999b), Troy VII reconsidered, *Studia Troica*, 9, 295-346.

[3] Papamarinopoulos St. P., Preka-Papadema P., Antonopoulos P., Mitropetrou H., Tsironi A., Mitropetros P. (2012), A new astronomical dating of Odysseus' return to Ithaca, Mediterranean Archaeology and Archaeometry, 12, 1, 117-128.

[4] Herodotus Histories, 2, 145,16-17, Les Belles Lettres, Paris (1962).

[5] Dicaearchus, Fragment 58 a 4-5, *Scholia vetera in Apollonii Rhodii Argonautica*, 278, 11-12.

[6] Sossivius Lacon, De die nat., c21.

[7] Parian Chronicle, paragraph 24, Ashmolean Museum of Art and Archaeology, Oxford (2001).

[8] Clement of Alexandria, Stromateis (Clementis Stromata), Stahlin O., Fruchtel L. and Treu U. (eds), Akademie-Verlag, Berlin (1960).

[9] Theodosiou E., Manimanis V. N., Mantarakis P., Dimitrijevic M. S. (2011), Astronomy and constelations in the Iliad and Odyssey, *Journal of Astronomical History and Heritage*, 14, 1.

[10] Schoch C. (1926), The eclipse of Odysseus, *The Observatory*, 49, 19-21.

[11] Baikouzis C. and Magnasco M. O. (2008), Is an eclipse described in the Odyssey? *Proc. Natl. Acad. Sci. USA*, 105, 26, 8823-8828.

[12] Henriksson G. (2012) The Trojan War dated by two solar eclipses, Mediterranean Archaeology and Archaeometry, 12, 1, 63-76.

[13] Apollodorus (1921), *The Library*, Cambridge, MA, Harvard University Press, London, w. Heinemman Ltd.

[14] John Malalas (2006), *Chronicle*, Sydney.

[15] Cedrenus G. (1889),*Compendium Historianum*, 1, 228, J. P. Migne, Ptrologia Graeca, 121, Paris.

[16] Howatson M. C. (1996), *The Oxford Companion to Classical Literature*, s.v. Paris.

[17] Papamarinopoulos St. P., Preka-Papadema P., Mitropetros P., Antonopoulos P., Mitropetrou H., Saranditis G. (2014), A new astronomical dating of the Trojan War's end, Mediterranean Archaeology and Archaeometry, 14, 1, 93-102.

[18] Espenak F. and Meeus J. (2006) Five Millennium Canon of Solar Eclipses -1999 to 3000, NASA Technical Publication TP-2006-214141.

B4.6 Astronomical Phenomena and the Dating of Odysseus Return

Papamarinopoulos S. ([1]), Preka-Papadema P. ([2]), Antonopoulos P. ([3]), Mitropetrou H. ([1]), Mitropetros P. ([1])
([1])University of Patras, ([2])University of Athens, ([3])InterMedia KT - Interactive Media Knowledge Transfer, Patras, Greece

A solar eclipse, the planet Venus' appearance in the east horizon early in the morning, and the simultaneous occurrence of the '*late setting*' Bootes and Pleiades in the night sky, referred in the Odyssey, helped us to date Odysseus' return to Ithaca. We combined these astronomical phenomena with the excellent Homeric seasonal description of '*long lasting nights*', the agriculture and bucolic scenes etc., which apparently indicate autumn. The time span of 1300-1130 BC, the period associated with the Trojan War's chronology according to the archaeologists and the ancient Greek writers, was taken into account. Based on the NASA's eclipses catalogue and in combination with the software Starry Night's results, we conclude that the solar eclipse of the 30th October 1207 BC, observable during late noon in the Ionian Islands, with a significant solar disc obscuration of 75% is the solar eclipse mentioned by Homer. Odysseus, returned to Ithaca five days before this date, early in the morning. The suitors' killing occurred under the solar eclipse's conditions according to the Homeric text: '*the sun has perished out of heaven and an evil mist covered all*'.

1. Introduction

During prehistoric and historic times many celestial phenomena were attributed to the gods as good or bad omens. It is known that the observation of the sky in ancient times was essential for setting up a calendar, for the determination of seasons, in connection with agricultural, animal breeding and navigation necessities. As Odysseus is sailing toward Ithaca he observes the night sky. The constellations Ursa Major, Orion, Bootes and Pleiades are present (Od. 5.270-277). But when he arrives in Ithaca it is already dawn. The planet Venus is located in the east and it is clearly visible before sunrise (Od.13.93-95).

In this sense, the Odyssey conceals another astronomical phenomenon noted by Heraclitus of Pontus (1st century AD) in his work Allegories (75, 1, 1-9, 3). It concerns the description of the suitors' killing from the seer Theoclymenus, sometime before it happens (Od. 20.356-357). So between blood and lamentations, it is declared that '*and the sun has perished out of heaven and an evil mist covers all*'. The loss of sunlight accompanied with mist is the precise description of a *partial solar eclipse*, because in the case of a total solar eclipse there is deep darkness for a few minutes. Heraclitus points out two pieces of information. The first is the symbolism of the name of the

seer, Theoclymenus, which means '*the one that 'hears' the divine*'. He is the one who recognizes the astronomical phenomenon behind theology. The second is that he recognized a New Moon in the phase of the full moon. The latter is as a prerequisite for a solar eclipse. It is clearly stated in the Homeric text ("*between the waning of this moon and the waxing of the next*", Od.19.306-307). Indeed, a solar eclipse occurs only when the Moon is located in complete alignment between the Sun and Earth, so the apparent diameter of the lunar disk is inserted and covers the apparent diameter of the solar disc, as seen by a ground observer located in the area in which the Moon's shadow falls.

Schoch (1926)[2] and Baikouzis and Magnasco (2008)[3] (based on Schoch's work) suggested that this eclipse was the total solar eclipse of April 16, 1178 BC which was visible on the Ionian Islands. Schoch did not explain the reasons for his choice. Baikouzis and Magnasco based on an *arbitrary assumption of Mercury's retrograde motion*, identifying the Homeric god Hermes with the planet Mercury. They proposed that the journey of god Hermes to Ogygia indicates the planet's Mercury retrograde motion that lasts only for one day. In reality it is known that this phenomenon, in connection with planet Mercury, lasts for several days and happens about three times per, year. It is not an extraordinary astronomical phenomenon. Following the Homeric text the reader can recognize that the god Hermes arrived to Ogygia by *sea*, making an arduous journey of several days (Od.5.43-55, Od.5.97-102).

After all these observations, we decided to look for the right solar eclipse using the Starry Night software and the NASA's catalogs of eclipses (Espenac and Meeus, 2006) [4], which covers the period from 4500 BC to 10000 AD.

2. Odysseus' autumnal return and the suitors' 'afternoon' killing

By reading the Homeric text very carefully, it becomes quite clear that Odysseus returned in the autumn and not in the spring. Therefore, the date proposed, by others of April 16, 1178 BC does not make any sense. The text describes cold, rain, strong wind, lighting fires to produce heat for people's warming and the use of thick blankets (e.g. Od.14.467-479, Od.14.518-522, Od.14.529-533, Od.17.23-25, Od. 1 7.190-191). The fruit which are mentioned are all autumn fruit (pears, pomegranates, figs, apples, grape vines full of grapes (e.g. Od. 5.68-68, Od.5.72-73, Od.7.114-116, Od.24.340-344) and many fallen leaves (Od.5.480-487). Detailed description of all of these details is given by Papamarinopoulos et al (2012) [5]. Also Odysseus' father, Laertes, winters in the palace but in the summer and in the autumn remains in his estate, where he meets Odysseus (Od. 24). Consequently summer is a season not consistent with the previous descriptions. Therefore, the meeting between Odysseus and Laertis took place in the autumn. Winter is excluded too as herds are still outdoors (Od. 24.407-408, Od. 15.397, Od. 17.170-171).

In addition to all these, the nights marked as "*athesfatoi*" (*αθέσφατοι*) meaning that they have long duration (Od. 15.391-394). This clearly indicates that Odysseus' return occurred after the autumnal equinox, because then the nights become longer. Due to the phenomenon of the precession of the equinoxes, the autumnal equinox of the 12th -13th century BC was shifted to 4th of October.

Finally, the Pleiades and Bootes, whose stars are observed overnight in the sky by Odysseus during his return journey (Od. 5.270-277) are simultaneously appearing in the night sky, at latitudes of the Mediterranean Sea (inside or outside it) only in Spring and Autumn. Spring is rejected, by us, for all of the above. Specifically, Odysseus travels exactly as described in the verses:

> *"He never closed his eyes, but kept them fixed on the Pleiades, on late-setting Bootes, and on the Bear - which men also call the Wain, and which turns round and round where it is, facing Orion, and alone never dipping into the stream of Oceanus- for Calypso had told him to keep this to his left."*

Obviously the Bear (also called Wain) is the Ursa Major/Big Bear, according to Aratos ("Phaenomena and Diosemeia", 6.26-44) which was utilized in order North to be defined. Thus, Odysseus was traveling from west to east. Homer gives the information of the circumpolar star stating that the Bear *does not bathe in the Ocean waters*, meaning 'Celestial Ocean' as it was perceived by ancient peoples round the globe. Orion, the celestial hunter, is a well distinct constellation beneath the constellation of Taurus.

The constellation of Bootes contains one of the brightest and most famous stars in the sky, Arcturus, which is behind the Bear-Wain. Arcturus is the 'guardian' of the Bear and Bootes (oxes' driver) is the guide of the seven stars-oxen of wain (oxcart). The Pleiades, a striking open star cluster in the constellation of Taurus, is visible *throughout the night*, in *the autumn* sky, moving from east to west. Instead, in springtime, they set a few hours after the sunset.

Accordingly, the nights of the characterized "*οψέ δύοντα*" Bootes are autumnal according to Aratos ('Phenomena and Diosimeia' 6.579-585). Also Papamarinopoulos et al. (2012)[5] pointed out that in the autumn, the constellation of Bootes is located west, moving from northwest to northeast, while two of its stars (β Bootis and γ Bootis), *at that time in remote antiquity*, remained marginally over the horizon. In this way, Odysseus observes throughout *the night*, the *Pleiades* and *Bootes on the autumn*.

The prophecy of the seer Theoclymenus is done during the lunch of the suitors, while Odysseus battle against the suitors starts a little bit later and finishes before the evening meal, called 'δόρπον:dorpon' (Od. 20.248-259, Od. 20.345-394, Od. 21.68-79, Od. 21.428-429). That means during *late* noon, "*as there is light yet*" as highlighted. Therefore, the solar eclipse should have occurred at midday since the sunlight's loss was visible. The latter is connected (by the prophecy) with the suitors' killing.

3. Search and identification of the eclipse

According to the archaeologists, the Homeric Troy match layers VI and/or VII and their substrates, dating from various excavators, based on the study of ceramics, from 1300 to 1180 BC. The excavators of Troy do not agree on a common date and suggest VIh or VIIa substrates as the Homeric Troy without necessarily accepting the historicity of the Trojan War.

The ancient Greek writers (see Table 1, Papamarinopoulos et al, 2012[5]) also place the fall of Troy in about the same time frame. Therefore the search for the solar eclipse must be done in the time frame from 1300 BC to 1130 BC when the Mycenaean centers no longer exist.

The eclipse cycle called Saros is well known (18 years and 11 days), i.e. the repetition of the same series of eclipses with the same geometry. This means that we can predict the future eclipses. NASA provides all this information (http://eclipse.gsfc.nasa.gov) with algorithms developed by Espenak and Meeus (2006) [4].

Author	layer	Years BC
W. Dörpfeld	Troy VI	ca. 1250 but after Kadesh's battle
C. Blegen	Troy VIIa	1270-1240
G. Mylonas	Troy VIIa	ca 1200
V.R.d'Desborough	Troy VIIa	1230-1250
C. Nylander	Troy VI	No historic Trojan War
M. Finley	-	No historic Trojan War
M. Wood	Troy VI	1250-1260
S. Hiller	Troy VIh Troy VIIa	Middle 13th century End 13th /beginning 12th century
S. Hood	Troy VII b2	10th century
P. Mountjoy	- -	ca. 1210 for VIIa ca 1300 for VIh
M. Korfmann	Troy VI/VIIa	1200- 1180

Table 1: *Archaeologists' and historians' dating on the Homeric Troy* (*Papamarinopoulos et al* (2012)[5])

According to the catalog, 64 solar eclipses (total, partial and annular) visible in the Ionian Islands took place within this time frame. But if we limit ourselves to the autumn, the eclipses are reduced to 14. Taking into account in addition the information that Venus was visible in the east *before* sunrise, five days before the eclipse, during the arrival of Odysseus, we reviewed these 14 dates using the appropriate software (Starry Night) in order to ensure this requirement. Eventually the candidate eclipses were limited to 5 (Papamarinopoulos et al, 2012[5]). Three of them were not detectable as the coverage of the solar disk was minimal (<2%) or the phenomenon occurred after sunset and the fourth happened during early morning hours (~8 am), which is inconsistent with the lunch hour of the suitors killing. Therefore, only one solar eclipse remains that meets all Homeric standards and this is the partial solar eclipse of October 30, 1207 BC having maximum disk coverage of 75%. The phenomenon is progressing through the afternoon (14.31-17.23 LT) and peaks at 16.03 LT (Fig.1). Right after the end of the phenomenon (and the suitors' killing), the Sun set (17.58 LT) and the maids brought

the light, as stated in the Homeric text (Od. 22.497). The "*evil mist*" of the Homeric text and not the total darkness, is the natural consequence of the partial solar eclipse with 75% coverage.

Moreover, a few days earlier, in the previous *full moon* on October 15 at dawn, a partial lunar eclipse took place (52% disc coverage at 5.30 LT), visible across the Mediterranean Sea, based in NASA's catalog and Starry Night's software (Fig. 2). The moon was close to Pleiades and was setting *under the eclipse* as the Sun rose (6.08 LT). For a person familiar with astronomy, as seer Theoclymenus was, this phenomenon (*lunar eclipse*) was the forerunner of the *solar eclipse* that occurred after a few days. We remind the reader that the *lunar eclipse* occurs always in the *full moon phase*. *Then* the Sun, the Earth and the Moon are in a complete alignment with the Earth standing between. The shadow of the Earth falls on the Moon giving it reddish darkening ("*blood moon*").

Fig. 1. The celestial dome over Ithaca on October 30, 1207 BC, at 4 pm. The Solar Eclipse (Sun and Moon) takes place close to the constellation Scorpius, next to the red star Antares. Almost all planets within an angular aperture of 75 degrees are presented.

Fig. 2. A partial lunar eclipse with its disk with 52% coverage is shown. It occurred in October 15, 1207 BC and was visible in the Ionian Islands. The eclipse started at 4.16 LT, when the moon was 21 degrees above the western horizon. Maximum coverage of the lunar disc was on 5.30LT, when the Moon was at just 7.6 degrees above the western horizon, while the sun rose in 6.08LT. The 'blood moon', which was visible near the Pleiades star cluster (Taurus) was in fact in its full moon phase (Od.19.306-307). This absolute astronomical necessity preceded of the partial solar eclipse, shown in Fig.1, was described clearly by Homer in its correct sequence.

4. Attributing astronomical phenomena to divinity

According to the beliefs of that era, astronomical phenomena should be attributed to a deity, in this case to goddess Athena. She appears as Mentor (Od. 22.205-206) and then she is 'transformed' into a flying swallow toward the palace's roof (Od. 22.239-240), while the suitors did not realize this transformation (Od. 22.249). The swallow that sat on the roof is the portent of imminent death (Stageiritis, Ogygia, a, 191) [1]. Simultaneously however, one could link the forked tail of the swallow and the black-white color, with the partial solar eclipse (Fig. 3). It is a Homeric mimesis of the phenomenon. The suitors did not realize it as they were located in the loft and the vestibule of the palace, with closed doors and windows.

As the battle progresses, the suitors are trying to push back Odysseus from the brink of the palace (Od. 22.250) and go out in the yard. As the suitors attempt to push back Odysseus, being in the yard, then they see the sky, perceive Athena as she shows her aegis "*on the roof*" (Od. 22.297-298) and get panicked (Od. 22.299, Od. 22.307). In fact what they might have seen is the 75% dark solar disk and the glare from the remaining part. It is the solar eclipse that is progressing between 20 to 30 degrees altitude above the western horizon. The divination of the natural phenomenon via the presence of Athena is on. Upon returning back to the loft, the "mnistirofonia" (suitors' killing) is committed (Od. 22.299-309).

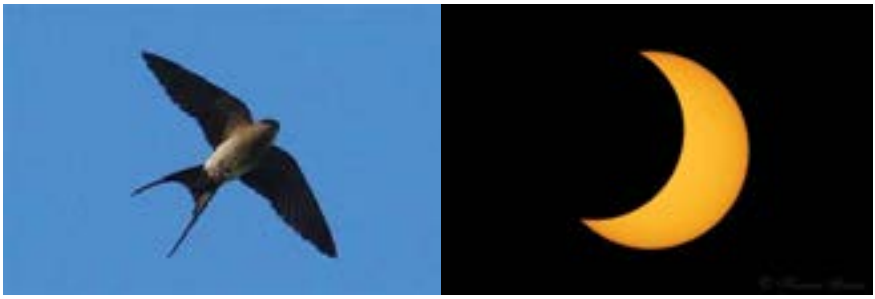


Fig. 3. A solar eclipse with 57% obscuration displayed in parallel with the forked tail of a swallow. (*From the archive of Dr. K. Gazeas, University of Athens*).

So actually in the words of seer Theoclymenus underlies the "physical science" i.e. the solar eclipse expressed by "myth and theology" via the presence of the goddess Athena. We remind the reader what the Delphic priest Plutarch said once: «*The old physical science for both Greeks and Barbarians is natural logos* (*logos in antiquity, in Plato's time, meant fact*) *hidden deeply within myths and occult and mystical theology, expressed mostly with enigmatic words and innuendo*", Plutarch (Fragmenta 157). Athanasios Stageiritis in his work "Ogygia or archaeology" [1] writes that historical myths are the stories about gods, heroes and other ancient symbols connected with myth. He notes that if we remove all the mythical data, true history remains such as the Trojan War for instance. Persons and places are mentioned in these myths that continue to have the same name as also other facts that confirm the validity of the story. What is lacking is the precision of time before the Trojan events. "And if it were possible for that to be found also, then mythology will receive the shape of regular history by the kingdom of Heaven."*And urges "these rules need to be guarded and observed if we want to clean ancient history or mythology as we call it*".

5. Conclusions

In antiquity, people believed that eclipses had a "negative impact" as recorded later on by another poet, Pindar (9th Paean, *Thivaiois in Ismenion* excerpt 52 k, 1-23). "*Civil war*" included as in the case of "mnistirofonia" (suitors' killing).

As it was natural at remote that time, the return of the King of Ithaca, Odysseus, and the extermination of all the pretenders to his throne was associated with the simultaneous occurrence of a solar eclipse, visible from the Ionian Islands. Moreover, this eclipse occurred on the day of the great celebration of Apollo, who was a solar deity (Od. 20.144-159, Od. 20.276-278). Also, a few days earlier, at sunrise, a lunar eclipse was preceded as "blood moon".

Such a serious event ("mnistirofonia", suitors' killing) framed by a "*divine intervention*" observed as a solar eclipse, surely spread throughout the country and the folk muse afterwards transformed it into a song.

References

[1] Athanasios Stageiritis, '*Ogygia or Archeology*', Vienna, 1817.

[2] C. Schoch, (1926), *The Eclipse of Odysseus*, The Observatory Vol. 49 p. 19-21'.

[3] C. Baikouzis and M. O. Magnasco, (2008), *Is an Eclipse in the Odyssey? PNAS* (*Proceedings of the National Academy of Sciences of the USA*), *Vol. 105*, p. 8823-8828.

[4] F. Espenak and J. Meeus, (2006), Five Millennium Canon of Solar Eclipses: -1999 to +3000, NASA Technical Publication TP-2006-214141.

[5] St. P. Papamarinopoulos, P. Preka-Papadema, P. Antonopoulos, H. Mitropetrou, Tsironi A. and P. Mitropetros, (2012), *A new astronomical dating of Odysseus' return to Ithaca*, Mediterranean Archaeology and Archaeometry, vol. 12, n.1, pp 117-128.

B4.7 A Description of a Meteor Shower in the Odyssey

Papamarinopoulos S. [1], Preka-Papadema P. [2], Antonopoulos P. [1], Mitropetrou H. [1], Mitropetros P. [3]
[1]*University of Patras,* [2]*University of Athens,* [3]*Keratsini, Piraeus, Greece*

Abstract

A meteor shower from the radiant point of Pleiades is described *poetically* as dove's feathers falling down, early before dawn, during Telemachus' arrival in Ithaca, two days before suitors' killing. The astronomical phenomenon is connected with the eastern appearance of the Corvus constellation in the sky and the hawk's appearance named kircos in the Homeric text, as both of them, kircos and Corvus were mythologically characterized as Apollo's messengers. We note that the suitors' killing occurred during a day of Apollo's great celebration. In the next days of the meteor shower, there are descriptions of a heaven glimmering at afternoon, Zeus' thunder in a 'clear cloudless sky' at dawn or/and at noon, strong Athena's voice accompanied with falling objects and a 'flaming thunderbolt' impacting on the ground caused terror and panic. We interpret these descriptions as the result of a bolide's explosion and the resulting blast wave respectively. The meteor showers are the remnants of various comets and are observed every year periodically, when the Earth's orbit intersects the cloud of such remnants.

1. Introduction

In his epic poetry, Homer appears as the 'Muse's executive instrument', which he calls in order to assist him *to describe the events and the situations of a heroic past*. The first passages of the Iliad and Odyssey justify this fact (Mitropetros and Dialectou, 2015) [1]. For this reason, while Homer lived in the 8th century BC, he commemorates events of the Mycenaean epoch but of some other periods too. Until that period, the bards were singing these events in every occasion. In the Odyssey, the bard Demodokos in the Phaeacians' palace sings Troy's fall with the Trojan Horse (Δούρειος Ίππος) trick in the gathering in Odysseus' honor (Od. 8. 487-522).

In these descriptions, one can find a lot of information of the way of life but also of the knowledge possessed by the people in that *remote period*, to which the poet was referring. Within the Homeric Epics there are reports about astronomical phenomena (Theodosiou et al., 2011) [2]. The oracle-tellers-augur-men, like Theoclymenus, mentioned in the Odyssey, knew of the phenomenon and the cycle of eclipses which is called Saros. For these reasons he announced suitors' killing and he related it with a solar eclipse in accordance with Heraclitus from Pontus ('*Allegories d' Homere*' (75, 1, 1-9, 3), 1962).

Baikouzis and Magnasco (2008) [3] in an effort to locate the solar eclipse, accepted Schoch's (1926)[4] suggestion, that the total solar eclipse, occurred on 16th April 1178 BC, was Odyssey's eclipse. However, Papamarinopoulos et al (2012)[5] noted that Odysseus' return realized in the autumn, as described in detail and very clearly in the Homeric text. The same researchers found and located the only Homeric solar eclipse described in the Odyssey. It occurred on the 30th of October 1207 BC. [56]

As Athanassios Stageiritis [said: 'The old people thought that a divine force was given to some people who could know about future and Gods' will through 'signs'. Thus, the people who received that charisma, were called oracle men and the procedure they used was called prophesy'. Such a man was Theoclymenus of the famous Melabidae's family, one of the greatest augur men in antiquity and who is mentioned in the Odyssey.

However, Theoclymenos, in accordance with the Homeric text, 'translated' another phenomenon as a good omen for Telamachus. Accepting Heraclitus of Pontus' observation that the very name of the oracle man (*Θεοκλύμενος= 'ο ακούων τα θεία'*) means the 'listener of the divines' and Plutarch's statement (*'Περί των εν Πλαταιαίς Δαιδάλων, απόσπασμα 157'*) that the '*the old physics was hidden behind myth and theology*', we wondered if the oracle man's intervention was connected with another phenomenon. Thus, using the software Starry Night and having the date of the suitors' killing available, based on the solar eclipse, we examined the celestial sphere of Ithaca during the described scene having as target the location of another astronomical phenomenon which might be hidden within the Homeric text.

2. Theoclymenus' prophesy

Theoclymenus met Telemachus in Pylos and asked him to take him to Ithaca, as he was fugitive due to murder which he had committed in Argos (Od. 15.224-281). The boat which transported Telemachus and the augur man reached Ithaca two days before the suitors' killing, in agreement with the Homeric text and landed in a 'hidden bay' and not in the port of the city, in darkness just before dawn (Od. 15.493-500, Od. 15.556-557, Od. 16.1-3), because Telemachus had been informed that the suitors had set an ambush in order to kill him.

Telemachus' arrival is escorted with a 'divine sign' which has been observed *only by Theoclymenus* which he interprets it as a good omen for the Laertides' House and a manifestation for Odysseus' return. This revelation was secretly communicated *only to Telemachus* and later to Penelope (Od. 17.150-161). The oracle man stresses to Penelope that *he perceived* that omen, when he was still opposite to the land, on the boat's deck. Later, he revealed the omen secretly to Telemachus, when they got out in the land in order to get food. In detail the phenomenon is described as follows (Od. 15.529-534):

> 'ὣς ἄρα οἱ εἰπόντι ἐπέπτατο δεξιὸς ὄρνις, κίρκος, Απόλλωνος ταχὺς ἄγγελος: ***ἐν δὲ πόδεσσι*** τίλλε πέλειαν ἔχων, κατὰ δὲ πτερὰ χεῦεν ἔραζε μεσσηγὺς νηός τε καὶ αὐτοῦ Τηλεμάχοιο'.

> 'Even as he spoke a *bird flew forth upon the right, a hawk, the swift messenger of Apollo*. In ***his talons*** he held a dove, and was plucking her and shedding the feathers down on the ground midway between the ship and Telemachus himself.'

As Papamarinopoulos et al (2013) noted the interpreter from the ancient Greek into English, (T. Murray, Harvard University Press), *paraphrases the 'εν πόδεσσι-in its feet'* of the Homeric text, with '*in its talons-in its nails*', because it is normal a vulture to hold the victim in its nails and not in its feet. Indeed, in another scene (Od. 15.160-179), which occurred in day light and which was observed by all attendees, an eagle rushed into a yard and grabbed a goose which it held in its nails (*'ονύχεσσι-in its nails'*). Why Homer does not use the same word feet in the case of the eagle and the *goose* and instead he uses the word talons, whereas in the case of the hawk and the *pigeon* he uses feet?

Moreover, this description, of the boat approaching Ithaca, *is understood* only by the augur man, but not by the attendees. The event, described above, takes place just before dawn and consequently there is no visibility, it is still dark. How it is possible, Theoclymenus to be able to distinguish through darkness, from afar, opposite to the land, *en route* to a small port, the hawk's ('kirko's') *flight* which is just 75 cm long with its feathers fully extended, and how he indeed managed to distinguish that 'kirkos' in addition was holding *a pigeon whose feathers were falling in the darkness?*

After all these questions, we decided to observe the celestial sphere above Ithaca just before the dawn of 28th October 1207 BC, in other words during Telemachus' arrival in accordance with our dating (Papamarinopoulos et al.[5, 6]) which was produced after Theoclymenus' second intervention, in other words the solar eclipse during suitors' killing.

3. Identification of the astronomical phenomenon

By means of Starry Night software, we reproduced the sky over the Ionian Islands (Fig. 1) at 6.10 LT, in other words just before dawn (Sunrise at 6.53 LT), of October 28th 1207 BC, (Papamarinopoulos et al, 2013) [8] . We observed that in south-east direction and at the height of 40 degrees above the horizon, the constellation Corvus, the sacred bird, Apollo's celestial messenger is located. The latter tried to steal Crater's content (adjacent constellation), but Hydra (the constellation around them) prevented him in accordance to the myth (Eratosthenes, Catasterismi, 1, 41R, 1-34). It should be noted that Corvus was not initially a black bird but changed its color from *white*, after delivering the message to *Apollo* that his woman who was pregnant to *Asclepius*, *his son*, was going to get married to a mortal man (Aratus Phaenomena, 1, 443-450).

Consequently, both celestial Corvus and *'κίρκος'* of the Homeric text are Apollo's *bird-messengers*. Kirkos' *flight* toward the '*right*' fits with constellation Corvus' appearance toward the East in the sky. In other words, at the time there was in the *starry sky* an '*Apollo's messenger*' and indeed in the *same direction*, to the East. If the darkness was preventing seeing a vulture with all these curious descriptions, it was, however, perfect to an experienced eye, to distinguish it in the sky, as a constellation and certainly the oracle man Theoclymenus did not have any problem with this.

Looking to the West, in the sky and indeed exactly anti-diametrically from Corvus constellation, in other words in Corvus' feet, in the antipode of Corvus, we observe that there is the Pleiades star cluster. But the name Pleiades ('*Πλειάδες*') is an abbreviation of the word Peleiades ('*Πελειάδες*') which means wild pigeons. The stars of this cluster mythologically present goddesses which are hunted by the 'sky hunter' Orion (Boeotian myths, Scholia in Pindarum, Ode N 2, scholion 17 c6-8). Consequently, the pigeon is located 'in the feet' of the vulture (the Apollo's messenger) and not 'in his talons'. Homer could not do such a mistake. The talons are not referred in the Homeric text, however are mentioned as such only by the interpreter as a conclusion. It is a serious misleading error.

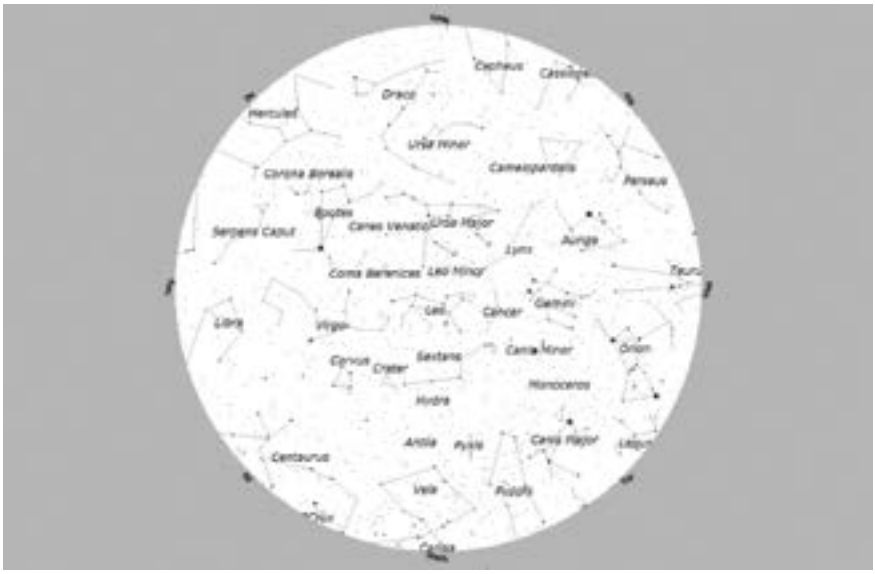


Fig. 1. *The sky above Ithaca is shown at the dawn of October 28th, 1207 BC during Telemachus' arrival.*

The *pigeon's* symbolic description whose *feathers are falling*, is a wonderful and exact way to present the meteor shower or the meteorites' fall in connection with the radiant point of the Pleiades of Taurus' constellation, in other words with a direction from that cluster.

The falling 'stars' are fragments of a comet which has left in its trajectory, as it passed from the perihelion (approaching the sun). It is known that the comets lose mass, every time they approach the sun. When the earth passes through that region, these fragments enter the atmosphere and appear as *shooting stars*. This phenomenon is more intensive, when it occurs in the same or in the next year after passing of the comet, since the fragments density and quantity has been increased. In agreement with today's termination, the *feathers* of the Homeric pigeon shall be called *Taurids*, since the meteor showers assume their names from the name of the constellation,

which defines sky's region, from which they originate.

Today, there is an analogous phenomenon with the same name, the same radiant point near to Pleiades and it appears in almost the same period, from the end of October to the beginning of November. Today's *Taurids* (known as Halloween *fireballs*) are the remains of a great comet, which was broken during passing from the perihelion, some tens of thousands of years ago. A small piece of that great comet is comet Encke that approaches Earth and Sun every 3.3 years. However, the comet's trajectories are changing due to the phenomenon of the perihelion's precession. Consequently, we cannot attribute the Homeric Taurids to the comet Encke. Close to the radiant point of the Taurids is located the radiant point of the Orionids (in Orion's constellation) from which the corresponding meteor shower appears almost *at the same time* with the Taurids (Fig. 2). The Orionids are the remains of comet Halley, approaching Earth and Sun every 76 years. Comet Halley is known since 467 BC.

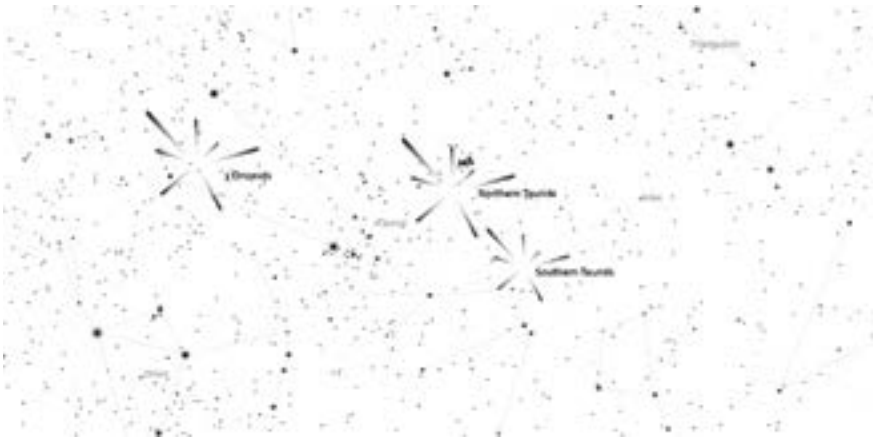


Figure 2. *The radiant point of Taurids and Orionids. These meteor showers are observed every year, from the end of October to the beginning of November.*

In agreement with the software Starry Night exactly on 20th September 1208 BC, Halley comet passed with perihelion only 0.15 AU. The comet was visible gradually all over Earth from 27th May 1208 till 6th May 1207 BC, whereas in Ithaca was visible in October-November 1208 BC, exactly one year before Odysseus' return, in accordance with the proposed dating. Comet Halley's 'recent' passing (1208 BC) certainly filled up with its debris the sky along its trajectory. If this phenomenon would occur today, it would intensify Orionids phenomenon in the next year. If, however, today's radiant point of the Orionids had, *then*, been displaced toward Taurus, near to Pleiades, due to the phenomenon of perihelion's precession, *then* (in 1207 BC) we would experience increased intensity of the Taurids phenomenon. In any case, because the two radiant points are close to each other, the density of the shooting stars, in 1207 BC, would be much more intense than usual and they would have direction near to Pleiades.

It seems that Theoclymenus was observing the phenomenon in the dawn of 28th October 1207 BC, as the boat was approaching Ithaca's small hidden port. He saw the first shooting stars from boat's deck and he continued to observe as they disembarked in order to get food. Then he decided to inform Telemachus secretly.

4. Explosions of fireballs

An intensive meteor shower lasts for some days and the solar light's scattering on the high density dust particles, existing in the atmosphere from meteors' breakage, produces intensive red color in the sky both during sunrise and sunset.

In other words, the so called zodiacal light is intensified. In the Odyssey, an analogous phenomenon is described in the next day of Telemachus' arrival, short before dark (Od. 19.4-50). It is the scene in which Odysseus and Telemachus hide the weapons. The sky had a 'strange' red color (*'πυρός αιθομένοιο'*). Telemachus points out that this red radiation reflected on the palace's walls and he attributes it to a 'divine miracle' and 'a presence of some god'.

In accordance with the Homeric text, the day of the suitors' killing starts with a thunder in a clear sky (*'αυτίκα δε εβρόντησε'*) just before dawn (Od. 20.91-121) as response to Odysseus' prays. A surprised maid went out of the palace and said:

> *'Zeus father you are King of gods and humans, you knocked strongly from the sky who is full of stars and in which no cloud exists. It is like you reveal a divine sign.'*

Clearly that it was still darkness and the stars were visible and no cloud existed in the sky. The poet in an artistic way draws attention to the origin of this 'divine' thunder. It is not the usual meteorological phenomenon. It is a bolide's explosion, in other words, a big meteor exploded somewhere in the atmosphere. If Odysseus or the maid were out of the palace, probably they would have seen the explosion's lightning too.

On the same day, but at noon, before the battle between Odysseus and the suitors starts, something similar are described (Od. 21.413 – 415): *'Ζεύς δε μεγάλ' έκτυπε σήματα φαίνων'*- 'Zeus knocked strongly showing signs'. The long lasting 'knocking' and not Zeus' single 'knocking', as well Zeus presents his 'signs', differentiates this phenomenon in connection with the bolide's explosion sequentially. It concerns the sound heard from a fireball breaking at low altitude. The phenomenon is not visible by Odysseus or the suitors since all of them were in the palace at the moment.

The next day, after the suitors' killing (Od. 24.526-544), at noon and as Odysseus was in the fields and faces in battle Ithaca's leaders; Athena's terrible sound was heard causing terror in the crowds and their weapons were fallen down from their arms. Moreover, it is emphasized that *everything* was fallen on the ground while the voice lasted. The crowds in panic were directed to the city. And then, Zeus sent a 'smoky thunderbolt'-'*ψολόεντα κεραυνόν*' in front of Athena. The word '*κεραυνός-thunder*' of the Homeric text is not literal but 'simulates' it, moreover, it has the adjective '*ψολόεντα*' which originates from the word '*ψόλος*' which means smoke, (Homeric Lexicon, I. Pantazidis,

Athens 1888, Editions Constadinidis). Therefore, the goddess is addressed to Odysseus giving order to 'stop the war'. Odysseus obeys and at this point the Odyssey ends.

This phenomenon is interpreted as a bolide's explosion (Athena's voice) at low altitude; in some distance from the battlefield and the produced by the explosion blast wave throws everything down ('falling objects as the voice lasts'). A bolide's fragment falls on the ground as a meteorite ('*smoky thunderbolt*').

It is a similar phenomenon with the Chelyabinsk phenomenon (Russia, 2013) which was a bolide's explosion and the blast wave produced a lot of damage and wounds of people, whereas a small meteorite was found in a nearby lake.

Moreover, when a thunder falls, besides the strong sound, it emits a strong light which is not described in the Homeric text. The battle continues normally without any mention of a storm. Finally, a thunder's fall will cause serious woundings and deaths but no such thing is mentioned in the Homeric text.

5. Astronomical phenomena as divine intervention

In antiquity, physical phenomena were always connected with some god. Thus, Telemachus related sky's 'redness', due to the light's dispersion within the high density of dust particles of the atmosphere, to the presence of some divinity. Similarly a bolide's explosion and the meteor's breakage are connected to Zeus, since their loud sound is equivalent with the thunder and, therefore, it is attributed to Zeus. Consequently the 'steaming' meteorite, originating from bolide's explosion, is attributed to Zeus, as it originates from his 'thunder'. Correspondingly, the bolide's explosion terrible sound, is connected to goddess Athena, a permanent Odysseus' ally.

The phenomenon of the meteor shower, with radiant point of Pleiades, is connected with Apollo's 'messenger'. The Pleiades-*Peleiades* (*pigeons*), since in Greek *Peleiades* are the *pigeons*, are located in the *Kirko's feet* (or *in Corvus' antipode*). Apollo preannounces, through his messenger, Odysseus' arrival and consequently Laertides' house rescue. Odysseus' revelation and the suitors' killing have occurred two days later exactly on the day of Apollo's great celebration. The archer god Apollo was 'assistant' of Odysseus, because on the day of his celebration, *Odysseus as an archer*, killed all the suitors, with his bow.

On the day of suitors killing, special preparations are described in the palace for the gathering of the leaders of Ithaca, since through Eurykleia's mouth (Od. 20.144-159) the poet informed us that '*επεί και πάσιν εορτή*'-'*today all people celebrate*'. The reference to '*ιεράν εκατόμβην*'-'*holy hecatomb*' that the preachers brought to Apollo's forest in which the crowd had come from the city, was already there gathered (Od.20.276-278), denotes the exceptional meaning of this celebration. Let us note Apollo's characterization as 'one hundred shooter'- 'εκατόβηλος' which signifies his ability as a great archer.

In the Homeric text is mentioned twice, with exactly the same words, and connecting it with the day of Apollo's great celebration (Od. 14.161-164):

> '*Του δ' αυτού Λυκάβαντος ελεύσεται ενθάδ' Οδυσσεύς, του μεν φθίνοντος μηνός του δ' ισταμένοιο, οίκαδε νοστήσει*'.

> *'In the course of this very month* (*Lykabas*) *shall Odysseus come here, between the waning of this month and the waxing of the next'.*

The latter means *Nouminia*, in other words New Moon. Consequently that day was the first of the month, since the *New Moon* usually corresponded to lunar calendar's *first day*. In accordance with our proposed dating, the day of the suitors' killing and the day of *Apollo's great celebration* was 30th *October 1207 BC*. This is the *first day* of the *first month after the autumn equinox*. The latter was *4th October*. It is displaced in comparison with the current day, due of the phenomenon of the precession of the equinoxes. This specific first of the month was celebrated with a hecatomb in Apollo's honor. If Eurycleia was literally speaking as she was saying 'today *all people celebrate*', then, this great Apollo's celebration was not confined only in Ithaca.

6. Conclusions

Sailors and augur men knew uranography by observing the sky in detail during the prehistoric and the historic era. Homer presents two astronomical events, as *prophesies*, of the well-known augur man Theoclymenus'. The first event is an intensive meteor shower observed during Telemachus' arrival and continues to exist and the next days. Within the domain of this phenomenon, two bolides' explosions (big meteors) are described in two-day time and a meteorite fall. The second event is a partial solar eclipse at noon bearing mist, in which the suitors' killing takes place, (see [6]). The two *prophesies* – two *astronomical phenomena*, which marked Odysseus' return, are connected with Apollo's great celebration. The latter in connection with our proposed dating is the *first day* of *the first month*, after the *autumn's equinox*.

The intensive meteor shower, observed end of October 1207 BC. is very likely to be connected with comet Halley's passing in 1208 BC, since the today's radiant point of the Orionids, which are the remnants of that comet, is located close to Pleiades, from which the Homeric 'shooting stars' originate. In addition, this radiant point, many thousands years ago, would be displaced, may be even closer to Pleiades, due to the phenomenon of the precession of the perihelion. The Orionids and the Taurids ('Halloween fireballs'), are observed today from October's end up to November's beginning, in other words in the corresponding season in connection with the Homeric 'shooting stars' from the Pleiades in Taurus' constellation.

Bibliography

[1] P. Mitropetrou and D. Dialektou, (2015), *Approaches to Pre-Socratic*, Ed. Aegeis Piraeus, (in Greek).

[2] E. Theodosiou, V. N. Manimanis, P. Mandarakis and M. S. Dimitrijevic, (2011), *Astronomy and Constellations in the Iliad and Odyssey*, Journal of Astronomical History and Heritage, 14, 1, 22-30.

[3] C. Baikouzis and M. O. Magnasco, (2008), *Is an Eclipse in the Odyssey?* PNAS (Proceedings of the National Academy of Sciences of the USA), Vol. 105, p. 8823-8828.

[4] C. Schoch, (1926), *The Eclipse of Odysseus*, The Observatory Vol. 49 p. 19-21'.

[5] St. P. Papamarinopoulos, P. Preka-Papadema, P. Antonopoulos, H. Mitropetrou, Tsironi A. and P. Mitropetros, (2012), *A new astronomical dating of Odysseus' return to Ithaca*, Mediterranean Archaeology and Archaeometry, vol. 12, n.1, pp 117-128.

[6] St. P. Papamarinopoulos, P. Preka-Papadema, P. Antonopoulos, H. Mitropetrou, Tsironi A. and P. Mitropetros, (2016), *Astronomical phenomena and the dating of Odysseus return*, in this volume.

[7] Athanassios Stageiritis, 'Ogygia or Archaeology', Vienna, 1817, Book A, 173 (in Greek).

[8] St. P. Papamarinopoulos, P. Preka-Papadema, P. Antonopoulos, H. Mitropetrou, Tsironi A. and P. Mitropetros, (2013), *The anatomy of a complex astronomical phenomenon described in the Odyssey*, Mediterranean Archaeology and Archaeometry, vol. 13, n.2, pp 69-82.

B4.8 Psychophysical Law of Pythagoras-Aristoxenus

Charalamos Ch. Spyridis
Professor, National and Kapodistrian University of Athens.

Abstract

The ancient Greek musicians established the science of Acoustics on the string musical instruments. Two are the pillars of the ancient Greek music: The Pythagorean and the Aristoxenian. According to the Pythagoreans the musical interval of two notes is defined as the ratio of their agents or stimuli, namely the ratio of the lengths of the vibrating parts of the string.

$$\text{Musical interval} = \left(\frac{L_i}{L_j}\right), \quad L_i > L_j$$

The Aristoxenians are based on the sense of hearing and intelligence, as well (Aristoxenus, *Harmonics*) and define the musical interval as the difference of the psychoacoustic magnitude "dynamis" of each two notes.

Musical interval = $(\text{dynamis of note})_i - (\text{dynamis of note})_j$

In order the two definitions to provide equal results, and lacking other information, I was led to acknowledge the "dynamis" of one note is relevant to the logarithm to base 2 - because of the octave - of its stimulus.

Dynamis of note = $k \cdot \log_2(L)$

Musical interval = $(\text{dynamis of note})_i - (\text{dynamis of note})_j =$
$= k \cdot \log_2(L_i) - k \cdot \log_2(L_j) = k \cdot \log_2(L_i/L_j), \; L_i > L_j$

The duality of the measurement of musical intervals is expressed via the verb *parametreo* (παραμετρέω-ῶ) (Ptolemy, *Harmonics*).

Did the Pythagoreans know about the logarithms twenty centuries before John Napier? According to me YES. They did know about the logarithms to base 2 and they calculated them, as I have managed to discover, based on other philosophy using the "Pythagorean theory of means" with absolute accuracy, when we are constricted in one decimal digit.

What a historic and scientific quote!

1. On the Musical Interval

According to Xenophon, Socrates began carrying out research on appellations, namely what exactly each appellation meant, because he was of the opinion that knowing what each one of them meant was the basis of education (Epictetus, 1, 17, 13).

The ancient Greek Harmony theorists corroborated and defined exactly each term they used; i.e. they used scientific terminology.

We, modern Greeks, lack this terminology and can therefore not grasp or understand many of their scientific opinions and theories.

According to Cleonides's definition in his work *Introduction to Harmonics* (*Eisagōgē harmonikē*, 1, 1-4) the harmonic science is both a theoretical and an applied science that studies the intervallic melody by the high and low notes.

This presentation focuses on the musical interval, namely the fundamental concept of Harmonics, researching ways of determining and measuring it. My ultimate goal and vision is to prove that

- ancient Greek Pythagorean and Aristoxenean musicians were familiar with the concept of the logarithm and
- were able to calculate the logarithms of numbers to base 2.

Numbers were selected to be the primary tool for establishing and developing the harmonic science (Pythagoras, *Fragments*, 164, 27-32).

Notes were determined through numbers and, consequently, musical intervals were determined by diving or subtracting numbers.

After studying ancient Greek music for many years and delving into the subject of musical intervals, I can guarantee that we haven't paid the necessary attention to these two simple mathematical operations, namely subtraction and division, in regard to their role in determining the meaning of the musical interval.

Porphyry clarifies what the Aristoxeneans subtracted in order to determine the musical intervals through distinction. They didn't care about the simple difference in size between a major and a minor quantity. Instead, they focused on the difference of the aural sensations, i.e. the difference between one that sounded higher and another one that sounded lower, or the difference between the *dynameis* of the sounds produced.

The essential role of the sensation, with regard to the philosophy of handling musical intervals, escaped us and continues to escape us (Aristoxenus, *Elements of Harmony*, 42, 8), even though the ancient Greek Harmony Theorists and Philosophers made various references to it.

We evaluate musical intervals intellectually based on the ratio of their stimuli, that is to say the ratio of the lengths of the vibrating parts of the string, whereas we evaluate musical intervals through hearing based on the sensations that these notes generate, namely based on psychophysical values associated with the mind and the intellect.

In case you wonder which approach in regard to the musical intervals is better than the other, Porphyry informs us in his *commentary on Ptolemy's Harmonics* (*Eis ta Harmonika Ptolemaiou hypomnēma*, 26, 26-29) that some consider both of them equally

important, while others, such as Archestratus, believe that defining musical intervals through ratios outweighs the other approach.

Porphyry also mentions in the same work the objection of Eratosthenes in regard to the definition of a size being either based on the ratio of two numbers or on the difference between two numbers claiming *that the ratio and the difference are two different things*.

Claudius Ptolemy mentions something amazing in his work *Harmonics* (1, 1). He officially states that the difference between the lengths of two vibrating parts of the chord whose ratio defines a specific consonant musical interval becomes smaller, as the vibrating parts of the chord approach the high sound area. Therefore, equal ratios of the vibrating parts of a chord, i.e. equal musical intervals according to the Pythagorean School, do not result in equal differences, namely equal musical intervals according to the Aristoxenean School.

Since I could not accept that the Aristoxeneans could in fact make such a mistake, I considered the possibility that the lengths that the Pythagoreans divided where different from the ones that the Aristoxeneans subtracted. However, they were related to one another in such a way that equal ratios of lengths of vibrating parts of a chord, regardless of the *dynamis*, result in equal differences in length, once again regardless of the *dynamis*.

In my opinion, the following question is inevitable: since the Aristoxeneans didn't want to know the lengths of the stimuli from their ratio, according to the Pythagorean definition of the interval, how did they calculate the difference between the lengths of these two stimuli?

I firmly believe that the Aristoxeneans also determined the size of musical intervals instrumentally comparing differences between numbers that determined the size of aural sensations. However, according to Porphyry (*Commentary on Ptolemy's Harmonics*, 29, 13], the Aristoxeneans never revealed a thing regarding these numbers.

Porphyry (*Commentary on Ptolemy's Harmonics*, 25, 7) cites the clear opinion of *Ptolemais of Cyrene* on the definition of the interval as follows: Some preferred the ratio per se, some the sensation and others both. The Pythagoreans, who knew the theory perfectly, were the ones to choose the ratio per se, as a stand-alone criterion. The musical instrument players, who had never been educated or had been slightly educated theoretically, preferred the sensation.

Aristoxenus of Tarentum chose both of them.

While researching various theoretical and practical musical matters based on records of ancient Greek Harmony theorists and philosophers, I was stunned by a statement of the great Claudius Ptolemy, who mentions in his work *Harmonics* (Chapter 1, §1, line 1) that the Aristoxeneans determined the consonant musical intervals correctly by comparing them to something else (παραμετροῦσι), which was neither musical intervals, nor musical notes.

I referred to the Dictionary of the Ancient Greek Language of Liddel & Scott and found the meaning of the ancient Greek verb "parametreo" (compare, contrast): measure something using something else, i.e. placing them in parallel to one another.

What is Claudius Ptolemy trying to clarify through this statement?

This "something else" is what I searched for and found and what I will try to present to you through this speech.

The Pythagoreans determine the differences of the notes using numerical ratios, while the Aristoxeneans measure the intervals between the notes accurately and assign incomprehensible numbers to these intervals that are the result of complex procedures. So this, despite the numerical ratio of the notes, is a mistake and they say that they clearly made a mistake, but they do not reveal the numbers that they use to measure sensations.

It is clear, from what has been mentioned so far, that in case when the stimulus refers to the length of the vibrating part of the chord, the sensation refers to the dynamis of the sound produced. This means that the musical interval for two given lengths of vibrating parts of a chord that produce sounds is defined through the ratio of said lengths, according to the Pythagoreans, while, according to the Aristoxeneans, it is not defined through the difference between the lengths of these two vibrating parts of the chord, but through the difference between the logarithms of these lengths to base 2, namely through the difference between the aural sensations caused by the sounds of the vibrating parts of the chord.

2. The concept of the "dynamis of the note" in ancient Greek Music

The acoustics of stringed musical instruments was theoretically and practically established by ancient Greek musicians, who formulated, correctly for the most part, the laws governing the strings.

Aristides Quintilianus explains the meaning of the practical musical "tasis" (stress) in his work *On Music* [*Perì musikês*] (1, 5, 21-26) claiming that:

[*"Tasis"(stress) is the holding and the stopping of the voice.*]

Cleonides clarifies in his work *Introduction to Harmonics* [*Eisagōgē harmonikē*] (§2, lines 17-21) that:

["taseis" (stresses) are also known as notes. The term "tasis" (stress) derives from the tension applied on the strings of stringed instruments, while the term "note" derives from the fact that each one of them is articulated through the voice.]

A stringed instrument can produce too many "taseis". Apart from 18 of them, no "tasis" belongs to a musical scale of some genus and they generally create the "psophoi". The aforementioned 18 "taseis" belong to a musical scale of some genus and they constitute the notes of said scale.

The aural sensation that is caused by a note is called *dynamis of this note*. It is of psychoacoustic nature. In order the two definitions to provide equal results, and lacking other information, I was led to acknowledge that the "dynamis" of one note is relevant to the logarithm to base 2 - because of the octave (2/1)- of its stimulus; i.e. of the length L of the vibrating part of the chord

$$\text{dynamis of the note} = k \cdot \log_2(L)$$

The piece of information that Cleonides provides us with, namely that the "dynamis of the note is the rank of the note within a musical system", made me choose log2(L) to express the "dynamis" of notes. It is indeed true that the longer the stimulus of a note, the higher the rank of said note in that particular musical system.

Ancient Greek music has two pillars: the Pythagorean and the Aristoxenean.

The Pythagoreans based their study of musical intervals on the ratios of the stimuli, i.e.:

$$\text{Musical interval} = \left(\frac{L_i}{L_j}\right), \quad L_i > L_j.$$

The Aristoxeneans calculated the size of each musical interval as the difference between the dynameis of the notes, based solely on audition.

Musical interval = $(\text{dynamis of the note})_i - (\text{dynamis of the note})_j$

But only after my accepting that the dynamis of the note = k·log2(L), the size of the vibrating parts of the chord that create each musical interval can really be taken into account.

Musical interval = $(\text{dynamis of the note})_i - (\text{dynamis of the note})_j =$
$k \cdot \log_2(Li) - k \cdot \log_2(Lj) = k \cdot \log_2(Li/Lj), \; Li > Lj$

The value of the constant k can be determined by the musical interval of a diapason (e.g. 4/2).

12 semitones = $k \cdot \log_2(4/2) = k \cdot \log_2(2) = k$

The number 12 means that there are 12 semitones per octave, implying the existence of some kind of equal temperament.

Therefore, it is obvious that the Pythagoreans defined intervals based on ratios, while the Aristoxeneans on differences.

It is said that the term "*dymanis of the note*" had the meaning of a specific quality of the notes, namely of a function that a note of the scale carries out in relation to the other notes of the scale.

Aristoxenus, who was the first one to systematically study the theory of ancient Greek music, tries to highlight that the concept of the "dynamis of the note" is a size of psychoacoustic nature, while the size of an interval is of a physiological one, as it is related to the physiology of our ear.

The ensemble of emotions that music generates inside the human soul is called ethos of the music and it is caused by the dynameis of the notes heard.

3. Logarithm calculation to base 2 in the archaic manner, based on the Spyridean version

In the history of mathematics, as it is recorded today, the Scottish mathematician John Napier (1550-1617) was allegedly the first to discover and focus on logarithms to base 2 in his work *Mirifici Logarithmorum Canonis Descriptio*, which was published in Edinburgh in 1614. A historical and scientific ordo inversus!

Did the Pythagoreans know about logarithms? In my opinion, the answer is yes. Pythagoras formulated a complete mathematical theory of logarithmic nature regarding musical intervals, given that musical intervals are added by multiplying their numerical relationships and subtracted by dividing them.

How could he possibly have achieved that without knowing what a logarithm is?

The Pythagoreans knew about and used logarithms to base 2 and, as I managed to discover, they calculated them using the theory of mean.

In support of all of the above, a numerical proof of the fact that every Pythagorean musical interval has an equal Aristoxenean one or, in other words, that equal ratios of stimuli give equal differences of sensations, namely equal differences of "dynameis" of notes, shall follow.

Aristoteles (*Problems* 910b, 23 - 911a, 4) mentions that the Pythagoreans made a distinction between odd (2k+1, k∈N) and even (2k, k∈N) numbers in music. They classified even numbers in the following three categories: even times even numbers (artiakis artioi) (2^{ν}, $\nu \in N$), even-odd numbers (artioperittoi) $[2\cdot(2k+1),\ k \in N]$ and odd times even numbers (perissartioi) $[2^{\nu} \cdot (2k+1)\ \nu, k \in N]$.

The integer β is inserted between two non-consecutive integers α and γ (α>γ), based on ten different Pythagorean definitions called "Pythagorean means".

If it is not required that the inserted number β be an integer, the numbers α and γ can also be consecutive integers.

The generating function $[L = (\frac{2^{\alpha}+2^{\gamma}}{2}) \quad \alpha, \gamma \in N]$ provides us with all of the aforementioned kinds of integers and it was selected to be used for the rest of our calculations.

<u>Definition</u>: From now on, I shall call the difference of the third mean $\beta_3 = \frac{2\alpha\gamma}{\alpha+\gamma}$ from two times the first mean $\beta_1\ \frac{\alpha+\gamma}{2}$, namely ($2\beta_1$-$\beta_3$), the Spyridean logarithm spyrlog(L), as I found out, with the assistance of the above mentioned integers α and γ, that it expresses $\log_2(L)$ pretty accurately.

As the following numerical relationship is easy to prove,

$$\beta_3 + \beta_4 = \frac{2\alpha\gamma+\alpha^2+\gamma^2}{\alpha+\gamma} = \frac{(\alpha+\gamma)^2}{\alpha+\gamma} = \alpha + \gamma = 2\beta_1, \text{ thus } \beta_4 = 2\beta_1\text{-}\beta_3$$

from now on and with the assistance of the above mentioned integers α and γ, I shall correspondingly call the mean , based on the fourth analogy of the Pythagoreans, the Spyridean logarithm spyrlog(L) in order to reduce the necessary mathematical operations.

Based on this two equivalent ways of defining spyrlog(L), I can bypass the obstacle

that Pythagoras only knew three means, β_1, β_2 and β_3, namely the arithmetic, the geometric and the harmonic one.

The closer to one another the numbers α and γ are, the greater the spyrlog$(L)=\beta_4 \rightarrow \log_2(L)$.

If α and γ are consecutive integers, we can have a perfect approximation to the first decimal place.

In support of all of the above, Table 1 follows.

Table 1: Calculation of the two spyrlogs(L) and comparison of them to log2(L).

α	γ	L	β_1	β_3	spyrlog(L)=β_4	spyrlog(L) =$2\beta_1$-β_3	$\log_2$(L)
1	2	3	1.5	1.3	1.7	1.7	1.6
2	3	6	2.5	2.4	2.6	2.6	2.6
3	4	12	3.5	3.4	3.6	3.6	3.6
4	5	24	4.5	4.4	4.6	4.6	4.6
5	6	48	5.5	5.5	5.5	5.5	5.6
6	7	96	6.5	6.5	6.5	6.5	6.6
7	8	192	7.5	7.5	7.5	7.5	7.6
8	9	384	8.5	8.5	8.5	8.5	8.6
9	10	768	9.5	9.5	9.5	9.5	9.6
10	11	1536	10.5	10.5	10.5	10.5	10.6

The following properties were identified after studying the spyrlog(L)=β_4:

1. Every time L is doubled, β_4 increases by one unit and every time L is halved, β_4 decreases by one unit.
2. If spyrlog(L)=β_4, then spyrlog(L^ν)=$\nu \cdot \beta_4$, $\nu \in N$.
3. Let spyrlog(L_1)=$\beta_{4,1}$ and spyrlog(L_2)=$\beta_{4,2}$.

