

ANCIENT GREEK HELIOCENTRIC VIEWS HIDDEN FROM PREVAILING BELIEFS?

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Abstract: We put forward the working hypothesis that the heliocentric, rather than the geocentric view, of the Solar System was the essential belief of the early Greek philosophers and astronomers. Although most of them referred to the geocentric view, it is plausible that the prevalent religious beliefs about the sacred character of the Earth as well as the fear of prosecution for impiety (*asebeia*) prevented them from expressing the heliocentric view, even though they were fully aware of it. Moreover, putting the geocentric view forward, instead, would have facilitated the reception of the surrounding world and the understanding of everyday celestial phenomena, much like the modern presentation of the celestial sphere and the zodiac, where the Earth is at the centre and the Sun makes an apparent orbit on the ecliptic. Such an ingenious stance would have set these early astronomers in harmony with the dominant religious beliefs and, at the same time, would have helped them to 'save the appearances', without sacrificing the essence of their ideas.

In Hellenistic and Roman times, the prevailing view was still the geocentric one. The brilliant heliocentric theory advanced by Aristarchos in the early third century B.C. was never established, because it met with hostility in Athens—Aristarchos was accused of impiety and faced the death penalty.

The textual evidence suggests that the tight connection which existed between religion and the city-state (*polis*) in ancient Greece, and which led to a series of impiety trials against philosophers in Athens during the fifth and fourth centuries B.C., would have made any contrary opinion expressed by the astronomers seem almost a high treason against the state.

Keywords: heliocentric Solar System, geocentric Solar System, spherical Universe, impiety, 'save the appearances'

1 INTRODUCTION: THE HELIOCENTRIC VERSUS THE GEOCENTRIC VIEW IN ANCIENT GREEK ASTRONOMY

In this paper we propose the working hypothesis that the actual belief of the early Greek philosophers and astronomers was the heliocentric, rather than the geocentric, view of the Solar System.¹ As an indication of the heliocentric view of the world we take the assumption of a spherical Universe, which is considered as "... the most fundamental assumption of Greek astronomy." (Evans, 1998: 75, cf. 216-219). It is possible that the idea of a spherical cosmos existed already among the Ionian philosophers, at least from Anaximander onwards (Kahn, 1960: 92-94; Vernant, 1983: 180, 183, 187, 190-211),² but perhaps even much earlier, and that it was not expressed clearly, because it ran counter to the conventional religious views and/or because it aided the perception of everyday celestial phenomena.

The earliest evidence about the astronomical knowledge of the ancient Greeks dates from the eighth century B.C. It is found in the epic poems of Homer and Hesiod (Aveni and Ammerman, 2001; Dicks, 1970: 27-38; Evans, 1998: 3-5; Papathanassiou, 2007), while some archaeological correlates to this written evidence have been pointed out recently (Coucouzeli, 2006; Dimitrakoudis et al., 2006). Astronomical knowledge appears to have been used in eighth century B.C. Greece for the purposes of cultivation, navigation, calendar regulation, worship and even politics.

However, astronomical interest in Greece seems to go much further back in time, to the second millennium B.C. An important source of information in this respect is the Orphic texts (*Orphica*). Although these texts were recorded and translated at the time of Peisistratos (sixth century B.C.) or, mostly, in later times (Kern, 1922; West, 1983), they seem to have existed for many centuries. According to Chassapis (1987), the Orphic Hymns were formulated in the period between 1841 and 1366 B.C. (i.e. during the Minoan and Mycenaean times), since they seem to refer to the vernal equinox and the summer solstice, when these took place in the Taurus and Leo constellations, respectively, up to 1841 B.C., as well as to the phenomenon of the equality of the summer and winter seasons, which occurred around 1366 B.C. In addition, the Orphics appear to have known about the sphericity of the heavens as well as the two basic postulates of the heliocentric theory, according to which: a) the Earth is spherical and rotates around its own axis; and b) the movement of the Earth around the Sun causes the occurrence of the four seasons. In fact, the Orphics were teaching about the equal duration of the Earth's rotation and of the apparent motion of the celestial sphere around the same axis (cf. Orpheus saying to his son Musaeus: "...as this (the Earth), which is round, rotates in equal time round its own axis."—Aristobulus' fragment '*Diatheke*' or 'Testament' from his *Explanation of the Mosaic Law* recorded in Eusebius, *Praeparatio Evangelica*, 13, 12), and they accepted the Sun explicitly as the centre of attraction, around which the Earth describes an ecliptic

