

SUNDIALS: CULTURAL HERITAGE OBJECTS AS PROOFS OF ANAXIMANDER'S ASTRONOMICAL KNOWLEDGE

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Abstract. Here are discussed ideas and philosophical views of Anaximander of Miletus (611/610 – 547/546 B.C.), one of the most important Pre-Socratic philosophers, the first who tried to give a scientific view of the World, free from mythology, about the nature of celestial bodies and Earth's position in the Universe, and his contribution to practical astronomy and introduction of sundials in Greek world.

Key words: History of Astronomy – Astronomy in culture – Anaximander – Sundials – Presocratics– Philosophy of Science .

1. INTRODUCTION

Anaximander of Miletus (611/610 – 547/546 B.C.) is one of the most important Pre-Socratic Philosophers. He was the first who tried to give a scientific view of the World, free from mythology (Diels (1996), fr. 2,7). He belonged to the Milesian school founded in the 6th century B.C. in Miletus in Ionia, Asia Minor (nowadays belongs to Turkey) and succeeded Thales of Miletus, the Greek mathematician, astronomer and pre-Socratic philosopher from Miletus who was the founder of the Milesian philosophical thought.

He introduced the prospect of an infinite Universe endless in time and space, and believed in the existence of a natural law, a kind of cosmic justice, keeping the four primary elements in balance (Theodossiou *et al.*, 2010/2011). Anaximander was a supporter of a unified account of all of nature and believed that the originating cause of the world is *ἄπειρον* (the 'infinite'), a common, undetermined principle substance (Simplicius (1895), *In Physics*, 24, 13 DK 12 a 9), eternal and unchangeable cosmological essence, which is the origin of all things who finally return in it. In his cosmology worlds are innumerable. They are born from the apeiron and, when destroyed, absorbed by it.

About the apeiron of Anaximander, Diogenes Laertius wrote:

“Anaximander, the son of Praxiades, was a native of Miletus. He laid down as his principle an element that which is unlimited without defining it as air or water or anything else. He held that the parts undergo change, but the whole is unchangeable” (Laertius (1964), Book II, 1).

He also has written about astronomy, geography and the nature of things.

In our work his philosophical thoughts about the nature of celestial bodies and Earth's position in the Universe are presented and then his contribution in practical astronomy is discussed.

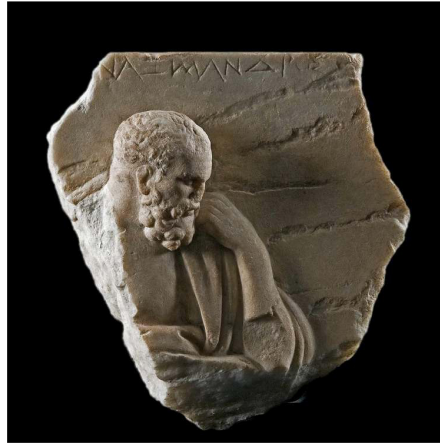


Fig. 1 – A marble relief depicting the Greek philosopher Anaximander of Miletus (*c* 610 – *c* 546 BC). Roman copy of a Greek original (Museo Nazionale Romano, Rome, <https://www.ancient.eu/image/6161/anaximander-of-miletus/>).

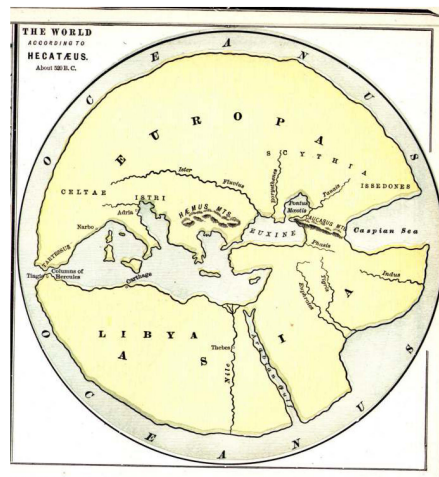


Fig. 2 – Anaximander's map, which includes North Africa, Asia and Europe encircled by Oceanus (<http://www.mappery.com/>).