Then the harmonic mean (β_3) of L_1 and L_2 has the arithmetic mean (β_1) of $\beta_{4,1}$ and $\beta_{4,2}$ as spyrlog. Namely: $spyrlog\left(\frac{2L_1L_2}{L_1+L_2}\right) = \frac{\beta_{4,1}+\beta_{4,2}}{2}$ and the geometric mean (β2) of L_1 and L_2 has the harmonic mean (β_3) of $\beta_{4,1}$ and $\beta_{4,2}$ as spyrlog.

Namely: $spyrlog\left(\sqrt{L_1 \cdot L_2}\right) = \frac{2\cdot\beta_{4,1}\cdot\beta_{4,2}}{\beta_{4,1}+\beta_{4,2}}$

Based on these properties, we can create a Table of spyrlogs that can help us solve any kind of logarithmic problems.

At this point, I would like to refer to the aforementioned statement of the great

Claudius Ptolemy (*Harmonics*, Chapter 1, 1, 1) that the Aristoxeneans... (παραμετροῦσι) compared the symphonies, meaning that they used something else to measure symphonies, placing them in parallel to one another; they compared and contrasted.

How was this comparison carried out?

In my opinion, it was carried out using a complicated ruler, i.e. a monochord; possibly the one that Claudius Ptolemy called *harmonic ruler* (*Harmonics*, 1, 2, 2-4).

I imagine there was a logarithmic ruler, i.e. a monochord, on both sides of the chord of which there were two different size scales starting from the bridge pin. One of them was used to calculate the size of the stimuli, i.e. the lengths of the vibrating parts of the chord that produce sound (from the bridge pin to the movable bridge), which were used to calculate each musical interval as the ratio of these lengths, according to the Pythagoreans.

The other one was used to calculate the size of the produced aural sensations, i.e. the β_4 values, each one of them next to the equivalent length of the vibrating part of the chord $\beta_4 = log_2(L)$. The Aristoxenean size of the musical interval that was measured each time was the result of the difference that occurred $12 \cdot \Delta\beta_4 = 12 \cdot (\beta_{41} - \beta_{42})$ in semitones.

Example

L_1	L_2	Pythagorean ratio L_2/L_1	$\log_2(L_1)=\beta_{41}$	$\log_2(L_2)=\beta_{42}$	$\Delta\beta 4$	Aristoxenean interval in Semitones=$12\cdot\Delta\beta_4$	Name of the Interval
18	24	4/3	4.14	4.56	0.42	5.04≅5	Diatessaron
12	18	3/2	3.57	4.14	0.57	6.86≅7	Diapente
6	12	2/1	2.60	3.57	0.97	11.64≅12	Diapason
6	18	3/1	2.60	4.14	1.54	18.48≅19=12+7	Diapason and Diapente

4. Conclusion

In summary, the above study helps us reach extremely interesting conclusions on Music (both in Theory and in Practice), Mathematics, Psychoacoustics, the History of Sciences and Greek History.

1. All of the mentioned and used sizes can be calculated through simple theories and operations that were known to the Pythagoreans and Aristoxeneans.
2. We can suppose that the logarithm of a number to base 2 resulted from the Pythagorean theory on Means, namely of the first (the arithmetic), the third (the harmon-

ic) and the fourth (the opposite of the harmonic) one.

3. The sizes of the sensations generated are added in an algebraic manner. Due to how simple that is, the Aristoxenean way of handling musical intervals prevailed over the Pythagorean one, which required more specific algebraic calculations.
4. Stimuli change in an arithmetic manner, while sensations in a logarithmic one[1], since the subjective aural sensation is proportional to the logarithm to base 2 of the stimulus.

Considering everything mentioned so far to be both correct and feasible based on Mathematics, Physics and the Music of the Pythagoreans and Aristoxeneans, I dare to pronounce the sentence "Stimuli change in an arithmetic manner, while sensations in a logarithmic one" as the *Psychophysical Law of Pythagoras – Aristoxenus.*

1. According to modern Physics, this observation was made in 1860 by Gustaf Fechner, who studied the results of experiments made in 1848 by the German naturalist Ernst H. Weber, and it constitutes the Psychophysical law of Weber-Fechner.

B4.9 The Catasterisms of Eratosthenes and the Pythagorean Harmonics

Spyridis Ch., Preka-Papadema P.
Department of Musical Studies, Faculty of Philosophy, National and Kapodistrian University of Athens
Sector of Astrophysics, Astronomy and Mechanics, Department of Physics, National and Kapodistrian University of Athens

Summary

Eratosthenes of Cyrene (276-194 BC) describes the constellations of the northern hemisphere in his extant work under the title "*Catasterismi*" determining the number of stars of each one of them.

After grouping these stars, we proceeded to a Pythagorean study of them by ratios. The result of this study is a series of musical intervals that, based on a note of reference, create a sequence of notes within the range of 4 octaves (diapasons) and 1 perfect fifth (diapente), which is inferior to the one mentioned by Plato in the *Creation of the World Soul* (*Timaeus*, 35a1-36b6) only by a single tone.

When these notes are reduced into an octave, they sound like tuning a seven-string lyre via two attached ascending Lydian tetrachords, proving Heraclitus Ponticus right (*Homeric Problems*, 12).

The light of all the resulting notes that are scattered throughout the night sky creates the "partiture of the sky". Pythagoras was probably "reading" this partiture as he gazed upon the constellations of the sky and "listened" to the "Harmony of the spheres" through the ears of his soul.

1. Preamble

From the ancient times until today, mankind has always tried to discover and express the nature and form of various phenomena through the available scientific knowledge, based on the platonic philosophical and scientific view of "saving the phenomena".

Scientific knowledge was transferred among the initiated followers of Pythagoreanism through symbolism, as was the case with each nation's clergy. For this reason, the fundamental principles of musical science remained a secret and were inextricably linked to points, symbols, numbers and constellations, in order to protect truths and ideals, which, otherwise, would have been distorted over time. Revealing the principles of any science to non-initiated individuals was prohibited "under penalty of death", as "not everything was to be told to everyone".

However, there were Greek philosophers, tragedians and poets who "philoso-

phized on myths" secretly offering some mystical teachings masterfully cloaked in a philosophical allegoric manner, namely a codified message addressed solely to initiated individuals.

Among such initiators in astronomic matters were Eudoxus of Cnidus (407-335BC), Aratus of Soli (305-240BC) and Eratosthenes of Cyrene (276-194BC), who focused on constellations, namely the bright stars of each area of the sky, which are not really close to one another, but when connected via imaginary lines form some kind of animal or human or object on an imaginary plane.

Every ancient nation gave various names to constellations. In ancient Greece, Eudoxus of Cnidus, a student of the Pythagorean Archytas of Tarentum, was the person who gave names to the constellations that could be seen in the Greek sky. These names are included in the extant poem of Aratus "Phaenomena and Diosemeia". Later, Eratosthenes described the constellations in his work "Catasterismi", mentioning the number of their stars. It should be noted that these astronomers included the whole Pythagorean theory of ancient Greek music in this representation of the constellations, declaring that "everything was created by God based on the laws of harmony" (Plutarch, *On Music*, 1147, A, 12).

For example, even though 80-85 stars are visible to the naked eye in the constellation of Gemini, Eratosthenes, based on the Pythagorean Harmonics, chose only 19 of them (9 for Castor and 10 for Pollux), as these are the numbers that create the Pythagorean musical interval of a minor chromatic tone (10/9).

2. The timbre of the tone from the rotation of the eighth sphere of the celestial spheres (of fixed stars)

Through this paper, we attempt to track ways of thinking, philosophies, theories and procedures in order to bring to light mystical dogmas, which were skillfully concealed by the initiators Eudoxus, Aratus and Eratosthenes, who invoked the king of gods and mortals, the celestial law, the one that classifies the stars in constellations (64th *Orphic Hymn*, lines 1-2).

The number of stars of each constellation is indeed not random. On the contrary, it is associated with the Arithmosophia (numeric wisdom) of the Pythagoreans.

The 44 constellations of the studied catasterism are classified in 23 categories based on the number of their stars, according to Eratosthenes.

Humans, as rational beings, always wondered about the order of things in the Universe, thinking that the perfect movement of celestial bodies was equivalent to the concepts of order and harmony. Therefore, they attempted to describe this universal order eloquently through a strictly organized "ratio", which was gradually developed, namely the "ratio" of Music.

Music as the Science and Art of the Appropriate, namely of the organization and association of sounds, is considered to have contributed significantly to the birth of science per se.

The architects of the Universe who attempted to systematize the concept of the interval since the ancient times were both Musicians and Astronomers at the same time.

Pythagoras and his followers, for example, tried to explain the position and movement of the planets in the sky based on a theory that combined cosmic harmony with musical harmony (theory of the Harmony of the Spheres).

Alexander mentions some useful Pythagorean opinions on numbers, music and the sky on a comment of his regarding Aristoteles.

"they claimed that every being is comprised of numbers. But they also noticed that harmonics were made up of numbers and they called those numbers the basis of harmonics, because the octave (diapason) had a double ratio, the perfect fifth (diapente) had a sesquialterate ratio and the perfect fourth (diatessaron) had a sesquitertiate ratio.

They also claimed that the whole sky was structured in harmony, as its structure was based on numbers, numerical relationships and harmony" (*Metaphysics*, 39, 18-24)

"numbers are the most probable basis of this harmony and they were considered the starting point for the sky, as well as for everything else" (*Ibidem*, 40, 1-3).

"the numerical elements and their principles were considered principles of the beings...

Number one was considered the first number...

They proved that the sky was structured by numbers based on harmony" (Ibidem, 40, 14-24)

"and that the whole sky is synonymous with harmony and numbers" (*Commentary on Aristotle's Metaphysics*, 986 a, 3).

Accepting the aforementioned Pythagorean dogmas, we thought that we should deal with the numbers of the stars of the 23 categories of Eratosthenes based on the Pythagorean Theoretical and Applied Music, in the light of modern Musical Acoustics. Therefore, we considered that these numbers represent the harmonics of the composite sound produced by the rotation of the eighth sphere of the Pythagorean theory of the Harmony of the Spheres, namely of the sphere of fixed objects, which takes part in the sky movement. We agreed that this composite sound has a fundamental frequency or first harmonic that is determined by a hypothetical constellation of one star, based on which the musical intervals of all the other 23 harmonics will be calculated. Thus, the 23 categories of Eratosthenes become 24, as the constellation of reference was added to them.

We do not consider the aforementioned 24 categories a random fact, as Alexander also mentions the following regarding the number 24:

"because the world is equal to 24 elements, since there are 12 zodiacs, eight celestial spheres and four Platonic elements" (*Ibidem*, 835, 16-18).

We checked the above mentioned twenty-four numbers on the basis of Aratus's remark (*On the zodiac*, 531, 13-15), namely that all of them can be expressed through the five divine musical ratios [the double, triple, quadruple, sesquialterate (3/2) and sesquitertiate (4/3) one, and we found out that that is true indeed.

Maybe Eratosthenes had also included in his mystical codification through the constellations' stars this fundamental Pythagorean piece of information on concordance provided by Aratus, who had also documented the same constellations.

3. Intervallic structure of the harmonic series of the sound of the eight sphere (of fixed stars) of the Pythagorean theory of the "Harmony of the Spheres"

Harmonics play a significant role in Acoustics and especially in the construction of instruments, as the participation of each harmonic in sounding contributes to the formulation of the tone quality (timbre).

The utter lack of harmonics in a sound, such as the sound of the tuning fork, makes this sound simple, poor or even boring. On the contrary, the presence of harmonics makes the sound interesting and special. Actually, each harmonic plays a specific role within the timbre. Some harmonics can make a sound bright, rich, full and deep with a hoarse and nasal tone quality, while others can make it sharp, rough and hard due to beats (cross-relations), making it sound "metallic", as if produced by a cymbal. It should be noted that both modern scholars who study timbre and the ancient Greek Acoustics philosophers, e.g. Pythagoras, Heraclitus, etc., used Optics to determine concepts of Acoustics and vice versa.

As it is possible to create a harmonic series on the basis of any fundamental note, in our case, we will regard the C1 note as the fundamental note, according to the European equal temperament (C note of the first octave of the audible spectrum with a frequency of 32.7 Hz), in order to simplify our calculations as we match each harmonic of the series to a particular note of the European musical scale.

The fundamental or first harmonic determines the musical height of the sound. In most cases, this is the strongest harmonic, because it has the greatest width of them all and, consequently, the greatest energy and intensity.

The second harmonic creates the interval of an octave with the fundamental harmonic $\frac{f_2}{f_1} = 2 = 1 \cdot 2 = \left(\frac{1}{1}\right) \cdot \left(\frac{2}{1}\right)$ and, consequently, represents the same note, yet an octave higher. The second harmonic makes the sound clear and bright due to the fact that it enhances the fundamental one.

The third harmonic creates the interval of $\frac{f_3}{f_1} = 3 = \left(\frac{2}{1}\right) \cdot \left(\frac{3}{2}\right)$ with the fundamental one, namely an octave and a perfect fifth or a twelfth. It represents the G2 note, which is different from the one of the fundamental harmonic and for this reason, the third harmonic brings about some kind of change to the timbre. The interval of the twelfth, reduced into an octave, gives the euphonic interval of a perfect fifth. According to Helmholtz's theory, a euphonic interval has no beats. For this reason, the third harmonic makes the sound bright, rich, full and deep with a hoarse and nasal tone quality, such as the one of the sound of a clarinet.

The fourth harmonic creates the interval of $\frac{f_4}{f_1} = 4 = \left(\frac{2}{1}\right)^2$ with the fundamental one, namely a double octave, and represents the same note with the fundamental harmonic, yet two octaves higher (C3). As the fourth harmonic represents the

same note with the fundamental one, it makes the sound clearer and brighter without altering the timbre.

From the fourth category onwards, the harmonics begin to make the sound somewhat sharp, as they increasingly generate different notes.

The fifth harmonic creates the interval of $\frac{f_5}{f_1} = 5 = \left(\frac{5}{4}\right) \cdot \left(\frac{4}{1}\right) = \left(\frac{2}{1}\right)^2 \cdot \left(\frac{5}{4}\right)$ with the fundamental one, namely a double octave plus one "epitetarton", and represents the E3 note, which is located two octaves and a major chromatic third higher than the fundamental tone. Being a different note from the one of the fundamental tone, E3 differentiates the tone quality. When the fifth harmonic sounds together with the fundamental and the third one, a triple major chord (C-E-G) occurs, which is euphonic and brightens the timbre.

The sixth harmonic creates the interval of $\frac{f_6}{f_1} = 6 = 2 \cdot 3 = \left(\frac{2}{1}\right) \cdot \left(\frac{3}{2} \cdot \frac{2}{1}\right) = \left(\frac{2}{1}\right)^2 \cdot \left(\frac{3}{2}\right)$ with the fundamental one, namely a double octave and a perfect fifth, and it represents the G3 note, which is located two octaves and a perfect fifth higher than the fundamental tone. The sixth harmonic enhances the homonymous note of the third harmonic and makes the timbre sharp and nasal.

The seventh harmonic creates the interval of $\frac{f_7}{f_1} = 7 = 6 \cdot \left(\frac{7}{6}\right) = \left[\left(\frac{2}{1}\right)^2 \cdot \left(\frac{3}{2}\right)\right] \cdot \left(\frac{7}{6}\right)$ with the fundamental one, namely a double octave plus a perfect fifth plus an enharmonic minor third and represents the slightly diminished B3@ note. This note, being foreign in relation to the previous ones (discordant), blurs the sound of the musical note.

The musical interval of an enharmonic minor third $\left(\frac{7}{6}\right)$ is theoretically generated by dividing the superparticular interval of the perfect fifth $\left(\frac{3}{2}\right)$ in three approximately equal musical intervals, based on the process of Archytas. It should be noted that Eudoxus of Cnidus, being a student of Archytas, was familiar with the process of dividing superparticular musical intervals in approximately equal musical intervals.

The eighth harmonic creates the interval of with the fundamental one, namely a triple octave, and it represents the C4 note, which is located three octaves higher than the fundamental tone. As the eighth harmonic represents the same note with the fundamental one, it makes the sound clearer and brighter without altering the timbre.

The ninth harmonic creates the interval of $\frac{f_8}{f_1} = 8 = 2^3 = \left(\frac{2}{1}\right)^3$ with the fundamental

one, namely a double octave plus a double perfect fifth, and it represents the D4 note, which is located two octaves and two perfect fifths higher than the fundamental tone. The ninth harmonic makes the sound nasal.

The tenth harmonic creates the interval of

$$\frac{f_{10}}{f_1} = 10 = 2 \cdot 5 = \left(\frac{2}{1}\right) \cdot \left[\left(\frac{2}{1}\right)^2 \cdot \left(\frac{5}{4}\right)\right] = \left(\frac{2}{1}\right)^3 \cdot \left(\frac{5}{4}\right)$$

with the fundamental one, namely a triple octave plus an "epitetartos", and it approximately represents the E4 note, which is located three octaves and a major chromatic third higher than the fundamental tone. The tenth harmonic enhances the note provided by the fifth harmonic and makes the timbre sweeter and brighter by strengthening the triple major chord (C-E-G).

The eleventh harmonic creates the interval of

$$\frac{f_{11}}{f_1} = 11 = 10 \cdot \frac{1}{10} = \left[\left(\frac{2}{1}\right)^3 \cdot \left(\frac{5}{4}\right)\right] \cdot \left(\frac{1}{10}\right)$$

with the fundamental one, namely a triple octave, plus an "epitetartos" plus an "epidekatos". It represents the significantly diminished discordant F4$ note, which is located three octaves, a major chromatic third and a minor tone higher than the fundamental tone.

The musical interval of an "epidekatos" $\left(\frac{1}{10}\right)$ is theoretically generated by dividing the superparticular interval of the perfect fourth $\left(\frac{4}{3}\right)$ in three approximately equal musical intervals, based on the process of Archytas.

The twelfth harmonic creates the interval of with the fundamental one, namely a triple octave and a perfect fifth. It represents the G4 note, which is located three octaves and a perfect fifth higher than the fundamental tone. The twelfth harmonic enhances the homonymous notes of the third and the sixth ones and makes the timbre sharp and nasal.

Ladies and gentlemen, I will omit the detailed matching of the rest of the harmonics to a melodic or discordant note, given the limited time at my disposal and I will conclude by matching the 48th harmonic, which is the last one.

The forty eighth harmonic creates the interval of

$$\frac{f_{48}}{f_1} = 2 \cdot 2 \cdot 12 = 2 \cdot 2 \cdot 2 \cdot 6 = \left(\frac{2}{1}\right)^3 \cdot \left[\left(\frac{2}{1}\right)^2 \cdot \left(\frac{3}{2}\right)\right] = \left(\frac{2}{1}\right)^5 \cdot \left(\frac{3}{2}\right)$$

with the fundamental one, namely five octaves and a perfect fifth. It represents the G6 note, which is located five octaves and a perfect fifth higher than the fundamental tone. The forty eighth harmonic enhances the homonymous notes of the third and sixth ones and makes the timbre sharp and nasal.

It is possible to identify some frequencies (a few or more) that are non-harmonic within the spectrum of a natural musical sound. Said frequencies are not integer multiples of the frequency of the fundamental tone. The existence of non-harmonic

frequencies within the spectrum tends to destroy the feeling of the musical height, creating a sound of undetermined musical height, as is exactly the case with the sounds produced by percussion instruments.

The previous analysis shows that every frequency of the harmonic series expresses a sinusoidal sound which creates either a euphonic or a dissonant musical interval in relation to the fundamental frequency. Thus, the notes of the scale of the European equal temperament were matched to the constellations in an absolutely objective and univocal manner. The results of the previous analysis are shown in Table 1.

Table 1: The notes corresponding to the harmonics of the composite sound of the 8th sphere (sphere of fixed objects) with C1 as note of reference.

Number of stars or harmonics category	Corresponding note with C1 as note of reference	Constellations
2	C2	Serpens
3	G2	Deltoton (today called Triangulum), Canis Minor
4	C3	Aquila, Sagitta, Ara
7	slightly diminished B3@ note	Ursa Minor (without Polaris), Pleiades, Lepus, Coma (or Coma Berenices), Corvus
8	C4	Ursa Minor, Auriga, Lyra
9	D4	Delphinus, Corona Borealis, the one of Gemini
10	E4	Crater, Lupus, the one of Gemini
12	G4	Piscis Austrinus, the one fish of Pisces and the 'linos' of Pisces
13	significantly augmented discordant A4@ note	Cetus, Eridanus
14	slightly diminished B4@ note	Bootes, Cygnus
15	~B4@	Cassiopeia, Drago, Sagittarius (without Corona Australis), the one fish of Pisces
17	C5$	Aquarius, Ophiuchus, Aries, Orion
18	D5	Pegasus, Cancer, Taurus (without Pleiades)
19	D5$	Cepheus, Heracles, Leo, Scorpius, Perseus, Gemini
20	~ E5	Virgo, Canis Major (Sirius), Andromeda
22	significantly diminished discordant F5$ note	Sagittarius and Corona Australis*

Number of stars or harmonics category	Corresponding note with C1 as note of reference	Constellations
24	G5	Ursa Major, Capricornus, Centauri (or 'Chiron')
27	~A5	Argo, Hydra, (both fishes of Pisces)
31	B5 augmented by approximately half a semitone	'Hydria' (it means 'jug')
34	C6$	Centauri and Lupus*
39	D6 augmented by approximately three quarters of a semitone	Pisces
44	significantly diminished discordant F6$ note	Hydra and Crater and Corvus*
48	G6	Aquarius and 'Hydria'*

** referred to as a single constellation*

4. Comments - Conclusion

The notes of Table 1 create the ambitus C2-G6, namely four octaves (C2-C6) and a perfect fifth interval (C6-G6). This ambitus is only lacking a single tone from the one mentioned by Plato in the *Creation of the World Soul* (*Timaeus*, 35a1-36b6).

The notes of Table 1, reduced into an octave and approximating notes that are either natural or altered by a sine, provide the notes C, C$, D, D$, E, F, G, A, B@ in ascending order.

The notes C, D, E, F, G, A, B@ sound like tuning a seven-string lyre via two attached ascending Lydian tetrachords, proving Heraclitus Ponticus right (*Homeric Problems*, 12). [All of them sound together with the notes of a seven-string lyre].

A tetractys (=tetrad) of notes creating the "cycle of the fifths" can be identified in this ambitus, which means that the respective numbers of their stars are integer multiples of the divine musical ratio (3/2), according to Aratus (*Διάφορα περί ζωδιακού - On the zodiac*, 531, 13-15). This proves that the catasterism has a specific internal structure and philosophy.

All of the notes of Table 1, which are the result of the previous Pythagorean musical analysis and correspond to the number of stars of the 44 constellations, scattered throughout the night sky create the "partiture of the sky" with their light. Pythagoras was probably "studying" this partiture, as he gazed upon the constellations of the sky and mentally "listened" to melodies, combing notes of the harmonics of the sound of the eight sphere (the sphere of fixed objects), according to the Pythagorean theory of the "Harmony of the Spheres".

B4.10 The Minoan Eclipse Calculator and the Minoan Cosmology Model

M. Tsikritsis
Directorate of Secondary Education, Heraklion, Crete

E. Theodossiou
University of Athens

1. Abstract

Seeking for Minoan findings of astronomical significance in the Archaeological Museum of Heraklion, Crete, we found a stone plate discovered in 1899 near Palaikastro, Crete. The first publication on this plate, including figures, was done by Xanthoudides in the difficult-to-find the journal *Archeologiki Ephemeris* (Xanthoudides, 1900). After 35 years, the British archaeologist Sir Arthur John Evans (1851-1941) suggested that the embossing symbols appearing on the surface of the stone plate associated with Sun and Moon (1935).

In this paper, the two left-sided embossing figures of the stone plate are analyzed, correlated and studied. Furthermore, for coherency purposes, the operation of the Minoan Eclipse calculator is briefly presented, as currently accepted by the scientific community.

2. Introduction

A note by Sir Arthur Evans in his book [**1**, p. 514] led us to search the three figures on Palaikastro plate. According to Evans, these engravings were representations of Sun and Moon. However, it must be noted that in this book the illustrator did not draw an accurate representation of the stone plate, which prevented researchers, unaware of the original, from deducing its proper function (Fig. 1a).

The images of the plate (Fig. 1A) were first published by Xanthoudides [**2**, p. 51-52] in *Archeologiki Ephemeris* (Archaeological Gazette) in 1900. In fact, as mentioned in the present, the findings consisted of two tiles discovered in a field 150 meters northwest of village Palaikastro of Sitia, Crete, dated to the 15th century BC.

The problem in dating the stone plates is that they were not discovered during an excavation, so they can't be dated from pottery and stratigraphy. In the Ph.D. dissertation of Alexiou [**3**, pg. 213], a dating of the dies is attempted by relating the figure of the deity appearing at the centre with other idols of the late Mycenaean period III (c. 14th-12th cent. BC).

M. Nilsson [**4**, p. 282] relates the form of Goddess holding lengths and appears in the middle plate (Figure 1) with the sealing ring of Mycenae (16th cent. BC). Overall, the

issue of dating is open. To our opinion the most likely date is the one of M. Nilsson or around middle 15th cent. BC.

Our team acquired high-definition photographs of the finding, provided by the Heraklion Archaeological Museum by special permission, which could be studied at a magnification of about 5×. By examining the magnified photographs of the plate (Fig. 1A), our team noticed that there were various depressions, notches and dots in number ratios that indicated a relationship to astronomical phenomena.

This stone plate is a stone die which carries four main embossing figures. Today it has been accepted to use two the right hand figures as a mould to produce copies to be imprinted on a soft solid (e.g., malleable metal or even soft wood). By this way the eclipse calculator, 6 pins and a pair of compasses can be produced. This type of eclipse calculator was an early mechanism for the determination of eclipses during the Minoan era (c. 15th cent. BC). Furthermore, it could work as a sun-dial and as a latitude calculation instrument [5].

In the following, the operation of the mechanism for calculating eclipses is briefly described and then the engraved motifs found on the left side of this stone die are analyzed, studied and correlated with other findings aa well as with mythological references.

Fig. 1 *(a) The stone plate from Palaikastro, (b) Imprint of the stone plate produced by the Archaeological*

Museum of Herakleion (A.M.H.).

3. The Minoan Eclipse Calculator

For the description of the "radiant disk" as a mechanism determining eclipses, its image as shown in the stone plate will be used. Fig. 2 shows the magnified photograph of radiant disk of Palaikastro die.

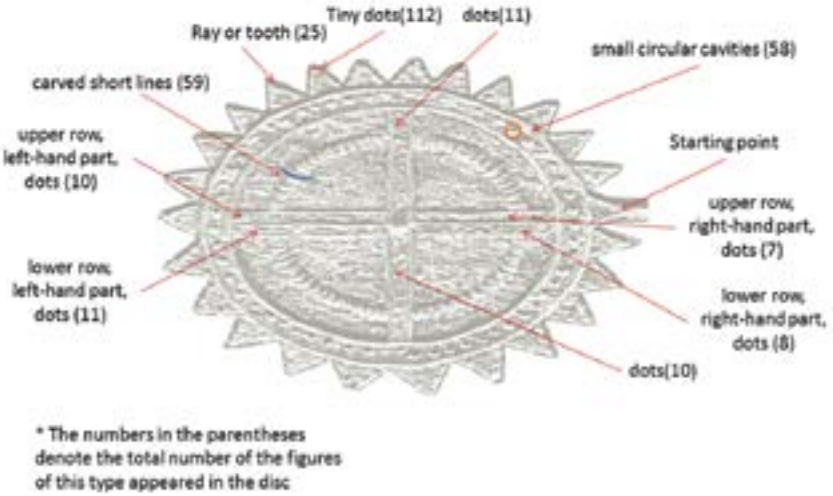


Figure 2: *A magnified image of the radiant disc with annotations of its features*

In the disc's circumference 25 triangular "rays" or "teeth" (Δ) appear. Each one of the 20 of them has 5 tiny dots (o) , while other 4 "rays" have three dots each and one ray has no dots at all, just one dash (-),denoting probably some starting point. The total number of these dots is 112.

Inside the disc two circles are engraved, an outer one containing 58 small circular cavities (**O**), and an inner one, which is a single depression containing 59 engraved short lines and is interrupted at four places by a cross. The two lines of the cross (diameters of the circle) bear dots in rows: The vertical line 11 dots in its upper part and 10 dots in its lower part. The horizontal line bears two rows of dots, the upper row of its left-hand part having 10 dots and of its right-hand part having 7. The lower row has 11 dots in its left-hand part and 8 dots in its right-hand part (11 + 8 = 19). The horizontal diameter of the cross divides the disc into two semicircles, each having 28 dots.

As already stated, if metallic imprints of this die are produced, then, in addition to the disc, there will be two pins, 6 cm long, and a flexible tweezer shaped object. Assuming that the disc and its engravings served the purpose stated, these objects, corresponding to horizontal forms to the right of the ray-bearing disc on the die (Fig. 1A) can be understood as tools for its proper functioning. The two pins could be cut into three parts each, yielding six pins. Six pins are required for the proposed operation of the device.

In what follows, the functions of the sun-dial and of the eclipse calculator of the "radiant" disc will be presented.

Operation as a sun-dial

If the 25 triangular "teeth" are enumerated per half-hour intervals and a pin is placed normal to the central cavity, then the pin's solar shadow indicates the point of disc's circumference corresponding to the time of observation when the central cross is aligned in the North-South direction. In this way, this simple device could be used as a portable sundial of 12.5 hours. Its "hour" corresponds to approximately 58 minutes, very close to current hour. The triangles ("rays" or "teeth") are not of equal size. This could probably be related to the fact that, in antiquity, hours were of un-equal length of time (It seems that the afternoon hours are shorter than the morning ones.)

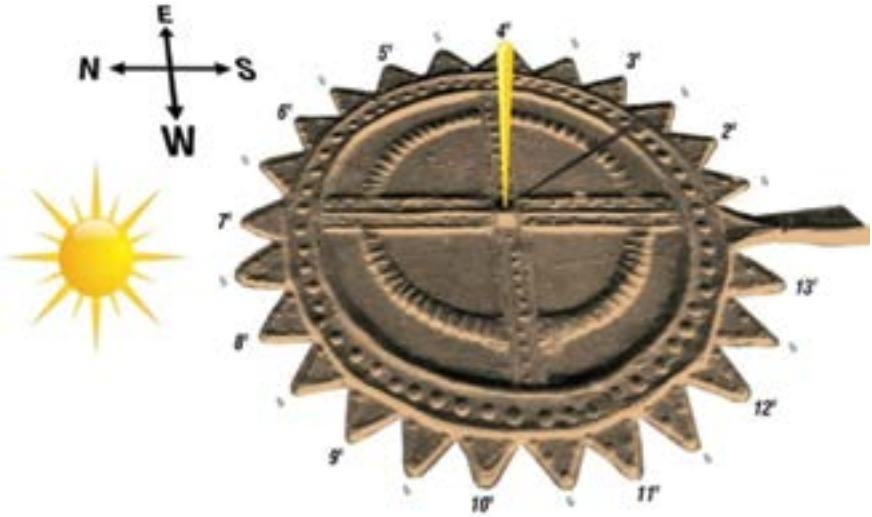


Fig. 3 Representation of the operation of the "radiant" disc as a sundial

Operation as a solar and lunar eclipse calculator

To use the die as eclipse calculator, six pins are required, corresponding to the following positions:

- **One** for the position of the Sun, moving counter-clockwise on the outer circumference with the 58 dots (small cavities on the imprint), approximately one position per 6 or 7 days. These dots are numbered in yellow in Fig. 5.
- **One** for the position of the Moon, revolving on the inner circumference with the 59 short engraved lines. These lines are within the green dashed circle in Fig. 5:
- **Two** for the nodes of the lunar orbit — the two points where the orbit of the Moon around Earth intersects the ecliptic (the plane of the Earth's orbit around the Sun), on the triangles or "rays" of the "radiant" disc. These are the 112 dots that run along

the edges of the triangles in Fig. 5. These nodes (Fig. 4) are the two points where the plane of the orbit of the Moon around the Earth intersects the ecliptic (the average plane of the Earth's orbit around the Sun). These two planes are inclined with respect to each other by 5° 8′ (5.145°).The lunar nodes shift in space, so that they complete a whole circle once every 18.61 lunar years, or 18.61 × 12 lunar months. This shift is tracked by moving the pins of the nodes clockwise by 6 dots every 12 lunar months, always keeping them in diametrically opposite positions, and

- **Two** on the dots of the cross in order to follow the number of the passing lunar months and years. The months are on the horizontal arm, and the 18 dots for the years are on the vertical arm in Fig. 5. When the Moon completes a full lunar month, a pin on the dots of the cross shifts by one position along the horizontal row of the cross, having 11 dots (left hand part of the horizontal line of the cross). When it reaches the 12th dot, a lunar year of 354 days has been completed. This fact is denoted by means of another pin, placed on the first one of the 18 dots of the lower right part of the horizontal diameter of the cross. This part of the horizontal diameter along with the lower right part of the vertical diameter corresponds to the saros[1] cycle. In this way the current lunar year is recorded.

In Fig. 4 Positions of the ray-bearing disc, used to monitor the movements of the celestial bodies in relation to the motions of the sun, moon and nodes are shown.

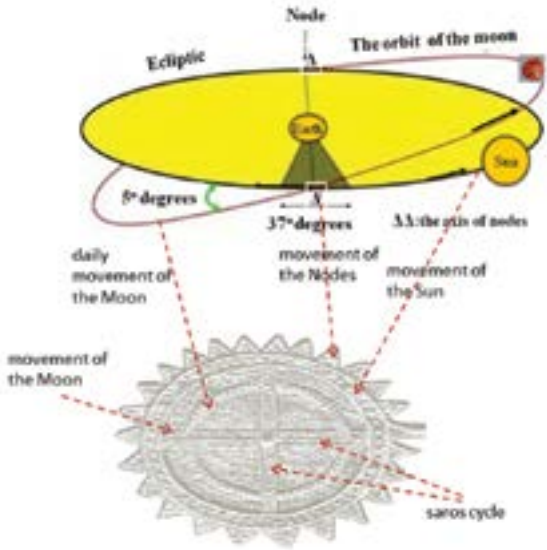


Fig. 4: Representation of the movements of the celestial bodies

1. Saros (=star) is a period of 6585.3 days (approximately 18 years and 11.3 days) by the end of which Sun, Earth and Moon return to the same relative positions and distances, and the cycle of solar and lunar eclipses is repeated. Each Saros is a period of 223 lunar months, during which 70 eclipses take place, out of which circa 42 are solar and 28 lunar. Solar eclipses are not always visible at the same places on earth, while lunar eclipses are visible from all places at night. On the basis of Saros phenom-enon, i.e. the repetition of lunar eclipses about every 18 years, ancient peoples could predict what was going to happen. In a certain year up to three eclipses may occur, while in other years none may happen [6, p. 60].

The device should be initialized after a lunar eclipse (preferably a full one) at a known date, through the following steps:

- A pin is placed on the inner circle with the 59 dots, on one of the positions of the full moon marked at the end/start of the lower semicircle (because in the lower semicircle there are 30 short engraved lines), the positions ◖ immediately under the horizontal diameter.
- Two pins are placed at the points of the nodes (denoted with Δ in Fig. 5), on the dots of the two diametrically opposite "rays"–triangles, where the extrapolation of the line of the horizontal diameter intersects the triangles. These dots are inside the 25 triangles.
- Another pin is placed on the initial position of the Sun ("58" in Fig. 5). The outer circle, which appears in the disc's circumference next to the triangles, is the circle that corresponds to the motion of the Sun.5.

Each day corresponds to the advancement of the Moon's pin by one short line, clockwise, along one of the two semicircles of the inner circle (Lunar Cycle).

Once every 7 or 6 days (Fig. 6), counted by the motion of the pin of the Moon, the Sun's pin moves one place counter clockwise in the circumference with the 58 dots (Solar Cycle). In other words, the number of days after which the Sun's pin moves by 1 place is the result of the motion of the Moon's pin according to the sequence 7, 6, 6, 7, 6, 6, 7, 6, 6, 7...

When the Moon's pin reaches position 29 of the inner semicircle, in the next step it jumps to position "1" of the other semi-circle, which represents the full moon (◖). Then it moves to the next engraved line, etc. When it reaches the thirtieth line (position "30" of the semicircle), i.e. at the next full moon, it is transferred to the position "1" of the next semicircle, and so on.

When the Moon completes a full lunar month (*Lunar Cycle*), a pin on the dots of the cross shifts by one position along the horizontal row of the cross, which has 11 dots (left hand part of the horizontal line of the cross).

When the Moon's pin completes two lunar months, Fig. 8, the pins of the nodes are shifted clockwise by 1 dot keeping them in diametrically opposite positions (*Nodical cycle*).

A total or a partial lunar eclipse occurs when the moon is full and at the same time the Sun is near one of the lunar nodes. When the Sun is very close to the point of the node, a total lunar eclipse occurs, while when it is just close to the node, the eclipse is partial.

If the Moon is at the new moon phase, then a total, partial or annular solar eclipse occurs, when the Sun is very close to the point of the node, a total lunar eclipse occurs, while when it is just close to the node, the eclipse is partial.

Figs. 5 to 10, present a practical example of the mechanism with real dates.

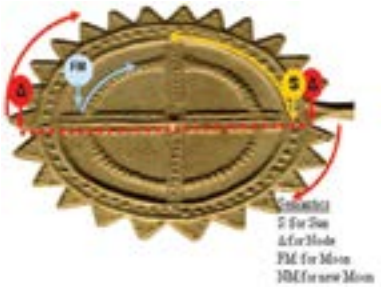


Fig. 5 The initial conditions when calcula-tion starts from the December 21, 2010, eclipse; we see the positions on the next day.

Fig. 6 The positions 7 days later. Moon has moved by 7 positions, while Sun has moved by 1 position to the oppo-site direction (counterclockwise).

Fig. 7: Positions 15 days after full moon of initializa-tion. Now the moon is new and the Sun has moved by two positions in the opposite direction. A partial solar eclipse appears (January 4, 2011)

Fig. 8: The positions of Moon, Sun and the nodes two lunar months later, on February 23, 2011 (2nd month).

Fig. 9: Positions of Moon, Sun and the nodes four lunar months later, April 24, 2011 (4th month).

Fig. 10: Positions of Moon, Sun and the nodes six lunar months later, June 15, 2011, predict the lunar eclipse of that date (6th month)

4. The Minoan Cosmological Model

Xanthoudides in [2] reports on the stone plate of Fig. 1, that "*the first left-hand Figure is in a bell-shaped base with horizontal stripes, on the top, there is a disc, inside the disc there are two concentric circles with engraved dots. Between the two circles, close to the base is the crescent moon and at the center of the inner circle a cross appears*". Evans, describing this Figure, states that "*at the top a small Figure, probably worshiper is held by the disc*."

By examining the magnified photographs of the stone plate of Fig. 1, various engraved dots and symbols are observed, in number ratios indicating a relation to astronomical phenomena.

The first left-hand Figure

In the first left-hand shape of Fig. 11, 18 engraved dots in the form of cycle are observed around the engraved symbol of cross. As well known, the cross is a solar symbol [7, p. 103].

Nilsson [4, p. 421] states that: «*As a sequel to the discussion of the representations of the sun, we must refer to the discussion of the cross symbol, for there is a wide-spread opinion that the equal-limbed cross is another symbol of the sun. It was, for example, a favorite theory of the late Professor Montelius, and has been embraced by many other archaeologists*».

Alexiou, in his *Minoan Civilization* [7, p. 103] attests the relationship of the cross or swastika with solar symbol. Also other archaeologists [8, 9] have expressed the same opinion while studying Creto-Mycenean religion. They mentioned that the cross symbol appears in various shapes, e.g. star, tetragamma (swastika) and wheel - all symbol of the sun or of a solar deity, appearing also as a rosette.

In particular, Marinatos [9, p. 60] in his teaching notes states: "*The representation of the Sun by the wheel is a commonplace practice among northern people. Once the bezel of the wheel is removed, typically the rays remain. Usually these count to four, in the very old type of wheels, hence the interpretation of the cross as solar and stellar symbols*".

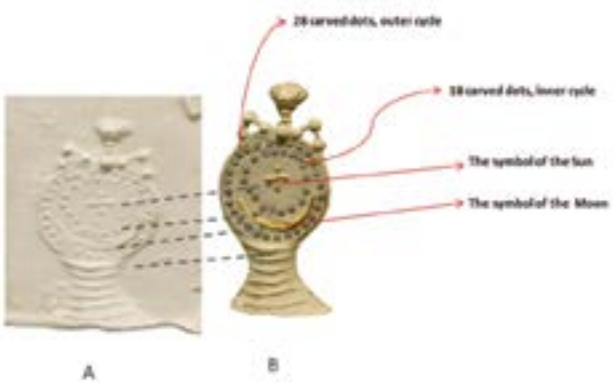


Fig. 11 A: the first left-hand Fig. is in a bell-shaped base with horizontal stripes, sizeς 3cm×6.2 cm, B: the same Fig. with proper corrections (contrast enhancement, sharpened resolution) to increase clarity.

In Figs. 11A and 11B, beneath the circle with 18 engraved dots and inside the outer circle with 28 engraved dots, one can distinguish the lunar symbol in the form of meniscus (or crescent moon), which is a widely accepted symbol for the Moon. This interpretation holds for the gold rings from Mycenae and Tiryns in *Corpus Mycaencensisi Scriptionis* (CMS) I, no. 17 and 179. Nilsson and Evans were the first to interpret these Figures as representing Sun and Moon (Nilsson, **4**, pp. 147, 347 and **1**, p. 453, Fig. 377].

The coexistence of symbols of Sun and Moon as well as the 18 and 28 engraved dots points to saros cycle. A period of 18 years and 11 months during which 28 lunar eclipse occur [6]. Suidas' Lexicon[2] (Byzantine lexicon of 11th century) says, "[*The saros is*] *a measure and a number among Chaldeans. For 120 saroi make 2222 years according to the Chaldeans' estimate, if indeed saros makes 222 lunar months, which are 18 years and 6 months*", Fig. 12. The earliest historical record discovered referring to saros is by the Chaldeans (ancient Babylonian astronomers) in the last several centuries BC [10, Tablets 1414, 1415, 1416, 1417, 1419], [6]. The entry for saros in Suidas' Lexicon is as follows (Fig. 12):

> *«...σάροι μέτρον καὶ ἀριθμός παρά Χαλδαίοις. οἱ γὰρ ρκ' σάροι ποιοῦσιν ἐνιαυτούς βσκ' κατά τὴν τῶν Χαλδαίων ψῆφον, εἴπερ ὁ σάρος ποιεῖ μήνας σεληνιακούς σκβ', εἰ γίνονται ιη' ἐνιαυτοί καὶ μῆνες ς'»).*

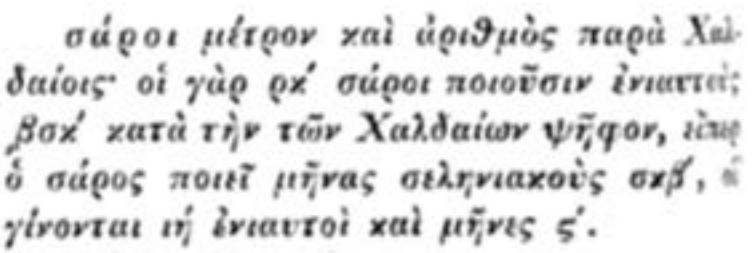

σάροι μέτρον καὶ ἀριθμὸς παρὰ Χαλ-
δαίοις· οἱ γὰρ ρκ' σάροι ποιοῦσιν ἐνιαυτοὺς
βσκ' κατὰ τὴν τῶν Χαλδαίων ψῆφον, εἴπερ
ὁ σάρος ποιεῖ μῆνας σεληνιακοὺς σκβ', εἰ
γίνονται ιη' ἐνιαυτοὶ καὶ μῆνες ς'.

Fig. 12: The entry for saros in Suidas' Lexicon

By considering:

(α) the statement of Nilsson [**4**, p. 420] «*What the meaning is, must remain uncertain; but because the sun and the moon are placed together here, as on the rings showing the firmament with the celestial bodies, it is probable that the representation refers rather to some cosmic beliefs or myths than to an actual cult of the sun*».

(β) the similarity of the representation of Sun in the engraved motifs at the top of the seal ring from Mycenae (Fig. 13),

2. https://books.google.gr/books?id=A5YCAAAAQAAJ&printsec=frontcover&hl=el&redir_esc=y#v=snippet&q=%CF%83%CE%AC%CF%81%CE%BF%CF%82&f=false

Fig. 13: *Gold seal, 15 c. BC, National Archaeological Museum (Id: K/EAM/A1/3861)*

Fig. 14 *The first left-hand engraved Figure with annotations shown, possible representations of the celestial bodies. Might this be a representation of the Minoan cosmological model?*

It could be argued that probably the upper part of the observed engraved Fig. represents the Sun, beneath it, the largest bullet represents the Moon, and the smaller bullets at the right and left of Moon represent the six known planets visible with naked eye. On both sides close to the Moon might be Mercury and Venus because they run the same course with the Moon during sunrise and sunset. Beneath these celestial bodies, the large circle, probably represents the Earth, since in the sky of the Earth the 28 lunar eclipses in 18 years can be noticed. It seems that the whole system of the large circle (Earth), and the celestial bodies is supported by a post with six horizontal notches. Does this Fig. represent the six days of creation of the world or the pillar supporting the created world?

Such an interpretation may reflect the geocentric cosmological conception of the Minoans and other eastern peoples, as expected. Perhaps, it could be stated that these representations express cosmic beliefs found to the representation of the sky goddess Nut of Egyptian mythology, who in her belly included the celestial bodies [10]. Nut belongs to the nine deities group associated with the cosmogonic myth of Heliopolis [**11, 12**]. Heliopolis is known with its Greek name and is one of the most ancient Egyptian cities. In Egyptian, was called Iunu or Onu meaning "Pillar City"[3]. Heliopolis was the seat of worship of the sun god, Re, also spelled Ra or Pra, in the ancient Egyptian religion. He was the god of the sun and god creator. He was believed to travel across the sky in his solar bark and, during the night, to make his passage to the underworld, in order to be reborn for the new day[4]. According to Egyptian mythology, Geb (God of Earth) and Nut (Goddess of Sky) form the mythical geosphere (Earth and Heaven). Nut is usually depicted as a woman with elongated and curved body, relying on earth only with ends of the toes and hands. The starry

3. https://www.britannica.com/place/Heliopolis-ancient-city-Egypt
4. https://www.britannica.com/topic/ancient-Egyptian-religion

belly of Nut forming the celestial vault is supported by Shu, like Atlas of the Greek mythology[5]. Also, sometimes, Nut was depicted as a cow, whose big body formed the sky and heavens and carries god Ra on her back. [10, **11, 12**].

Finally, due to the small size of the engraved Fig., only 62 mm, possibly it was used for religious purposes. It might be associated with the concept of the cosmic order of the periodicity and recurrence of eclipses every 18 years, an event where the basic deified celestial bodies of sun and moon participated.

The second left-hand Fig.

In the second engraved Figure from the left of the stone die from Palaikastro a feminine divine Fig. appears in devotional attitude in Y form holding in each hand two poppy flowers. The deity on the head bears the symbol known from Linear B of value re [**15**]. It might point to Titan goddess Rhea.

The nature of the latter is one of the most complicated subjects in ancient mythology. Some consider Rhea to point to another form of era, the earth, while others connect it with rheô (ῥέω, i.e. flow, Plato, Cratyl. p. 401, &c.); The Thracians identify her with the Thracian goddess Bendis or Cotys (Hecate), which in turn is identified with Demeter (Strab. x. p. 470). In Phrygia, Rhea was identified with Cybele[6], who is said to have cured Dionysus of his madness.[26][7], thus their cults shared several characteristics (Apollod. iii. 5. § 1). Moreover, Demeter, daughter of Rhea, is sometimes mentioned with all of her attributes (Eurip. Helen, 1304.) Worship of Cretan Rhea was associated with that of the Phrygian mother of gods [17].

Diodorus (v. 66) saw the site where her temple had once stood, near Knossos and he stated that Crete was undoubtedly the earliest seat of Rhea worship. According to Hesiodic Theogony (133; comp. Apollod. i. 1. § 3), Rhea was daughter of Uranus and Ge (=Gaea), and sister of Oceanus, Coeus, Hyperion, Crius, Iapetus, Theia, Themis, and Mnemosyne.

Greeks sometimes assimilate goddess Nut with their own Titan goddess Rhea [13], [15]. Plutarch, in *De Iside et Osiride* (351: Stephanus p. 373 s B,9), mentions Rhea as the mother of Osiris and Isis. [Greek text of Plutarch: "῾Ρέας ὄντων ἐξ ᾿Ισιδος καὶ ᾿Οσίριδος λεγομένη γένεσις"]

Pernier and Milani were the first to identify the deity depicted with raised hands, holding either an axe or flowers, to the Goddess Rhea and chronologically place this form in the MM II period [17].

Finally, in the image of Fig. 15, one can note the symbol Ψ (= re, at the head of the deity with raised hands). Also the outline of the figure of the deity points to the shape Ψ.

5. https://en.wikipedia.org/wiki/Atlas_(mythology)
6. https://www.britannica.com/topic/Rhea-Greek-goddess
7. https://en.wikipedia.org/wiki/Cybele

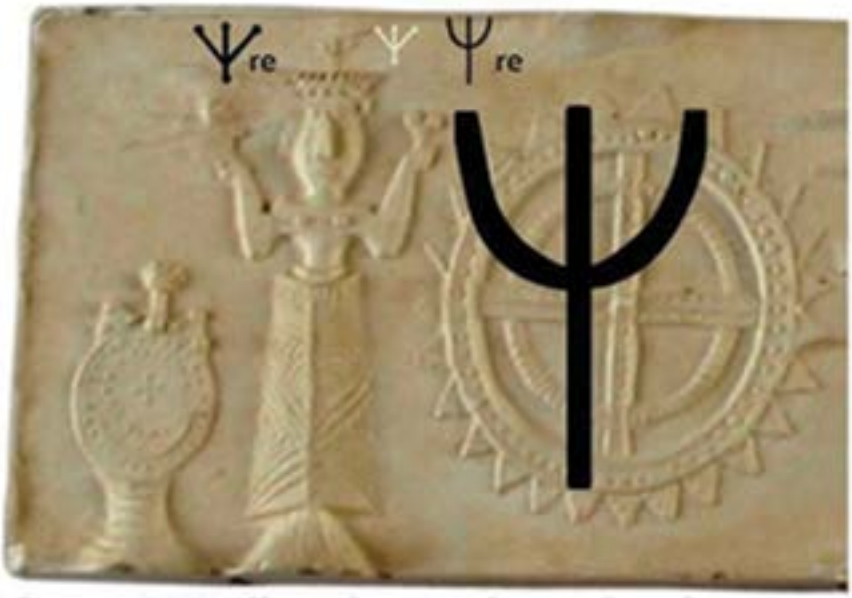


Fig. 15. Photograph of the stone plate taken by A.M.H. with annotations shown the various expressions of symbol Re found in the Figure of deity

5. Conclusions

In this paper, it was pointed out that all of the engraved Figs on the stone plate of Palaikastro, may share the same concepts about cosmic beliefs. The two left-hand relief representations, because of their small size, may have been used for religious purposes, while the third one is a mechanism predicting the motions of Sun and Moon, the deified celestial bodies.

The first left-hand Figure might be associated with the concept of the cosmic order denoted by the periodicity and recurrence of eclipses every 18 years, a fact to which sun and moon participated. It seems that it is related to similar cosmic concepts found in the representation of Egyptian goddess Nut. This interpretation agrees with the second engraved Figure of the stone plate.

The second left-hand Figure is associated with the Titan goddess Rea, known also as "the mother of gods" and is strongly related to Gaia and Cybele and Nut, performing similar functions. Also, the appearance of symbol having value re at the top of this Figure, provide strong evidence that the name of this goddess might be associated with Rhea's.

As a final conclusion one may state that the stone plate of Plaikastro is a further evidence that Crete was the earliest seat of Rhea worship, as suggested by Diodorus.

6. References

1. Evans, Sir A. J. *The palace of Minos at Knossos*, vol. IV, London: Macmillan & Co., 1935
2. Xanthoudides, S., Ancient dies from Sitia, Crete. Archeologiki Ephemeris, period III. Published by the Archaeological Society of Athens, Athens, pp. 51-52 (1900) [in Greek]. http://www.archive.org/stream/ephemerisarchai01900arch#page/n33/mode/2up
3. Alexiou, S. The Minoan Goddess with raised hands. Cretan Chronicles (Kritika Chronika), vol. XII (IB), (1958)178-299, esp. [in Greek].
4. Nilsson M., The Minoan-Mycenaean Religion and its Survival in Greek Religion, Second Revised Edition. Lund, 1950
5. Tsikritsis M., Theodossiou E. , Manimanis V.N., Mantaraki P., Tsikritsis D., 2013 "A Minoan Eclipse Calculator", Mediterranean Archaeology and Archaeometry, Vol. 13, No 1, pp.267-277, Athens, 2013
6. Theodosiou S., Danezis M., "The Odyssey of Calendars", Diavlos, Athens, 1996 [in Greek]
7. Alexiou, S., "Minoan Civilization", Published by Stylianou Alexiou & Sons, Heraklion, Crete, 1969. [in Greek]
8. Vassilakis A., Minoan Crete, Published by Sfakianakis, Heraklion 1991 [in Greek]
9. Marinatos S., Cretan-Mycenean Religion, University Notes, Athens, 1948 [in Greek]
10. Pinches, J. N. Strassmaier, "*Late Babylonian Astronomical and Related Texts*". A. J. Sachs (ed.), Brown University Press, 1955
11. Casson L. et al. 1969, "Ancient Egypt", Time-Life International (Nederland) N.V.
12. Joshua J. Mark. "The Egyptian Pantheon," Ancient History Encyclopaedia. Last modified April 14, 2016. http://www.ancient.eu /article/885/.
13. Ancient Egyptian Religion. 2016. Encyclopaedia Britannica Online. Retrieved 04 July 2016, from https://www.britannica.com/topic/ancient-Egyptian-religion/The-Gods
14. Pinch Geraldine, "Egyptian Mythology, A guide to the Gods, Godesses and Traditions of Ancient Egypt", Oxford University Press, 2002
15. M. Ventris - J. Chadwick, "Evidence for Greek Dialect in the Mycenaean Archives", Journal of Hellenic Studies 73, 1953: 84-111
16. Νουτ, https://el.wikipedia.org/wiki/%CE%9D%CE%BF%CF%85%CF%84 [accessed 4/7/2016]
17. Roller Lynn E., "*In Search of God the Mother: The Cult of Anatolian Cybele*", University of California Press, Ltd., Berkley and Los Angeles, California, 1999

B4.11 Travelling From Canada to Carthage in 86 AD

Dr. Minas Tsikritsis
Researcher of Aegean Script, Adjunct Scientist, Department of Astrophysics, Astronomy and Mechanics, Faculty of Physics, School of Science, National and Kapodistrian University of Athens, Greece and Acting director, Educational Center for New Technologies, Secondary Education Department Heraklion, Crete, Ministry of Education

1. Abstract

In the text by Plutarch "On the Apparent Face in the Orb of the Moon," in paragraphs 941A-942F, it comes out that a servant of the temple of Cronus travelled from the great continent beyond Brittany in Carthage. Previous investigators [5],[13] have mentioned this event trying to identify the route without having been able to identify the time.

In this presentation it is analysed and commented the text of Plutarch, it is confirmed and established the route and the time of this journey by the use of computers and by association with some extraordinary finds and place names.

2. Introduction

Reliable sources of knowledge are considered the perception, introspection, memory, reason, and testimony according to [11]. Thomas Reid suggested that, by our very nature, we accept testimonial sources as reliable and tend to attribute credibility to them unless we count special contrary reasons. In this work, a testimony found in Ploutrach and archaeological finds are evaluated for revealing a forgotten historical reality about prehistoric Greeks especially Minoans' expeditions to the present day land of Canada. Plutarch[1] was a prolific writer [8]. He seems to have been an independent thinker rather than an adherent of any particular school of philosophy. The catalogue of Lamprias, an ancient library catalogue, supposedly compiled by Plutarch's son Lamprias, lists 227

1. Plutarch born on 46ce at Chaeronea, Boeotia and died after 119ce. He was a biographer and author whose works strongly influenced the evolution of the essay, the biography, and historical writing in Europe from the 16th to the 19th century. He was the son of Aristobulus, himself a biographer and philosopher. In 66–67 Plutarch studied mathematics and philosophy at Athens under the philosopher Ammonius. Public duties later took him several times to Rome, where he lectured on philosophy, made many friends, and perhaps enjoyed the acquaintance of the emperors Trajan and Hadrian. Plutarch travelled and visiting central Greece, Sparta, Corinth, Patrae (Patras), Sardis, and Alexandria, but he made his normal residence at Chaeronea, where he held the chief magistracy and other municipal posts and directed a school with a wide curriculum in which philosophy, especially ethics, occupied the central place. He maintained close links with the Academy at Athens (he possessed Athenian citizenship) and with Delphi, where, from about 95, he held a priesthood for life; he may have won Trajan's interest and support for the then-renewed vogue of the Oracle

works, several of them no longer extant. Plutarch's works divide into philosophical and historical-biographical. Also he paid special attention to “physics”, which in antiquity included metaphysics, natural philosophy, psychology and theology. Plutarch shows quite some interest in the explanation of natural phenomena in several surviving works, most importantly in: *On the Face Which Appears in the Orb of the Moon* (*De facie quae in orbe lunae apparet*). In this dialogue, Lambrias asks Sylla the Carthagean to narrate once more a story that he had heard from the servants of the temple of Cronus in Carthage. The story was originally told by a foreigner who was visiting the temple and came from the great continent and the description of this journey is appeared on the paragraphs 941A-942 of the “On the Face Which Appears in the Orb of the Moon”. In this narration Plutarch describes accurate sailing directions on how to reach the American Continent from Britain. The directions given in this text are so precise that someone may wonder, how Plutarch, a lifelong resident of a region of warm climate actually made precise reference to this large area of frozen ocean? An obvious answer might be that this information is provided to him by seamen who had actually sailed those waters. The current study takes into account the conclusions and discussions from previous works [5], [13], trace the route suggested in those by using Google Earth, examined the celestial phenomena by using the Stellarium software [10] and provides additional evidence including place names and finds. In Figure 1 the English translation of this text, provided by [7], is presented.

Figure 1 The English translation of paragraphs 941-942 of Plutarch

3. A journey in 86 AD from Canada to Carthage

In [5],[13] the authors are presented and analysed the physical and oceanographic characteristics found in the writings of (a) Homer's Iliad and Odyssey, (b) Hesiod's Theogony and Works and Days, (c) Orphics' Argonautica and (d) Plutarch's Moralia collection ("The Face which appears in the orb of the Moon") (e) The American Practical Navigator published by U.S. Navy Hydrographic Office (1938,pg 298) and came to the conclusion that the prehistoric Greeks, already as far back as the times of Titan Cronus, up until the times of Hercules and Odysseus, should had known plenty of the present day Atlantic Ocean and its islands, as well as the lands located beyond the Pillars of Hercules.

Figure 2: A google earth image showing the ancient routes which are mentioned to [11], [5]

The outcomes of this reasearch are:

1. The journey described in [7], [14], **Figure 1**, determines correctly the distance from Britain to the island of Ogygia which is identified with the present day island of Iceland [5], [13] This distance can be covered by a boat that sails with oars for 5 days since it is a distance about 880 km as it is shown in **Figure 2**.

2. It is mentioned[7], [14] a great continental land in the area of which there were three islands. These are identified with the present day islands of Greenland, Baffin Island, Newfoundland since they are in the same distance on the northwest of Britain. In Figure 2 they are marked with the white lines these distances. Also Mariolakos in [5] came to the same conclusion by using detailed paper maps.