orbit (*dromos*, i.e. ‘way’). They also appear to have introduced the notion of the zodiac circle, the names of the constellations, etc. (see also Ovenden, 1966; Papaathanassiou, 1991; 2007).

Turning to archaeology, there is now increasing evidence concerning the astronomical interest of the Minoans and Mycenaeans, thanks to numerous archaeoastronomical studies, which were conducted during the last decade in peak sanctuaries, palaces and tombs on Crete (Blomberg and Henriksson, 1996; 2000; 2003; 2005). The study of orientations of buildings has shown that the sunrise and sunset positions at the four solar stands, the full Moon and the heliacal setting of Arcturus, were all taken into account by the ancient inhabitants of Crete since the Early Minoan Age in an effort to establish a physical relationship between themselves and the sky for the sake of keeping a calendar, for navigation, and perhaps also for religious and political purposes (Henriksson and Blomberg, 1996: 113). Apart from orientations, a number of ceramic figurines representing animals, humans or parts of the human body from two peak sanctuaries on Crete have been interpreted, on the basis of ancient written accounts (e.g. Aratos), as having had an astronomical significance related to the recognition of the zodiac (Blomberg, 2000). Finally, a number of Linear B tablets from Pylos and Knossos, dating from later Mycenaean times, record calendar months (Papaathanassiou, 2007).

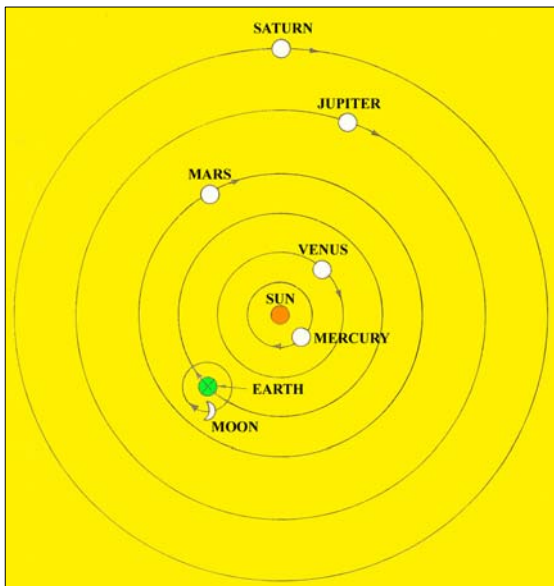


Figure 1: The heliocentric system of Aristarchos.

It is therefore possible that Greek astronomy slowly built upon this earlier knowledge going back to the Minoan and Mycenaean civilizations, which were as developed as those of Egypt and Babylon. This knowledge would have been transmitted from generation to generation into the so-called ‘Dark Ages’ (ca. 1100–700 B.C.) and into Archaic and Classical Greek times (e.g. Liritzis and Vassiliou, 2003). Observations may have been carried out by means of various types of sighting aids and measuring devices, such as the *gnomon*, the *klepsydra*, the *polos* or the *parapegma*, perhaps also including simple forms of armillary spheres (Dimitrakoudis et al., 2006) or even wooden

tubes (containing lenses?)³ in the manner of a primitive *dioptra* (cf. Evans and Berggren, 2006: 27–42).