2. ANAXIMANDER'S VIEWS ABOUT CELESTIAL BODIES

Anaximander's work on astronomy and his systematic philosophical view of the world is highlighted in other works and historical documents (see *e.g.* Theodossiou *et al.* (2010/2011)). For example, he discovered astronomical facts as the rotation of Earth and its separation from the celestial sphaera. According to Theon of Smyrna, Greek philosopher and mathematician (70 AD – 135 AD), who is strongly influenced by the Pythagorean school of thought, Anaximander asserts that the Earth is flat and cylindrical, having the shape of a drum, and float free in the universe and moves around its center (κινείται περι το του κοσμου μεσον) (Theon of Smyrna, *De utilitate mathimatecae* 198, 19). Consequently, He was probably the first Greek philosopher who spoke about movement of the Earth around the center of the world who may be even the Sun (Theodossiou *et al.*, 2009), and abandoned the geocentric system, which, due to its accordance with the everyday experience, has predominated over long time. Apart from this motion around the center of the Cosmos the Earth is unsupported (μετεωρος) as he seems to have intuitively perceived the Earth's position in the universe.

However, later Anaximander accepts a geocentric arrangement of the Cosmos, inside the spherical Universe, and spherical shape of the Earth, while the rest of the planets are orbiting around Earth: “*That the earth, which is of spherical shape, lies in the midst, occupying the place of a centre*” (Diogenes Laertius, Book II, 1, p. 131). Earth is on the equilibrium in the center of the spherical Universe, because it is on equal distances from the ends of this sphere, while the stars are fixed on the inside of it.

Moreover, according to Anaximander, the Moon is a non-luminous object and glows by reflecting the light of the Sun; the Sun is bigger than the Moon and consists of purest fire (καθαρωτατον πυρ) (Diogenes Laertius, *Vitae*, II, 1, 6). These views are reinforced by modern experimental astronomical research. The Sun is much bigger than the Earth and thermonuclear reactions occurring inside the Sun, indeed, produce large amounts of energy.

Concerning the creation of celestial bodies, he claims that they are created after the separation of a fiery circle from the fire of the world and are surrounded by air. Astrophysical research shows that the heavenly bodies are made up of chemical elements which are initially created by nuclear fusion reactions within stars (stellar nucleosynthesis) and surrounded by a layer of gas or a set of layers of gases (atmosphere).

Regarding celestial bodies, the philosopher argues that they are created after the separation of a fire cycle from the fire of the world and are surrounded by air. Inside these circles there are exhalation holes, pores like grooves, through which the celestial bodies are visible, while when they are blocked, the eclipses are caused. If

we consider that the creation of the stars is indeed intertwined with fire, then we will see the correctness of the philosopher's views on the nature of the Sun. Something similar obviously does not apply in the case of eclipses. In fact, the Moon shows when to fill and when to fall, depending on the opening of resources (Hippolytus, *Refutatio*, I, 6, 4–8). The circle of the Sun is 27 times larger than the Earth, while that of the Moon 18. A relative explanation is that these circles refer to the rotational motion of celestial bodies on huge rings. The Sun is also higher than the celestial bodies, while the circles of the simple stars are lower. Despite the fact that these positions contradict scientific data, they nevertheless show that Anaximander gave the structure of the world on a mathematical basis, possibly influencing Pythagoras as well (Kirk *et al.*, 2001). It is important to note, however, that Anaximander's activity has shown that the language of mathematics is an important tool for understanding the physical world.

Anaximander was earliest Greek known to have made a map of the world (πρωτος ετολμησε την οικουμενην εν πινακι γραψαι) (Anaximander, DK A, 6, 2). Then, Hecataeus of Miletus (550 BC – c. 476 BC), Greek historian and geographer improved Anaximander's map, which includes North Africa, Asia and Europe encircled by Oceanus (Figure 2).

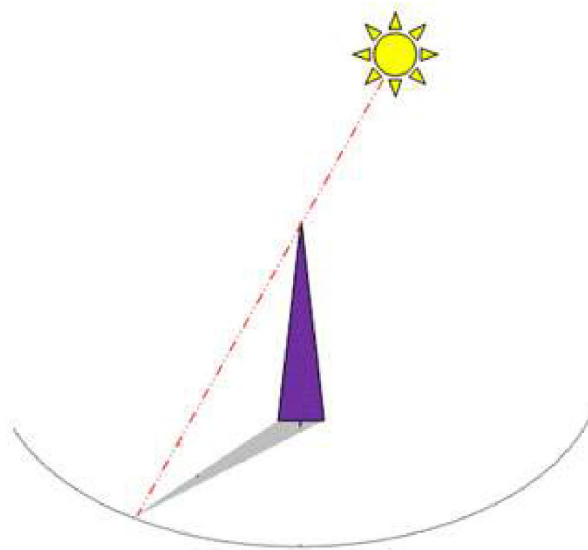


Fig. 3 – The gnomon and its shadow Panou (2016a), p. 78.

