The Antikythera Mechanism

The oldest computer

Based on science

A brief history of Greek Science

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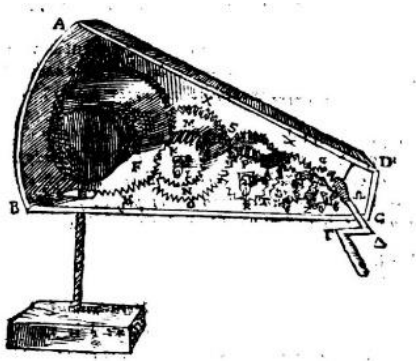

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Figure 0: of the cover page: A complex mechanism with many gears, from the book of Pappus Mathematicae Collectiones (17 centuries ago).

Figure 1 The largest fragments of Antikythera Mechanism, the oldest known computer that works with gear that perform mathematical calculations to predict astronomical phenomena, the position of the Sun (A), the Moon (C1), the phase of the Moon, lunar and solar eclipses, lunisolar calendars (B) when the Olympic games will start and possibly the position of the planets. This instrument has a manual (M and C2). National Archaeological Museum, PTM image created by XM using the method and software of Maltzbender, T. et al 2003 of HP.

CONTENTS

SYNOPSIS

The Antikythera Mechanism is an ancient Greek computer that is the epitome of Greek philosophy. This astronomical handheld computer is programmed to calculate astronomical phenomena, to depict the sky at any given time. It calculates the position of the Sun and the Moon and possibly the Five Planets. The program of this computer is written in the gears of the mechanism. The designer transformed the mathematics that predict the celestial phenomena (position of the Sun, the Moon, the eclipses etc) in series of gears. The mathematics for the calculations were written based on the laws of physics according to Greek science 22 centuries ago. This computer is the epitome of Greek philosophy.

To design and to program this computer, to create a mechanical universe, like the Mechanism, you need to have accepted and assimilated Greek Philosophy, the philosophy of the Ionian philosophers, and put it into practice. The mechanism is designed and made following the doctrine of Pythagoras that nature's elements are mathematics, i.e. that the laws of physics are expressed in appropriate mathematics.

Pythagoras' signature is present on the Mechanism, where the Pythagorean pentagon (symbol of Pythagoreans based on the orbit of planet Venus) is engraved on one of its gears. With this symbol the constructor states "I am a Pythagorean, a philosopher that studies nature with mathematics".

Astronomy in Greece probably started 80 to 85 centuries ago, as archaeoastronomical data suggest. Th beginning of astronomy is marked by the solar orientation of Neolithic orthogonal buildings that look towards the position of sunrise (or sunset at places) on the horizon at solstices and equinoxes. Astronomy as Plato says was born for the prediction of the weather and for travelling. The prediction of weather is based on climatological data using calendars. This process lead, to the notion of causality and the laws of physics and to the birth of natural philosophy. The study of nature, the understanding of natural phenomena in terms of nature, without the use of theology, without divinities and supernatural views.

This process of understanding nature in terms of nature lead to the development of physical philosophy and with it the birth of civilization as Plato implies in his book *Cratylus*

(0059: 005) where he writes according to my interpretation "We are called Humans (Anthrpos/oi), as we mainly differ from the other living creatures, because we look up the sky, we observe, we think, analyze and interpret what we see and (in this effort) we become Humans".

Astrophysics in Greece was born 27 centuries ago through the effort of natural philosophes, Thales, Leucippus, Democritus, Anaximander, Anaximenes, and others to understand the Cosmos, the Galaxy, the microcosmos, the atoms and even evolution of life.

The greatest development was theoretical mathematics with proofs and theorems that has gradually led to today's physics and technology. This led to the development of the Platonic regular polyhedra and the two Platonic rectangular triangles, that are equivalent to atoms and quarks. With these platonic solids were all made exclusively with only two constituents, two "elementary" particles. A comparison of the two very important theories

1) the atomic theory of the Democritus, and
2) the theory of platonic elements, polyhedra and the two triangles

have in essence conceptual similarities, as both construct the Cosmos with what are called with modern terminology *elementary particles, quarks,* and *chemical elements*.

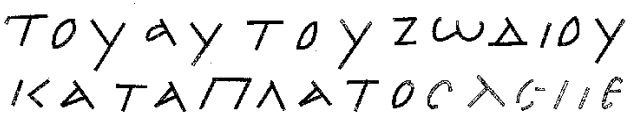

Figure 2 Part of the famous Hipparchus manuscript with the catalog of stars with their coordinates and magnitudes. Created 15-16 centuries ago it led to the discovery of the presession of the equinox with a period of 26000 years, . It states, "of the same zodiac", "in latitude 26 degrees…". Modified from Gysembergh, V., J. Williams, P., & Zingg, E. (2022).

The importance of astronomical automatic mechanisms to various applications, teaching, geography, navigation, and more is presented with emphasis to China and fSouth-East Asia, from Ganges to Guangzhou, as more than 55 cities with their geographical coordinates and all the islands up to Guinea and the Unknown Southern Land (Australia) are mentioned, including two Emporia and Doris of Asia, cities that were probably of some Greek influence.

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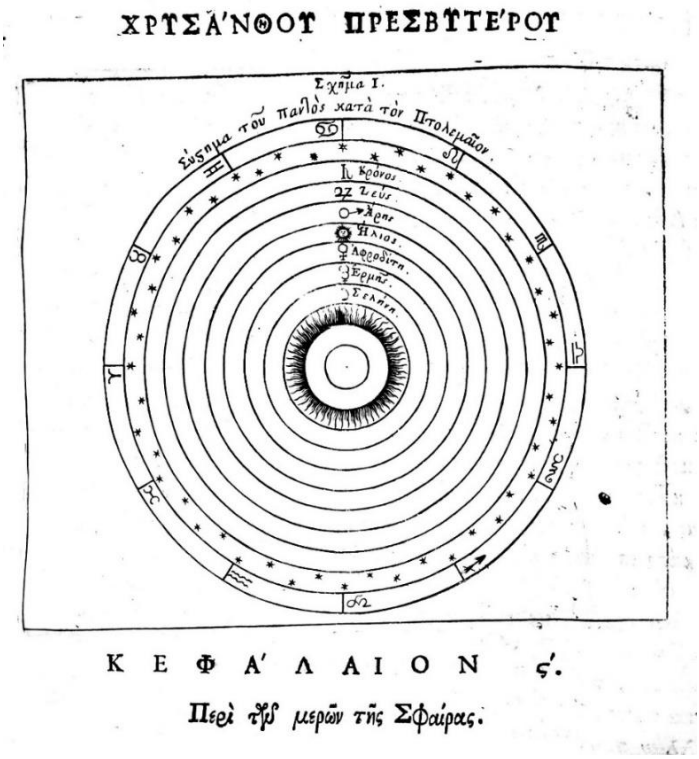

Figure 3 the Geocentric system with the Earth at the centre.

1 SCIENCE AS PART OF CIVILIZATION

Science is an important achievement of civilization and part culture has as the Greek philosophers introduced it some 26 centuries ago, if not earlier. Today's technological world is based on science. It is only with science always based on mathematics that today's technological miracles, like telephones, tablets and more can be created. How has all this started?

An extremely important advancement in the birth and evolution of civilization is according to great mathematician, physicist and engineer Hero is the invention of theoretical mathematics and especially its beneficial use in applications. Theorems with undeniable proofs are used in the exact sciences like astronomy, physics, mechanics, pneumatics, and hydraulics. Theoretical mathematical methods are used today as they were used by Greek philosophers, like Archytas, Archimedes, Hero and Anthemius to construct the first flying machine, engines, musical instruments and buildings with huge domes or stable well-balanced ships. Hero using mathematics and theory constructed (hydraulis, the organ), automations, his robots that he managed to develop very successfully show the strength of theoretical physics to the design,

development, and application of advanced technology.

The importance of science based on mathematics is promoted by many philosophers including the great Plato, as it is presented in the following. Aristotle too underlies the use of mathematics, geometry and arithmetic in science, astronomy, optics, mechanics as these use the same geometric principles.[i] Today modern theoretical physics continues in the same road, using the same scientific methods. Science today analyzes the observations of space telescopes or particle accelerators as the ones conceived by Plato that constructs accurately his four chemical elements with two triangles and then all the Cosmos.

Mathematics are important in science as they are easy to use for the benefit of every discipline and mathematician philosopher Nicomachus Gerasinus presents why. Arithmetic is important for calculations, to share, divide things, and make your contributions like taxes to society. Geometry is useful to design and construct cities, buildings like temples and to divide the fields and plots. Music that is based on harmony and mathematics is useful in festivities, and religious practices. Astronomy is necessary for agriculture, and seafaring, and travelling in general All these are made easier and successfully using theoretical mathematics. Hence, the

philosophers and the people understand the usefulness of the use of mathematics and science based on theoretical mathematics and proofs in their lives.[ii] Science are mainly characterized by the fact that are based on proofs of theorems. Joannis Philoponus says that the most exact scienes are geometry and astronomy.

In this book the hidden secrets in the orientations of ancient buildings, city streets, as early as the 7th-6th millennium BC in the oldest citadels and organized cities in Europe in Thessaly (Sesklo, Dimini) and a little later in Crete and all over Greece, including the Acropolis of Athens. These orientations prove knowledge of astronomy and its use in society.

Astronomical and some mathematical knowledge hidden in symbolic depictions with repeated "symbols", specks, helices and other motifs on ancient vases, terracottae, such as the so called fry-pan vessels is also presented. These studies show that there is basic mathematized astronomical knowledge as early as the prehistoric period (4th and 3rd millennium BCE), which can be read in prehistoric vessels and structures.

Of course there is a lot of hidden information still waiting to be deciphered, although it was once the property of many. Ancient Greek texts show that every architect, or even builder ought to use

astronomy for the orientation of a state building, a theatre a road or even a tomb maker; the same applies for a potter that designs a vase, that has to use a particular number of repeated symbols so that to give a number with astronomical importance at times. Such numbers are periodicities of celestial phenomena, like periods of planets. The periodicities of the planets, the Sun and the Moon are used to keep correct calendars. The same applies to the orientations of the buildings that look towards solstices and equinoxes and another important day in October that marks the beginning of cereal sowing.

The principles of physical cosmology founded in Ionia, are presented in the book too. This astronomical and astrophysical knowledge may have roots in the Orphic traditions a millennium earlier according to some. The same tradition of cosmology of the Greeks is continued today by NASA and space programs.

Science can be dangerous without ethics. Today the cse of ethics in science and technology is extremely important. Plato already put forward this important issue in a perfect way.[iii]

2 ASTRONOMY

As Plato says and as it will proven, the history of astronomy is essentially the history of civilization, but also of humanity to a large extent. The writing of this book has been based on ancient Greek sources, some Latin, as well as many other writings, archaeological finds, especially prehistoric ones interpreted on the basis of archaeoastronomy, such as orientations of buildings, roads, etc., many for the first time worldwide. In parallel facts from the Antikythera mechanism, the oldest computer are used to study astronomy, mathematics, physics, technology and automata of the Greeks in an undeniable way. Of course, the interpretation of ancient texts and archaeological findings is mine. Especially for ancient literature I do not rely on translations and interpretations of other scientists, mainly because when the writings concern astronomical phenomena the non-specialist translator or interpreter of ancient texts sometimes cannot fully grasp the meaning of the writings of the ancient author, especially when words that have many meanings are used.

What is astronomy?

A simple definition of the science of astronomy is given by Xenophon, a Greek philosopher, historian and general, in his *Memoirs* where he describes to us what is astronomy:

> *Astronomy is the study of the motion of the celestial object, of the planets, the immeasurable stars and the comets, the measurement of their distances from the earth and the periods and the causes of these phenomena.*[iv]

Plato, his comrade at the philosophical school of Socrates has a similar definition of astronomy:

> *Astronomy is the science that studies the stars, their motions, periods, the length of the year and the seasons.*[v]

It is evident that the astronomers and philosophers at that time 25 centuries ago, were also interested in the causes, the reasons, that is, the laws of physics, which created the heavenly bodies and make them move with emphasis to the planets and their retrograde motions. Plato according to Eudemus of Rhodes (c. 370 to 300 BCE) who

was perhaps the first historian of science says that Plato, the Pythagoreans and the Eleatians (Greek Philosophers in the Greek city of Elea in Great Greece, South Italy) promote the study of nature introducing the elementary principles and the first principles. Plato introduces the poetic cause and the final cause. Plato introduces his ideas. Aristotle continued along the concept of his teacher Plato, and later introduced the species and in parallel to the poetic cause he introduced the concept of *noos*, which can be interpreted as the laws of nature that are present everywhere. The word *theios* means orginally something that is everywhere and not necessarily divine as usually interpreted. So it is the *noos* in the sense of laws of nature and not as a god as it is wrongly believed.[vi]

Theon of Smyrna also called Theon the Platonic, is an important Pythagorean, Neoplatonic philosopher, who lived probably between 70-135 in Smyrna (Asia Minor, Anatolia). He should not confuse him with Theon the Alexandrian, father of Hypatia, also an important philosopher, astronomer, and mathematician. Theon of Smyrna has an excellent astronomical and mathematical work with subjects such as number theory, geometry but also algebra, which was also

created by the Greeks, harmonic theory, theory of music and astronomy. Theon of Smyrna in his book "Mathematics useful for understanding Plato" gives epigrammatically astronomy and the other sciences that are required to be known by anyone who wants to be taught philosophy and in particular for students of mathematics and not just to read Plato. Then uses this title because it was known that Plato believes that the usefulness of mathematics is of capital importance. The truth of mathematics is undeniable and for this he probably introduces the platonic ideas, which can be interpreted as mathematical accurate representations of objects. This interpretation is based on Aristotle views on this, although his views greatly differ in several aspects. The philosopher Alexander writes: … the ideas of Plato that he also calls essence or substances are expressed by arithmetic and are based on measurements and from this one concludes that the ideas, the essence of things are mathematics and Aristotle adds that the essence differs from the quantity, but the quantity is included in the measurement.[vii] Plato's ideas preexist, as mathematical identities while Aristotle believes that matter has to be created somehow and does not preexists before the

beginning of the Cosmos and Nature as Michael Psellus.[viii]

As Plato uses mathematics, astronomy, harmony, says that we must master five disciplines before one becoming wise, before studying philosophy: arithmetic, geometry, stereometry, music, astronomy. It is said that at the door of his Academy in Athens (that was the first and most important university for a thousand years) Plato wrote "do not dare to enter if you do not master mathematics".[ix]

Similarly and in a wonderful way, Joannis Laurentii Lydi Philadelpheni (c. 490 – c. 560) in his book *De mensibus* (a book about months and calendars) describes the music of the spheres, the motion of the planets. Joannis Laurentius uses the same principles of Pythagoras and his students to perceive, the resonances of the planets and introduced them into the musical scale that we use until today. Joannis Laurentius writes "All the rhythms come from the movement of the planets; Saturn dances following the Doric rhythm, and Zeus the Phrygian, while Mars the Lydian and the others to the others and they move according to Pythagoras following the sound of the vowels of the Greek alphabet; Mercury the alpha (a),

Venus the epsilon (ε), the Sun the eta (η), Saturn iota (ι), Mars micron (ο), the Moon hypsilon (υ), Jupiter omega (ω) and the sound of the rhythms, like ours, cannot be heard because of the large distance". In reality Joannis is not correct, as the Pythagoreans use the resonances of the planets, with the Earth and the Sun, the ratios of the periods of the planets, to create the musical scale. It is worth saying the Pythagorean musical scale is close to the prehistoric one as both have been developed by humans having the same brain and ears and following the same psychophysiological laws.[x]

Humans create astronomy to be used for agriculture or travelling. They like the process and continue to develop it just from curiosity and eventually even for fun. In this process and their observations humans realize that there is normality, causality, and there are laws of physics. The laws are expressed in mathematics, as Pythagoras and the Pythagorean philosophers, his students, and disciples, perhaps first explicitly formulated. Astronomy needs arithmetic to count the days and in parallel geometry to find the position of the sunrise on a particular day of the year. These are necessary to create and keep correct calendars.

This is how from astronomy and astrophysics came many laws of physics, especially the first laws of physics, such as Kepler's laws, the laws of the motion of the planets and the laws of the motion of bodies found by Newton based on Kepler's laws. This way Newton established the law of gravity. The laws of electricity by Coulomb mimicked the law of universal gravitation assuming a generalization and same harmony and symmetries as Newton.

3 AN ANCIENT COMPUTER BASED ON PYTHAGOREAN PHILOSOPHY AND THE LAWS OF PHYSICS

The Antikythera Mechanism is an ancient digital computer working in the unary system of numbering. The complex machine that works with gears the positions of the Sun and the Moon, the phases of the Moon (new Moon, first quarter, full moon…), the eclipses of the Sun and the Moon, and possibly the positions of the planets. The bits are the teeth, and the gears are the bytes of this ancient computer. A number if the unary system is represented by the repetition of a symbol. For example the numbers 1, 2, 5, 10

are represented respectively by I, II, IIIII, IIIIIIIIII, etc.

Many similar mechanisms are mentioned the Greek and Latin literature over the centuries. This means that there were many mechanisms that imitated the celestial bodies. It seems that the first mechanisms of this category were made by Archimedes. Powerful machines for military use were made for centuries and existed well before the time of the Antikythera Mechanism (Russo, 2003; Cuomo, 2007). It is evident that the Greeks had a long tradition in mechanisms, as it is evident even in Homer that describes automations for ship guiding. This type of mechanisms were in use in Greece till the late 1960's. These were a simple system of strings and pulleys with a small guiding triangular sail, like a small flag, that by turning by the wind direction forced the steering system to direct the ship to the desired direction, even at a difficult angle with respect to the prevailing wind.

Figure 4 The Greek astronomer Claudius Ptolemy (Clavdio Tolomeo) with a measuring instrument, woodcut from the book Del Misuarar by Silvio Belli, Venice, 1570. Anonymus, 1564, wood engraving, image 11,4 x 10,9 cm, sheet 22 x 15,6 cm

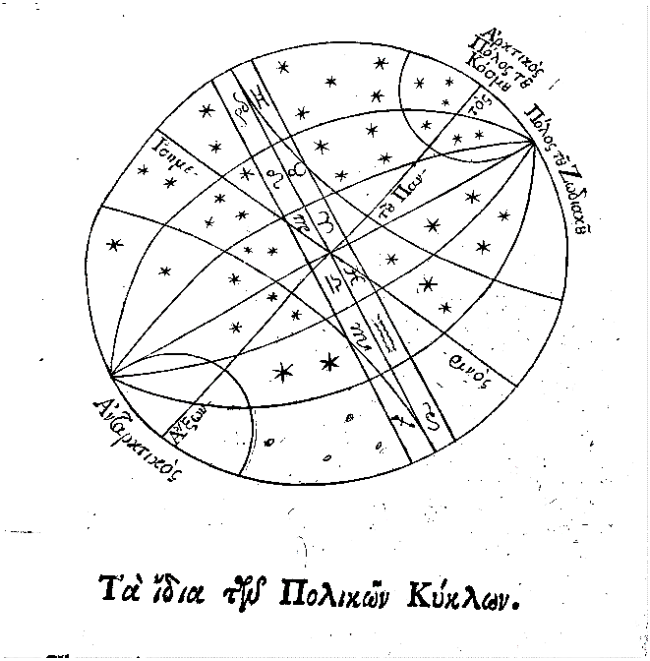

Figure 5 Celestial sphere, the axis, the equator, the meridians, and the ecliptic.

The ancient Greeks referred to these mechanisms as spheres, astrolabes or tablets Spheres, or astrolabes, or tablets! (Πινακίδιον in Greek, i.e. little table).

Made somewhere in the Greek World around 22 centuries ago, the Mechanism is an Astronomical computer, possibly a Planetarium (as I have already written since 1996 in the Educational Greek Encyclopedia of the Athens Publishing House), it is a

mechanical Calendar that shows the date in various Greek calendars. It is also a Meteorological - Climatological weather forecasting device (using a 42-line table).

Science must be as simple as possible but not simpler than necessary.[1] Pythagoras introduced this principle the so called Occam's razor in science 26 centuries ago for the simplicity that is necessary in order to achieve the best result with the minimum complexity. This is what in Latin is called *Pluralitas non est ponenda sine necessitate*. This principle of precision through minimalism, which is internationally called the Occam razor, after the scientist who re-introduced it to William of Ockham (1287–1347). Proclus (410-485 AD) and Syrianus (4th5th century) in his commentary to Aristotle, state that one of the doctrines of the Pythagoreans is that we

[1] "Albert Einstein: It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience. '*On the Method of Theoretical Physics*', lecture delivered at Oxford, 10 June 1933; Oxford *Essential Quotations (4 ed.) Edited by: Susan Ratcliffe Publisher: Oxford University Press Published online: 2016 Online Version: 2016 eISBN: 9780191826719*

should use the minimum assumptions to explain natural phenomena and in particular for the motion of the planets in his book *Diacochi Hypotyposis astronomicarum*.[2]

The mechanism is also an educational tool and a navigational instrument. It can be used for the measurement of latitude, possibly also longitude. The unknown longitude may be estimated may be estimated from the difference of the measured position of the Moon and the lunar position ephemerides at a place of a reference longitude (e.g., a home port).

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[2] Proclus, Hypotyposis astronomicarum positionum, Chapter 1, section 34, line 1 "τῶν μὲν Πυθαγορείων ... παρακέλευσμα ἦν ..... δι' ἐλαχίστων καὶ ἁπλουστάτων ὑποθέσεων ἐπειδὴ δὲ καὶ τοῖς κλεινοῖς Πυθαγορείοις" … "δεῖν γὰρ ἐπ' ἐκείνων καὶ αὐτὸν παρακελεύεσθαι τὸν Πυθαγόραν ζητεῖν ἐξ ἐλαχίστων καὶ ἁπλουστάτων ὑποθέσεων δεικνύναι τὰ ζητούμενα·" and Syrianus Phil., In Aristotelis metaphysica commentaria, page 185, line 5 καὶ ἄξιον μὲν θαυμάσαι τὸν Ἀριστοτέλην καὶ ἐν τούτοις, ὅπως εἶδέ τε τὰ ἑπόμενα ταύτῃ τῇ ὑποθέσει ἄτοπα καὶ δι' ἐλαχίστων παραδέδωκεν· οὐ μὴν διὰ τοῦτο καὶ λέγειν τι πρὸς τοὺς Πυθαγορείους οἰητέον αὐτόν· οὐδαμοῦ γὰρ ἐκεῖνοι τὸ κακὸν ἐν ταῖς ἀρχαῖς παρελάμβανον.

The mechanism is an astronomical computer. The position of the Moon can also be estimated with the Antikythera Mechanism which can be used instead of an ephemeris. This method has been in use by ancient astronomers from the time of Hipparchus 22 centuries ago. The exact solution has been given only after the development of exact clocks, the marine chronographs, developed by John Harrison between 1762-64 decades after Newton attempts to measure accurately the longitude.

Figure 6 the largest part, fragment A, of the Antikythera Mechanism. It is made using the PTM method of Dr. T. Malzbender (HP) using 40 photographs taken with 40 different lamps at given points, created by the author.

predicts the positions of the Sun and the Moon, the phases of the Moon. Specifically, the Moon indicator in the mechanism has a realistic variable speed. It predicts the lunar and solar eclipses, year, month, day, time.

Surprisingly, the mechanism determines the position of the Moon, which is calculated using a substitute for Kepler's 2nd law. The

speed is maximum at the perigee and minimum at the apogee and the motion of the moon is reproduced very realistic. The machine shows the date in various lunisolar calendars that the Greeks used at the time, including a calendar that is based on the sun, which is the Egyptian calendar and very close to the Julian calendar.

Hence the Antikythera Mechanism is suitable for cartography and navigation. Ancient maps have been developed using similar instruments. These types of mechanisms are useful to the military and ideal for teaching.

The mechanism was optimally designed with minimal friction to allow the teeth and gears to function without bearings. The positioning of the axis and gears for the given size of triangular teeth gives the smallest possible size of the ancient computer to be somewhat smaller than a shoebox, somewhat narrower than a A4 page (see Roumeliotis 2017). The mechanism is functional, durable, without problems of teeth and gear breaking or bending and it functions with minimal torque.

Calendars are very important for societies to regulate their lives. The Antikythera Mechanism has many calendars that were

simultaneously in use by the Greeks and other peoples for centuries or millennia. One of the calendars is based on the Solar year (the so-called Egyptian Calendar, which evolved to the Julian) calendar by astronomer Sosigenes, advisor of Queen Cleopatra, 21 centuries ago. Other ancient calendars of the Greeks and other peoples and cultures are lunisolar.