To return to our basic assumption of a spherical Universe, it is worth pointing out that the symbolism of the circle was pre-eminent in traditional Greek cosmological thought. The two-dimensional circular shape was considered as the most perfect and sacred, and it must reflect some concept of the wider Universe as a sphere, the most beautiful and divine three-dimensional shape (Edmunds, 2006; cf. also Geminus’ *sphairopoieia*, i.e. the spherical construction of the cosmos according to nature, in his *Introduction to the Phenomena*—see Evans and Berggren, 2006: 51–53). The Greek philosophers’ consideration of the sphere as the shape of the divine substance is attested as early as Xenophanes (sixth century B.C.); it is further elaborated by Plato (*Timaeus*, 33b) and it is also encountered in Aristotle (*On the Heavens*, II. 286a10: “But such is the heaven, viz. a divine body, and for that reason it possesses the circular body which by nature always moves in a circle.”; Leggatt, 1995: 227; cf. Vernant, 1983: 183). However, the symbolism of the circle and the sphere may be a lot older. As we have seen, the accounts attributed to the Orphics refer to a spherical Universe with revolving celestial bodies and a solar centre. As far as the archaeological evidence is concerned, it is worth mentioning that a circle representing the two celestial hemispheres connected with the Dioskouroi, Castor and Pollux, seems to appear on a cryptographic seal dating from ca. 750–700 B.C. (Coucouzeli, 2006), while a series of votive artefacts, dating from ca. 750–480 B.C., may well represent celestial spheres with meridians and sometimes also an equator (Dimitrakoudis, et al., 2006).

The astronomical views and discoveries of the ancient Greek philosophers and astronomers, in particular those regarding the relative positions of the Earth and the Sun, are well-known and they date from the earlier historical era of Thales (ca. 624–547 B.C.) to the later times of Ptolemy (A.D. 87–150) (see, for instance, *Aristarchos the Samian*, 2003; Dicks, 1966, 1970; Heath, 1913; 1932; Kahn, 1960; Kirk, Raven and Schofield, 1983; Lloyd, 1970; 1973; 1991; Noack, 1992). All of them held the picture of a spherical Universe (see Dicks, 1966: 30) and, as we will show below, most of them seemed to artificially consider the Earth at the centre of the Universe. Indeed, throughout Greek cosmological thought, as a general rule, man’s position in the Universe is considered as a privileged one. Nevertheless, the doctrine that the Earth we inhabit occupies the centre of the Universe was contested. Some philosophers and astronomers even went as far as setting the Sun (or a fiery substance reminiscent of the Sun) in a central position, at the risk of being subjected to public anathema. A small number of relevant views is discussed below.

Thales (ca. 624–547 B.C.) conceived the Earth as a disc at the centre of the Universe, floating on water (an implication of the celestial equator?). He seems to have predicted the total solar eclipse on 28 May 585 B.C.—a major achievement, which cannot be explained on the basis of the existing evidence about his knowledge—and to have produced a model of the celestial globe. Thales may well have known about the actual movements of the celestial bodies, but could not express his views openly in opposition to existing

religious beliefs (the story about Thales' prediction of the solar eclipse has been widely discussed, e.g. by O'Grady, 2002). Anaximander (ca. 610-546 B.C.) envisaged the Earth suspended at the centre of a spherical Universe, he distinguished between fixed stars and planets, and he made the first attempt at a 'mechanical model' of the Universe, which appeared as a revolving sphere (Lloyd, 1970: 17). Anaximenes (ca. 585-525 B.C.) gave a privileged status to the Sun against the other celestial bodies in the spherical cosmos, arguing that it gave light to the Moon. A central role was also given to the Sun by Heraclitus (ca. 540-480 B.C.), who postulated that the celestial orbit had characteristics related to a constant law of cosmic fire (this is vaguely reminiscent of Newton's Law of global attraction). Pythagoras (ca. 572-495 B.C.) pictured a spherical Earth kept at the centre of the world by its equilibrium and containing a fiery core, the central 'hearth' ('Hestia'); he also advanced the idea of the revolution of the cosmic sphere on an axis passing through the centre of the Earth and he identified the five zones of the Earth (which were also adopted slightly later by Parmenides, ca. 504-450 B.C.). Oinopides of Chios (ca. 490-420 B.C.) identified the ecliptic as the oblique orbit of the Sun with respect to the celestial equator, which led to the definition of the four solar stands and the four seasons. Anaxagoras maintained that the Sun and all the stars in the spherical Universe are fiery stones, while the Moon is made of earth and receives its light from the Sun, thus providing the clearest explanation of the solar and lunar eclipses. The intriguing theory of Empedocles (ca. 484-424 B.C.), according to which there are two suns, a real or archetypal one (the fire of the Earth in the centre) and an apparent one (the visible Sun), which is a reflection of the archetype on a crystal bowl, a theory that stresses the Sun's extrapolated projection opposite the Earth, probably implies knowledge of the obliquity of the ecliptic, but also a representation of the Sun revolving around the Earth, which would have served pedagogical purposes.