3. In [7],[14] it is stated correctly that the land which is identified in [5],[13] with the present day of the Gulf of Saint Lawrence is a little bigger than Lake Maeotis

–present day Sea of Azov (Figure 3) and both of them are in the same latitude. This is a fact which it may be even noticed in Google Earth (latitude of Golf of Saint Laurence is 470 N and latitude of Caspian sea is 46,5 0 N.); the long straight line in **Figure 2.**

Figure 3: *St. Lawrence Gulf vs Maeotis Lake*

4. It is mentioned in [7], [14] that this land - the Gulf Coast was inhabited by Greeks since the very old times and after the expedition of the Mycenaean Hercules, possibly during the 14th century BC, the Greek element was revitalized after it reached a near-extinct point due to the constant miscegenation with the locals. It is obvious that Hercules was not accompanied only by Iolaus, but it was rather an expedition of hundreds of Greeks that changed demographically the area of the Gulf of Saint Lawrence, which they inhabited. Also in [13] it is mentioned that in the language of Micmac Indians of Nova Scotia there are a large number of Greek-root words.
5. It is described in [5], [11] a period of 30 years after which the journey back(from the present day land of Canada to Carthagene) started; when planet Cronus appears in Taurus constellation before the sunrise. By the use of Stellarium software, it is confirmed that in the north latitude 470, in the 1st century AD, that period coincided with the end of May 86 AD. This is shown in **Figure 4**

Figure 4: planet Cronus appears in Taurus constellation before the sunrise in the 1st century AD (screen dump from Stellarium s/w)

6. It is referred [7], [14] that when the journey home began, they stayed for three months in the island, where the sun sets only for one hour during the summer solstice. This island is identified by with the present day island of Greenland in [5],[13] on the north (600 N) since in this island, in that period the sun set for one hour during the summer solstice. By making simulation with Stellarium software, it is determined that this period should be the days between June 10 and July 10. This definition confirms that the island of Greenland must be identified with the underworld, where Cronus had been buried in a cave and was being kept there by Zeus as it is stated in [7], [14].

Figure 5: Oak island, source: google maps

7. The reason for these long journeys during the Bronze Age is documented by the pure copper (99%), which was found in large quantities in the region around Lake Superior and the island Royale, both located in Canada, according to the University of Wisconsin-Milwaukee, Dept. of Anthropology and Museum Studies [3], [6],[7], [9] about 50,000 tons of copper were mined from this area between 2400 BC and 1200 BC.[2]
8. As Plutarch states the sailors did not carry copper but golden cups and urns, inside which they kept the provisions for the journey. This is in accordance with the latest discoveries in Oak Island. Researchers, led by Jovan Hutton Pulitzer, claim they have evidence that Roman ships visited North America 'during the first century or earlier[3]. Oak Island is a 57-hectare island in Lunenburg County on the south shore of Nova Scotia. Gold Carthage coins have also been discovered on the mainland near this island.
9. It is known and widely accepted that in the ancient times the Oracles were centers where they kept chronicles of geographical knowledge, and as a result they gave advices about the future colonization. Therefore, it is acceptable that since Plutarch was a priest in the Oracle of Delphi after 86 AD, he had this knowledge.

It seems that the journey home was made from the north; starting from Canada they went to Greenland (island of Cronus), then they reached Iceland and finally Britain. A confirmation of this route is the station-island which still bears the name Mykines the most west island of the Faroes. As it may be observed in Thesaurus of Geographic Names of Getty turned his men into swine after feeding them according to the Greek

2. https://en.wikipedia.org/wiki/Copper_mining_in_Michigan
3. http://www.dailymail.co.uk/sciencetech/article-3364818/Did-ROMANS-discover-America-Sword-Oak-Island-suggests-ancient-mariners-set-foot-New-World-Columbus-according-radical-theory.html

mythology[4] only two places have been documented as "Mykines: in Faroe and in Peloponnese, in Greece. In the greater area of this island there are until now place name such as Kirkja and Svínoy[5] [6] . The Svínoy island is located in the north-east of the Faroe Islands[7] **Figure 6**. Its name origin is from Old Norse, Svíney, meaning "Swine Isle". Homer refers that the witch-goddess Circe[8] [9] turned his men into swine after feeding them according to the Greek mythology[10]. In [2], it is presented the meaning according to etymology and suggested that Kirke was a witch-goddess that "tied down" her victims, and was created or conceived by divine, heavenly forces of both Light and Darkness.

The **Table 1**, presents the association of these present day names with names in Homer and their transliteration and transcription in Latin alphabet. It may be observed similarities between the present day place names and their transcription from Linear B.

Table 1:

In present day Danish	In Homer	Transliteration / transcription from Linear B	Translation in English	Translation in modern Greek
Mykines	Μυκήνη	My-ke-ne/ My-ke-ne	Mycenae	Μυκήνες, Μυκήναι
Kirkja	Κίρκης	Ki-ki-ja/ ki-rki –ja	of Kirki/ Kirke/Circe	Κίρκης
Svín	Σῦς	si-a2-ro / sihalon	Swine	χοίρος, γουρούνι

The references of the above place names along with the island of Ogygia are in accordance with the route of Odysseus. Ogygia is the island, mentioned in Homer's Odyssey, Book V[12], of the nymph Calypso, the daughter of the Titan Atlas, also known as Atlantis (Ατλαντίς[13]) in ancient Greek. In Homer's Odyssey, Calypso detained Odysseus on Ogygia for 7 years and kept him from returning to his home of Ithaca, wanting to marry him. According to paragraph 941 in [7], [14] Hercules was the first travelled there. Odysseus, the next generation of Hercules, might be also travelled following the routes of Hercules. A reason of Odysseus traveling there might be the copper with purity 99% since the Greeks had consumed all their resources in Trojan War.

4. https://en.wikipedia.org/wiki/Odyssey#Odysseus.27_account_of_his_adventures
5. http://www.getty.edu/vow/TGNFullDisplay?find=Sv%C3%ADnoy&place=&nation=&prev_page=1&english=Y&subjectid=1009308
6. https://en.wikipedia.org/wiki/Sv%C3%ADnoy
7. https://en.wikipedia.org/wiki/Faroe_Islands
8. https://en.wikipedia.org/wiki/Circe
9. HOM.OD.K213
10. https://en.wikipedia.org/wiki/Odyssey#Odysseus.27_account_of_his_adventures
11. Transliteration is the letter-mapping from Linear B into Latin Alphabet, transcription is the sound-mapping from Linear B into Latin Alphabet
12. HOM.OD.A13
13. See entry Ατλαντίς inLiddell & Scott. See also Hesiod, *Theogony*, 938.

Figure 6: *Faroe islands with marked present day place names which are also referred to Homer's Odyssey*

4. Additional evidence

The following archaeological finds are extraordinary which have issues pertaining to the authenticity which may be questioned, as these came to light not through the process of a formal archaeological excavation. For the sake of completeness of this study, short descriptions of these items and summaries of corresponding studies are included in this work.

The Newberry Tablet

In November 1896, in the northwest area of Newberry in Michigan, two woodsmen found a tablet [4] (**Figure 7**[14]), 26 cm high and 19 cm wide, divided by 10 vertical and 14 horizontal lines into 140 quadrangles, each containing one symbol. Three small statuettes were found next to the tablet. Here some statistics are presented which are among the conclusions in ESOP.

The tablet contains 137 symbols of which only the 39 of them are different. 23

14. The tablet was held at the Smithsonian for some time, and then went to a local museum where it sadly disintegrated over time. This photo was taken in 1896

15. It will be appeared in ESOP (Epigraphic Society Occasional Papers) volume 30, Epigraphic Society, MA, USA

symbols out of 39(59%) are similar to Cypriot-Minoan, 7 symbols out of 39(21%) are similar to Linear A and B ideograms. In the study that it will be appear on ESOP[15] it is suggested that the inscription was created between the12th and the 8th century BC and it was influenced by the Cypriot-Minoan script. However, a percentage of 20-30% of its symbols has to be of local creation. We should also note that the horizontal and vertical lines of the Newberry Stone is a characteristic not found in other script artifacts of the Cypriot-Minoan writing system. Regarding the authenticity of the tablet, it should noted that when it was found -in 1896- the symbols of the Cypriot-Minoan script had not been found yet. The cylinder seals that were found in 1875 were bearing 5 and 4 symbols respectively. Even if we do not take into account the fact that they were not published before 1957, there are only two of these symbols on the inscription

of the Newberry Stone.

Figure 7: Newberry Tablet. Source Smithsonian *Figure 8: Henrietta's Mertz transcription*

The Cleveland Pendant

The pendant [1] in **Figure 9** is a Unicom discovered in 2006 by Mr. D. Byers by using a metal detector in a football field in Cleveland, Ohio, close to the Great Lakes, in a depth of 40 cm. The area of the discovery does not allow the verification of the authenticity of the pendant, as it was privately found in an area where large quantities of fill soil had been brought in from the neighboring region. The pendant, is delta-shaped (Δ) bearing the following characteristics: Weight: 40 gr, Depth: 0.33 cm, Height: 4.7 cm, Maximum Width: 3.8 cm (1.9 cm. at the top). The argumentation about this finding is described in [15] In Figures 9, 9a,10, 11,12, it might be observed similarities with Minoan representations and particularly with the "Prince of Lilies" while in the back side of the pendant (**Figure 10**) it is appeared a Double Axe in a representation whose center probably indicate a pubic triangle incised especially a vulva.

Figure 9: *The front side of the Minoan Pendant (Cleveland, Ohio, Ref.1, Courtesy D.Byers)*

Figure 10: *The back side of the Minoan Pendant (Cleveland, Ohio, Ref.1, Courtesy D.Byers)*

Figure 11: *"Prince of lilies"or "Priest-king Relief" Knossos*

Figure 9a: *Detail of figure 9*

Figure 12: *Detail of figure 12*

The symbol in **Figure 9a** is possibly related to the Constellation of Scorpio or acts as a symbol of death. Metaphorically, it may also be connected to the Minoan snake symbol. The symbol of Scorpion is found in many Minoan signets for 1, 2 or 3 representations per signet, as can be seen in Figure 12, 13 and 14.

Figure 13: *Siegel CMS IS 150*

Figure 14: *CMS-II1-250b-*

Figure 15: *Siegel CMS II,1 248b*

The Double Axe or Labrys is depicted in many finds and is considered to be a sacred Minoan symbol of fertility. The naming Labrys is connected to the word labyrinth (house of the **labryos**) according to Hesychius (L.33, 2) Labyrinth – spiral-shaped location (Κοχλιοειδής τόπος).

Figure 16: *Siegelabdruck CMS II,5 234*

Figure 17: *Palace Style pithos, with double axes, Knossos*

Figure 18: *Museum Heraklion*

Figure 19: *Zakros 1500 B.C*

Figure 20: *Siegelabdruck CMS II,5*

Figure 21: *double axes Arkalochori – Herklion- Crete*

Figure 22

The find represents a new concept that connects the young prince with lilies to bring in his left hand the symbol of death the scorpion, while the other side displays a double ax having vulva shape.

In the Minoan civilization sacrificed bull fertilizes the cave of mother earth. In America where, according to Plutarch Kronia worship (human sacrifice) was taken place, the young prince, instead of Minoan bull, having different facial features of the Minoans possibly is sacrificed to fertilize mother earth which is symbolized by the vulva shape ax. Possibly, this interpretation is associated with that region, as a metaphor of a Minoan religious worship.

Finally, about authenticity, it is considered that perhaps the find were influenced by local origins of Minoan civilization because of (a) the vulva shape of figure 10 and (b) the association with the interpretation [12] of the double ax of Arkalochori since a present day forger does not know.

5. Conclusions

In short the outcomes of this study are in accordance with the outcomes of [5] [13]. Additional evidence are provided about

- The date that the journey home started. This date is May 86AD
- Place names found in Faroe Islands such as Mykines, Kirkja and 'Swine Isle' (Svinoy) somehow might be related with those referred to Homer's Odyssey since these places are detected in the route of North Britain - Faroe – Iceland –

Greenland – Nova Scotia – Gulf Saint Laurence. They might be places- stations for provisions during the journey.

Figure 23: *the route: North Britain - Faroe – Iceland – Greenland – Nova Scotia – Gulf Saint Laurence. Source google maps*

If it is established the authenticity of the Newberry tablet, the Pendant from Cleveland and the Greek route words of Micmac Language of the natives of Nova Scotia it can be argued that there are strong evidence that prehistoric Greeks- Minoans had visited and may had established colonies in that places, in the route from Britain to Gulf of St Laurence. In fact it is the same route has been traveled through history and is still being traveled today [13].

Further study and research is needed in the history and mythology of local societies of all these places as well as comparative studies of local dialects with prehistoric Greek script Linear B. Also further investigation should be made in the texts of Homer in Odyssey and in Greek mythology as well as in the legends of natives Americans.

Taken into account the outcomes of this study it may be said that the testimony in Plutarch[7],[14] *saying that during the ancient times before Hercules' expedition, the area in the Gulf of St. Laurence had been visited by ancient Greeks, ie probably the Minoans* should be reliable. It seems that even before Columbus, the Chinese and the Vikings, the Greeks had been to America at least during the 1st century AD and possibly had already been there as far back as the 2nd millennium BC.

6. References

[1] Byers, D., & Joseph, F., "A Minoan Pendant found in Ohio", Ancient American, Vol 13, #83, July, 2009, p.6.

[2] George-Kokkinaki M., 2008, Literary anthroponymy: Decoding the characters of Homer's Odyssey, ANTROCOM: Online Journal of Anthropolgy, Vol 4 - n. 2 145-157, 2008

[3] Griffin, James B. 1961 "Lake Superior copper and the Indians: miscellaneous studies of Great Lakes prehistory", .Anthropological Papers 17. Museum of Anthropology, University of Michigan.

[4] Joseph, F., May W., "Minoans in America", Ancient American,volume 7, Issue Number 43, December 2002 pg.34

[5] Mariolakos I.D., 2010, "THE FORGOTTEN GEOGRAPHIC AND PHYSICAL – OCEANOGRAPHIC KNOWLEDGE OF THE PREHISTORIC GREEKS", Bulletin of the Geological Society of Greece, 2010, Proceedings of the 12th International Congress Patras, May, 2010

[6] Martin, Susan R., 1999, Wonderful Power: The Story of Ancient Copper Working in the Lake Superior Basin. Wayne State University Press.

[7] Plutarch, "The Face which appears in the orb of the Moon" , Translation and Notes with appendix, By A.O. PRICARD M.A., WINCHESTER : WARREN AND SON, LTD., PRINTERS AND PUBLISHERS, LONDON : SIMPKIN AND CO., LTD., STATIONERS' HALL COURT. (accessible through: https://archive.org/details/plutarchonfacewh00plut , last accessed May 2016)

[8] Plutarch, Stanford Encyclopedia of Philosophy, accessible through http://plato.stanford.edu/entries/plutarch/, (last accessed by 1/6/2016)

[9] Ritzenthaler, Robert E. and Warren Wittry, 1957, The Oconto Site - an Old Copper Manifestation, The Wisconsin Archeologist 38(4):222-243.

[10] Stellarium, free open source computer program for planetarium accessible through http://stellarium.org/ (last accessed by 1/6/2016)

[11] Steup, Matthias, 2014 "Epistemology", The Stanford Encyclopedia of Philosophy (Spring 2014 Edition), Edward N. Zalta (ed.), URL = http://plato.stanford.edu/archives/spr2014/entries/epistemology/

[12] Tsikritsis Minas, 2006, Phaistos Disk – A Guide to its Decoding, p. 40-45 &133-135, Heraklion 2006.

[13] Wall,A., "An Ancient Greek Historian's Sailing Directions to America", Ancient American, Vol 6, Issue Number 37, February 2001,p.20.

[14] Πλούταρχος 1996, Πλούταρχος: Περί του Εμφαινομένου Προσώπου τω Κύκλω της Σελήνης, «ΟΙ ΕΛΛΗΝΕΣ», Αθήνα, Εκδόσεις ΚΑΚΤΟΣ, 1996

[15] Tsikritsis 2016 (in Greek), "Is Cleveland's Medalion Authentic?", ΙΧΩΡ, 151, 40-48, 2916, Evandros Publ.

B4.12 The Minoan Eclipse Calculator and the Minoan Cosmology Model

M. Tsikritsis[1], E. Theodossiou[2],
[1] *Directorate of Secondary Education, Department of Informatics and New Technologies, Heraklion, Crete*
[2] *Department of Astrophysics, Astronomy and Mechanics, Faculty of Physics, National & Kapodistrian University of Athens*

1. Abstract

Seeking for Minoan finds bearing features of astronomical significance in the Archaeological Museum of Heraklion, Crete, we found a stone plate discovered near Palaikastro in Crete, Greece, in 1899. The first publication of this plate, including figures, was done by the archaeologist Stephanos Xanthoudides in the difficult-to-find journal Archeologiki Ephemeris (Xanthoudides, 1900). After 35 years, the British archaeologist Sir Arthur John Evans (1851-1941) suggested that the embossing symbols that appear on the surface of the stone plate associated with the Sun and the Moon (1935).

In this paper, the two left sided embossing figures of the stone plate are analysed, correlated and studied. Furthermore, for coherency purposes, the operation of Minoan Eclipse calculator is briefly presented, as it is accepted by the scientific community

2. Introduction

An observation by the British archaeologist Sir Arthur Evans in his book [1, pg. 514] led us to research the three figures he includes in the book of the Palaikastro plate. According to Evans, these carvings were representations of the Moon and the Sun. However, it must be noted that in this book the illustrator did not draw an accurate representation of the stone plate, which prevented researchers from deducing its proper function (Fig. 1a) since they have not seen the authentic one.

The images of the plate (Figure **1A**) were first published by archaeologist Stephen Xanthoudides [**2**, pg.51-52] in the Journal Archaeology Newspaper of 1900. In fact, as it is stated in the this publication, the finds were two tiles discovered in a field 150 meters northwest of the village Palekastro of Sitia in Crete, which they have been dated to the 15th century BC.

The problem in dating the stone plates is that they were not discovered during an excavation, so they can't be dated from pottery and stratigraphy. In the Ph.D. dissertation of the archaeologist Stylianos Alexiou [**3**, pg. 213], a dating of the dies is attempted by relating the figure of the deity that appears at the centre with other idols of the late Mycenaean period III (14th– 12^{th}centuries BC).

The Martin Nilsson in [4, pg.282] relates the form of Goddess holding lengths and appears in the middle plate (Figure 1) with the sealing ring of Mycenae (16th c. P. X) where there appear or same image. Overall, the issue of dating is open in our opinion the most likely date is that of M. Nilsson or intermediate of the 15th century B.C.

Our team acquired high-definition photographs of the finding, provided by the Heraklion Archaeological Museum after issuing a permission to study, which could be studied at a magnification of about 5×. By examining the magnified photographs of the plate (**Figure 1A**), our team observed that there were various depressions, notches and dots in number ratios that indicated a relationship to astronomical phenomena.

This stone plate is a stone die which carries four main embossing figures. Today it has been accepted by the scientific community the use of two the right hand figures as a mould for producing copies in order to imprint this copy on a soft solid (e.g., malleable metal or even soft wood). By this way the eclipse calculator, 6 pins and a pair of compasses may be produced. This type of eclipse calculator was an early mechanism for the determination of eclipses during the Minoan era (c. 15th century BC). Besides it could be functioned as a sundial, and as latitude calculation instrument [5].

In the following chapters, it is described briefly the operation of the mechanism for calculating eclipses and then the carved motifs found the left side of this stone die are analyzed, studied and correlated with other finds and mythology.

Figure 1: A: The stone plate from Palaikastro, B: Imprint of the stone plate produced by Archaeological Museum of Heraklio(A.M.H.), (No. of permission to publish: A.M.H. L 116/ 192/ 7-2-2011).

3. The Minoan Eclipse Calculator

For the description of "ray bearing disk" as a mechanism for determining eclipses the image of it as it shown in the stone plate will be used. **Figure 2** shows the magnified photograph of ray bearing disk of Palaikastro die.

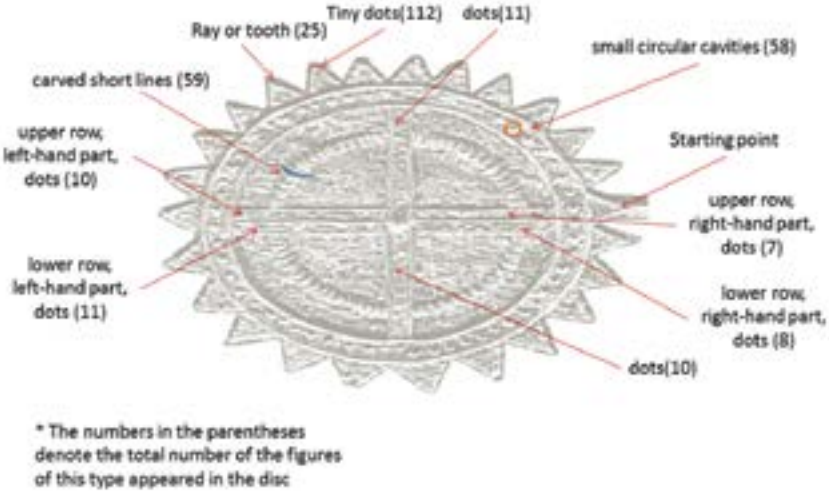


Figure 2 : A magnified image of the ray bearing disc with annotations of its characteristics

In the disc's circumference appear 25 triangular "rays" or "teeth" (Δ). Each one of the 20 of them has 5 tiny dots (o) , while other 4 "rays" have three dots each and one ray has no dots at all, just one dash (-),denoting probably some starting point. The total number of these dots is 112.

Inside the disc there are carved two circles, the outer one, which contains 58 small circular cavities (**O**), and the inner circle, which is a single depression that contains 59 carved short lines and is interrupted in four places by a cross. The two lines of the cross (diameters of the circle) bear dots in rows as follows: The vertical line bears 11 dots in its upper part and 10 dots in its lower part. The horizontal line bears two rows of dots, the upper row of its left-hand part having 10 dots and of its right-hand part having 7. The lower row has 11 dots in its left-hand part and 8 dots in its right-hand part (11 + 8 = 19). The horizontal diameter of the cross divides the disc into two semicircles, each of which has 28 dots.

It have been already stated that, if metallic imprints of this die are produced, then, in addition to the disc, there will be two pins, each 6 cm long, and a flexible tweezers shaped object. Assuming that the disc and its carvings served the stated purpose, then these objects, which correspond to horizontal forms to the right of the ray-bearing disc on the die (**Figure 1A**) can be understood as tools for its proper functioning. The two pins could be cut into three parts each, yielding six pins. Six pins are required for the

proposed operation of the device.

In what follows, the functions of the sun-dial and of the eclipse calculator of the "ray-bearing" disc will be presented.

The function as a sun-dial

If the 25 triangular "teeth"are enumerated per 0.5-hour intervals and a pin is placed perpendicular to the central cavity, then the pin's solar shadow indicates the point of the disc's circumference that corresponds to the time of the observation when the central cross is aligned in the North-South direction. In this way, this simple device could be used as a portable sundial of 12.5 hours. Its "hour" corresponds to approximately 58 minutes, very close to the modern hour. The triangles ("rays" or "teeth") are not of equal size. This could probably be related to the fact that in antiquity the hours were of un-equal length (It seems that the afternoon hours are shorter than the morning ones.)

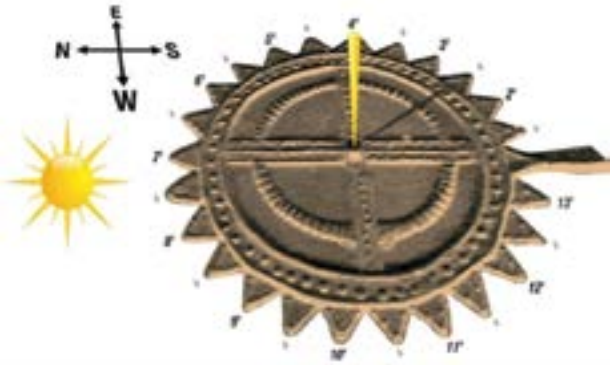


Figure 3 Representation of the function of the "ray-bearing" disc as a sundial

The function as a solar and lunar eclipse calculator

To use the die as an eclipse calculator, six pins are required, corresponding to the following positions:

· **One**: for the position of the Sun, which moves counter clockwise on the outer circumference with the 58 dots (small cavities on the imprint), one position per approximately 6 or 7 days. These dots are numbered in yellow in **Figure 5**.

· **One** for the position of the Moon, which revolves on the inner circumference with the 59 short carved lines. These lines are within the green dashed circle in **Figure 5**.

· **Two** for the nodes of the lunar orbit — the two points where the orbit of the Moon around the Earth intersects the ecliptic (the plane of the Earth's orbit around the Sun), on the triangles or "rays" of the "ray-bearing" disc. These are the 112 dots that run along the edges of the triangles in **Figure 5**. These nodes (**Figure 4**) are the two points where the plane of the orbit of the Moon around the Earth intersects the ecliptic (the average plane of the Earth's orbit around the Sun). These two planes are inclined with respect to each other by 5° 8′ (5.145 °).The lunar nodes shift in space, so that they complete a

whole circle once every 18.61 lunar years, or 18.61 × 12 lunar months. This shift is tracked by moving the pins of the nodes clockwise by 6 dots every 12 lunar months, always keeping them in diametrically opposite positions.

· and **two** on the dots of the cross in order to follow the number of the lunar months and years that pass. The months are on the horizontal arm, and the 18 dots for the years are on the vertical arm in **Figure 5**. When the Moon completes a full lunar month, a pin on the dots of the cross shifts by one position along the horizontal row of the cross, which has 11 dots (left hand part of the horizontal line of the cross). When it reaches the 12_{th} dot, a lunar year of 354 days has been completed. This event is denoted with the help of another pin, which is placed on the first one of the 18 dots of the lower right part of the horizontal diameter of the cross. This part of the horizontal diameter along with the lower right part of the vertical diameter corresponds to the saros[1] cycle. In this way the current lunar year is recorded.

In **Figure 4**, The positions of the ray bearing disc that are used to monitor the movements of the celestial bodies in relation to the motions of the sun, moon and nodes are shown.

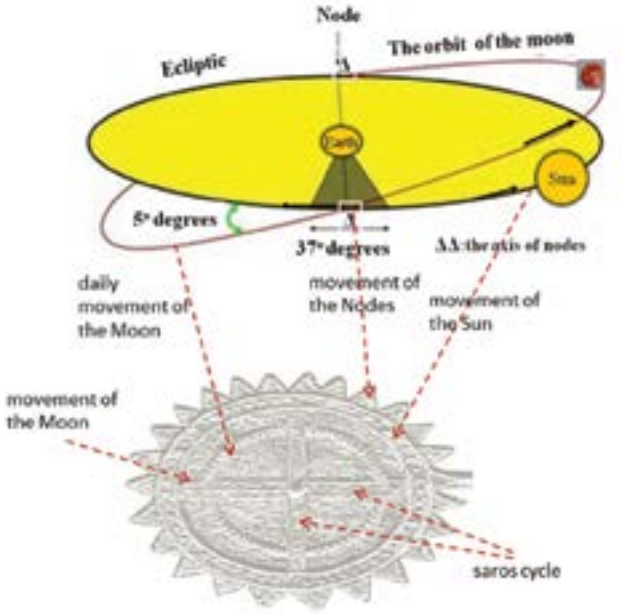


Figure 4: Representation of the movements of the celestial bodies

1. σάρος=αστρον (=star). It is a period of 6585.3 days (approximately 18 years and 11 days) during which the relationship of the Sun, Earth and Moon will return to the same configuration as the starting eclipse. Each Saros is a period of 223 lunar months, which occur 70 eclipses of which about 42 are solar and 28 lunar. Solar eclipses are not always visible in the same places of the earth, while the lunar are visible from all places during the night. Because of Saros phenomenon ie repeats the phenomenon of lunar eclipses about every 18 years, ancient peoples foretold what will happen. During one year may occur up to three eclipses and there are years that may not happen any.. [6,pg. 60].

The device should be initialized after a lunar eclipse (preferably a total one) at a certain known date, with the following steps:

- A pin is placed on the inner circle with the 59 dots, on one of the positions of the full moon marked at the end/start of the lower semicircle (because in the lower semicircle there are 30 short carved lines), the positions ◖ immediately under the horizontal diameter.
- Two pins are placed at the points of the nodes (denoted with Δ in **Figure 5**), on the dots of the two diametrically opposite "rays"–triangles, where the extrapolation of the line of the horizontal diameter intersects the triangles. These dots are inside the 25 triangles.
- Another pin is placed on the initial position of the Sun ("58" in Figure 5). The outer circle, which appears in the disc's circumference next to the triangles, is the circle that corresponds to the motion of the Sun.5.

Each day corresponds to the advancement of the Moon's pin by one short line, clockwise, along one of the two semicircles of the inner circle (**Lunar Cycle**).

Once every 7 or 6 days (**Figure 6**), counted by the motion of the pin of the Moon, the Sun's pin moves one place counter clockwise in the circumference with the 58 dots(**Solar Cycle**). In other words, the number of days after which the Sun's pin moves by 1 place is the result of the motion of the Moon's pin according to the sequence 7, 6, 6, 7, 6, 6, 7, 6, 6, 7...

When the Moon's pin reaches the position 29 of the inner semicircle, in the next step it jumps to the position "1" of the other semi-circle, which represents the full moon (◖). Then it moves to the next carved line, etc. When it reaches the thirtieth line (position "30" of the semicircle), i.e. at the next full moon, it is transferred to the position "1" of the next semicircle, and so on.

When the Moon completes a full lunar month (**Lunar Cycle**), a pin on the dots of the cross shifts by one position along the horizontal row of the cross, which has 11 dots (left hand part of the horizontal line of the cross).

When the Moon's pin complete two lunar months, **Figure 8**,the pins of the nodes are shifted clockwise by 1 dot keeping them in diametrically opposite positions (**Nodical cycle**).

A total or partial lunar eclipse occurs when the moon is full and at the same time the Sun is near one of the lunar nodes. When the Sun is very close to the point of the node, a total lunar eclipse occurs, while when it is just close to the node, the eclipse is partial.

If the Moon is at the new moon phase, then a total, partial or annular solar eclipse occurs when the Sun is very close to the point of the node, a total lunar eclipse occurs, while when it is just close to the node, the eclipse is partial.

The Figures 5 to 10, present a use example of the mechanism with real dates.

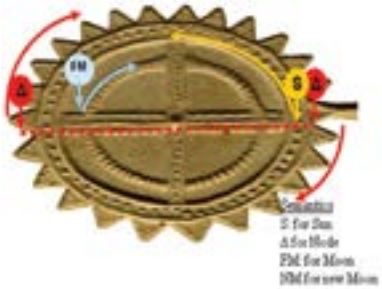


Figure 5 The initial conditions when the calculation starts from the December 21, 2010, eclipse; we see the positions on the next day

Figure 6 The positions 7 days later. The Moon has moved by 7 positions, while the Sun has moved by 1 position to the opposite direction (counterclockwise)..

Figure 7: The positions 15 days after the full moon of the initialization. Now the moon is new and the Sun has moved by two positions to the opposite direction. A partial solar eclipse is observed (January 4, 2011)

Figure 8: The positions of the Moon, the Sun and the nodes two lunar months later, on February 23, 2011(2nd month)

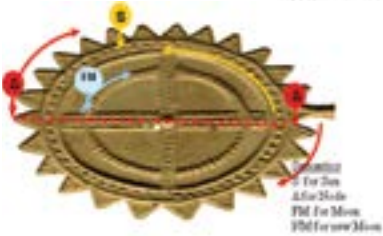


Figure 9 :The positions of the Moon, the Sun and the nodes four lunar months later, on April 24, 2011(4th month)

Figure 10 : The positions of the Moon, the Sun and the nodes six lunar months later, on June 15, 2011, predict the lunar eclipse of that date(6th month)

4. The Minoan Cosmoly Model

Stephanos Xanthoudides reports to [2] about the stone plate of **Figure 1**, that "*the first left-hand figure is in a bell-shaped base with horizontal stripes, on the top, there is a disc, inside the disc there are two concentric circles with carved dots. Between the two circles, close to the base is the crescent moon and in the center of the inner circle a cross appears "Evans, describing this figure, states that" at the top a small figure, probably worshiper is held by the disc.* "

By examining the magnified photographs of the stone plate of **Figure 1**, it is observed various carved dots and symbols in number ratios that indicated a relationship to astronomical phenomena.

The first left-hand figure

In the first left-hand shape of **Figure 11**, 18 carved dots in the form of cycle are observed around the carved symbol of cross. It is considered worldwide that the symbol of the cross represents the Sun. [7, pg. 103]

The professor of archaeology Martin Nilsson at [4, pg. 421] states that: «*As a sequel to the discussion of the representations of the sun we must refer to the discussion of the cross symbol, for there is a wide-spread opinion that the equal-limbed cross is another symbol of the sun. It was, for example, a favourite theory of the late Professor Montelius, and has been embraced by many other archaeologists.*».

The archaeologist Stylianos Alexiou, in his book Minoan Civilization [7, pg 103] attests the relationship of the cross or swastika with solar symbol. Also other archaeologists such as Anthony Vassilakis [8] and Spyridon Marinatos [9] have expressed the same opinion when they were studying cretomycenean religion. They mentioned that the symbol of the cross appearing in various shapes such as a star, a swastika and a wheel is the symbol of the sun / a celestial deity which appears also as a rosette.

In particular, the excavator in Santorini, Professor Spyridon Marinatos [9, page 60] states to his teaching notes: "*The representation of the Sun by the wheel is a commonplace concept among people from the north. Once be removed the bezel of the wheel, typically the rays remain. Usually these count to four, in the very old type of wheels, hence the interpretation of the cross as solar and stellar symbols*".

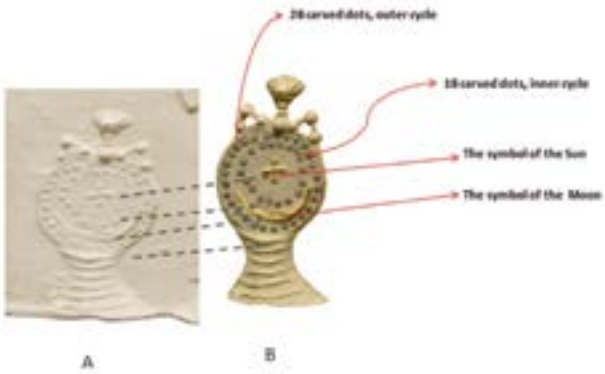


Figure 11 A: *the first left-hand figure is in a bell-shaped base with horizontal stripes, sizeς 3cm × 6,2cm, B: the same figure with suitable corrections (contrast enhancement, sharpen resolution) to increase visibility.*

In Figure **11A** and **11B**, beneath the circle with 18 carved dots and inside the outer circle with 28 carved dots , it is distinguished the lunar symbol in the form of meniscus (or crescent moon). It is widely accepted that symbol of meniscus represents the Moon. This interpretation holds for the gold rings from Mycenae and Tiryns in Corpus Mycencensisi Scriptionis (CMS) I, no. 17 and 179. M. Nilsson and Sir A. Evans are the first two who adopt the interpretation of these figures as representations of Sun and Moon. Nilsson [**4**, pp. 147, 347], [**1**, pg.453, fig. 377].

The coexistence of symbols of Sun and Moon as well as the 18 and 28 carved dots points to the saros cycle. A period of 18 years and 11 during which 28 lunar eclipse occur. [6].The Suidae Lexicon[2], a Byzantine lexicon of the 11th century, says, "[*The saros is*] *a measure and a number among Chaldeans. For 120 saroi make 2222 years according to the Chaldeans' reckoning, if indeed the saros makes 222 lunar months, which are 18 years and 6 months*". Figure 12. The earliest discovered historical record referred to saros is by the Chaldeans (ancient Babylonian astronomers) in the last several centuries BC.[10, Tablets 1414, 1415, 1416, 1417, 1419], [6]

σάροι μέτρον καὶ ἀριθμὸς παρὰ Χαλδαίοις· οἱ γὰρ ρκ' σάροι ποιοῦσιν ἐνιαυτοὺς βσκ' κατὰ τὴν τῶν Χαλδαίων ψῆφον, εἰπερ ὁ σάρος ποιεῖ μῆνας σεληνιακοὺς σκβ', ἅ γίνονται ιή ἐνιαυτοὶ καὶ μῆνες ς'.

Figure 12: The entry for saros in Suidae Lexicon

Taken into account:

(α) the statement of Martin Nilsson[4,pg. 420] «*What the meaning is must remain uncertain; but because the sun and the moon are placed together here, as on the rings showing the firmament with the celestial bodies, it is probable that the representation refers rather to some cosmic beliefs or myths than to an actual cult of the sun.*»,

(β) the similarity of the representation of Sun as it is appeared in the engraved motifs at the top of the seal ring from Mycenae **Figure 13**,

2. https://books.google.gr/books?id=A5YCAAAAQAAJ&printsec=frontcover&hl=el&redir_esc=y#v=snippet&q=%CF%83%CE%AC%CF%81%CE%BF%CF%82&f=false

Figure 13: *gold seal, 15 ce. BC., National Archaeological Museum* (*Id: K/EAM/A1/3861*)

Figure 14 *the first left hand engraved figure with annotations shown possible representations of the celestial bodies. Is this a representation of the cosmological model of Minoans?*

It could be supported that probably the upper part of the observed carved figure represents the Sun, beneath it, the largest bullet represents the Moon, and the smaller bullets at the right and left of Moon represent the six known planets visible to the naked eye. On both sides close to the Moon might be Mercury and Venus because they perform the same journey with the Moon during the sunrise and the sunset. Beneath these celestial bodies, the large circle, probably represent the Earth since in the sky of the Earth the 28 lunar eclipses in 18 years can be observed. It seems that the whole system of the large circle (Earth), and the celestial bodies is supported by a post with six horizontal notches. Does this figure represent the six days of creation of the world or the pillar which supports the created world?

Such an interpretation may reflect the geocentric cosmological conception of the Minoans and other eastern peoples as might be expected. Perhaps, it could be stated that these representations express cosmic beliefs found to the representation of the goddess of the sky Nut of the Egyptian mythology, which in her belly has included the celestial bodies [10]. Nut belongs to the nine deities group associated with the cosmogonic myth of Heliopolis [11], [12]. Heliopolis is known with its Greek name and is one of the most ancient Egyptian cities. In Egyptian it was called Iunu or Onu meaning "Pillar City"[3] . Heliopolis was the seat of worship of the sun god, Re, also spelled Ra or Pra, in ancient Egyptian religion. He was the god of the sun and creator god. He was believed to travel across the sky in his solar bark and, during the night, make his passage the underworld, in order to be born again for the new day[4]. . According to Egyptian mythology, Geb (God of the Earth) and Nut (Goddess of Sky) form the mythical geosphere (Earth and Heaven). Nut is usually depicted as a woman with elongated and

3. https://www.britannica.com/place/Heliopolis-ancient-city-Egypt
4. https://www.britannica.com/topic/ancient-Egyptian-religion

curved body, relying on earth only with ends of the toes and hands. The starry belly of Nut forming the celestial vault is supported by Shu, like Atlas of Greek mythology[5]. Also, sometimes, Nut was depicted in the form of a cow whose great body formed the sky and heavens and carries the god Ra in her back. **10**], [**11**], [**12**].

Finally due to the small size of the engraved figure, only 6.2 cm, possible it was used for religious purpose. It might be associated with the concept of the cosmic order of the periodicity and recurrence of eclipses every 18 years, an event where the basic deified celestial bodies of sun and moon participated.

The second left-hand figure

In the second engraved figure from the left of the stone die from Palekastro appears a feminine divine figure in devotional attitude in Y form holding in each hand two poppy flowers. The deity on the head bears the symbol known from Linear B of value re [**15**]. It might point to Titaness goddess Rhea.

The nature of goddess Rea is one of the most difficult subjects in ancient mythology. Some consider Rhea to to point to another form of era, the earth, while others connect it with rheô, means flow (Plat. Cratyl. p. 401, &c.); The Thracians identify her with the Thracian goddess Bendis or Cotys (Hecate), which in turn is identified with Demeter. (Strab. x. p. 470.). In Phrygia, Rhea was identified with Cybele[6], Cybele is said to have cured Dionysus of his madness.[26][7], thus their cults shared several characteristics. (Apollod. iii. 5. § 1). Demeter, moreover, the daughter of Rhea, is sometimes mentioned with all the attributes belonging to Rhea (Eurip.Helen.1304.) The worship of the Cretan Rhea was associated with that of the Phrygian mother of the gods[17].

Diodorus (v. 66) saw the site where her temple had once stood, near Knossos and he stated that Crete was undoubtedly the earliest seat of the worship of Rhea. According to the Hesiodic Theogony (133; comp. Apollod. i. 1. § 3), Rhea was a daughter of Uranus and Ge (Gaea), and sister of Oceanus, Coeus, Hyperion, Crius, Iapetus, Theia, Themis, and Mnemosyne.

Greeks assimilate sometimes the goddess Nut with their own Titan goddess Rhea [13], [15]. Plutarxus, in De Iside et Osiride (351: Stephanus p. 373 s B,9), states that Rhea was the mother of Osiris and Isis. [the Greek text of Plutarch : "'Ρέας ὄντων ἐξ "Ισιδος καὶ 'Οσίριδος λεγομένη γένεσις"]

Pernier and .Milani were the first who identify the deity depicted with raised hands holding either ax or flowers to the Goddess Rhea and chronologically place the appearance of this form in MM II period.[17]

Finally, in the image of Figure 15, it might be observed that at the head of the deity with raised hands the symbol 𐄇 (= re). Also the outline of the figure of the deity points to the shape 𐄇.

5. https://en.wikipedia.org/wiki/Atlas_(mythology)
6. https://www.britannica.com/topic/Rhea-Greek-goddess
7. https://en.wikipedia.org/wiki/Cybele

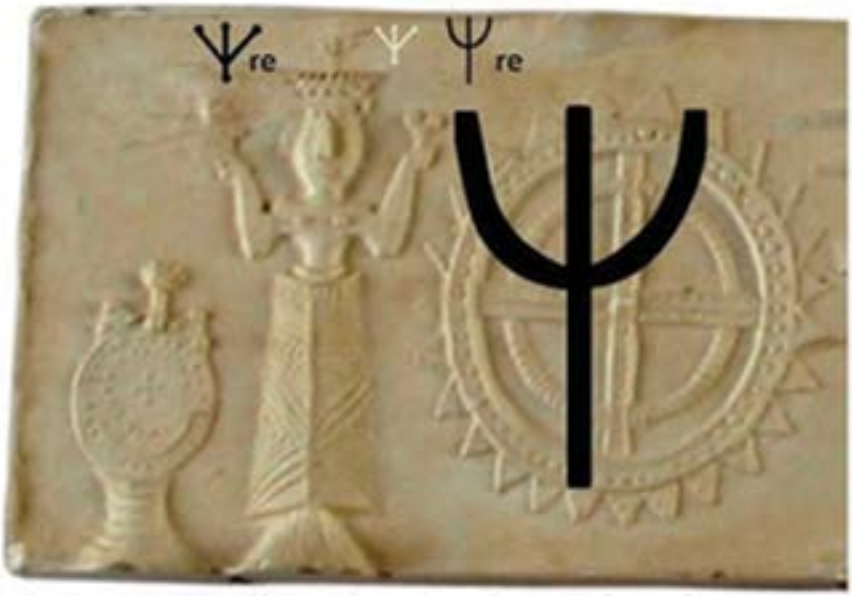


Figure 15. *Photograph of the stone plate taken by A.M.H. with annotations shown the various expressions of symbol Re found in the figure of deity*

5. Conclusions

Summarizing, it was point out to this paper that all the engraved figures in the stone plate of Palaikastro, may share the same concepts about cosmic beliefs. The two left-hand relief representations may be used for religious purposes because of their small size while the third one is a mechanism for predicting the motions of the deified celestial bodies, Sun and Moon.

The first left-hand figure might be associated with the concept of the cosmic order of the periodicity and recurrence of eclipses every 18 years, an event where the basic deified celestial bodies of sun and moon participated. It seems that shares similar cosmic concepts found in representation of Egyptian goddess Nut. This interpretation is in accordance with the second engraved figure of the stone plate.

The second left-hand figure is associated with the Titaness goddess Rea, known also as "the mother of gods" and strongly associated with Gaia and Cybele and Nut, who have similar functions. Also the appearance of symbol having value re at the top of the head of this figure, constitute strong evidence that the name of this goddess might be associated with Rhea.

Concluding we may say that the stone plate of Plaikastro is one more evidence that Crete was undoubtedly the earliest seat of the worship of Rhea as already mentioned by Diodorus .

6. References

1. Evans, Sir A.J., The *palace of Minos at Knossos*, vol. IV, London: Macmillan & Co., 1935
2. Xanthoudides, S. Ancient dies from Sitia, Crete. Archeologiki Ephemeris, period III. Published by the Archaeological Society of Athens, Athens, pp. 51-52 (1900) [in Greek]. http://www.archive.org/stream/ephemerisarchai01900arch#page/n33/mode/2up
3. Alexiou, S. The Minoan Goddess with raised hands. Cretan Chronicles (Kritika Chronika), vol. XII (IB), (1958)178-299, esp. [in Greek].
4. Nilsson Martin,. The Minoan- Mycenaean Religion and its Survival in Greek Religion, Second, Revised Edition. Lund, 1950
5. Tsikritsis M., Theodossiou E. , Manimanis V.N., Mantaraki P, Tsikritsis D., 2013 "A MINOAN ECLIPSE CALCULATOR", Mediterranean Archaeology and Archaeometry, Vol. 13, No 1, pp.267-277, Athens, 2013
6. Theodosiou S., Danezis M., "The Odyssey of Calendars", Δίαυλος(Diaylos), Athens, 1996 [in Greek]
7. Alexiou, S., "Minoan Civilization", Published by Stylianoy Alexioy Sons, Heraklion, Crete, 1969. [in Greek]
8. Vassilakis Antonis, Minoan Crete. Published by Sfakianakis, Heraklion 1991 [in Greek]
9. Marinatos Spyridon, The Cretanmycenean Religion, University Notes, Athens, 1948 [in Greek]
10. Pinches, J.N. Strassmaier, "*Late Babylonian Astronomical and Related Texts*". A.J. Sachs (ed.), Brown University Press 1955
11. Casson L. et al. 1969, "Ancient Egypt", TIME-LIFE INTERNATIONAL (Nederland) N.V.
12. Joshua J. Mark. "The Egyptian Pantheon," Ancient History Encyclopedia. Last modified April 14, 2016. http://www.ancient.eu /article/885/.
13. Ancient Egyptian religion. 2016. Encyclopædia Britannica Online. Retrieved 04 Ιουλίου, 2016, from https://www.britannica.com/topic/ancient-Egyptian-religion/The-Gods
14. Pinch Geraldine, "Egyptian Mythology, A guide to the Gods, Godesses and Tranditions of Ancient Egypt", Oxford University Press, 2002
15. M. Ventris - J. Chadwick, "Evidence for Greek Dialect in the Mycenaean Archives", Journal of Hellenic Studies 73, 1953: 84-111
16. Νουτ, https://el.wikipedia.org/wiki/%CE%9D%CE%BF%CF%85%CF%84 [accessed 4/7/2016]
17. Roller Lynn E., "*In Search of God the Mother: The Cult of Anatolian Cybele*", University of California Press, Ltd., Berkley and Los Angeles, California, 1999

B4.13 Minoan Solar Calendars Carved On Flat Kerni. The Riddle of Kernoi

Alexis Pliakos
Independent Researcher

Abstract

The distribution of 365.25 days of one **solar year** in Egypt as well as in Babylonia before 2000 BCE was as follows: The Egyptians divided the solar year in 12 months of 30 days each + 5 days at the end of the 360 days. The Babylonians divided 6 solar years as follows: the first 5 years of 360 days each, had 12 months of 30 days each, while the sixth 390-day solar year had 13 months of 30 days each. Both calendars failed to calculate a quarter (0.25) of one day. Around 1800 BCE the Minoans used at least four flat stone kernoi as solar year calendars, which divided the 365 days of 1 solar year as follows: 3 celebration days at the beginning of the year, on 22nd, 23rd, and 24th September + 5 months of 36 days each (= four 9-day weeks) + 2 celebration days in the middle of the year, on 24th and 25th March + 5 months of 36 days each (= four 9-day weeks). However, there are also kernoi representing calendars of shorter periods of time, such as months and weeks, for instance: a) One kernos consisting of a group of 4 similar cups for counting 4 weeks, of 9 days each and a group of 9 bigger cups for counting 9 days. b) One kernos consisting of 18-day similar cups + 1 bigger cup for counting the current 1st or 2nd 18-day period of the month. c) one kernos consisting of 9-day similar cups + 1 bigger cup for counting the current 1st , 2nd , 3rd , or 4th 9-day period of 1 month. All the above mentioned types of calendars are presented in this article as well as a 9-day week calendar consisting of 9-day similar cups. The Minoan flat stone kernoi, under a predetermined number of a) similar cups, b) similar and bigger cups, or c) similar, bigger and separated cups are either lunar, lunisolar or solar calendars, or parts of each one of them, on condition that such corresponding calendric configurations exist. Thus the riddle of kernoi is answered after 110 years.

1. Introduction

The decipherment of several flat kernoi led the author to conclude that at least 80 of them, under strict predetermined conditions of their similar number of cups, size and distribution of cups on their surface, were either integrated or parts of lunar, lunisolar, or solar calendars. Thus, the riddle of "what the kernoi are" and "what they were used for" is solved, Pliakos [15]. One should bear in mind that the above predetermined conditions are very "sensitive". If someone breaks or adds one or more cups on a kernos, the result will be a kernos which used to be a calendar, but can no longer be decoded

as such. That is the case with the two kernoi found on Mt. Juktas, Knossos, Herakleion Museum (H. M.) 3587 and 3588, Karetsou [14] and the kernos at Mallia, Herakleion, Van Effenterre H. & Van Effenterre M. [8]

2. The development of calendars in Minoan Crete

The development of calendars in Minoan Crete followed 4 steps:

The first step was the **lunar calendar**, invented either locally or transferred from somewhere else, probably from a kernos unearthed by Samson [16], in Mykonos, which dates back to 4500 - 4300 BCE. The author has studied 48 kernoi and categorized them into 18 different models of lunar calendars.

The second step was the **lunisolar calendar**, invented either locally or transferred from somewhere else, probably from an Aegean artifact, which was unearthed by Doumas [6], in Keros, which dates back to 2800 - 2300 BCE. The author has studied 12 kernoi and categorized them into 9 different models of lunisolar calendars.

The third step was the **one-year Minoan solar calendar**, invented by the Minoan priesthood in Crete, which was different from the corresponding Egyptian and Babylonian ones of the same period (2100-2000 BCE). The **beginning** of the Minoan solar calendar was, supposedly, the next day of the autumn equinox, its **time unit** was a month of 36 days and its **duration** was 365 days. In this article the author studies 21 kernoi which he categorizes into 8 different models of solar calendars. In addition, he studies the function and the uniqueness of the one-year Minoan solar calendar.

The fourth step was **the 4-year Minoan solar calendar** with the additional 366th day every 4 years, Blomberg & Henriksson [1]. It was invented by the Minoan priesthood in Crete and it is depicted in a world-wide unique artifact, concerning its concept and execution. The artifact was brought to light by Evans [9], who dated it back to 1550 BCE. He reconstructed almost accurately the small broken pieces into a whole, without knowing what it was (!), and named it "Royal Game", H.M., case 171. It was partly deciphered by Gregoriades [12] and its documented integration was made by the author [15a]. The current 4-year solar calendar was introduced by Julius Caesar to the peoples of the Roman Empire in 45 BCE. Therefore, the 4-year solar calendar of the Minoan priesthood preceded the Julian one by about 1500 years!!!

3. Solar calendars in the region, before 2000 BCE

The *Egyptian* one-year solar calendar had its **beginning** on the day when the Dog Star and the sun rose simultaneously around the middle of July, its **duration** was 365 days and its **time unit** was a 30-day month. Twelve months covered 360 (=12 x 30) days and the remaining 5 days were celebration days at the end of every year, devoted to the 5 main Egyptian deities. The institution of the Egyptian calendar was made in the first half of the third millennium BCE, Chatley [5].

However, the accurate duration of the solar year is 365.2422 days. Thus, in every solar year the Egyptian solar (seasonal) calendar fell behind by 0.2422 days. In 372 years the calendar lacked one season (90 days) compared to the actual seasonal one and as a

result the seasons of the year "drifted" backwards, Britannica on line [3].

The *Babylonians* had divided the endless time into 6-year periods, of which the first five were divided into 12 months of 30 days each, while the sixth had 13 months of 30 days each. This calendar was in effect between 2400 and 2100 BCE. After 2100 BCE, the Babylonians returned to the lunar calendar, for unknown reasons, Britannica on line [3].

The Aegeans divided time into 8-year solar periods (total 2922 days) or 96 lunar months + 3 inserted 30-day lunar months (total 2922 days). The first kernos of this kind was unearthed by Doumas [6] in Keros and dates back between 2800 and 2300 BCE. The decipherment of the artifact as an 8-year lunisolar calendar was made by the author [15]. The Minoan priesthood either invented, or transferred and improved the Aegean lunisolar calendar around 2100 BCE. This is verified by two kernoi unearthed by Karetsou [14] on Mt. Juktas, Knossos, which are exposed at H.M., 3587 and 3588. They have been decoded by the author as 8-year lunisolar calendars. There are seven more kernoi-lunisolar calendars, unearthed in Crete.

4. The riddle of kernoi

Several scientists have tried to answer questions such as "what were the kernoi?" and "what was their function?", but they gave conflicting answers. Archaeologists adopted the answer given either by Evans [9], that "flat kernoi were boards for playing games on, like the ones played on pavements", version (a) or by Boyd-Haws [2], that "games like backgammon or roulette were played on flat kernoi", version (b) or by Chapouthier and others [4], that "flat kernoi were used as libation disks, for putting offerings in and pouring them in front of deities" version (c).

5. Comments on the above answers.

Regarding versions (a) and (b) the author argues that so far no scientist has published any rules as to how a game was played even on one kernos! After all, it is illogical that the same rules could be applied in a group of games played on kernoi with either 4, or 8, or 12+1, or 20, or 29+1, or 33+1, or 40+1, or 48+3, or 99+5, or 99+8 cups. Let alone when the +1, +3, +5, +8 cups are bigger than their closest ones. Therefore, the author believes that kernoi were not flat boards for playing games.

Regarding version (c) the author argues that:

i) There is no season in Crete when more than 20 different kinds of seeds are produced to put into the 30, or 30 + 1, or 33 + 1, or 40 + 1, or 48 + 3, or 99, or 99 + 5, or 99 + 8 cups of a kernos and offer them to deities.

ii) Kernoi are usually made of heavy materials, stone or ceramic, meaning their weight would not allow worshippers to transfer them to places for rituals. For instance, the portable (?) kernos of the Heraklion Museum, no. 3588, Karetsou [14], with 100 or 99 similar cups + 5 bigger ones weighs about 45 kilos.

iii) Several flat kernoi were found in "situ" and therefore, it was impossible for worshipers to transfer offerings on them during a religious procession. For example,

the surface of the stone kernos found "in situ" at the Queen's Megaron, Knossos, is 1.20 m x 1.20 m, Fig. 2, Hood [11];

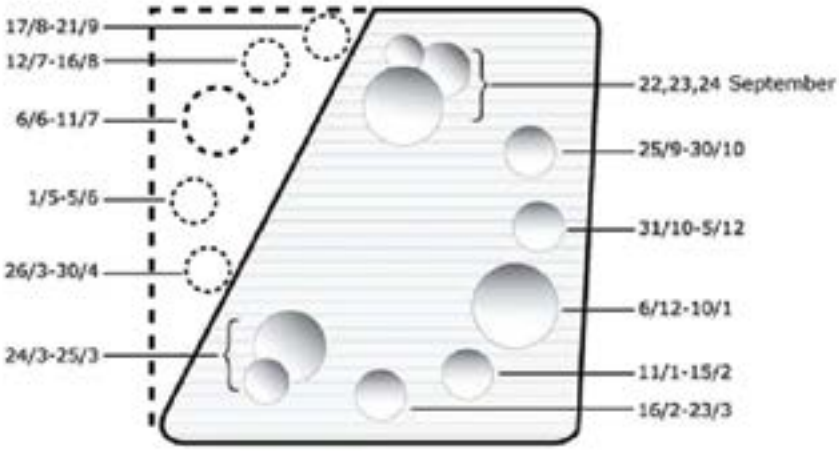


Fig. 1. Minoan solar calendar of one year, drawn by A. Kassidakis

iv) The dimensions of cups of kernoi are usually 2.5 - 4.0 cm in diameter and 0.8 - 1.2 cm in depth, therefore the quantity of offerings in them would be extremely small. Nevertheless, the fresco of the sarcophagus of Aghia Triada (H.M. room XIV, case 171) clearly shows that solid offerings such as fruit and cereals were carried in baskets, whereas liquids such as oil and wine in earthen pots, therefore the quantity of offerings was not small. Flat kernoi are not depicted on the fresco. Therefore, the flat kernoi were not used as libation disks/tables.

The author, after a 5-year study and research into more than 80 Minoan flat kernoi through the writings of 22 archaeologists who made excavations in 16 Cretan archaeological sites gives a documented answer to the riddle of kernoi, as to "what they were" and "what they were used for". The data were given by Hillbom [10]. The conclusion is that the Minoan flat stone kernoi, under a predetermined number of: a) similar cups, b) similar and bigger cups, or c) similar, bigger and separated cups are either lunar, lunisolar or solar calendars, or parts of each one of them, on condition that such corresponding calendric configurations exist.

6. Approaching and solving the Minoan solar calendar based on a specific kernos of Knossos.

Evans [9] made excavations at the Queen's Megaron, Knossos, where he unearthed a half-broken flat kernos on which 5 simple and 2 composite double cups were carved in a semi-cyclical configuration, Fig. 1. The full dimensions of the kernos were probably

46 cm x 46 cm. According to the Evans's description, the kernos had 2 opposite, double (composite) cups. He probably did not notice that there were not two double cups on the kernos, but one triple and one double (composite) cups; i.e. 5 cups, Fig. 1, as it was published by Evans [9]. Between the two (composite) cups there were another 5 (simple) cups, the one of which in the middle was bigger than the other four. Evans and his collaborators integrated the half-broken kernos, symmetrically.

The two groups of 3+2 composite cups make a sum of 5, which is the number of the additional days in the 360-day solar year. The 360 days are split into 5+5 (simple) cups on this kernos, thus, in each cup 36 days could be counted (=360:10) one Minoan solar month. The middle of the periods of the two bigger cups shows the winter (22/12) and the summer (22/6) solstices.

7. The above distribution of 365 days does not comprise a calendar

Although **the duration** of the period of 365 days, and its **time unit**, which is a Minoan solar "month" of 36 days, are defined, **the beginning** of the period is not (Webster's Dictionary [19] definition of what a calendar is) a calendar. Archaeoastronomers Blomberg & Henriksson [1] noticed that the reflection of the rising sun on the day of the autumn equinox was mirrored at a standard spot of the altar room, next to the throne chamber in the Knossos Megaron for 3 years (of 365 days). In addition, they also noticed that every 4 years the rising sun was mirrored one day later at the same spot which made them conclude that the Minoans knew that the 4th solar year counted 366 days.

Since the beginning of the Minoan solar calendar is defined (supposedly the day after the autumn equinox, i.e. the 22nd September), the 365 days of a solar year can be distributed as follows: the 22nd, 23rd and 24th September are the 3 celebration days at the beginning of the year, followed by 5 months of 36 days each (5 x 36 = 180 days). Then, 2 middle-year celebration days are celebrated on the 24th and 25th March. Finally, the remaining 5 months (5 x 36 = 180 days) follow, until 21st September. The beginning and the end of each 36-day Minoan month, in correspondence with our current calendar, are depicted in Fig. 1.