Although Anaximander's views about cosmos and celestial bodies have no empirical data or other scientific findings, his philosophical approach concerning the

description of the model of Cosmos in antiquity is of great importance.

3. ANAXIMANDER: ASTRONOMICAL INSTRUMENTS AND TIME MEASUREMENTS

Anaximander's of Miletus contribution in practical astronomy and scientific tradition is crucial. He invented and constructed astronomical instruments for sky observations and measuring time intervals. Anaximander was the first in Greece to construct a time-telling instrument, the gnomon, which was erected in the prominent city-state of ancient Greece, Lacedaemon (modern Sparta) in order to mark the solstices and equinoxes (Diogenes Laertius, II, 1, 7)*

According to Herodotus the gnomon as well as the celestial sphere and the division of the day into twelve parts became known to Greeks by Babylonians (Herodotus, *Historiae*, II, 109, 11). However, Anaximander is said to have invented (Suda, lexical entry: Γνωμων † 346, 1 (Gnomon)) and designed the first gnomon for distinguishing the solar tropics, times, seasons and equinoxes (Eusebius in his work *Praeparatio Evangelica*, (10, 14, 11)).

The gnomon is a style that is placed perpendicular to the ground (Figure 3). It is the symbol of the axis mundi; an imaginary line connecting heaven and Earth. When it is exposed to the sun light a shadow is created on the ground which represents the projection of the orbit of the Sun on the Earth's surface. Gnomon is the first simplified astronomical instrument. In antiquity, it was placed in open air spaces for measuring Local True Solar Time (LTST), which is measured from the lower culmination (Foken, 2017, p. 345) and is different for each place. Gnomon was also widely used in antiquity in many countries such as Egypt where it was of great importance for these societies since their activities such as planting had to be accurately calculated. Moreover, a gnomon was used in order to find the time of the year and geographical direction (Isler, 1991). Also, a typical giant-sized gnomon widely used may be a pillar named obelisk such as the Obelisk/Gnomon of the Horologium of Augustus initially erected in Heliopolis Egypt (7th century BC). The obelisk was taken in Rome by Caesar Augustus and was set up in the Campus Martius near the Ara Pacis Augustae and was used as the gnomon (or needle) of the Horologium, a great sundial and calendar (Figure 4).

*Anaximander DK A 1, 7. ευρεν δε και γνωμονα πρωτος και εστησεν επι των σκιοθηρον εν Λακεδαιμονι, καθα φησι Φαβωρινος εν Παντοδαπη ιστοριαι [fr. 27 FHG III 581], τροπας τε και ισημεριας σημαινοντα και ωροσκοπεια κατεσκευασε). He was the first inventor of the gnomon and set it up for a sundial in Lacedaemon, as is stated by Favorinus in his Miscellaneous History, in order to mark the solstices and the equinoxes; he also constructed clocks to tell the time.

†Γνωμων το εν τοις ηλιοτροπιοις πηγνυμενον οπερ εφευρεν Αναξιμανδρος και εστησεν επι των σκιοθηρων which is translated in English as *sticked for the solar tropics and invented by Anaximander who sticked it for hunting the shadows*

Gnomon gave a boost to astronomy as it is the ancestor of other simple complex astronomical instruments. The most common astronomical instrument in Greco-Roman world was the sundial. Sundials as well as the gnomon measured true solar time. A sundial consists of a gnomon inclined in respect to the geographical latitude of the place and a plate (dial plate).



Fig. 4 – Obelisk/Gnomon of the Horologium of Augustus
<https://deathintheancientworld.files.wordpress.com/2018/05/5.jpg>

Anaximander used the gnomon for determining the duration of the seasons and pointed out that the created shadow at noon is longest at summer solstice, the longest day of the year. Despite difficulties in determining the length of the median shadow

(the shadow at noon) at equinoxes he finally managed to determine the solstices and the equinoxes. The use of gnomon in measuring time in antiquity and its contribution in astronomy is also mentioned by Proclus in (the) *Commentary on the First Book of Euclid's Elements* (41, 25-42). Hipparchus of Nicaea, Greek astronomer and mathematician of the 2nd century B.C. uses the gnomon as an astronomical instrument for measuring time intervals. Hipparchus' contribution in astronomy is crucial as he is considered as a distinguished inventor and manufacturer of astronomical instruments. It is also mentioned that he was always taking care of his astronomical equipment such as rings in order to achieve as much accuracy he could in his measures (Panou, 2016a). In the literature is also mentioned that the great ancient Greek astronomer was the only one who had to a great extent the sense of the principles of accuracy in measurements and the continuous and uninterrupted observation and recording of phenomena (Antoniades, 1938, p. 25). The Hipparchus catalog and the accuracy of determining the positions of the stars using appropriate astronomical instruments enabled to him to know at any time the position of the celestial bodies, if one disappears or appears and moreover if their brightness changes (see also Pliny, *Natural History*, II, 95).