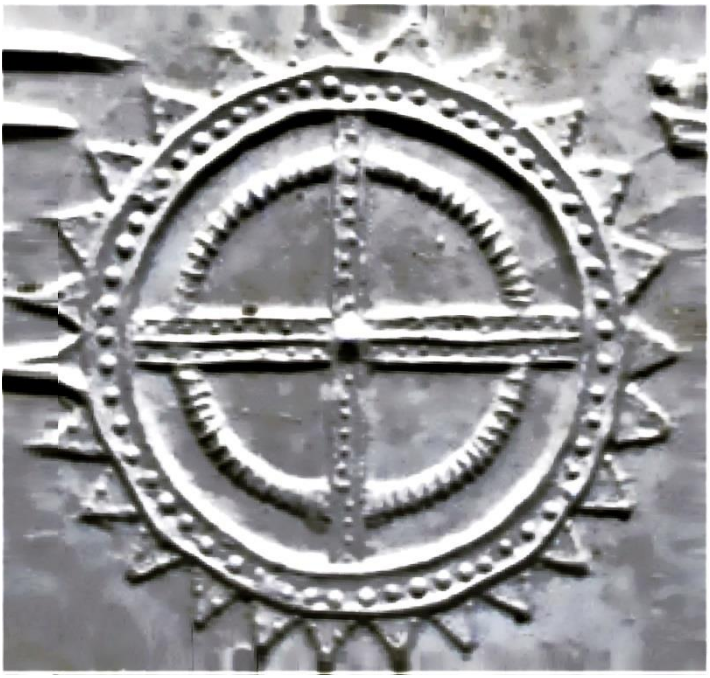

Figure 7 A prehistoric mold (c. 1800 BCE) possibly used as an astronomical calendaric instrument and predictor of eclipses. It is like a "pocket Stonehenge" that humans 38

centuries ago used (Tsikritsis et al 2013). Archaeological Museum of heraclion,

4 The Cosmic Dance: Calendars and resonances of celestial bodies

Almost all prehistoric and ancient people use lunisolar calendars. The lunar synodic month, a lunation, is 29.5 days. So, to count integer number of days for every month they usually use periods of 29 and 30 days in a sequence so that to keep the month with the phases of the Moon and the beginning of the month with the new Moon. Sometimes ancient civilizations use a period of 59 days instead of two months of 29 and 30. Sixty day months were used too. Prehistoric and ancient people needed to regulate their calendars with the Sun. A solar year (~365,25 days) is longer that 12 lunar months by 11 days. A good calendar must be in phase with the lunation and with the Sun. To keep both phases, solar and lunar, prehistoric and ancient scientists invented calendars that add these 11 days at the end of the solar year or by adding an extra month every three or four years. These extra months are

added in the Oktaetiris and the 19-year Metonic period at appropriate times.

The Oktaeteris (also Octaeteris, or 8 solar years synchronize with lunar and Venusian phases) is an important basic prehistoric lunisolar eight-year calendar used by the Greeks and other people. The Olympiad is a four-year period of the Sun and the Moon, which is essentially half the Oktaeteris. Oktaeteris is divided into two Olympiads of 49 and 50 months respectively. Oktaeteris was formerly also used for *Paschalion*, i.e. the determination of the date of Passover (first full moon after the Vernal Equinox) for Jews and Easter for Christians.[3] The Mechanism has two more lunisolar calendars. In the mechanism is another lunisolar period, a calendar based on the cycle of Meton. The mechanism also has the lunisolar cycle (periodicity) of Callippus lasting 76 years. It has the ecliptic period of Saros, (18 years, 11

[3] Anastos, M., 1948, Pletho's Calendar and Liturgy, Dumbarton Oaks Papers, 4, 183-305. doi:1. Retrieved from http://www.jstor.org/stable/1291051 doi:1, Anecdota Graeca, ed. J.A. Cramer, 1, 379.16-29, and Henri Omont, Inventaire som-maire Manuscript Grecs de la Bibliotheque Nationale, 1 Paris, 1886, 160.

days, and 8 hours) to predicts the solar and lunar eclipses.

The Olympic period of four gears, is based on an eight-year lunisolar cycle which is equal to 99 lunar synodic months (lunations) that was the traditional Greek calendar. The Oktaeteris consists of 8 Tropical years which are 2921.93754 days, approximately equal to 99 Synodic lunar months or 2923.528230 days or 107 Sidereal lunar months or 2923.417787 days, 5 Venusian synodic periods equal to 2919.6 days, 13 Venusian sidereal periods of 2921.07595 days.

Most of these periodicities were noticed by prehistoric people and the ancients used these periods as calendars that based on the Sun, the Moon and Venus can be kept by a clever peasant in almost every village, in parallel with a tropical year. Agricultural, pastoral, seafaring and fishing activities can be regulated well with Oktaeteris.

The names of the months of the Metonic calendar that is in the Antikythera mechanism, which lasts 19 years, implies that it is an Epirus lunisolar Metonic calendar that belongs to the family of Corinthian calendars

which belong to the much wider family of Doric calendars used all over the Mediterranean. This periodicity is used today (probably since the 11th or 13th century) to calculate Easter (Paschalion) and the Passover of the Hebrew, similar to Buddhist and other lunisolar calendars.

The mechanism shows that humans conceived, designed, and built a mechanical computer, a clockwork mechanical automatic Cosmos, a planetarium based on exact science, Greek philosophy, Pythagorean. This was a huge step for humanity. Men commit "blasphemy" when they predict what their gods will do, as the Sun, Moon, and planets are their first gods, as Plato (ca. 426–348 BCE) says. Humans have been committing such blasphemy since prehistoric times when they created the first calendars. Calendars actually predict the position of the Sun and Moon. People are forced to do this infamy because Necessity, *Anange*, which is stronger than the gods (Plato), as even the gods obey her (Pittacus 640–568 BCE). By the term Anange, Necessity, and more specifically the term *Adrasteia*, the Greeks mean the unescapable law of nature that everything obeys in the Cosmos. In the prehistoric Orphic Hymns (Papathanassiou,

2016) they consider the Celestial Law, the law that none can deviate from, that is equal to all and for all.

Figure 8 Another part of the Minan computer (c. 1800 BCE).

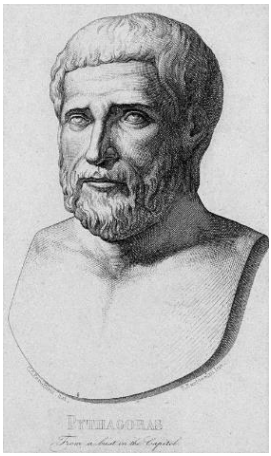

Figure 9 Pythagoras. Line engraving by B. Bartoccini after C. C. Perkins, 1823-1886, Wellcome Collection, Ref: 8003i

Figure 10 A seal depicting the oddess of nature receiving the goods of the four seasons (?) of the four years (?). The Sun and the Moon at the top represents the equinox according to M. Tsikritsis (private communication). This proves the existence of prehistoric calendars.

Man, many millennia before present, carried out many experiments, first randomly, and then systematically, with measurements. Such were experiments with tools, with stone tools, with wooden levers, and later with physics experiments for example to make musical instruments. It is certain that these experiments led Pythagoras to theoretical physics and mathematics and to the notion that nature is properly described only by mathematics, that is, by the laws of physics. Experiments in music led by observation and exact measurements to the relationships of the periods of the planets, to establish the laws relating length of strings and the force of the weight f its tension of a musical instrument to the laws of strings.

Figure 11 Talos or Talon a mythical prehistoric automaton, a robot.

The positions and the periods of the planets, their coordinates with time led the Pythagoreans to the creation of the musical scale based on the movements of the planets. Pythagoras and his school realized that strings of various lengths under the same tension produce frequencies inversely proportional to the length. They have studied the relation between the frequencies produced by a given length string tensioned under various weights.

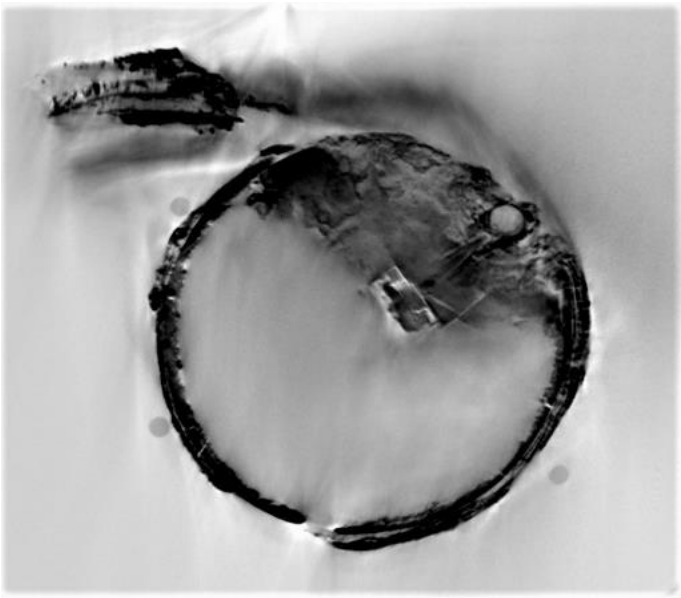

Figure 12 The gearbox of the Moon. The Moon changes phases during the month by a rotating crown (cylindrical) gear.

The Antikythera mechanism predicts the lunisolar eclipses. It has a spiral dial for the eclipses and a spiral dial for the phases of the Moon, the Metonic cycle, the Greek traditional 19 year calendar. There is a dial for the Olympic games and other important Greek festivals, that are called games. The four year cycle of the Olympiad one Olympiad lasts 49 months and the next one lasts 50 months.

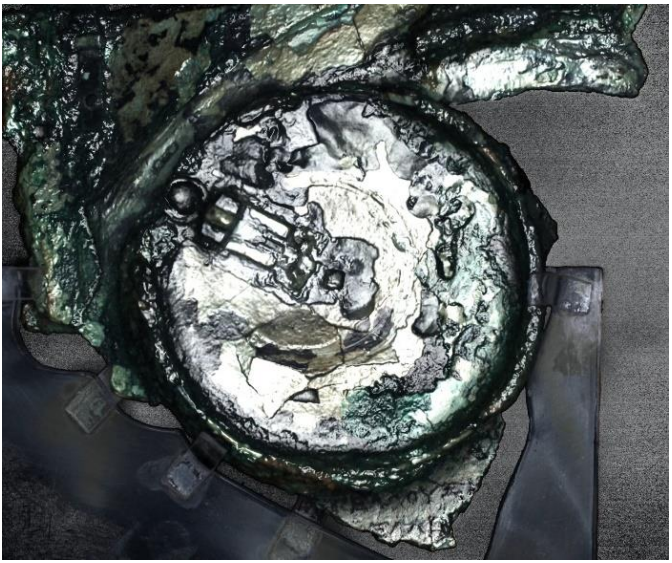

Figure 13 fragment C, of the Antikythera Mechanism showing the mechanism of the moon (upper left part of photography). The moon moves following the second law of Kepler to a good approximation. The moon orbits the earth in the mechanism following Kepler's second

The 8-year Oktaetiris lasts 99 lunar synodic months. During this eight year calendar, the Oktaeteris, the Greek Crown Games, Olympic at Olympia, the Pythian at Delphi, the Nemean at Nemea, the Isthmian at Corinth, the Naa or Naia at Dodona and the Aleia at Rhodes and Alia (Elia) at Elis, next to Olympia.

We probably have in the National Archaeological Museum, Athens, all the

necessary gears to understand properly the motion of Moon and the lunisolar calendars, the Olympic dial, the eclipses and perhaps one gear of one planet (fragment D).

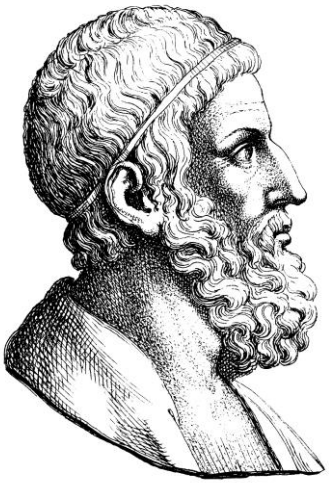

Figure 14 Archimedes, great philosopher, mathematician, physicist, astronomer, and engineer that constructed two planetaria and an astronomical clock with automations. Gravure based on a portrait at the Musei Capitolini, Rome.

The ancient computer follows exactly the well-known Pythagorean principles, Nature is described by mathematics (laws of physics), symmetry, and simplicity. The principle of simplicity has been renamed as *Occam's razor*, Occam's razor of simplicity, and in Latin *Pluralitas non est ponenda sine necessitate* in Latin, is the second rule set by

the Pythagoreans, as Proclus taught (you can still visit today at the southern part of Acropolis), the Pythagoreans used the simplest and least possible hypotheses in their mathematics, for example in their theories for the planetary orbits. The rule of simplicity of Pythagoras is called today Occam's razor, or Pythagoras second rule as I call it. This is one important rule used for the design of the Antikythera Mechanism.

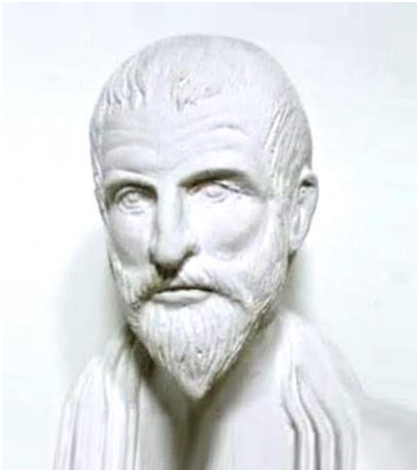

Figure 15 Proclus (17 centuries ago), the last philosopher in Athens describes machines similar to the Antikythera Mechanism that he calls "Pinakidion", i.e. tablet in Greek. These machines calculate the orbits of celestial objects, and define their perigee and apogee.

Descriptions of similar machines, especially a machine named *PINAX* and when small or

PINAKIDION (table and tablet respectively in Greek) can be found in several ancient Greek and Latin texts including the greatest Roman philosopher and statesman Cicero and the last Athenian philosopher, Proclus, who was also an excellent mathematician and astronomer.

The mechanism has survived in 82 fragments which is what exists of this oldest known computer that is 22 centuries old. Although these are only a part of the entire instrument. The surviving gears and inscriptions and scales, enable us to understand very well the motions of the moon, the lunar and solar eclipses, the phases of the moon, how to keep a good accurate lunisolar calendar, which days to exclude from every month of 29 days, when to add a 13th month in which years of the 19th year Metonic period, when the ancient people celebrated their festivities, like the Olympic games, the Pythian etc based on the eight year, two Olympiad cycle of Oktaeteris.

Figure 16 Pythagoras and his student Philolaus perform experiments in music and physics to deduce the laws of physics of strings.

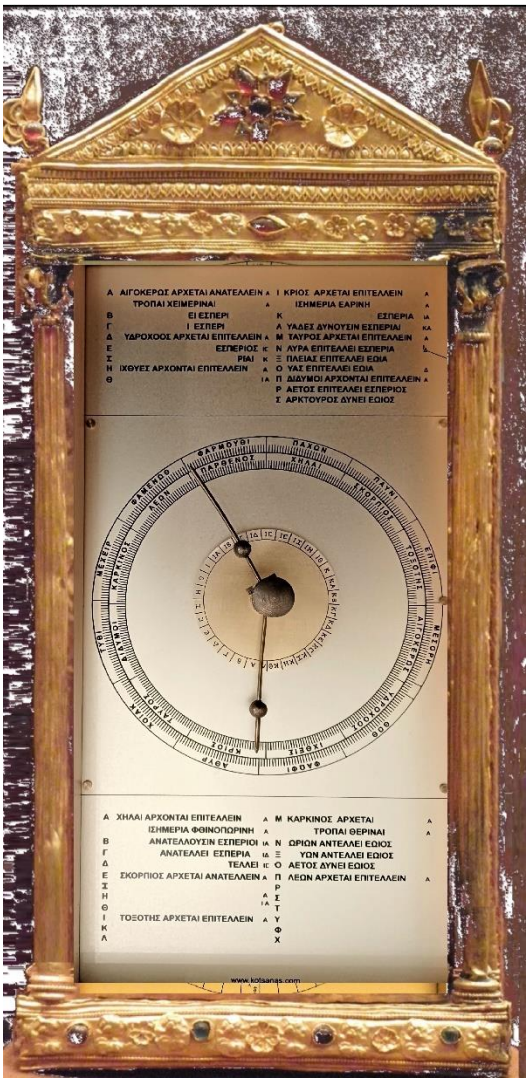

Figure 17 Front of a reconstruction of the ancient computer based on our theories. , Kotsanas Museum of Ancient Greek Technology and XM.

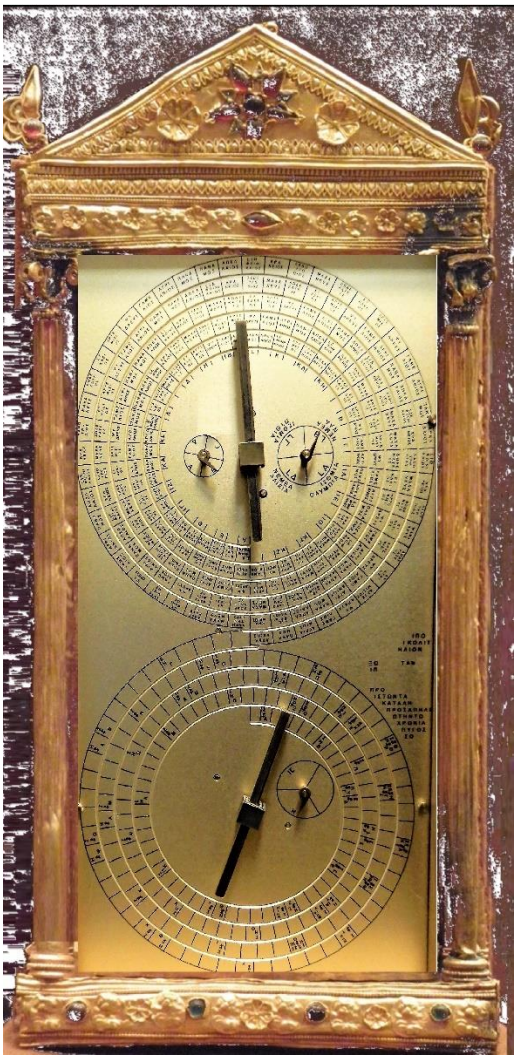

Figure 18 Back side of a reconstruction of the ancient computer based on our theories. , Kotsanas Museum of Ancient Greek Technology and XM.

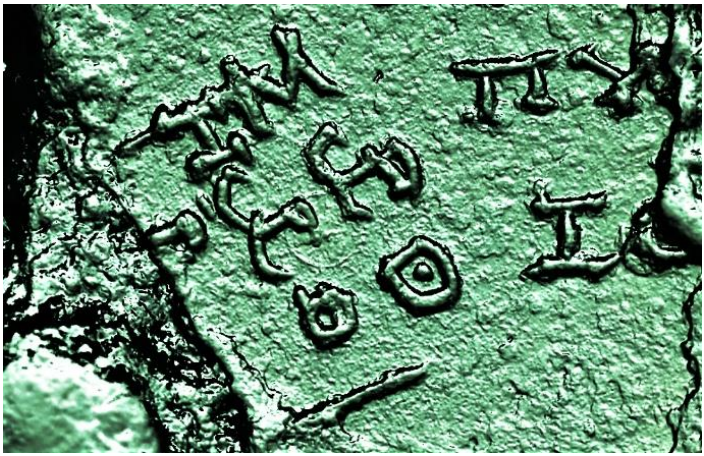

Figure 19 A solar and a lunar eclipse. It is made using the PTM method of Dr. T. Malzbender (HP) using 40 photographs taken with 40 different lamps at given points, created by the author.

Moreover, the astronomical computer from 38 centuries ago could have been used to keep a good calendar and to predict eclipses (Tsikritsis et al 2013). The evidence for a Minoan computer is a mold used to manufacture bronze, copper or gold astronomical computers which means that there may have been a market of pocket astronomical computers and hence many people that knew astronomy and that could afford to buy an expensive astronomical item to be used for time keeping and as status symbol.

A large part of the manual, probably 75% of the texts. are lost or still wait for the archaeologist to discover them at the bottom of the sea at Antikythera, where still some 700 to 1000 tons of antiquities with the remains (45m X 10m X 1m) of the huge shipwreck at the bottom of the sea at depths between 40 to 65 m. As at the depth of 65m, a cliff drops off to 120-130 m. It is expected that many more antiquities are at a depth of some 120 m below the cliff.

As we attempt to understand this mysterious object with its 30 gears that are now in the fragments, it is helpful to consider a few hypothetical gears if they fit appropriately with the mathematics, physics, astronomy, and engineering of the mechanism. In science it is necessary to have hypotheses.

5 PYTHAGOREAN DOCTRINES, NATURE, AND TECHNOLOGY

Pythagoras is the first to introduce the term *Philosophy* and *Philosopher*. An important part of his philosophy is based on exact mathematics. Pythagoreans based their natural philosophy on mathematics. Pythagoras did not allow their doctrines to be written in books as he was afraid that the knowledge and the power it provides could be used inappropriately by villains against humanity. All known about Pythagoras is from some writings by some of his students and others.

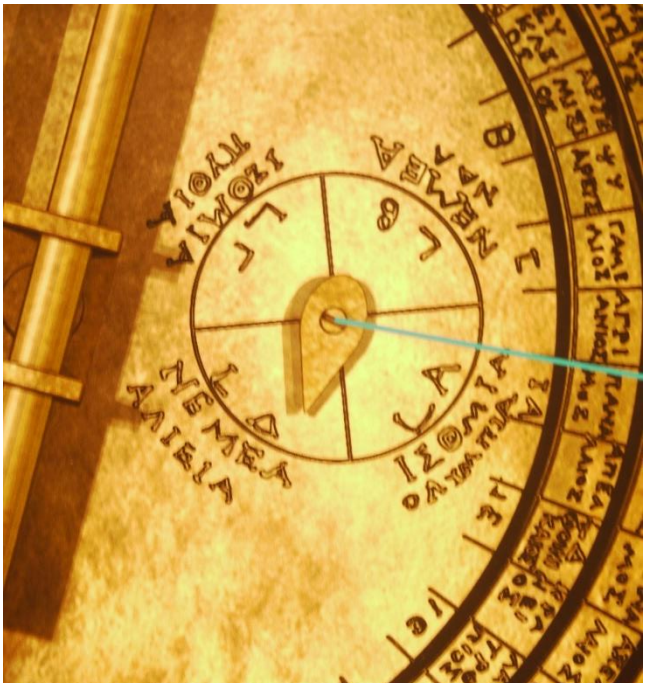

Figure 20 The Olympic dial that determines when the Olympic games starts.

Despite this embargo of Pythagorean knowledge to non-initiated to this philosophe individuals, the prohibition to teaching everyone without taking into account her/his view on ethics, the teachings of Pythagoras influenced Greek philosophy. Pythagorean views forged the development of sciences and especially technology based on science and mathematics, the laws of physics. So

today all scientists are Pythagoreans as I used to say to students in physics at the University of Athens for some 40 years.

Pythagoras states: "the elements of nature are numbers", i.e. to understand nature we need to use mathematics and the laws of nature that are expressed with mathematics. Galileo, who was a follower of Pythagoras, repeats the same two millennia later which is the "language of nature".

Figure 21 Two of the four gears (left) that make the moon to move following Kepler's second law using the epicyclical theory. The four gears add two circular motions. This image is made using the PTM method of Dr. T. Malzbender (HP) using

40 photographs and appropriate algorithm and software. Image by the author.

Of course, mathematics is a human invention. Today we are Pythagoreans because our science, technology and applications are based in the principle that nature can be studied, understood and some phenomena (like the phase of the moon, eclipses) can even been predicted at times using mathematics. Pythagoras and other philosophers set theoretically the foundations of philosophy, science and technology based on *principles* and *elements*. This is really yht beginning of systematics science and technology based on.

Almost all Greek philosophers understand and accept the existence of the laws of physics and causality and the universality of these notions. Philosophers use terms like mind, reprimanded, providence (in Greek nous, eimarmene, pronoia, νους, ειμαρμένη, πρόνοια) which I interpret as laws of nature. These created and till today govern the Cosmos.

More specifically he teaches that the study and understanding nature can only be done with mathematics, considering that

symmetries and harmony are everywhere in natural phenomena.

Heraclitus, Pythagoras and Theano, his wife, are the first to have discovered the mathematical relations in harmony in music and in the motion of the planets.[xi] Aristoxenus says that Pythagoreans used healing of the body and soul using medicines and music.[xii]

The Pythagorean doctrines for science can be summarized in:

a) nature can only be understood with the laws of physics that are written with mathematics.
b) symmetry and harmony help to better understand nature, to formulate the most general possibles laws of nature to explain and predict various phenomena, not just one phenomenon or effect
c) based on these to develop science, with laws of physics
d) to develop technology based on science.
e) the principle of simplicity (called today Occam's razor), the simplest possible assumptions and simplest possible mathematics when formulating a law of physics, when developing modeling of natural phenomena.

f) to predict phenomena, based on the mathematically formulated laws of physics.

6 ECLIPSES

The mechanism predicts the eclipses using the lunar period of Saros, (18 years, 11 days, and 8 hours), with which the solar and lunar eclipses repeat themselves and the lunar Exeligmos period (54 years and one month, equal to 3 Saros cycles), which covers a longer period of time for solar and lunar eclipses and is more accurate.

The term *Saros*, is a period of eclipses, and means in Greek sweeping (of time and sky of the eclipses. The eclipses sweep the sky in 223 months, equivalent to 18 years, 11 days, and 8 hours (18.029 years, 18.999 eclipse years, 38 eclipse seasons, solar days, 241.999 draconic months, 238.992 anomalistic months, 6,585.321347 days). This periodicity is programmed in the mechanism with appropriate physics, mathematics translated to a train of gears with axis, shafts, and pointers on scales. The ancient computer has the appropriate train of gears to predict eclipses based on this periodicity and the

triple periodicity of Exeligmos 54.087 years (3 X 18.029 years).

Synodic lunar month is the period of the Moon as seen from Earth with respect to the Sun, a Sidereal month is the period of the Moon with respect to the stars, and Draconic months is the period the Moon returns to the ascending point of the line of intersection of the orbit of the Earth around the Sun (ecliptic plane) with the plane of the Moon around the Earth. The angle between these planes is ~5.145 degrees.