8. Other Minoan solar calendars

a. The archaeologist Boyd-Haws [2] unearthed an identical kernos to the one in Fig. 1 on the peak of Mt. Kavousi, St. Nikolaos, at the residence of "Captain", room 1.
b. The archaeologist Warren [18] unearthed during the excavation for the foundation of the stromatographical Museum of Knossos.
c. The archaeologist H. Van Effenterre [7] found an identical kernos to the one in Fig. 1, on the surface of a rock, on Mt. Oxa, Lassithi. Hood [11a] published a photo of it.

9. How to divide the 36-day Minoan month

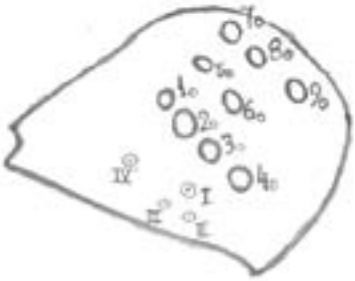


Fig. 2 *Kernos for counting four 9-day "weeks", Knossos, Hood.*

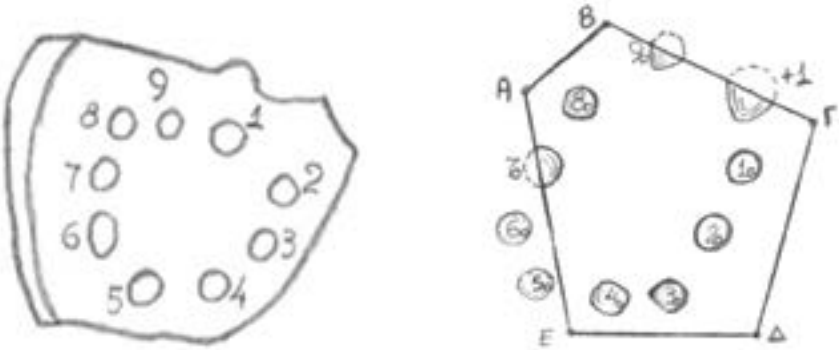


Fig. 3 *Kernoi with 9 similar or 9 + 1 bigger cups, Kommos, Whittaker.*

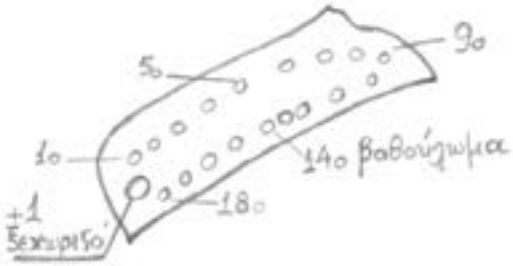


Fig. 4 *Kernoi with 18 similar cups or 18 + 1 bigger cups, Gournia, Soles*

In all probability, the calendar-tender of the Minoan solar calendar found it difficult to count 36 days in cups of 4 - 5 cm in diameter and 0.8 - 1.2 cm in depth each; thus, the Minoan priesthood constructed at least one kernos of two groups of cups, one with 4 similar cups and one with 9 bigger ones, in total 36 places (=4X9), so that the 36 days of a month could be counted with 9 day pawns and 4 "week" pawns of 9 days each. Its decipherment has been made by the author. Hood [11] unearthed a kernos of the above characteristics, Fig. 2, at the Queen's Megaron, Knossos, five meters away from the kernos of Fig. 1. The interconnection between the two kernoi is evident.

10. Kernoi with 18 similar cups or 18 + 1 bigger cup and with 9 similar cups, 9 + 1 bigger cup

The archaeologist Soles [17] unearthed a kernos of 18 similar cups in Gournia, Lassithi. The 36 days of a Minoan solar month can be counted in them using 2 pawns in each cup (2 x 18 = 36).

The archaeologists H. Van Effenterre [7] and Soles [17], [17a] have unearthed 4 different models of kernoi of 18 similar and 18 similar + 1 bigger cups. In case a kernos has 18 similar +1 bigger cups, this is used at the beginning of the 1st or 2nd eighteen-day period, with 1 or 2 pawns, Soles [17a].

The archaeologist Whittaker [20] unearthed models of kernoi of 9 similar and 9 similar +1 bigger cup, in Kommos, Phaestos. Soles [17] also unearthed a kernos of 9 similar cups at Gournia, Lassithi.

11. Conclusions

The Minoan priesthood keeping peak sanctuaries on several peaks of mountains all over Crete, had noticed that the duration of the year is 365 days for three successive years, but 366 for the fourth one, Blomberg & Henriksson [1]. By the priesthood's orders world-wide unique kernoi were constructed: a) the unique in the world kernoi-models for the one-year Minoan solar calendar since 2100 BCE, Fig. 1, and the unique artifact in the world, the 4-year Minoan solar calendar dated back to 1550 BCE. This was decoded partly by Gregoriades [12] and integrated by Pliakos [15b].

-The Minoan priesthood, apart from the autumn and spring equinoxes, knew the winter and summer solstices, too. This is deduced from the fact that in the 5 + 5 cups, Fig. 1, the 3rd and the 8th are bigger (a sign that something special happened in those Minoan months). So, in the middle of them and in correspondence with our current calendar the two solstices happen, on 22 December and 21 June.

-The 365 days of the year in a Minoan solar calendar are divided into "months" and "weeks" differently from the respective Egyptian and Babylonian ones. Therefore, the one-year and the 4-year Minoan solar calendars were developed in Crete and were not transferred from elsewhere.

Bibliography.

(1) Blomberg, M., & Henriksson, G. 2011. The evidence from Knossos on the Minoan calendar. Journal of Mediterranean Archaeology and Archaeoastronomy. vol.11, no 1, pp. 59-68.

(2) Boyd, H. (Mrs. Boyd-Hawes), 1901, Excavations at Kavousi, Crete, in 1901, A.J.A., 5, pp. 125-157.

(3) Britannica on line. Egyptian and Babylonian Calendars.

(4) Chapouthier, F. 1928, Une table a offrandes au Palais de Mallia, Bulletin de Correspondance Hellenique, 52, pp.292-323.

(5) Chatley, H. 1943, The Observatory, Vol. 65, pp. 121. NASA Astroph. Data Sys.

(6) Doumas, C. 1968, The N. P. Goulandris Collection of Early Cycladic Art.

(7) Van Effenterre, H. 1955, Cupules et naumachie, BCH 69,541-548.

(8) Van Effenterre, H. & Van Effenterre, M. 1976, Fouilles executees a Mallia. EtCret, 22.

(9) Evans, A. 1930, The Palace of Minos, vol. III, fig.261, p 391, London.

(10) Hillbom, N. 2005, Minoan games and game boards, Ph.D. thesis, Lund, Minoan cup holes, p. 117.

(11) Hood, S. 1995, Minoan cup-marks, Eirene 31, pp. 7-43, figs. 16-18.

(11a) Hood, S. 1974, Primitiverock engravings from Crete. The J. Paul Getty Museum Journal, Vol. 1, 101-111, fig. 16a.

(12) Gregoriades, P.D. 2008, Enneoros Minos, Science and Technology in Homeric Epics, (ed.) S. A. Paipetis, Springer, pp. 319-334.

(13) Karageorgis, 1976, KITION.

(14) Karetsou, A. 2012, Two Stone Kernoi from the Juktas Peak Sanctuary. Prehistory Monogr. 36 ed. E. Mantzourani & Ph. P. Betancourt, INSTAP Academic Press, Phil. Penns.

(15) Minoan Calendars on Flat Kernoi (2600-1100 BC), in Greek, Αθήνα.

(15a) Pliakos, A. 2015b, Minoan solar calendars carved in stones and the riddle of kernoi: A new hypothesis. EIRENE, LI, 221-234

(16) Samson, A. 2002, The Neolithic settlement at Ftelia, Mykonos, p.122, fig. 132.

(17) Soles, J. 1973, The Gournia house tombs, Ann Arbor.

(17a) Soles, J. 1979, The Early Gournia town, AJA 83, PP. 149-167.

(18) Warren, P. 1984, Circular platform at Minoan Knossos, BSA 79, pp. 307-323.

(19) Webster's 3rd International Dictionary, 1961, Konemann; Calendar; Kernos.

(20) Whittaker H., 1996, Stone slabs with depressions, in Kommos I:2. Eds. J. Shaw & M. Shaw, Princeton, 321-323.

B4.14 The Cycles of Saros and Exeligmos and the Centuries Lasting Minoan Pax

Alexis Pliakos
Independent Researcher, Athens

Abstract

The Minoan Pax has been sufficiently documented by archaeologists, such as Driessen [2] and Krzyszkowska [6], as they found no evidence of large-scale disasters caused by men, such as revolts or rebellions. Then, what was the reason for the centuries lasting Minoan Pax? Most probably, the Minoans were convinced that King Minos could use his "supernatural" powers by partly or totally hiding the moon or the sun on a pre-announced date, in case they did not obey his orders. The King and his priesthood knew the Saros and Exeligmós cycles through which they could foresee lunar and solar eclipses by consulting written observations collected years before on perishable material which did not survive and consulting a counter of lunar months which survive and it is carved on the "Phaestos Libation Table". They did so about 1000 years prior to the Chaldeans, to whom the knowledge of the Saros cycle is attributed, around the 9th century BCE, NASA [10].

1. Introduction

According to the Saros cycle, every 223 lunar months the same partial or total **lunar** eclipses are repeated, visible 120° west of the place of the previous eclipse. According to the Exeligmos cycle, every 669 lunar months a) the same partial or total **lunar** eclipses are repeated, visible from the same place and b) the same partial or total **solar** eclipses are repeated, visible about 600 miles away north or south of the previous place, NASA [10]. It is known that Minos and his officials had close relations with the Minoan priesthood. The priesthood maintained peak sanctuaries throughout Crete and for celestial observations, because during the prehistoric and historic periods people believed that whatever happened in the sky was a herald of what would soon happen on earth (the genesis of horoscopes).

Thus, the priesthood observed the repeated eclipses of the moon and the sun, keeping records of them on perishable materials for a long time. Minos and the priesthood kept those records secret, discovering that the cycles of Saros and Exeligmos defined the eclipses of the moon and the sun, as it is happened today. Thus the need for a counter of 223 lunar months was imperative. These records on perishable materials did not last up to our days but an artifact-counter did and it is the "Phaestos Libation Table". The ceramic "Phaestos Libation Table", constructed under the spiritual guid-

ance of the Minoan priesthood, was unearthed by the archaeologist Pernier [11], at the first Palace of Phaestos and dates back to "the epoca di Kamares", i.e. 2000 - 1700 BCE, Fig. 1. The archaeologist Dussaud [3] dated it back to MM I era, i.e. 2100 - 1900 BCE. It is a rectangular ABCD, 55 cm. x 45 cm. and looks like a kitchen sink in three levels. The first level has a decorated rim of 11 cm. width. The second (44 cm x 34cm) lies 1.6 cm lower than the first. The third is a semi-spherical cup of 10 cm in diameter, in the centre of the second level. The artifact is showed at the Herakleion Museum room III, case 42 and weighs approximately 20 kilos.

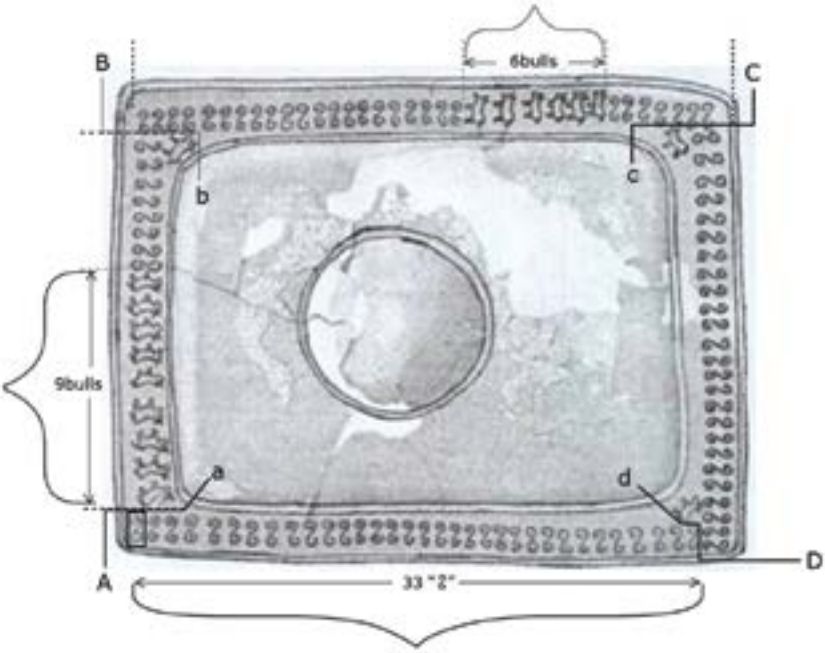


Fig. 1 The Phaestos Libation table with 112 symbols on its rim, Pernier.

The rim is decorated with 112 symbols, 94 double spirals and 18 bulls. If these symbols are counted clockwise and the 112th symbol is counted once, and the previous 111 symbols are counted again, but this time anticlockwise, then we have a total of 223 symbols/lunar months (111+1+111), comprising one Saros cycle. If it is counted three times, the product is 669 lunar months, i.e. one Exeligmos cycle. Another interesting cycle is the Sar cycle, consisting of 111 + 0.5 lunar months or 9 years and 5.5 days. The importance of the Sar cycle in forecasting eclipses, is mentioned in paragraph 5, Meeus [8].

To decode the "Phaestos Libation Table" as an artifact-counter, we need to pose certain questions, the answers of which will make us kneel to the combinatorial way of thinking of the Minoan priesthood.

2. Annotation on the artifact "Phaestos Libation Table"

The "Libation Table" cannot have been used as a libation tray, because: a) there are not any documented libation trays of more than one level, while the above-mentioned artifact has three; b) libation trays are light and simply constructed, able to be easily transferred by one person, while this one is of a complex construction, and weighting about 20 kilos and c) if it were a libation tray, its rim need not have been decorated with 94 double spirals and 18 bulls, which added up make one Saros cycle.

What was then the "Phaestos Libation Table" and what was its use? The answer of the question will be answered below.

3. Analysis of the symbols of the double spiral and the bull

Each double spiral symbolizes three phases of the moon, i.e. one lunar month. One end of it symbolizes the first tiny crescent (the waxing period), its middle the full moon and its other end the last tiny crescent (the winning period). Dr. Alexander Jones claimed, in a documentary film on "The Antikythera mechanism", that the prehistoric symbol of the moon was the horns of a bull, which form one crescent, therefore they symbolize one lunar month.

Since each double spiral and each horned bull symbolize the same time period, why did the constructor use two different kinds of symbols? The question will be answered

4. How to mark one Saros cycle

It is evident that this ceramic artifact serves for counting 223 lunar months, i.e. a Saros cycle. However, **where** do we have to start counting? We have no choice but to start from the inside corner **a**, because it is the only one not depicting a bull. Which direction should we take, clockwise or anticlockwise? We take the clockwise direction, because the corner **b** bull looks to the right. After placing the 112th pawn on the 112th symbol, we remove the previous 111 pawns and we take the anticlockwise direction, because corner **c** and **d** bulls look to the left. Thus, the calendar-tender counts a second set of 111 lunar months on the precedent 111 symbols, in total 223 lunar months (or 18 years, 11 days and 8 hours), i.e. one Saros cycle. The clockwise direction in counting days and other time units is common and verified in about 80 Minoan kernoi, which have been deciphered as calendars, by Pliakos [12].

5. How to mark one Exeligmos cycle

The bulls in corners **b, c** and **d** are the starting points to count three Saros cycles, meaning one Exeligmos cycle, either (3X223=) 669 lunar months, or [3 x (18 years + 11 days + 8 hours) =] 54 years and 33 days.

6. How to mark one Sar cycle

The priesthood may have noticed that after a lunar or solar eclipse, another one fol-

lows after 9 years and 5.5 days, solar or lunar reversely but with the same properties. This period, called Sar, corresponds to half a Saros cycle, Meeus [8].

Why was this specific distribution of symbols (111+1+111) adopted and not another one, like 55 + 1 + 55 + 1 + 55 + 1 + 55? Because this distribution helps the 111 + 0.5 lunar months of a Sar cycle to be counted easily.

7. The role of the 112th double spiral symbol

Does the 112th double spiral (the last one in a series of symbols at corner A), on which the 112th corresponding lunar month is counted, play a special role? Yes, it does, because it is counted once and then the counting is made anticlockwise on the previous 111 spirals symbolizing the remaining 111 lunar months up to the 223th (111 + 1 + 111), which finishes the Saros cycle. **The decoding of one Saros cycle of 223 lunar months on any artifact has been made for the first time worldwide.**

8. Beginning and end of one Exeligmos cycle

Minoan priesthood used the double spiral = one bull= one lunar month, in counting the Saros cycle. For the counting of Exeligmos cycle, by two ways, the two symbols were used differently. The process of one Exeligmos counting is the same as three of the Saros cycles. Counting the first, the second and the third Saros cycle, with one pawn on the corner bulls' **b, c** and **d** respectively, one Exeligmos cycle of 669 lunar months is counted. **The decoding of one Exeligmos cycle of 669 lunar months on any artifact has been made for the first time worldwide.**

9. Second deciphering of one Exeligmos Cycle of 54 years and 33 days

The Minoan priesthood used 18 bulls to count a number of lunar months. Three of them, in corners b, c and d were also used to count three Saros cycles.The rest 15 bulls, 9 consecutive ones on the side AB and 6 consecutive ones on the side BC of the rectangular ABCD give a product of 54, which is the number of years in one Exeligmos cycle. Moreover, the priesthood used 33 double spirals on the side DA, denoting the 33 supplementary days in one Exeligmos cycle. Each of these 54 years could be counted on one year solar calendar, used in Crete since 2000 BCE, Pliakos [12]. The two ways of counting the Exeligmos a) in 669 lunar months and b) in 54 years + 33 days reveals, once again, the magnitude of the combinatorial thinking of the Minoan priesthood. **The decoding of one Exeligmos cycle of 54 years and 33 days on any artifact has been made for the first time worldwide.**

10. Saros and Exeligmos cycles: calendars or time cycles?

A calendar is a management time system in which the beginning, the duration and the time unit used are predetermined, Webster's [14]. For instance, our solar year calendar starts on 1st January, its duration is 365 or 366 days and its time unit is one month

either of 28 or 29 or 30 or 31 days. Although the duration of the Saros and Exeligmos cycles are predetermined having 223 and 669 lunar months respectively, and their time units are lunar months, their beginnings has not be predetermined. After all, how significant would be a calendar of 18 or 54 years in everyday life? Therefore, Saros and Exeligmos are **not** calendars.

11. Etymology of the words "Saros" and "Exeligmos"

The term "Saros" is attributed to Chaldean astronomers, around the 9th century BCE, NASA [10]. The Babylonian verb "sâru (m)" means either *to rotate, whirl* (of wind, or water), or *to dance* with a person. The Babylonian noun "Sar" means *inscription, vegetable(s), a surface area measured* of 36 sq. m., or *the number 3600*, Halloran [4].

The Greek verb *saroo-saro* (*σαρόω-σαρώ*) derives from the ancient Greek *sero* (*σαίρω*), meaning *sweep*, *clean*, Liddell & Scott [7]. In Modern Greek the verb is sarono (σαρώνω), meaning sweep, clean, Hornby [5]. It is worth mentioning that the gulf west of Attica is called Saronic Gulf, because this region used to be land, swept by upraised waters 90 - 110 m. high during a cataclysm around 9500 BCE, Plato, Kritias (111-112).

Therefore, the Greek word *sarono* (*ΣΑΡΩΝΩ*) is the nearest in meaning to the word, *saros* because in a Saros cycle, the moon and the sun eclipses were "swept out", i.e. recorded on perishable material by the Minoan priesthood. The help of the lunar month counter, the "Phaestos Libation Table", was essential and very enlightening.

The word *Exeligmos* is definitely of a Greek origin, meaning the movement or rotation of stars, Theologoumena Arithmitika (Θεολογούμενα Αριθμητικά) [13].

12. The uniqueness of the artifact "Phaestos Libation Table" up to now.

Such an artifact-counter has **not** been published yet, proving that probably the knowledge of the cycles of Sar (?), Saros and Exeligmos is Minoan. However, the mechanical calculation of the Sar (?), the Saros and Exeligmos cycles is done on the Antikythera mechanism, constructed around the end of the 2nd century BCE, Moussas [9] and its manual is written in Greek.

Conclusions

- The PAX MINOA did not probably last for so long due to the Minos justice exerted on the Minoans, but due to the fact that Minoans had experienced sun or moon eclipses, deterministically dictated by the cycles of Saros and Exeligmos, which had been heralded by Minos well in advance. As a result, the Minoans obeyed to whatever decision he made, without complaining or revolting.
- The artifact "Phaestos Libation Table", was not used for libations due to its weight (about 20 kilos) and its unusual construction (three levels). It is a counter of either 223 or 669 lunar months of a Saros and an Exeligmós cycles respectively. In addition the 54 years and the 33 days of an Exeligmós are counted in the artifact.

- The Saros and the Exeligmos cycles do not comprise calendars, but cycles of time periods which dictate lunar and solar eclipses forever.

References

1. Britannica on line, Saros and Exeligmos cycles.
2. Driessen, Jan, 1999."The Archaeology of Aegean Warfare," pp. 11–20 in Laffineur, Robert, ed., *Polemos: Le Contexte Guerrier en Egee a L'Age du Bronze*.
3. Dussaud, R, 1914, "Les Civilisation Prehellenique", p. 125, fig. 36 (9), Libr. Geuthner, Paris.
4. Holloran, J., 1972, "Babylonian Lexicon", Logogram Publ., Los Angelees, California 90075.
5. Hornby A.S., 1974, "Oxford Advance Dictionary".
6. Krzyszkowska, Olga, 1999. "So Where's the Loot? The Spoils of War and the Archaeological Record," pp. 489–498 In Laffineur, Robert, ed., *Polemos: Le Contexte Guerrier en Egee a L'Age du Bronze*.
7. Liddell, H. G. & Scott, R., 2001, "Great Lexicon of the Greek Language".
8. Meeus, Jan, "Mathematical Astronomy Morsels", p.110, Chapter 18, *The half-saros cycle*.
9. Moussas, X. D., The Antikythera Mechanism, UHP, p. 170
10. NASA, Saros and Exeligmós cycles.
11. Pernier, L., "Il Palazzo Minoico di Festos", 1900 – 1903, Vol. I, p. 229, 1st Poligr. Dello Stato Liberia, Roma, 1935.
12. Pliakos, A. A., 2015, "Minoans calendars on kernoi, 2300-1100 BCE", in Greek.
13. Θεολογούμενα Αριθμητικά, 1817, Έκδοση Ast. Lips., p. 74.
14. Webster's Dictionary (1961). Calendar.

B4.15 The Antikythera Mechanism: A New Approach towards Lost Gear Teeth, Scales and Displays of the Upper Back Dial Consistent with the Chronological and Geographical Context of its Construction

Kostas Kotsanas
Museum of Ancient Greek Technology
Ancient Olympia & Katakolo, Greece

Abstract

According to evidence, the Antikythera mechanism was built in the second half of the 2nd century BC and was the product of a Rhodian or Asia Minor workshop. The upper part of the mechanism's back dial was devoted to the calculation of the lunisolar year with a spiral of 235 lunar months (based on the 19-year Metonic cycle), whereas on the inside there is a circular arrangement for the timing of six "crown" games (stephanites) - four Panhellenic and 2 local - one of which has not yet been identified (M. Right and the International Antikythera Mechanism research project team: T. Freeth, X. Moussas, I. Seiradakis, Bitsakis, et al.). Inside the spiral, the 76-year Callippic cycle is proposed to be adapted to symmetrically mirror the cycle of athletic competitions to adjust the Metonic cycle. In addition, there are already two proposals for the 7 intercalary months of the Metonic lunar calendar: the Eukleius (T. Freeth) and the Machaneus (M. Anastasiou).

The present paper attemps a different approach in this field towards the mechanism's lost gear teeth, scales and displays, consistent with the chronological and geographical context of its construction and the already established findings. Specifically, the following data are investigated and reviewed: a) research on the local crown games that have not been deciphered yet b) research on the 7 intercalary months of the Metonic calendar in relation to the time scale of crown games and c) research and calculation of the arrangement for maximum accuracy of the lunisolar calendar. This new approach provides for the modern world an additional insight towards the concepts of science and technology in ancient Greece.

1. INTRODUCTION

In 1901, Symian sponge divers retrieved artistic ancient Greek treasures from the wreck of a large Roman ship in a cove of Antikythera Island from a depth of about 50 meters. Jacques-Yves Cousteau, who researched the wreck anew in 1976, recovered, among others, utilitarian coins of Pergamum and Ephesus that pinpoint the shipwreck chronologically between 76 and 60 BC and the location of the last trading station geograph-

ically on the coast of Asia Minor. From the moment the shipwreck was discovered, Pergamum, Ephesus, Rhodes, Corinth, Syracuse as well as Alexandria have been proposed as possible sites of the trip's departure, while there is consensus that Italy was the destination. [10] The timber used to build the vessel was cut between 210 and 40 BC, according to recent radiocarbon dating conducted by Andrew Wilson of Oxford University.

The famous "Antikythera mechanism" was retrieved among other artifacts from the shipwreck and is now on dislplay in the National Archaeological Museum in Athens. At times, it was considered an astrolabe, a planetarium/orrery, etc., whereas current evidence suggests that it is an astronomical and calendrical computing device of either a utilitarian value, e.g. used for navigation, or had a scientific/educational function. The inscriptions found on the mechanism date its construction between 150 and 100 BC. [10] The most important milestones in decoding the mechanism's structure were set by Derek De Solla Price and Michael Wright's work (initially with A. Bromley) and finally, by the International Research Group called The Antikythera Mechanism Research Project (Freeth, Mousas, Seiradakis, Bitsakis, etc.).

2. DESCRIPTION OF THE MECHANISM

The mechanism consists of plates with scaled display indications, pointers and inscriptions and a gearwork of at least thirty interlocking gearwheels with triangular teeth. Two scaled dials displaying the Egyptian Calendar and the Greek Zodiac Calendar, the sun and moon with its orbit and phase are distinguished at the center of the left plate. A pair of concentric toothed gearwheels, inside of which was another pair of eccentric gearwheels (with 50 teeth in total), was used to simulate the moon's variable speed in its mean and extreme position by engaging a special pin-and-slot motion transmission device. On the upper part of the right plate, the spiral Metonic cycle consisting of 235 synodic (lunar) months (based on the Corinthian calendar) is distinguished, covering 235X29.5/365=19 years (twelve 12-month years and seven 13-month years, i.e. with an intercalary month). It is suggested that the Callippic cycle that corresponded to a period equal to four Metonic cycles, i.e. 4X19=76 years, was used inside the Metonic spiral, on the left, to accurately calculate the lunar year's correspondence to the solar year. The Olympiad cycle, which is distinguised on the right, was used for the timing of the four ancient Panhellenic athletic competitions (Olympia, Pythia, Isthmia, Nemea) and two biennial local games, one of which is Naa, whereas the second one has not been identified yet. The spiral "Periodic Cycle" (Saros), consisting of 223 synodic months with a total duration of 223X29.5/365=8 years, is distinguished at the bottom of the right plate. The Exeligmos cycle, which corresponded to a period of time equal to a triple Saros Cycle, i.e. 3X18=54 years, is distinguished inside the Saros Dial. By turning a crank handle and thus selecting a date on the front 365-day dial, the other pointers moved to demonstrate all available astronomical information for that date, e.g. the position and phase of the moon, the correspondence between the solar and lunar calendar, the possible solar or lunar eclipses (within an hour's accuracy), etc. Alternatively, if the instrument's operator set a pointer to a particular astronomical or calendrical

event, e.g. a lunar eclipse or the Olympic Games, the date of the relative occurence in the past or future was demonstrated. [3, 4, 6, 7, 10]

3. THE GEOGRAPHICAL AND CHRONOLOGICAL CONTEXT OF THE MECHANISM'S CONSTRUCTION

M. Anastasiou, in her doctoral thesis, in 2010, studied the six astronomical events recorded on the mechanism's CI-a fragment for the year 150 BC with a 50-year deviation. According to her estimates, these events are better adapted to the geographical area between 33,3° S and 37° S, which includes Syracuse, Rhodes and, marginally, Corinth and Tauromenion. [5] On this basis, we may assume that this zone was directly related to the place of manufacture or the intended use of the mechanism.

Two local games with a four-year occurence, one of which one has not been identified yet, are displayed on the dial of athletic competitions. The one that has been deciphererd is NAA (Νάϊα). [4] These were athletic (and theatrical) games held in honor of Zeus every four years at Dodona from the 3rd century BC to the 4th century AD We may assume that the selection of both these 2 local games (the NAA and the unidentified one) were directly related to the place of manufacture and the intended use of the mechanism. This does not agree, however, with the mechanism's astronomical data mentioned above and leads to the assumption that Naa constituted the cultural past of the mechanism's intended use and therefore, the unidentified local games should be investigated in the geographical area between 33,30 S and 370 S.

All the months and their sequence displayed on the lunar calendar in the Metonic cycle have survived, mainly on the right lower part of the spiral: 1. Phoinikaios, 2. Kraneios, 3. Lanotropios, 4. Machaneus, 5. Dodekatheus, 6. Eukleios, 7. Artemisios, 8. Psydreus, 9. Gameilios, 10. Agrianios, 11. Panamos, 12. Apellaios. [3] This (Corinthian) calendar is extremely consistent with the partially known calendars from Northwestern Greece (Epirus) and specifically Corcyra, Dodona, Buthrotum, etc., on a lesser degree with Syracuse and Tauromenion, whereas it is quite diversified from Rhodian calendars. This fact, combined with the selection of the local Naa games, reinforces the cultural background of the mechanism's intended use significantly.

The moon's variable position and speed (mean-extreme position) with an ingenious eccentric gear arrangement and a pin-and-slot motion transmission device, as well as the 9-year periodic orbit of the direction of the moon's mean and extreme position were demonstrated in the mechanism's structure. The above data along with the parapegma's astronomical data indicate that the mechanism's intended use was rather scientific/educational than utilitarian ("fit for any purpose"), the accuracy of which would fall short due to its inevitable manufacturing and operational limitations. Calculating the eccentricity of the sun's and the moon's variable orbit falls absolutely within the scientific background of the time the mechanism was constructed and is specifically traced to Hipparchus (Rhodes, 190-120 BC) [1], [11], who was the only astronomer who executed precise astronomical measurements, such as the periodic precession of the equinoxes with a duration of 26.000 years and the most accurate calculation of the solar year (up until 1582 AD), which was, however, not established.

Other candidates, who rival for the scientific background of the mechanism, is Archimedes (Syracuse, 287-212 BC), Poseidonius (Rhodes, 135-51 BC) and Apollonius of Perga (Alexandria, 260-221 BC).

Based on the above, we can estimate the candidate cities of the mechanism's origins/use.

Syracuse: it is consistent with the geographical zone of astronomical data and partially with the mechanism's lunar calendar, as well as the chronological scientific background, whereas it does not agree with the ship's area of departure.

Northwestern Greece (Corfu, Dodona, Buthrotum, etc.): it is fully consistent with the mechanism's lunar calendar and the local athletic events, but it is excluded from the geographical zone of astronomical data, the chronological scientific background and the ship's area of departure.

Southeastern Aegean (Rhodes, Pergamum, Ephesus): it is fully consistent with the ship's area of departure, only Rhodes agrees with the geographical zone of astronomical data and the chronological scientific background (Hipparchos), whereas it does not agree with the mechanism's lunar calendar and local athletic events.

Alexandria: it is partially consistent with the ship's departure area and the chronological scientific background, but it is excluded from the geographical zone of astronomical data, the mechanism's lunar calendar and local athletic events.

If we consider the ship's departure area, the geographical zone of astronomical data and the chronological scientific background as necessary conditions, then we should limit our search in the zone of southeastern Aegean and target Rhodes exclusively. This implies that the mechanism was intended for a community of settlers in Rhodes who had come from Epirus - Northwestern Greece (Naa, lunar calendar). In 168 BC, the Roman legions of Aemilius Paulusplundered and savagely destroyed 70 cities in northwestern Greece, enslaved and shipped 150.000 Epirotes to Italy. The famous Epirote Confederacy was dissolved as a result of the Molossi alliance with the Macedonians and the other two partners', Chaones and Thesproti, alliance with the Romans. Due to the absolute devastation, no human activity is reported for a period of 500 years in Epirus. The cultural group recorded in the mechanism's lunar calendar and the local games is not bound to their actual living space but to their place of enslavement in Italy or settlement in the free cities of Greece. [2] During the same period, Rhodes allows various populations to settle on the island. As a typical example, we mention the emigration of Jews during the 2nd century BC. It seems, therefore, likely that settlers from Epirus, for whom the particular mechanism was built, had moved to Rhodes. It makes perfect sense that a number of equivalent mechanisms would have been produced for other cultural groups residing on the island. Therefore, the rest of the mechanism's characteristics should be sought in Rhodes.

The Dipanamia - Halieia

In the southeastern Aegean area (departure point of the ship) the major athletic festivals were Halieia and Halia in Rhodes, Artemisia and Ephesia in Ephesus and Halia in Pergamum. Especially as far as Rhodes is concerned and taking into account that the

Games took place at four-year intervals, evidence points to the Great Halieia, which was a prestigious festival that took place from 300 BC until 300 AD in honor of the Sun - Apollo, "patron" god of Rhodes ("Aliu" in Dorian dialect), every four years at the summer solstice during the intercalary month Panamos (Dipanamos), hence it was also called "Dipanamia". The winners of the athletic competitions were awarded a wreath of poplar leaves ("Aigeirou") as prize. [9]

The Dipanamos intercalary month

The Rhodian calendar is a very special and highly sophisticated calendar. The Halieia took place exclusively during the intercalary month of Panamos, the last month of the Rhodian calendar. This creates significant problems for the 19-year Metonic calendar. First, it requires the use of the intercalary month of Panamos every 4 years in the 1st,5th,9th,13th and 17th year of the 19-year cycle, whereas the two extra intercalary months should be equally divided, e.g. in the 3rd and 11th years. The resulting distribution is (2-2)-4- (2-2)-4-3, which can obviously start from any year in the cycle but does not constitute a mathematically equal distribution. Second and more importantly, the fact that the number of athletic competitions staged every four years in the 19-year cycle is not an integer (4 ¾), establishes a 76-year lunar calendar that includes 19 athletic competitions with 4-year intervals. This can be practically implemented by repeating the last (19th) year during the first three 19-year Metonic calendars and removing the last three years in the fourth 19-year calendar by adding an intercalary month. It would be plausible that the mechanism's, potentially Rhodian, manufacturer, captured this complex reasoning in the mechanism's lunar calendar, even though the Dipanamos month, as preparation month for the Dipanamia Rhodian festival, would be the penultimate month displayed on the mechanism. (In a period of eight years, the three intercalary months would be incorporated in the 1st, 4th and 5th year.)

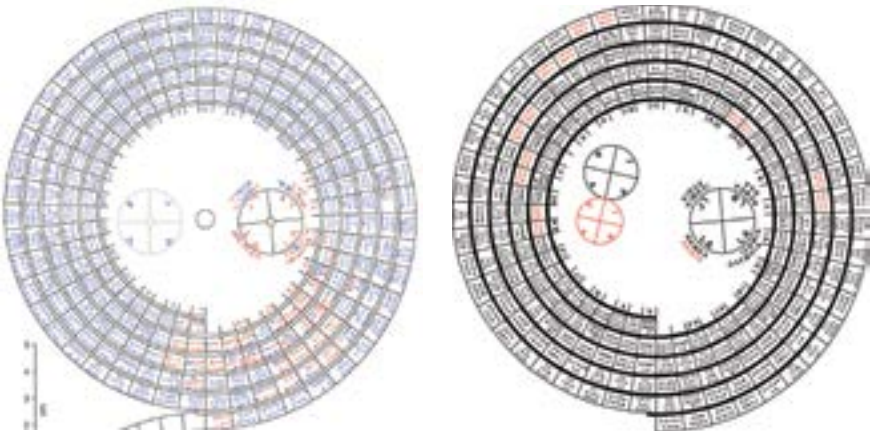


Figure 1. On the left, the considered up to date upper back dial of the mechanism [4] and on the right, the proposed arrangement

In Figure 1 on the left, the Metonic spiral calendar is displayed. Red letters indicate the months of the calendar that have been deciphered, while EUKLEIOS is proposed as intercalary month, present in all seven years, which incorporate intercalary months in the following sequence: 1st,3rd,6th,9th,11th,14th and 17th year in the 19-year cycle that applies the equal distribution 2-3-2-3-2-3-3-3. [3, 4]

M. Anastasiou deciphers four additional months on the Metonic spiral in her doctoral thesis in 2010: during the 1st year, the month of Lanotropios (subdivision 3), during the 3rd year, the month of Dodekateus (subdivision 31) and most significantly, during the 11th year, the month of Machaneus (subdivisions 128 and 129) that establishes this month as intercalary for the 11th year. [5] This finding excludes the month of Eukleios as intercalary month for the 11th as well as the 3rd year, during which the intercalary month is placed within the first 4 months of the calendar. According to the above mentioned research, the intercalary month of the spiral calendar is either fixed and identified as Machaneus or different every time with no mathematical criterion. If it was chosen with the use of interpolation, this month would be (235/7)th months apart from the previous one.

The present study proposes Panamos as an intercalary month of the Halieia games for the 1st, 5th, 9th, 13th and 17th year in the 19-year Metonic cycle and Machaneus for the 3rd and 11th year as a differentiation. The proposed lunar calendar of the Metonic spiral is reconstructed and illustrated in Figure 1 on the right and is not in conflict with the up to date established readings.

The “Hipparchian cycle”

It would be reasonable to assume that Hipparchus, to whom the mechanism's construction is attributed, as already mentioned above, had made precise estimates of the tropical solar year, i.e. 365+1/4-1/300, in the 2nd century BC Rhodes. [1, 11]. This was also dictated by the mechanism's scientific/educational intended use. Therefore, according to our proposal, the Callippic cycle is slightly reduced in size and a "Hipparchian cycle" is introduced. This cycle should form a dial with four quadrants and anticlockwise indications, corresponding to 4 Callippic cycles, i.e. 304 years. Mechanically speaking, only two toothed gearwheels are required, i.e. a 15-tooth gearwheel embedded on the Callippic shaft and a 60-tooth gearwheel on the Hipparchian shaft. The device's operator would have to subtract 6 hours every 76 (conjectural) years or a day every 304 years.

4. CONCLUSIONS

The present research, based on the geographic and chronological context of the mechanism's construction assumed Rhodes as the place of its manufacture and identified Hipparchos behind its conception. The Dipanamia - Halieia festival was proposed as the unidentified to date local athletic competitions. Panamos was proposed as the intercalary month that corresponded to Dipanamos of the Rhodian Halieia (and Machaneus) as an intermediate month. The mechanism's lunar calendar was reviewed to agree with this hypothesis and the up to date data of the inscriptions. Moreover, the

adoption of a 304-year "Hipparchian cycle" after the Callippic cycle was proposed, so that the most important astronomical instrument of antiquity would be consistent with the perceived duration of the solar year at the time of its construction.

5. REFERENCES

[1] Ptolemy, Mathematical Syntax (Almagest), TLG

[2] Polybius, Histories XVI, TLG

[3] Freeth, T.; Bitsakis, Y., Moussas, X., Seiradakis, JH, Tselikas, A., Mangkou, E., Zafeiropulou, M., Hadland, R., Bate, D., Ramsey, A., Allen, M., Crawley, A., Hockley, P., Malzbender, T., Gelb, D., Ambrisco, W., & Edmunds, M.G. "Decoding the ancient Greek astronomical calculator known as the Antikythera Mechanism" (2006) Nature 444.

[4] Freeth, T. Jones Al., Steele J. & Bitsakis, Y., "Calendars with Olympiad display and eclipse", (2006), Nature 454.

[5] Anastasiou M., The Antikythera Mechanism: Astronomy and Technology in Ancient Greece (2014), Ph.D thesis.

[6] Moussas X. “The Antikythera Mechanism, Table ”, (2012), Hellenic Union of Physicists Editions

[7] Price D. S., “Gears from the Greeks: The Antikythera Mechanism - A Calendar” (1975).

[9] Danezis M., Theodosiou S., “ The Odyssey of Calendars ”

[10] Hellenic Ministry of Culture and Tourism, "The shipwreck of Antikythera - The Ship, the Treasures, the Mechanism" (2012)

[11] Hipparchus, Commentary on the Phaenomena of Eudoxus and Aratus, TLG

B5. TECHNOLOGY

B5.1 The Greek Legacy in Mechanical Engineering for its Development and Promotion.

Marco Ceccarelli
University of Cassino and South Latium, Italy,

Abstract

Greek Mechanics can be still recognized in modern mechanical engineering both in concepts and procedures as well as in mechanism designs. The paper illustrates what is old in what is considered new by highlighting the Greek legacy that are still persistent in modern developments and promotion activities of mechanical engineering. Greek legacy can be recognized mainly in the concepts for mechanical analysis of machine functioning, in the machine designs with visionary applications (like those automata for theater plays or religious acts), and in the optimistic spirit that Science and particularly Mechanical Technology with their applications will give benefits and improvements in the Society.

1. Introduction

Nothing is new except what has been forgotten: this was written by the Roman engineer Julius Sextus Frontinus in 1st century BC. Are today mechanical systems really new? How much in Mechanism Design has fundamentals in concepts and approaches from Ancient Greek Mechanics?

This paper presents a personal perspective of the author on how much can be still recognized in modern mechanical engineering mainly related to Mechanism Design with characters of ingenuity of Ancient Greek achievements.

In general, the fundamental contribution of Ancient Greek culture (Philosophy and particularly Mechanics) is well recognized in historical evolution of Science and Technology, within a huge literature. A considerable literature can be referred to on such a historical views with different viewpoints. However, specific considerations on developments of machine technology with ancient Greek characters is very seldom worked out, as pointed out by Dimarogonas (1993).

The history of mechanical engineering is also usually attached with timeline con-

tributions that often forget background of fundamentals, like for example in Bautista et al, 2010; Rossi and Pagano, 2011.

However, attention is recognized in searching principles guiding machine developments over time, like for example in Roth (2004). Specific studies and investigations are also elaborated to keep record and give interpretation for an inspiration from the past for modern development, as reported in the Proceedings of HMM Symposia (from 2000 up to 2016) and even in Dictionary series on Legacy of past figures (Ceccarelli 2007, 2010, 2015).

In this paper a brief survey is presented with examples that can show the ancient Greek ideas still persistent in modern engineering as a tribute to the Ancient Greek capability to transfer Science results into practical applications, despite of the general belief that the ancient Greek philosophers/scientists were not interested in applying their speculations.

The discussion is focused on three main aspects, namely development of theories with algorithm formulation for designing and testing, identification and formation of professionals in machine design, and multidisciplinary integration. Examples are presented to show how much is old in what is considered today new, but with Greek legacy.

2. Greek legacy in modern times

It is known that in Antiquity Science and Philosophy were considered activities with contents of high significance, while Technology was treated as a means that was no-strictly related to scientific knowledge but rather as an activity of manual labor and therefore of minor significance for culture (Ceccarelli and De Paolis 2008). Nevertheless, the Greek philosophers were always looking for application of Science results and even within technological advances.

It is also recognized that the service that Technology can offer to Science developments can be relevant as pointed out in Ceccarelli (2012).

Thus, the interaction and mutual influence of Science and Technology has been established since their beginnings and the Greek approaches are somehow still persistent nowadays as a cultural backgrounds.

In the following main aspects in machine technology are discussed with few emblematic examples also for further considerations by readers.

3. Theory and experimental activity on machine designs

Today Theory of MMS is considered as related to abstraction and algorithm deduction, which are indeed invented by the Greek philosophers.

But the meaning of the word ``theory'' needs a clear explanation. The Greek word for Theory comes from the corresponding verb, whose main semantic meaning is related with examination and observation of existing phenomena. Even in its classical meaning the word theory includes practical aspects of observation as experiencing the reality of phenomena, so that theory means also the application of results from anal-

ysis. In fact, this last meaning is what was included in the discipline of modern TMM (today MMS) as Monge established it at Ecole Polytechnique at the beginning of the XIX Century (see, for example, the book by Lanz and Betancourt (1808), including synthesis procedures). In conclusion, the modern meaning of MMS is of a discipline that treats both analysis and synthesis of mechanisms and machines. In fact, the IFToMM Terminology, published in Mechanism and Machine Theory in 1991 and 2003 states:

Machine: mechanical system that performs a specific task, such as the forming of material, and the transference and transformation of motion and force.

Mechanism: system of bodies designed to convert motions of, and forces on, one or several bodies into constrained motions of, and forces on, other bodies.

As an example let's refer to the mechanics of levers that was and still is somehow the basis of mechanics of mechanisms. The ideas come from Archimedes, who, after abstracting all the machines with elementary elements (which is an important basis for modern mechanism design and rationalization), formulated its functioning with mechanical principles (being the first stating the equilibrium of momentum), (Ceccarelli 2014). Fig.1 summarizes the above as from the work of Galilei as pointed out in (Ceccarelli 2006) by considering the real system in a) with its early kinematic diagram in b) and interpreted model in c) from the fist academic approach on analysis and design of machine in 1593-98. This is an example that can be used to consider the modern classifications of machines via machine elements and elementary machines coming from the Greek mechanics and its speculations. The analysis of the functioning of machines is a result of observation and abstraction with a deduction process that was invented by the Greek philosophers and still nowadays we still use it also in machine analysis and design. The mathematical formulation of the mechanical principles is a modern means but it can be recognized with a reasoning that is due again to the Greek philosophers. In addition it is not of least observation to remark that the mentioned 'theoretical' activity is based on experimental results of observation of machine functioning, as Galilei following the Greek traditions made as fundamental for Science and Technology developments.

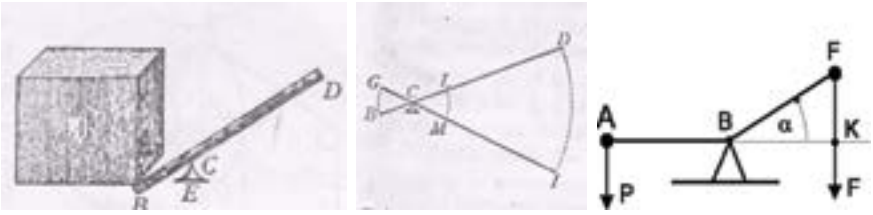


Fig1. The Greek concepts in analysis of machine elements by Archimedes: a) the mechanical lever; b) its kinematic diagram; c) its interpreted mechanical model

Professionals with specific dedication in machine technology

The scientific activity in mechanical engineering and MMS both in research and teaching is today aimed to form new generations of engineers and scientists, who while de-

veloping engineering science and transferring its results in applications, will improve the quality of life of mankind.

The figure of professionals in machine technology was determined at the time of Roman Empire with person who were devoted to the construction and operation of machines through a practical expertise. The modern figure of engineers in machine technology can be considered established at the time of Renaissance (Ceccarelli 2008), but the full identity and dignity were achieved during the Industrial Revolution in the 19th century.

In Greek antiquity it is possible to recognize those figures in the μηχανικοί (engineers) and philosophers with interest in applications, respectively. Therefore it can be considered that since Greek antiquity it was understood and successfully experienced that machine technology need professionals with full dedication and with link to Science developments. Actually today it is also more and more evident that Science achievements are strongly linked to Technology developments with figures that have expertise in both areas – this is the case of MMS scientists, who work for theoretical developments and apply those results in novel designs within the same activity frames.

The need of dedicated professionals required specific formation and community aggregation. The Greek culture developed schools of philosophers and the Alexandria School with more evident link to technology, as emblematic frames that were of inspiration for the modern academic systems and research centers with formation of engineers. This happened in many disciplines but particularly significant was in the arras for machinery and machine technology.

The community aggregation can be recognized in the philosophy schools in antique Greece and nowadays in the engineer professional unions, but even more in associations and societies with key role of individuals. Of relevant significance in mechanical engineering but in MMS is the community of IFToMM; the international Federation for the promotion of MMMS (www.iftomm.net) with those Greek legacy characteristics of collaboration and share knowledge for dissemination and mankind improvement without any political or geographical barriers, Fig.3.

Fig.2 A historical moment of the foundation of IFToMM, the International Federation for the Theory of Machines and Mechanisms, in Zakopane (Poland) on 27 September 1969, (Courtesy of IFToMM Archive) in which one can recognize: 1- Prof. Ivan Ivanovic Artobolevskii (USSR); 2- Prof. Adam Morecki (Poland); 3- Prof Kurt Luck (Germany); 4 – Mikael Konstantinov (Bulgaria); 5- Prof. Nicolae I. Manolescu (Romania); 6- Prof. Erskine F. Crossley (USA); 7- Prof. Giovanni Bianchi (Italy); 8-Prof. Aron E. Kobrinskii (USSR); 9- Prof. Werner Thomas (Germany); 10- Prof. Jan Oderfeld (Poland).

2. Vision with multidiscipline integration

Today the modern systems are developed by using mechatronic concept of multidiscipline integration as fundamental for designing and operating efficient systems, Fig.3 a). Mechatronics is considered an engineering technology that has been developed in last few decades but its conception can be found in the Greek designs of automata, since their first solutions for the theater play assistance.

Mechatronics is usually considered a last achievement of modern engineering by which modern systems are designed and operated because of integration of several components of different natures with a multi-disciplinary engineering approach. Although engineer formation was and is still achieved by teaching separately courses on specific disciplinary subjects, nevertheless machines have been always treated by looking at the integration of different aspects. Of course, nowadays the multitude and sophistication of those multi-disciplinary aspects require to emphasize on the multi-discipline characters asking expertise in specific fields but in a wide context. Technical integration of different engineering aspects was considered also in the past, (Ceccarelli 2007). In fact, one can find early mechatronic designs in Greek machine solutions like in the example of Fig.3b) in which a complex machine by Heron of Alexandria (who lived in 2nd century BC) is reproduced in a drawing during Renaissance to show a so-called hydraulic organ with a combination/integration of mechanisms, hydraulic actuators, and regulation devices.

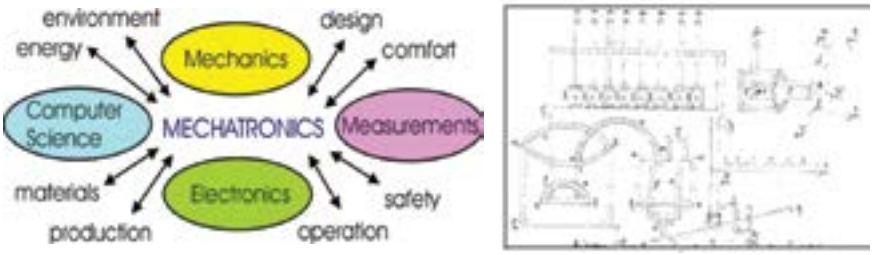


Fig.3. Multidiscipline integrated design of machines: a) the modern mechatronic concept; b) hydraulic organ designed in the 2nd century BC by Heron of Alexandria as redrawn in 15th century

4. Conclusions

This paper presents the author's understanding of the Greek legacy in modern MMS with characteristics that are still persistent in modern activity and can be worth full to be made aware even for future developments. The main points of the paper can be summarized in recognizing relevant Greek legacy in mechanical engineering, even specifically in MMS, within modern engineering analysis and design, formation activity with dissemination purposes, and visionary multidiscipline solutions with modern features.

5. References (limited to the author's works and experience for space limits)

Bautista Paz E., Ceccarelli M., Echavarri Otero J., Munoz Sanz, J.J., A brief illustrated history of machines and mechanisms, Springer, Dordrecht, 2010.

Ceccarelli M., 1999, "On the meaning of TMM over time", Bulletin IFToMM Newsletter, Vol.8. Nr.1.

Ceccarelli M., "Early TMM in Le Mecaniche by Galileo Galilei in 1593", Mechanisms and Machine Theory, 2006, Vol.41 No.12, pp 1401-1406.

Ceccarelli M., What is old in what is new in MMS research, Special Lecture, Proc. of 13-th Symposium on MMS, Japan Council of IFToMM,Tokyo, 2007, pp.1-11.

Ceccarelli M., An Outline of History of Mechanism Design in servicing Science, In Physics, Astronomy and Engineering: critical problems in the History of Science and Society – Proc. of SISFA 2012, The Scientia Socialis Press Siauliai, (Invited lecture) pp.1-10. ISBN 978-609-95513-0-2

Ceccarelli M., De Paolis, A Brief Account on Roman Machines and Cultural Frames, Proceedings of HMM2008- the Third IFToMM International Symposium on History of Machines and Mechanisms, Springer, Dordrecht, 2008, pp. 83-100. ISBN 978-1-4020-9484-2

Dimarogonas A.D., 1993, "The Origins of the Theory of Machines and Mechanisms", in Modern Kinematics – Developments in the Last Forty Years Ed. by A.G. Erdman, Wiley, New York, pp.3-18.

Ceccarelli M. (Ed.), International Symposium on History of Machines and Mechanisms - Proceedings of HMM2000, Kluwer, Dordrecht, 2000.

Ceccarelli M. (Ed.), International Symposium on History of Machines and Mechanisms - Proceedings of HMM2004, Kluwer, Dordrecht, 2004.

Yan H.S. and Ceccarelli M. (Eds.), International Symposium on History of Machines and Mechanisms - Proceedings of HMM2008, Springer, Dordrecht, 2008.

Koetsier T. and Ceccarelli M. (Eds.), Explorations in the History of Machines and Mechanisms - Proceedings of HMM2012, Springer, Dordrecht, 2012.

Lopez-Cajùn C. and Ceccarelli M. (Eds.), Explorations in the History of Machines and Mechanisms - Proceedings of HMM2016, Springer, Dordrecht, 2016

Ceccarelli M. (Editor), Distinguished Figures in Mechanism and Machine Science: Their Contributions and Legacies – Part 1, Book series on History of Machines and Machine Science, Vol.1, Springer, Dordrecht, 2007.

Ceccarelli M. (Editor), Distinguished Figures in Mechanism and Machine Science: Their Contributions and Legacies – Part 2, Book series on History of Machines and Machine Science, Vol.1, Springer, Dordrecht, 2010.

Ceccarelli M. (Editor), Distinguished Figures in Mechanism and Machine Science: Their Contributions and Legacies – Part 3, Book series on History of Machines and Machine Science, Vol.1, Springer, Dordrecht, 2014.

Lanz J.M. and Betancourt A., Essai sur la composition des machines, Paris, 1808.

IFToMM, IFToMM Commission A. Standard for Terminology, Mechanism and Machine Theory, 1991, Vol.26, n.5.

IFToMM 2003, special issue 'Standardization and Terminology', Mechanism and Machine Theory, Vol.38, n.7-10.

Marco Ceccarelli, Contributions of Archimedes on mechanics and design of mechanisms, Mechanism and Machine Theory, 72 (2014) 86–93, http://dx.doi.org/10.1016/j.mechmachtheory.2013.10.005 .

Rossi C., Pagano S., A Study on Possible Motors for Siege Towers, J. Mech. Des 133(7), 071009 (Jul 19, 2011) (8 pages) doi:10.1115/1.4004197

Roth B., The Search for the Fundamental Principles of Mechanism Design, Proc. of HMM2000 - the First IFToMM International Symposium on History of Machines and Mechanisms, Kluwer, Dordrecht, 2000, pp.187-195.

B5.2 The Genesis of the Science of Machines: Theory and Practice Combined.

Teun Koetsier
VU University, Amsterdam, Netherlands

Abstract

Presumably Archytas of Tarentum wrote the first book on Mechanics. In the Hellenistic period Mechanics developed into an accepted sub-discipline of Mathematics consisting of a theoretical part and a practical part. In the present paper we will make some remarks about the genesis of the discipline with special attention in the role played by mathematicians.

1. Introduction

Geminus (1st century BC) distinguishes two kinds of mathematics: mathematics dealing with intelligibles (arithmetic and geometry) and mathematics attending to sensibles (mechanics, astronomy, optics, geodesy, harmonics, calculation) [20], pp. 31-32. Compared to the traditional Pythagorean quadrivium there are four new subjects. This paper is about one of them: *mechanics or the science of machines*. We will attempt to sketch the genesis of mechanics before Geminus and concentrate on the role of mathematicians in the process.

What do we know? Vitruvius (1st century BC) in *De Architectura* mentions twelve authors of works on mechanics.[1] Vitruvius seems to have seen their works. With the exception of Archytas, Archimedes, Ctesibius and Philon, however, we do not know anything about these men and their work. Elsewhere Vitruvius mentions Archimedes and Archytas again and this time together with Aristarchus of Samos, Philolaus of Tarentum, Apollonius of Perga, Erathostenes of Cyrene and a Syracusan Scopinas as men who left to posterity "many things connected to mechanics and sundials".[2] We know these men, but as for their work in mechanics we do not know much with certainty. Many manuscripts were lost. Actually all we have in more or less complete form are the following texts directly dealing with machines: Mechanical Problems from the Aristotelian cor-

1. [27] Book VII, Introduction, Paragraph 14. They are: Diades, Archytas, Archimedes, Ctesibius, Nymphodorus, Philon of Byzantium, Diphilus, Democles, Charias, Polyidus, Pyrrus, and Agesistratus.
2. [27] Book I, Chapter I, Paragraph 16.
3. The fact that Heron's mechanics only survived in an Arabic translation illustrates how easily major works could get lost.

pus (4th or 3d century BC), the artillery manual of Philon of Byzantium, the *Belopoeica* (probably 3rd century BC), Biton's text on war machines and artillery, *Construction of war engines and catapults* (probably 3rd century BC), Vitruvius' book (1st century BC) and several of Heron's works (1st century AD): in particular *the Belopoeica on artillery and the Cheiroballistra* (on the hand-ballista), *the Mechanica*[3] and the *Automata*.

Because of the lack of sources our reconstruction is necessarily hypothetical.

2. The Athenian period

In his description of the life of Marcellus, Plutarch writes: "*For the art of mechanics, now so celebrated and admired, was first originated by Eudoxus and Archytas* (Emphasis is mine- TK)".

He describes how the mathematicians Archytas of Tarentum and his pupil Eudoxus in solving the geometrical problem of finding two mean proportional lines, had recourse to mechanical arrangements. Plutarch adds: "*But Plato was incensed at this, and inveighed against them as corrupters and destroyers of the pure excellence of geometry, which thus turned her back upon the incorporeal things of abstract thought and descended to the things of sense, making use, moreover, of objects which required much mean and manual labour. For this reason mechanics was made entirely distinct from geometry, and being for a long time ignored by philosophers, came to be regarded as one of the military arts*" [19] chapter 14.

In Plutarch's story Plato defends the purity of mathematics and criticizes Archytas and Eudoxus. It seems that Plato's criticism did not have much effect. Archytas, for example, was genuinely interested in machines. According to Aristotle he designed a rattle for children and probably an automaton in the shape of a wooden dove. The dove may have been connected to a pulley and a counterweight in order to "fly" upwards in the twilight (to make the strings invisible). Moreover, Archytas was not only interested in practical mechanics, but in its theory as well. Diogenes Laertius writes that Archytas wrote a systematic treatise on mechanics based on mathematical principles [6]. Vitruvius mentions Archytas too as author of a text on mechanics. The oldest extant book about mechanics is Mechanical Problems. It is often assumed that it was written by a pupil of Aristotle in the time of Strato, who was a contemporary of Euclid. Yet Krafft has argued that the text was probably written by the young Aristotle and he traces part of its contents back to Archytas [12].[4] I assume that Archytas' treatise will at least have contained in some germinal fashion the results that we find in the *Mechanical Problems*[5].