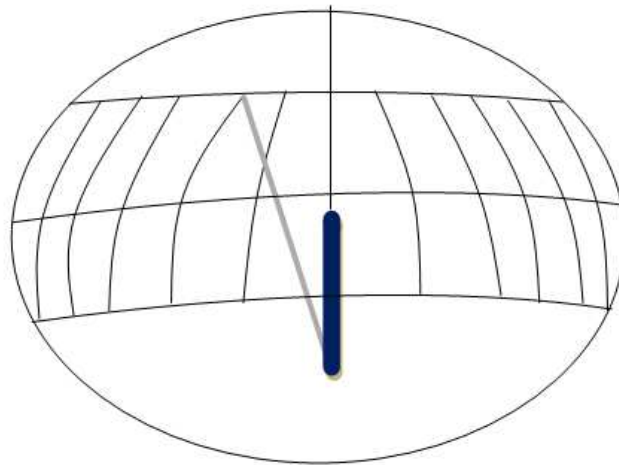


Fig. 5 – Hemispherical sundial with a central gnomon point.

Concerning the astronomical instruments, Anaximander also constructed time-telling instruments known as *ωρολογεῖα* or *ωροσκοπεῖα* for measuring time intervals and marking the solstices and equinoxes (Diogenes Laertius, II, 1, 7). It is said that Anaximander was the first in Greece who invented the sundials and marked the solstices (Suda, lexical entry: *πρωτος δε ισημεριαν ευρε και τροπας και*

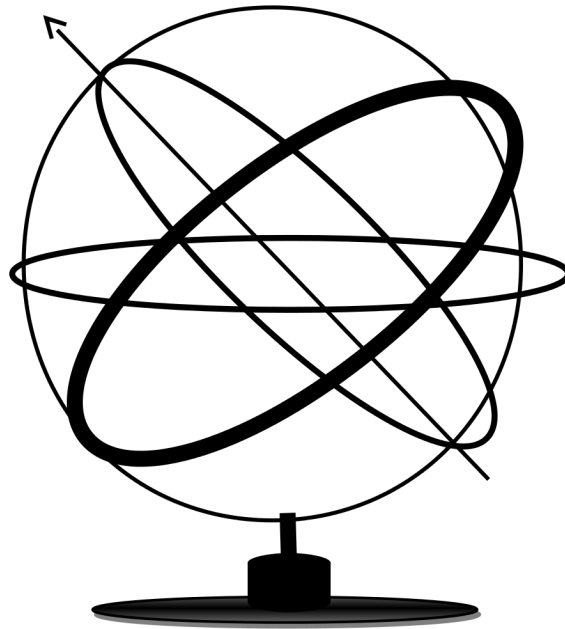


Fig. 6 – Armillary (celestial) Sphere.

ωρολογεα). In ancient Greece sundials were called heliotropes. Around 250 B.C. Eratosthenes created a variety of sundials called scaphions (bowl) which formed the basis of hollow sundials (Rohr, 1996, p. 10). In the literature is stated that Anaximander and Eratosthenes improved a hemispherical sundial with a central gnomon point (Figure 5). This implies that Anaximander was expert in sundials' construction and time measurements.

He attempted to describe the earth rotation, the fixed stars and the celestial sphere (Suda, lexical entry: Αναξιμανδρος εγραψε περι φυσεος γης περιδον και περι των απλανων και σφαιραν και αλλα τινα. He also built a (celestial) sphere (Diogenes Laertius, II, 2) which later was widely used by prominent astronomers such as Hipparchus and Claudius Ptolemy (extensively see his work *Syntaxis Mathematica* - Almagest). The celestial sphere known as armillary sphere is an astronomical instrument representing the apparent surface of the heavens. It consists of spherical fixed and movable rings that represent the principal circles of the heavens, such as the celestial equator and the ecliptic, on which the stars seem to be fixed. It is constructed on the basis of the geocentric model. Therefore, the Earth is placed at the center.