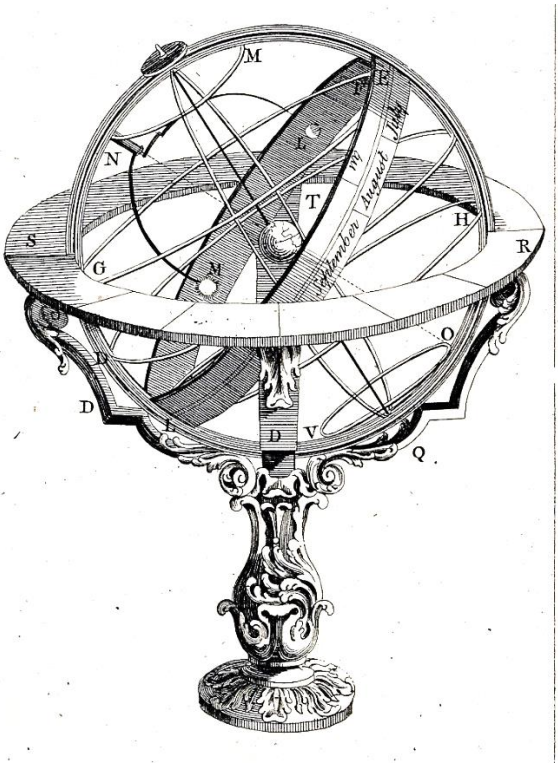

Figure 22 Celestial spheres with nested the Earth, the motion of the Moon. Modified detail of an etching, 1769, Wellcome Collection,22731i

7 A PROGRAMMABLE COMPUTER

The mechanism is a computer programmed to receive an input, date, and location

(latitude, longitude of observer) and apply the celestial motion laws, the lws of the motion f the Sun, the Moon, the fixed stars, and the planets with respect to the Earth.

Figure 23 Part of the eclipse dial. It shows in every month if there is a lunar (Σ) or solar (H) eclipse. It shows the hour of the eclipse. The small circular dial shows how may hours (8 or 16) to add the hour indicated in case f the second or third Saros cycle.

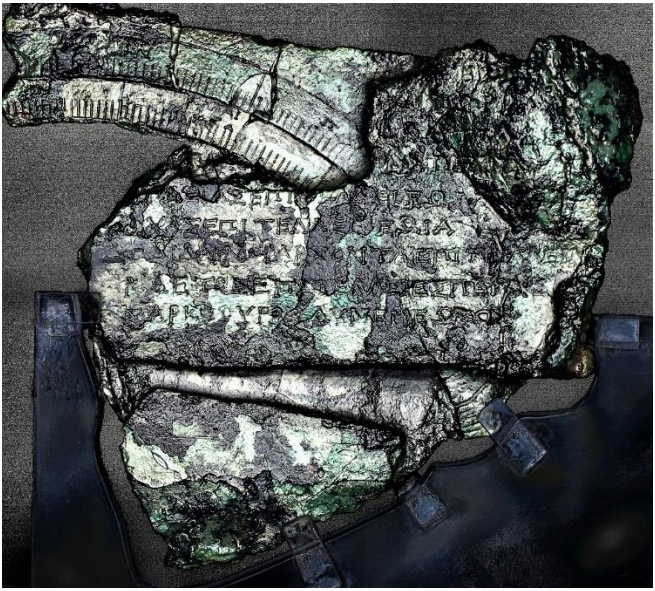

Figure 24 This image of the manual of the computer and two circular scales of the year and the ecliptic with the zodiac. The manual shows the parapegma a forty line table that enables the user t keep an accurate calendar. The image is made using the PTM method of Dr. T. Malzbender (HP) using 40 photographs taken with 40 different lamps positioned at different given points, created by the author.

It is surprising that humans develop a computer to predict the position of the Sun and the Moon at such an early time. Plato says that the first gods of humans were the Sun, Moon, and planets. One could say that it was "blasphemy", “hubris” when humans predict what the planets, the Sun, the Moon

will do, as these are their gods. They have been doing this blasphemy since prehistoric times when they created the first calendars. Calendars predict the position of the Sun and Moon. People are forced to do this infamy because Necessity, Ananke in Greek, which is stronger than the gods (Plato, ca. 426–348 BCE), as even the gods obey her (Pittacus ca. 640–568 BCE). Ananke in many aspects really means laws of physics.

Man many millennia before present carried out many experiments, first random, and then well-designed, with measurements. Such were experiments with tools, with stone tools, bones, with wooden levers, or experiments in physics to make musical instruments.

The machine that is called Antikythera Mechanism is a programable computer. It is programmed with gears. The programming requires careful design of a series of gears using the least possible number of gears and teeth for every gear, frequently using prime numbers when possible in terms of construction, torques, strength f material etc.

Modern civilization is based on the scientific principles methods (laws of physics) and the Pythagorean Basic principles:

Nature is described by numbers (arithmetic), geometry (mathematics), it contains harmony and symmetries. All these have been established by the time of Alexander the Great and used extensively in applications at the time of his successors and onwards. Alexander has learned science from his great teacher Aristotle. Alexander was educated especially in mathematics. His teacher of mathematics was the great mathematician Menaechmus, student of Plato and Eudoxus and friend of Aristotle. Menaechmus has contributed in the invention of algebra, conic sections, formulated for the first time the equation of parabola ($yy=y^2=Lx$), solved the long standing unsolvable problem of doubling the volume of a cube. It is known that Alexander asked his teacher Menaechmus if there was an easier way to geometry and his teacher answering, "in the country there are private roads and royal ones, but there only one road in geometry".[4] Menaechmus in known as using algebra and finally a mechanical

[4] Joannes Stobaeus, *Anthologium*, (2,31, 115, 1) Μέναιχμον τὸν γεωμέτρην Ἀλέξανδρος ἠξίου συντόμως αὐτῷ παραδοῦναι τὴν γεωμετρίαν· ὁ δέ "ὦ βασιλεῦ", εἶπε, "κατὰ μὲν τὴν χώραν ὁδοί εἰσιν ἰδιωτικαὶ καὶ βασιλικαί, ἐν δὲ τῇ γεωμετρίᾳ πᾶσίν ἐστιν ὁδὸς μία".

construction to double the volume of the cube. It is to believe that he taught the young king the art mechanical constructions that were extremely important at war and perhaps this guided Alexander to have scientists with him at his expedition in Egypt and all of Asia, including India, and to develop in secrecy military machines, catapults and many more machines, for his army (Hacker, 1968. Manicas, 1982; Roland, 1992; Humphrey et al, 1998; Wilson, 2009; Parker, 2021).

Figure 25 Olympias Stratonice, mother of Alexander the Great. Archaeological Museum of Thessaloniki

Alexander's education came because of the proper education and ambitions of his mother, Olympias, princes of Epirus (north western Greece), fourth wife of the mighty king Philip. Olympias was an extremely strong queen that reigned Macedonia for the decade Alexander was in Egypt and Asia. Olympias was renamed Stratonice as she even becomes a successful military leader

and general at war after the death of Alexander. She probably selected the educators of her son Alexander selecting the son of the palace doctor great philosopher Aristotle and the great mathematician Menaechmus that had a talent for mechanics too.

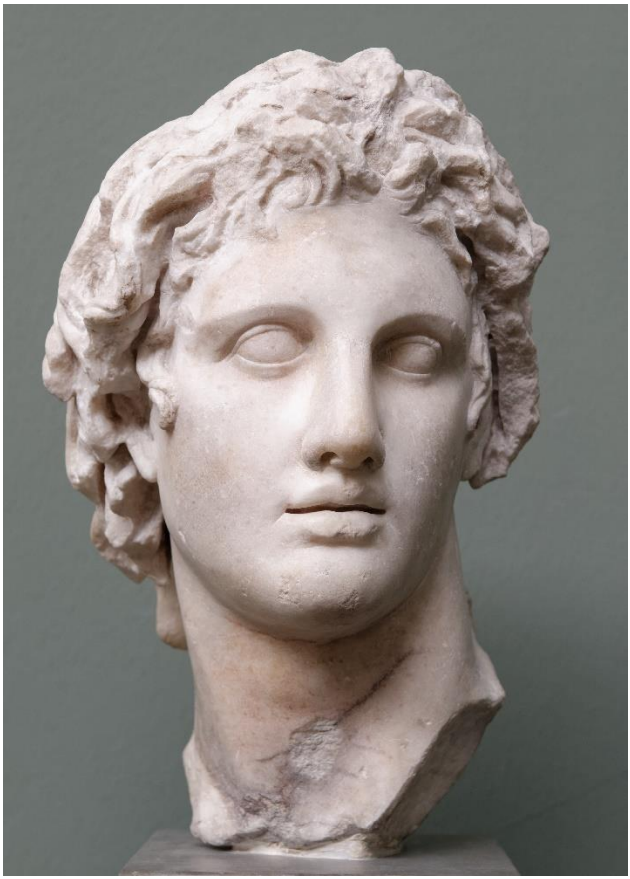

Figure 26 Alexander. Ny Carlsberg Glyptotek.

Consequently, Alexander was properly educated.[5] He was well educated in

[5] For Alexander's education see primarily Plutarchus, *Alexander*; Some alternative views are in Merlan, P., 1954. *Isocrates, Aristotle and*

diplomacy, political sciences, decision making and even medicine and science by Aristotle and appreciated both technology and science, especially science and technology based on mathematics, the laws of physics for practical reasons trained by Menaechmus and others. His knowledge of medicine saved himself and his soldiers on several occasions.[6] Technology as part of civilization is extremely important. Technology based on science and especially mathematics is a giant leap that civilization made at the time of Alexander and the Hellenistic period, thanks to the great king.

The importance of machines at war developed and used by Alexander are mentioned by Arrianus[7] and Diodorus[8] and

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Alexander the Great. Historia: Zeitschrift für Alte Geschichte, (H. 1), pp.60-81.

[6] Lainas, P., Panutsopulos, D., Skandalakis, P.N., Zoras, O. and Skandalakis, J.E., 2005. *"Most Brilliant in Judgment": Alexander the Great and Aristotle*. The American Surgeon, 71(3), pp.275-280.

[7] Flavius Arrianus*, Alexandri anabasis*, Book 1, chapter 21, section 5; Book 1, chapter 22, section 1; Book 1, chapter 22, section 2; and many more.

[8] Diodorus Siculus, *Bibliotheca historica* (lib. 1-20) 17, chapter 43,4,1 ὁ δ' Ἀλέξανδρος τὰς τριήρεις ζευγνύων καὶ μηχανὰς παντοδαπὰς αὐταῖς

others. The Byzantine Emperor Constantinus VII Porphyrogenitus describes war machines with up to 20 wheels.[9] According to the very popular romance of the history of Alexander (Historia Alexandri Magni) the king learned how to use a machine like the Antikythera Mechanism.[10] It is known that tradition is automata based on laws of physics[11] and

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ἐπιστήσας κατέβαλεν ἐπὶ πλέθρον τοῦ τείχους· καὶ διὰ τοῦ πτώματος εἰσέπιπτον εἰς τὴν πόλιν.

[9] Constantinus VII Porphyrogenitus Imperator, *De strategematibus* (olim sub auctore Herone Byzantio) Wescher p238,13.

[10] Historia Alexandri Magni, Recensio a sive Recensio vetusta Book 1, chapter 14, section 4 ἄγει γὰρ αὐτὸν ἔξω τῆς πόλεως ὁ Νεκτανεβὼς καὶ ἀναβλέπων εἰς τὸν οὐρανὸν ἐδείκνυε τῷ Ἀλεξάνδρῳ τοὺς ἀστέρας, διδάσκων τὴν ἑαυτοῦ μηχανίαν.

[11] Proclus gives an excellent description of the use of laws of physics to automata. Proclus Phil., In primum Euclidis elementorum librum commentarii p41, Πρὸς δὴ ταύταις ἡ μηχανικὴ καλουμένη τῆς περὶ τὰ αἰσθητὰ καὶ τὰ ἔνυλα πραγματείας μέρος ὑπάρχουσα, ὑπὸ δὲ ταύτην ἥ τε ὀργανοποιϊκὴ τῶν κατὰ πόλεμον ἐπιτηδείων ὀργάνων, οἷα δὴ καὶ Ἀρχιμήδης λέγεται κατασκευάσαι τῶν πολεμούντων τὴν Συράκουσαν ἀμυντικὰ ὄργανα, καὶ ἡ θαυματοποιϊκὴ τὰ μὲν διὰ πνῶν [using compressed air] φιλοτεχνοῦσα, ὥσπερ καὶ Κτησίβιος καὶ Ἥρων πραγματεύονται, τὰ δὲ διὰ ῥοπῶν, ὧν τῆς μὲν κινήσεως τὴν

machines in general existed in various Greek cities, like Rhodes, Tralles[12] and Alexandria and that even Pythagoras has been taught automation.

These are the principles used for the construction of the Mechanism of Antikythera. Various automata are designed and constructed based on the laws of physics at the time of Alexander and his successors. Archimedes in his effort to construct a stable huge ship develops several new mathematical methods, including analysis and integration of Archimedes used later by Newton and by all scientists since then. Greek scientists, philosophers develop Mechanics, Statics, Hydrostatics, Aerostatic, Pneumatics to name

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ἀνισορροπίαν αἰτιατέον [using weights and counter weights], τῆς δὲ στάσεως τὴν ἰσορροπίαν, ὥσπερ καὶ ὁ Τίμαιος διώρισεν, τὰ δὲ διὰ νεύρων καὶ σπάρτων ἐμψύχους ὁλκὰς [Aautomatically taking decision, an automaton] καὶ κινήσεις ἀπομιμουμένων [using strings to make automata and guide ships automatically].

[12] Agathias Scholasticus., Historiae 171,7 οὗτος γὰρ δὴ ὁ Ἀνθέμιος, πατρὶς μὲν αὐτῷ ὑπῆρχεν αἱ Τράλλεις ἡ πόλις, τέχνη δὲ τὰ τῶν μηχανοποιῶν εὑρήματα, οἳ δὴ τὴν γραμμικὴν θεωρίαν ἐπὶ τὴν ὕλην κατάγοντες μιμήματά τινα καὶ οἷον εἴδωλα τῶν ὄντων δημιουργοῦσι.

a few. It is no surprise that technology flourished in Alexandria, at the Libraries and the Museum (research centre and university) with renown inventors, scientists, and engineers like Ctesibius and Hero.[13]

[13] Athenaeus Mech., De machinis, Section 29, line 9, Κτησίβιος δὲ ὁ Ἀσκρηνὸς ὁ ἐν Ἀλεξανδρείᾳ μηχανικὸς ἐν τοῖς Ὑπομνήμασι κατεχώρισεν, ὥστε ἐπὶ τεῖχος ἄνευ κλίμακος ἀναβαίνειν διὰ μηχανήματος τοιούτου.

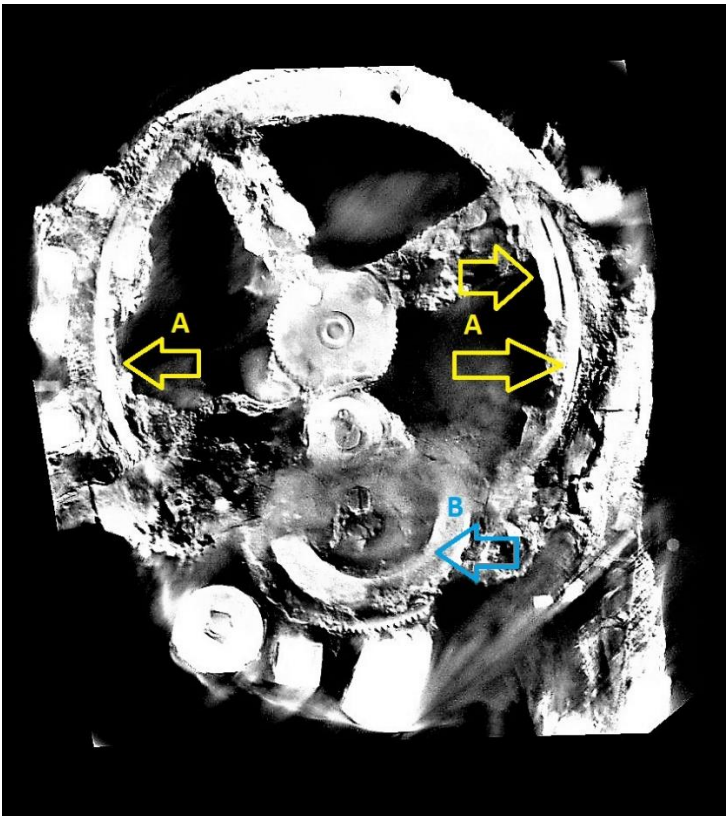

Figure 27 computed tomography of the largest part of the Antikythera Mechanism shows several gears and spacers (A, B), that keep the gears in place and prevent bending like in mechanical clocks.

The concept of this oldest known programmable computer is based on these Pythagorean principles. The laws of physics for the position of celestial bodies, the Sun, the Moon and possibly the planets are

predicted by models developed with mathematics that express the laws of physics of the motion of the Sun and the Moon, as the understand them at the time. Pythagoras teaches his students that the Cosmos can only be described properly with mathematics. Natural phenomena can be understood and predicted with the laws of physics, described with appropriate mathematics.

These are expressed in mathematics and then programmed with gears in the unary system, where every number is expressed in units that are written in teeth of every gear. We do not know who invented gears. Probably gears were in use in primitive water and wind-mills over millennia. The constructors of these mills understand the relations between number of teeth of two tangent gears used in these simple machines. Eventually a great mind like Aristotle discusses the motions of the gears and a century later Archimedes constructs complicated machines working with gears including planetaria, astronomical clocks and one that ejects 100 iron arrows automatically.

8 MACHINES

Greek like many people construct machines from very early times, probably from prehistoric era when they construct cyclopean walls and buildings. War machinery, weapons and more, were very important over millennia and have played important role in the development of machines. Shipping too has greatly contributed in technology and science. Archimedes complex machines are well known, and even more as they are based on science and exact mathematics. Archimedes studies the center of mass theoretically, introduces calculus with exact integrations of various functions including parabolas, studies theoretically stability, equilibria, buoyancy, and hydraulics and then constructs a gigantic ship gift to king Ptolemy (not the astronomer Ptolemy). Uses gears to construct a hodometer. He studies theoretically mirrors, and constructs concave mirrors used ar war, some to burn the Roman fleet others on shields of the Greek soldiers to blind the enemy. Constructs and builds a cannon, a machine gun, that works with steam and fires balls made of iron, one after

the other, to a distance of some 1200 meters. The image of a cannon of Archimedes is drawn by Leonardo da Vinci.

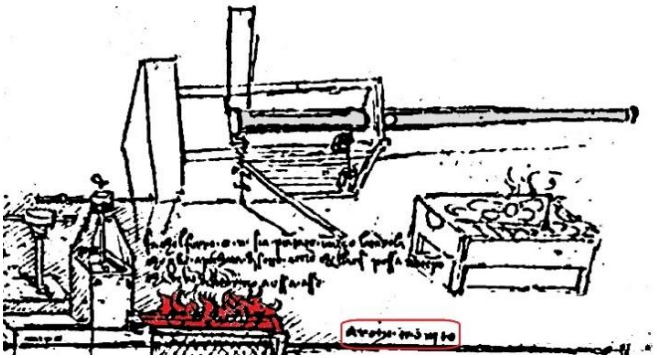

Figure 28 The canon of Archimedes that probably works with steam described by Leonardo da Vinci (15th century). Da Vinci writes "Architonnerre", i.e. Invention of Archimedes.

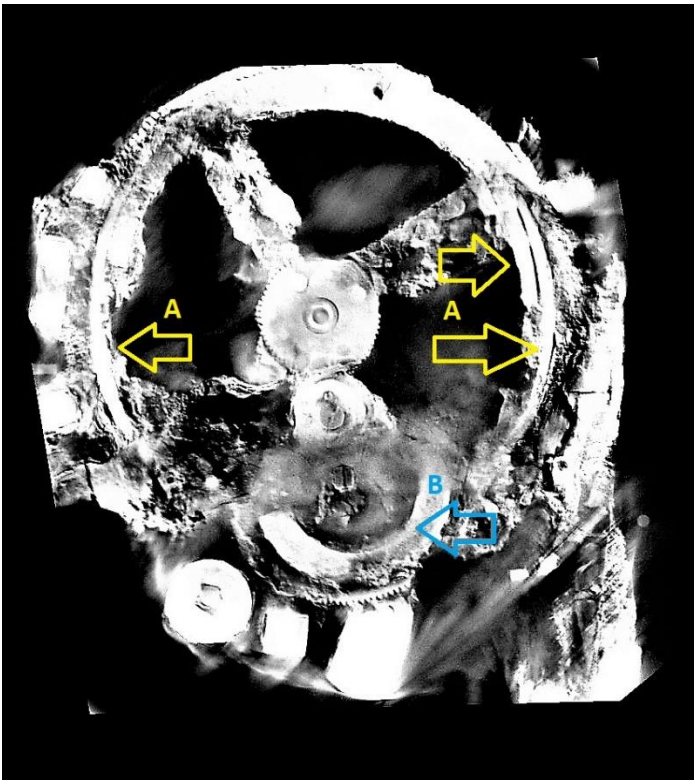

Figure 29 computed tomography of the largest part of the Antikythera Mechanism shows several gears and spacers (A, B), that keep the gears in place and prevent bending like in mechanical clocks.

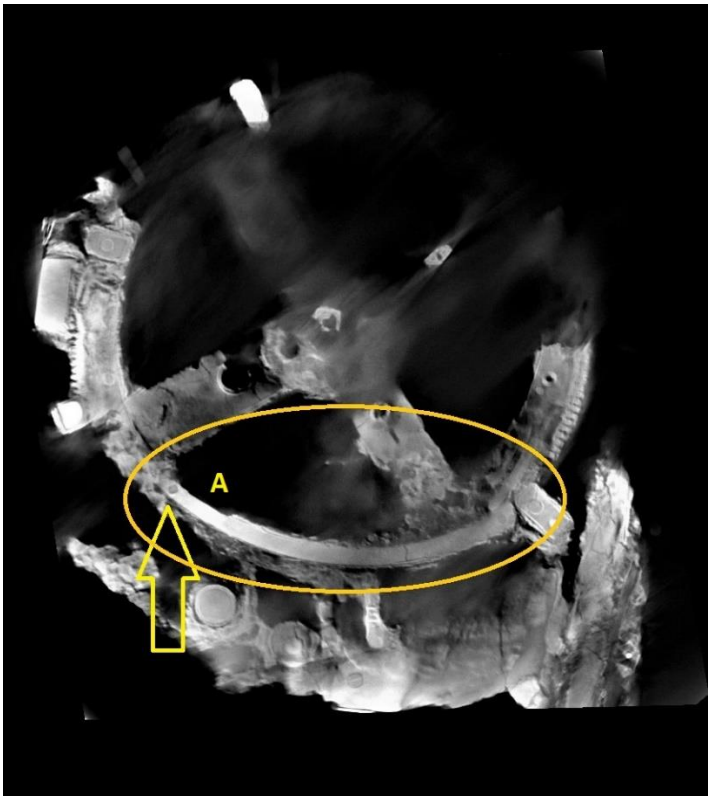

Figure 30 computed tomography of the largest part of the Antikythera Mechanism shows several more gears and spacer (A), that keep the gears in place and prevent bending.

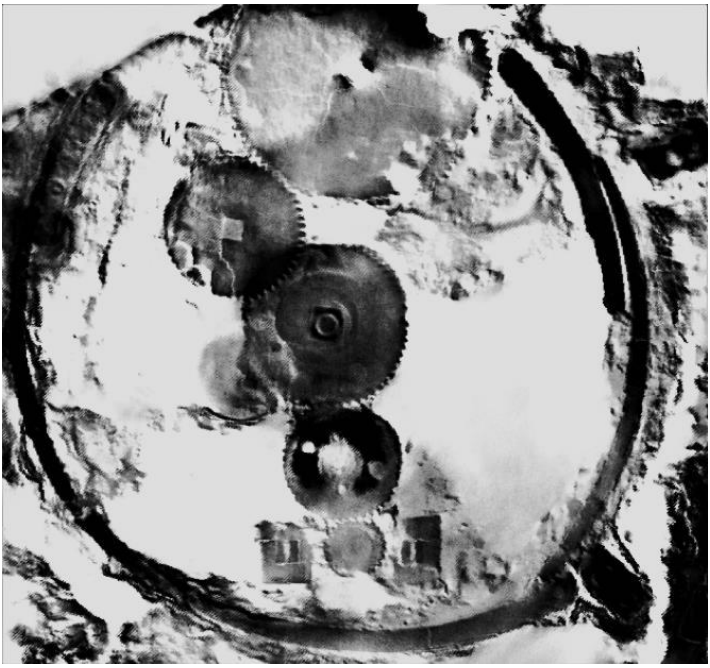

Figure 32 CT scan of the Mechanism. Gears and arc like blades can be seen, that protect the gears from breaking as they rotate and deform from the torque.