4. Recently Thomas Nelson Winter has given an argument that identifies Archytas as the most likely author [28].

5. According to Humphrey et al the steelyard (balance with unequal arms) replaced the Bronze Age balance pans for weighing sometime in the Hellenistic period [7], p. 50. At the time *Mechanical Problems* was written the steelyard was generally used. Mark Schiefsky has correctly pointed out that in *Aristophanes' Peace* (421 BC), 3d Act, 1st Scene, the main character Trygaeus suggests an arms dealer to transform a trumpet into a steelyard for weighing figs: "Well, here's another idea. Pour in lead as I said, add here a dish hung on strings, and you will have a balance for weighing the figs which you give your slaves in the fields". Source: http://classics.mit.edu/Aristophanes/peace.html. Conclusion: the steelyard was known much earlier than the Hellenistic period.

The basic idea of the *Mechanical Problems* is that the functioning of many tools can be understood by means of the law of the balance and the law of the balance is related to circular motion: the effect of a weight is viewed as proportional to the distance covered when we rotate the balance. *Mechanical Problems* is a book on theoretical mechanics aimed at understanding, not at design. A clever Pythagorean like Archytas, keen on discovering regularity in terms of numbers in the world, will have appreciated the law of the balance.

The problem that Eudoxus and Archytas attempted to solve by mean of 'mechanical' methods was the problem of finding two mean proportional lines: Given two straight line segments A and B find by means of a construction two other straight line segments X and Y such that A:X=X:Y=Y:B, This is a problem from pure mathematics. The well-known problem of the doubling of the cube (given the edge of a cube, find the edge of a cube that has a volume that is twice as big) is a special case. When we have the two mean proportional lines X and Y of A=1 and B=2 we have $X^3=2$. This means that we doubled a cube with edge length 1.

Plato imagined a solution based exclusively on the use of compass and ruler. We do not know which 'mechanical' solution Plato must have referred to in the case of Eudoxus. Archytas' very ingenious construction takes place in space and requires several rotations. For a recent discussion see [16]. It is based on a curve that is being generated by rotating a semicircle about one of its tangents and intersecting this semicircle during its motion with a cylinder. The generation of the cylinder requires a rotation as well. Moreover, the curve that we get in this way is intersected with the surface of a cone, obtained by rotating a triangle about a straight line. According to the story, for Plato all these motions made the solution mechanical and unacceptable. It is hardly a practical solution but it is a wonderful example of visual thinking, of the kind that mechanical engineers are good at [3].

At the end of the years of Athenian glory dramatic events radically changed the world. King Philip of Macedonia prepared the ground and his son Alexander (356-323) took the dynamic of the Macedonian conquest to unprecedented lengths. Alexander's father was one of the first to use torsion catapults. It is possible that the Greek engineers had drawn the conclusion that of the three materials in the composite bow, sinew, wood and horn, the major contribution to the power came from the sinew. The next question is: How can we better use the sinew? Their answered was: by twisting a sinew bundle! The basic idea is that one can plait sinew into cords and wrap the cords around two parallel beams. By twisting one of the beams the bundle of cords can be stretched considerably and a huge tension builds up. A lever pushed through the middle of such a stretched bundle can exert an enormous force if pulled out of its position. The torsion catapult was based on two of such bundles. See Figure 1. In Alexandria mathematicians would get involved in the design of such machines. We saw above that Plutarch hinted at the military origin of mechanics.

3. The Alexandrian period: Erathostenes

The successors of Alexander in Egypt, the Ptolemies, turned Alexandria into the power

house of Greek culture. They founded the famous Museum with its library in which they collected men with very different backgrounds and abilities, not only theoreticians but engineers as well.

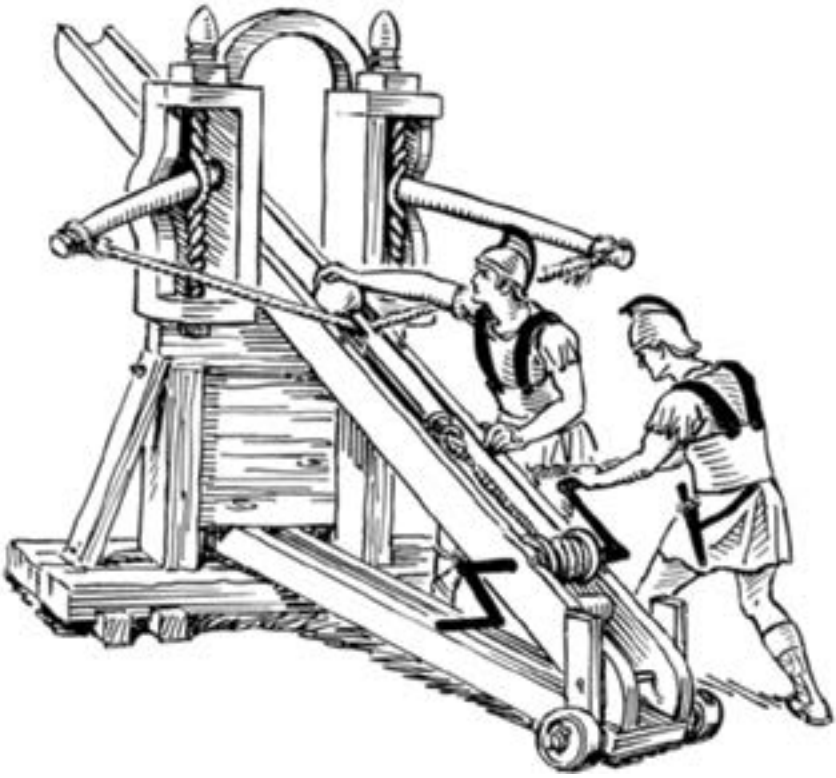


Figure 1 Sketch of a torsion catapult.[6]

In Alexandria the engineers were highly respected individuals. In the anonymous *Laterculi Alexandrini* from probably the 2nd century BC, which contains some sort of "hall of fame"[7], the engineer Abdaraxus is mentioned as "*he who constructed the machines in Alexandria*" [5], p. 429. The engineers impressed the kings with remarkable machines. We have a description by Kallixeinos of Rhodes of a Grand Procession that took place in Alexandria in the early third century BC. In Kallixeinos' description we read: "[...] *a four-wheeled cart was led along by sixty men* [...] *twelve feet wide, on which there was a seated statue of Nysa twelve feet tall, wearing a yellow chiton woven with gold thread, and wrapped in a Laconian himation. This statue stood up mechanically without anyone laying hand on it, and it sat back down again after pouring a libation of milk from a golden phiale*".[8]

6. Source: Person Scott Foresman, https://commons.wikimedia.org.
7. In the words of Lucio Russo [21], p. 96.
8. See [22], pp. 10-13. We discussed this automaton in [11].

Understandably the Alexandrian engineers spent considerable time on the engines that were used in warfare. According to Philon the methods to design catapults that would throw a specific weight over a specific distance were discovered after experimentation and investigation and discovered at "*Alexandria through much association with the craftsmen engaged in such matters and through intercourse with many craftsmen in Rhodes, from whom we understood that the most efficient engines more or less conformed to the method we are about to describe.*" [15], p. 109.

Heron wrote: "*When one efficient engine has been completed, it is possible to calculate others from it. Let the diameter of the engine be AB, and let it be required that we construct from it another engine throwing, let us suppose, a missile treble the size of the one mentioned. Now, since the spring is the cause of the discharge of the stone, the engine to be calculated will need a spring treble the size of the one whose diameter is AB, and not with just any sort of hole, but with the spring's height proportionate to the hole, so that the cylinders formed by the springs are similar*" [15], p. 41.

This immediately leads to the calibrating formula for stone-throwers. Let us suppose the Alexandrians experimented with an engine with a spring diameter of 11 dactyls (21 cm), hurling weights of 10 minae (4366 grams) over a distance of several hundred meters. Merging three of such machines gives an engine that can throw 30 minae. This means we triple the volume of all parts. This gives more generally, if we want to throw a weight of λ.10 minae, that we need a sinew cylinder with a volume equal to λ times the volume of the original cylinder. For the diameter this means that we have to multiply it with the cube root of λ, which immediately leads to the calibrating formula

$$diameter = \mathbf{11} . \sqrt[3]{(\frac{weight}{10}} = 1{,}1 . \sqrt[3]{100 . weight}$$

Here 11 is the diameter of the engine that can throw 10 minae over several hundred meters. This formula is given by both Heron and Philon, although in words [15], p. 41.

Mathematicians were involved. Erathostenes of Cyrene (3rd century BC) served under King Ptolemy III Evergetes, the third ruler of the Ptolemaic dynasty in Alexandria. In order to thank Ptolemy Erathostenes erected a monument. It consisted of a column with an epigram inscribed on it:

"*If you purpose, o good sir, to build from a small one a double cube, or any solid nature into another well to transform, this is possible for you* [...] *but the hardly contrived works of Archytas' cylinders and the cone-sectioning of Menaechmean triads seek you not, neither seek to trace out some such curvilinear form of the god-like Eudoxus; for in these very plates you could easily build ten thousand means-tracers, beginning out of a slight base.* [...] *anyone seeing this monument, may he say, this is* (*the gift – TK*) *of the Cyrenean Erathostenes*" [9], p. 150.

The text refers to an instrument that Erathostenes had devised to determine the mean proportional of two arbitrary given lines. Just below the crown of the column the instrument made of bronze was fastened and below it there a short proof of its functioning correctly together with a figure [26], pp. 294-295.

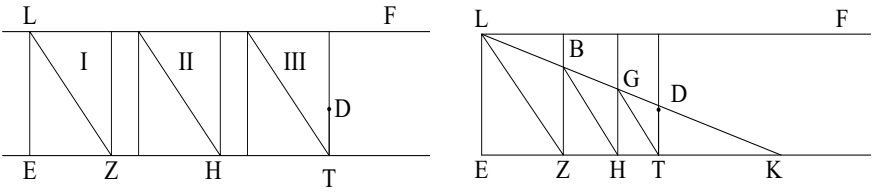


Figure 2 and 3 Erathostenes' instrument.

Consider Figure 2. The three rectangular plates, I, II and III, are congruent. The one in the middle is fixed, the other two can slide between the two parallel lines LF and ET. Rectangular plate number III slides to the left under de one in the middle and rectangular plate number I slides to the right above one in the middle. While the rectangular plates are sliding G is the point of intersection of the diagonal of III and the right edge of II. Point B is the point of intersection of the diagonal of II and the right side of I. The point D is a point that we have marked on the right edge of III. The goal is to find the two mean proportionals of LE and TD. Figure 3 shows that we can slide the rectangular plates in such a way that the points L, B, G and D are collinear. This is realised by means of a ruler LK. We have

$$LE:BZ=BZ:GH=GH:DT.$$

Erathostenes' instrument was designed to be used also by the builders of torsion catapults. Eutocius wrote about it: "*and this conception will be useful also for those wishing to increase artillery and stone throwing devices; for all these must be increased relative to both the thicknesses and the sizes, and the apertures and the washers and the inserted cords, if also the shot is to be increased proportionately and these cannot be done without the finding of the means*" [9], p. 148. Independent of whether Erathostenes' instrument was really useful, the interaction between Alexandrian scholars and craftsmen was considerable.

The catapults did not radically change the way in which wars were fought. Yet they could inflict considerable damage. Flavius Josephus (1st century AD) wrote: "*The force of the spear-throwers and catapults was such that a single projectile ran through a row of men, and the momentum of the stones hurled by the engine carried away battlements and knocked the corners off tower*" [8]. Modern research confirms that the machines must have worked quite well [23].

4. The Alexandrian period: Archimedes (c. 287 – c. 212)

Archimedes is considered to be the greatest mathematician of classical antiquity. It seems probable that his father, the astronomer Pheidias, taught him the fundamentals of mathematics and sent him afterwards to Alexandria. There he will have met Erathostenes and Conon of Samos and maybe Dositheus of Pelusium, later Archimedes' main correspondent in Alexandria.

9. Source of figure and proof: [2], p. 36.

Archimedes may even have met the old Euclid in Alexandria. It is interesting that there is an Arabic manuscript of a text called *Euclid's book about the balance* in which an axiomatic deduction of the law of the balance is given. This work is theoretical mechanics, like the *Mechanical Problems*, although the approach is different and not based on the properties of circular motion.

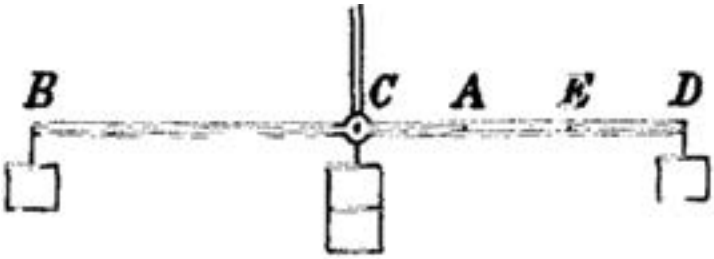


Figure 4 Euclid's proof of the law of the balance.[9]

Duhem summarized the idea of the proof as follows. Equals weights W are suspended in B and D with CD=CB. WE have equilibrium. CA=AE=ED are each one third of CD. One of the axioms now says that if in a situation of equilibrium we move on one arm a weight over a certain distance d towards the centre and at the same time on the same arm an equal weight d over an equal distance away from the center equilibrium is maintained. We apply the axiom twice and move the weight *W* from D to A in two steps. The result is equilibrium with B stil hanging from B and now *3W* hanging from A.

Nota bene: the axiom is rather natural: it concerns changes on one arm symmetrical with respect to its middle. The text shows how mathematicians attempted to give the the approach to machines that we find in *Mechanical Problems* a more rigorous foundation.

When Archimedes returned to Syracuse he had absorbed everything there was to know about in mathematics and mechanics. In a way he is the typical Alexandrian mathematician, interested in both pure mathematics and in its applications. His geometrical work shows strong influence from mechanics: not only did he create statics and hydrostatics as pure mathematical disciplines, he also used mechanical arguments to solve difficult problems concerning ratios of areas and volumes of geometrical figures. His work on statics is obviously related to *Euclid's book about the balance*. Although the Archimedean statics and hydrostatics are highly theoretical and references to practice are absent, they were definitely seen as concerning mechanics. E. g. Heron in his mechanics refers to Archimedes' work for the proof of the law of the balance.

Archimedes was actively involved in the design of machines. Unfortunately we do not know the details, but his reputation in antiquity was such that this conclusion is inevitable. He wrote a book on mechanics that is lost, although some of it can be reconstructed on the basis of *Heron's Mechanics*. Elsewhere I argued that he indeed may have invented the screw and the screw pump and that his work on spirals may have helped him there [10]. It seems reasonable too to assume that theory of simple

machines that Heron describes to us in his *Mechanics* was born in this period.

Well known is the text in which Plutarch writes that Archimedes was not at all inclined to apply his geometrical knowledge and only designed the engines that helped to defend Syracuse after King Hiero had begged him to and "*at last persuaded him to turn his art somewhat from abstract notions to material things*" [19], chapter 14. This cannot be true. It is out of the question that only after being urged by the king, Archimedes turned to mechanics and suddenly out of the blue started designing fantastic machines. Yet Plutarch's remark reflects an attitude that was quite common among the elite in classical antiquity: manual labour was viewed as inferior.

5. Apollonius and Hipparchus

Many pure mathematicians must in one way or another have been involved in mechanics. Apollonius of Perga (c. 262 – c. 190) is famous in particular because he wrote a brilliant book on conic sections. Yet he also wrote a lost work called *On the cylindrical helix*. We know this from Proclus who adds that Apollonius did prove that the cylindrical helix can slide along itself by means of a screw motion: it can move while it goes on coinciding with itself. This is precisely the property that makes it useful in bolts and nuts. In Arabic a manuscript survives which is called *The construction of the machine of the flute player*. Apollonius the carpenter and geometer is mentioned as author. Lewis has convincingly argued that this must be the same Apollonius as the author of the Conics [13]. One of his arguments is that Vitruvius associates Apollonius with mechanical work. In the 9th century the Banu Musa read the Greek manuscript, developed the idea, and left us too with a description of a mechanical flute player. Pins on a rotating drum open via levers holes on a flute. The wind is generated by water that fills a reservoir and forces the air out.

Some of the key words that characterize Hellenistic mechanics are: measurements, experiments, application of mathematical knowledge and instruments. Exactly the same attitude we find in the astronomer Hipparchus (c. 190 – c. 120 BC). The early Greek astronomers came up with the first kinematical models of the universe.

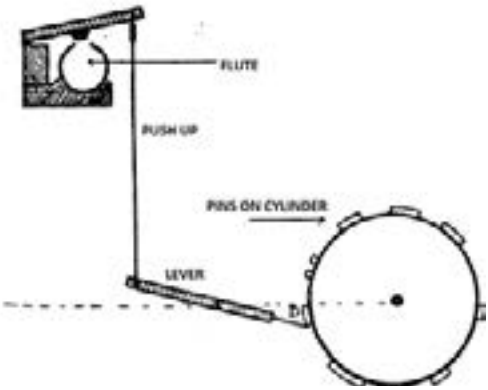


Figure 5 Reconstruction of Apollonius' flute player. Based on [4]. *p. 101.*

Eudoxus attempted to describe the motion of the Sun the Moon and the planets by means of a model in which spheres were rotating with uniform velocities inside the rotating sphere of the fixed stars. Such models could generate the retrograde motion of the planets but they were only qualitatively correct. It seems to have been Apollonius who suggested the possibility to use planar kinematical models based on uniform circular motion. Hipparchus, however, turned Greek astronomy into a true empirical science and succeeded in producing kinematical models that were in wonderful accordance with the observations. Famous is his very accurate model for the motion of the Sun. There is evidence that the idea of the astrolabe goes back to Hipparchus [17], p.124. Because the astrolabe is based on a stereographic projection of the spherical universe it is quite possible that the armillary sphere came first and it is tempting to associate this instrument too with the name of Hipparchus. The anaphoric clock described by Vitruvius is based on the idea of the astrolabe. Such a clock was constructed on the Tower of Winds in the old marketplace of Athens c. 50 BC.

Although we have no evidence it seems probable that Hipparchus was in some way involved with the tradition of planetarium building of which the Antikythera mechanism is such a beautiful example, it represents a fine example of the Hellenistic mechanics: theory and practice combined.

6. Conclusion

Heron's work (1st century AD) shows us where the development of mechanics that presumably started with Archytas' work ended. Mechanics had become a coherent subject with the theory of the five simple machines as a core theory. It encompassed on the more theoretical side treatises like Archimedes' work on statics and hydrostatics and on the practical side, works on specific machines, like war-engines, or automata. Schiefsky has analysed Heron's *Mechanics* from this point of view [24].

A question that we will not try to answer is what impact on society the developments that we have described had. We should not overestimate the impact. The elite often looked down on manual labour, and for a long time the fact that mechanics enables us to do things that are against nature – for example lift weights that are bigger than the ones we can lift naturally – worked against a positive attitude towards technology. Moreover, the heavy work could be done by slaves. Geminus listed under mechanics four subdivisions: military engineering, wonderworking, the study of equilibrium and sphere-making. Military engineering is primarily destructive, wonderworking is entertainment (toys, automata), the study of equilibrium is the theoretical part of mechanics while sphere-making concerns the building of mechanical models of the universe. None of these will significantly have affected the economy[10].

10. For a balanced view see Pleket [18].

References

[1] Marco Ceccarelli (ed.), *International Symposium on History of Machines and Mechanisms, Proceedings HMM2004*, Kluwer Academic Publishers, Dordrecht etc., 2004

[2] P. Duhem, *Origines de la statique* , Tome 1, Bordeaux, 1905

[3] Eugene S. Ferguson, *Engineering and the Mind's Eye*, MIT Press, 1994

[4] H. G. Farmer, *The organ of the ancients from eastern sources* (*Hebrew, Syriac and Arabic*), London, 1931

[5] Peter Marshall Fraser, *Ptolemaic Alexandria*, Clarendon Press 1972

[6] Sir Thomas Heath, *A history of Greek mathematics*, Vol. I, From Thales to Euclid, Oxford, 1921. References are to the Dover reprint of 1981

[7] John W. Humphrey, John P. Oleson, Andrew N. Sherwood, *Greek and Roman Technology: A sourcebook, Annotated translations of Greek and Latin texts and documents*, Routledge, 1998

[8] Josephus, *The Jewish War* (trans. by G.A. Williamson), London, 1959

[9] Wilbur Knorr, *Textual Studies in Ancient and Medieval Geometry*, 1989

[10] Teun Koetsier, Hendrik Blauwendraat, The Archimedean Screwpump: a note on its invention and the development of the theory, In [1], pp. 181-194

[11] Teun Koetsier, Hanfried Kerle, The Automaton Nysa, Mechanism Design in Alexandria in de 3d Century BC, in [25], pp. 347-366

[12] Fritz Krafft, *Dynamische und Statische Betrachtungsweise in der Antiken Mechanik*, Franz Steiner Verlag GMBH, Wiesbaden, 1970

[13] M. J. Lewis, *Millstone and Hammer: the Origins of Water-Power*, University of Hull Press, 1997

[14] E. W. Marsden, *Greek and Roman Artillery, Historical development*, Oxford, 1969

[15] E. W. Marsden, *Greek and Roman Artillery, Technical treatises*, Oxford, 1971

[16] Ramon Masià, A new reading of Archytas' doubling of the cube and its implications, *Archive History Exact Sciences* 70. 2016, pp. 175-204

[17] John North, *Cosmos: An Illustrated History of Astronomy and Cosmology*, Chicago and London, 2008

[18] H. W. Pleket, Technology in the Greco-Roman World: a general report, *Talanta*, *Proceedings of the Dutch Archaeological and Historical Society* V, 1973, pp. 6-47

[19] Plutarch, *Plutarch's Lives*, with an English Translation by Bernadotte Perrin. Cambridge, MA. Harvard University Press. London. William Heinemann Ltd. 1917

[20] Proclus, *A Commentary on the First Book of Euclid's Elements*, Translated with Introduction and Notes by Glenn R. Morrow, Princeton university Press, Princeton, New Jersey, 1970

[21] Lucio Russo, *The Forgotten Revolution, How science was born in 300 BC and why it had to be reborn*, Springer, 2004

[22] E. E. Rice, *The Grand Procession of Ptolemy Philadelphus*, Oxford University Press, 1983.

[23] Cesare Rossi, Ancient Throwing Machines: a Method to Compute Their Performances, Mechanism and Machine Theory 51, 2012, pp. 1-13

[24] Schiefsky, Mark J., Theory and practice in Heron's Mechanics. In *Mechanics and Natural Philosophy before the Scientific Revolution*, ed. W. R. Laird and S. Roux. Boston Studies in the Philosophy of Science 254. New York: Springer, 2007

[25] Francesco Sorge, Giuseppe Genchi, *Essays on the History of Mechanical Engineering*, Springer, 2016

[26] Ivor Thomas, *Selections Illustrating the History of Greek Mathematics*, Vol. I, From Thales to Euclid, London William Heinemann Ltd & Harvard University Press, 1951

[27] Vitruvius, The ten books on architecture, Dover Publications. New York, 1960, See e. g. http://www.gutenberg.org/files/20239/20239-h/29239-h.htm

[28] Thomas Nelson Winter, *The Mechanical Problems in the Corpus of Aristotle*, Faculty Publications, Classics and Religious Studies Department, University of Nebraska, Lincoln, 2007

B5.3 Purple-Dye Industry in Greece from Prehistory to the End of the Byzantine Empire.

Lilian Karali-Giannakopoulou
University of Athens

Abstract

Purple, the secret of purple dye production, the origins, symbolism, diffusion and purple dyed goods trade are some of the most popular research topics among scholars worldwide. This paper presents a project of the Laboratory for Environmental Archaeology of the Department of Archaeology and the History of Art of the National & Kapodistrian University of Athens. The aim is to define the workshops, the variations of the red/purple color shades based on the sea species used for the preparation of the dye and the variations of price according to the shades and the distance. Purple dye has been a valuable trade good from prehistory to the end of the Byzantine Empire. The study is based on the archaeological and archaeo-environmental remains of the purple dye production centres in Eastern Mediterranean from prehistory to history. A data base, a GIS and a digital map are under construction. The project will systematically compare places and periods in order to generate new perspectives on critical issues of social, economic and cultural change and to provide a scientific background for this important discussion. The subject is strongly thematic, diachronic, comparative and interdisciplinary.

1. Mediterranean Sea, Environment Archaeology and mollusks

On the Mediterranean shores, great civilizations have flourished from prehistory to nowadays. Communication in the Mediterranean Sea was and still is an important cultural issue. From prehistory it has enabled contact and exchange of goods, knowledge, ideas and technology to such a degree that detection of the origins of many inventions and innovations is not always easy.

Excavations in coastal sites brought to light a great amount of archaeo-environmental data about marine, aquatic and terrestrial fauna and flora. Among them, the archaeomalacological material (land snails and sea mollusks) reflect specific environmental and human behavioral patterns, if considered within a concrete archaeological context.

2. Archaeomalacological material in archaeological context

Shells of gastropods and lamellibranches are frequently found on archaeological sites, quite often in middens near coastal sites. Mollusks may give a variety of indications

having to do with environmental and climatic conditions, the date of the deposit, the ways of consumption and the fishing techniques. Furthermore shells worked or not have been used as: tools, ornaments, for the decoration of ceramic pots, building material (sediments, ingredients, and for insulation purposes), pigments, mortar, in the ceramic clay and for the production of lime and purple dye. Mollusks, their form and properties have been a source of inspiration as shown by artistic and symbolic representations (Karali 1999). Some mollusks and the products deriving from them have been traded around the world and the Mediterranean. However shell uses cannot be easily detected if the appropriate methodology is not meticulously applied.

3. Purple dye production

Nowadays among the natural dye sources for the production of natural dyes about 300 plants and 30 animals (marine mollusks and insects) are known worldwide. The most expensive from the antiquity to our days has been shell Purple dye. The preparation of this expensive dye has been kept secret for many centuries. The existing knowledge about the whole procedure, and the variety and differentiation of the methodology applied by the groups of different geographic area are not yet known in detail. The mollusk species may vary according to the biotope and the general environmental conditions. In the Mediterranean and in the Aegean area three murex species have been used in order to obtain a vast range of red shades : *Murex/ Bolinus/ brandaris Linne, Murex /Hexaplex truncularіopsis/trunculus Linne, Buccinum haemastoma Linne and Thais/Purpura haemastoma Linne/Buccinum cingulatum Lamarck. It is known that Murex brandaris L. gave a more reddish- purple color; Murex trunculus* L. gave a more blue-purple color; Murex and Thais combined in different proportions were used for a more bluish/reddish dye (Karali, Reese).

4. Purple dye archaeological evidence

In the Greek coastal sites large deposits of shells are found, many of them from the muricidae family. However a murex is not by itself a safe indicator for purple dye production, the archaeological context, the mollusk species and the morphological alterations on the original shell must be seriously taken into consideration before concluding to the above specific use (Fig.1):

- The typology of the shell: most of the shells found in excavations are fragmented.
- The fragmentation techniques vary according to the chronological periods: in the prehistoric deposits most of the shells are not carefully broken; later on there is a hole on the larger (ventral) part, or the shell is broken in larger pieces.
- Installations (cisterns, water canalization etc.) are imperative. However in prehistory there is not always such evidence and in a number of sites there is a small scale production.
- Relevant objects (pots, woven materials etc.) are important indicators of the product, the storage vessels and the secondary uses of it in a variety of materials that were usually dyed.

FIGURE 1 : Fragmented Murex species found in excavations

Purple invention and production in Greece

Greece played an important role in the emergency of eminent prehistoric civilizations in the East Southern Mediterranean. During the Bronze Age, in Crete a close relation with the marine world is attested. Archaeomalacological research has developed particularly in the Aegean region. The archaeomalacological data from Crete suggest that the purple-dye production begun on the island around the end of Middle Minoan I period or during MM II (ca. 1900-1700 BC) and was widespread in the Aegean centers (Fig. 2)

The archaeological evidence available today indicates that shell purple dye was quite probably produced in the Aegean during the Middle Bronze Age period (Reese 1987, Stieglitz 1994, Karali 2003) before being introduced into the Near East. (Stieglitz and Reese have surveyed and studied the earliest archaeomalacological sites of purple-dyeing in Near Eastern sites). Additionally the Levantine Phoenicians of the Iron Age were producing the famous Tyrian purple, from the Late Bronze Age onward. The archaeological evidence from Greece shows that significant amounts of murex shells and dye-related installations were found in Crete and the Aegean Islands. In the sites of Mainland Greece the number of murex shells is considerably smaller. Therefore it seems that the knowledge was widespread but the scale of production was different (Veropoulidou, , Andreou, Kotsakis, 2008) .

FIGURE 2: Bronze Age Aegean Purple dye production centers

The oldest evidence of purple dye production in prehistoric Greece comes from Middle Bronze Age islet of Lefki/Koufonisi in southeastern Crete, where a considerable amount of crashed murex shells were found together with Middle Minoan (MM2) ceramic (Stieglitz, 1994). In Akrotiri some of the buildings (Santorini) have floors made with crushed murex shells and on the wall frescoes the red pigment is proved to derive from murex shells (Fig. 3). These are considered to be that the remains of purple dye industrial activities from a workshop somewhere close to the settlement. In Crete the evidence of Purple dye comes from many important sites (such as Palaikastro, Knossos, Zacros,, Myrtos, Pyrgos Myrtou, Makris Gyalos, Petras, Mallia, Tylissos, Yiouchtas, Chania, Kommos etc.) Additional information about the importance and the symbolism of the precious dye comes from two tablets in Linear B discovered at the palace of

Knossos, where among the precious belongings of the king, some purple garments are mentioned (Karali, Reese).

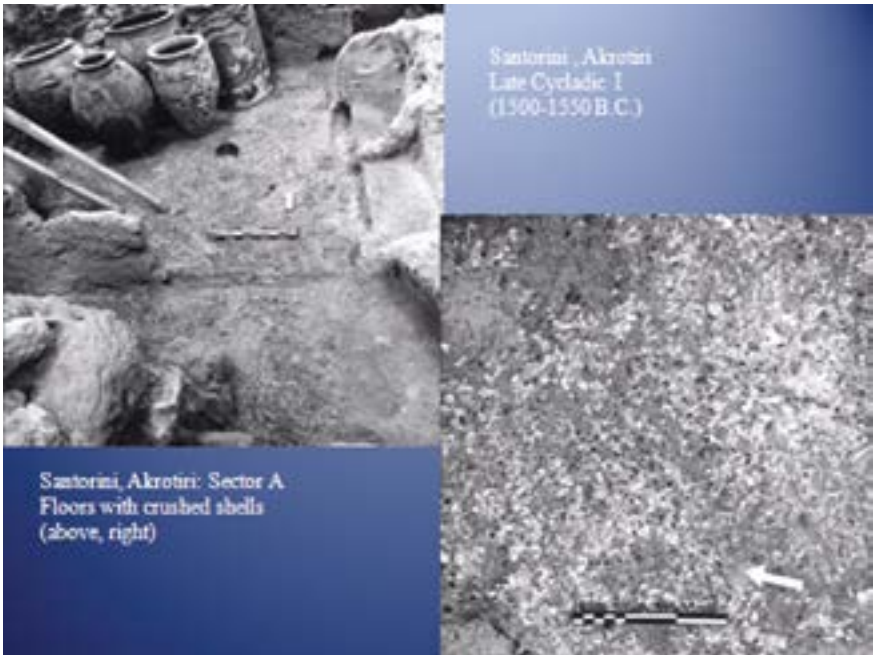


FIGURE 3: *Floors out of fragmented Murex shells from the Aegean site of Akrotiri*

After the Minoans the Mycenaeans have adopted and continued this industry and created an extended trade net. Workshops can be found in many important Mycenaean sites such as Thebes, Athens etc (Constantinidis 2008)

The Classical Period is much better documented by the purple workshops, the relevant archaeological findings and also by the literary sources. Pliny the Elder (Historia naturalis IX, 124 - 142) is the first to provide information about the recipe and some of the most important production and trade centers, such as Crete, Rhodes, Kos, Amorgos, Nisyros (called also Porphyris), Chios, the west coast of Asia Minor, Phocaea, Lydia and Phrygia, Laconia, Cythera, Corinth (on Corinthian coins was depicted a murex) Hermione etc. The importance of purple dye from the last city is proved by the following historical fact. When Alexander the Great occupied Susa (330 BC) found among the royal treasures some 5.000 talanta of purple dye (or purple cloth) bought from Hermione and stored in Persia for about two centuries. This must have been a very precious good because of its quality and value. The mighty kings of Persia preferred buying such goods from a Greek city than from the Middle Eastern purple production centers.

Actually estimations are made about the approximate number of shells fished and processed for the local Hermione Purple industrial activities (Protopapas & Gatsos,

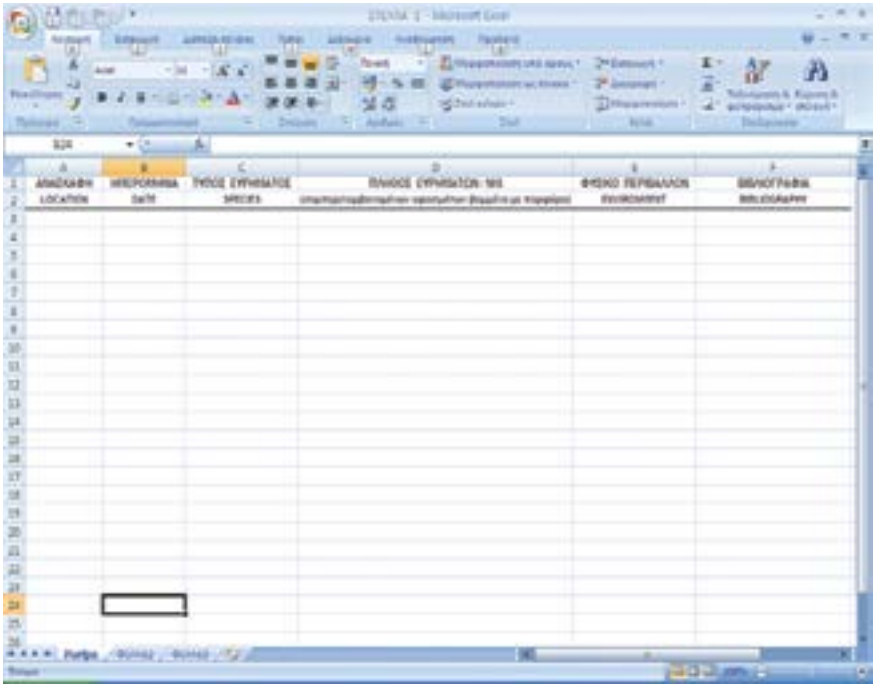
2003). Based on the amount of the fragments of crushed shells, used as mortar for the construction of the city walls, it seems that about 10.000.000 shells have been processed for the extraction of the shell gland, at the periods that preceded the construction of the walls. Thus diachronically a least some thousand shells were processed daily, producing around 10 to 20 kilograms of purple dye. Accordingly the city's importance and fame, the temples, the rich estates and the extensive walls were due to a vast class of rich producers and merchants. If we make the assumption that the purple industry lasted for about 1.000 years, from the 6th century BC to the 6th century AD one could estimate the approximate total number of murex fished and proceeded as follows:

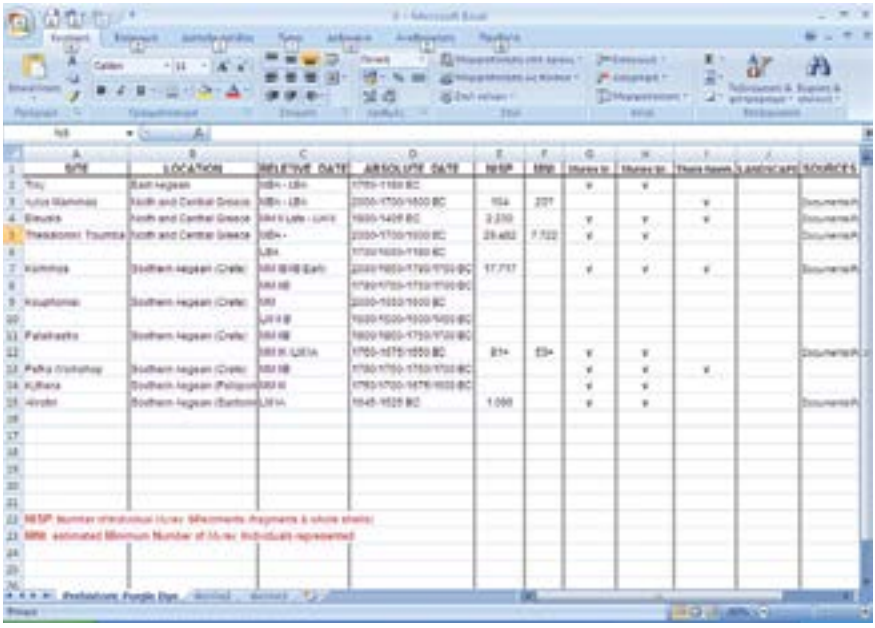
10.000 sea mollusks per day
1.000 years x 360 days= 360.000 days
10.000 shells x 360.000 days= 3.600.000 shells
If size of the shell and the degree of fragmentation are taken into account there should have been fished +/- 2-3.000.000.000 Murex shells

In the following periods, great importance was again attributed to this precious dye. During the Roman period purple was the symbol of priesthood, of political and military authority. Purple dyed products imported to Rome came as well from Phoenicia and from Greece. Similar use and symbolism inherited from both eastern and western traditions prevailed also in Byzantium and Christianity. During the Byzantine period the most important purple dye industrial centers were located in Southern Greece and Asia Minor. The production of Murex purple for the Byzantine elite came to an end firstly with the sack of Constantinople in 1204 AD and afterwards by the fall of Constantinople at 1453 AD. Some of the reasons for the decay and the disappearance of the production centers and the use of purple garments were the lack of the financial resources required for the purchase of murex purple, expansion of piracy, continuous war activities and the Muslim beliefs about the negative meaning of the red color.

Establishing a Murex Data Base

In order to better understand the centers and the trade networks of dye, the analysis and display of all the existing information is imperative. The database we are constructing includes the name of the relevant archaeological site, the geographic location, the relative and absolute date of the shell material, the Murex species, the NISP (Number of Individual Specimens) fragments and whole shells, the MNI (the estimated Minimum Number of Murex Individuals represented), and the existing information about the landscape and the sources in which the data are stored (Fig.4). Articles related to shells are stored by the name of Author, the title and the geographic area, providing the possibility to easily find and read the selected article in pdf format (Karali in print).




SITE
LOCATION
RELATIVE DATE
ABSOLUTE DATE
NISP
MNI
SOURCES

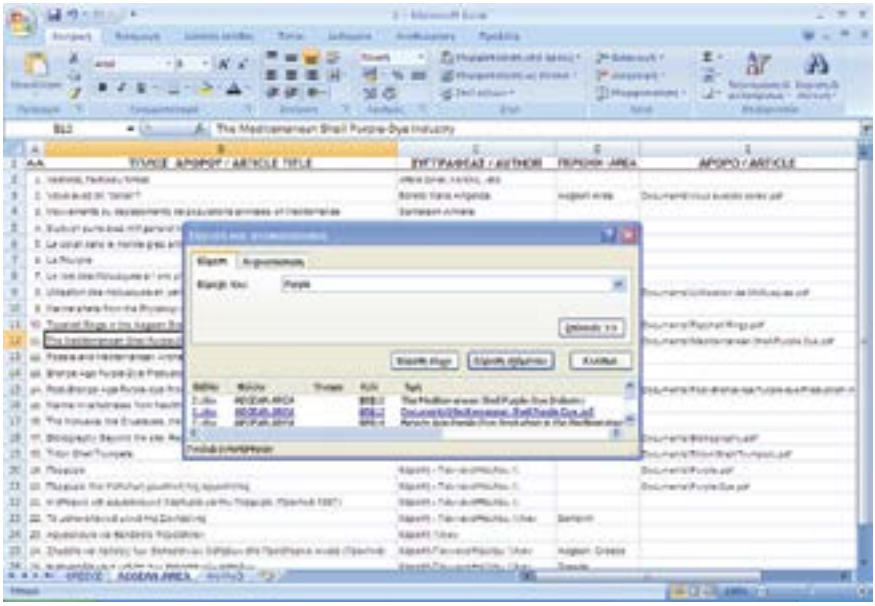


FIGURE 4: Descriptive data base

A GIS database (Fig. 5) is accompanying it, with layers referring to murex shells, correlating the sites and determining the distribution of murex shells around the Mediterranean. Thus could be possible to define the geographical boundaries of the areas of influence of the related cultural groups by period (Constantinidis, Karali 2014). A digital map of the Mediterranean is under construction, showing diachronically the sites, the amount of murex middens and the types of shells found at each geographic unit. This analysis is correlated to other significant trade routes in the area and it will certainly give a better understanding of possible factors influencing communication networks in the past. Since different murex species produce different shades of purple dye, this database aims at determining the different ecosystems from where they come and will make possible the identification of specific sites that produced different shades of red and violet. Combining all these different layers of data a well-documented analysis will be possible and will help to reach to new conclusions

GIS to murex heaps locations, and other contextual evidence
· Location · Context · Species · Environment
GIS Purple dye production layers - Typical GIS landscape layers (Constantinidis and Karali 2011)

5. Conclusions

The invention, the production, the trade as well as the archaeological and the ethnographic debate with emphasis on the Greek mainland and the Aegean islands have been discussed in this brief presentation. Archaeology and Archaeomalacology have established the origins of purple-dye. Murex-shell deposits found in Minoan sites indicate that purple dye was produced in Middle Bronze Age Aegean and in Late Bronze Age Middle East in Lebanon, in Israel, Syria and in other Middle Eastern areas. The Phoenician marines traded purple and established production centers around the Mediterranean Sea. This is the reason why purple dye is mostly known as Tyrian purple and has been associated with the Levant and Phoenicia of the Iron Age. Greek purple dye has been a valuable good and provided the production centers as well as the relevant ports with wealth and fame from Bronze Age to the end of the Byzantine Empire. The specialized production, the trade as well as the archaeological and the ethnographic debate with emphasis on the Greek mainland and the Aegean islands have still to be studied and analyzed.

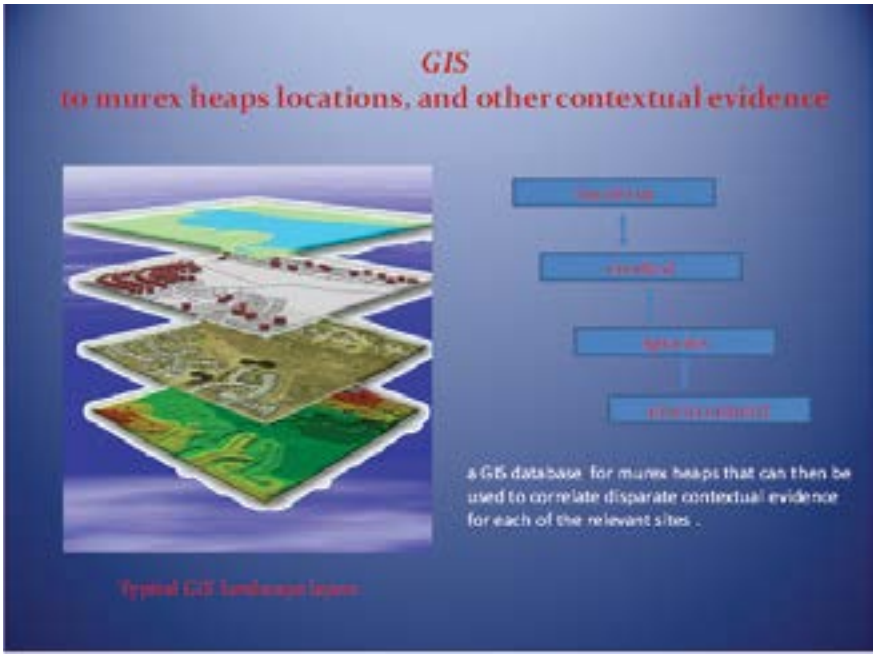


FIGURE 5: *GIS; excavations and shells of the muricidae family* (*Constantinidis , Karali 2011*)

Selected bibliography

- ALBERTI M. E. (2008). Murex shells as raw materials: purple industry and its by-products. Interpreting the archaeological record, *Kaskal* 5, pp. 73-90.
- CARANNANTE A.(2010). "Archaeomalacological Data from the Bronze Age Industrial Complex of Pyrgos-Mavroraki (Cyprus). A Non-dietary Mollusc Exploitation Case", in D. Rocío Carvajal Contreras, E. Alvarez Fernandez (eds.), *Not only food: Marine, Terrestrial and Freshwater molluscs in Archaeological sites* (*Proceedings of the 2nd ICAZ Archaeomalacology Working group, Santander, 2008*), MUNIBE, Donostia-San Sebastian, pp. 34-45
- Cardon, D., 2007 Natural Dyes. Archetype Books.
- Carannante A. (2014).Archaeomalacology and Purple-Dye. State of the Art and New Prospects of Research, pp.273-282 in Juan Jesús, Cantillo Darío, Bernaljosé Ramos (Eds.) "Moluscos y púrpura en contextos arqueológicos atlántico-mediterráneos", Actas de la III Reunión Científica de Arqueomalacología de la Península Ibérica, Universidad de CádizConstantinidis D., Karali L., 2014. "Designing a database to trace purple dye trade routes during the historical period in Greece", Alfaro C., Tellenbach M., Ortiz J., (ed) in Purpurae Vestes IV. Productions and Trade of textiles and dyes in the Roman Empire and neighbouring regions . PV IV UV, Valencia, 2014, pp 143-148
- Constantinidis D. and Karali, L., 2011. A Proposed survey of East Mediterrranean Murex heaps from the Bronze Age to Roman Times: A GIS Analysis of possible Trade Networks. In: C. Alfaro, Brun, J.-P., Borgard, Ph. and Pierobon, B. eds. *Purpurae Vestes III. Textiles y tintes en la ciudad Antigua*. PUV CJB, Valencia, 151-155.
- Edmonds, J., 2000. *Tyrian or Imperial Purple: The Mystery of Imperial Purple Dyes*. Historic Dye Series, no. 7. Little Chalfont, Buckinghamshire: John Edwards.
- Goldstream, J.N. and Huxley, G.L., 1972. *Kythera. Excavations and studies conducted by the University of Pennsylvania Museum and the British School at Athens*. London: Faber and Faber Limited.
- Haubrichs, R., 2005. L'étude de la pourpre: histoire d'une couleur, chimie et expérimentations. *Prehistoria Alpina*. Suppl. 1, v.40, 133-160.
- Karali, L., 1988. Porfyra: Mia polytimi chrostiki tis Archaiotitas. *Anthropologika Analekta*. 49, 41-43. (in Greek)
- Karali L., 1997. I istoriki kai archaeologiki martyria gia tin porfyra. *In: Ancient Greek technology*, Proceedings 1st International Conference, Thessaloniki, 325-330. (in Greek)
- Karali, L., 1999. *Shells in Aegean Prehistory*. BAR International Series 761, Oxford.
- Karali, L., 2002. Exploitation du genre Murex en mer Égée. In: A. Gardeisen, ed. *Mouvements ou déplacements de populations animales en Méditerranée au cours de l'Holocène*. (UMR 154 – CNRS) Lattes – Montpellier (France), BAR International Series 1017, Oxford, 105-108.
- Karali, L., 2003, La porpora prima dei Fenici, *In*: O. Negra and Zobele Lipparini, G., eds. *Dentro la conchiglia. I molluschi alla conquista del mondo*, Museo Tridentino di Scienze Naturali, Trento Italy, 410-413.
- Karali, L., 2005. Testimonianze della produzione della porpora nell' Egeo nell' antiquità.

Preistoria Alpina. v. 40, 3-9.

- Karali, L., Megaloudi F., 2008. Purple Dyes in the Environment and History of the Aegean: A short review. *In: C. Alfaro AND Karali, L. eds. Purpurae Vestes II. Vestidos, textiles y tintes. Estudios sobre la producion de bienes de consumo en l' Antiguedad*. PUV, Valencia, 181-184.
- Karali L., 2014. Recent Research on purple dye production in the Meditteranean: "How many purple dye cosmic worlds? The Caves of Greece", pp. 283-285 in Juan Jesús, Cantillo Darío, Bernaljosé Ramos (Eds.) "Moluscos y púrpura en contextos arqueológicos atlántico-mediterráneos", Actas de la III Reunión Científica de Arqueomalacología de la Península Ibérica, Universidad de Cádiz
- Karali L., (in print) Aegean and the Middle East in prehistory. Purple-dye invention, production and diffusion, UNESCO FORUM V «the alphabet road», Mediterranean Heritage and Challenges», 11-12/10/ 2014.Piraeus/Athens.
- Kardara, Chr., 1974. Vafi, vafeia kai vafai kata tin archaiotita, Hesperia XLIII, 447-453. (in Greek)
- Pliny the Elder, The Natural History, eds. John Bostock, Henry Thomas Riley (London, England: Taylor and Francis, 1855), Book IX. The Natural History of Fishes. Chapters 60–65.
- Protopapas St. AND Gatsos V., 2003. I perifimi archaia porfyra tis Ermionis kai i technologia tis. *Archaiologia kai technes*. Vol. 89, 87-92. (in Greek)
- Reinhold, M., 1970. *History of Purple as a Status Symbol in Antiquity*. Collection Latomus No. 116. Bruxelles: Latomus.
- Reese D.S., 2010. Shells from Sarepta (Lebanon) And East Mediterranean Purple- Dye Production. Mediterranean Archaeology and Archaeometry, Vol. 10, No. 1, pp. 113-141
- Reese D.S., 2000. Iron Age Shell Purple-Dye Production in the Aegean. In: J.W. Shaw AND Shaw, M.C., eds. *Kommos IV: The Greek Sanctuary*. Princeton: Princeton University Press, 643-645.
- Reese D.S., 1987. Palaikastro Shells and Bronze Age Purple-Dye Production in the Mediterranean Basin. *Annual of the British Schools at Athens*. 82, 201-206.
- Reese D.S., 1986. The Mediterranean Shell Purple-Dye Industry, *American Journal of Archaeology 90*, no. 2, 183.
- Reese, D.S., 1980. Industrial Exploitation of Murex Shells: Purple-dye and Lime Production at Sidi Khrebish, Benghazi (Berenice). Libyan Studies 11 (1979-1980), 79-93.
- Ruscillo, D., 2005. Reconstructing Murex Royal Purple and Biblical Blue in the Aegean. *In*: D.E. Bar-Yosef Mayer, ed. *Archaeomalacology*. Molluscs in Former Environments of Human Behaviour. Proceedings of the 9th Conference of the International Council of Archaeozoology, Durham, August 2002. Oxford: Oxford Books, 99-106.
- Ruscillo, D., 2005. Faunal Remains and Murex Dye Production, in J. W. Shaw and M. C. Shaw (eds.), *Kommos V: The Monumental Minoan Buildings at Kommos. Princeton University Press*, pp. 776-840.
- Stieglitz, R.R., 1994. The Minoan Origin of Tyrian purple. *Biblical Archaeologist*. 57(1), 46-54.

- Theodoropoulou, T., 2012. Neolithic and Minoan marine exploitation at Petras: diachronic trends and cultural shifts. *In*: M. Tsipopoulou, ed. *Petras, Siteia – 25 years of excavations and studies*. Acts of a two-day conference held at Danish Institute at Athens, 9-10 October 2010. Monographs of the Danish Institute at Athens, vol. 16. Aarhus, 89-103.
- Veropoulidou, R., Andreou, S. AND Kotsakis, K., (2008). Small Scale Purple-Dye Production in the Bronze Age Northern Greece: The Evidence from the Thessaloniki Tsoumba. *In*: C. Alfaro AND Karali, L., eds. *Purpurae Vestes II. Vestidos, textiles y tintes. Estudios sobre la producion de bienes de consumo en la Antiguedad*. PUV, Valencia, 171-179.
- Veropoulidou, R. (2012): «The Tyrian Purple, a royal dye», P. Adam-Veleni & E. Stefani (eds.):*Greeks and Phoenicians at the Mediterranean Cross roads*, Arch. Museum of Thessaloniki, Thessaloniki.

B5.4 The Bow of Odysseus.

A. S. Paipetis*, S. A. Paipetis**
**Materials Science & Engineering Dept., University of Ioannina,*
paipetis@cc.uoi.gr
***Mech. Engineering & Aeronautics Dept., University of Patras,*
paipetis@upatras.gr

Abstract

In Book XXI of the Odyssey, the faithful Queen Penelope is suffering by the crowd of suitors moved into Odysseus palace, who claim her along with Ithaka's throne. To relieve her from the unpleasant situation, goddess Athena put into Penelope's mind the idea of proclaiming archery games with herself as a prize. However, not with any bow, but with the famous bow of Odysseus, manufactured by Eurytus, whose son Iphitus had given to Odysseus as a gift, which only the latter was capable of stringing. This bow was of reverse tension (palintonos), i.e. even untensioned was already containing considerable potential energy to increase its performance. By such a bow, Odysseus was capable of shooting an arrow through the holes of twelve aligned axes. Using as a criterion the high initial velocity of the arrow, necessary for this latter achievement and by means of an elementary mechanical analysis, the reason is explained, for which only a man of unusually high muscular strength and skill, like Odysseus, was capable of shooting with the bow.

1. Introduction

The mighty bow of Odysseus was given to him as a present by Iphitus, son of Eurytus. Odysseus, while travelling to Pherae, met Iphitus whom he recognized as a dear friend of his father Laertes of Ithaca and presented him with the sword and spear of his father. Iphitus, in return, presented him with the bow of Eurytus which he described as "the most wonderful ever made next to Apollo's silver weapon" [1]

Odysseus did not take the bow with him to Troy, since he cherished it as a token of his friendship with Iphitus [2].

Thus the bow remained in Ithaca, and Penelope used it for the contest among the suitors with herself as a prize, after being prompted by Athena:

"*I will bring you the great bow of the divine Odysseus, and whosoever shall most easily string the bow with his hands, and shoot through all the twelve axes, with him will I go and forsake this house, this house of my marriage, so beautiful and filled with fair things, which I think I shall yet remember, aye, in a dream.*" [3]

Although no details regarding the weapon itself are explicitly given, the description

of the task that the successful suitor had to perform is given with sufficient detail. Telemachus, Odysseus's son, is the one who lays down the axes for the competition (Fig. 1):

"First he set the axes in a row, in a long groove which he had dug for them, and had wade straight by line. Then he stamped the earth tight round them, and everyone was surprised when they saw him set up so orderly, though he had never seen anything of the kind before." [4]

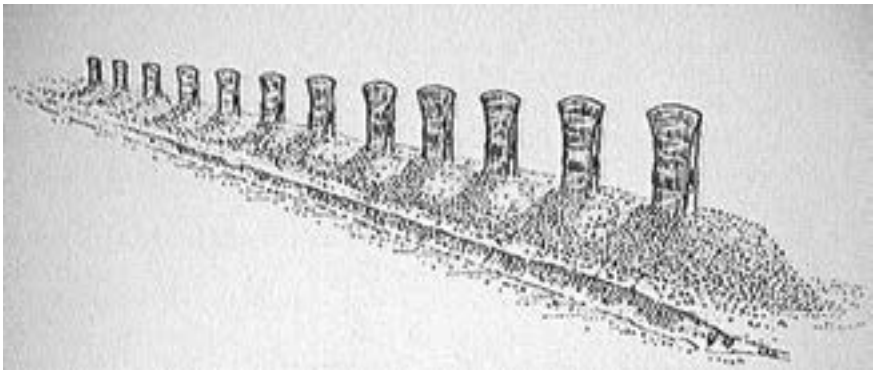


Fig. 1: Artist's impression of the setup of the axes

The accurate positioning of the axes by Telemachus is also praised by Homer as a prerequisite for a successful trial. As soon as he set up the axes, Telemachus made three unsuccessful tries to string the bow and stopped although it was implied that his fourth trial would be successful. Following Telemachus, the suitors tried and failed. Ulysses disguised as a beggar was given permission to try and of course managed to string the bow and shoot through all twelve axes:

"*He took an arrow that was lying upon the table- for those which the Achaeans were so shortly about to taste were all inside the quiver- he laid it on the center-piece of the bow, and drew the notch of the arrow and the string toward him, still seated on his seat. When he had taken aim he let fly, and his arrow pierced every one of the handle-holes of the axes from the first onwards till it had gone right through them, and into the outer courtyard.*" [5]

The scope of this work is to study the "impossible" task performed by the Homeric hero as described in *Odyssey XXI*. Within the scope of the study is to perform the elementary analysis of the physics of the arrow flight in order to calculate the arrow velocity making basic assumptions regarding the geometrical parameters that define the test as posed by Penelope.

2. Basic assumptions for the contest setup

In view of the hypothetical setup of the axes as shown in Fig. 1 basic geometrical assumptions regarding the trajectory of the arrow can be made, the first one regarding the axe dimensions. No information of the axe shape and dimensions is available. However, specific assumptions may be made with the parameters limiting the trajec-

tory of the arrow. Fig.1 depicts the most realistic representation of Telemachus's arrangement of the axes. As the arrow has to pass through all the eyes of the twelve axes, assumptions for the two fundamental dimensions of the problem may be made, i.e. the horizontal travel length of the arrow and the relative perpendicular drop due to gravity as the arrow is performing a typical projectile motion. As depicted in Figure 2, the horizontal distance R of the arrow travel through the axes is $12_{s1}+11_{s2}$, where $_{s1}$ is the blade length and $_{s2}$ the interim distance. In order to find the total travel length, the relative distance from the sitting Odysseus has to be added which is at least one arrow length plus a reasonable distance that may be arbitrarily defined, given the confinement that the contest was not performed in open space. The vertical drop should correspond to the eye hole minus the width of the arrow.

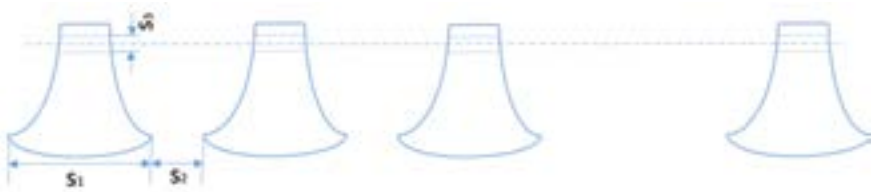


Fig. 2: Geometrical parameters for the arrow trajectory definition.

Figure 3:From top left clockwise: (a) Bronze axes with a semi-circular blade dated around XIII-XI century BC are attested in some settlements in Crete, (b) Bronze double-axes from the area of Pylos, (c) Different example of Late Helladic bronze double-edge axes from Pilikata museum in Ithaka, (d) Bronze battle-axe probably dated 1500-1450 BC found in Vapheio [6].

According to findings from the late bronze period in Greece, axe shapes and dimensions may vary considerably. The axes may possess characteristically semi-circular blades (Fig. 3a), have double edge, similar to the Minoan double axes (Fig 3.b &c), or possess the characteristic "Epsilon" shape, as the specimen from the 15th century BC,

found in Vapheio [6]. The last one could pose an interesting alternative to the reconstruction of the contest, where Homer not specifically refer to the handle hole [5]. In all cases, and as in a typical modern axe, the long axis of the ellipse of the eye of the axe could be safely assumed to be in the range of 50 mm to 70 mm, whereas the length of the blade could vary from 30 cm to 50 cm. However, if we consider that Odysseus took his shot while sitting and that the axes were laid and supported on the ground, the size of each axe should be relatively large.

As the axes were placed in a groove and the earth was "stamped tight round them" the interim space between them may be assumed to be of a minimum of 30 cm up to an arbitrary maximum of 50 cm, or equal to the axe blade length.