Fig. 7 – Sundial with the sculptures of Atlas, Heracles and Iphicles (twin brother of Heracles), Sirmium, Pannonia Inferior, Serbia. Author Carole Raddato (commons.wikimedia).

4. SUNDIALS: OBJECTS OF ASTRONOMICAL KNOWLEDGE

Anaximander was the first to construct in Greece the simple astronomical instrument, gnomon, and sundial based on it, known for centuries in Egypt and in the Middle East. For example, the Old Testament mention, describing events from 8th century B.C., the sundial of Akhaz (Isaiah 38:8 and 2 Kings 20:9). After Anaximander, great ancient Greek astronomers continue the astronomical tradition and improve the astronomical instrumentation. The most known is Aristarchus of Samos

(c. 310–250 BC), Eudoxus of Cnidus (409–356 BC), Apollonius of Perga (261–190 / 179 BC), Hipparchus of Nicaea (or Rhodes) (2nd century BC), Heron of Alexandria (1st century BC–1st century) and Claudius Ptolemy (2nd century). Ancient inventors and manufacturers of sundials who lived from the 6th century to the 3rd century B.C. are mentioned in Vitruvius' catalog. They constructed sundials with a grid of lines (hour lines) and curves (solstices, equinoxes) in order to identify the daily hour and the season of the year. Therefore, the sundial served as a calendar. Moreover, earlier astronomers such as Thales (Aetius, *De placitis reliquiae*, 340, 19–22) and Oenopides are credited in Greece with the discovery of solstices and the discovery of the obliquity of the ecliptic respectively (Heron, *Definitiones*, 138, 11, 6). Both the identification of the solstices and the obliquity of the ecliptic are crucial for constructing sundials.

Archaeological excavations of Greek and Roman sites led to the discovery of stone/marble objects which have been labelled “sundials” (Gibbs, 1976). Some sundials and sundials' fragments from Greek and Roman antiquity are displayed at museum exhibitions in Europe such as the sundials at Museum of Athens (Panou, 2016a; Panou *et al.*, 2020) and in the museum of Sirmium in Sremska Mitrovica (Tadić, 2002); others are parts of a monument such as the sundials of the Horologion of Andronikos Kyrrehestes (Tower of Winds), Athens, Greece (Panou and Liritzis, 2017–2018).

The sundials displayed at Museums of Athens (National Archaeological Museum, Piraeus Museum, Stoa of Attalos at the Athens Agora, Epigraphical Museum of Athens) date to the Hellenistic and Roman Period. They are all mass sundials. Two of them still have gnomon (Panou *et al.*, 2020; Panou, 2016a,b; Panou *et al.*, 2013c). The majority of them are of conical type (Panou *et al.*, 2020; Panou, 2016a; Panou *et al.*, 2014); two are of cylindrical type (Panou, 2016a; Panou *et al.*, 2013b); one of spherical type (Panou, 2016a; Panou *et al.*, 2013c); and two wall sundials (Panou, 2016a; Panou *et al.*, 2013a). The study of these ancient sundials lead to conclusion that sundials were used as common instruments for measuring time in antiquity and as astronomical instruments for measuring small or/and large time intervals throughout the year as well. The carved curves and lines on the surface of these sundials shows that the astronomical knowledge was essential for ancient daily life. The accuracy of their construction shows that in ancient times the identification of the solstices, the equinoxes and the value of obliquity of the ecliptic was of great importance for measuring time intervals. The majority of these sundials have been constructed for regions surrounding the Mediterranean Sea due to the sunny weather. Therefore, the sundials were astronomical instruments used in regions where the ancient Greek civilization and culture flourished (Panou *et al.*, 2020).

5. CONCLUSION

As a conclusion Anaximander's contribution to science should not be limited only on Philosophy but also extends to the Astronomy and particularly to the field of instrumentation. Not only had he attempted to explain celestial phenomena such as eclipses but he also tried to understand the nature of celestial bodies as well as developing the proper instruments in order to observe their positions. To Anaximander is attributed the introduction of sundials in Greek world, and the construction of the first simple sundial in Greece based on the use of gnomon. Nowadays, the sundials displayed at museums of Athens show that humans organize their life using exact measurement of time continuously over the centuries. Their ornamental character of several of them also shows that they were on display in public places and that they were a status symbol as well. Generally, the study of the sundials permits a better and appropriate Greek as well as universal scientific cultural heritage presentation. Finally, it can be said that the sundials are ancient cultural heritage objects which verify the astronomy knowledge written in ancient astronomical and mathematical treatises.

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