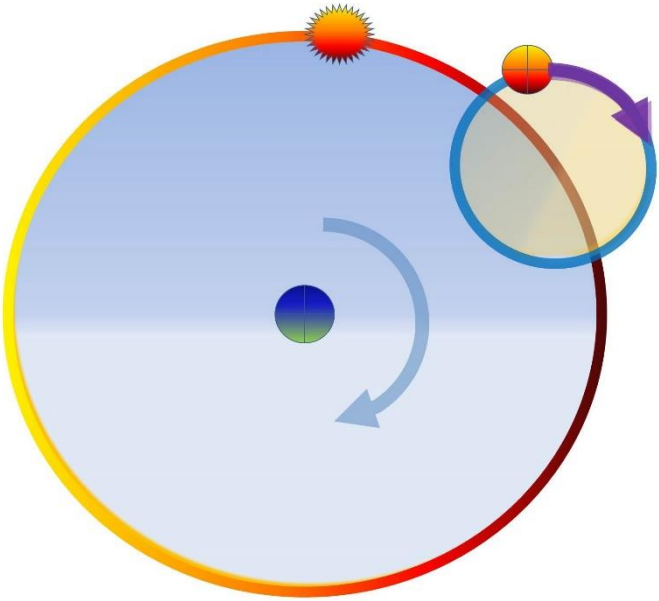

Figure 33 The principle of epicycles used for the planetary orbits by adding two circular motions.

9 PLANETARIUM

Machines related to astronomy, instruments and even complicated ones like a planetarium started developing gradually. It is not known who first used gears in this type of machines related to astronomy. Any craftsperson, any engineer familiar with gears for wind or water mills can easily think in terms of introducing gears in other fields of engineering, like war machines, clocks, or planetarium.

It is known that Archimedes constructed a couple of planetaria and an astronomical clock. The two planetaria are described quite well by several authors, like Cicero and Plutarch. Cicero writes that celestial bodies move with variable speeds and that every one of the two planetaria realistically reproduce the motions, their variable speeds, the retrograde motions and finds the positions of celestial bodies.

Is it possible that the Antikythera mechanism is a planetarium? In the manual of this instrument, this computer that is written onto two coper made pages. In the very limited

space, the planets are mentioned in both pages. In the first one where the instrument is described physically and in the second page, where the motions of the planets are mentioned which are probably the laws of physics that the constructor uses to design and program the computer, where it sets the parameters of every planet. We can suggest that it is possible that the mechanism had the planets too and that it was a planetarium.

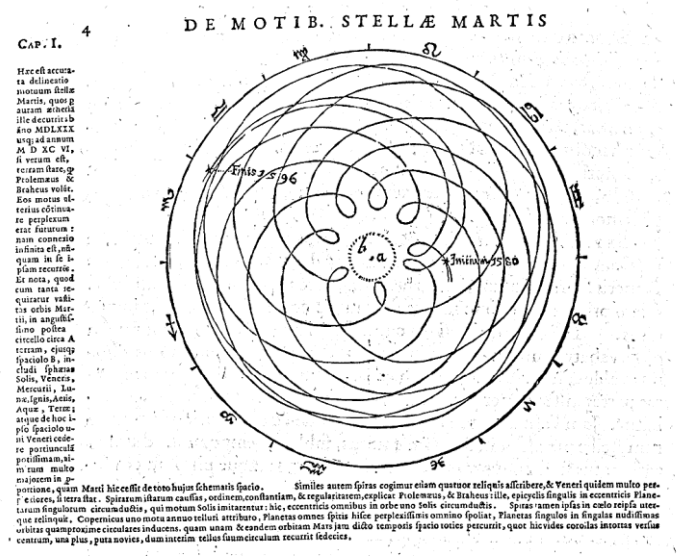

Figure 34 the orbit of Mars as seen from Earth, made by Kepler, using epicycles.

The mechanism is much more complex and advanced that any other instrument from antiquity, from any astrolabe of all times. It is

known that astrolabes, both spherical and plane are a Greek invention. The plane one designed and constructed for the first time by Hipparchus, at the same time as the mechanism was constructed. A planetarium was build and in use at Rhodes by Posidonius, where Cicero studied for a long period and describes in detail, in parallel to the planetaria of Archimedes. So it is known that the Greeks had automatic planetaria at that time. The most complex machine of that kind is very possible that it was a planetarium too. One of the gears, fragment D, has an epicyclical design and function and it is possible to associate this gear with the movement, the retrograde motion of planet Jupiter.

The designer of the Antikythera mechanism, of this mechanical Cosmos, included all the *Music of the spheres*, the harmony of the Cosmos, the resonances of the planets of the solar system in the mathematics and physics of the mechanism. Ioannis Lavrentios describes the rhythms of the planets that correspond to some specific traditional rhythms and the vowels of the Greek language and alphabet, Ioannis adds that the sounds of the planets cannot be heard

as they are very far away.[14] All the physics is written in the program of the computer that is programmed with gear. We read the laws of physics and the mathematics together with the algorithm in the gears and the manual of this ancient computer that runs a planetarium.

The models of the Cosmos have a long prehistory too. The prehistoric people that create accurate models are models of the cosmos that describe the motion of the Sun and the Moon. Prehistoric people have

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[14] Ioannis Lavrentios, On the months. Ιωάννη Λαυρέντιου, Περί Μηνών:
Πάντας τοὺς ῥυθμοὺς ἐκ τῆς τῶν πλανήτων κινήσεως εἶναι συμβαίνει·
ὁ μὲν γὰρ Κρόνος τῷ Δωρίῳ,
ὁ δὲ Ζεὺς τῷ Φρυγίῳ,
ὁ δ' Ἄρης τῷ Λυδίῳ καὶ
οἱ λοιποὶ τοῖς λοιποῖς κινοῦνται κατὰ τὸν Πυθαγόραν
πρὸς τὸν ἦχον τῶν φωνηέντων·
ὁ μὲν γὰρ Ἑρμοῦ τὸν α,
ὁ δ' Ἀφροδίτης τὸν ε,
ὁ δ' Ἥλιος τὸν η,
καὶ ὁ μὲν τοῦ Κρόνου τὸν ι,
ὁ δὲ τοῦ Ἄρεος τὸν ο,
καὶ Σελήνη τὸν υ,
ὅ γε μὴν τοῦ Διὸς ἀστὴρ τὸν ω ῥυθμὸν ἀποτελοῦσιν· ὁ δὲ ἦχος τῶν ῥυθμῶν ὡς ἡμᾶς οὐκ ἀφικνεῖται διὰ τὴν ἀπόστασιν.

knowledge of the motion of the planets too (Tsikritsis et al 2016). This millennia long tradition lead to the Greek astronomy and the astronomy of other civilizations too.

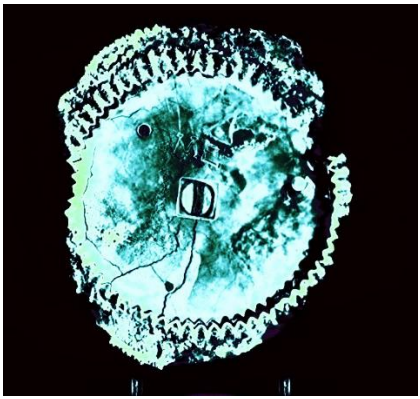


Figure 35 Fragment D is a normal gear inside a hollow gear. If the inner one moves tangentially inside the outer one a pointer attached to the inner gear performs an epicyclical motion, like the orbits of a planet. Dividing the radius of the gear by the maximum distance between the two gear one gets the distance of the planet in astronomical units, that come to be 6, close to the distance of Jupiter (5.2 astronomical units, AU, 1AU is the average distance of the Earth to the Sun).

10 PLANETARY ORBITS

The stars as seen from and observer at the Earth rotate once every night and once more in one year. Anaximander claims that the earth floats in space and moves around the center of the world. The philosophers understand that the moon, the sun and planets, are closer to the Earth than the fixed stars. Autolycus publishes two books with few hundred theorems and lemmas concerning the motion of the stars, their rising and setting at a given observer latitude. An observer of the sky looking the stars time and time again notices that there are some celestial objects that have different distinct motions with respect to the fixed stars. The call them planets, which means in Greek wanderers.

The motion of the planets, their trajectories, their variable speed, the retrograde motions, the difference of the motions of Venus and Mercury to the motions of Mars, Jupiter, and Saturn, as seen by an observer at the Earth, mesmerizes the ancient people and of course even more the ancient astronomers.

The regular harmonic motions of celestial bodies, the stars, Sun, Moon, and planets gradually permit humans to predict their motions they conceive the music of the spheres, they discover causality, they understand that there are laws of physics and develop appropriate mathematics to model the Cosmos using the Pythagorean notion that nature can only be described properly with mathematics, with the laws of physics. The Greek dances are inspired and imitate to an extend the cosmic dance of the planets.

Astronomers introduce various mathematical and physical models. The models of ancient astronomers try to reproduce the observed motions of the planets.

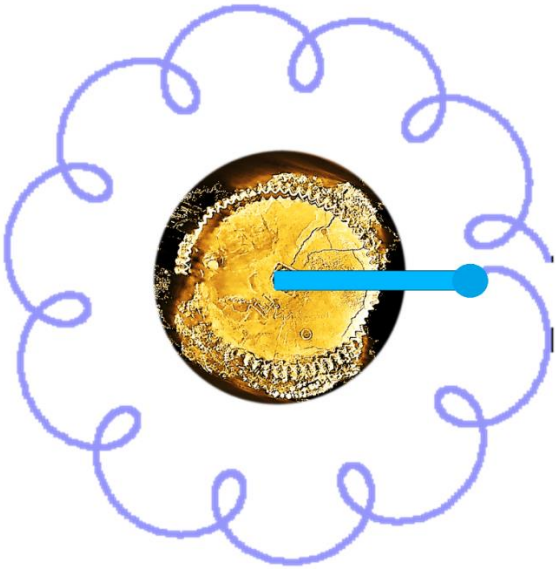


Figure 36 The epicyclical motion of Jupiter reproduced by fragment D (schematic, not to scale, the orbit is exaggerated).

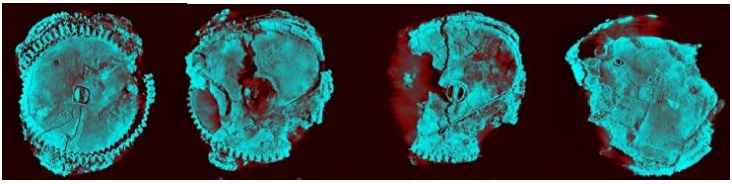


Figure 37 Structure of the epicyclical system of planet Jupiter in fragment D

Figure 38 Democritus. Etching by A. Houbraken Houbraken, 1660-1719 G.K. Nagler, Die Monogrammisten, München: G. Hirth, 1860, vol. 1, no. 676, pp. 325-326 Besonders zu erwähnen sind die Büsten des Demokrit und Heraklit, Wellcome Collection.

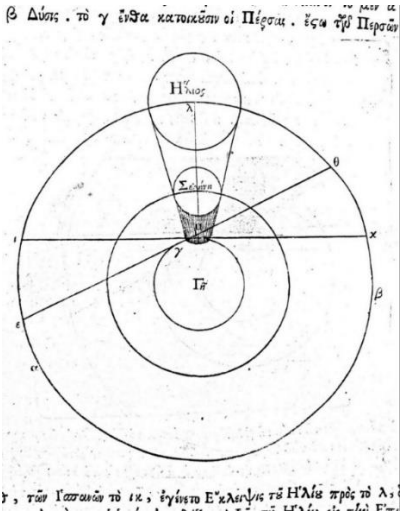


Figure 39 Philosophers understand that the Moon is like the Earth during a solar eclipse

11 HELIOCENTRIC MODELS OF PYTHAGORAS AND ARISTARCHUS

How humans conceive the Cosmos, is basic question. At first glance the sky gives you that is half a sphere because the horizon looks to be a circle. So various cultures believe the Cosmos a sphere, a rotating sphere. They have the impression that they are at the center of the Cosmos, so they accept this as reality, although it is a misconception. Some travelers understand that as one goes far from the equator the inclination of the Sun thinkers understand that the earth is not flat, but a sphere and this explains the change in the inclination of sunrays.

It is believed that Thales (27 centuries ago) understood first that the Earth s a planet. Pythagoras divides the Earth in the five climatic zones.[15] It is certain that Pythagoras

[15] The so called Pseudo Plutarch writes in Placita philosophorum on the division of the Earth that the Pythagoreans divide the spherical Earth in climatic zones. Περὶ διαιρέσεως γῆς, πόσαι εἰσὶ ζῶναι αὐτῆς Πυθαγόρας τὴν γῆν ἀναλόγως τῇ τοῦ παντὸς οὐρανοῦ σφαίρᾳ διῃρῆσθαι εἰς πέντε

understands that the Earth is a planet, and he is the one that divides the Earth in the five zones, arctic, temperate, tropic, southern temperate. The Pythagoreans even discuss the possibility of planets around other stars, as the consider the Sun as a star. PseudoPlutarch says that the division of the arth is similar to th division of the sky.[16]

These are based on various ancient Greek, Byzantine, and mainly Arabic texts. It is said that the Pharos, the Lighthouse used the sun as a source of light during the day and fire at night as a means of casting its light into the sea.

ζώνας, ἀρκτικὴν θερινὴν χειμερινὴν ἀνταρκτικὴν ἰσημερινήν, ὧν ἡ μέ-ση τὸμέ σον τῆς γῆς ὁρίζει, παρ' αὐτὸ τοῦτο διακεκαυμένη καλουμένη· ἡ δ' οἰκητή ἐστιν ἡ μέση τῆς θερινῆς καὶ χειμερινῆς, εὔκρατός τις οὖσα

[16] Θαλῆς Πυθαγόρας οἱ ἀπ' αὐτοῦ μεμερίσθαι τὴν τοῦ παντὸς οὐρανοῦ σφαῖραν εἰς κύκλους πέντε, οὕστινας προσαγορεύουσι ζώνας· καλεῖται δ' αὐτῶν ὁ μὲν ἀρκτικός τε καὶ ἀειφανής, ὁ δὲ θερινὸς τροπικός, ὁ δ' ἰσημερινός, ὁ δὲ χειμερινὸς τροπικός, ὁ δ' ἀνταρκτικός τε καὶ ἀφανής· λοξὸς δὲ τοῖς τρισὶ μέσοις ὁ καλούμενος ζῳδιακὸς ὑποβέβληται, παρεπιψαύων τῶν μέσων τριῶν· πάντας δ' αὐτοὺς ὁ μεσημβρινὸς πρὸς ὀρθὰς ἀπὸ τῶν ἄρκτων ἐπὶτὸ ἀντίξουν τέμνει

The Pythagorean doctrines for nature are applied to the orbits of the planets. These Pythagorean principles have been in use by the Greek philosophers that we know as physicists (examining nature). Pythagoreans accept an almost heliocentric view, where the central fire is the center of the Cosmos, where Zeus throne, Jupiter's castle is, Theano (6th century BCE), the wife of Pythagoras wrote a book on the structure of the Cosmos. She has ten nested co-centric spheres around the focus, the central fire, the Earth, and the Anti-Earth (Antichthon), the Moon, the Sun, Mercury, Venus, Mars, Jupiter, Saturn, and the fixed stars. The distances of the spheres are related to the musical scale, the Pythagorean scale of music.

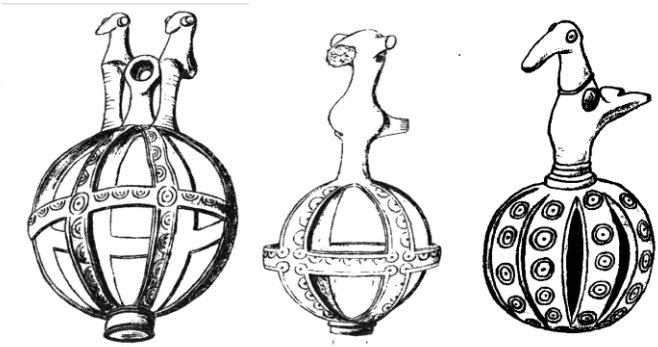


Figure 40 Ancient celestial sphere, 28-29 centuries before present from Thessaly. They probably represent the sky with the stars. They have an equator, an axis, and several

meridians with stars. Archaeological Museum of Volos, Greece. According to Greek tradition they were in use by Centaurus Chiron Musaeus, Jason and the Argonauts to travel around the Mediterranean and especially the Black Sea.

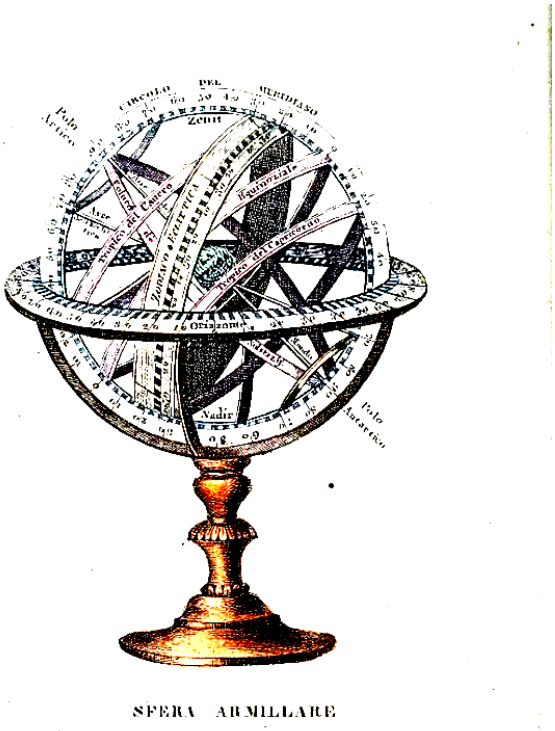


Figure 41 gure: An armillary sphere. Colored engraving, early 19th century, Wellcome Collection, ref. 4a6643i

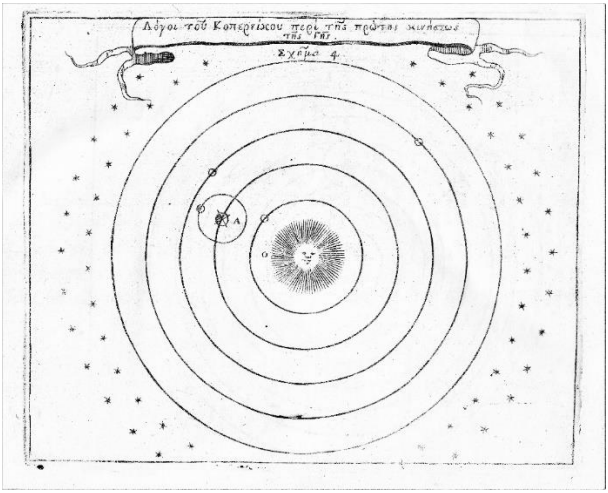


Figure 42 Heliocentric Cosmos after Copernicus, from a Greek book by Chrysanthos Notaras, c. 1700.

Figure 43 Ancient observers, "astronomers?" of rising sun at peaks. Archaeological Museum of Chania, Greece.

Figure 44 Ancient "astronomer" probably observing the rising Sun from the Daskaleio cave, island of Kalymnos, Greece.

The Pythagorean Cosmos, the planetary model with the ten spheres centered around the central fire, is known by the teachings of philosopher Philolaus (~470 to ~385 BCE), disciple of Pythagoras. The center of the Cosmos is fixed in space Philolaus says. In this Philolaus according to some authors is based on the very initial teaching of Pythagoras, greatly influenced by his wife Theano that was his inspiring Muse.

These philosophers knew the mathematical notion of the center of gravity and the fact that the Sun is the largest and hence more massive body of the solar system. So as Aristarchus (310 – 230 BCE). The bodies of the solar system circle the center of the world. The Earth too goes in an oblique circle around the central fire, the focus, Philolaus writes. In similar circular trajectories the planets and the Sun orbit the central focus according to Pythagoreans. Pythagoras and the Pythagoreans develop the musical notes following the resonances of the planets, the ratios of the periods of the planets, as Philolaus teaches according to Pythagorean Philosopher mathematician and theorist of music Nicomachus of Gerasa.

Heraclides the Pontic (387 BC 312 BC), and possibly others, had formulated eccentric models of the movement of the planets that were rejected, rather uncritically, because the Earth was supposed to be the center of the Universe.

Heraclides as well as Ekphantos knew that the Earth rotates on its axis in one day and that the fixed stars are seemingly stationary in the sky as they are very far from the Earth, as Leucippus and Democritus first realized when discussing gravity.

Figure 45 Pythagoras writing one of his theorems and Theano with the harmony and the music of the spheres in her tablet, The School of Athens (detail), Fresco by Leonardo, Stanza della Segnatura, Palazzi Pontifici, Vatican, 1509

Heraclides may have attempted a model that the Earth moves. Another version says that Heraclides realizes that the Earth rotates on its axis. Heraclides' model, the geometric view of the solar system, that is, that the inner planets Mercury and Venus revolve around the Sun, certainly influenced Eudoxus and vice versa, since both were students of Plato and certainly discussed these issues daily. Heraclides believed that Mercury and Venus move around the Sun because these two

planets never move more than a given angle from the Sun and for certain days each and then return to the Sun, as described in his user manual mechanism of Antikythera. So Heraclides correctly concludes that each of these two planets revolves around the Sun.

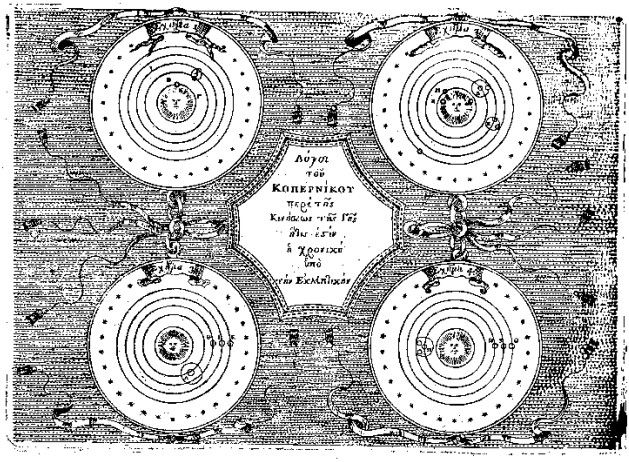


Figure 46 Four images showing why the heliocentric system is the best representation of the solar system. From a Greek book by Chryssanthos Notaras, c. 1700.

Of course, everyone in the school of Athens, in the various schools of Athens, knows the essentially heliocentric system of Pythagoras described by Philolaus, which is reintroduced as purely heliocentric by Aristarchus and which Copernicus finally reintroduces to be established little by little with the telescopic observations of satellites of Jupiter which

revolve around the planet and not around the sun and to fully understand how and why the planets in the solar system revolve with Kepler's laws which are triumphantly interpreted with the laws of universal attraction and repulsion Newton. Heraclides' model was not accepted, perhaps because it did not respect the axiom of the stationary Earth, and that the Earth is the center of the universe. It should be mentioned that Heraclides, as the great Poseidonius tells us, knew the movements of the tides, their nature and even their cause their extend and the role of the lunar gravity, which is a surprise, but of course three centuries before them Leucippus and Democritus imply the existence of universal gravity in their understanding of the Cosmos. So universal gravity was known to Posidonius and other used it in their understanding of the Cosmos.

It is incredible that heliocentric rational models which were much simpler than the geocentric one was rejected by such giants as Plato and Aristotle. The difficulty these philosophers to accept heliocentric models was probably theological and political, rather than rational and for the same reasons Aristarchus had to leave Athens to Alexandria when he reintroduced the Heliocentric model of Pythagoreans. These

models do not reproduce retrograde motions.

12 THE CONCENTRIC SPHERE MODEL OF THE SOLAR SYSTEM

The heliocentric model is very natural, simple, easy to understand. It presents the solar system very well for an observer outside the solar system. Scientists and teachers especially want to present the solar system, the planets, the Sun, and the Moon, for an observer at the Earth. For the representation of the solar system to an observer at the Earth one needs a Geocentric system. Today in our computers when we present the sky tonight at 10 pm we use a Geocentric system and even more one must take into account its position, Beijing, Sandong, Athens, or Rome etc.

Astronomers and philosophers in general want to create a realistic model that gives the retrograde motions of planets, an effect that is caused by the motion of the Earth around the Sun at the same time that the other planets rotate too, every planet with its speed, which is different for every planet. A realistic model has to take into account and reproduce properly the orbit of every planet that its plane makes an angle with the plane of the Earth's orbit, the ecliptic. Every planet has its orbt around the Sun in a different

period, in a different plane. The different planes of orbit make the planet to go up and down during its orbit with its period around the Sun. Another periodic motion is the periodic motion of the Earth around the Sun in one year.

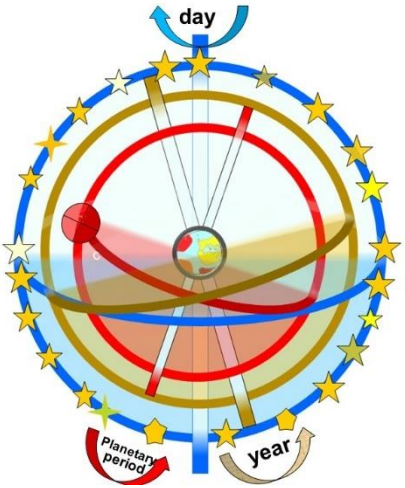


Figure 47 Eudoxus concentric sphere model for the Sun or the Moon. For Mercury or Venus we add one more sphere. For Mars, Jupiter and Saturn we add two more spheres

Eudoxus of Cnidus (408 BC - 355 BCE) was an important mathematician and astronomer that created a catalog and a map of the sky with coordinates, student, and friend of Plato and Archytas that even contributed to the famous book of *Elements* by Euclid. Eudoxus knows very well the retrograde motions which were known to humans from

prehistoric times. Eudoxus wrote books the motion of planets, on eclipses, on mirrors, on Oktaeteris the 8-year lunisolar-Venus calendar used in the Antikythera Mechanism, and a more general book of astronomy, called celestial phenomena. Eudoxus travelled all around the World, including Asia as described by the great geographer Strabo.