Reconstruction of the arrow is also a demanding task. The information available may come from arrow heads from the late bronze period. Again, there is a vast number of specimens found dating to the late Bronze Period, so a representative sample should be chosen. In [7], in an attempt to reconstruct ancient linen body armor, typical arrows are reconstructed according to findings from the period. As extensively described, bronze arrowhead dimensions (length by width/diameter) would range from 27 mm by 17 mm to 50 mm by 20 mm with respective masses ranging from 15 g to 30 g. In the aforementioned study, the employed wooden arrows were made from ash-wood with a diameter of ca. 0.01m and length of ca. 0.8m and a mass of ca. 40 g. These dimensions correspond to a mean total mass of ca. 65 g. However, arrowhead specimens found from the late bronze period possess lengths in the area of 45 mm which would raise the total mass of the arrow up to 120 g. A conservative estimate for the arrow would be in the area of 0.9 kg or higher for arrows used in battle (although this is not necessarily the case for the bow of Eurytus).

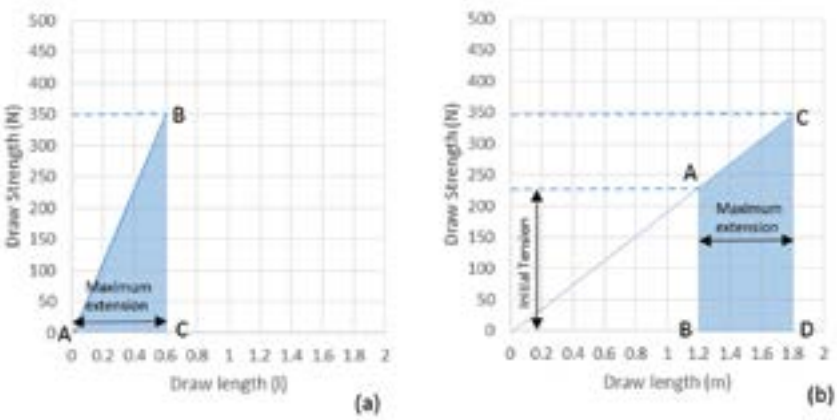


Fig.5: Energy stored in (a) an un-tensioned bow and (b) in a pre-tensioned bow [8].

Finally, the bow of Iphitus, was referred to as "the most wonderful ever made next to Apollo's silver weapon". There are no other references to the bow design, but it may be assumed that the weapon was of unique strength and only a highly skilled warrior,

such as Odysseus could make use of it. Eurytus was so proud that he could skillfully use the bow that dared Apollo and was finally slayed by Hercules due to performing "hubris" in his foolish pride. The skill required together with the strength of the bow directly refers to a more intricate design together with high draw strengths that would be able to provide the arrow with its lethal energy. As aptly posed by Gordon [8], this bow had to be a composite bow, with a core of wood which, being near the middle of the thickness of the bow was only lightly stressed. To this core was glued a tension surface made from dried tendon and a compression face made of horn. On top of that, assuming that the maximum draw length of the bow is ca. 0.60m, in order to store more potential energy in the bow, the latter had to be pre-tensioned to a considerable degree. Figure 4 depicts the energy stored in the bow (a) assuming no initial tension in the bow string and (b) assuming that the bow is pre-tensioned.

The energy stored corresponds to the area ABCD in the second case and to the area ABC in the first case for a given force exerted by the archer, increasing the energy storing efficiency, in the case of the "palintonos" bow. All bows when stringed are pre-tensioned, however a composite structure gives the liberty of designing for pre-stressing giving the bow the shape of a "cupid bow" (Fig.6). The combination of materials such as wood, tendon and horn make the task of reducing the size to strength ratio, enabling the realization of a mighty weapon.

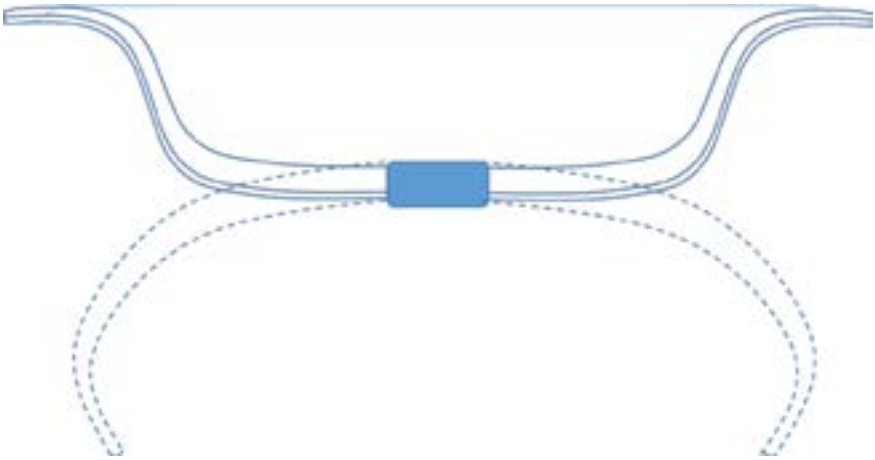


Figure 5. *Composite bow, unstrung and strung* [8]

3. Fundamentals of the projectile flight of the arrow

In this section, the arrow flight will be considered in terms of the geometrical constraints posed by the flight through the handle holes of the axes in order to provide an estimate of the parameters needed to perform some a task. In this initial study effects that are related to air resistance will be ignored, as well as phenomena in-

trinsically related to arrow flight. These phenomena may relate to other oscillatory and rotational motions related to the stiffness of the arrow and flight dynamics. A well-known example is the "archer's paradox" whereby "an arrow traveling in the direction it is pointed at full draw, when it seems that the arrow would have to pass through the starting position it was in before being drawn, where it was pointed to the side of the target" [9].

The arrow may be assumed to perform a projectile flight after it leaves the bow with a specific kinetic energy and angle which defines its initial speed v0. The governing equations in this case are for the position $\mathbf{r}(t)$, the velocity $\mathbf{v}(t)$ and the acceleration a:

$$\boldsymbol{r}(t) = \boldsymbol{r}_0 + \boldsymbol{v}_0(t) + \frac{1}{2}\boldsymbol{a}t^2 \quad (1)$$

$$\boldsymbol{v}(t) = \boldsymbol{v}_0 + \boldsymbol{a}t \quad (2)$$

In the simplest case, we may assume that the motion of the arrow is only subjected to gravitational forces and thus its motion is accelerated only in the vertical direction. In this case the scalar form of equations 1 and 2 is:

$$x(t) = v_0 \cos\theta\, t \quad (3)$$

$$v_x(t) = v_0 \cos\theta$$

$$y(t) = v_0 \sin\theta\, t + \frac{1}{2}gt^2 \quad (4)$$

$$v_y(t) = v_0 \sin\theta\, t - gt \quad (5)$$

Where g and v_o are the algebraic measures of the gravity g, and initial velocity v_o respectively and v_x and v_y the components of the velocity. The projectile motion is governed by the equations:

Trajectory: $$y = x \tan\theta - \frac{gx^2}{2v_0^2 \cos^2\theta} \quad (6)$$

Flight time: $$t = \frac{2v_0 \sin\theta}{g} \quad (7)$$

Height: $$H = \frac{v_0^2 \sin^2\theta}{2g} \quad (8)$$

Range: $$R = \frac{v_0^2 \sin 2\theta}{g} \quad (9)$$

It is interesting to note that:

$$\frac{H}{R} = \frac{1}{2\tan\theta} \quad (10)$$

The above ratio is independent of the initial velocity and is only a function of the shooting angle.

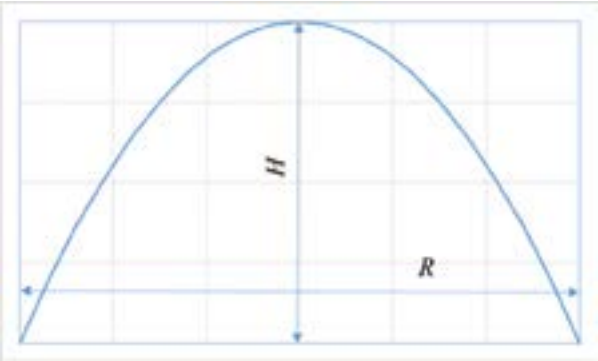


Fig. 6: Arrow trajectory as a function of the shooting angle.

In this trivial case the trajectory of the translational motion of the arrow is shown in Fig.6 as a function of shooting angle. As is obvious the allowable height of the part of the trajectory that the arrow should not exceed the height *H* (which corresponds to the eye size minus the diameter of the arrow) and be able to pass through the total length R which corresponds to the length of the axes put in series. Whereas, for the small angle involved, the relationship between the entrance angle and *H/R* is almost linear, the velocity rapidly decreases with increasing *H/R* (Fig.7):

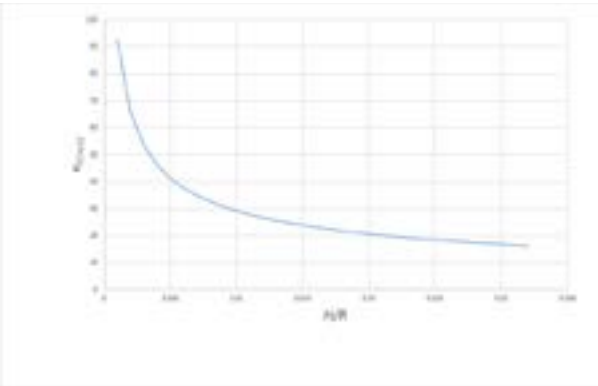


Fig. 7: Entrance velocity vs. range to height ratio for a range of 5m

However, a more elaborate solution of the problem would take into account the finite length of the arrow. If the arrow is assumed to perform a simple projectile motion under the effect of gravity, it would be expected to perform a simple translation in space, retaining its original shooting angle, as seen in the beginning of the trajectory in Fig. 8. However, this would considerably reduce the available height for the arrow movement that is by the projection of the arrow length in the *y* axis.

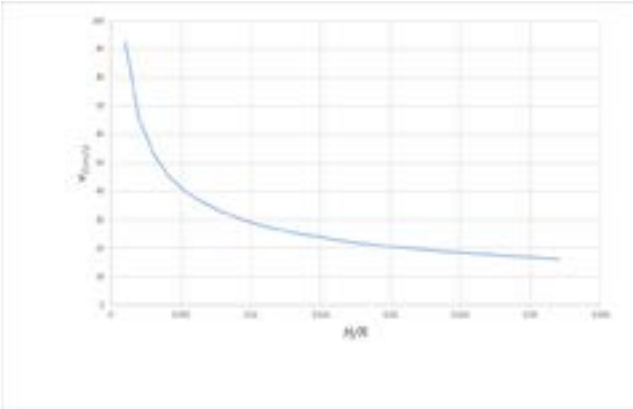


Fig. 8: Entrance angle and tangential movement of the arrow

It is well known that the arrow always aligns itself with its velocity vector, in order to minimize the air resistance during flight. This is also creating a rotational motion of the arrow with an axis of rotation perpendicular to the plane of motion. A way to simulate this motion while ignoring the air drag, is to make the fundamental assumption that the arrow motion, its velocity vector is always on the tangent of its trajectory, no matter what this trajectory is (Fig. 8). In this case, while at the beginning the arrow is performing a simple projectile motion, the end of the arrow is performing a trajectory every point of which is translated by the length of the arrow on the tangent of the trajectory, in the direction of the flight. In this way, we can simulate the complex movement of the arrow geometrically.

Let the parabolic trajectory of the initial point of the arrow (equation 6) be of the form:

$$y = ax^2 + bx \qquad (11)$$

$$\frac{dy}{dx} = 2ax + b \qquad (12)$$

Let $\frac{dy}{dx} = \lambda$. The coordinates of the end of the arrow *xf* and *yf* should satisfy the equation of the tangent line:

$$y_f - y(t) = \lambda(x_t - x(t)) \qquad (13)$$

At the same time the length of the arrow *l* should always satisfy the equation:

$$l = (x_f - x(t))^2 - (y_f - y(t))^2 \qquad (14)$$

From equation 13 and 14:

$$x_f = x(t) \pm \frac{l^2}{1+\lambda(x)^2} \qquad (15)$$

As noted in equation 15, λ is also a function of x, therefore, the solution of the above equations, in order to yield the values x_f and y_f, is not straightforward. A simpler approach to the above problem could be based on the assumption that since the trajectory of a free falling projectile is parabolic, the change of its slope is a linear function of distance, as is also obvious from equation 12. This assumption is not strictly satisfied, as the arrow end does not necessarily follow a parabolic trajectory. In this case, we may assume that the additional ΔH required for the rotating arrow that enters the axe holes is changing linearly from the point where the arrow completely enters the axe hole until it is changing to 0 at the apex of its trajectory. Thus, an additional linearly varying Δy has to be added to the projectile trajectory in order to define the position of A' and B' (Fig. 8) as defined by the initial arrow end point ($l\cos\vartheta$, $l\sin\vartheta$) the point where the arrow reaches the apex of its trajectory and its end is at ($l + R/2$, 0). An additional assumption made above is that the height drop in the projectile trajectory over an arrow length is negligible. This linear contribution is maximum at the entrance i.e. $l\sin\vartheta$ and 0 at the apex, as the arrow end reaches a horizontal position, at $l + R/2$. (For $x > R/2+l$, i.e after the apex of the trajectory, the contribution Δy is again positive with the opposite slope). The governing equation using the above assumption is:

$$\Delta y = \frac{l(\sin\theta)}{l(1-\cos\theta)+R/2}(x(t) - l\cos\theta) + l(\sin\theta), \text{for } 0 \le x \le R/2 \qquad (16)$$

The limiting condition now is that ¨

$$H_{total} < H+\Delta y \qquad (17)$$

Fig. 9 depicts the trajectory of the tip of the arrow together with the typical projectile trajectory.

Employing the equations derived above, together with typical values for the parameters involved, the expected values for the velocity and angle of the arrow as it enters the first axe hole may be derived:

i) R, or total length that the arrow has to travel. By assuming a typical length for the blade of the axe as well as an equal interim distance. A moderate estimate for the blade length would be 0.3 m to 0.5 m, so that 6.9 m ≤ R ≤ 11.5

ii) D, or the diameter of the eye hole. The range of D would typically be 0.05 m ≤ D ≤ 0.07 m

iii) d, or the arrow diameter. d is defined so that $H=D-d$. A conservative estimate for d as elaborated in section 2 is 0.02 m.

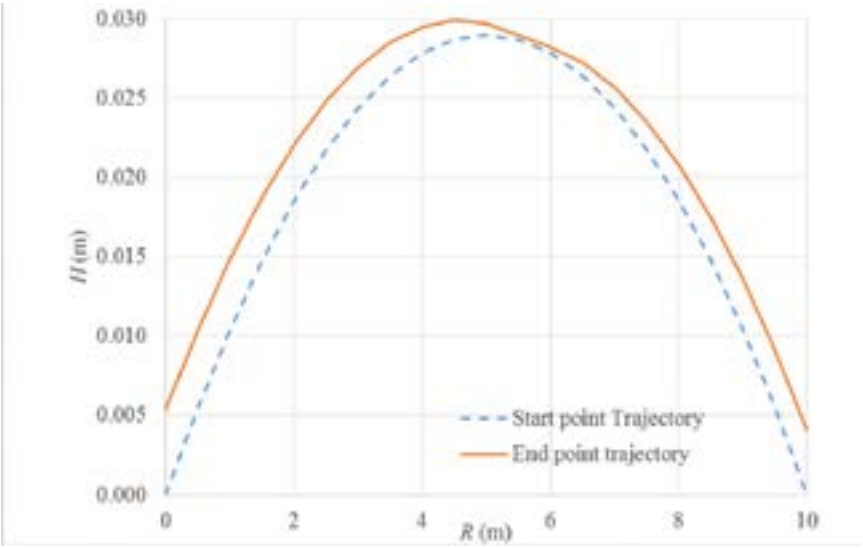


Fig.9: Trajectories of the start and end point of the arrow assuming a parabolic trajectory for the end point. The irregular form at x=R/2+l is due to the discontinuity of the derivative at this point.

Using the above assumptions, estimates of the entrance velocity may be made (note that as the velocity vector is at an angle, the velocity should be higher as it left the bow; for an estimate of this further assumptions should be made regarding the position of Odysseus relative to the axes).

Fig. 10 depicts the required entrance velocity for 0.3 m, 0.4 m and 0.5 m blade length corresponding to distances 6.9 m, 9.2 m and 11.5 m respectively. The range of the calculated velocity values range from ca. 50 m/s to 105 m/s.

Given the initial velocity of the arrow, its kinetic energy may be defined as if the mass of the arrow is known:

$$E_k = \frac{1}{2} m {v_0}^2 \qquad [18]$$

This energy is given by the tension of the arrow, which may be typically regarded as a spring tensioned by the archer according to his strength and physical ability, if the bow is not pre-stressed (see fig. 5a):

$$E_p = \frac{1}{2} k x^2 \qquad [19]$$

We may define the bow force constant $k = m\, v^2/x^2$ and calculate the force needed for the archer to shoot the arrow at the initial speed as:

$$F = kx \qquad [20]$$

F expressed in lb is usually referred to as “draw weight” and is a measure of the strength of the bow and consecutively the archer.

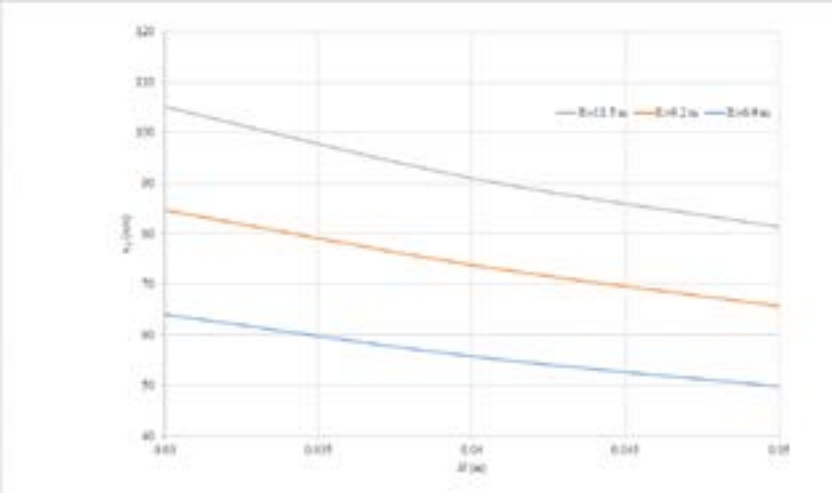


Fig. 10: Entrance velocity as a function of H, for the ranges studied.

With a “palintonos”, i.e. pre-stressed, bow the initial stressing force is higher than 0 (see fig. 5b). In the extreme case, the pre-stressing force is almost as high as the draw weight, and *Ep* is:

$$E_p = Fx \qquad [21]$$

Where *F* is constant. For a given draw length, the draw weight is than readily defined as *F= E_p/x.*

Assuming a typical draw length of 0.6m [8], typical draw weight values in lb are shown in Fig. 11 for unstressed and “palintonos” bow respectively. A typical arrow mass range of 0.08 kg to 0.1 kg was considered for the calculations.

As should be noted, draw strengths for Intermediary compound bows and for men and women with strength above average range from 50 to 60 lb (220 N to 265 N) [http://www.learn-archery.com/proper-draw-weight.html#why]. A strong archer would be expected to have a draw strength of ca. 80 lb (355 N) and the world record held since 2004 is 200 lb (890 N) for a longbow (i.e. not a ‘palintonos”) [10]. According to the calculations:

i) the draw weight values for the un-stressed bow range from a minimum of ca. 75 to a maximum of 454 lb (333 N to 2020 N). The minimum values are at the border of the draw weight for “strong” archers whereas the maximum values supersede any plausible record.

ii) the draw weight values for the “palintonos” bow range from a minimum of ca. 37 to a maximum of 207 lb (165 N to 920 N). The minimum values are in a reasonable range for draw weights whereas the maximum values are in the range of the current

world record. This further supports the argument that the wondrous bow of Eutytus would most possibly be a "palintonos" one.

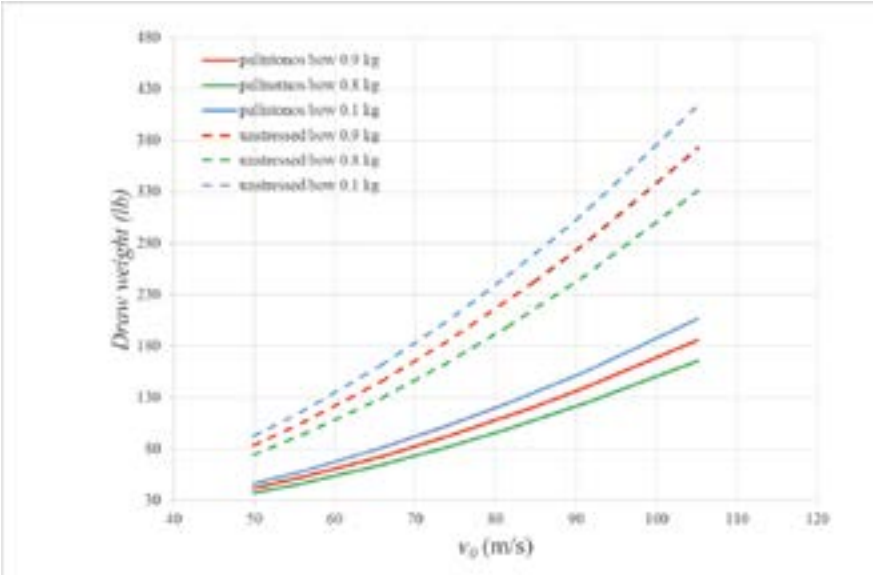


Fig. 11: Draw weights (lb) for unstressed and "palintonos" bow

4. Concluding remarks

In this work, an attempt was made to calculate the physical quantities that governed the legendary bow contest declared by Penelope in *Odyssey* XXI with herself as a prize. As the legend has it, her husband Odysseus won the prize after stringing the bow and passing the arrow through the handle holes of twelve axes in a row. Modest assumptions together with elementary calculations led to the conclusions that Odysseus was most probably using a bow of unique design, his strength could range from impressive to extraordinary and his dexterity as an archer was exceptional. More elaborate calculations which would include air drag and secondary phenomena related to the arrow flight would most probably extend the current calculations to extraordinary values suitable for an epic hero.

5. Acknowledgement

A. S. Paipetis is grateful to Prof. L.N. Gergidis for fruitful discussions on the problem.

6. References

[1] https://en.wikipedia.org/wiki/List_of_mythological_objects

[2] Frederick Ahl, Hanna Roisman, The Odyssey Re-formed, Cornell University Press, 1996 p.247.

[3] *Odyssey* XXI 74-78.

[4] *Odyssey* XXI 121-131.

[5] *Odyssey* XXI, 415-422.

[6] http://www.salimbeti.com/micenei/weapons4.htm

[7] G.S. Aldrete, S. Bartell, A. Aldrete. Reconstructing ancient linen body armor: unravelling the linothorax mystery, The John Hopkins Univeristy Press, Baltimore 2013.

[8] J. E. Gordon. The New Science of Strong Materials or Why You Don't Fall through the Floor, Penguin Books, 2001.

[9] https://en.wikipedia.org/wiki/Archer%27s_paradox

[10] http://www.guinnessworldrecords.com/world-records/heaviest-longbow-draw-weight

B5.5 Ferguson's Model in Collections of Mechanisms of MGTU of Bauman and the Antikythera Mechanism as a Demonstration of the Movement of Planets.

Olga Egorova[1] V. Omelchenko[2] R. Yakovlev[3]
Bauman Moscow State Technical University, Moscow, RUSSIA

Abstract

Before the moment when computer science, functioning through the processing of electrical signals, had been implanted in modern society there were the mechanisms that allowed people to determine and to predict different kinds of events. It comes from the planetary mechanisms, mainly through the demonstration of the movement of the planets in our solar system. From 3000 years ago when the simplest gear-wheels were chained and carried out the circular motion. In ancient Greece, people used wood and metal gear-wheels with wedged teeth. Later, in the Roman Empire, wooden gear-wheels had been used in grain mills, and metal gear-wheels in multiple small mechanisms. This transmission of motion also exists today, but planetary mechanisms demonstrating the movement of celestial bodies are less common nowadays and they are being created mostly by enthusiasts and small businesses. It's more practical now to look through Ephemerides, compiled by Regiomontanus and published by him in Nürnberg in 1474 or to use computer programs like Stellarium.

1. Introduction

Beginning from ancient times people have been trying to engineer the relative positions of celestial bodies. One of the ways to do it was to put the modeled stars and constellations on the outer surface of the Globe. One of the first known planetary mechanisms showing the movement of the planets was Antikythera Mechanism created in 100 BC. It has been found that this mechanism was once used to determine the date of the start of the Olympic Games. Archaeologists believe that it existed in all big cities where the athletes lived. It was not just the positions of the Sun and Moon or the occurrence of eclipses (both solar and lunar) that the Antikythera Mechanism calculated, but it also embraced all planets known at that time. Presumably this mechanism helped to determine the elliptical form of the lunar orbit. Finally, this functional application of the Antikythera mechanism was extended to the calculation of cycles in other Games such as of Delphic competitions and games at Corinth. Modern men could consider this device as an antique calendar, though not everyone could use it accurately. Commanding was carried out with the same handle that was used by researchers to pick a desired date. As a result the Antikythera mechanism had giv-

en us a great deal of interesting astronomical information. The front and rear panels showed the locations of the celestial bodies, while a black and white ball indicated a phase of the moon. You could also find out where the planets were relative to the stars. One of the dials could even show the time of the start of solar and lunar eclipses. The mechanism also showed the cycle of 223 lunar months, called Saros, during which the eclipses are repeated in the regular intervals. The other dial helped to find out about the Metonic lunar cycle. There was so much information that Greeks managed to gain using the device that has succeeded in outstripping the development of technology for a thousand years to come!

2. Bauman Moscow State Technical University

2.1 Brief Historical Overview

Bauman Moscow State Technical University (BMSTU), www.bmstu.ru (Figure 1) was founded on July 1st, 1830, when Nicholas I of Russia (1796-1855) approved the «Statute of Moscow Craft School» (MCS). New school was organized to teach students various crafts as well as fundamental sciences. Trained as an engineer the Emperor Nicholas I is famous that he was spreading education through the Empire at all levels, and he paid special attention to engineering.

Figure 1. *Main Building of Bauman Moscow State Technical University* (*today*) [17]

In July 27, 1989, MHTS was renamed for Bauman Moscow State Technical University (BMSTU). However, throughout its long history, BMSTU had a special responsibility for the development of national science and education, particularly in the field of mechanical engineering [8-12]. Nearly 200,000 engineers graduated from the University. Today, Bauman Moscow State Technical University is one among 29 National Research Universities of Russia and as always, it is ranked the first among Russian engineering education institutions.

2.2 The "Russian Method"

The "Russian method" [10, 12-13,16-17] became especially known after Vienna World Exhibition (1873) where it was awarded the Big Gold Medal (Figure 2a).

Figure 2. a) Vienna, 1873 b) Paris, 1900 [17]

IMTS was recognized not only as the best engineering educational institution of Russia but it joined the ranks of the world leading polytechnic schools. Soon after the first success, the famous "Russian method" had resulted in several 1st grade prizes at industrial exhibitions in Philadelphia (1876) and Paris (1900), Figure 2b.

The President of MIT became aware of the "Russian method" as he was greatly impressed by the combination of theoretical and practical learning. Manual training was introduced into the institute curriculum largely at his instance. In 1876 in Boston John D. Runkle published a small brochure in English "The Russian system of shop- work instruction for Engineers and Machinists" [15] and the "Russian method" was put in the basis of educational system of MIT.

3. The Russian Mechanisms Collection

One of the founders of the higher technical education in Russia was the great scientist in mechanics of the time, a Spanish engineer Agustin de Betancourt (1789-1824) [18-22]. The Institute knew its heyday, became one of the leading scientific and educational centers, and exerted a great influence on the entire system of higher engineering education in Russia.

Within the Institute (PSTU) Agustin de Betancourt organized the first collection of mechanisms for supporting teaching by showing students scaled models of machines, mechanisms and instruments. Later, in 1837, the graduate from the PSTU Adolf Rosenkampf was appointed a Director of MCS (the predecessor of BMSTU). He followed Betancourt's experience and gave the birth to foundation of mechanisms collection, now in Moscow.

Figure 3. Unique models with authors' surnames and dates of manufacturing [4]

Nevertheless, officially I. Balashev [4, 7] is considered the founder of the Department of Applied Mechanics (the predecessor of TMM) at BMSTU and the first Russian Mechanisms Collection in 1840's. Later, the Director of IMEI (the predecessor of BMSTU) Alexander Yershov brought a considerable contribution to the collection development in the period from 1845 to 1869. Under his supervision, students made about hundred models of mechanisms and some of them were copies of well-known models of Ferdinand Redtenbacher (1809-1863).

4. Ferguson's Planetary Train from BMSTU

Investigations through literary sources confirmed the hypotheses that the model №9 "Ferguson's planetary train" is a truncated model of Ferguson's Orrery [25-30]. Most likely, the model was manufactured in the workshops of BMSTU in the middle of 20th century to illustrate Ferguson's Paradox: rotational movement of input link is converted into a forward motion of the output link. This can be observed by placing, for example, a glass of water on the plate attached to the gear 3 (Fig. 4, Z3).

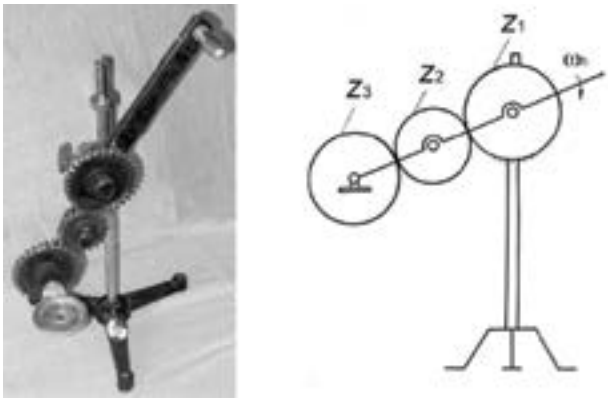


Figure 4. Ferguson's planetary train. Model № 9 a) photo of a model; b) drawing [7]

5.1. James Ferguson

James Ferguson (1710-1776) was the self-educated son of a Scottish crofter (Figure 5, a) [25, 32]. The story is told of young Ferguson's fascination with mechanics being inspired by watching his father use a large lever to adjust the roofline of their house.

(a) **(b)**

Figure 5. a) James Ferguson (1710-1776); b) his Orrery [26]

George III, while Prince of Wales, attended Ferguson's lectures and rewarded him with an annual pension of £50 from the Privy Purse until his death in 1776 [25-26].

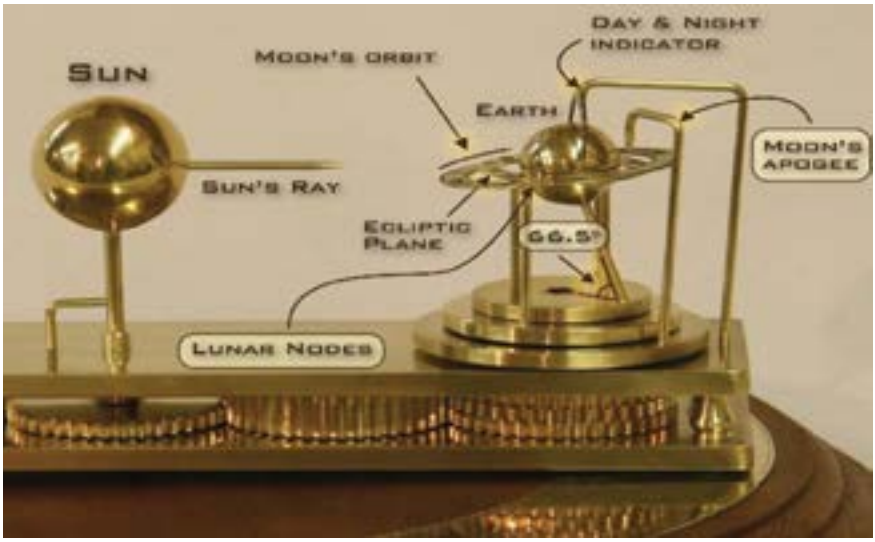


Figure 6. Ferguson's Orrery. Illustration by L. Whittemore [27]

Ferguson designed orreries and a number of clocks. He knew Benjamin Franklin and apparently was inspired by

Franklin's famous 3-wheeled clock, later designing his own versions. Ferguson was a very prolific inventor, making many devices for use in research and lecture demonstrations.

5.2. James Ferguson's Orrery

In 1764, James Ferguson built an Orrery [27] for use in lectures about the solar system. He wrote:

> *"This machine is so much of an ORRERY, as is sufficient to show the different lengths of days and nights, the vicissitudes of the seasons, the retrograde motion of the nodes of the Moon's orbit, the direct motion of the apogeal point of her orbit, and the months in which the Sun and Moon must be eclipsed."*

5.3. Ferguson's Paradox

A simplified version of Ferguson's Paradox reads:

> *"Three wheels on the same axis mesh with one thick wheel. Turn the thick wheel. One of the thin wheels goes forward, one backwards, and one goes no way at all!"*

What Ferguson was really doing with his Mechanical Paradox was emphasizing the importance of defining "rotation" with respect to a fixed frame of reference. They say he volunteered to construct a mechanical device, which seemingly was contrary to all mechanical laws and declared as impossible by those with him [27].

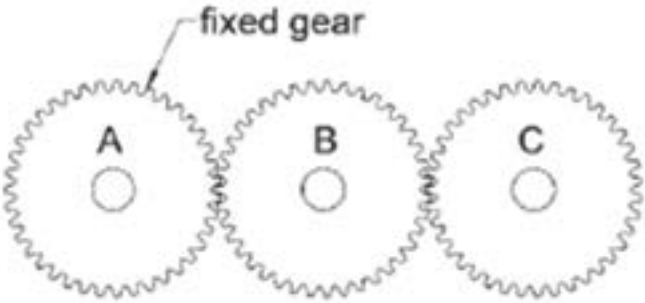


Figure 7. Ferguson's Paradox [27]

James appeared by appointment a week later, however, with the arrangement of gears given in the following description, which greatly mystified his associates, who were unable to solve the reason why the gears moved contrary to recognized laws.

The original model made by Ferguson was of wood, and became a good puzzle to study over and show the extent of the knowledge of gears.

The "paradox" arises when in a train of gears – A, B, and C – gear A is fixed and gears B and C have epicyclic motion around it (Figure 7). Gear A is the gear under the sun and is fixed to the base. When all three gears have the same number of teeth, gear B rotates twice for each rotation and gear C maintains its orientation to a fixed frame of reference. That keeps the Earth's axis pointed in the same direction. When gear C has fewer teeth than gears A and B, it turns in the direction opposite the mechanism, in this case illustrating the regression of the nodes. When gear C has a few more teeth, it will slowly turn in the same direction as that of the mechanism, illustrating the advancement of the apogee of the Moon's orbit [27].

6. 3D modeling of Ferguson's Planetary Train

6.1. Advantages of Autodesk 3ds Max

3D modeling of "Ferguson's Planetary Train" (a model №9) was carried out with the help of a program Autodesk 3ds Max. This program has a high performance and provides a comprehensive modeling, animation, simulation, and rendering solution for motion graphics as well as for teaching purposes. Autodesk 3ds Max has grown to be one of the top 3D animation software options nowadays. It is developed and produced by Autodesk Media and Entertainment [34].

6.2. 3D Modeling

Before we started a 3D modeling of the model, "Ferguson's planetary train" was analyzed and highlighted several of its elements (Fig.8). We called a link of a mechanism deemed to be fixed as a frame. Therefore, we started modeling a frame with three legs (1), then a holder, a planet carrier (2), and three gears (3-5). We began with 3D modeling of each element, which later were joined together (in a single assembly).

Figure 8. Ferguson's modal main elements

Autodesk 3ds Max includes a wide range of standard objects and modifiers, such as 3D geometry and 2D shapes. For creating the first element (frame) we required.

"Cylinder" object, then set its size and press "Create" button (Figure 9). Next step allowed us creating the "legs" of the frame locating them at an angle of 120 degrees from each other and using the function "Copy" (Figure 9).

Figure 9. 3D modeling of a frame and the frame's legs

On the Figure 10 we show a 3D modeling of a holder. We made it out of three elements using function "Box" and adding half a cylinder on the left side using the "Extrude" and "Smooth" commands.

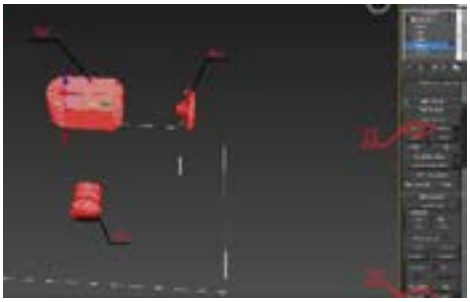


Figure 10. 3D modeling of a holder and a planet carrier

Next step (Figure 11) was a 3D modeling of a planet carrier, a link of a planetary gear train on which the axles of the planetary gears are arranged.

Figure 11. 3D modeling of a planet carrier

We used functions "Cylinder" and "Cubic" with a cube of 28 mm to 220 mm in size, using polygons and changing the shape with the help of "Extrude" function. At the end, we connected our cube with three (3) cylinders, using "Attach" function. Finally, we got

the geometrical features of the planet carrier that did not differ from the real model. Then we started a 3D modeling of the cylindrical gears (Figure 12). We used the "Cylinder" function, just adding 64 polygon edges since we have 32 teeth; and 32 polygon edges since we have 16 teeth on the smaller gear.

The Fig. 13 shows a 3D document of a rack that is made by functions "Extrude", "Smooth".

Next, we made a "plate" using a cone and a button to make a small hole on the right side of it ("Proboolean") (Figure 13).

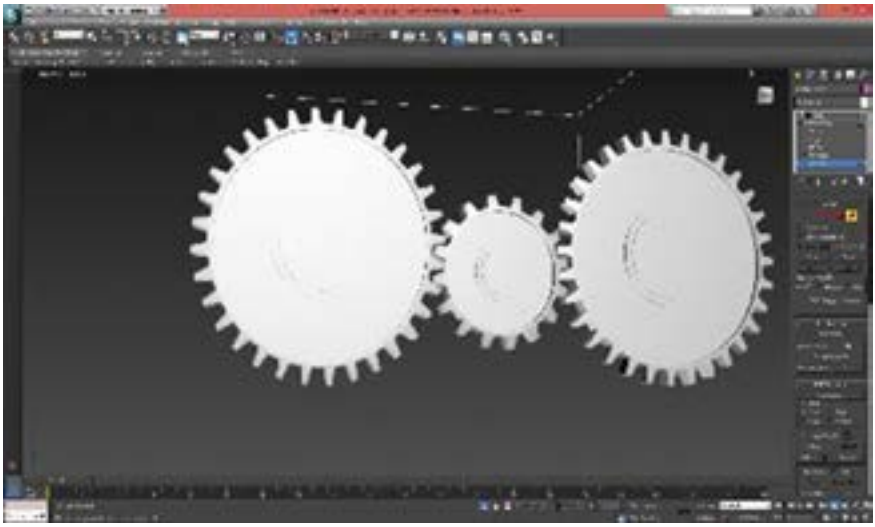


Figure 12. 3D modeling of the cylindrical gears

Then we add a "bearing". Separate elements were assembled using button "attach".

Figure 13. 3D modeling of a rack and a plate with a hole

7. 3D Animation

To create a 3D animation (Fig.14) of "Ferguson's planetary train" we need to arrange 3 bones in the main parts, which really are the shafts gears bearings; then to create them using the link using the standard functions of the Autodesk 3ds Max.

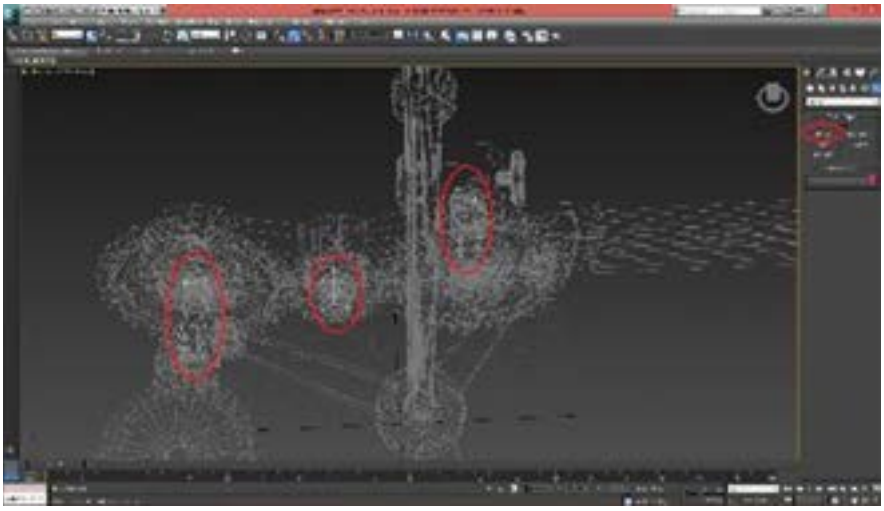


Figure 14. *3D Animation*

7. Conclusions

The Conclusion can be drawn as follows:

(1) The scaled model № 9 under the name of "Ferguson's planetary train" at Bauman Moscow State Technical University is proved a truncated model of Ferguson's Orrery.

(2) James Ferguson (1710-1776) was a famous Scottish astronomer who invented, manufactured and sold many teaching aids (orreries) for showing the motions of the planets, places of the Sun and Moon.

(3) "Ferguson's Paradox" shows the motion of the output link of "Ferguson's planetary train", in which it remains parallel to its initial direction. That means the rotational movement of input link could be converted into a forward movement of the output link.

(4) 3D document of "Ferguson's planetary train" and its animation created by students of BMTSU using Autodesk 3ds Max allowed them fully to understand, study and analyze the Ferguson's Paradox as well as the basic principles of the scientific discipline of TMM, history of MMS, and peculiarities of planetary gears in particular.

(5) 3D modeling of well-known mechanisms could be considered as innovative educational technologies in teaching of TMM and serve as a basis for further research and solving the problems of synthesis and analysis of mechanisms.

(6) Created 3D document of "Ferguson's planetary train" from Russian Mechanisms collection at BMSTU could be copied (printed) with the help of 3D printer and demonstrated through Internet in any other place in the world.

(7) Acknowledgements

This research is sponsored by BMSTU and the Department of Theory of Mechanisms and Machines in particular.

References

[1] Evgrafov A., Egorova O., Khisamov A. Experience of Modernization of the Curriculum TMM in St. Petersburg State Polytechnical University. In: *New Trends in Educational Activity in the Field of Mechanism and Machine Theory*, Springer, Volume 19, pp. 239-247, 2014.

[2] Ceccarelli M. Evolution of TMM (Theory of Machines and Mechanisms) to MMS (Machine and Mechanism Science): An Illustration Survey. In: *Proc. of nth IFToMM World Congress, Tianjin* (*PR China*), vol. 1, pp. 13-24, 2004.

[3] http://www.scholarly-societies.org/history/1666as.html

[4] Tarabarin V., Carbone G. Application of collection of mechanisms in teaching mechanism design (in Russian). *Electronic scientific and technical journal, Science and Education*, (6), June, 2009.

[5] http://technomag.edu.ru/en/doc/127492

[6] http://www.arts-et-metiers.net/musee/histoire-du-musee

[7] Golovin, A., Tarabarin V. *Russian Models from the Mechanisms Collection of Bauman University*. Series "History of Mechanism and Machine Science", vol. 5, Springer, 2008.

[8] Egorova O. The contribution of Russian and Soviet scientists for the promotion of the History of Engineering. *International Journal of Terraspace Science and Engineering*, *Global Scientech*, Volume 5, Issue 2, November, pp.137-144, 2012.

[9] Egorova O., Tarabarin V., Timofeev G. On the History of Formation of the Russian School of Applied Mechanics. *Izvestie vuzov*. *Mechanical Engineering*, №2, pp. 76-83, 2013.

[10] Egorova Olga. Konstantin Vasiljevich Frolov (1932-2007). In: *Distinguished Figures in Mechanism and Machine Science. Their Contribution and Legacies*. Part 3: London, Springer, pp. 63-86, 2014. [11] Egorova O., Timofeev G. Konstantin Frolov Continuing the Soviet School Traditions on MMS. In: Explorations in the History of Machine and Mechanisms, Proceedings of HMM2012, Series: History of Mechanism and Machine Science, Vol. 15, Springer, Amsterdam, pp. 160- 169, 2012.

[12] Egorova O., Timofeev G. Academician Frolov K.V. at Bauman Moscow State Technical University. In: Proc. of IFToMM Workshop HMMS-2013, Palermo, Italy, November 22-23, 2013.

[13] Egorova O., On "Russian Method" of training of engineers. *International Affairs*, 2014, http://interaffairs.ru/read.php?item=10459 [15] Runkle John D. The Russian system of

shop-work instruction for Engineers and Machinists, Boston, Kingman, 1876.

[16] http://dates.gnpbu.ru/3-8/Sovetkin/sovetkin.html

[17] www.bmstu.ru

[18] Egorova O., Timofeev G. Agustin de Betancourt, one of the founders of higher engineering education in Russia (in Russian). *Vestnik MGTU*. Machine building, №1 (78), pp. 115-124, 2010.

[19] Egorova O. Agustin de Betancourt. *Secretos cubanos de un ingeniero hispano-ruso* (in Spanish). Ediciones Abril, La Habana (Cuba), 2010 [20] Egorova O. In the footsteps of the "Russian Spaniard" (in Russian),

[20] Egorova O. In the footsteps of the "Russian Spaniard" (in Russian), *International Affairs*, №10, pp. 120-140, 2011.

[25] http://en.academic.ru/dic.nsf/enwiki/962220

[26] http://en.wikipedia.org/wiki/James_Ferguson

[27] http://armstrongmetalcrafts.com/Products/ParadoxOrrery.aspx

[28] http://en.wikipedia.org/wiki/Sun_and_planet_gear

[29] http://www.mekanizmalar.com/fergusons_paradox.html

[30] http://bbs.homeshopmachinist.net/threads/37031-Ferguson-s-Paradox/page2?s=5d-405fc43abb4fd2c603933bf40da438

[31] Tony Buick. Orrery. A Story of Mechanical Solar Systems, Clocks, and English Nobility, http://www.pdfmagaz.in/02144521-tony-buick-orrery-a-story-of-mechanical-solar-systems-clocks-and-english- nobility/#sthash.tYZkz58X.dpuf

[32] Ferguson, James. The description and use of a new machine, called the mechanical paradox; invented by James Ferguson, F.R.S. 1764; London (Reprinted in Select Mechanical Exercises..., 1773; London)

[33] http://chestofbooks.com/crafts/popular-mechanics/Amateur-Work- 4/Ferguson-s-Mechanical-Paradox.html

[34] http://www.autodesk.com

[35] http://www.arts-et-metiers.net

[36] http://www.dmg-lib.org/dmglib/main/portal.

B5.6 Examples of Environmental Engineering Infrastructure Works from the Greek Antiquity.

Efstathia Odysseos Valiantza
Visiting Professor, Civil Engineering School, University of Thessaly

Abstract

Paper refers to three specific examples of infrastructure works related to environmental engineering, developed in the Greek Antiquity, mainly in the area of retrieving and treating rainwater: (a) Delos collection, treatment and storage system of rain water. (b) Knossos palace collection and treatment system of rain water for secondary uses and (c) The treatment system of Kladeos River water and use for the needs of Leonidaion, the big hotel establishment in Olympia Archeological site.

The presentation of the examples is based not only on bibliographic references, but mainly on data from in situ visits and relative innovative assessments, which have been made by the author, in the course of several years. Adequate photographic material is also used.

The comments on the works which are presented, are derived from the present contemporary knowledge of the relevant environmental engineering technology, due to the professional orientation of the author.

These comments concern the comparison of the knowledge level between present times and Greek Antiquity, as well as the natural water protection efforts of the ancient Greeks, proved by the construction of such works.

1. Intoduction

An important sector of the environmental engineering technologies is that of the water collection and treatment, so that it becomes suitable for the desired uses. The water is collected mainly from natural surface sources (ex. lakes or rivers), underground sources, or from recycling of the urban rainwater runoff. Nowadays, several water treatment methods have been developed, depending on the initial water quality and that required for the desired uses. Nevertheless, in the majority of water intake cases from natural surface sources, there are basic stages of treatment, which are always included, like the removal of the coarse solid particles through sand collectors, and the removal of fine suspended solids through properly designed precipitation tanks.

In the present, a number of examples of infrastructure works for the collection and treatment of water in the Greek Antiquity have been examined, to investigate the ways of water management applied at the time, and the level of environmental engineering knowledge for its treatment.

2. Water intake treatment and storage at the ancient Delos settlement

The myth says, that the island of Delos in the Aegean was the birth place of Apollo, god of light and Artemis (Diane) his twin sister, goddess of hunting, both born by Leto, who got together with Zeus, the father of Olympian gods. Due to the jealousy of Hera, Zeus's wife, no land was accepting Leto to deliver the babies, but finally a small lost rock "wandering" in the Aegean Sea, decided to stop and accept her, becoming in this way Delos, which in Greek means "obvious".

On this dry, fruitless Delos rock, a land area of the order of 5 km^2, like a pebble thrown in the Aegean Sea, between Mykonos and Rineia islands, but with worldwide fame, human settlements since the middle of the 3rd millennium BC existed, and were highly developed around the middle of the 2nd millennium BC.(1-p.6). Because of this, reserving water was of vital importance, since water shortage was always a problem in most of the Aegean Islands. So, there are astonishing public and private infrastructure works for collection and recycling of rain water from the various surfaces of the Delos settlement, like the ones described below:

2.1 Water intake barrage at Inopos River

The only river in Delos is Inopos, collecting the surface runoff from mount Kynthos (112m. height) (1-p.5).Close to Inopos house, there is a barrage structure, which retains river water, and has an overflow 8-10m long. According to the French archeological school, who performed many excavations in the area, the water after overflowing is conducted to a sequence of two basins, the one overflowing to the other. The second basin contains 22 staircases for the approach of water levels (2-p.224-225).

To our opinion, these two basins serve in essence a two stages sedimentation treatment operation for the removal of fine suspended solids, while the staircases in the second basin, are also useful for the necessary removal of the sludge, eventually collected at the bottom of the basin.

It is noticeable that, Delos water basin walls are covered with special waterproof mortar, preventing water from leaking to the underground.

2.2 The Theater water basin

The most admirable hydraulic work of the ancient Delos settlement is the water basin of the Theater, capacity 5500 seats, made of granite and marble (2-p.247).

Rain water is collected by gravity through aqueducts all along the theater stage (picture 1), while an underground structure 6x22.5m, with 8 stone arches supporting its roof, serves as water storage tank.

This arrangement is protecting water from evaporation and pollution (picture 2). However, judging from the progressive reduction ending height of the arches along the basin, we conclude that besides their role to support the roof, these walls could also serve as overflow areas from one part of the basin to the next, so that a multistage sedimentation of suspended solid particles is obtained, as well as a retention of the latter behind the base walls of the arches. The retention time of the water, due to the total

volume of the basin could facilitate a good water treatment by sedimentation.

Picture 1: *The theater and open duct for the collection of rain runoff water*

Picture 2: *The theater water basin*

2.3 House rainwater collection basins and wells

It is interesting that in Delos not only public but also private infrastructure works for the collection of rain water from the roofs exit, as well as arrangements of sand collectors followed by primary sedimentation tanks (ex. The Diadoumenos house, where the famous statue of Diadoumenos has been found –a young man trying to wear a head ornament). Many water wells are obvious in several private houses internal yards (ex. House of Hermes). Some of these wells are still working today and are used by the guards of the archeological area.

3. Works for the collection and treatment of rainwater at Knossos palace

Knossos in Crete Island of the Greek Aegean Sea, is well known that consists one of the most ancient cities of the Aegean area, with a history of 8000 years of human presence (4-p.23).

The Minoan civilization which was developed in Crete, can be considered as the first example of what is known today as European culture (5-p.46). The existing today archeological site of Knossos, counts from the years 1600-1500 BC and has a surface area of 17400 m2 (5-p.48).

In this place, there is an impressive surface network of ducts for the collection of the rainwater runoff, along the various yards and staircases. The rainwater was thus conducted to basins for secondary uses. Before its storage, it was passing through many small enlargements of the ducts cross sections, which resulted to its sequential short term sedimentation due to the diminution of its velocity. These enlarged cross sections could be considered as sand collectors arrangements.

The rainwater collection network was separated from another network collecting the wastewater of the palace. The Queen's toilet located at the east side of the palace, where also her bath was located, had a continuous run of water for the removal of wastes (5-p.48), which can be considered as the oldest water closet in the world.

B5.7 The Anyang and the Achaean Chariot Parallel Development in the Late Bronze Age.

Kypros F. Milidonis , Thomas G. Chondros
Univ. of Patras

Abstract

Light chariots with spoked wheels were developed initially in Syria or Northern Mesopotamia at about the beginning of the 2nd millennium BC and quickly propagated all over Middle East. The two-wheeled horse-drawn chariot was one of the most important inventions in history. Information of chariots of Mesopotamia, Egypt, China, Achaean and Mycenaean Greece, with light and flexible spoked wheels was used for a reconstruction of the dual chariot in China and the Achaeans. A design study for the dual chariot provides information on the parallel development of an efficient ground transportation system that lasted for almost 20 centuries as the key military technology and gave humanity its first concept of personal transport. A detailed design along with traction dynamics and lateral stability is presented here. Its development is of great engineering significance since it involves the seeds of a primitive design activity.

1 Introduction

The chariot, an open, two- or four-wheeled vehicle of antiquity, first used in royal funeral processions and later employed in warfare, racing, and hunting, apparently originated in Mesopotamia in about 3000 BC. The two-wheeled horse-drawn chariot was one of the most important inventions in history. It gave humanity its first concept of personal transport, and for two thousand years it was the key technology of war. It also became the world's first mass spectators sport event. It was used in warfare during the Bronze and Iron Ages, and continued to be used for travel, processions and in games after it had been superseded as a military machine [1-5].

During excavations in 1927/8 by the British archaeologist Sir Leonard Woolley in the Royal Cemetery of Ur in modern day Iraq, an artifact known today as the Royal Standard of Ur was discovered. It is dated to the third millennium BC. Portrayed on one side of this artifact is the Mesopotamian four-wheel, cart-like structure pulled by four donkeys (Fig. 1). The artist depicts it in different states of motion. Initially, the donkeys shown walking, begin to trot, and then gallop. To clarify that this was a war machine a trampled enemy or two are shown under it [5].

Fig. 1 shows details of the chariot as used in royal parades (Top), and in the battlefield (Bottom). The solid wheels consisting of two similar semi-circular parts connected together and with the axles. The wheels rotated on a fixed axle linked by a draft pole

to the yoke of two pairs of donkeys or a pair of oxen. This earliest known depiction of the Mesopotamian chariot was carrying a spearman and a charioteer, and fighting could be also conducted from on-board the vehicle. Shields seem to be applied abreast of the donkeys serving also as the link with the drawbar, which in the left bottom depiction seems to be bent upwards, from the chariot floor towards the donkeys' necks. A twin circular link is put on top of the drawbar for the harness to pass by, and control the left and right pair of donkeys separately [5].

Fig. 1. Standard of Ur, 26th century BC. Bottom panel depicts chariots in action [5].

The wheel was further improved in the Near East, and contributed to the development of the chariot with four spoked wheels. Representations of chariots can be found on Anatolian seal impressions from the second millennium BC. Unlike their Mesopotamian predecessors, these chariots have spoked wheels. Four small cast copper/bronze wheels (170-177 mm in diameter) found in a context of the first half of the 18th century BC in the Burnt Palace at Acemhöyük in Anatolia provide the earliest three-dimensional evidence for spoked wheels so far known. These four-spoked wheels can be compared with extant examples of spoked wheels from Egyptian chariots from later second millennium BC [5-6].

The excavation of *kurgans*, graves covered by earth mounds in the Sintasha-Petrovka region in the northern Eurasian steppe on the borders of Eastern Europe and Central Asia, around the Ural and upper Tobol rivers dated to the period 2100–1800 BC, have yielded objects believed to be the earliest known chariots. Sintashta settlements are remarkable for the intensity of copper mining and bronze metallurgy. The lower part of their wheels left an imprint of their shape and design into slots cut in the floor of the burial chamber. Some parts of the chariot structure were also preserved in this way. [5-7].

The two-wheeled version proved superior in battle because of its higher maneuverability. Greater speed was attained by the use of teams of two or four onagers and by the evolution of the light, spoked wheel. The introduction of the horse as a draft animal in about 2000 BC in Mesopotamia was the final step in the development of the chariot into a military weapon that revolutionized warfare in the ancient world by providing armies with unprecedented mobility. A horse can pull a chariot at a trot at up to 8 miles an hour - and at a gallop twice as fast.

Light two-wheeled chariots with spoked wheels were developed initially in Syria or

Northern Mesopotamia at about the beginning of the 2nd millennium BC and quickly propagated all over the Middle East. Its superstructure is made of light wood, and wheels rims of bent wood, held in place by spokes. The weight of a third-millennium European wagon, the product of stone-tool carpentry, might be 600 or 700 kg. By Tutankhamun's time sophisticated joinery, carefully chosen woods, and spoked wheels had achieved vehicles as light as 35 kg [4-5].

Based on archaeological evidence, anthropometrical standards, performance flexibility, aesthetics considerations of the time, safety and construction capabilities of the time, a preliminary design study of various versions of the dual chariot is attempted here. Transport kinematics is investigated too. The proposed methodology provides sufficient information about ancient chariot design and operation, and renders for similar investigations of ancient transport equipment and reconstruction

2 Egyptian Chariotry

The Egyptians improved the design of the chariot by making it lighter, changing the position of the chariot's axle so that the driver would stand closer to it and covering parts of the axle with metal in order to reduce the friction between it and the wooden wheelhub. A single shaft attached to the yoke pulled the chariots. Various kinds of wood were used: elm, ash for the axles and sycamore for the footboard. Wood used by the ancient empires for carts and wheels had been imported in its majority from West Asia and in different species. Some wooden parts were strengthened by covering them with metal sleeves. These changes reduced the load on the horses and greatly improved their performance.

In chariots found in Egypt, the wheels were very light and each such chariot consisted from more than 50 different pieces. Spoked wheels, appear at the beginning of the era of bronze. Spoke wheels were much lighter and could be made in a much larger diameter, up to 2 meters, so that a chariot could be driven at much higher speeds over rough terrain, Their development could not have become reality without the metal saw. The invention of the lathe although not definitely known, from the artifacts found it appears to be in use by 1500 B.C. in the area of eastern Mediterranean. It is used frequently after 900 B.C. and Plato refers to lathes by 400 B.C. The use of the lathe has also greatly enhanced the development of light chariots. Fig. 2 depicts a light chariot found in Thebes, Egypt in 1828-29 by I. Rossellini, manufactured around 1500 B.C. (it has been dated to the 18th Dynasty (1550-1292 B.C.) The chariot with 4-spokes wheels provides the first evidence of lubricated wheel bearings with animal fat, a technique that was still in use up to 100 years ago. The Egyptian horse drawn chariot consisted of a light wooden semicircular frame with an open back surmounting an axle with two wheels of four or six spokes [4-11].

Fig.2 A two-horse chariot with 4-spoke-wheels and lubricated wheel bearings, Thebes, Egypt, ca. 1500 B.C. [9].

By 1435 B.C. Egyptians were making chariots, and by the end of the century chariots with four-spoked wheels and light design had been introduced to Minoan Crete and the southern European mainland. Six chariots preserved in the fourteenth-century tomb of Turankhamun, intended for one or two standing passengers with railings reaching to hip height, had floor dimensions averaging 1030 mm wide and 470 mm front to back; wheel averaged 930 mm in diameter, and wheel track averaged 1700 mm.

A carpenters' shop manufacturing spoked wheels for carriages is shown in Fig. 3 [4]. On top the picture shows clearly consecutive phases of wheel production by different workers. Another important information yielding from Fig. 3 is the availability of the various parts required for the final carriage assembly [4-11]. In Fig. 3 (Bottom) in the left, two wheelwrights are forming rims, bending two lengths of wood inserted between two upright poles stuck in the ground. Working in such a way, the strain on the uprights is minimal. At the centre a seated worker is shaping a piece of wood with an adze. On his right two hoops, probably part of the framework, and what looks like the chassis with the axle. At the far right one of two wheelwrights putting together a wheel.

Fig. 3. A carpenters' shop manufacturing spoked wheels for carriages [4].

The Egyptians knew two types of chariots, the war-chariot which had six-spoked wheels while the carriage chariots had only four spokes. The six spoked wheels could be made lighter and were better supported than the heavier four spoked wheels, making the whole chariot more reliable. The lack of springs made the chariots unsuited for use in rocky terrain, where they could easily overturn or break. Egyptian war chariots were manned by a driver holding a whip and the reigns and a fighter, generally wielding a bow or, after spending all his arrows, a short spear of which he had a few [12-14].

Pharaohs, used chariots in warfare, the most famous perhaps being Ramesses II at the Battle of Kadesh (Fig. 8), where both the Egyptians and their enemies, the Hittites, had chariots in their armies. The chariots of the Egyptians, unlike the Hittite chariots, were lighter and faster. The Egyptian chariot was also perfectly suited to chasing down fleeing enemies [15].

When a chariot was not in use the constant pressure of its own weight tended to deform the wheels. When the vehicle was stationary for any extended period of time, they were therefore removed -as was done in the tomb of Tutankhamen-or the chariot could be turned over. German carpenters who reconstructed such a chariot needed about six hundred man-hours to complete it [14].

3. Chinese Charotry

Horses were not native to China but probably existed in Mongolia. Although domestication of the horse goes back at least to the fourth millennium B.C. in the steppes of western Asia, horses were not used there as draft animals until after long experience with oxen, donkeys, and other equids. In China no wheels of any kind earlier than the spoked wheel of Anyang chariots have been found (1200 B.C.). From the oracle inscriptions and bronze inscriptions found at the Anyang or Yinxu site, in the angle of the Huan River north-east of todays Xiaotun city and across the river at Sanjiazhuang, identified as the last capital of the Shang dynasty, it is estimated that the reign of the first of the nine kings of the dynasty Wu Ding was around 1200 B.C. Among the well preserved findings of the excavations in Anyang there are a 10,000 m² bronze foundry, more than 1200 scrificial pits, and cemeteries with large tombs excavated since 1935, 1950, 1976 and in continuation up today. Textual records of China were not as durable and cheap as the clay tablets of the Near East of the same period. The earliest samples of cryptic royal texts on bones oracle inscriptions were apparently copied from writings on perishable materials. [16].

An impressive finding of a well preserved chariot burial, at Guojiazhuang M52, Anyang, Yinxu is shown in Fig. 4. The square pit dimensions are 3,500 mm and 1800 mm deep. Two men twenty-five to thirty years old and two horses were killed and laid in the pit before the chariot was lowered into place. The wheels, axle, and draft pole were fitted into trenchcs allowing the chariot box to rest on the bottom of the pit, thus preventing deformation of the wheels. Similar chariots found in tombs provide information that the lightly constructed chariots with multispoked wheels up to 1460 mm dia. proved effective for command, observation and archery and were supported by the infantry of the Shang army. Dimensioning of the chariot on the picture provides additional information for the reconstruction of this chariot [16].

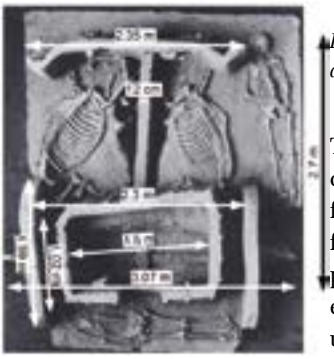


Fig. 4. A well preserved chariot burial at Guojiazhuang M52, Anyang, Yinxu [16].

The M52 chariot was unusually big but standard in construction, with two spoked wheels rotating on a fixed axle. The axle is located halfway between the front and back edges of the chariot box. The dratft pole is 2680 mm long with square cross-section. rested on top of the axle, it was curved upward from the underside of the box to the height of the yoke. The

yoke, 2350 mm long, carried inverted-V-shaped yoke saddles which rested on horses' necks forward of the withers. The wheels had eighteen spokes and were of ca. 1600 mm dia. The construction of the wheel rims implied by other Anyang chariots reveals they were made from two pieces of bent wood, into which the spokes were fastened. Bronze axle caps with wood linchpins kept the wheels in place on the axle, but the wheels themselves had no metal parts (the rims and hubs of Zhou Chariots were sometimes reinforced with metal fittings).

The axle had an overall length of 3080 mm and the distance between the wheels was 2300 mm. The chariot superstructure box sat on top of the draft pole and axle. It measured 1500 mm from side to side and nearly 1000 mm from front to back, large enough for three kneeling passengers. The sides of the box were formed by a lattice of wooden bars about 500 mm tall; the entrance, 400 mm wide at the back. Traces of red and black lacquer were found on the floor and sides, and may be all wooden parts of the chariot were lacquered, for protective as well as for decorative reasons. Yoke saddles, axle caps, a mechanism joining the draft pole to the box, and a few small ornaments were made of bronze. The horses wore bronze frontlets, headstalls ornamented with cowry shells, and perhaps red cloth, and one had a bronze bell of the type *ling* at its neck. No bits or cheek pieces were found, but both are known from other Anyang chariot burials. Skilled carpenters were necessary not only to build the Zchariots, but also to keep them in running order. Harness making was another essential specialty. Measurements available for six Anyang chariots provide the following averages: floor dimension 1340 by 850 mm, wheel diameter 1370 mm, wheel track 2270 mm [14-16].

The horse-drawn chariot is a technically sophisticated artifact requiring special skills and resources for its construction, use, and maintenance. Two specific features of Anyang chariots are the large number of wheel spokes (from eighteen to twenty-six, as compared with four, six, or eight in the Near East) and the mounting of the axle not at the rear edge of the box, but midway between front and back. In western Asia, both features are known only from mid second-millennium chariots buried at Lchashen in the Caucasus, and for the moment these are the closest relatives of Anyang chariots, indicating a strong influence from those areas.

4. Draft Beam and Axle

A spreadsheet was used for preliminary stress analysis of the draft beam and the axle for the Anyang Chariot [1]. It will be assumed that the draft bar is simply supported on the wheels axle and the yoke on the horse necks, and a uniformly distributed load from crew and supplies, totaling 2550 N is applied along the box-structure. At the support stations arbitrary reactions are assumed initially. Then, the EXCEL Tools Solver was applied to solve for the unknown reaction by making zero the shear and bending moments at a dummy station on the right end of the draft beam. Since the problem is linear, Solver returns with a unique solution. For the chariot draft beam reactions at front edge and the back edge are calculated; 290 N acting on horse necks and 2220 N supported by the wheels' axle. Maximum bending moment 650 Nm occurs at 2300 mm from front end. Figure 5 shows the shear forces and bending moment diagram for the draft pole.

Fir wood properties comprise strength in tension and compression, shear strength, static bending strength, impact strength. Fir is repeatedly mentioned in Homer, praising its good properties [1]. Fir wood is orthotropic, with unique and independent mechanical properties in the directions of three mutually perpendicular axes: longitudinal, radial, and tangential. Modulus of elasticity along the longitudinal axis parallel to the fiber (grain) is $E = 1.01^{10}$ Pa, and material density 520 Kg/m^3. Tension perpendicular to grain is 1.86 MPa. Static bending stress for dry cypress-tree wood is 76 MPa and allowable stress for wood in construction 25 MPa [32].

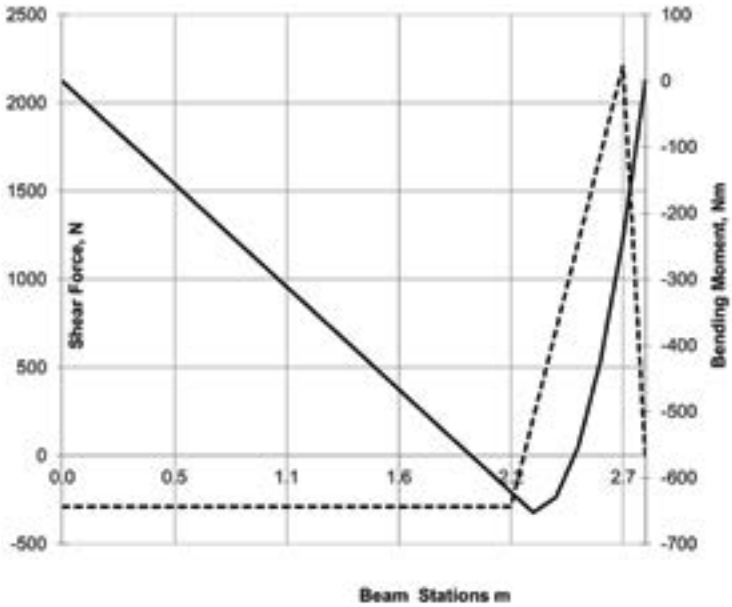


Fig. 5. The Anyang chariot shear forces - bending moment diagrams along the draft pole (continuous line: internal moment Nm, dashed line: shear force, N).

Section modulus in bending for the draft beam of rectangular cross-section bx-h=110x110 mm^2, is calculated as [1]:

$$W_x \cong bh^2/6 \tag{1}$$

or $W_x = 0.000288$ m^3. Then, maximum stress in pure bending $\sigma max = M_b/W_x$ yields $\sigma_{max} = 7.68$ Mpa. From the basic design equation for bending of beams [1] yields

$$\sigma_{max} \leq \frac{S_L}{N} \tag{2}$$

where $S_L = 25$ MPa, the limiting stress for fir wood, yields safety factor $N = 3.25$, a quite safe value for dynamic loading.

Assuming a 2.80m active axle length, 120 mm axle diameter, and 2250 N loading uniformly distributed along the 1500 mm box width, the same spreadsheet used for solving the draft pole stresses is used again for the wheels axle internal loading [1]. Spreadsheet-drawn internal loading diagrams are depicted in Fig. 6.

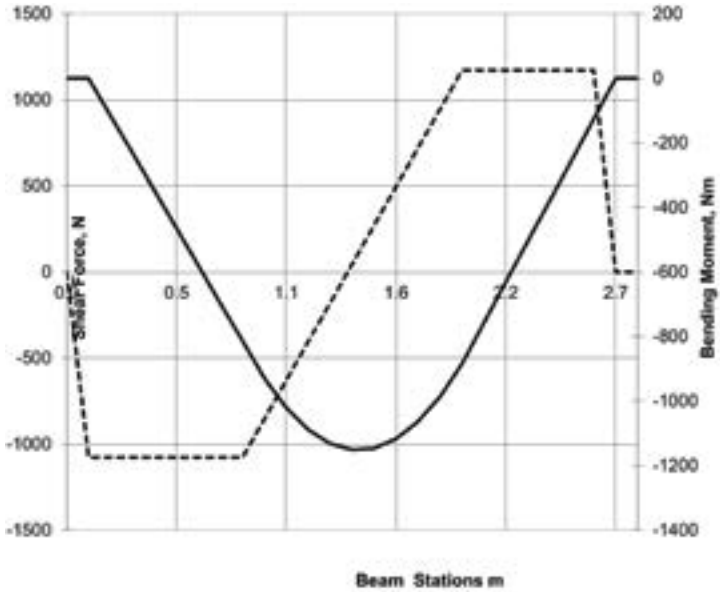


Fig. 6. The Anyang chariot, spreadsheet-drawn internal loading diagrams for the wheels axle (continuous line: internal moment Nm, dashed line: shear force, N).

From Fig. 6 maximum internal moment 1,151 Nm and 1,172 N shear force yield for the wheels axle. Section modulus in bending for the circular cross-section with D = 120 mm is calculated as [1]:

$$W_x \cong 0.1\,D^3 \tag{3}$$

or W_x= 0.00017 m³. Then, maximum stress in pure bending σmax = Mb/Wx yields σ_{max} = 6.61 Mpa. From the basic design equation for bending of beams, Eq. (2) [1] yields N = 3.75 safety factor in bending, a rational number for this design.

There are two sections of the shaft subjected to shear in each side adjacent to each wheel. Failure criterion for pure shear, considering the influence of normal stress yields the design equation [1],

$$\tau = \frac{4V}{3A} = \frac{4V}{3\pi D^2/4} = \frac{S_{sy}}{N} \tag{4}$$

where d=60 mm the axis diameter at wheel bearing, V = 2250 N, shear force at wheel bearings considering the case that all chariot weight is loading one wheel at turns, S_{sy} = 4.79MPa yield strength of wood in shear (perpendicular to grain), and N safety factor.

Then the solution of Eq. 4 yields $\tau = 0.26$ MPa, and safety factor in shear, $N = 18.05$. Considering the high level of stresses due to the diameter reduction at this area of the shaft a reduction of this safety factor by 4 times is a rational choice. Then, the safety factor in shear becomes, $N = 4.05$, similar to the safety factor in bending, again providing a very good margin of safety for the design. Eqs (2) and (4) yield that the wheels shaft is sufficient for the combined shear and bending loading conditions.

5. Conclusions

The two-wheel horse-drawn chariot was one of the most important inventions in history. It gave humanity its first concept of personal transport, and for two thousand years it was the key technology of war. It also became the world's first mass spectator sport attraction. Its development is of great engineering significance incorporating the seeds of a primitive design activity. Based on the archaeological evidences, a design study on the evolution of the dual horse chariot is presented here, along with a design study of the main structural components and loading of the Anyang chariot, based on archaeological evidence. This study lends itself for further development of a detailed reconstruction of two-wheeled chariots accompanied with static, kinematic and dynamic analysis.

References

[1] Dimarogonas, A.D., *Machine Design A CAD Approach*, John Wiley and Sons, New York, 2001.

[2] Dimarogonas, A.D., *The Origins of the Theory of Machines and Mechanisms. Proceedings 40 Years of Modern Kinematics: A Tribute to Ferdinand Freudenstein Conference. Minneapolis, Minn.*, pp. 1-2 to 1-11, 1991.

[3] Dimarogonas A.D., Philosophical Issues in Engineering Design, *Journal of Integrated Design and Process Science*, Vol. 1, pp. 54–75, 1997.

[4] Dimarogonas, A.D. *History of Technology I, II*, Macedonian Publications, Athens, 2001.

[5] Anthony D.W. and N.B. Vinogradov, Birth of the Chariot Archaeology, Vol. 48, No. 2, pp. 36-41, 1995.

[6] Littauer M. A. and J. H. Crouwe Earliest Known Three-Dimensional Evidence for Spoked Wheels, *American Journal of Archaeology* Vol. 90, No. 4, pp. 395-398, 1986.

[7] Cotterell A. Chariot: *The Astounding Rise and Fall of the World's First War Machine*, The Overlook Press, Peter Mayer Publishers Inc. Woodstock & New York, 2005.

[8] Conter C.N. *The Greek Age of Bronze Chariots Chariot usage in Greek Dark Age warfare*. The Florida State University Publications, 2003.

[9] Paipetis S.A. *The Unknown Technology in Homer*, History of Mechanism and Machine Science 9, Springer, London, New York, 2010.

[10] Niemeier, W.-D. Mycenaeans and Hittites in War in Western Asia Minor, *Aegaeum* Vol. 19, pp. 141–155 1999.

[11] Shaw I. *The Oxford History of Ancient Egypt*, Oxford University Press 2000

[12] Hoffmeier J. K. Observations on the Evolving Chariot Wheel in the 18th Dynasty, *Journal of the American Research Center in Egypt*, Vol. 13, pp. 43-45, 1976.

[13] Anderson J. K. The Homeric, British and Cyrenaic Chariots,*American Journal of Archaeology*, Vol. 69, No. 4 pp. 349-352, 1965.

[14] Heathcote H. L. Wheels, Ancient and Modern and their Manufacture *Journal of the Royal Society of Arts*, Vol. 59, No. 3046, pp. 515-535, 1911.

[15] Healy M. *The: Rameses II and the Battle of Qadesh*, Osprey Publishing, 1993.

[16] Loewe M. and E.L. Shaughnessy Editors *The Cambridge History of Ancient China-From the Origins of Civilization to 221 BC*, Cambridge University Press, 1999.

B5.8 The Origins of Beginnings Engineering Design Based on Logic, Philosophy and Knowledge.

Thomas G. Chondros[1]

Abstract

Development of logic into a science served as an instrument for the progress in natural philosophy and the scientific method in the 6th and 5th Centuries BC in China, India, the Arabian world, the Middle East, the Ancient Greece and Rome. Rapid advancements in natural sciences were followed by systematic attempts to organize knowledge in the 4th to 1st Centuries BC in the Greek and the Hellenistic world, reaching maturity in the Roman Empire after the 2nd Century AD. The essentially random growth of machines and mechanisms driven by the pressure of necessity was followed by the development of complicated machines using design rules and concepts in a systematic way, and not arrived at empirically through a process of long evolution, were investigated very early in history. The influence of Logic, Philosophy in Knowledge based engineering design in classical times up to Roman Times is discussed here.

I. Introduction[1]

The history of philosophy is interconnected with the history of the natural sciences. Philosophy of science, refers to the elements of scientific inquiry from a philosophical perspective that led to the development of a generalized science as distinct from a set of unrelated empirical rules. Machines are spoken early in history, since man found his power inadequate for the tasks he set himself, among them moving heavy weights. Lever and the wedge are technology heritage from the Paleolithic era. Dimarogonas[2] in his many works on integrating the history of mechanical engineering and contemporary design investigates a wealth of issues related to the axiomatic foundation of engineering design and the origins of Technology and Crafts [1-5]. Vitruvius (1st Century AD) [6] defined a machine as "a combination of timber fastened together chiefly efficacious in moving great weights". A century later, Heron of Alexandria (10-70 AD) summarized the practice of his day by naming "the five simple machines" for "moving a given weight by a given force [1]. The first known written record of the word machine

1. University of Patras, Department of Mechanical Engineering & Aeronautics, 265 00 Patras, Greece chondros@upatras.gr

2. Professor Andrew D. Dimarogonas (1938-2000) was widely recognized as a distinguished authority in various specialties of mechanical engineering. He made important contributions to the mechanical design and vibrations, and received the 1999 ASME Engineer-Historian Award.

appears in Homer (ca. 800 BC) and Herodotus (ca. 484-425 BC) [7], to describe political manipulation. The word was not used with its modern meaning until Aeschylus ca 450 BC used it to describe the theatrical device used extensively in the ancient Greek theatre as a stage device to lift actors, chariots or flying horses in the air, as though flying, portraying the descent of gods from the sky and similar purposes. The mechane is also known with the Latin term *Deus Ex Machina. Mechanema* (mechanism), in turn, as used by Aristophanes (448-385 BC), means an assemblage of machines [2].

The development of the theory of machines and the principles underlying design activity were investigated very early in history. The essentially random growth of machines and mechanisms was driven by the pressure of necessity. Making the tools of labor, buildings, and the first machines, regarded in antiquity as the science of machines, has been developed under the influence of the practical demands of society that are linked to production, technology, and the study of the motion of celestial bodies (primarily for navigation) [8].

The term "Engineer" comes from the Latin word "ingenium" that can be translated with "geniality"; the linguistic root of the Latin word that came from the Sanskrit root "gen". The same root is still found in English and Greek words like genealogy, genetics, etc. Dimarogonas mentions that the term Engineering has been used, especially in literature on the History of Engineering, as synonymous with Technology and, in many instances with Craft. The first design theory was part of aesthetics, where aesthetic (beautiful) included also functional (useful) and ethical (the good) attributes. Function and Ethical were inseparable from Form [1-2].

Aristotle (384-322 BC) gave Engineering a sense of wonder: Nature works against the man's needs, because it always takes its own course. Thus, when there is need for achieving something going beyond Nature, difficulties can be overcome with the aid of Engineering. Technology encompasses *Craft, Invention* and *Engineering* without any distinct dividing line, each of the three including part of the other two [1-5]. The accrediting agency for U.S. engineering curricula, the Accreditation Board for Engineering and Technology (ABET), proposes the following definition: "Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind". Both definitions explain that engineering is based on mathematics and science but is focused on the solutions of specific problems that meet certain legal, environmental, and economic constraints [1-2,8].

Engineering and design are interrelated through mechanics and mathematical foundation. The precise nature of the design process is infinitely varied and therefore difficult to summarize in a simple design formula, or a precise definition. Whatever the particular situation, machine design today is a process of creation, invention and definition, involving an eventual synthesis of contributory and often conflicting factors, capable of reproduction, with acceptable quality of products and with specified reliability [1,8]. Machine design is an applied science relying heavily on engineering science because no machine can defy the laws of physics or the strength limits of the materials the machine is made of. Machine design is a systematic process. Even if a

new machine was conceived by invention systematic machine design is needed to transform the invented concept into a working system that users will appreciate [1,9].

Initially in history of engineering conception, design, and manufacture were the work of a single person and consequently, the first products were simple and of human proportions. Machine designers were the master builders of the Potamic Civilizations (Mesopotamia, India, China, and Egypt). Those designers rose to the level of engineering in the Thalassic (great seas) societies of ancient Greece and Rome. Much later, mass production caused the breaking of this process into distinct smaller ones and led to the separation of design from manufacturing. However, the principles underlying design activity were investigated very early in history [1-5].

The philosophical foundation of knowledge, aesthetics and ethics and their implications in engineering design are discussed in the works of Dimarogonas [1-4]. He documented that although the fundamental axioms of design were discovered during the middle of the last century in Europe, design rules and concepts were practiced extensively by the engineers of ancient times leading to machine design from machine elements to the design of a machine as a system [1]. Dimarogonas traced the origin of vibration theory in classical times and brought to light certain important historical developments in the field of engineering design [5].

On the other hand, recent research on ancient machines, the Trojan Horse and the dual chariot at the late Bronze Age by 1100 B.C. reveal achievements of engineering (intelligence) in response to specifications imposed by the needs of the war. This development is of great engineering significance since it involves the seeds of a primitive design activity [11-13]. The mêchanê built and operated for the stage needs in the ancient drama some centuries later in the 5th century B.C., probably the first machine obeying specific design rules [2,14], provides the incentive for the investigation of rapid progress in Technology and Engineering under the influence of philosophy and scientific inquiry developed in the 6th to 4th Centuries B.C. up to the Hellenistic Times.

II. Logic and Natural Sciences

The wealth of empirical knowledge generated in the great Potamic civilizations of the Neolithic and Bronze ages was transformed by the ancient Greeks into science [15]. Since the 6th century BC parallel development of philosophy and logic took place in China, India, Iran, the Middle-East and Ancient Greece. Lao Tzu (ca 600 *BC*) wrote the *Daodejing*, one of the most significant treatises in Chinese cosmogony. Similar principles can be found in Heraclitus and the dialectical method used by Socrates as described by Plato [16].

Plato (429-347 *BC*) and Aristoteles (ca.384-322 *BC*) developed logic into a science and this served as an instrument for the parallel development of the natural sciences. The search for Reason led to the development of a generalized science as distinct from a set of unrelated empirical rules. Rapid advancement in natural sciences was followed by systematic attempts to organize knowledge [17]. The appearance and refinement of mathematical methods permitted the statement and solution of complicated problems in mechanics. Rigorous proof was introduced, based in deductive logic

and mathematical symbolism Abstract reasoning based on mathematical analysis and rigorous proof, distinguished from mere empiricism, formed the basis for engineering as a science beyond the level of a mere craft. In classical times concrete principles upon which engineering is developed as a science using mathematics and reason were established [1-5].

III. The Ionian and Eleatic philosophers

Diogenes Laertius (ca. 3rd century *BC*) [18] was a biographer of ancient Greek philosophers. His *Lives of the Philosophers* (*Philosophoi Bioi*), in ten books, is still extant and is an important source of information on the development of Greek philosophy. Diogenes divides all the Greek philosophers into two classes: those of the Ionic and those of the Italic school, the *Eleatics*. He derives the first from Anaximander from Miletus (ca. 610 *BC*), the second from Pythagoras of Samos (ca.569-475 *BC*). The first seven books are devoted to the Ionic philosophers and the last three to the *Italic* school [19].

In the 6th century *BC*, Thales (620-546 *BC*), founded the *Miletian* School of natural philosophy and developed the scientific method to investigate the basic principles and the question of the originating substances of matter [18]. The *Miletian* (*Ionian*) philosophers in the cities of Ionia, the Greek-inhabited coast of Asia Minor, sought the principle of the Universe in the concrete material substance that is perceivable by the senses. The Ionian philosophers are also referred to as pre-Socratic philosophers, as much of their contribution was completed before the time of Socrates (469-399 *BC*). After Socrates, Diogenes Laertius [18] divides the Ionian philosophers into three branches: (a) Plato (429-347 *BC*) and the Academics, down to Clitomachus (187-110 BC) head of the Academy in Athens around 127 *BC*; (b) the Cynics, down to Chrysippus (280–206 *BC*); (c) Aristotle (384-322 *BC*) and Theophrastus (c.372-c.287 *BC*) who headed the Academy at Athens from 323 *BC* until his death.

Thales (620-546 *BC*), Anaximander (ca. 610 *BC*) and Anaximenes (ca. 560-528 *BC*), all inhabitants of Miletos, developed their views about Universe and the laws describing its behavior [30-31]. The later Ionians were Heraclitus of Ephesus, in the coast of Asia Minor (ca. 550-475 *BC*), Anaxogoras of Clazomenae (500-428 *BC*), Empedocles of Acragas (in Sicily) (492-432 *BC*), (470-385 *BC*), and the Atomists Leucippus (5th century *BC*) and Democritus (460-370 *BC*) from Abdera [17-20].

Heraclitus of Ephesus (ca. 550-475 *BC*), was active around 500 *BC* [20]. Heraclitus was a contemporary of Pythagoras, Lao-Tzu, Confucius, and Siddhartha, the Buddha. He is best known for his doctrines that things are constantly changing (universal flux), that opposites coincide (unity of opposites), and that fire is the basic material of the world. Heraclitus appears to have been the first to separate the study of motion itself from dynamics, the forces causing the motion, and introduced the principle of retribution, or change, in the motion of celestial bodies [2-3,17-20].

Anaxagoras (500-428 *BC*), an important Presocratic natural philosopher and scientist lived and taught in Athens for approximately thirty years. He was the first to formulate a molecular theory of matter and to regard the physical universe as subject to the rule of rationality or Reason. Although he insisted that the earth is flat he was

the first to describe the circumstances under which eclipses occur and the way light is reflected by the moon [17-20].

Leucippus (5th century *BC*) is regarded as the founder of atomic physics. Possibly, student of Zeno of Elea (490-420 *BC*), devised the atomic philosophy in order to answer the problems raised by Parmenides of Elea (515-450 *BC*) and his followers. Democritus (460-370 *BC*) expanded the atomic theory of Leucippus [2-3,17-20]. He maintained the impossibility of dividing things *ad infinitum*. Epicurus (341-270 *BC*) borrowed the principal features of his philosophy from Democritus.

Pythagoras of Samos (ca.569-475 *BC*) made important developments in mathematics, astronomy, and the theory of music. Pythagoras studied under Thales before traveling to Egypt and Mesopotamia, then establishing his own school of philosophy in Croton (southern Italy). The theorem known as Pythagoras' theorem was probably known to the Babylonians 1000 years earlier, but he was the first to prove it [21-24]. The Pythagoreans describe the three "lower" arts: logic, grammar, and rhetoric and the four “mathematical” arts: arithmetic, geometry, astronomy, and acoustics [25]. Philolaus (470-385 BC) from Croton was a student of Pythagoras a contemporary of Socrates and probably he has written the book *On Nature* [26].

The *Eleatic* philosophy was founded by Xenophanes of Colophon who lived in various parts of the ancient Greek world during the late 6th and early 5th centuries BC. Xenophanes was associated with the founding of the city state of Elea in Southern Italy in 540 BC. Parmenides of Elea (515-450 BC), Zeno of Elea (490-420 BC), and Melissus of Samos (475-410 BC), student of Parmenides, are considered to be the Eleatic philosophers. In the search for truth, the *Eleatics*, in contrast with the Ionian philosophers rejected any input from sensory experience. The *Eleatics* felt mathematics to be the method of arriving at the truth. They argued that the true knowledge of being can be discovered through Reason, beyond the false impressions of the senses. Empedocles, Anaxagoras, and Philolaus, tried to meet the same challenge, and did so in very different ways [10,11-13, 15].

Parmenides of Elea (515-450 BC) is one of the most significant pre-Socratic philosophers; however, of his known work only the conventionally entitled *On Nature* (written between 480 and 470 BC) has survived. Student of Ameinias (6th century *BC*) was influenced by the philosophy of Samos through Xenophanes (6th century *BC*). Parmenides' considerably influenced the thinking of Plato, and in this respect Parmenides has influenced the evolution of Western philosophy [15-22].

Zeno (490-420 *BC*), through his effective argumentation, contributed to make clear the unfeasibility of Ionian natural philosophy, which presupposed the motion of generation and corruption. Aristotle and his school are the main sources on Zeno. Zeno, according to Aristotle was the inventor of “dialectic” and the so called "indirect proof". Melissus (475-410 *BC*) from Samos, grew up with the Pythagorean philosophy, together with the tradition of the Ionian natural philosophers. He was the last significant member of the Eleatic school of philosophy. [23-26].

Although the *Eleatic* thinking was not perfect, important beginnings of logic were developed. Platon (429-347 *BC*) and Aristoteles (ca. 384-322 *BC*) formulated the *Eleatic* philosophy into a science that served as an instrument for the parallel development of

the natural sciences, especially mathematics and physics [2-3]. The search for *Reason* led to the development of a generalized science as distinct from a set of unrelated empirical rules. The subject of philosophy, as it is often conceived - a rigorous and systematic examination of ethical, political, metaphysical, and epistemological issues, armed with a distinctive method – is considered Plato's invention. The most fundamental distinction in Platon's philosophy is between the many observable objects that appear beautiful (good, true, big), and one object, absolute beauty (goodness, justice, moral) from which those many beautiful things receive their names and corresponding characteristics [27-28].

The student of Pythagoras, Archytas of Tarentum (ca. 400-365 *BC*), is said to have written the first systematic treatise on machines based on mathematical principles. This is lost. Archytas built an air-propelled flying wooden dove (Aulus Gellius, ca. 150 AD). Details about Archytas's dove are not known but it seems to be the first flying machine. Archytas provides a complex solution for doubling the cube and defended the view that the universe is unlimited [29].

Aristotle from Stagirus, Thrace (384-322 BC) at the age of 17 joined the *Academy* and studied under Plato, for a period of twenty years. At the invitation of Philip of Macedonia he became the tutor of his 13 year old son Alexander. Upon the death of Philip, Aristotle returned to Athens, which he had not visited since the death of Plato. He found the *Platonic* school flourishing under Xenocrates (396-314 BC) head of the Academy for 25 years after Speusippus (ca 410-339/8 BC) the successor of Plato, and *Platonism* the dominant philosophy of Athens. [28-29].

Aristotle mentions gears around 330 BC, (wheel drives in windlasses). He said that the direction of rotation is reversed when one gear wheel drives another gear wheel. A single pulley provides little mechanical advantage, but by about 400 BC the Greeks had put to use compound pulleys, or ones that contained several wheels. The earliest indisputable evidence for knowledge of compound pulley systems is referred in the *Mechanical Problems* attributed to Aristotle [1-4].

The principles of statics and dynamics were discussed by Aristotle (ca. 384-322 BC) in *Mechanica* (*Problems of Machines*), the first extant treatise on the design of machines, probably written by one of Aristotle's students in Lyceum. *Mechanica* starts with the definition of *machine*, which in that era was synonymous with *mechanism*. In. fact, mechanisms were the only machines known. *Mechanica* contains remarkable discussions of the mechanics of the lever, the balance, the wedge, rolling friction, the strength of beams, impact, mechanical advantage, and the difference between static and kinematic friction. Aristotle, further discusses several purely kinematic aspects of mechanisms. such as: the vectorial character of velocity, the superposition of velocities, and the parallelogram law for velocity addition, the concepts of absolute and relative velocity of points along a link of a machine. For the rhomboid four-bar linkage and the relative velocities of the opposing joints Aristotle developed rational geometric methods and proofs [1-4]. Aristotle's work on explaining how machines function, making a first attempt for machine dynamics, unlike the approaches of Euclid (330 BC - 260 BC) and Archimedes (287 BC – 212 BC), who studied situations of equilibrium in machines, establish him as the founder of machine theory [1-4,8].

Xenocrates of Chalkedon (396-314 BC) was explicit about the division of philosophical topics implicit in Plato, into 'physics', 'ethics', and 'logic'; this became the norm in Stoicism. Metaphysics and theory of knowledge are included in 'physics' and 'logic', respectively. Epicurus, (341–270 BC) was raised in Samos, he came to Athens when he was eighteen, when Xenocrates was head of the Academy. The philosophy of Epicurus was a complete and interdependent system, involving a view of the goal of human life, an empiricist theory of knowledge, a description of nature based on atomistic materialism, and a naturalistic account of evolution, from the formation of the world to the emergence of human societies [18].

Strato (Straton) of Lampsacus, (ca. 340–270 BC), was known in Latin as *Strato Physicus*. His extensive writings included a non-teleological reinterpretation of Aristotle's physics, which influenced Alexandrian philosophers such as Hero. His view - that the universe is self-explanatory and self-sustaining, and thus in no need of the introduction of a god or other extra-natural explanatory factor - was known as *Stratonician atheism*. Strato introduced an important kinematic criterion of equilibrium, the *principle* of *virtual velocities*. Straton corrected Aristotle's claim that bodies fall at a constant speed, noting that in fact they accelerate [30].

IV. The Alexandrian Times

The decline of Greek civilization is followed by the rise of Alexandria, founded in honour of Alexander the Great (356–323 *BC*) in the Nile Delta in Egypt. Alexandria was the greatest city of the ancient world, the capital of Egypt from its founding in 332 *BC* to *AD* 642, and became the most important scientific centre in the world at that time and a centre of Hellenic scholarship and science [8].

Euclid of Alexandria (325-265 *BC*) is the most prominent mathematician of antiquity best known for his treatise on mathematics *The Elements*. Euclid was one of the most well-known scholars who lived in Alexandria prior to Archimedes' arrival in the city. Euclid's *Elements*, written about 300 *BC*, a comprehensive treatise on geometry, proportions, and the theory of numbers, is the most long-lived of all mathematical works. This elegant logical structure, formulated by Euclid based on a small number of self-evident axioms of the utmost simplicity, undoubtedly influenced the work of Archimedes [8].

Eratosthenes (273-192 BC) was born in Cyrene, now in Libya North Africa. Among his teachers were the scholar Lysanias of Cyrene and the philosopher Ariston of Chios (3rd century *BC*) who had studied under Zeno of Elea, the founder of the Stoic school of philosophy. Eratosthenes became the third librarian at Alexandria in about 240–235 BC. Eratosthenes proved the earth was spherical, and measured its circumference within one percent accuracy. Eratosthenes stated explicitly that the catapult was the chief practical reason for working on cube-root problems [8].

Ctesibius (ca. 283-247 BC), was the designer of the precision water clock, and a device for lifting a mirror for a barber shop that can be considered the first original mechanism designed to order on the basis of engineering reasoning. Philo of Byzantium (ca. 280-220 BC) also known as Philo Mechanicus (Engineer in Greek), was a student

of Ctesibius at the Museum, one of the first who used gears in water raising devices. In Philo's *Pneumatics* is included the first description of a water mill in history [2-4].

Archimedes (287-212 BC) was born in Syracuse, in the Greek colony of Sicily. Archimedes introduced step-by-step logic combined with analysis and experiments in solving mechanical problems and the design of machines and mechanisms. His works contain a set of concrete principles upon which design can be developed as a science using mathematics and reason [8].

The Greeks from Syracuse developed the first catapults; a result of engineering research financed by the tyrant Dionysius the Elder in the early 4th century BC. One of the crucial steps in designing the torsion springs was establishing a ratio between the diameter and the length of the cylindrical bundle of elastic cords. This optimization of the cord bundle was completed by roughly 270 BC, perhaps by the group of Greek engineers working for the Ptolemaic dynasty in Egypt, Thera and at Rhodes. Archytas of Tarentum (450-428 *BC*) and Eudoxus of Cnidus (ca. 400-350 *BC*) had devised elegant theoretical solutions for the stone-thrower formula, [1-4,8].

V. China

Red and black pottery craft industries since the Yangshao culture (4950 BC-2950 BC, the Neolithic times) have been reported in China. Silk weaving might be well advanced by 3650 BC. Spinning and weaving indicate the use of advanced tools with wheels. Writing, mathematics and astronomy came to be part of Chinese civilization. Textiles and tapestry weave possibly of the Han Dynasty (202 BC- 220 *AD*) with figure of centaur: half animal-half human creature indicate distinctive Greek influence since this figure can be found only in pottery of Greek origin. Trade within the Chinese borders was established in very early times. Trade with the west officially began during Emperor Wu Di's reign (140 BC – 87 BC) [31-32].

The magnetic compass, gunpowder, cast iron, the sciences of astronomy, physics, chemistry, meteorology, seismology, engineering, and mathematics can trace their early origins to China. Cast iron, abacus, calendars were in use in China before the reign of the Qin Dynasty (221-206 *BC*). Though Chinese were not the first to make steel, they did invent two particular steel manufacturing processes: removing the carbon out of cast iron and melting wrought and cast iron together to produce steel. [33-34].

VI. Conclusions

It was among the Eleatic philosophers that important beginnings of Logic were developed by Platon and Aristoteles into a science and served as an instrument for the parallel development of the natural sciences, especially mathematics and physics, by such pioneers as Pythagoras, Aristoteles, Euclid and Archimedes. The search for Reason led to the development of a generalized science as distinct from a set of unrelated empir-

1. Dimarogonas, A.D. Machine Design A CAD Approach, John Wiley and Sons, New York. 2001
2. Dimarogonas A.D. Philosophical Issues in Engineering Design, Journal of Integrated Design and Process Science, 1, 54–75. 1997

ical rules. The rigorous proof was introduced, based in deductive logic and mathematical symbolism. Experimentation was established as a method for scientific reasoning.

Basic scientific principles discussed and explained by Archimedes in the 3rd century BC formed the instrument upon which engineering was established as a science distinct from crafts and unrelated empirical rules. Ctesibius, and his students Philo and Heron, and Pappus of Alexandria have introduced analytical methods for the study and design of advanced machines and mechanisms, not always driven by practical needs. Design methodologies appeared in gear sizing, screw threads, weight lifting, catapult engineering, pneumatic machines, and hydraulics.

References

[1] Dimarogonas, A.D. *Machine Design A CAD Approach*, John Wiley and Sons, New York. 2001

[2] Dimarogonas A.D. Philosophical Issues in Engineering Design, *Journal of Integrated Design and Process Science*, 1, 54–75. 1997

[3] Dimarogonas, A.D. On the Axiomatic Foundation of Design. In: *ASME Design Engineering Conferences*, Albuquerque, NM, Design Theory and Methodology, DE-53, 253–258, 1993.

[4] Dimarogonas, A.D. *History of Technology I, II*, Macedonian Publications, Athens, 2001.

[5] Dimarogonas A.D., *Vibration for Engineers*, Prentice-Hall, Second Ed., 1996.

[6] Vitruvius, M.P., 1st Century AD. *De Architectura* (*On Architecture*) BOOKS I-V Loeb Classical Library, Translator Frank Granger, 1970.

[7] Herodotus *Histories*. 5th Century BC.

[8] Chondros T. G., 2010 Archimedes life works and machines *Journal of Mechanism and Machine Theory* **45** 1766-1775.

[9] Dieter G. *Engineering Design, A Materials and Processing Approach* Mc Graw-Hill N.Y. 1987

[10] Reuleaux, E, *Der Konstructeur. Braunschweig*: J. Vieweg. 1872.

[11] Paipetis S.A. *The Unknown Technology in Homer,* History of Mechanism and Machine Science 9, Springer, London, New York, 2010

[12] T.G. Chondros, K. Milidonis, S. Paipetis, and C. Rossi 2015 The Trojan Horse reconstruction. *Mechanism and Machine Theory* 90 261-282.

[13] Cesare Rossi, Thomas G. Chondros, Kypros F. Milidonis, Sergio Savino, Flavio Russo 2015 Ancient road transport devices: Developments from the Bronze Age to the Roman Empire *Frontiers of Mechanical Engineering* **11** (1) 12-25

[14] Chondros T. G., K. Milidonis, G. Vitzilaios, J. Vaitsis 2013 Deus Ex Machina reconstruction in the Athens theatre of Dionysus. *Mechanism and Machine Theory* **67** 172-191

[15] Farrington, B. *Greek Science*. London: Hardsmondworth, 1944.

[16] Sih G. C. Survive with the time o'clock of nature RRRTEA 04 Restoration, Recycling, and Rejuvenation Technology for Engineering and Architecture Application] Proceedings of the

International Conference, Cesena, Italy, Edited by G.C. Sih, L. Nobile, Aracne 3-22, 2004.

[17] *The Oxford Dictionary of Philosophy*. Copyright © 1994, 1996, 2005 by Oxford University Press.

[18] Diogenes Laertius. *Lives of Eminent Philosophers*, tr. R.D. Hicks, Loeb Classical Library: Cambridge Mass, 1925.

[19] Gıadett P. *Greek Science in Antiquity*. Aberland-Schuman, Inc. New York, 1955.

[20] Granger, H., Heraclitus' Quarrel with Polymathy and Historie *Transactions of the America Philological Association*, **134**, 235-261, 2004.

[21] Huffman C. Philolaus *The Stanford Encyclopedia of Philosophy*, E. N. Zalta (ed.), 2003.

[22] Preus A. (ed.) *The pre-Platonic Philosophers: Before Plato. Essays in Ancient Greek Philosophy VI*. Notes on the Eleatics (Parmenides, Zeno, Melissus), Suny Press, Albany. 2001.

[23] Kraut R. Plato *The Stanford Encyclopedia of Philosophy* E. N. Zalta (ed.), 2009.

[24] Schofield, M., "The Ionians" in C.C.W. Taylor, *Routledge History of Philosophy: Volume I* (Chapter 2), London and New York: Routledge, 47-87, 1997.

[25] Kimball B. A. *Orators and Philosophers: A History of the Idea of Liberal Education* New York: College Board Publications, 1995.

[26] Huffman C. Philolaus *The Stanford Encyclopedia of Philosophy*, E. N. Zalta (ed.), 2003.

[27] Preus A. (ed.) *The pre-Platonic Philosophers: Before Plato. Essays in Ancient Greek Philosophy VI*. Notes on the Eleatics (Parmenides, Zeno, Melissus), Suny Press, Albany. 2001.

[28] Kraut R. Plato *The Stanford Encyclopedia of Philosophy* E. N. Zalta (ed.), 2009.

[29] Koetsier T. *Motion in Greek Geometry* Workshop on Founders and Theorems of Mechanism Theory of the IFToMM Permanent Commission (PC) for the History of Machines and Mechanisms (HMM) at the Technical University of Dresden, Germany, October 6 – 8. 2004.

[30] Konstan D. *Epicurus The Stanford Encyclopedia of Philosophy* E. N. Zalta(ed.), 2009.

[31] Langford H. *The Textiles of the Han Dynasty & Their Relationship with Society*. Master Thesis, University of Adelaide, Centre of Asian Studies, 2009.

[32] Wood, F. *The Silk Road: 2000 Years in the Heart of Asia*, Berkley, California: University of California press, 2002.

[33] Adshead, S. A. M. *T'ang China: The Rise of the East in World History*, New York: Palgrave Macmillan, 2004.

[34] Lewis, M.E. *The Early Empires: Qin and Han*. Cambridge, Massachusetts: The Belknap Press of Harvard University Press, 2007.

B5.9 The Trojan Horse, a Study of Primitive Engineering Design

Thomas G. Chondros, Kypros F. Milidonis
University of Patras

Abstract

Doureios Hippos or the Trojan Horse was a huge wooden structure, built by the Achaeans on Odysseus' suggestion, hiding a number of fully armed warriors inside, that was left before Troia city walls as offering to the gods from the Greeks, who pretended to depart and give up siege. It was moved inside the city walls and eventually ended the ten years long siege of Troy (1194-1184 BC) during the Bronze Age. From the references in the Iliad and vase paintings, archaeological evidence concerning the Troy siege, anthropometrical standards of the time and the fact that Epeios a naval architect and sculptor was the master builder of the Trojan Horse, the reconstruction based on Homeric shipbuilding, along with a study of traction dynamics and lateral stability, offers significant details of a primitive design activity. The Trojan Horse can be considered as an achievement of engineering (intelligence) in response to specifications imposed by the needs of war in the late bronze age (1100 BC). Its development is of great engineering significance since it involves the seeds of a primitive design activity.

1 Introduction

Various opinions exist on whether the Trojan War is a product of Greek historical fiction or a fact. The date given by ancient historian Eratosthenes 1194-1184 BC is the most likely date by which transpired the Trojan War. The main cause of the war was the abduction of Helen, wife of the king of Sparta, Menelaus, by Prince Paris of Troy. The causes, however, in Greek mythology, discounted to a divine conflict between Athena, Hera and Aphrodite, while Eris gave them a golden apple with the inscription “to the fairest”. Zeus, in order to resolve the controversy on who deserves the golden apple, referred to the Trojan prince Paris, who chose Aphrodite. As a reward for his judgment, Aphrodite rewarded Helen, the most beautiful mortal woman, to fall in love with Paris and follow him to Troy. Immediately after rapture, Agamemnon, king of Mycenae and brother of Helen's husband, Menelaus, led a campaign of widespread Greek cities kingdoms. The campaign was launched from the Greek mainland with about 1,200 ships, and the Achaeans besieged Troy on the Hellespont for ten years in trying to conquer it. The end of the war came with the conception of Ulysses, Doureios Hippos, the Trojan Horse, a giant hollow wooden horse, a sacred animal to the Trojans, hiding a number of fully armed select warriors inside. The Trojans, discovering the "offering", and intense arguments developed among them: the suspicious ones maintaining that

the Greeks should not be trusted, but the pious insisted that the gods should receive what belonged to them. The latter prevailed, and eventually it was decided to bring the horse into the city [1-2].

For the time of the Trojan War (12th century BCE) the conception and subsequent successful operation of the Trojan Horse remains a pioneering design task, incorporating skills and knowledge accumulated at the time. Andrew Dimarogonas (1938-2000) documented that although the fundamental axioms of design were discovered during the middle of the last century in Europe, design rules and concepts were practiced extensively by ancient engineers leading to machine design from machine elements to the design of machines as systems. He also mentions that the term Engineering has been used, especially in literature on the History of Engineering, as synonymous with *Technology* and, in many instances with *Craft*. The successful implementation of the Trojan Horse renders for a detailed reconstruction attempt to answer the question of the feasibility of design, and furthermore, whether this machine embodies the seeds of a primitive design synthesis [3-5].

The reconstruction is based on archaeological evidences, the anthropometrical standards of the time, and accommodation needs along with aesthetics considerations, safety and performance flexibility. The reconstruction is based on the shipyard facilities of the Greeks in the vicinity of the Troia Walls. Transport dynamics was investigated and the required number of horses for traction is estimated along with lateral stability, supported by analytical and numerical solutions [3] and the use of solid modelling software [6]. The proposed methodology provides sufficient information about the Trojan Horse design and operation, and renders for similar investigations of ancient machine reconstruction.

2. Archeological Evidences

'Iliad' is the great epic marking the onset of Greek literature in the 8th century BC. The Iliad is full of reference to places that can be located. Ilios is, located between Mount Ida and the Hellespont in the geographical area described from Homer in the 8th century BC. Schliemann excavated this place from 1871 and called it correctly Ilios, and then Troja. During about 2700 years the region was known, explored and settled. The Greeks and Romans of the historical era since about 300 BC, after Alexander the Great visited the place which they called Ilion or Ilium in Latin [1-2].

Epeios the son of Panopeus from Phokis, according to the mythological resources from Plato's Ion and Pausanias has prevailed as a naval architect and a sculptor, his famous piece of work is the Trojan Horse [7]. Figure 1 depicts Epeius, holding hammer and chisel, between Athena and Agamemnon presenting the wooden horse clay model, from a red-figured Attic cup [2].

Fig. 1. *Epeius, holding hammer and chisel, between Athena and Agamemnon presents the wooden horse clay model, PLATE ab, Red-figure Attic cup, Munich* [2]

This piece of information is very important since it refers to the idea of prototyping, a prerequisite for any design process that is common six centuries later at the time of Archimedes. Again, prototyping is shown in Figure 2 Athena working on a horse in clay, from an Attic red-figured *oinochoe* attributed to the Group of Berlin, from Capua dated ca. 470-460 BC [2].

Fig.2 *Athena modeling a horse in clay, behind Athena, the sculptor's tools of work hanging in place* [2]

The oldest trace preserved of the 12th-century BC Trojan Horse is the Mykonos vase of the early Archaic Period (ca. 670 BCE), the first artifact found to depict the Trojan Horse (Fig. 3). The scene on the vase neck shows the preparation of the crew before departure, soldiers bearing the arms and supplies outside the Trojan Horse, and the soldiers inside get the inventories from the outside. The dimensions of this depiction are comparable to those of human proportions, with 7 soldiers shown at each side, this yielding a first estimate of the crew of this siege machine to 14-16 soldiers in total [2].

Fig.3 The Mykonos vase, early Archaic Period (ca. 670 BCE), left, detail of the Trojan Horse depicted on the vase neck, right. The first artifact found to depict the Trojan Horse, [1].

3. Homeric Ships

The history of the Aegean ships and naval trades goes back in the depths of centuries. In the geographical area encountering 150 km away from sea, the Aegean areas populations and the Greeks developed from Prehistoric Age societies, which were Thalassic civilizations in their majority [8-9]. One of the first ship names are the Danais, and the Argo named after her shipbuilder Argus (Fig. 6). The ship Argo set sail from *Iolcos* to the Black Sea and back after a long trip around the Mediterranean with a crew of fifty demigods and princes, the Argonauts under Jason's leadership in the 13th century BC.

The cross section of the Homeric ship hull is shown in Fig. 4. These hulls have an almost round bottom and curved transverse sections. The galley was propelled by oars and sails together, the mast being raised or lowered according to the wind strength. When raised it was held in a sort of box, and kept in its place by forestays [8]. For a twenty-oared typical Homeric ship 20m long by 2.20m wide, the two halves connected together will form the fuselage with 2.20m internal diameter.

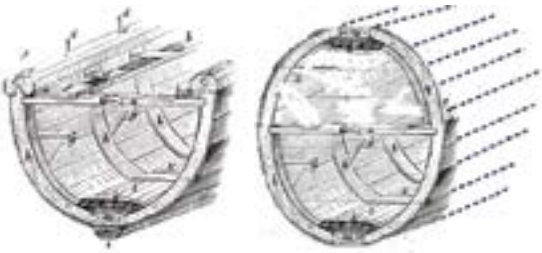


Fig. 4 The cross section of the hull of an Homeric ship: a. mast box, b. beams parallel to gunwale, c. gunwale, d. rowlocks, e. bed of oar, f. thwarts, g. braces for the feet, h. ribs, i. keel, k. slabs sustaining the floor, l. floor, m. keelson. [16,19-24]. *Two ship halves connected together to form the crew accommodation room, (lower).*

4. Trojan Horse Reconstruction

From the archeological and historical evidence discussed above, the following specifications for the *Trojan Horse* reconstruction seem rational [3]: (a) Maximum dimensions of the crew accommodation space should be related to a small 20 oars Homeric ship, 2 m wide, (b) The number of the crew yields from the initial estimation of the overall dimensions of the Trojan Horse hull, based on ergonomic considerations. (c) According to the narrative, the warriors should remain in the horse for at least five days. (d) Weight for each warrior with armor and equipment, plus food and water should be of the order of 120 kg. (e) The structure should have ventilation openings and a waterproof drainage system. (f) The inner arrangement should consist of seat rows with a corridor between seats. (g) Well-balanced and stable structure should provide safety during transportation. (i) The structure should remain geometrically similar to a horse and its analogies. (j). the construction works in the small Greek shipyard outside the walls of Troy with two ship halves would form the Trojan Horse habitacle. (k) The traction force to be transported safely inside the city should be maintained at a reasonable level.

Assuming average height of a man during the 12th century BC around 1.65 m, corresponding to the 5th percentile for the US General Forces - Males (MIL-HDBK-759C 1998) [3], yield the seating design requirements for the 5th Percentile. For a twenty-oared typical Homeric ship 20 m long by 2.20 m wide, putting two halves together as shown in Fig. 5 will form the habitacle for the crew. The main habitacle dimensions yield by superimposing the scaled fuselage on the *Equus Caballus* horse as shown in Fig. 5. The crew habitacle accommodating 16 men, 14 in two opposing seat rows and two on the ends, with 4 masts as legs on the wheeled carriage is shown in Fig. 6.

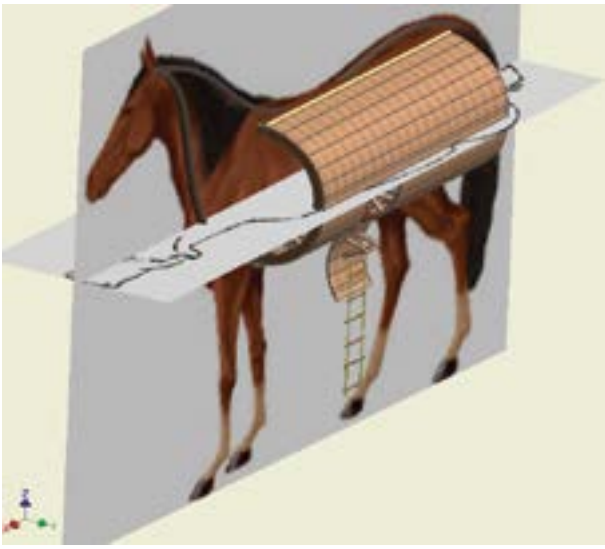


Fig. 5 *Two ship halves connected together to form the crew accommodation room, and cross-section of the hull.*

The dimensions of the scaled Trojan Horse and wheeled carriage for the reconstruction yield: total length 11.60 m, height from ground to ridge 6.90 m, from ground to ears 9.80 m, feet height 4.15 m, habitacle width 2.40 m, total width 3.70 m, wheelbase 8,00 m. The horse head is fixed on curved timber elements from the ship stern and stem. Ship masts 4.20 m long, 0.25 m mean diameter support the structure on the wheeled carriage used for transportation as shown in Fig. 6.

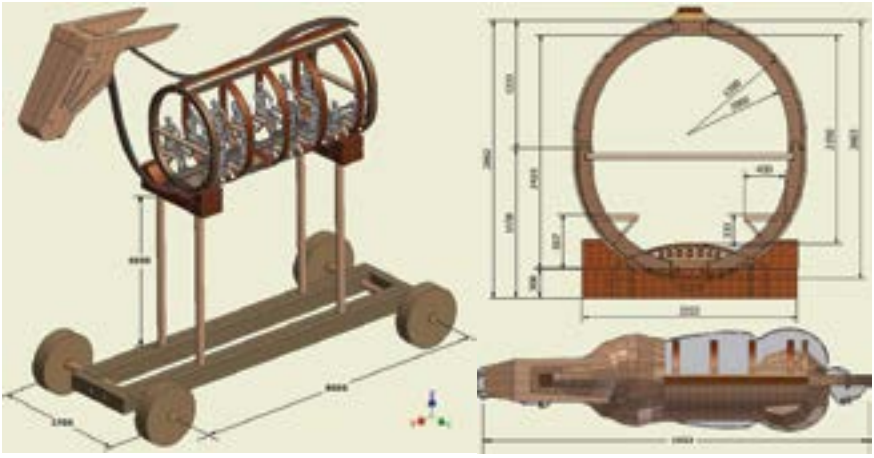


Fig. 6 The crew habitacle with legs on the wheeled carriage.

The reconstructed Trojan Horse along with a rational visualization of the horse body contour and the addition of a timber skin would fulfill the aesthetic requirements of the design.

For loading analysis it will be assumed that the keel (i) and keelson (m) shown in Fig. 4 bear a continuous load of the structure, crew and supplies, totaling 40,000 N. Forces acting on the keelson main beam yield reactions on the four vertical poles, forming the legs of the reconstructed Trojan Horse. In order to analyze the most conceivable loading situations, simplified analyses were followed for the design with the procedure presented in Example 3.8 [3].

Main keelson beam length is assumed 5.00 m, and cross-section dimensions b=0.17 m and h=0.10 m. Internal loading diagrams were produced in a spreadsheet for the keelson main beam.

Equilibrium equations for force V_i and moment M_i were solved with Excel SOLVER [3]. For each station the equilibrium equations are:

$$\begin{aligned} V_{i+1} &= V_i + q_i \Delta x_i + F_i \\ M_{i+1} &= M_i + V_i \Delta x_i + m_i \end{aligned} \tag{1}$$

Successive application of Eqs (1) from one end of the beam to the other allows for the determination of shear forces and bending moments along the beam. Slope and

deflection along the main beam's length can be found similarly. For each station, corresponding slope Θi and deflection yi are calculated as [3]:

$$\Theta i+1 = \Theta i + M_i \Delta x_i / EI_i$$
$$yi+1 = yi + \Theta_i \Delta x_i \qquad (2)$$

For maximum loading (W=40,000N) maximum bending moment at midspan is calculated as M_b = -3,000 Nm. Section modulus in bending for the keelson rectangular cross-section is calculated as [3]:

$$W_x \cong bh^2/6 \qquad (3)$$

or Wx= 0.0003 m3. Then, maximum stress in pure bending $\sigma_{max} = Mb/Wx$ yields σ_{max} = 10.62 Mpa. From the basic design equation for bending of beams [3] yields

$$\sigma_{max} \leq \frac{S_L}{N} \qquad (4)$$

where S_L = 25 MPa, the limiting stress for cypress wood, and N = 2.3 the safety factor calculated from Eq. (4). Shear forces and bending moments calculated with this algorithm are shown in Fig 9.

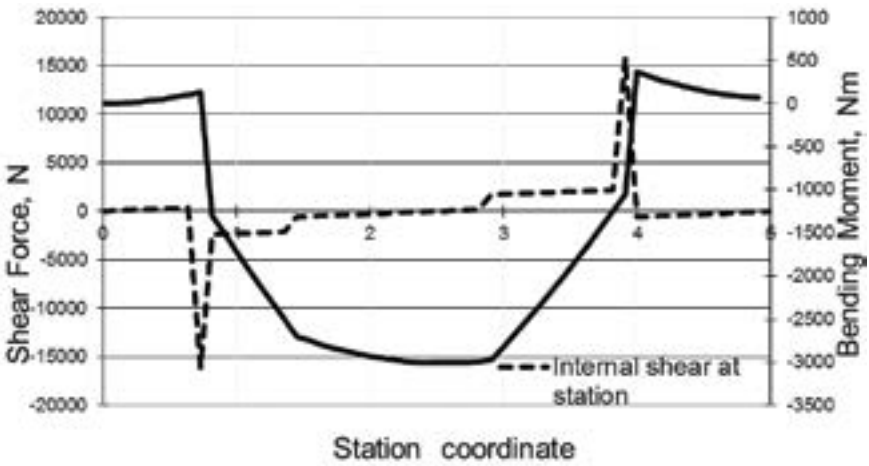


Fig. 9. Spreadsheet-drawn internal loading diagram for a continuous load, 36,000N, along the main beam [3].