Eudoxus introduces a mathematical system of nested spheres one inside the other, rotating about axes that are perpendicular to the orbit of planet Earth and the plane of the orbit of the planet and the axis of the Earth, with periods of one year, the period of the planet and the 24 hour period. The concentric spheres consider the inclination of the orbit of every planet to the orbit of the Earth.

This model of homocentric spheres is excellent to determine the position of the planet in the sky. It fails to predict the changes of the planet luminosity, cause by the change of the distance to the Earth as both the Earth and every planet rbit the Sun with different periods.

Around the earth they use several concentric spheres for every planet. The planet is in the

inner sphere. The outer sphere rotates once every day and the planet rises and sets. Another sphere rotates once every year and represents the phenomenal motion of the planet due to Earth's yearly orbit.

Eudoxus knows all aspects of the motion of the planets as seen at the Earth. Eudoxus first realizes, probably in collaboration with his teachers nd friends, certainly based on their endless discussions, that he can reproduce a realistic model of the planetary orbits, a model of the Cosmos, that can reproduce the movements of each planet, the Sun and the Moon, using concentric spheres that are nested one inside the other, concentric, to model with simple and easily calculable mathematics the movements of any individual planet by adding the rotations of the planet with its period, the inclination of the particular planetary orbit with respect to the Earth's orbit, the period of the Sun around the Earth (Earth's around the Sun).

The Greek philosophers gradually develop mathematical models to reproduce and explain the observed phenomena. The philosophers develop the epicycle model for the planets. introduce the addition of two circular motions. This is the Superposition Principle in mechanics and physics in

general. The Greeks wanted to calculate the position of planets in the sky. Every planet has a very complicated motion on the sky because the Earth is a planet, as probably Pythagoras is the first to understand that our planet is a sphere and the first to divide this sphere in the five zones and Pythagoreans model all the planets, including the Sun and the Earth, going around the central fire. I mention this to understand the scientific milieu of the time. Humans observe the sky as the Earth moves around the Sun.

The Earth and every planet has a different period, a different distance from the Sun of the central fire, the center of mass perhaps, and its own plane of orbit So every planet's position from night to night and month to month depends upon the position of the Earth around the Sun and the position of the planet around the Sun. To this one must add the daily rotation of the Earth around its inclined with respect to the ecliptic, the plane of Earth's orbit around the Sun. It sounds complicated and it really is.

Two spheres with opposite motions and give the retrograde motion of the planet. This is repeated for every planet.

The Eudoxus model is the world's first complex mathematical and physical model of the universe and indeed very successful and effective. Eudoxus uses 3 spheres for the Sun and Moon and 4 spheres for each planet. Callippus alters the model of Eudoxus by adding two more spheres for Sun and Moon, one more sphere for Mercury Venus and Mars achieves a better prediction of their position. Callippus' spheres reproduce the movements of the planets more accurately and better than Eudoxus's.

Callippus, known to us by his 76 year lunisolar cycle that is in the Antikythera Mechanism, adds several more spheres and Aristotle even more to make it mechanically construct-able. This system of concentric spheres is a precursor of spherical harmonics (that come from Laplace equation) that are used in quantum chemistry, nuclear physics, geophysics, and many other applications that need spherical representation.

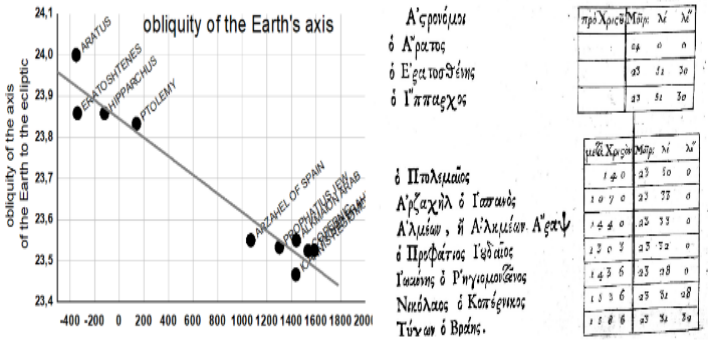


Figure 48 The obliquity, the inclination of the Earth's axis with respect to the plane of its orbit around the sun varies with time.

Based on this advanced model of the Cosmos and the astronomical knowledge Callippus improves it. He introduces to the model of the solar system several more spheres for every planet (see table). Aristotle adopts this model and makes it more mechanical, to transform it from a mathematical modeling to real construction with material spheres for the layperson to understand adding more spheres. Aristotle adds four spheres to the sun, and the moon, Venus, and Mercury, three to Jupiter and Mars. It is not known if they had in mind the possible application of a real material mechanical Cosmos or a model. Probably they all use these models as theoretical reconstructions that can be transformed to a planetarium. It is certain that the celestial

sphere of Plato and the Pythagorean Cosmos had dominant influence both on their conception of the Cosmos and its modles, mathematical and/or mechanical.

Table of universe models with concentric spheres

Object, spheres of Eudoxus (first number0, Callippus (second) and Aristotle (third column)

Sun 3 5 9

Moon 3 5 9

Mercury 4 5 9

Venus 4 5 9

Mars 4 5 8

Jupiter 4 4 7

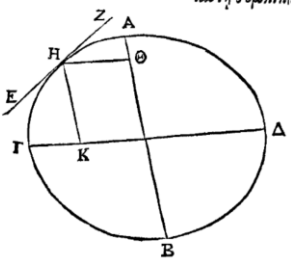
Saturn 4 4 4

fixed stars 1 1 1

Total for all planets, the Sun, and the Moon 27, 34. 55

SIT ellipſis, cujus diametri A B, Γ Δ; & ipſi occurrat recta E Z inter duas diametros in puncto H; & producta in utramque partem extra ſectionem cadat: dico E Z cum utraque diametro A B, Γ Δ convenire.

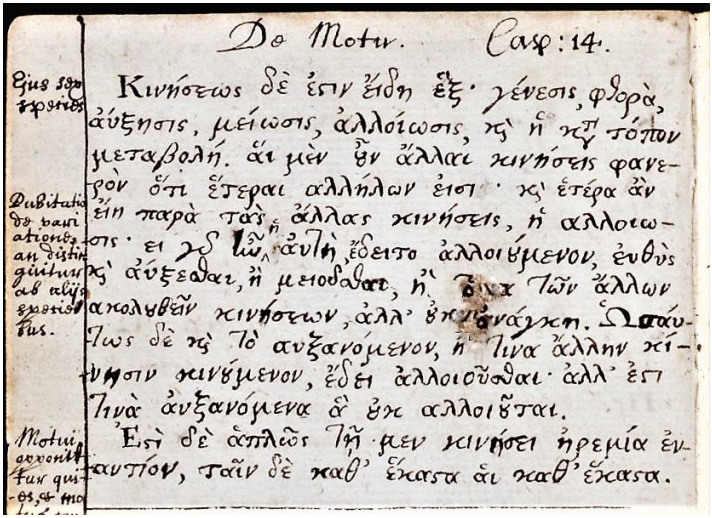
Applicentur enim à puncto H ordinatim ad diametros A B, Γ Δ rectæ H Θ, H K. itaque quoniam H K eſt parallela ipſi A B, convenit autem quædam E Z cum H K; cum ipſa quoque A B conveniet. eodem modo & E Z cum diametro Γ Δ convenire demonſtrabitur.



ΕΣΤΩ ἔλλειψις, ἧς διάμετροι αἱ Α Β, Γ Δ, καὶ τεταγμένως ἐπὶ τὴν συμπίπτέτω τις εὐθεῖα μεταξὺ τῶν δύο διαμέτρων ἡ Ε Ζ καὶ τὰ Η, καὶ ἐκβαλλομένη ἐφ' ἑκάτερα ἐκτὸς πιπτέτω τῆς τομῆς· λέγω ὅτι ἡ Ε Ζ συμπεσεῖται ἑκατέρα τῶν Α Β, Γ Δ.

Κατήχθωσαν γὰρ ἀπὸ τῶν Α Β, Γ Δ τεταγμένως αἱ Η Θ, Η Κ. ἐπεὶ οὖν παραλλήλος ἐστὶν ἡ Η Κ τῇ Α Β, συμπίπτουσα δέ τις τῇ Η Κ ἡ Ε Ζ· καὶ τῇ Α Β ἄρα συμπεσεῖται. ὁμοίως δὴ καὶ τῇ Γ Δ συμπεσεῖται Ε Ζ.

Figure 49 The conic sections and ellipse in particular have used by Kepler and Newton to establish modern physics. An ellipse invented by Apollonius Pergaeus (Appolonii conicorum Pappus, Eutocius).


Do Motu. Cap: 14.

Κινήσεως δὲ ἐστιν εἴδη ἓξ· γένεσις, φθορὰ, αὔξησις, μείωσις, ἀλλοίωσις, καὶ ἡ κατὰ τόπον μεταβολή. ἄτι μὲν οὖν ἄλλαι κινήσεις φανερὸν ὅτι ἕτεραι ἀλλήλων εἰσι· καὶ ἑτέρα ἂν εἴη παρὰ τὰς ἄλλας κινήσεις, ἡ ἀλλοίωσις· εἰ γὰρ ὧν, ἀνάγκη, ἔδειτο ἀλλοιούμενον, εὐθὺς καὶ αὔξεσθαι, ἢ μειοῦσθαι, ἢ ἐκ τῶν ἄλλων ἀκολουθεῖν κινήσεων, ἀλλ' οὐκ ἀνάγκη. Ὁ δὲ αὐξανόμενος καὶ τὸ αὐξανόμενον, ἢ τινα ἄλλην κίνησιν κινούμενον, ἔδει ἀλλοιοῦσθαι· ἀλλ' ἔστι τινὰ αὐξανόμενα ἃ οὐκ ἀλλοιοῦται.

Εἰ δὲ ἁπλῶς τῇ μὲν κινήσει ἡρεμία ἐναντίον, ταῖν δὲ καθ' ἕκαστα αἱ καθ' ἕκαστα.

Figure 50 Newton's notebook in Greek, leanig on the motion based on Aristotle (Physics, Categoriae (0086: 006)

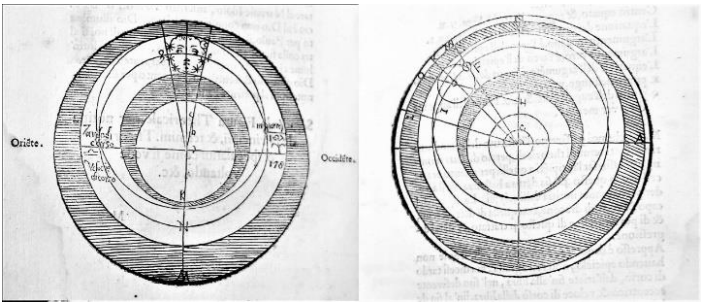


Figure 51 Epicyclical models of two planets from Ioannes Sacrobosco book. Sphaera Joannis de Sacrobosco, : typis auctior quam antehac. praemissa Philippi Melanchtonis, praefatione, c.1550

13 THE REALISTIC EPICYCLICAL MODEL OF PLANETARY ORBITS

The concentric sphere models fail to reproduce the changes of the luminosity of a planet as they do not determine a variable distance of the planets that will result to a change of their brightness.

Epicyclic theory is an excellent advancement of science based on all Pythagorean principles, doctrines, including simplicity and generalization of laws of physics.

The Greek astronomers develop a model with superposition of two circular motions, one on top of the other. Apollonius, who is the inventor of conic sections, ellipse, parabola, and hyperbola is the inventor of this epicyclical method. The Greeks prefer cyclical instead of elliptical orbits because circles are defined easily very accurately (with the center and the radius) and can be translated into gears that work without braking easily.

Proclus (5th century), the last philosopher in Athens that ha a university that one can step in it remains today below Acropolis and can see some of its remains in the nearby museum of Acropolis, explains that the epicycles or eccentric cycles is the preferable model for planetary orbits by the Pythagoreans of his time.

Pythagoreans prefer it because it is simple, it has the less possible necessary hypotheses, and gives the correct position of the planets with a variable ecliptic that was one of the assets of the concentric sphere models. For almost two millennia the Greeks, the Romans, the Byzantines, and then the Arabs with the Abbasids that take Greek scientists and translate the Greek astronomy and mathematics and optics for the benefit of science spreading it to the world. This is then transmitted to Europe. Naturally it was transmitted to Asia at the time of Alexander and the Hellenistic period. This continues in the Roman period and the Byzantine. Epicycles is the oldest form of Fourier series,[17] which is an excellent mathematical method used today for the analysis of various data. In

[17] Fourier, Jean-Baptiste-Joseph. 1822, Théorie analytique de la chaleur.

Islam and Byzantium the epicycles increase up to 7 for every celestial body.

The planets, that their motion are exhaustively described in the very fragmented manual of the mechanism. There are even small but very clear and sufficient details of the motion of all the planets, Mercury, Venus, Mars, Jupiter, and Saturn. I belong to those that believe that the motion of planets was reproduced in the Antikythera Mechanism with appropriate displays and pointers, and I have even publish this in my books and presented it since my very first public talk in 2006.

14THE MANUAL OF THE COMPUTER

The mechanism, as all scientific instruments has an instruction manual, with instructions on how to use it, how to open it, set it up. It mainly is a compendium of astronomy. It is a densely written astronomical booklet with letters around 2 millimeters. It shows what you expect to see in this mechanical World, how to use it constructively. The texts of the manual are written on all available plane surfaces on copper sheets, which are the two covers of this double-sided astronomical clock.

Most importantly it contains the laws of physics, as understood at the time, which they use to predict the position of the Sun and the Moon. eclipses, solar and lunar, and the phases of the moon, and posibly the movements of all five known planets. From the computer manual it becomes clear, for the first time, that the Greeks knew very long periods of the planets, of the order of 500 years, periodicities that are related to resonances of the planets, the Sun, the Earth, and the Moon. It is evident that they knew very wel that the solar system is a cosmical clockwork. A big surprise is that the Mechanism's user manual details the motion of all the planets, including some extremely long planetary periods of the order of five centuries: 462 years for Venus and 442 years for Saturn. The period of 462 years is the time that Venus orbits the Sun 289 times (synodic periods), as seen from Earth. This time period of 462 years does not exist elsewhere in the world's astronomical literature, Greek or other peoples, such as the Babylonians, who are the only ones that refer to any long period of time. The emphasis is on the forward motion, but also the retrograde (backward) motion of all the planets with much detail fortunately apparent in the fragmented and damaged text.

Figure 52 A part of the manual with the laws of physics to predict the phases of the Moon and the eclipses. It is made using the PTM method of Dr. T. Malzbender (HP) using 40 photographs taken with 40 different lamps at given points, created by the author.

The Greeks, led by Pythagoras and the Pythagoreans, had realized the harmony of the movements of the planets and the musical notes were mathematicalized based on the movements, the coordinations, of the planets. It is no surprise that the Greeks and other peoples had connected the planets. Pythagoras and his followers associate the periodicities and resonances of the planets with the musical scale, the musical notes, and the dances they danced. This includes not only the mechanism doors that protect

the instrument during transport, but also the circular and spiral scale plates.

Although only a few fragments of the copper sheets on which the manual is written have been lost, perhaps still lying at the bottom of the sea, where I'm sure archaeologists working there will eventually find them, there is plenty of useful material that enabled us to read many characters and to know a large part of the text by re-composing all the broken pieces. We also read many inscriptions that are hidden, but also well protected in the rust. In the remains of the mechanism, about 20% of the front door of the mechanism has been saved, which includes about 90 degrees of the zodiac and three months of the annual cycle and a very important part of the so-called parapegma.

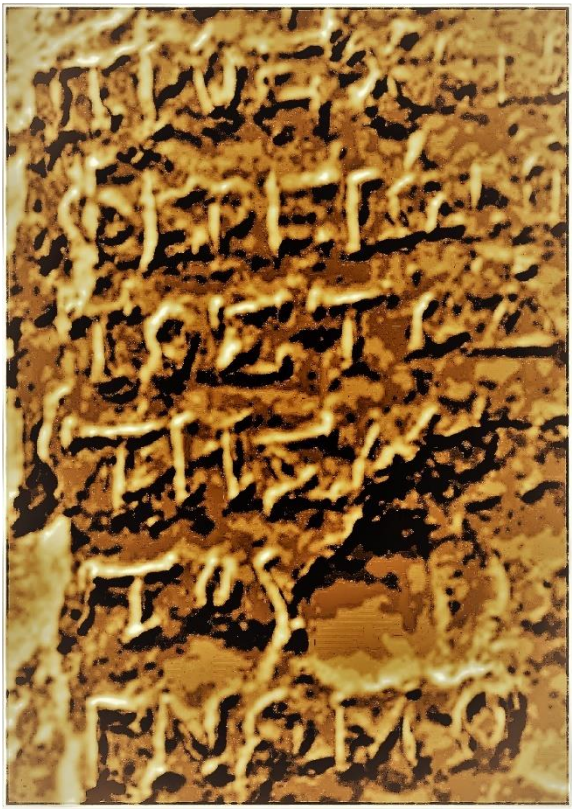


Figure 53 a small part of the manual written on copper plates, PTM method.

Of the inscriptions that have survived, we have about 25% of the back of the Mechanism and roughly 1/3 of the inscriptions of the Metonic cycle, which was

enough to figure out almost everything about it.

All the Epirotic months of this 19-year cycle of Meton were read. The calendar of the mechanism that is based on the metonic 19 year cycle which regulates the life in Greece, including the festivities which are related with the phases of the Moon. At that era the Greeks had movable holidays that continued with other names in the Christian era, albeit with other names. Today the 19-year cycle of Meton is used to calculate the date of Easter.

We also read almost the entire four-year or more correctly the 8-year calendar of the Olympics and other important Greek games. We read 1/3 of its scale of Saros, the eclipse calendar of 18 years, 11 days, and 8 hours, 2/3 of the auxiliary scale with the number of hours to be added to the indication of the helical (spiral) scale of eclipses, but unfortunately the sign for zero is missing. It is known that the symbol for zero probably was a small "o", the initial of the word none. The other two indications of the auxiliary hour scale read 8 (Θ) or 16 (IC) hours.

There is a section of the back door that was saved in bits and pieces, and which contains

a part of the astronomical handbook with the movements of the planets in incredible detail. These contain the laws of physics concerning the motion of the planets. Based on these inscriptions and a planetary gear of Jupiter we estimate that the Mechanism apparently gave the positions and movements of the five planets known in antiquity.

15THE PARAPEGMA

Papapegma is a table that contains some 26 lines with instructions on how to know the date of the year by observing which star rises or sets together with the setting or rising Sun. A series of 36 sunrises and sunsets of a bright star every ten days or ten degrees in the sky gives the possibility to correct, the calendar. Each line of the graph tells us that such-and-such star rises or sets on that date along with the rising or setting of the Sun. These sunrises or sunsets correctly mark the date during the year and allow an accurate calendar to be kept, to know when the equinoxes are, solstices, the beginning of the year, and especially when is the sowing period. With the calendar they regulate rural, social, and political life.

16 THE MECHANISM AS AN ASTRONOMICAL CLOCK

The astronomical clock that Archimedes constructed is an advanced quite complicated astronomical clock with automations and very impressive robotic actions.
It is posible that this machine had a continuous motion, as Proclus says that this type of machines showed the motion of the Sun continuously, so the show the time, hence probably they were clocks, astronomical clocks. The motion is given by weights made of lead, and counterweights and floats made of corks regulated by water as Hero for example describes in his book of automata. Similar movement mechanisms are described in detail in the astronomical clock of Archimedes. It is no surprise that Price (1955) names it a clock before the clock in a talk given at a meeting of the British Horological Institute and the Antiquarian Horological Society.
An automatic astronomical clock designed and constructed by Archimedes (23 centuries ago) is also described, while many automations concerning the construction of

similar machines is given in the books of Hero (who lived 21 to 19 centuries ago). Proclus says that there were several of these machines, the most expensive made of gold, other of coper (bronze) and the less expensive made by wood. I have discovered three broken calendric machines in Iceland made around 1780.
So this instrument that we call Antkythera Mechanism and the Greeks for a long period of time called tablet (ΠΙΝΑΞ, PINAX and ΠΙΝΑΚΙΔΙΟΝ PINAKIDION) and according to Proclus a *Pinakidion* is an astronomical clock, a planetarium as many similar instruments described by Greek, Latin and Arabic texts, many of which are in the National (French) Library.
The mechanism shows that humans conceived, designed, and built a mechanical computer, a clockwork mechanical automatic Cosmos, a planetarium based on exact science, Greek philosophy, Pythagorean philosophy. The concept of an automatic computer, the design and the creation of this computer was a giant leap for science, humanity, and civilization.
The designer has to take into account the strength of material, bronze, the size of the selected teeth size, the torque necessary to drive the mechanism, especially if it is an

astronomical clock with continuous motion to be a clock and a planetarium, as I suggest, an anaphoric clock. There are remains of a few clepsydrae, automatic water clocks of various periods of antiquity in Athens. The most famous is the one just below the Acropolis of Athens at the north-western cliff, where the famous spring too. Remains of another water clock are in the Agora of Athens. This one is a container of water with a faucet that with another system of constant pressure (constant height) provides the same amount of water at equal times, let say 20 liters every hour.
The level of water increases constantly. A float made of cock, as mathematician, physicist and engineer Hero describes in his book of automata. The float is tied to weight (made of lead, Hero says) and a string or a chain like to one of a bicycle. The chain goes around a gear or the string is rolled around a winch that drives, turns an axis on which the pointer of the hour is fixed.

Figure 54 Important astronomer Hipparchus of Rhodes. He created many astronomical instruments, inventor of trigonometry. He created the first plane astrolabe by projecting correctly the sphere on a plane. He catalogued the stars with magnitude and tabulated their celestial coordinates, equivalent to longitude and latitude, and their magnitudes, their luminosities.

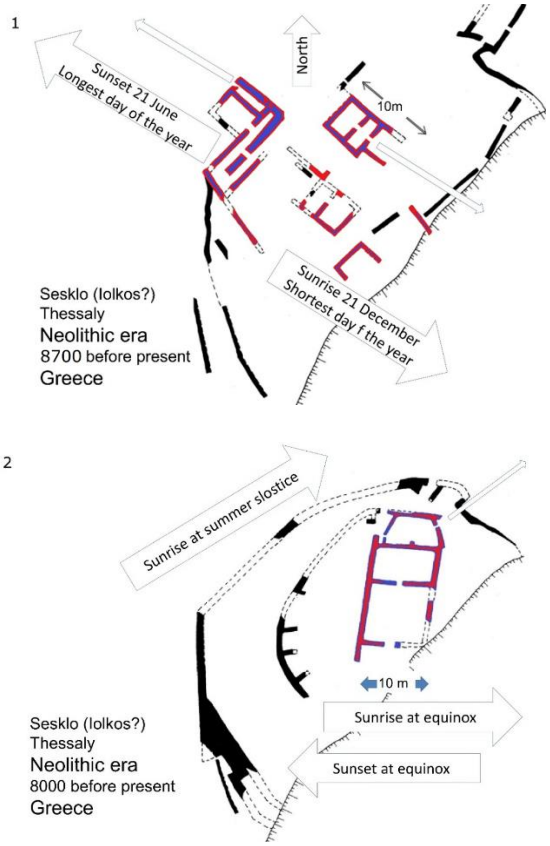


Figure 55 Sesklo, Iolkos (?). Orientation of the oldest rectangular prehistoric buildings towards sunrise and sunset at solstices (1. first phase before 8500 BP and towards solstice at equinox (2. second phase around 8000 ago), Thessaly, Greece.

17 HUMANS AND ASTRONOMY

Why humans have astronomy? Is there anything special with astronomy? What is the relationship of man with astronomy? Is there an impulse that drives man to develop astronomy or a need for survival in a difficult world? The answer is given by Plato 25 centuries ago "humans develop astronomy because they need it (to predict the weather) for agriculture mainly; additionally, astronomy helps humans to travel in land and sea".

The birth of astronomy in Greece starts at neolithic prehistoric times, more than 8000 years ago in Thessaly, as we read in the orientation of buildings towards solstices or equinoxes and in the Cyclades and all around the archipelago of the Aegean, as we "read" interpreting the repeated motifs that are in prehistoric teracottae. These archaoastronomical finds suggest that astronomy is used for practical reasons and for spiritual satisfaction by satisfying the curiosity of humans. It is worth noting that 9000 bp there is extensive agriculture (wheat, barley), fermentation of grapes to wine and domesticated animals (goats, pigs) in Greece.

Sesklo and many more prehistoric small towns built with rectangular buildings 8000 to 8500 years ago (Tsountas, 1908, R. Theocharis 1973, Liritzis, 1981, Liritzis and Galloway, 1982, Liritzis and Dixon, 1984) show that they are all oriented towards cardinal points or the sunrise at solstices. This shows that they probably have calendars based on the Sun, possibly the moon too. We can conclude that the Greeks have a solar year from prehistoric times, as the orientation of 8000-year-old buildings proves and the certainly had at the time of the Trojan War and Homeric texts as the Helios charioteer implies too (Papathanassiou, 2008). Hence the calendars are based on the periodicities of the Sun and the phases of the Moon.

Interpreting a phrase of the great philosopher Plato I believe that he says that Astronomy made us human, civilized, we became humans, because as we look at the sky we admired the stars, the Sun, the moon and in our effort to understand what these luminous objects are, why they move as they do, we developed science, reason, and civilization, we became humans. In the article this view is examined how sound this interpretation of Plato is, and how correct the

great philosopher's statements about astronomy are. This way we will better understand how humans were able to understand the Cosmos, to develop the laws of physics and eventually conceive, design, and construct a computerized mechanical universe.

Man is the only living being that significantly improved his life by drastically changing the conditions in an initially hostile environment to live better on Earth with technology, arts, sciences, crowning philosophy starting with astronomy.

18 THE MUSIC OF THE SPHERES IN THE MECHANISM

Any seemingly chaotic system of celestial bodies eventually, in appropriately long time period, will become a very well-tuned, well organized, as gradually many resonances develop in almost any chaotic system in nature. Ancient philosophers discovered that the ratios of the periods of planets are fractions of small integer numbers, that they are in resonance. The prehistoric calendar of

Oktaetiris, the eight-year period, is a characteristic one, Venus, Earth, Moon, and the Sun 5/8/99. Modern astronomy has discovered that all exoplanetary systems, planetary system around other stars obey this "law of resonances". In the manual of the Antikythera Mechanism we have discovered several extremely long period resonances of the planets Saturn 442 years (442 years are 15 periods of Saturn) and Venus 462 years (462 years are 300 synodic periods of Venus).

The term *music of the spheres, harmony of the spheres,* called in Latin *musica universalis* which means universal music, has been coined, introduced, and established by the wife of Pythagoras Theano (26 centuries ago). Theano was a philosopher mathematician and astronomer that influenced the Pythagorean views about the Cosmos and significantly changed astronomy. Theano was Pythagoras gifted student, mathematician, and physicist. It is considered as possible that all the Pythagorean philosophy and doctrines are Theano's ones.

Figure 56 a model of an ancient Greek guitar, usually a seven string musical instrument. The seven strings probably represent the seven heavenly bodies, the Sun, the Moon and the five then known planets.

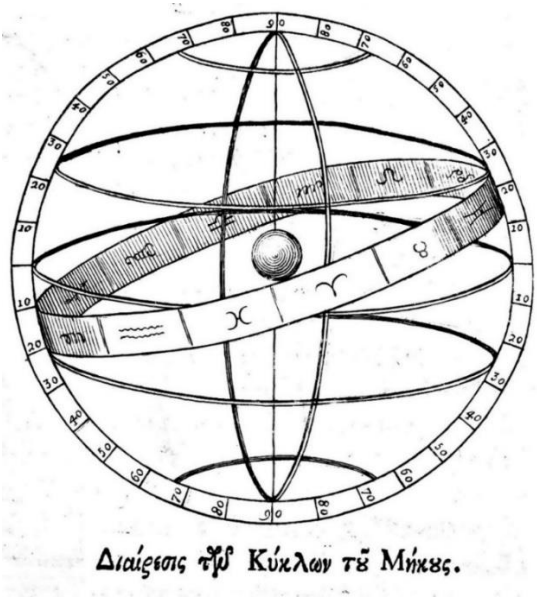


Figure 57 celestial sphere with the ecliptic and the zodiac, The divisions f the celestial sphere are shown.

It is very probable that Theano first introduced the model of the Pythagorean Cosmos with the central fire and the planets (including the Earth as a planet) going around the center of mass of the system.

Figure 58 Architas was an important mathematician, physicist and engineer, friend of Plato that greatly influenced the major philosopher. Detail from Mathematicians and astronomers twenty portraits. Engraving by J.W. Cook, 1825. Wellcome Collection.

The music of the spheres is well described by Ptolemais (23-21 centuries ago) in her book *Pythagorean Elements of Music* of which we only have a few fragments, Iamblichus (18 to 17 centuries ago), in all Ptolemy's books and Porphyry (13 centuries ago) in his book *Commentary on the Harmonics of Ptolemy*. These Pythagorean theories of the music f

the planets were accurate and difficult at the same time so much so that the great mathematician, physicist, and engineer (and politician and general) Archytas that he comments on Pythagoreans' errors in symphonic music with concords.

In the mechanism we have resonances of the planets. The Oktaetiris, the 8 year resonance of the Earth, the Sun and the Moon in evident in the four year Olympic dial. Two Olympiad period follows exactly the calendar of the *Oktaeteris*. Two Olympiads (four year periods) are defined in each Oktaeteris. The first four-year Olympiad lasts 49 lunar months and the next 50 synodic lunar months.

The Olympiad is based on the Oktaeteris, it is half an Oktaeteris. The Oktateris is based on coordination of the movements of the Sun, two planets, the Earth and Venus and the Moon. These heavenly bodies dance in concert a well-planned dance of great precision, a cosmic ball, a cosmic minuet. People since prehistoric times observe that eight years are 99 lunar synodic months and

5 conjunctions of Venus.

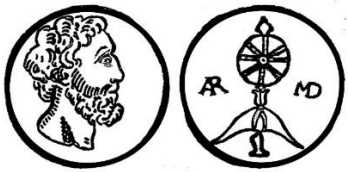


Figure 59 Archimedes and one of his mechanical celestial spheres – planetaria. From medallion based on ancient coin

The orbit of Venus is like a pentagon. The Pythagoreans used the pentagon as their symbol. We have discovered a pentagon inside the mechanism, hidden between two gears that give variable speed to the Moon, following Kepler's second law to a good approximation.

Resonances of the planets, the Sun, and the Moon, appearing in the mechanism:

1. Oktaeteris (Venus, Earth, Sun, Moon),
2. Metonic cycle (Earth, Sun, Moon),
3. Callippic cycle (19 years, Earth, Sun, Moon),
4. Saros (Earth, Sun, Moon, 18 yars 11 days),

5. Exeligmos, (Earth, Sun, Moon, 4 years, 1 month),
6. A 462 year periodicity (resonance of three bodies: Earth, Sun, Venus),
7. A 442 year periodicity (resonance of three bodies: Earth, Sun, Saturn),

The periodicities of 442 and 462 years are mentioned in the manual of the mechanism, and they are not mentioned in any other text internationally.

All the motions up and down the ecliptic plane of the orbit of the Earth and of every planet with all the details with the number of days of every phase of the motion of every planet are included in the texts of the manual of the Antikythera Mechanism.

These numbers, these periodicities of planetary resonances, of duration of the phases of the synodic periods of every planet are the "laws of physics" as the scientists understand them at the time. These laws of physics enables science to describe and possibly reproduce these motions. These laws of physics appear in the manual of the mechanism. We are very lucky that fragmented texts that survived include the periodicities of the phases of the moon, the

Metonic and Callippic cycles and the Saros cycle which combined with the ancillary dial of the Exeligmos cycle gives us sufficient information to understand the laws of physics they use to predict the lunar phases and the eclipses.

The Antikythera Mechanism uses not the Eudoxean model of the Cosmos, but the next one that is simpler and according to Pythagoras and Occam a better model. A serious problem of the concentric spheres is that they cannot reproduce the changing distance of a planet during its synodic period, the variation of the distance caused by the notion of the Earth around the Sun during this period and the variation of luminosity of the planet that is obvious to the lay person at the time when there is no artificial light at night.

To account for the variation of the distance of the planets as seen from Earth a century later the Greeks device a new model, the epicyclical theory based on the addition of circular motions with different radii and different periods, of two circles moving one on top of the other. Epicycles or eccentric circular orbits have been invented by Apollonius Pergaeus (23-22 centuries ago) who is the philosopher (mathematician) that

has observed and studied extensively the motion of the Moon, created useful tables with the trajectory of the moon and studied ellipses, parabolas, and hyperbolas (conic sections) that have used 18 centuries later by Kepler for the planetary orbits and by Newton to calculate the gravitational forces.

The epicyclical theory has been refined by Hipparchus of Rhodes (190-120 BC), Hipparchus is considered by many as the greatest Greek astronomer as he has made lots of novel developments in astronomy.

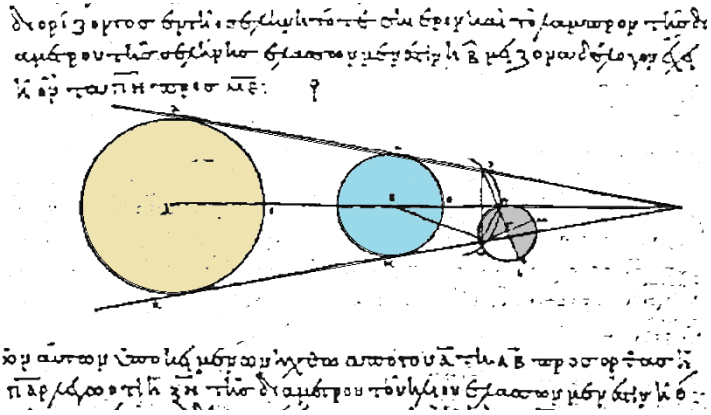


Figure 60 An eclipse from an ancient manuscript describing the methd used to omeasure the distance to the Moon. Eratosthenes measured the distance to the Sun accurately.

Hipparchus by comparing the dates of equinox and the positions of the fixed stars

with the stellar coordinates of previous Greek stellar catalogs by Meton (5th centuey BC), Aristarchus (3rd century BC), Aristyllus (3rd century BC) and Timocharis (3rd century BC) discovered the precession of the equinox, that the stars move one degree every 72 years. Hipparchus measured the luminosity of the stars and enabled their classification in terms of luminosity and created an exact map of the sky with proper coordinates for 850 stars and their luminosities putting in practice the well known Weber Fechner law.

With Hipparchus luminosities (the power of stars arriving to the eye of the observer), or stellar magnitudes (their logarithms with a negative sign multiplied by a constant plus another constant), he created the magnitude scale we use today to measure the brightness of the stars, their power to classify them. Hipparchus classification of the power of stars has been quantified in the 19th century by Pogson using appropriate mathematics.

Hipparchus invented trigonometry, an extremely useful discipline of mathematics. He created excellent maps of the Earth greatly improving the map of Eratosthenes. Hipparchus invented the plane astrolabe by projecting the sphere on a plane. He has

measured the radius of the Moon to be 1/3rd of the one of the Earth and the perigee and apogee of the Moon 59 and 67.3 Earth radii.

Figure 61 an astronomer various astronomical instruments. Woodcut, Credit Wellcome Collection. Attribution 4.0 International (CC BY 4.0).

This eccentricity of the lunar trajectory is the one we have measured in the Antikythera Mechanism, this being another signature of Hipparchus. He has measured exactly the length of the year to be 365.242 days and in the mechanism there is provision to add an extra day every four years and this was the base of introduction of the Julian year by Sosigenes in 46 BC and as a result this year lasted in Rome 445 days to account for the error of the Roman year. Hipparchus discovered the precession of the equinox, that the stars move one degree every 72 years. The equinox moves towards west gradually and this is caused by the changing direction of the axis of rotation of the Earth in a cone with a period of ~25800 years or one zodiacal sign every 2150 years. This precession of the Earth's axis can be taken into account in the Antikythera Mechanism and the user changes a movable ring with stars in fragment C if the mechanism, correcting the position of fixed stars over the years.

Hence one can say that there are signatures of Hipparchus in the Mechanism of Antikythera, one is the correction of the position of the stars due to the change of the axis of the Earth and the second signature of Hipparchus is the epicyclical motion of the

Moon and the planets. I have discovered the epicyclical system of planet Jupiter in fragment D.

The Pythagorean principle that nature is described with mathematics is the most important principle, the real foundations of the construction of the Antikythera Mechanism, which is based on causality and the principle of simplicity of Pythagoras, the so called Occam's razor.

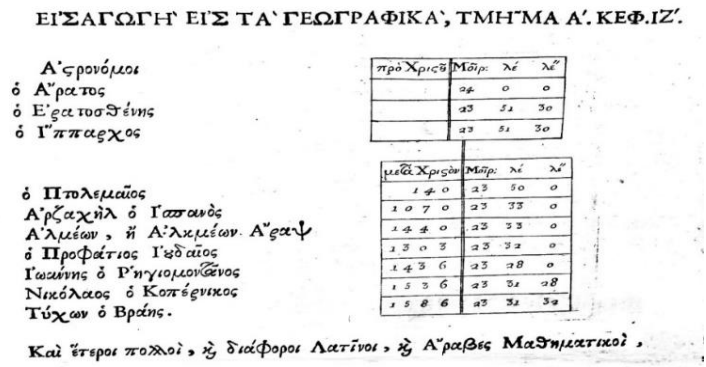


Figure 62 Greek astronomers and many other later measure the change of the inclination of the axis of the Earth with respect to the ecliptic, The table shows the values from Eratosthenes, Aratus, Hipparchus, Ptolemy, Arjachel, Almeon, Proftius, Regiomontanus, Copernicus, Tycho Brahe.

How humans conceive to construct a mechanism to measure the time? What is the time? The definition according to Plato is "time is the motion of the Sun" [Plato Phil.,

Definitiones [Sp.] (0059: 037) "Platonis opera, vol. 5", Ed. Burnet, J. Oxford: Clarendon Press, 1907, Repr. 1967. Stephanus page 411, section b, Χρόνος ἡλίου κίνησις, μέτρον φορᾶς.]. Why to measure the time? Who wants calendars? Who bothers for eclipses and why? How they predict astronomical phenomena? These are basic questions related to the construction of the mechanism. The main reason humans created astronomy and the mechanism was to predict the weather using calendars and simple climatic knowledge like: the appropriate time of sowing cereals in Greece and related climates is that it rains in October and November.

How humans measure time periods of periodic astronomical phenomena like the length of the year, of the month, of the eclipses, of planet Venus etc. and based from these numbers go to a machine that works with gears? The answer to this very basic question is the birth and evolution science. They use the shadow of a stick, the rising position of the Sun and the Moon, and, as I have discovered in Thessaly, Greece, they construct buildings that have very astronomical orientations to mark the beginning of the year. The lines of the oldest rectangular buildings in Greece (well before

6000 BC), as I have discovered, show the rising fo the Sun at equinox, and the next generation of buildings denotes the solstices. This is the beginning of astronomy in Greece. Other astronomical orientations of prehistoric buildings has be reported (Liritzis, & Artelaris (2010).

This mechanism does not come from nothing, from parthenogenesis. It is the product of an advanced society, a scientific society, that believes in causality, the laws of nature and the importance of mathematics to understand and predict natural phenomena. In Greece, long before the creation of the mechanism there is an advanced *scientosphere,* a knowledgeable society, that has a well and properly educated body, the philosophers, the physiologist philosophers (that we call physicist, astrophysicists and cosmologists today) in particular, the mathematicians, which are what we call theoretical physicist today, physiologist that to explain nature use mathematics that are the principles according the Pythagoras. Science and technology require precision, clarity, elegance, brevity, and economy in practice.

These philosophers discuss the nature of celestial bodies, that are made of

substances like the Earth, the stars including the Sun and the Moon. This knowledge is based on actual observations of celestial phenomena, including meteorites and comets, that guided the philosophers directly to realistic views about the nature of stars, that they understand that are made of rotating clouds in the Cosmos, as Leucippus and Democritus teach, that concentrate gradually, and as they turn fast the heat up and emit light. These vortices are made of various atoms. Heavy atoms go to the center and light atoms at the outer layers. All these are correct even today. It is interesting to note that these ancient philosophers use solid astrophysical knowledge and methods

(I) the stars are hot and made of gasses,

(II) universal gravity concentrates the gas to create the stars and the planets,

(III) planetary orbits can be modeled and the positions of planets predicted using:

(a) exact mathematical methods of the concentric spheres or

(b) the addition of accurate circular motions.

The motion of the planets is a complicated problem that Greek Philosophers try to solve. These are the mathematicians, which are really what we call theoretical physicists that use mathematics to study nature using the laws of nature and even to discover new ones.

The first successful mathematical model is the one of Eudoxus (408 BC-355 BC) for the motion of planets that reproduces successfully and accurately the position of the planets in the celestial sphere is based on a series of 27 homocentric spheres that turn one inside the other, one for the fixed stars, 3 concentric spheres for the moon, 3 for the sun, 4 for every planet. Callippus (370–300 BC) improves the mathematical model adding spheres so that the Sun and the Moon are modelled by 5 spheres each, Mercury, Venus and Mars are modeled by 4 spheres each and by 5 spheres Jupiter and Saturn, i.e. 33 in total and Aristotle adds two more spheres for every planet using 55 spheres that can be modeled not only mathematically, but also with a mechanical construction.

The equators of the Eudoxean, Callippean and Aristotelean spheres of a given planet, of the Moon and the Sun coincide with a) the equator of the Earth and accounts for the rotation of the Earth, b) the ecliptic and accounts for the yearly motion of the Earth around the Sun and c) the plane of the orbit of the planet around the Sun. The periods of the spheres are the one day of the rotation of the earth around its axis, the year, the period of every planet or the Moon. The inclination of the orbit plane of every planet is the angle this plane makes with the plane of the ecliptic, the Earth's orbit around the Sun, and the sphere of the fixed stars is inclined with respect to the ecliptic by the 23.4 degrees of the axis of our planet.

It is known that Archimedes successfully constructed two centuries later. In fact the great mathematician and physicist constructed two automatic celestial spheres that are precursors of the Antikythera Mechanism detailed described among others by Plutarch, Cicero, great philosopher and admirer of Archimedes, who had the opportunity to examine them one in the house of the grandson of general Marcellus (Marcus Claudius Marcellus) and the other in the Temple of Vesta (or Virtue) at the Roman Forum in Rome. The two Archimedes celestial

spheres were plunder of the Romans under Marcellus when they conquered Syracuse and killed Archimedes in 212 BC in Syracuse.

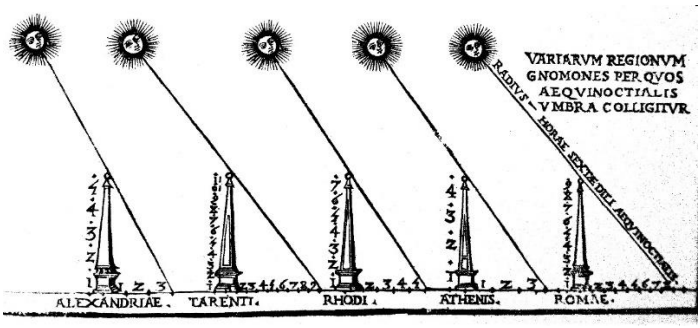


Figure 63 The inclination of the sunrays increases as one goes towards the north in the northern hemisphere. The latitude is measured by triangles.

Callippus that develops the 76 year lunisolar calendar that is the Antikythera Mechanism refines the epicyclical model by adding 7 more spheres and the great Aristotle and his colleagues made it even more realistic and logically sound using 55 spheres. It sounds complicated and it really is. Although it give the exact celestial coordinates, similar to latitude and longitude that we are familiar for the Earth, it does not reproduce the correct distances from the Earth to explain the changes of the brightness of the planets, especially of Venus and Mars.

To fix this problem Apollonius of Perga (240 BC -190 BC) invents the method of adding two independent motions to one, two circular motions that are both exact and easy to define, provided their radii and periods are known, because the periodontics of all the planets are known and the angles of retrograde motions of the planets in the sky are known. The ratio of the radii of the two circles are defined by the extend of the retrograde motions, as it provides exact distance of the planets from the Earth. This exact and successful mathematical and physical method is translated into simple ratios of integer numbers and programmed with gears that run the system.

All the motions of the planets around the Sun are described in the fragmented manual of the mechanism, although the method used in the mechanism is the one of epicycles, adding two circular motions with the period of the Earth and the planet.

This very successful epicyclical method is in use for more than two millennia, from the great astronomer Hipparchus of Rhodes who works in Rhodes that was a center of excellence with several universities (Greek philosophical schools) for centuries in which many famous Romans, politicians, many

generals, statesmen, philosophers, poets and more, including the great Cicero, Lucretius, Emperor Julius Caesar, Cato, Titus Torquatus, Scaevola, Gaius Cassius and Loginus.

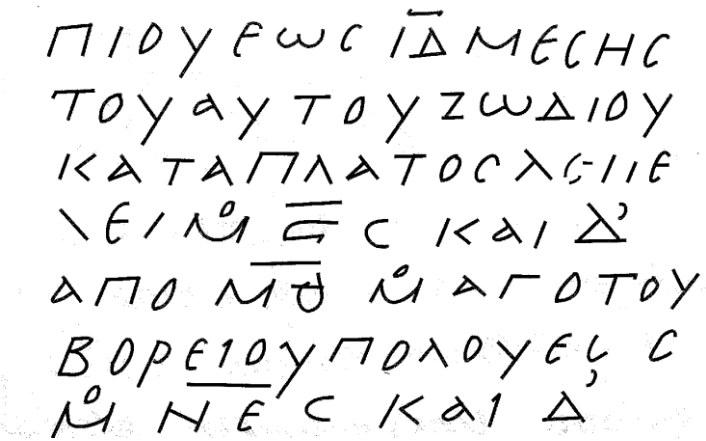


Figure 64 Part of the famous Hipparchus manuscript with the catalog of stars with their coordinates and magnitudes. Created 15-16 centuries ago it led to the discovery of the presession of the equinox with a period of 26000 years, . It states, "of the same zodiac", "in latitude 26 degrees…". Modified from Gysembergh, V., J. Williams, P., & Zingg, E. (2022).

19 ANTIKYTHERA MECHANISM AS A TOOL OF CARTOGRAPHY AND GEOGRAPHY

As Plato says astronomy is useful for traveling. Humans can orient using the position of celestial object. A traveler can calculate the latitude using very simple means by the inclination of the Sun at noon.

ά. ἡ Περίμετρος τῆς Γῆς περιέχει ὡς λέγει		
ὁ Ἀριστοτέλης	Στάδια Μίλια	4 0 0 0 0 0 0 5 0 0 0 0
ὁ Ἵππαρχος	Στάδια Μίλια	2 7 7 0 0 0 0 3 4 6 2 5
ὁ Ἐρατοσθένης	Στάδια Μίλια	2 5 2 0 0 0 0 3 1 5 0 0
ὁ Πτολεμαῖος	Στάδια Μίλια	1 8 0 0 0 0 0 2 2 5 0 0
ὁ Ἀλφραγάνος	Στάδια Μίλια	1 6 3 2 0 0 0 2 0 4 0 0
ὁ Φερνέλιος	Στάδια Μίλια	1 9 6 1 1 4 $\frac{8}{25}$ 0 2 4 5 1 4 $\frac{32}{100}$
οἱ Νεώτεροι	Στάδια Μίλια	1 5 2 6 4 0 0 1 9 0 8 0

Figure 65 many philosophers measure the perimeter oof the spherical Earth: Aristotle, Eratosthenes, Hipparchus, Ptolemy, and others by various methods.

Greek philosophers understand the Earth is spherical from the time of Thales, 27 centuries ago, probably from the circular shape of the shadow of our planet on the Moon during lunar eclipses. Humans understood the relation between latitude and shadow of a vertical stick, by the inclination of the sunrays at noon. This shadow of the vertical stick can be measured by simple means, with a variable triangle made of wood, that can be marked with the latitude with the help of a table that determines the latitude based on the inclination at a given date of the year. Latitude can be measured by the length of the longest day of the year. For example, many ancient Greek books give the latitude of Thule (Iceland) stating that this island has longest day 20 equinoxial hours. The calculation of the longitude is much more difficult. It requires accurate determination of time and good knowledge of astronomy.

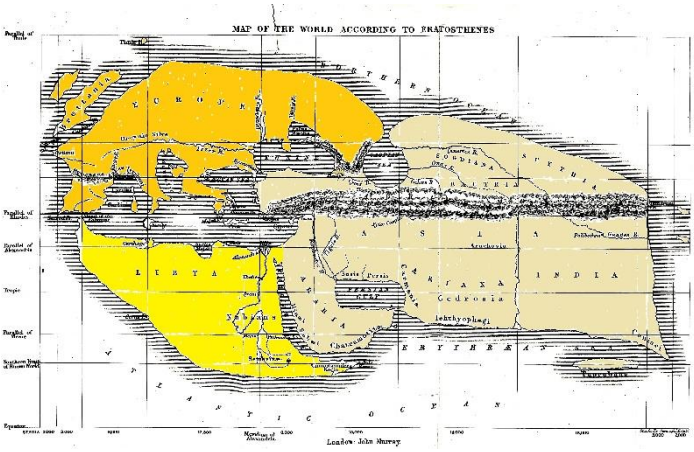


Figure 66 The map of the Earth according to Eratosthenes.

The calculation of the latitude needs a very accurate clock. Even if the Antikythera Mechanism was a clock as I suggest, it was nt that accurate. The accurate determination of the longitude has been solved many years after Newton with very accurate clocks. They use accurate measurement of a lunar eclipse at two cities to calculate the longitude difference of the two cities. I suggest tht the ancients use Machines like the Antikythera mechanism to predict the position of the Moon and check it with observations to calculate the longitude too without having to observe an eclipse. In this they could use tables and perhaps for this the mechanism is called a tablet.

Figure 67 Part of Asia in a Greek map of 1700 based on an ancient map by ancient geographer Dionysius.

The importance of geography was fundamental from prehistoric times, as Plato underlines and as Homer first, Anaximander, Democritus, Eudoxus, and others. I suggest that astronomical automatic mechanisms like the Antikythera Mechanism are extremely useful to various applications. Scientific endeavors, teaching, geography, travelling and more have benefited greatly by machines like this mechanism. There are many books of geography with the latitude and longitude of many cities around the world. These books include geographical coordinates of places from Spain to China. Let us present a few examples from Ptolemy's

Geography book. In Iberia, Britain, and the rest of Europe in general, the errors of longitudes and latitudes are systematic.