Concerning each vertical leg, maximum vertical loading will be assumed 36,000 / 4 = 9,000 N. Also, a horizontal component equal in magnitude to 40% of the vertical loading acting on top of each vertical pole (Fig 10) will be considered. The horizontal component acting on top of the leg produces bending moment 8,000 Nm at the lower end

of the leg. For this loading case the secant formula for the critical load can be used [3]

$$P_{cr} = \frac{AS_{yc}}{1+(ec/r^2)sec[(\,l/2r)\sqrt{P/AE}} \tag{5}$$

where e load eccentricity, c=2m maximum distance of the centroid from cross-section contour, $I = \pi D^4/64$, the moment of inertia, $r^2 = I/A$ ratio of the moment of inertia versus cross-section area-the radius of gyration of the section, l = 4.2 m, length of the vertical leg, E = 1.01E10Pa, Young modulus for cypress timber, Syc = 25 MPa. Eq (5) cannot be solved explicitly and will be solved by iteration. Excel Solver solution yields leg vertical beam diameter d=0.20 m, corresponding to the mean diameter of ship masts used for the Homeric ships, allowing for critical buckling load P_{cr} = 11,162 N. A vertical force P = 3600 N acting at each leg, at distance e = 2 m from the beam axis will be assumed as an additional dynamic loading during an abrupt stop, while vertical legs bend. Again d=0.20 m yields from the secant formula, Eq. (5), assuring safety during stops.

For the carriage 1.50 m dia wheels 0.40 m wide were selected. Assuming 2.80 m axle length, 0.20 m axle diameter, and 20,000 N loading of front and rear axles respectively, the same spreadsheet used for solving Eq. (1) is used again for the wheels axles' internal loading [3]. Spreadsheet-drawn internal loading diagrams for each axle are depicted in Fig. 10.

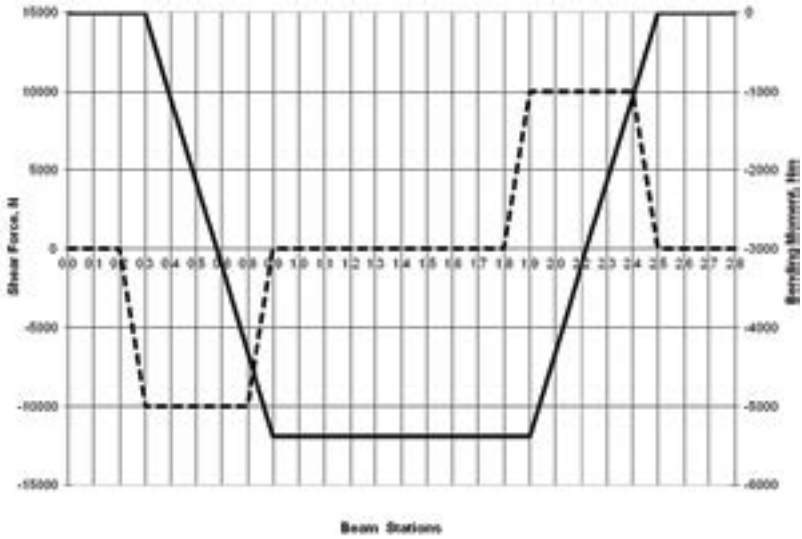


Fig 10. Spreadsheet-drawn internal loading diagrams for the wheels axles (*continuous line: internal moment Nm, dashed line: shear force, N*).

Maximum bending 5,385 Nm and shear force 10,000 N yield for the wheels axles from Fig. 10. Section modulus in bending for the circular cross-section with D = 0.20 m is calculated as [3]:

$$W_x \cong 0.1D^3 \qquad (6)$$

or Wx= 0.0003 m3. Then, maximum stress in pure bending σmax = Mb/Wx yields σmax = 6.73 Mpa. From the basic design equation for bending of beams Eq. (4), for SL = 25 MPa, the limiting stress for cypress wood yields N = 3.70 safety factor in bending.

There are two sections of the shaft subjected to shear in each side adjacent to each wheel. Failure criterion for pure shear, considering the influence of normal stress yields the design equation [3],

$$\tau = \frac{4V}{3A} = \frac{4V}{3\pi D^2/4} = \frac{S_{sy}}{N} \qquad (7)$$

where D is the axis diameter, V shear force at wheel bearings, Ssy = 4.79MPa yield strength of wood in shear (perpendicular to grain), and N safety factor. Shear force V = 10,000N due to shaft loading adjacent to each wheel will be considered here. For shaft diameter D = 0.20 m, the shaft cross-section area A= 0.03 m2, and then, Eq. (7) yields τ = 0.42 MPa, and safety factor in shear, N = 11.30. From Eqs (4) and (7) one concludes that the wheels axle is sufficient for the combined shear and bending loading conditions.

For the wheels bearings, maximum safe value for mean pressure in wooden bearings is given as p = 4.80x106 N/m2. Assuming maximum radial force V = 10,000 N for each wheel bearing, and Aj = π D l / 2, peripheral half-journal area, and 10% contact of wheel and axle due to imperfect finishing of the mating surfaces, the minimum length for the bearings of the wheels axle is calculated as [3]

$$l = 2\,V / 0.10\,\pi\,p\,D \qquad (8)$$

or l > 0.07m. Eq. 8 ensures proper length of the wooden bearings on the horizontal shaft, if bearing length is larger than 0.07 m. With 0.40m wheel width selected, a safe mean pressure for the wheels wood bearings is maintained. The wheels and axles weight calculated with the same spreadsheet yields 6000 N and 1000 N respectively, totaling 7000 N for the Trojan Horse carriage.

6. Traction requirements and lateral stability

The Trojan Horse total weight with personnel and equipment is assumed 40,000N. Two wooden masts of circular cross-section 0.20 m in diameter formed the wheel-base for the Trojan Horse's transportation from the sandy coast into the city. To make the carriage suitable for cross-country travel, the specific ground pressure σ_{gr} should not exceed 1 kgf/cm² (0.1 MPa). For 4 wheels, 1.50m dia., and 0.33x0.33 m² ground contact area, the surface pressure exerted from each wheel is calculated as [3]:

$$\sigma_{gr}=10{,}000N/0.11m^2 = 91{,}827N/m^2 \text{ or } \sigma_{gr}= 0.09MPa$$

Watt determined the number of horses his steam engine could replace by using horses

to pull a rope passed over a pulley attached to a weight at the bottom of a deep well. Watt established 33,000 ft lb (4562.4 kg m) per min or 550 ft lb (76 kg m) per s as the unit of power, or 1 horsepower (hp). The draft necessary to pull wheeled implements, e.g., wagons, carts, cultivators, is influenced by axle friction, grade, and rolling resistance. The tractive pull required to overcome axle friction varies directly with the radius of the spindle and inversely with the radius of the wheel.

Grade resistance is equal to the weight pulled multiplied by the percentage of grade and the coefficient of rolling resistance, i.e., the ratio between implement draft and total gross weight moved. 1 hp was required to pull 85 kg draft load at a speed of 3.2 km on level ground. 3.3 hp and 5.7 hp were required to pull a similar load at the same speed for 5% and 10% grade. For the Trojan Horse and the 4T gross weight of the structure, assuming 1:7 draft to weight ratio, 8.4 horses are required to pull the structure, while for 5% grade the number of the horses required to pull the machine increases to 36, this being a rational number for the time and the dimensions of the Trojan Horse. For a safe transportation on the sandy coast a systematic drawbar configuration depicted in Fig. 11 would have been incorporated. Again, ship masts with 0.20m diameter, 5.00m long interconnected as shown in Fig. 11, are used both for the attachment of the pulling ropes connected with each horse, and maintain horses properly spaced longitudinally as well as transversely.

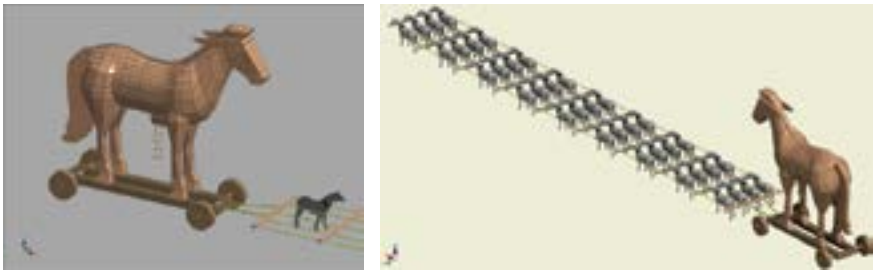


Fig. 11 Trojan Horse on a wheeled carriage pulled by traction horses.

For lateral stability the following Equation holds (Fig. 12)

$$0.5\ TW_1 = H_1 \tan a \qquad (9)$$

where TW_1 = 3.2m track width, H_1 = 6m the combined CG of the structure. From Eq. (9), maximum lateral slope that the carriage can overcome safely is a=14 degrees.

Figure 12. Trojan Horse: Lateral stability

6. Conclusions

Epeios, the fleet shipbuilding master proved very effective with the design of the Trojan Horse and implementation with the limited shipyard capabilities at Troia. Epeios, the wooden-horse maker is directly linked to the *mechanopoios*, the machine maker or engineer, the man who designed, built and operated the mêchanê for the stage needs in the ancient drama some centuries later in the 5th century BC.

The Trojan Horse can be considered as the achievement of engineering (intelligence) in response to specifications imposed by the needs of the war at the late bronze age by 1100 BC. Its development is of great engineering significance since it involves the seeds of a primitive design activity. Static, kinematic and dynamic analysis of the reconstructed Trojan Horse is performed from the point of view of design methodology, rather than element function, and design for strength prevails in this work. The proposed reconstruction based on a systematic design process lends itself for further development, in accordance with further historical evidences that are expected to appear.

References

1. Paipetis S.A. *The Unknown Technology in Homer*, History of Mechanism and Machine Science 9, Springer, London, New York, 2010.

2. T.G. Chondros, K. Milidonis, S. A. Paipetis, and C. Rossi 2015, The Trojan Horse Reconstruction, Mechanism and Machine Theory 90 261-282.

3. Dimarogonas, A.D., *Machine Design, A CAD Approach*, 2001 John Wiley and Sons, New York.

4. Dimarogonas, A.D. The Origins of the Theory of Machines and Mechanisms. Proceedings 40 *Years of Modern Kinematics: A Tribute to Ferdinand Freudenstein* Conference. Minneapolis, Minn., pp. 1-2 to 1-11, 1991.

5. Dimarogonas A.D., Philosophical Issues in Engineering Design, *Journal of Integrated Design and Process Science*, **1** 54–75, 1997.

6. Dassault Systèmes, SolidWorks Corp, Solid Works, 2010.

7. Zachos G.A., Epeios in Greece and Italy, Two Different Traditions in One Person, *ATHENAEUM, Studi di Letteratura e Storia dell' Antichita*, Universita di Pavia, Como-New Press Edizioni, 2013.

8. Casson L. Ships and Seamanshiping the Ancient World, Johns Hopkins University Press, 1995.

9. Wedde M. *From Classification to Narrative: The contribution of Iconography towards Writing a History of Early Aegean Shipbuilding*; on Mediterranean Historical Review, Mannheim, 2008.

B5.10 Telecommunications in the Greek Antiquity.

Kostas Kotsanas
Museum of Ancient Greek Technology
Ancient Olympia & Katakolon, Greece

Abstract

The present paper examines the telecommunication methods of the ancient Greeks and mainly the "pyrseia", which is an ancient pentad coding system for optical message transmission (letter by letter) between remote hills through a torch combined system invented by Kleoxenos and Demokleitos, 3rd century BC, and the 'hydraulic telegraph", an ingenious method of transmitting pre-agreed messages remotely by using hydraulic equipment invented by Aeneas Tacticus. By applying experimental technology, functional giant models as well as experimental jigs and simulation devices in physical size were designed and manufactured, reviving these methods. Suitable sites of ancient solar topography were sought and comprehensive measurable representations of these telecommunications were carried out. The results of the measurements were recorded and analyzed, charts were designed and the relevant conclusions which defeat our perceptions so far were drawn, regarding especially the distances between beacons and messaging times. Furthermore, an attempt was made to match the coding, particularly "pyrseia", with modern digital technology, and search for other possible alternatives that could be used effectively.

1. Introduction

Telecommunication (as it is historically clear) determines not only the outcome of a war but also the fate of a whole civilization. For instance, the spread of the Greek city-states to all of the Mediterranean and the renowned expedition of Alexander the Great would not have been successful had it not been for the exceptional network of telecommunications. [1], [2], [3]

Classical dramatists (e.g. Aeschylus, etc.) mention message transmission through fire, a method which goes back to an ancient tradition of the early Trojan War period and refers to the use of simple fire signals (optical transmission of a pre-agreed message with the use of fire) and a network of beacons (message retransmission stations). [4]

The need for quick transmission of multiple and varying messages led the Greeks to the astonishing conception of the "hydraulic telegraph" (4th cent. BC), a hydraulic device that required the use of only one torch fire for the transmission of predetermined messages. [1]

The need for secure message transmission led to the ingenious invention of the coded fire-signals (the transmission of a message letter by letter, 3rd century BC). The

combined torch signal system resulted in the unavoidable increase in the number of beacons due to their weakness in distinguishing the multiple and various torch lights from great distances. [1]

This study was inspired by the numerous and diverse views entertained by modern scholars who speculate on the functionality of these methods, e.g. regarding the distance between the stations that received and transmitted the optical message: 20-30 km (Stamatis), 100 km (Diels), 180 km (Darmstaedter), etc., as well as the message transmission rate: 20 letters/hour (Forbes) 20 words/hour (Lazos), etc., and the number of staff involved: 10 persons per station (Forbes), etc. [5], [6], [7].

2. Encoded fire signals

2. 1. Description of the process

Beacons were built on carefully chosen mountains. Each beacon consisted of two walls at the height of a man, with 5 torch holders each, which made it possible to put up 1 to 5 lit torches on each wall at a time. Between the two walls there were special binoculars so that the beacon "receiver" operator could distinguish the right firelights from the left ones at the opposite "transmitting" mountain beacon. Moreover, both beacon operators had at their disposal 5 plates with the letters of the alphabet inscribed on them, divided into sets of five (Figure 1). The firelights on the left-hand side of the "transmitter's" beacon determined the plate number which had the desired transmitted letter (1 bale-fire put up: the 1st plate was indicated, and so on). The firelights on the right-hand side referred to the desired transmitted letter on that specific plate. (1 torch put up: the first letter was indicated, and so on). The transmission of a message started as follows: the "transmitter" put up two torches and the "receiver" confirmed by doing the same and then both operators brought down the torches. For instance, if two torches were put up on the left wall and four on the right wall, this corresponded to the transmission of the letter "I". [1]

2.2. Reconstruction

The codification of torch signals that includes the number of elevated torches (from 1 to 5) and two positions (left and right wall) is a two-digit (position) quinary system. The resulting values appear in Table 1:

Left wall values	Right wall values
1	1
2	2
3	3
4	4
5	5
6	6

Table 1. *The quinary system*

Figure 1. *The letters of the alphabet*)

Consequently, the transmission of the phrase "enemy ahead" corresponded with the code: «15 52 23 42 35 43 15 33 35 53 15 24». Thus, this two-digit quinary system (5^2= 25) required in practice the use of up to nine torches for a 24-letter alphabet. Alternatively, the five-digit binary system (2^5= 32), three-digit ternary system (3^3= 27), three-digit quaternary system (4^3= 64) with one to two, one to three or one to four torches to five and three walls respectively could be used to cover the 24 letters of the alphabet. A codification could also be used according to the measure or position mode of the torch condition (lighted-put out) instead of the number of torches (2^5= 32) or walls (5^2= 25) respectively.

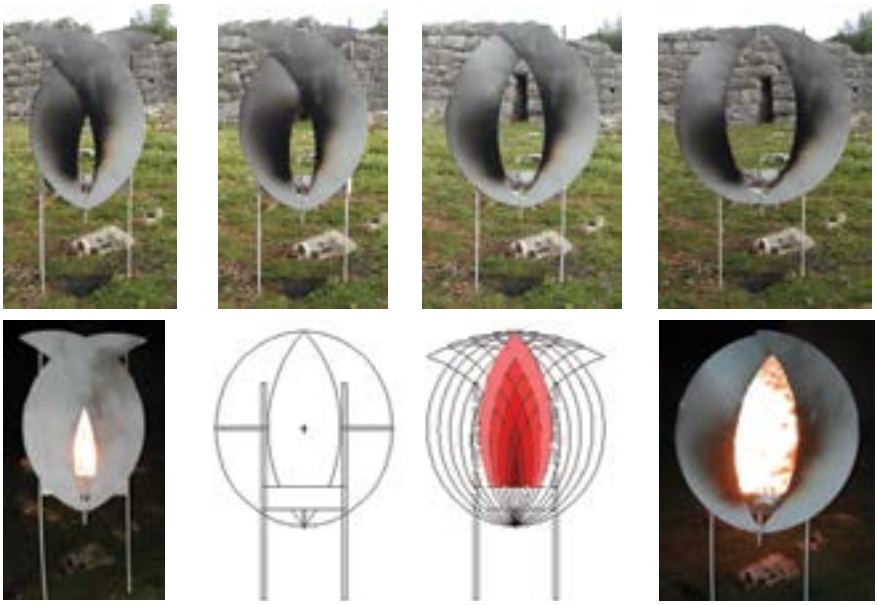
The first case leads to an obvious waste of resources, while the second one is dysfunctional due to the inability of distinguishing the position of put-out torches. Consequently, the optimal coding system was used.

2.3. According to Polybius [1] the following data result:

- Length of diaphragms: 3m
- Height of diaphragms: 1.8m
- Distance between diaphragms: a few meters (3m presumably)
- Optical medium: 10 torches
- Distance of torches (between them): 0,8 m (It is concluded)
- Use of a (non-telescopic) diopter of optical range: 5m per sight

2.4. Experimental procedure

An experimental proprietary device (Figure 2) was built to calculate the relation of Flame size - distance of optical perception.



For the Experimental process simulation layout we use also:

- Tinder torches of an effective diameter 10 cm.
- A double diaphragm beacon 3m long and 1.80m high within a distance of 2m.
- A diopter (non-telescopic) with two small copper tubes 1m long with a diaphragm of 2mm.

Figure 3 shows these beacons in the archaeological area of Ancient Samia, while Figure 4 shows the 7 research areas (The mounds along the former Agoulinitsa Lake from Ancient Samia to Ancient Epitalio and Ancient Pheias - Katakolo)

Figure 3. The research areas (Google Earth)

Figure 4. (a) The archaeological area of Ancient Samia and the beacons, (b) The torches

2.5. MEASUREMENTS AND ANALYSIS OF RESULTS

Initially, 6 observers are standing on each of the areas shown above and as we adjust the flame size in the experimental proprietary device (Figure 2) until at least 5 out of the 6 observers are able to see the flame. Table 2 shows the Coordinates of the said areas, their distances (km) from the beacons of Ancient Samia and the flame size that is required for each case.

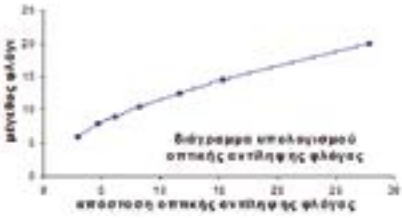
Secondly, two torches of a functional diameter 10 cm (Figure 4b) are set at consecutively increasing distance between them until at least 5 out of the 6 observers are capable of distinguishing the flames as two separate flames and not as one. Table 3 displays the Coordinates of the said areas, their distances (km) from the beacons of Ancient Samia and the minimum distance (m) between two torches.

	Coordinates		**L (km)**	**d (cm)**
Ancient Samia	287762	4156422	0	
Kato Samiko	287592	4159347	2,9	6
Samiko	286281	4160776	4,6	8
Raches	285067	4161904	6,1	9
Anemochori	283486	4163450	8,2	10,5
Agridi	280680	4165592	11,6	12,5
Epitalio	277787	4168013	15,3	14,5
Katakolo	263465	4170026	27,8	20

Table 2. The calculated rates of flame size -optical perception distance

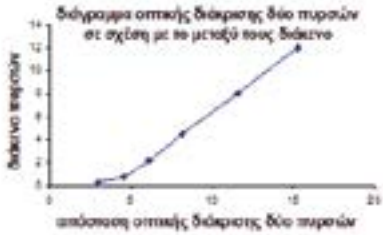
	Coordinates		**L (km)**	**D (cm)**
Ancient Samia	287762	4156422	0	
Kato Samiko	287592	4159347	2,9	0,3
Samiko	286281	4160776	4,6	0,7
Raches	285067	4161904	6,1	2,2
Anemochori	283486	4163450	8,2	4,5
Agridi	280680	4165592	11,6	8
Epitalio	277787	4168013	15,3	12
Katakolo	263465	4170026	27,8	20

Table 3. The calculated rates of the maximum optical discrimination distance of two torches in relation to the interval between them



Distance of fire optical discrimination distance

Figure 5. *Flame size - Optical perception graph*



Torch optical discrimination distance

Figure 6. *Optical discrimination of two torches graph in relation to their interval*

2.6. Conclusions

Consequently, we reach the following conclusions:

- Maximum distance of the torch's optical perception: 30 km
- Maximum distance of the torches' optical discrimination: 5 km
- Ideal distance of the torches' optical discrimination: 4 km
- Ideal distance of torch signal stations: 3-5 km

Calculation of message transmission time under the assumption of minimum staff (1 operator per diaphragm and 1 transmission coordinator):

a) Letter transmission - Elevation of 1-5 torches / diaphragm (1-3 movements per operator)
b) Stand-by in the letter transmission position: 10 sec
c) Lower the torches (1-3 movements per operator) 5-10-15 sec
d) Wait at rest: Average letter transmission time: 10 sec
e) Ideal distance of torch signal stations: 40 sec

Therefore:

A) For beacons using "codified" torch signals
   - Digital coding using the two-digit quinary system ($5^2 = 25$) is the optimal solution.
   - Distances of transmitting and receiving stations: up to 5 km
   - Message transmission rate: 1.5 letters/min
B) For beacons with a simplistic use of fire
   - Distance of transmitting and receiving stations: (under investigation)
   - Message transmission rate: Immediate (only pre-agreed messages)

3. The "hydraulic telegraph" of Aeneas

3.1. Description of the process

Messengers stood at carefully chosen hills and used clay or metal cylindrical contain-

ers of equal size filled with water (up to 3 cubits in height and up to 1 cubit in width). In each container there was a cork floating – a little narrower than the opening of the container. Rods, divided into equal parts, were inscribed with the same pre-agreed messages on each and attached to the center of the floats, (e.g. “Horsemen have entered the country”). The operator “transmitter”, by lifting a burning torch, signaled the operator “receiver” for the sending of the message and then waited for confirmation with the rising of the torch from the “receiver”. After that, he lowered his torch, signaling for the simultaneous opening of both taps on their devices. The rods with the messages descended and when the desired message to be sent appeared at the rim of the “transmitter's” device, he raised the torch again, signaling the “receiver” for the simultaneous interruption of the outflow. Due to the geometric similarity of the devices, the desired pre-agreed message also appeared on the “receiver's” device. [1]

2.2. Reconstruction

Table 4 displays the dimensions of the final device suggested along with Polybius’ device [1] (Scale 1:2).

Data	Simulation	Polybius
Vessel diameter	23.5 cm	46.32 cm (1 cubit)
Vessel height	74.5 cm	149 cm (3 cubits)
Effective height		137 cm?
Message Distance		5.86 cm (3 rings)
Optical medium	1 torch	
Vessel thickness	0.5 cm ?	
Number of messages	20 pre-agreed messages ?	

Table 4. *The data by Polybius and experimental process simulation layout*

Firstly, a cylindrical vessel was built with a diameter of Φ120 mm and a usable height of (Polybius data) 137 cm as shown in Fig. 7a. It was used to experimentally calculate the outflow rate (water level versus the time needed for the vessel to empty) through a side hole of 5 mm length placed at the bottom of the vessel and a ranging diameter of Φ8, Φ12, Φ16 and Φ20 mm sequentially. The following table (5) displays the average values that derived after 10 tests, while picture 8 shows the respective Graph of Distance and Time of outflow according to Table (5).

Cylinder Φin: 120 mm (113.04 cm2) and hole Φ8, Φ12, Φ16, Φ20 mm				
t (sec)	s (cm)			
	Φ8	Φ12	Φ16	Φ20
0	0	0	0	0
5	8	17.5	34.5	52,5
10	15.5	33	61.3	90.5
15	23	47	84.4	118
20	29.7	61	104	137
25	36.6	74	122.5	
30	43.2	85	136.7	
35	49.3	95.7		
40	55.5	106.7		
45	61.3	116		
50	67.4	124		
55	73.2	131,5		
0	78.7	137,3		
65	83.6			
70	88.8			
75	93,5			
80	98,3			
85	102,7			
90	107,2			
95	111,1			
100	114,9			
105	118,8			
110	122,2			
115	125,5			
120	128,7			
125	131,2			
130	134,1			
135	137			

Table 5. *Outflow rates*

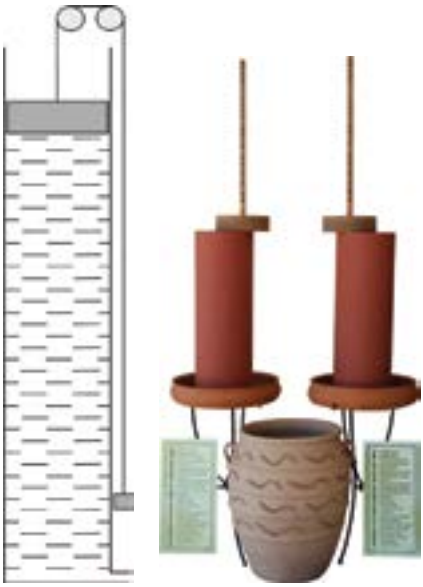


Figure 7.
a. Experimental process simulation (cm/sec)
b. The final experimental device

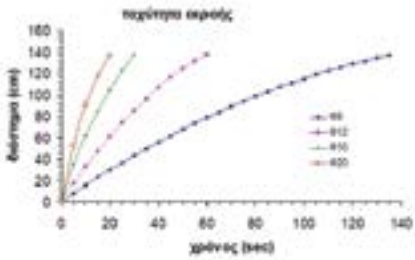


Figure 8. *Water level – Time of outflow Graph according to Table 5*

Next, using the graph of picture 8, the minimum and maximum message transmission rates (sec/ message distance or sec/ 5.86 cm) were calculated for the Φ120 mm diameter (S=113.04 cm2) and the data were adjusted to the other instances, diameter of Φ 440 mm (S′=1519.76 cm²) and useful height of 137 cm corresponding to Polybius' dimensioning and diameter of Φ 235 mm (S”=433.51 cm²) and useful height of 68 cm for the constructed vessels used in the experimental process simulation. All the data are displayed in table 6.

Table 6. Calculation of message transmission rate according to Fig. 8

	minimum transmission rate (sec/ message)				maximum transmission rate (sec/ message)			
(mm)	Φ8	Φ12	Φ16	Φ20	Φ8	Φ12	Φ16	Φ20
Φ120	3.63	1.66	0.84	0,55	10.00	5.00	2.04	1.53
Φ235	13.90	6.36	3.22	2.12	38.35	19.18	7.83	5.85
Φ440	48.74	22.28	11.30	7.43	134.44	67.22	27.46	20.52

Lastly, adjusting the data from table 5, the maximum total transmission duration (min) and the average water outflow rate (cm/sec) were calculated for Polybius' device (Φ =440 mm) on each hole size Φ20, Φ16 and Φ12 mm respectively, presented in table 7.

Table 7. Calculation of maximum transmission duration and Average water outflow rate

Hole Diam.	Maximum transmission duration (min)	Average water outflow rate (cm/sec)
Φ20 mm	Δt.(S′/S)/60=20X13.44/60=4.5 min	137/(13.44X20)=0.51 cm/sec
Φ16 mm	Δt.(S′/S)/60=30X13.44/60=6.7 min	137/(13.44X30)=0.34 cm/sec
Φ12 mm	Δt.(S′/S)/60=60X13.44/60=13.4 min	137/(13.44X60)=0.17 cm/sec

3.3. Conclusions

Consequently, we reach the following conclusions:

- Distance between transmitting and receiving stations using simple torches: up to 30 km
- Water outflow opening: a ring of 19.3 mm (based on the assumption of 15 sec/ message on the average and at a minimum of 10 sec/message
- Maximum transmission duration: 5 min
- Average water outflow rate: 28 cm/min (40 lt/min)
- Maximum number of previously agreed messages: 22-24
- Message transmission rate: 10-20 sec/message
- Frequent and urgent (panic) messages were placed in the beginning, whereas a process malfunction message was placed in the end.

5. Final remarks

- Hypotheses regarding the use of combined torch signals with large-size flames to maximize communication distance since it is limited (to 5 km) exclusively by the maximum distance of optical discrimination of the torches (between them) are discarded.

- The result of the research is consistent with the mapping of the unique extensively surviving beacon networks in Greece, i.e. in some Aegean islands (e.g. Amorgos), where the distance between these constructions is less than 5 km, which puzzled researchers who assumed that some of them had a different use.

- The extension of communication distance by using combined torch signals and increasing the distance between torches (e.g. a distance of 15 km required a total length of 120-meter diaphragms) is not implied by the ancient literature.

- The argument that the telescopic diopter was discovered and used in torch signaling to increase the communication distance is claimed as a plausible hypothesis, but it cannot be supported by ancient testimonies and has not been proposed by any researcher.

- The result justifies the need for the alternative use of Aeneas' hydraulic telegraph to cover longer distances (up to 30 km using one torch) with the ability to send many different pre-agreed messages.

- The maximum communication distance (30 km) using Aeneas' hydraulic telegraph could be extended by using large-size fire to launch the process, but this cannot be supported from ancient literature.

- The result justifies the development of a combined torch signaling system in Roman times with the combined use of three torches in greater distance between them.

- The result justifies the prevalence of a sophisticated hydraulic system type (e.g. the clocks of Leo the Wise) in Byzantine times to cover long distances with the possibility of transmitting pre-agreed messages.

- The maximum optical perception distance can be extended to 200 km (under investigation) in ideal weather conditions using large-size flame to send only a pre-agreed message.

6. Bibliography

[1] "Polybius, History X, TLG"

[2] "Philo, Mechanical Syntax V, TLG"

[3] "Polyaenus, Stratagems IV, TLG "

[4] "Aeschylus, Agamemnon V, TLG "

[5] "Christos Lazos, Telecommunications of Ancient Greeks, edition AIOLOS, Athens, 1997, ISBN 960-521-006-1"

[6] "Herman Diels, Antike Technic, edition OTTO ZELER, Osnabruck, 1965"

[7] "Evaggelos Stamatis, Scientific works B' (The Cryptic Telecommunications of Ancient Greeks), Athens, 1973"

B5.11 The Knossos Palace and the Restoration of the Columns. Was it Porphyra?

Wako Nishiyama
Yuzen, the Japanese traditional fabric-dyeing artist

Abstract

The color of the columns of Knossos Palace and the possibility of being Porphyra is investigated in the present. The author was unaware of the material of the columns, whether stone or wood. But as for the color, in 1979 he heard an interesting story, i.e. that they were painted with porphyra. Eversince he has been studying and investigating porphyra. Based on this information and by means of experimental work, he managed to paint a column with porphyra, getting very important results eventually. In fact, it was proved that porphyra could be reused as a most precious material, while at the same time the columns were utilized for porphyra storage.

Preface

The color of the columns of the Knossos Palace, Was it porphyra? This was a longtime unknown subject. The color and the material of the columns of Knossos Palace were still unknown. One day, in 1979, the author encountered the view that they were painted with porphyra, and was deeply interested in it, and this how research on ancient Greek fabric-dyeing started.

The following is an account on research on paintings of porphyra on the columns of Knossos Palace along with the processes of the actual experiments based on the author's career as a traditional Japanese fabric-dyeing artist.

1. Restoring the columns of Knossos Palace: The following tests were intended to determine whether painting with porphyra was possible. In the first place, it was assumed, that Knossos columns were indeed painted with porphyra, although it was not known if they were made of stone or wood. First, fresco painting technique was applied, to paint porphyra dyestuff on a piece of wood, 20 x 13 cm, after painting with plaster. The result was that the color became uneven with unsatisfactory texture. However, the next several tests, to paint with porphyra mixed with lime at various compositions, were successful.

2. Material of the columns-Perfect form of a wooden column Wood used was Japanese hinoki cypress, dried for more than one hundred years. A cylindrical specimen 30 cm high, 9 cm diameter at the top, 7 cm at the bottom was utilized. By the first trial, paint plaster was applied on the surface. Two longitudinal cracks appeared in front

and back through the center of the circle, and gaps between wood and plaster were observed.

To prevent cracking and peeling-off, several tests were performed by changing the form of the cylinder. The final test was to curve sixteen flutings. Width and depth of flutings were important parameters. It was noticed that the inner perimeter of the plaster on the column should be the same with the outer perimeter to prevent cracking. This was successfully applied to the real scale.

Plaster constituents to prepare the primer coating were: (a) 200 g slaked lime, (b) 300 g sand of 1mm grain to shave the porphyra dyestuff and make the surface thinner, while sand of 1-2mm grain was used for the middle and the base paintings. To make the plaster last longer, 10 g of boiled-down hemp fibers were prepared. To improve durability and better color of the plaster, 10 g of boiled-down bark fibers were prepared. 25 g olive oil was mixed with water to get 500 g plaster. The constituents were stirred in carefully one after the other.

As far as premier coating of the plaster is concerned: Coating the plaster got easier for a sixteen-fluting cylindrically shaped wood specimen 30 cm high, diameter 9 cm at the top and 7 cm at the bottom. Coating of the plaster was carried out by a trowel by pressing and proceeding obliquely upward to make a circle. As a result of drying test for seven days, peeling-off and gaps between wood and plaster appeared, but no cracking on the surface. No problem appeared after the middle coating. It was left unattended to do the surface coating for a week.

3. Coating with plaster mixed with porphyra dyestuff: Kneading 200 g hydrated lime pouring 1 liter aqueous with 1 g porphyra dyestuff. The nearly perfect plaster coating was completed with about 2mm thick layer following the way already shown. It was found that summer is the best season for plaster coating.

Especially, for coating with plaster, the best season is midsummer, and also from early summer to early autumn. Considering the winter in Crete with strong winds and cold weather, some tests under various conditions were conducted. With drying under temperature of 2~3°C, it became fragile, and easily peeled off under 0°C to about 2-3°C below zero. The results were the same with various compositions.

The condition of columns after ten years: The color tone was still beautiful, but the color intensity decreased by half, probably due to the effect of sunlight. However, the following account shows the surprising power of porphyra:

Seven years after the test, the color faded out a little. In order to strengthen the fastness of the color, the plaster were coated three times with the same ratio of dyestuff. To know the inner condition, the surface was shaved as thin as possible. The stronger color was found. By proceeding, the stronger colors appeared. After the three layers of the plaster, the pure white plaster was found. That was unexpected and called for further investigation.

These six years since 2006 should be sufficient time to study the changes of cracking, peeling-off and durability of the color tone. There were no changes except for the color tone.

Finally, in order to test the strength of the plaster, the object was impacted twenty times by a hammer. No peeling-off appeared.

Reusing porphyra: The possibility of reusing porphyra after peeling off was confirmed, which is a proof that the columns of Knossos Palace were painted with porphyra. Also, this shows a strong possibility that the columns were made of wood, since wood was abundant in Crete, and no remains of the columns were found.

Picture of the columns completed

Impact test with a hammer, white part porphyra dyestuff shaven with a chisel

5. Review and conclusions.

In May 1993 the author' s dream, to visit the remains of Crete civilization, came true. In 1979 he came across "porphyra", in the birthplace of porphyra as described in ancient myths. Porphyra was said to be the dyestuff to paint the columns of Knossos Palace in Crete, but even experts ignored the fact. So he decided to search the issue in depth and find the way to dye with porphyra dyestuff by himself, hoping to contribute to that field of study.

B5.12 Hephaestus, the Smith God of the two Lame Legs

Euterpe Bazopoulou-Kyrkanidou
University of Athens

Abstract

Hephaestus, the Olympian god of metallurgy, famed for inventions, taught men great crafts. The fixed epithet for Hephaestus, used by Homer, Hesiod, and other ancient authors up to the fifth century AD, is "*Ἀμφιγυήεις*", the god of the two lame legs. He is also called "*κυλλοποδίων*", clubfooted. His posture and his typical gait are characteristically described by Homer and help in making a diagnosis.

Vase paintings of the sixth century BC depict Hephaestus' lameness, but this is not emphasized by the fifth century and thereafter. His anomaly is described as being congenital, and two sons are reported as having deformed feet. For this disablement, several interpretations and contemporary medical diagnoses have been proposed. Furthermore, literal and visual indication suggests that Hephaestus performed the first recorded craniotomy on Zeus' skull.

In this article, information derived both from ancient Greek texts and illustrative arts are combined. It is concluded that Hephaestus disability seems to be a congenital bilateral talipes equinovarus, clubfoot.

1. INTRODUCTION

The scientific and medical study of human abnormalities continues to be greatly expanded in our days. However, empirical observations on malformed individuals can be traced in ancient Greek and Latin [1, 2, 3, 4], and Hebrew [6] literature, and in pictorial representations on vase paintings, coins, sculptures and other works of art [5, 6, 7]. For today's clinician it is a challenge to study the descriptions and illustrations of malformed people given by authors and artists in those ancient sources and to try making a "diagnosis". Such an effort provides an opportunity to appreciate acute observations by ancient "non medical specialists" and their contribution, which gradually led to modern medical knowledge. In early ancient writings, myth and reality are inextricably interwoven and it is difficult to separate out the truth. Probably the best way to approach and appreciate past knowledge is trying to uncover the truths hidden beneath each verse.

In this work, based on literary and visual sources, I will try to present Hephaestus, the malformed god of the ancient Greek pantheon. Hephaestus is essentially a divinity of the "Pelasgic" Aegean area and his cult principally developed on the island of Lemnos and the neighboring regions [8]. He is also connected with the city of Athens.

Here, as a result of his thwarted encounter with goddess Athena, he became father of one of the first kings of Athens Erichthonios, and ancestor of the Athenians. Athena fostered the child. Earth's involvement in Erichthonios's birth was probably meant to preserve Athena's image as virgin goddess. Fowler [9] has argued that the myth of Erichnonios may well be a "notion of immaculate conception".

In Classical Age, a monumental temple was accorded to Hephaestus, along with Athena, sometime after 450 BC. [10].

Hephaestus, god of fire and technology, was born on mountain Olympus, the fabled abode of the greater Greek gods. He had crippled feet, making him an outsider among the perfect Olympians. For this disability realistic, mythological explanations [4, 10, 15, 16], and medical diagnoses have been proposed [18, 19, 20, 21, 22, 23].

In this article I attempt to interpret this god's disability in medical terms, using the relevant evidence from ancient Greek writings and visual arts.

2. EVIDENCE FOR HEPHAESTUS LAMENESS

2.1 Literary Sources

The most important evidence for Hephaestus' lameness remains in the following sources: Homer, Hesiod, Herodotus, Apollonius Rodius, Diodorus Siculus, Apollodorus, Pausanias and Nonnos.

According to Herodotus, Homer and Hesiod first declared the external forms of the gods [25].

2.2 Conception and Birth

Hera bore Hephaestus by parthenogenesis [11, 12]. According to Homer [26], his parents were Hera and Zeus. Both versions are cited by Apollodorus [27].

2.3 Congenital Anomaly

Hephaestus says that his anomaly was congenital. His mother Hera repeats this, and expresses her disappointment [26].

In the Homeric references, there is no clear evidence to show that his legs were broken, when he was hurled down from Olympus. But later, this is suggested. Hera ashamed of her baby's deformity flung him from Olympus [29]. Zeus threw him, as well [26]. It was again Zeus, who flung Hephaestus from Olympus. This time the fall caused his lameness; this was written later, in the 1st-2nd cent. [27].

The sequel of Hephaestus expulsion, which tells us how he took his revenge by ensnaring his mother in an artfully constructed throne, from which she was eventually released by Hephaestus only after Dionysus brought him back drunk to Olympus, became a favorite subject for Dionysian vase paintings of the 6th and 5th centuries BC.

This story was cast in literary form by Alcaeus [30] around 600 BC [19] and was recorded by Pausanias [31]

So Hephaestus, nine years after his expulsion from Olympus [29] was called back

to the divine abode, where he lived thereafter in his own palace, working in his forge.

3. TYPE OF ANOMALY

Hephaestus' fixed epithet is *αμφιγυήεις* [9]. There has been much debate about this word among scholars [29]. Most of them: [32, 33, 34; 35, 36, 37], argue that the meaning is: with both feet crooked, severely bow-legged.

In the second edition (1999) of both I and II vol. of the *Iliad*, revised by W.F. Wyatt , the epithet *αμφιγυήεις* is translated: the god of the two lame legs, replacing the older one: of the two strong arms, given by A.T. Murray in Loeb Classical Library I (1924-1988) and II (1925-1985).

The word *αμφιγυήεις* is composed of two words: αμφί and γυήεις. The word αμφί is a preposition that means bilateral. On the other hand γύης is the curved piece of wood in a plough to which the share was fitted (Fig. 1)

Fig. 1.Folk Museum "The Village," Corfu.

This kind of plough and its γύης was described by Hesiod in his *Works and Days* [38]. The similarity between γύης and the form of a clubfoot is obvious (Fig. 2).

Fig.2: Infant with bilateral congenital clubfoot (*Dr. George Pistevos*)

So, the meaning of *αμφιγυήεις* should be taken as bilaterally clubfooted. Hephaestus is, also, called *κυλλοποδίων* (clubfooted and bandy-legged), which more clearly refers to the abnormality of his feet. In addition, Hephaestus had slender legs; He was shriveled of foot, crooked. He was born weakly, halting of Hephaestus [26].

Hephaestus' lameness is not a secret; many times he is mentioned just by epithets that refer to his halting gait [38, 39, 12, 26, 40]. Surprisingly, his lameness does not prevent him from having beautiful wives: Charis, Aphrodite (Venus), and Aglaea. He also had an encounter with goddess Athena.

Now, let us turn to stories about some of Hephaestus' glorious craftsmanship, the "Hephaestoteucta" and, at the same time, about his physical appearance and manner of walking, from Homer's narrative. The first story is about the visit of Achilles' mother Thetis, who comes to ask Hephaestus to make her son a new armor:

"He spoke and rose from the anvil, a huge, panting bulk, limping along, but beneath him his slender legs moved nimbly. ...and with a sponge he wiped his face and both his hands, and his mighty neck and shaggy breast, and put on a tunic, and grasped a stout

staff, and went out limping; and there moved swiftly to support their lord handmaids made of gold in the semblance of living girls. In them is understanding in their minds, and in them speech and strength ...They busily moved to support their lord, and he, limping near to where Thetis was, sat down on a shining chair" [29].

Summing up Hephaestus physical status, as given in the literary sources, we see that Hephaestus appeared as a large man, with a mighty neck, hairy chest, massive shoulders, slender legs, and bilateral clubfoot.

4. HEPHAESTUS IN ILLUSTRATIONS

Original representations of the gods appear from about 700 BC. Gods are not fixed and motionless objects of veneration; they are drawn into the hurly-burly of mythical action [9].

A rule of iconographical attributes to identify gods was developed. Hephaestus carries tongs and hummer or a double axe [8].

Art in the Classical Age tends to dispense with attributes and to characterize the gods solely by their ethos.

In the *Lexicon Iconographicum Mythologiae Classicae* (LIMC) (1988) [41], there are more than 100 illustrations of Hephaestus from vase paintings, sculptures, coins, and other works of art. Most date from the Archaic and the Early Classical Age. Some clearly depict Hephaestus' lameness, while others simply indicate it. Two vase paintings and a carnelian scarab having a design in intaglio are very important, for these four items definitely depict his lameness. The first is a Corinthian amphora of the first quarter of the 6th century BC (Fig. 3).
(National Archaeological Museum, Athens, Greece) *Fig.3*

It depicts Hephaestus on his return to Olympus as a beardless individual with crooked feet, drinking, while is riding on one side of a donkey. One more painting in a Caeretan hydria dating to 525-520 BC illustrates Hephaestus as a young, clubfooted boy riding a donkey on his return to Olympus, since, according to the Homeric tradition, he should be aged about 9 years at the time [41, 103].

A carnelian scarab (Etruscan) date from 520-510 BC depicts Hephaestus, bilaterally clubfooted, between Thetis and Achilles, who is receiving his armour [41, 18a].

In the rest of the illustrations of archaic art, Hephaestus is generally represented as a middle-aged, bearded man riding a donkey on his return to Olympus, or sitting on a winged chariot [41], 44], or wearing winged sandals , as having his feet turned inward and backward [41], 198].

The riding of the donkey, the winged chariot and sandals indicate his incapacity for normal locomotion, a characterization of the god fundamental in the *Iliad* [8].

Of special interest is the vase painting from about 540 BC depicting Hephaestus to have just split open the skull of Zeus, while Athena springs fully armed from his head. He holds a two-headed axe, evidently used to perform the craniotomy (Fig.4) © The

Trustees of the British Museum

Hephaestus' lameness is no longer emphasized by the fifth century and thereafter [43]. After 470-460 BC, Hephaestus is illustrated as a perfectly normal bearded man. He stands naked with Athena and Gaea (Earth) at Erichthonios' birth, or, at Athena's birth from Zeus' head, he wears a short, sleeveless tunic and carries a double axe, or else tongs and hammer.

From this review of the relevant sources, it seems that the literary evidence on Hephaestus' lameness is more reliable than depiction in the visual art.

5. DISCUSSION

Hephaestus' lameness has been a favorite subject, indeed a diagnostic challenge, for several authors in recent medical literature. Five papers [1, 18, 19, 20, 21], a letter to the editor [18] and observations based on illustrations [41, 129, 103] by Silverman, Bartsocas, and Schadewaldt [7], have made the diagnoses: achondroplasia [17, 18], diastrophic dysplasia [18]. Hephaestus was short, a dwarf [18, 19, 20], bilateral clubfooted [20, 21] occupational disease i.e., peripheral acquired arsenic-neuritis (Verkerdi, 1986, cited in [19]).

The diagnosis of achondroplasia by Aterman [17, 18] was mainly based on two points: Firstly, his thesis is based on the conviction that Hephaestus is a direct descendant of the Egyptians gods Ptah and Bes, both of whom were depicted as deformed, bow-legged dwarfs. But, Herodotus [26] describes an image of Hephaestus in Egypt, which would not necessarily be the same with the Greek image of the god. From this text it becomes apparent that the particular image was not like the known image of Hephaestus.

Secondly, Aterman [17] argues that Hephaestus was originally thought of as a dwarf, and his unsuccessful attempt to rape Athena, ending with an ejaculation "against her thigh, a little above the knee" is well keeping with this image'.

The text [40] refers to the leg in general and not to any particular site. Besides, how would a dwarf ever dare attempt to rape a normal woman standing erect?

Coming to the diagnosis of diastrophic dysplasia [19, 22] based on figure 3, we repeat that Hephaestus was not short. He appeared as a "huge, panting bulk". Besides, how would an individual with diastrophic dysplasia, having deformities of the hands, such as hitchhiker's thumb, symphalagism, and limited mobility and dislocation of major joints [43], ever be able to construct the marvel Hephaestoteucta, including tripods and robot handmaids [29].The automatic nature of these constructions has been theoretically ascribed to Hephaestus's magical power to infuse life into inanimate materials [16]. But why call him 'magician' and not 'inventor'? Hephaestus was famous for skill and for his art. His automatic constructions appear to be the very first examples of automata, i.e., figures which simulate the actions of living beings, robots [44]. It seems that "each generation needs" not only "a new translation of Homer" [45], but also a reinterpretation of the legend under the contemporary technological knowledge.

A diagnosis of bilateral clubfoot has been made by Bartsocas [20], Bartsocas and Schadewaldt [7], and Jobba [21] based mostly on the early vase paintings [41, 129].

There is no particular mention in the sources that Hephaestus' birth was premature. His deformity was nonsyndromic. It was congenital, so, it could not be an occupational disease, such as paralysis brought on by arsenic bronze (Vekerdi, cited by [21, 23]. Consequently, we can agree with Bartsocas, Schadewaldt, and Jobba that, most likely congenital bilateral clubfoot makes Hephaestus lame.

Warkany [6, 1005] gives a description of the patient with clubfoot that parallels the detailed and vivid one of Hephaestus made by Homer. "The deformity may be so severe that the patient walks on the outside of the foot, which is turned directly inward, upward and backward. The muscle mass of the gastrocnemius is reduced and located very high, just below the knee, so that the lower part of the leg appears very thin."

Clubfoot is one of the most frequent malformations noticeable at birth, averaged 1.8/1.000 from various countries [6, p.1004]. Clubfoot may be rarely transmitted as an autosomal dominant trait [6, p1007, 45].

The birth of Athena, described by Hesiod in *Theogony* circa 700 BC, has been analysed from different perspectives. From a medical perspective, however, her birth represents the first record of a rudimentary craniotomy. The figure of Hephaestus was endowed with characteristics similar to those expected in a surgeon during the time of Hesiod: highly skilled, clever as needed to accomplish a craniotomy without resources, and disregarded by upper classes. Not surprisingly, Hephaestus was chosen to perform the first craniotomy among the gods.

This myth describes the association between an intracranial lesion and the development of headaches, and depicts the rudimentary use of craniotomy for medical purposes [47].

Craniotomies in the form of trepanation were practiced throughout most of the ancient world. Nonetheless, it was in Greece that craniotomies were first described in texts by Hippocrates and Galen [48].

6. HEPHAESTUS' SONS

Hephaestus' sons, Palaemonius and Periphetes, are reported as having crippled feet: Palaemonius was one of the Argonauts [27, 40], while Periphetes was a criminal [27].

7. CONCLUSIONS

From the analyses of the ancient descriptions of Hephaestus and his reputed sons, we can say that there is a reflection of reality in this mythical individual.

He represents a hardworking charismatic craftsman able to construct even automatic pieces of mechanism reminiscent of modern robots. Not surprisingly, Hephaestus was chosen to perform the first craniotomy among the gods. His physical condition appears to be an example of congenital bilateral clubfoot, talipes equinovarus.

Indeed, to quote the Modern Greek Nobel prized poet Odysseus Elytis, these myths "broke the gates of their silent palaces yelling a new truth" [49].

REFERENCES

1. Bartsocas SC (1982): An introduction to ancient Greek genetics and skeletal dysplasias. Pro Clin Biol Res 104:3-13.
2. Bartsocas SC (1985): Goiters, dwarfs, giants and hermaphrodites. In Papadatos CJ, Bartsocas CS (eds): "Endocrine Genetics and Genetics of Growth." New York: Liss, 1-18.
3. Bazopoulou-Kyrkanidou E (1996): Mythos and logos in Hesiod's *Theogony*, circa 700 B.C. Am J Med Genet 62:125-144.
4. Garland R (1995): "The Eye of the Beholder: Deformity and Disability in the Graeco-Roman Word". Ithaca, New York: Cornell University Press. 61-63, 113-114. 63.
5. Czeizel A (1980): Life and death of Tutankhamun from human genetic aspects. Ther Hung 28:40-43.
6. Warkany J (1981): "Congenital Malformations". Chicago: Year Book Medical Publishers, pp. 6-20, 425, 1004-1009.
7. Kunze J and Nippert I (1986): "Genetics and Malformations in Art". Berlin: Grosse Verlag, p. 44, Fig. 47, p. 45 fig. 48.
8. Hermarry A, Jacquemin A (1988): `Hephaistos' in LIMC IV. 1. 627-654.
9. Burkert W (1977): "Greek Religion". English translation (1985) Basil Blackwell Publisher and Harvard University Press, Cambridge, Mass. pp. 123-4, 167-8.
10. Fowler M (1943): The myth of 'Εριχθόνιος. C Ph 38:28-32.
11. Hesiod, *Theogony*. 927-928 Edited and Translated by Glenn W. Most, Loeb Classical Library 2006, London: Heinemann/Cambridge, Mass.: Harvard University Press. II, 1999, 2^{n} ed. London: Heinemann/Cambridge, Mass.: Harvard University Press.
12. Nonnos, *Dionysiaca*, II. 224-226; IV. 956-958; V.140-141, 218-219; IX. 228-231; XXX. 95. Translated by WHD Rouse (1940) Loeb Classical Library I (1962), London: Heinemann/Cambridge, Mass.: Harvard University Press.
14. The Homeric Hymns, To *Hephaestus*, 1-7. In: Hesiod, Homeric Hymns and Homerica. Translated by HG Evelyn-White (1914), Loeb Classical Library (1982), London: Heinemann/Cambridge, Mass.: Harvard University Press.
15. Diodorus of Sicily, V. 1-4; V. 74. 2-4. Translated by CH Oldfather (1939) Loeb Classical Library III (1970), London: Heinemann/Cambridge, Mass.: Harvard University Press
16. Paulys RE (1883- ^{28}1930): "Realencyclopadie der Classischen Altertumswissenschaft". Stuttgart: Druckenmuller, VIII pp. 333-337.
17. Delcourt M (1957): "Hephaistos ou la Legende du Magicien" Paris: Societe d' Edition "Les Belles Lettres", pp. 56-57, 110-136.
18. Aterman K. (1965) Why did Hephaestus Limp ? Am J Dis Chil 109 :381-392.
19. Aterman K (1999): From Horus the Child to Hephaestus Who Limps: A Romp through History. Am. J. Med. Genet. 83:53-63
20. Silverman FN (1965): RE: "Why did Hephaestus limp?" [letter] Amer. J. Dis. Child 109:392.

21. Bartsocas SC (1972): Hephaestus and clubfoot. J. Hist. Med. All. Sci . 27:450-521.

22. Jobba G (1990): What could have caused the limping of Hephaestos? Br. J. Reumatol. 29:451-453.

23. Ramachandran M, Aronson J (2006): The diagnosis of art: Diastrophic dysplasia and Hephaistos. J. R. Soc. Med. 99:584-585

24. Arnott R (2007): The diagnosis of art: Diastrophic dysplasia and Hephaistos. J. R. Soc. Med. 100:67.

25. Lesky A (1963): "A History of Greek Literature" Translated by J. Willis and C. de Heer (1966), London: Methuen. 14, 91, 307, 728-9, 778, 817, 856-7.

26. Herodotus, Book II. 53; III. 37. AD Goodley (1920-1975); (1921-1957) Loeb Classical Library I, London: Heinemann/Cambridge, Mass.: Harvard University Press.

26. Homer, Odyssey. 7; 88; 312; 312; 316-317; 316-320; 571-572 ;586-594; 927-921.Revised by George E. Dimock, Loeb Classical Library I, 1995, 2nd edition., London: Heinemann/ Cambridge, Mass.: Harvard University Press.

27. Apollodorus, *The Library*, I. iii. 5; I. iii. 6; I. iv. 4; I. ix 16; III. xiv. 6; III. xvi. 1.Translated by J G Frazer (1921), Loeb Classical Library I (1954-1956) London: Heinemann/Cambridge, Mass.: Harvard University Press.

28. Homeric Hymns, III. *To Pythian Apollo*, 316-318; XX. In: Hesiod, Homeric Hymns and Homerica. Translated by H.G. Evelyn-White (1914), Loeb Classical Library (1982), London: Heinemann/Cambridge, Mass.: Harvard University Press.

29. Homer, *Iliad*. 16. 118.217; 373-377; 369-422; 395-402; 410-422; 417-418; 586-594. Revised by William F. Wyatt, Loeb Classical Library I, 2001 2nd edition.

30. Page D (1955): "Sappho and Alcaeus. An Introduction to the Study of Ancient Lesbian Poetry"3. The Hymn to Hephaestus. Oxford at the Clarendon Press, 258-261.

31. Pausanias, *Description of Greece*, Attica, I. xx. 3; *Elis I*, V. xix. 8. Translated by W.H.S. Jones (1918-1969); (1926-1966), Loeb Classical Library I; II (London: Heinemann/Cambridge, Mass.: Harvard University Press.

32. Liddell HG, Scott R, Jones H.S. (1990): "A Greek-English Lexicon." (1843) reprinted in 1990, New York: Oxford University Press.

33. Kirk GS (1985): "*The Iliad*: A Commentary". Volume I: book 1, Cambridge, Mass: Cambridge University Press, 114.

34. Snell B (1955): "Lexicon des Fruhgriechischen Epos." Gottingen: Vandenhoeck & Ruprecht. 674.

35. Etymologicum Magnum, Gaisford T, Oxford 1848.

36. Schmidt's MIAE. Lexicon of the Greek Language, Antoniadis, Athens 1888.

37. Stamatakou I Lexicon of the Ancient Greek Language, Phoenix, 1972

38. Hesiod, *Works and Days*. 70-77,427, 436, 571-572. Edited and Translated by Glenn W. Most, Loeb Classical Library 2006, London: Heinemann/Cambridge, Mass.: Harvard University Press.

39. Hesiod, *The Shield*. 70-71, 218-219. Edited and Translated by Glenn W. Most, Loeb Classical Library 200218-2196, London: Heinemann/Cambridge, Mass.: Harvard University Press.

40. Apollonius Rhodius, *The Argonautica*, I.202-206; III.37; III. xiv. 6; IV. 956-958. Edited and Translated by William H. Race, Loeb Classical Library (2008), Cambridge, Mass.: Harvard University Press/ London, England.

41. "Lexicon Iconographicum *Mythologiae* Classicae" (LIMC) (1988) IV. 1. pp. 627-8, 650-659, 681-684. IV. 2. pp. 386-405.

42. Boardman J (1991): "Athenian Red Figure Vases: The Archaic Period." London: Thames and Hudson. 225

43. Horton WA, Rimoin D.L., Lachman R.S., Skovby F., Hollister D.W., Spranger J. Scott CI, Hall JG (1978): The phenotypic variability of diastrophic dysplasia. J. Pediatr. 93: 609-613.

44. Little W, Fowler HW, Coulson J (1967): "The Oxford Universal Dictionary Illustrated". C.T. Onions, Oxford, at the Clarendon Press: The Caxton Publishing Co.

45. Fagles R, (translator: HOMER, *THE ILIAD*, Penguin Books, 1991). Interview in H ΚΑΘΗΜΕΡΙΝΗ (Athens), 3 November 1996.

46. Wang J., Palmer R.M., Chung C.S. (1988): The role of major gene in clubfoot, Am. J. Hum. Gen. 42:772-776.

47. Brasiliense BC, Safavi-Abbasi et al: The legacy of Hephaestus: the first craniotomy. NEUROSURGERY 2010: 67(4) 2010.

48. Missios S (2007): Hippocrates, Galen, and the uses of trepanation in the ancient classical world. Neurosurgery Focus 23(1): E11

49. Elytis O. (1966): "*Orientations*" Dionysos, d' Athenes: Icaros

The present volume includes the works presented at the international Conference "Ancient Greece and Contemporary World", held in Ancient Olympia on 28-31 August 2016. This Conference came as the sequence of at least twenty years of effort of several colleagues at the University of Patras, originating from all disciplines. In fact, this Conference was preceded by four others[1] with similar scope, which made us realize that the ancient Greek civilizations, besides what has already offered to humanity, there is still a lot it has to offer. To the extent that, without a shred of exaggeration, we can reasonably claim that many of the answers to the critical problems of the modern world may exist hidden somewhere in the great achievements of that civilization. A civilization that remains a timeless source of knowledge, inspiration and new ideas, important in encountering the current threats against life itself on our already unbearably burdened planet.

The Conference was organized based on two basic ideas: (a) The separation of knowledge into many isolated disciplines is artificial and is due to man's inability to conceive knowledge in its totality, the result of which is άκρατη specialization, which deprives him from a holistic view of the world and causes substantial losses while searching for new knowledge, while, in the extreme case leads to the creation of the so-called τεχνοκράτη, e.g. a person very knowledgeable on a very narrow scientific or technological area, in which can be very productive, however, being unconscious of the potentially negative consequences of his own activities and (b) The ancient Greek world should not be approached by the various disciplines separately, but, on the contrary, it must take place from the aspects of each one in coordination or interaction with the others, to such an extent that an integrated view of things will be produced.

1. Two of them had the same title "Ancient Greece and Contemporary World", 1997 and 2002 respectively (Proceedings published by the University of Patras) and another two, titles, «Extraordinary Machines and Structures in Antiquity", 2001 and "Science and Technology in Homeric Epics" (Proceedings published in Greek by "Peri Technon", Patras and in English by Springer).

UNIVERSITY OF PATRAS

International Center for Sciences and Hellenic Values

ISBN 978-960-530-171-2