Ptolemy geography, 22 centuries ago, is mainly based on two Greek seafarers. Mainly to Marinus. Ptolemy and other Greek geography books give the extend of the ten largest islands of peninsulas of the world: Shri Lanka, Britain, Malay, Ireland, Sicily, Sardinia, Corsica, Crete, Cyprus. In this the book is not correct, as almost all South-East Asian islands are not mentioned in this comparison. In Ptolemy's Geography book there are some 5500 cities, rivers, gulfs, and mountains. May cities are mentioned several times in various volumes of the Geography. Guangzhou for example is mentioned.

The contribution of such machines and instruments to geography are presented with emphasis to China and South-Eastern Asia. Greek geographies include detailed descriptions to South Asia and here the emphasis is from Ganges to Guangzhou. More than 55 cities, with quite accurately measured coordinates.

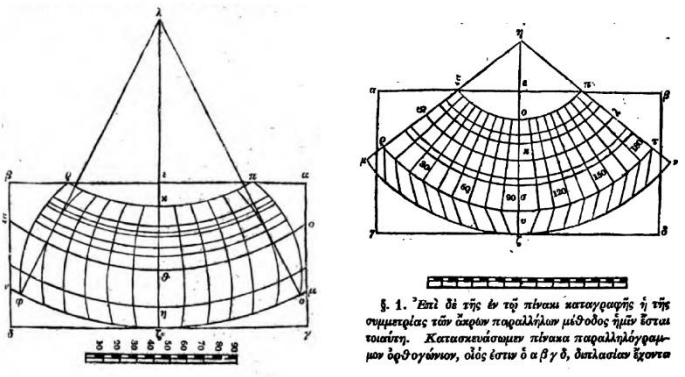


Figure 68 Ptolemy using the methods of Hipparchus shows how to project the sphere of the Earth using two cone (right) that can be depicted on a plane surface of a map.

The Greek geography books have been the basis for medieval books and maps even the ones used by Columbus and the Conquistadores that conquered the Americas and other countries, almost 15 centuries later. The cities are displaced systematically almost all in the same direction, almost by the same amount. The shape of the countries is systematically distorted. It seems that the radius of the Earth used is perhaps larger than the real one. It is surprising that the books give dimensions of straights as sea. For example, the straight of Malay.

The books of geography contain detailed descriptions of all the islands up to Guinea

and even mention the Unknown Southern Land (Australia) which is depicted in some maps of Asia, are mentioned. The cities include two Emporia and a city named with the Greek name Byzantium which given on the latitude and longitude is probably Nha Trang of Viet Nam, named like this perhaps because it has some geomorphological similarities with Byzantium.

The geography books include India with Ganges and Indus rivers, Afghanistan, with its longitudes and latitudes with errors of the order of 3 to 5 degrees, Shri Lanka depicted much larger, Malay is named Golden Peninsula or Golden Island in Greek. The Greek books of geography give frequently dimensions of straights in the sea. Ptolemy Kattigara (Καττίγαρα) which is certainly Guangzhou as it is evident from the geographic coordinates. Guangzhou is mentioned in the different volumes of Geography's Ptolemy book more than ten times.[18] Ptolemy mentions the city of Tamala (Indonesia) and gives the distance to Golden Peninsula.

[18] Καττίγαρα I 1,1. 14, tit. 1.4. 10. 17,5. VII, 3, 3. VIII, 27, 14

Ptolemy's geography gives the extend of the Golden Peninsula (24.8 degrees) which means that he perhaps means Indochina. Singapore is mentioned too as the cape Kori (Cori) at longitude 100 degrees (125 degrees from the Canary Islands (Makaron Nisoi) where the first meridian was for the Greeks before the time of Ptolemy). Many more other cities, capes in South-East Asia, especially along the coast are mentioned in Ptolemy. A geographer writes China is the end f known world.

Figure 69 A version of Ptolemy's World map, Ulm, Lienhart Holle, Wikipedia

In China the books of geography distinct two vast regions of Sinae (Qin) and Seriki (Land of Silk, Serike, Serica, or Sirika, or, Zou, Qin, Han).

The book of Geography by Ptolemydescribes in detail how to go to Alexander (not to be confused with Alexander the Great) and oldest geography books now lost, including notes and pams by various scientists including the geat mathematician Eudoxus. Ptolemy gives the time in days it takes to go from one place to another. For example from Java to Tamala and Kattigara (Guangzhou). It seems that geographer Marinus made four times this journey, twenty days every leg of the trip. The 8th table of Asia in Ptolemy' geography contains some of the cities of China. Ptolemy mentions Issidon the Chinese, Wuwei, Gansu, (also Issidon Sirica, Ἰσσηδὼν Σηρικὴ) where the longest day has a duration of 15 hours and longitude around 120 degrees Lanzhou (Aspakara or Aspakaia, Ἀσπακάρα ἢ Ἀσπακαία) and the city of Huangshan (Drosachi, Δρωσαχὴ) with longest day 15 hours and 6 minutes, Huangshan mountain, (Ὀττοροκόῤῥα) with longest day 14 hours and 3 minutes and the metropolis Luoyang, Xian (Sira, Σήρα). This geography and other books give the geographic coordinates of 55 cites in South-Eastern Asia, details of the distances

between them and from Greece dimensions of straights and islands too. From this it is evident that Sinhellenic civilization relations have a history of at least 3000 years and probably longer if we believe to Greek Mythology and the travels of Dionysus to Asia.

20 EARLY ASTROPHYSICS AND COSMOLOGY

Astrophysics really started together with philosophy, natural philosophy with the first Ionian philosophers. It seems very surprising that the very early ideas of the presocratic philosophers are exact and correct gross modo to the present views of astrophysics. Since ancient times, since the time of Thales, astronomy and astrophysics become the science of the universe, the science of studying the Cosmos based on observations of the sky, the star, the Sun, the Moon, with measurements interpreted with physics and mathematics, essentially just as today. They understand that the Mon has a lower temperature than the Sun. Anaximenes showed that the moon receives the light of the sun and how for this reason it disappears when the shadow of the Earth falls on its satellite which is a different light body.

Figure 70 a seal with a symbolic representation of the fall of a meteorite, possibly from the constellation of Corvus. Philosophers studied the fall of the meteorites and understood that the heavenly bodies are made of the same material as the Earth.

Figure 71 A golden ring with a symbolic representation of the fall of a meteorite. Philosophers studied the fall of the meteorites and understood that the heavenly bodies are made of the same material as the Earth.

Figure 72 comet Hale – Bopp. It is evident by eye that it contains gasses. Photographe by Dr. Miloslav Druckmüller

Figure 73 Ancient seal with an ancient "astronomer" observing a comet. Philosophers studying the comets that have based very close to the Earth realized that they are made of gases. They generalize and conclude that the stars are conglomarations of hot gasses, as they say correctly.

The philosopher Theon (335-405) in Alexandria, mathematician, important astronomer, father of astronomer Hypatia, informs us that Plato advises those studying philosophy to start with arithmetic and, after learning it well, to continue with geometry, then with stereometry for to understand the real three-dimensional World, then astronomy and fifth harmonics, music.

Thales believes the stars are very hot and celestial bodies are earthly with the same matter as the Earth. Anaxagoras and Democritus understand that the comet have trajectories like the planets and that at times they come very close to the Earth. I believe that his gives them the opportunity to study the nature of comet and then to generalize for all celestial bodies.
They see he jets of gases ejected by the comet as it approaches the Sun and from deep freeze they heat up and eject their volatile constituents. They observe strs through the material of the comets, so they conclude that the material of the comet is gaseous. This helps the philosophers to stars astrophysics properly. They conclude that the stars are made of concentrations of hot gasses (even though cometary gasses in reality are very cold). Anaxagoras says the Sun is hot stone, probably because he has examined some meteorite falls and concludes that some stars (meteorites) are hollow, like pumice. This suggests that they have been examining meteorites that at occasionally have cavities.

Figure 74 Thales, one of the oldest philosophers. Introduced theoretical proofs in geometry. He also predicted eclipses. Thales of Miletus. Stipple engraving by J.H. Ramberg.Ramberg, Johann Heinrich, 1763-1840. Reference 9127i Wellcome Collection.

Philosophers conclude that stars have no feelings, they are not gods as people believed up to that time and that they are parts of nature, like the Earth, which the know is spherical and some of them believe that is a planet.

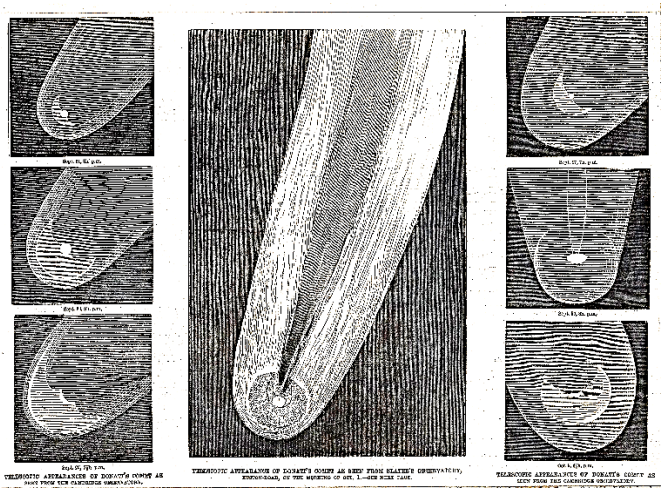


Figure 75 Image of a comet showing the structure of this type pe celestial bodies that inspired ancient philosophers to understand the real nature of celestial bodies. various views of Donati's comet in the night sky. Process print. Wellcome collection, Reference: 46241i

Perceptions of the Cosmos vary amongst philosophers. Homer believes that the Cosmos is limited and not infinite. Thales, Pythagoras, Empedocles, Ekphantos, Parmenides Melissos, Heraclitus, Anaxagoras, Plato, Aristotle, Zeno maintain that there is only one Cosmos. Anaximander, Anaximenes, Archelaus, Xenophanes, Diogenes, Leucippus, Democritus, and Epicurus support infinite worlds in the infinite void born in each cosmic period. So they introduce a series of Cosmoi (plural of Cosmos), Universes, the are born die and rebirth, not necessarily the same. The same

applies for the stars are born and they live and die. Some stars have planets, other stars do not. There are even planets without a star. Empedocles considered the Sun's orbit around the Earth to be the limit of the Universe. Seleucus the Erythraean and Heraclides the Pontic consider the world to be infinite, while Diogenes and Melissus consider that the Universe is infinite while the World is finite. The Stoics consider that the Universe differs from the whole as it is together with the void within the infinite. The Cosmos is not considered without the void. Atomic philosophers, Leucippus, and Democritus, using the concept of universal attraction, gravity (although they do not name it), consider that the Universe is created by the union of many atoms due t their mutual gravitational attraction. The atoms are pulled together by gravity and constantly swirl around creating a vortex. This is how the Cosmos; a star and the Earth is born. I take it that atomic philosophers Leucippus and Democritus by the term "Cosmos' mean Universe, or star, or planet. This is how the Earth was created in the center. Likewise stars are superheated by fast rotation, ignite and radiate. Before the invention of lighters and matches people lit a fire with a rapidly rotating piece of wood and firewood. The worlds are born from the pre-

existing atoms in the infinite void. Atoms come together and create the world. Since there are infinitely many voids it is possible to create many worlds.
Atoms make matter, bodies, by union. Under certain conditions the bonds of the atoms are broken by a repulsive force and the Cosmos or the stars or the planets are dismantled and die. Big Cosmoi absorb small ones. I estimate that by the term world they again mean all three, Universe, star, and planet. The atomic philosophers also put a physical limit to the universe, a membrane. Most Stoics also consider the Universe to be eternal, but they believe that it is destroyed from time to time and after long periods is reborn by the process of *purpura (ekpyrosis)*, which is a kind of great explosion that destroys everything with the indomitable power of fire, as they say in which *ekpyrosis* the World is destroyed, before it is rebuilt with the *palligennesis* (rebirth) which follows the expiation. It is worth mentioning that these have been studied by modern astrophysics and cosmology and there are models of the universe with consecutive superimposed big explosions, which create the oscillating universes, as they are called, via a cyclic model. Therefore the Universe according to many philosophers is immortal, even through many Big Bangs one after the other.

The ancient Greeks and Chaldaeans know that every comet has its own orbit like a planet. They point out that as they get closer to the Earth or the Sun, they get brighter. They know that some comets move quickly and change position, others move slowly. They record the form of comets and perceive their nature from this. They write: *they seem to change as if the comets are driven by a wind* (today we know that the solar wind changes the shape of comet tails from hour to hour) andthat a cosmoc storm can changes them abruptly (indeed when a cosmic storm occurs the comets and especially their tails that they are vulnerable to the solar wind they drastically change shape and extent. Ancient philosophers called *coma* both the part of the comet's atmosphere that we now call the coma, and the elongated parts of the tail, as we now call the elongated portion of gas and dust that the comet ejects . The ancient philosophers describe very well the comets, the coma which is the atmosphere of the comet as having usually oval, ellipsoidal shape. They discover that stars are visible through the comet coma and tail and conclude correctly that the comet tail consists of condensed gases. They conclude that comets are composed of compressed materials that are vented, and they

conclude that cometary materials are terrestrial. They conclude that comets cease to exist as the materials are consumed. They mistakenly conclude that they are consumed because they rotate. Infact the opposite is correct. The rotation is a result of the jets of gases they emit. The comets are consumed, they loos material every time they pass by the Sun, they heat up (as the ancient philosophers found) and give off currents regardless of whether they rotate or not. The philosophers generalize for the stars and conclude that all stars are concentrations of hot gasses.
They also observe that some comets disintegrate and disappear when warmed up by the Sun. Some comets when they come close to the Sun are no longer observable since their light is very feeble compared to that of the sun. It is very impressive that with the naked eye they distinguish the rotation of comets and that from the comets they project rotating jets. They conclude (incorrectly) that the rotation is due to the rotation of the celestial sphere due to friction, which does not exist in reality. It is possible that the swastika is a representation of a rotating comet with its jets, whose gas streams bend sharply due to th interaction with a fast stream of the solar wind, a shock wave of the fast stream.

Democritus realizes that comets are iridescent bodies that reflect the light of the Sun. Anaxagoras and Democritus must have seen comets braking up into many parts, just as we happened to see a comet braking up in 16 pieces by the tidal force of the planet Jupiter, for some philosophers including Democritus believe that some comets are aggregates of many "stars" together. Philosophers find that the streams of gas emitted by comets and the tails of comets are sometimes of various colors, and consider them to be a resolution of light, an iris, as they call it. They mistakenly think that cometary gases are hot and have flames, while comets are icy frozen bodies.

It is remarkable as well as admirable that the early philosophers establish astrophysics so well, scientifically, they understand the nature of celestial bodies that are made of the same material as the Earth, that the stars are made of concentrations of hot gasses, that stars are born and that they decay and die.

The philosophers create physical Cosmology based on physics. They discuss the birth and nature of the Cosmos. They generalize their knowledge about the planets for the Cosmos, they discuss the case of an eternal universe, or a birth of the Cosmos, and even successive births and deaths of the Cosmos

through an explosion. The philosophers theorize about oscillating universes, repeated Big Bangs and Big Crunches. They understand that the laws of physics are universal, gravity is universal, but that the laws of physics can depend on conditions like the density and temperature, exactly as modern theoretical physics implies. Democritus believes there in one Cosmos in the void, tis limit is spherical and the limit is made by atoms that have hooks and are linked with these one to the other to form the surface of the limit of the Cosmos inside the void, the infinite space, but outside this Cosmos probably there are other Cosmoi (plural of Cosmos).

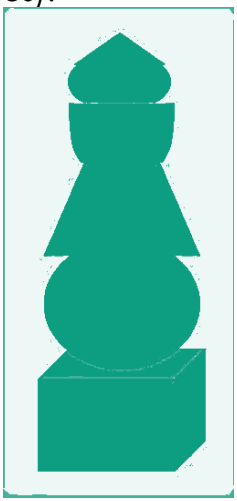


Figure 76 Platonic polhedra have an influence to the Gorintos, as the represent the very platonic idea of the Cosmos be made of the five elements.

21 ATOMIC PHYSICS AND ELEMENTARY PARTICLES

Democritus based on his teacher Leucippus doctrines and Metrodorus and Epicurus that follow them, use the notion of indivisible entities, the *atoms*, as the elementary constituents of matter. Atomos in Greek means indivisible. Atoms are hard, they cannot compress, they have given uniform shapes, forms. Atoms are in constant motion in space, in the void. The atoms of the soul, psyche, are spherical as the atoms of fire. The atoms of other elements are different, like the atoms of gold for example, and every substance has a different shape atoms. The human senses, the human thought is made of atoms and they are part of the human body. Atoms are invisible by eye. Atomic philosophers create all the world with these atoms. Heraclides of Pontos and Asclepiades of Bithynia introduce something similar, some very specific volumes without joints to create nature, Anaxagoras the *homomerias* (particles that are all the same, a kind of chemical elements, or elementary particles), Diodorus uses the very small bodies "*ameres*" (something that has no parts), while Straton the "qualities". In contrast Pythagoras uses the numbers as constituents

of nature. Homer considers the water as initial constituent of Cosmos,
Pherecydes, the teacher of Pyhtagoras and Perictione, Plato's mother, considers the earth as the first constituent of the Cosmos, Thales, water, Anaximander the *apeiron* (the thing we do not know what it is, or the infinite), Diogenes, believes the elements are the air and fire, Hippassus, Xenophanes, Hippon, earth and water, Reginos the fire and water, Oinopidis fire and air, Onomacritus earth, fire and water, and the Stoics the four elements, earth, fire, water and air. Aristotle adds to these a fifth body the circulating one, Empedocles the four elements adding philia and neikos (attractive and repulsive forces). The philosophers called mathematicians use special volumes. All these theories in fact are very similar, even if the terminology is different. Even the views of Plato and Democritus are very close, as explained in the appropriate section.

Figure 77 The invention of theoretical proofs in geometry is a gigantic leap in human history. A theoretical prof of theorem from the famous Oxyrhynchus Papyri manuscripts (c. 100 BCE), part of Book II, Proposition 5 of Euclid.

22 PLATO VERSUS DEMOCRITUS

Plato follows a very accurate sophisticated mathematical method to create the world. Plato uses four convex, regular polyhedra to create all the world. They are the mathematical presentations of his "ideas", as he calls them. Plato's Ideas are probably what are called today mathematical models.

An extremely important progress in theoretical mathematics and physics is the

introduction of proofs with theorems and exact mathematics. This has gradually led to today's physics and technology. This Pythagorean view and practice changed science to be exact to the maximum. The same practice guided Plato to the development of his regular polyhedra and to the extremely mathematical view of the Cosmos. Plato use two rectangular triangles to construct the polyhedra, which are the chemical elements, or the Platonic atoms and the triangles are the proton, neutrons, and electrons. These platonic polyhedra are the only ones that can be created with the use of two rectangular triangles.

Alternatively the Platonic polyhedra and the triangles are equivalent to atoms and quarks. With these platonic solids everything was made in the Cosmos, from the Microcosmos to Megacosmos, made exclusively with only two constituents, two "elementary" particles. So eventually a comparison of the two very important theories

1) the atomic theory of the Democritus, and
2) the theory of platonic elements, polyhedra made all with the two Platonic triangles

The two theories show their intrinsic essential conceptual similarities. Both theories construct all the Cosmos with what are called with modern terminology *elementary particles, quarks,* and *chemical elements*.

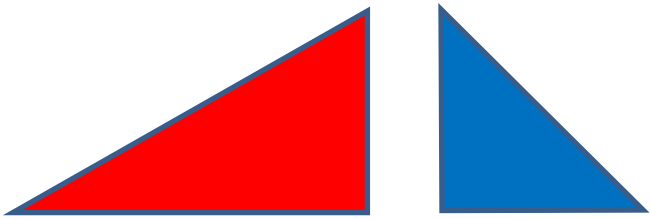


Figure 78 The two rectangular triangles of Plato. These triangles can create the elements o Plato and with them all nature, the Cosmpos.

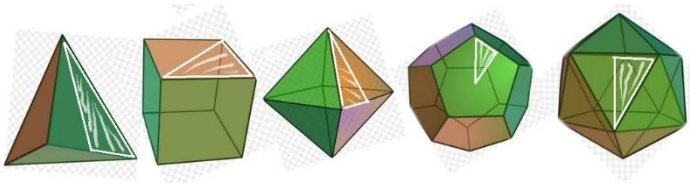


Figure 79 The five polyherda that Plato creates with just to rectangular triangles. Euclid proves that these are the onl possible ones to be created by two triangles. Wikipedia, Cyp, DTR, Kjell André, Stannered, XM.

23 EARLY OPTICS

Optics as a science was born and developed in Greece using experiments and theory ith mathematics. One ca assume that optics contributed significantly to the study of nature, particularly the composition of matter, probably contributing to the notion that matter is made of crystals (Platonic solids) as some philosophers observed materials, rocks, and even meteorites with the help of lenses like the ones we have in the Greek museums. I have studied many of these lentoid objects that are in the Archaeological Museum of Heraklion, the Archaeological Museum of Rhodes, the Archaeological Museum of Agios Nikolaos and the Pushkin Archaeological Museum in Moscow. Even if these lentoid objects were made for decoration the creator, the craftsman that made them must have realized that they magnify what one sees through the lentoid object.
Results are presented based on measurements of all the lenses we had access to (Archaeological Museum of Heraklion and Rhodes) and 1700 passages of Greek philosophers that refer almost exclusively to mirrors with only a few references to lenses and a few Arabs and Latins, who always refer to Greeks.

Ancient lenses appear in Greece and elsewhere, as early as 4 millennia ago. Almost all these lenses are quite well made. I have measure the magnification and distortion to many of them. The magnifications varying from 1.2X to nearly 3X. and focal lengths from about 1.5 cm to 30 cm. The quality of the lenses is satisfactory and the images are quite good. We have created real images on drapes with all lenses which are of satisfactory quality with little distortion and allow the use of lenses from small craft makers such as seals. I believe that lenses were made that were used both for display and decoration, but also in the workshop of a maker or scientist. The great comic writer Aristophanes (c. 446 - c. 386 BCE) in one of his plays informs us that in the pharmacies of his time in Athens they were selling lenses to light up a fire using the Sun. I created an experimental telescope using two of these ancient lenses.

It is very important that the theoretical knowledge of optics is based and progressed on the Greek invention of mathematical proofs with theorems. There are several theorems that survived in the books of Euclid in optics. Unfortunately, a great part of his writings about optics has been lost. There are several theorems on optics for example concerning reflections in more than one

mirror in Euclid's, Archimedes, and other books.

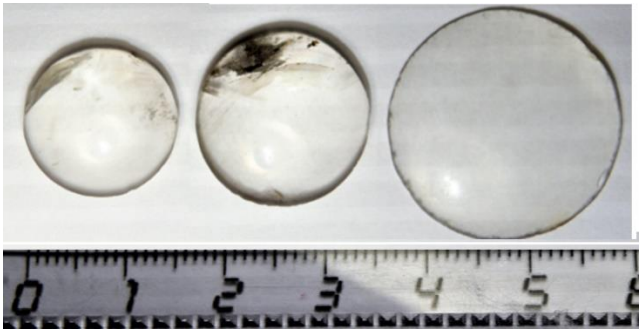


Figure 80 Lenses 4000 years old from Greece, from tha cave where Jupiter was born, Crete. Various focal lengths and magnifications. Archaeological Museum of Heraklion.

At least 1700 passages refereed to mirrors and a few on lenses and optics in general from ancient Greek and some Latin and Arabic books have been analyzed for this study, lenses. There are detailed reports by Plutarch concerning the qualities and properties (magnification, real or imaginary image, distances) of images after multiple reflections in concave and convex mirrors essentially show that optics was already very advanced. As these are presented by non-science writers addressed to the public, it seems that it was common knowledge included in the education of some people. From the numerous accounts of ancient authors, and especially from the most thorough of them, it is certain that ancient philosophers studied complex optical

devices which they made, or which were available to them.
The ancient philosophers, like Euclid, Archimedes, Diocles (), have studied plane spherical, parabolic, and other, convex, and concave mirrors and they were using them to set fire even at a distance. It is said that Archimedes burned the Roman fleet using many mirrors. Diocles (c. 240-c. 180 BCE) *On burning mirrors* book contains sixteen propositions concerning light focusing by conic section made mirrors.
According to Greek mythology the first mirror was made by the god Hephaestus for the god Dionysus as described by Proclus in his book Commentaries on Plato's Timaeus. Democritus and Epicurus teach that some mirrors construct inverse real images in front of them. The Pythagoreans say that the images in mirrors are made by light rays that propagate along straight lines that are reflected on the mirror, while images from lenses are made by refraction that changes their direction. The construction of a convex mirror is described by Agathias in his book *Histories* who states that the convex mirror focuses the sun's rays to a focus. According t o Greek history Thales was the first to predict an eclipse of the Sun he saw "mirrorly" (using a mirror?) the eclipse. If the interpretation means really using a mirror probably means

that he used a concave, spherical or probably parabolic mirror, therefore a form telescope, and perhaps thus perceived that the Moon is of earthy nature. This is written by several ancient authors (Aetios, Pseudo-Plutarch, Eusebius). Did Thales really used a telescope, as these ancient writers tells us?

Figure 81 Archimedes' mirror burning Roman military ships. Painted by Gieulio Parigi (1600), Galleria degli Uffizi a Firenze.

Ancient scientific texts that demonstrate the use of complex optical systems consisting of more than one mirror or possibly lenses of the Greek philosophers, as we are informed by Aristotle and even the playwright Aristophanes, are also presented as evidence. The ancient natural philosophers refer to systems of two or more mirrors, concave and convex, having the proper properties to enable the user to have real or imaginary images, spectra, or images, as

they are called. In some of these texts it is evident that they were used for astronomical purposes to see "stars", as they write, they name comets and we can assume that they possibly mean planets. All this proves that people in Greece developed complex optical systems, probably used for observations of objects on Earth and celestial bodies such as comets and the moon.

24 POSSIBLE OPTICAL SYSTEMS OF THE PHAROS, THE LIGHTHOUSE OF ALEXANDRIA

Pharos, the Lighthouse of Alexandria is one of the Seven Wonders of Antiquity and it has been argued that it probably had optical systems that:

(a) they allowed it to be visible a few tens of kilometers in the Mediterranean, some ancient writers say 70 km and one mentions up to 300 kilometers away, i.e. almost all over the eastern Mediterranean which seems like an exaggeration

(b) permitted sighting into the sea to a great distance, as judged using some kind of telescope.

There are several written sources that describe these optical systems. The great Arab scholar geographer Al Muqaddisi (also known as el-Mukaddasi or al-Maqdisī, (946 - 991)), in his book *Guide to Alexandria*, mentions that a mirror was used as a telescope on the top of the Lighthouse of Alexandria from ancient times. With it the Greeks and later the Arabs could see every ship passing even at a great distance and thus guard against their enemies. Al

Muqaddis gives a description of the telescope which was made with a glass mirror.
A similar description is given in the book *The Itinerary of Benjamin of Tudela*, a renown Jewish geographer and historian born in Tudela Kingdom of Navarre who lived mainly in Castile (1130-1173). Benjamin also describes a telescope with a glass mirror on top of the Lighthouse that allows observation over a huge distance.
Any ship that attempted to attack the city, coming from Greece or from the western lands, could see (the Arabs) through this looking-glass at a distance of twenty days' journey, and the inhabitants could assemble their garrison. Benjamin goes on to describe how a Greek captain destroyed the telescope so that they could not see the Greek and other ships traveling in the Mediterranean and after this destruction of the mirror the Greeks the (East) Roman Empire, (named Byzantium) could retake Crete and Cyprus from the Arabs.
Another source is from Al-Hassan al-Haytham (Abū'Alī al-Ḥasan ibn al-Ḥasan ibn al-Haytham,965-1040), called "Ptolemaeus Secundus". He studied optics in Cairo. His studies include the eye, lenses as well as mirror focusing of convex, concave and especially cylindrical mirrors. Al-Hassan al-

Haytham wrote four books, but only one survives. One book summarizes Optics based on the two books of Euclid and Ptolemy.

25 THE ANTIKYTHERA MECHANISM AS AN EDUCATIONAL DEVICE

The mechanism inspires young to study in different fields and to plan their future by setting high goals. Educates in many subjects: technology, computers, mathematics, physics, modeling nature, astronomy, history, philosophy, linguistics, topography, geography.

We have already successfully held many good exhibitions in Greece and other countries, mainly in Museums, schools, and Universities, on the history of astronomy and sciences focusing on the Antikythera Mechanism, the oldest computer and scientific instrument.

The Antikythera mechanism inspires young people to study science, technology, arts, philosophy.

The exhibition uses a mysterious and attractive ancient object presents science and technology based on knowledge of the laws of physics and at the same time it initiates the young to the classics.

1. Inspires the young to set high goals like the constructor of the mechanism,
2. Inspires the young to study mysterious things,
3. Highlights the ingenuity of people and inspires the young to,
4. It initiates pupil to the classics, to have an interest and study previous civilizations,
5. Inspires the young to study to unexpected aspects of history, and archaeology.
6. It inspires young people showing that humans can set difficult targets that they envisage, that can achieve with appropriate careful plan and hard work.
7. Inspires the young to invent new things,
8. Inspires the young to become industrious,
9. Leads young people to acquire self-confidence (if the ancient did this they can do miraculous things better today),
10. Inspires the young to be trained in many disciplines (technology, computers, mathematics, physics,

astronomy but also history, philosophy, geography, linguistics),

11. The mechanism teaches science, mathematics, history, geography.
12. The mechanism shows that science is based on causality,
13. That there are laws of physics,
14. That the laws of physics have to be be expressed with appropriate mathematics (Pythagoras, Plato),
15. The Mechanism of Antikythera is an excellent educational device to teach modeling of natural phenomena and even to predict some of them,
16. That mathematics can be expressed with trains of turning gears that enable humans to create and program the first computer.
17. The Mechanism of Antikythera is the best educational instrument to teach Greek Philosophy and especially the Pythagorean one.
18. The mechanism and the exhibition show that the Greeks develop high technology in antiquity, in contrast to what is generally believed,
19. Highlights the creations of Greek and other ancient civilizations.

20. Teaches a lot more, even to experts, about the mechanism and even the possibility that the mechanism as a astronomical clock and mechanical planetarium.

The Antikythera Mechanism is a unique ambassador of Greece and Greek civilization that visitor will probably remember forever. We use exhibitions where the mechanism is the central object, together with some other models of ancient astronomical instruments.

Objective of the exhibition:

The objective of the exhibition educational program is to prepare an exhibition that will acquaint the people with some aspects of Greek civilization, especially this ancient astronomical instrument that is the oldest known computer and astronomical clock, a mechanical Cosmos, a planetarium. The exhibition shows that the Greeks have developed technology not only for war but also for science and that the Greek automate we read in the literature are real, that they existed and that there were several examples of them.

The young visitors of the exhibition will be inspired to study more classics, mathematics, physics, and technology, including computing and informatics, engineering, astronomy, archaeology, and philosophy.

The Antikythera Mechanism is an ancient machine, a computer, and a wonderful educational tool for young people in Philosophy, Science, Mathematics, Astronomy and Technology. I use him as such to attract young people.

The exhibition presents the Antikythera Mechanism, which is the oldest computer and at the same time a complex astronomical instrument and probably, as I argue with my research, an astronomical clock and planetarium. The Mechanism is much more advanced than the astronomical clocks that appeared in Western Europe after the 14th century and which are children of the Mechanism. This ancient object is in the National Archaeological Museum in Athens.

The exhibition can be made in several copies and be at the same time for a period of time in various regions of Greece, but also in other countries given that the report is available in

several languages. A simpler version of it can even go to all schools.

Exhibits and educational software and material of the exhibition:

- A bronze model of the mechanism,
- A couple other ancient instruments
- A part of the lunar motion made with transparent gears,
- 20 to 25 posters with presentation of the mechanism and Greek Science,
- Two interactive simulations,
- A couple or more films,
- Many interactive 3D photos, the ones used to study the surface of the original mechanism.

The exhibition is available at request in 14 languages.
If you want to have this exhibition, please let us know.
xmoussas@phys.uoa.gr
A new working model of the Antikythera Mechanism that is also an astronomical clock and a planetarium, have been designed and constructed with the participation of Universidad de Sonora, the company of monumental clocks Relojes Olvera III Generation and the University of Athens. I am indebted to my colleagues Dr. Raul Perez-Enriquez, rd. Julio Cesar Saucedo Morales, Dr.

Ezequiel Rodriguez Jauregui, Dr. Armando Ayala, Sr Ing Jesus Clemente Olvera Trejo, Sr Ing. Alfredo Carmona. This monumental clock will be established in Museums, starting with the Museum of the University of Sonora, and in various cities.

26 APPENDIX

26.1 THE PARAPEGMA

Α ΑΙΓΟΚΕΡΩΣ ΑΡΧΕΤΑΙ ΑΝΑΤΕΛΛΕΙΝ Α

Capricorn begins to rise

ΤΡΟΠΑΙ ΧΕΙΜΕΡΙΝΑΙ Α

Winter solstice

Β ΚΥΩΝ ΕΠΙΤΕΛΛΕΙΕΙ ΕΣΠΕΡΙΟΣ Η

The Dog rises at sunset

Γ ΑΕΤΟΣ ΔΥΝΕΙ ΕΣΠΕΡΙΟΣ Κ

Aegle sets at sunset

Δ ΥΔΡΟΧΟΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Aquarius begins to rise

Ε ΔΕΛΦΙΣ ΔΥΕΤΑΙ ΕΣΠΕΡΙΟΣ ΙC

Delphis sets at sunset

I ΛΥΡΑ ΔΥΕΤΑΙ ΕΣΠΕΡΙΑ K

Lyra sets at sunset

H ΙΧΘΥΕΣ ΑΡΧΟΝΤΑΙ ΕΠΙΤΕΛΛΕΙΝ A

Pisces begin to rise

Θ ΑΡΚΤΟΥΡΟΣ ΑΝΑΤΕΛΛΕΙ ΕΣΠΕΡΙΟΣ ΙΑ

Arcturus rises at sunset

I ΚΡΙΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ A

Caprcorn besins to rise

ΙΣΗΜΕΡΙΑ ΕΑΡΙΝΗ A

Spring equinox

K ΠΛΕΙΑΔΕΣ ΔΥΝΟΥΣΙ ΕΣΠΕΡΙΑΙ ΙΑ

Pleiades set at sunset

Λ ΥΑΔΕΣ ΔΥΟΝΤΑΙ ΕΣΠΕΡΙΑΙ ΚΑ

Hyades set at sunset

M ΤΑΥΡΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ A

Bul begins to rise

N ΛΥΡΑ ΕΠΙΤΕΛΛΕΙ ΕΣΠΕΡΙΑ Δ

Lyra rises at sunset

Ξ ΠΛΕΙΑΣ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ I

Pleiades rise in the morning

Ο ΥΑΣ ΕΠΙΤΕΛΛΕΙ ΕΩΙΑ Δ

Hyades rise in the morning

Π ΔΙΔΥΜΟΙ ΑΡΧΟΝΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Gemini begin to rise

Π ΑΕΤΟΣ ΕΠΙΤΕΛΛΕΙ ΕΣΠΕΡΙΟΣ I

Aegle rises in the evening

Σ ΑΡΚΤΟΥΡΟΣ ΔΥΝΕΙ ΕΩΙΟΣ I

Arcturus sets in the morning

Α ΧΗΛΑΙ ΑΡΧΟΝΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Libra begin to rise

ΙΣΗΜΕΡΙΑ ΦΘΙΝΟΠΩΡΙΝΗ Α

Autumn equinox

Β ΕΡΙΦΟΙ ΕΠΙΤΕΛΛΟΥΣΙΝ ΕΣΠΕΡΙΟΙ

Chevres (little stars next to Spica, also Haedi or "the Kids") rise in the evening

Γ ΠΛΕΙΑΣ ΕΠΙΤΕΛΛΕΙ ΕΣΠΕΡΙΑ ΙΔ

Pleiades rise in the evening

Δ ΣΤΕΦΑΝΟΣ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ ΙC

Crown rises in the moorning

Ε ΣΚΟΡΠΙΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Scorpio begins to rise

Ζ ΑΡΚΤΟΥΡΟΣ ΔΥΝΕΙ ΕΣΠΕΡΙΟΣ Α

Arcturus sets in the evening

Η ΠΛΕΙΑΔΕΣ ΔΥΝΟΥΣΙ ΕΩΙΑΙ ΙΔ

Pleiades set in the moorning

Θ ΛΥΡΑ ΕΠΙΤΕΛΛΕΙ ΕΩΙΑ ΙΔ

Lyra rises in the morning

Ι ΤΟΞΟΤΗΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Sagittarius begins to rise

Κ ΚΥΩΝ ΔΥΝΕΙ ΕΩΙΟΣ Α

The Dog set in the morning

Λ ΩΡΙΩΝ ΔΥΝΕΙ ΕΩΙΟΣ

Orion set in the morning

Μ ΚΑΡΚΙΝΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Cancer (The Crab) begins to rise

ΤΡΟΠΑΙ ΘΕΡΙΝΑΙ Α

Sumer solstice

Ν ΩΡΙΩΝ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ ΙΑ

Oorion rises in the morning

Ξ ΚΥΩΝ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ ΚΖ

The Dog rises in the morning

Ο ΑΕΤΟΣ ΔΥΝΕΙ ΕΩΙΟΣ ΚΗ

Aegle sets in the mrning

Π ΛΕΩΝ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Leo begins to rise

Ρ ΙΠΠΟΣ ΕΠΙΤΕΛΛΕΙ ΕΣΠΕΡΙΟΣ ΙC

Horse rises in the evening

Σ ΛΥΡΑ ΔΥΝΕΙ ΕΩΙΑ ΙΖ

Lyra sets in the morning

Τ ΔΕΛΦΙΣ ΔΥΝΕΙ ΕΩΙΟΣ ΙΗ

Delphis sets in the morning

Υ ΠΑΡΘΕΝΟΣ ΑΡΧΕΤΑΙ ΕΠΙΤΕΛΛΕΙΝ Α

Virgo begins to rise

Φ ΟΙΣΤΟΣ ΔΥΝΕΙ ΕΩΙΟΣ Θ

Sagitta (Canna, Calamus), sets in the morning

Χ ΑΙΞ ΕΠΙΤΕΛΛΕΙ ΕΣΠΕΡΙΑ Ι

Capella rises in the evening

Ψ ΠΡΟΤΡΥΓΗΤΗΡ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ ΙΘ

Protrygerer (star next to Spica, Virgo) rises in the morning

Ω ΑΡΚΤΟΥΡΟΣ ΕΠΙΤΕΛΛΕΙ ΕΩΙΟΣ

Arcturus rises in the morning

26.2 Olympic dial

LA ΙΣΘΜΙΑ (Isthmia)

ΟΛΥΜΠΙΑ (Olympia)

LB ΝΕΜΕΑ (Nemea)

ΝΑΑ (Naa)

LΓ ΙΣΘΜΙΑ (Isthmia)

ΠΥΘΙΑ (Pythia)

LΔ ΝΕΜΕΑ (Nemea)

ΑΛΙΕΙΑ (Halieia)

26.3 Epirotic (Corinthian, Doric) Months

ΦΟΙΝΙΚΑΙΟΣ (Phoinikaios)

ΚΡΑΝΕΙΟΣ (Kraneios)

ΗΛΙΟΤΡΟΠΙΟΣ (Helliotropios)

ΜΑΧΑΝΕΥΣ (Machaneus, "mechanic",

ΔΩΔΕΚΑΤΕΥΣ (Dodekateus)

ΕΥΚΛΕΙΟΣ (Eukleios)

ΑΡΤΕΜΙΣΙΟΣ (Artemisios)

ΨΥΔΡΕΥΣ (Psydreus)

ΓΑΜΕΙΛΙΟΣ (Gameilios)

ΑΓΡΙΑΝΙΟΣ (Agrianios)

ΠΑΝΑΜΟΣ (Panamos)

ΑΠΕΛΛΑΙΟΣ (Apellaios)

ΦΟΙΝΙΚΑΙΟΣ (Phoinikaios)

ΚΡΑΝΕΙΟΣ (Kraneios)

ΗΛΙΟΤΡΟΠΙΟΣ (Helliotropios)

ΜΑΧΑΝΕΥΣ (Machaneus, "mechanic",

ΔΩΔΕΚΑΤΕΥΣ (Dodekateus)

ΕΥΚΛΕΙΟΣ (Eukleios)

ΑΡΤΕΜΙΣΙΟΣ (Artemisios)

ΨΥΔΡΕΥΣ (Psydreus)

ΓΑΜΕΙΛΙΟΣ (Gameilios)

ΑΓΡΙΑΝΙΟΣ (Agrianios)

ΠΑΝΑΜΟΣ (Panamos)

ΑΠΕΛΛΑΙΟΣ (Apellaios)

26.4 Zodiac

ΚΡΙΟΣ (Krios [Ram], Aries)

ΤΑΥΡΟΣ (Tauros [Bull], Taurus)

ΔΙΔΥΜΟΙ (Didymoi [Twins], Gemini)

ΚΑΡΚΙΝΟΣ (Karkinos [Crab], Cancer)

ΛΕΩΝ (Leon [Lion], Leo)

ΠΑΡΘΕΝΟΣ (Parthenos [Maiden], Virgo)

ΧΗΛΑΙ (Chelai [Scorpio's Claw or Zygos], Libra)

ΣΚΟΡΠΙΟΣ (Skorpios [Scorpion], Scorpio)

ΤΟΞΟΤΗΣ (Toxotes [Archer], Sagittarius)

ΑΙΓΟΚΕΡΩΣ (Aigokeros [Goat-horned], Capricorn)

ΥΔΡΟΧΟΟΣ (Hydrokhoos [Water carrier], Aquarius)

ΙΧΘΥΕΣ (Ichthyes [Fish], Pisces)

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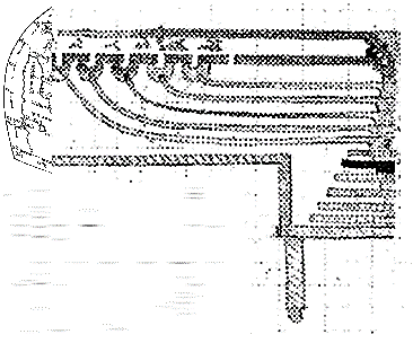

Figure 82 A schematic of a planetarium by Albert Rhem, 1910

Figure 83 A portable solar clock and mini astrolabe, 23-24 centuries ago from Greece. Suitable to be used in many cities and at all latitudes. Construction by Mr Dionysis Kriaris

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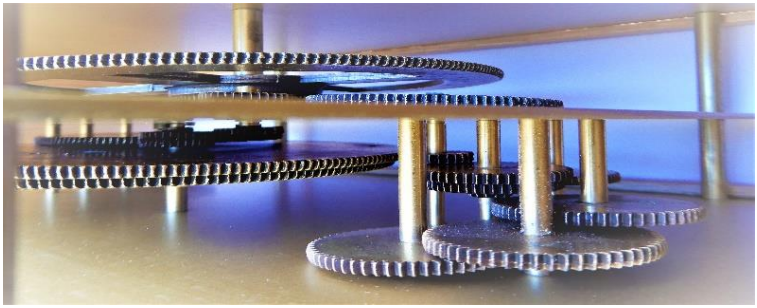

Figure 84 Gears of the mechanism.

[i] Alexander Phil., In Aristotelis topicorum libros octo commentaria Page 22, line 21 συγγενεῖς δὲ λέγοι ἂν

γεωμετρίᾳ ἐπιστήμας ἀριθμητικήν (καὶ γὰρ αὕτη περὶ ποσόν, ἀλλὰ διωρισμένον), ἔτι δὲ ἀστρονομίαν καὶ ὀπτικὴν καὶ μηχανικήν· προσχρῶνται γὰρ αὗται ταῖς γεωμετρικαῖς ἀρχαῖς.

[ii] Nicomachus Math., Introductio arithmetica (0358: 001) "Nicomachi Geraseni Pythagorei introductionis arithmeticae libri ii", Ed. Hoche, R. Leipzig: Teubner, 1866. Book 1, chapter 3, section 7. … καθὰ καὶ ὁ παρὰ Πλάτωνι ἐν τῇ πολιτείᾳ Σωκράτης τοῦ προσδιαλεγομένου αἰτίας τινὰς εὐλόγους ἐπιφέρειν δοκοῦντος τοῖς μαθήμασιν, ὡς εὔχρηστά εἰσι πρὸς τὸν ἀνθρώπινον βίον, ἡ μὲν ἀριθμητικὴ πρὸς λογισμοὺς καὶ διανομὰς καὶ συνεισφορὰς καὶ ἀμείψεις καὶ κοινωνίας, ἡ δὲ γεωμετρία πρὸς στρατοπεδεύσεις πόλεών τε καὶ ἱερῶν συγκτίσεις καὶ γεωμορίας, ἡ δὲ μουσικὴ πρὸς ἑορτὰς καὶ θυμηδίας καὶ θεῶν θρησκείας, σφαιρικὴ δὲ καὶ ἀστρονομία πρὸς γεωργίας τε καὶ ναυτιλίαν καὶ τὰς ἄλλας καταρχὰς τῶν πράξεων εὐχερείας καὶ ἐπιτηδειότητας προδηλοῦσα, ἐπιπλήττων φησίν· ὡς ἡδὺς εἶ, ὅτι ἔοικας δεδιέναι, μὴ ἄρα ἄχρηστα ταῦτα τὰ μαθήματα προστάττοιμι·

[iii] Πλάτωνος, " Μενέξενος" 347a πᾶσά τε ἐπιστήμη χωριζομένη δικαιοσύνης καὶ τῆς ἄλλης ἀρετῆς πανουργία, οὐ σοφία φαίνεται.

[iv] *Xenophontis commentarii,* τὸ δὲ μέχρι τούτου ἀστρονομίαν μανθάνειν, μέχρι τοῦ καὶ τὰ μὴ ἐν τῇ αὐτῇ περιφορᾷ ὄντα, καὶ τοὺς πλάνητάς τε καὶ ἀσταθμήτους ἀστέρας γνῶναι [κομήτες;], καὶ τὰς ἀποστάσεις αὐτῶν ἀπὸ τῆς γῆς καὶ τὰς περιόδους καὶ τὰς αἰτίας αὐτῶν ζητοῦντας κατατρίβεσθαι.

[v] Plato Phil., Symposius, Stephanus page 188, section b, line 6 … ἐπιστήμη περὶ ἄστρων τε φορὰς καὶ ἐνιαυτῶν ὥρας ἀστρονομία καλεῖται.

[vi] Eudemus Phil., Fragmenta (1357: 001) "Eudemos von Rhodos", Ed. Wehrli, F. Basel: Schwabe, 1969; Die Schule des Aristoteles, vol. 8, 2nd edn.. Fragment 31,

line 2 Simplicius In Aristotelis Physica I comment. Prooemium p.7, 10 Diels: πλὴν ὅ γε Πλάτων τά τε τῶν Πυθαγορείων καὶ τῶν Ἐλεατικῶν ἐπὶ ὸ σαφέστερον προαγαγὼν τά τε ὑπὲρ τὴν φύσιν ἐξύμνησεν ἀξίως κἀν τοῖς φυσικοῖς καὶ γενητοῖς τὰς στοιχειώδεις ἀρχὰς τῶν ἄλλων διέκρινε καὶ στοιχεῖα πρῶτος αὐτὸς ὠνόμασε τὰς τοιαύτας ἀρχάς, ὡς ὁ Εὔδημος ἱστορεῖ, καὶ τὸ ποιητικὸν αἴτιον καὶ τὸ τελικὸν καὶ ἔτι πρὸς τούτῳ τὸ παραδειγματικόν, τὰς ἰδέας, αὐτὸς θεασάμενος διέκρινε· καὶ γὰρ τὴν ὕλην ταῖς αὐταῖς χρώμενος ἐννοίαις ἐς ὕστερον Ἀριστοτέλης ἀνεῦρε, καὶ τὸ εἶδος ὁμοίως· ποιητικόν τε αἴτιον τὸν θεῖον ἐφίστησι νοῦν καὶ τελικὸν τὴν τούτου ἀγαθότητα, δι' ἣν τὸ αἰσθητὸν πᾶν πρὸς τὸ νοητὸν παράδειγμα ἀφωμοίωσεν.

[vii] Alexander Phil., In Aristotelis metaphysica commentaria (0732: 004) "Alexandri Aphrodisiensis in Aristotelis metaphysica commentaria", Ed. Hayduck, M. Berlin: Reimer, 1891; Commentaria in Aristotelem Graeca 1. Page 812, line 6 τοῦ Πλάτωνος δὲ τὰς ἰδέας, ἃς καὶ οὐσίας καλεῖ, καὶ μᾶλλον οὐσίας, ἀριθμοὺς λέγοντος, τῶν δὲ ἀριθμῶν ποσῶν ὄντων, καὶ διὰ τούτου συναγομένου τοῦ τὰς οὐσίας εἶναι ποσά (εἰ γὰρ αἱ ἰδέαι ἤτοι αἱ οὐσίαι ἀριθμοί, οἱ δὲ ἀριθμοὶ ποσά, δῆλον τὸ συμπέρασμα), ἐρωτᾷ ὁ δαιμόνιος Ἀριστοτέλης, πότερον διαφέρει ἡ οὐσία τοῦ ποσοῦ ἢ ἡ αὐτή ἐστι τῷ ποσῷ.

[viii] Michaelis Pselli theologica, vol. 1, Ed. Gautier, P.Leipzig: Teubner, 1989. Opusculum 55, line 125 ὁ μὲν γὰρ Ἀριστοτέλης καὶ τῆς ὕλης κατηγορεῖ τὸ ἀγέννητον· ὁ δὲ Πλάτων ἀγεννήτους τὰς ἰδέας φησίν

[ix] Μηδείς αγεωμέτρητος εισίτω μου την στέγην [also θύραν]

[x] Gibson, G.N. and Johnston, I.D., 2002. New themes and audiences for the physics of music. Physics Today, 55(1), pp.42-48.

Gibson, S., 2014. Aristoxenus of Tarentum and the Birth of Musicology. Routledge.

[xi] Foster, B., 2005. CERN, the violin and the music of the spheres. CERN Courier, p.41.

[xii] Aristoxenus (Fr. 29, Wehrli)