As for the Pythagoreans, the evidence is somewhat confused, but they essentially denied that the Earth is at the centre of the Solar System. Some inklings of a heliocentric view of the world appear in the theory of the Pythagorean Philolaos (ca. 480-405 B.C.), who posited the existence of a central fire ('Hestia' or 'Tower of Zeus'), around which revolve the celestial bodies, including the Earth (see Gavroglou, et al., 2003; Huffman, 1993).

Plato (ca. 427-347 B.C.) adopted the Pythagorean theory of the circular motion of the Earth ('winding round' – *eillomenen*) up and down on the axis of the Universe. He assimilated the latter with the spindle of Necessity, which in his view consisted of eight nested whorls representing successively the circle of the fixed stars ('circle of the Same') and the circles of the Sun, the Moon and the five planets ('circles of the Other'). In his mystic vision of the Universe, Plato also distinguished between two kinds of motion, the motion along the equator (or 'circle of the Same') and the motion along the ecliptic (or 'circle of the Other'). Plato uses an obscure language probably in order to avoid expressing the heliocentric view in a straight manner. Nevertheless, it is clear that he considers a spherical Earth revolving around itself and around the Sun, and that he describes a very complex cosmologi-

cal model, which combines the shared characteristics of an articulated sphere, a planar astrolabe and the forerunner of an orrery.

In an interesting passage given to us by Aristotle (*On the Heavens*, II. 293a17-293b1) it is stated that, besides the Pythagoreans, "... many others ..."—whom some assume to have been Plato himself and/or a group associated with Plato's Academy (see Leggatt, 1995: 253-254)—held the view that fire occupies the centre of the Universe and the reason they gave is that fire, rather than earth, is the most honourable thing and therefore deserves the most honourable place. Up until the time of Aristotle, therefore, there were astronomers who had no qualms about abandoning the traditional view, which gave the Earth the central position. Their motivation may have been a purely religious or symbolic one (Lloyd, 1970: 27; 1991: 157). As for Aristotle himself, he states that the centre is the reference point of all motions and that the (spherical) Earth happens to be at the centre (*On the Heavens*, II. 296a24-298a15).

On the other hand, there were those who clearly adopted the geocentric view of the cosmos and even introduced additional mechanical models regarding the spherical Universe in order to explain the planetary movements, to save the appearances and to offer a theory on the real nature of the celestial bodies. These are, for instance, Eudoxos of Cnidos (ca. 408-355 B.C.), who, while being influenced by the cosmological speculation of Pythagoras and Plato (Goldstein and Bowen, 1983) suggested that the celestial bodies revolve around the Earth upon a series of interconnected concentric spheres turning on their own axes; Aristotle (384-322 B.C.) with his theory of crystalline interconnected spheres in a uniform circular motion around the Earth; Heraclides of Pontos (ca. 387-312 B.C.), who argued that the alternation of day and night is caused by the eastward rotation of the Earth on its axis once a day, rather than by the rotation of the heavenly bodies around the Earth, and who probably also put forward a circumsolar theory of the planets Venus and Mercury (but see Eastwood, 1992); and, later on, Apollonios of Perge (ca. 262-190 B.C.), who introduced the geocentric model of the epicycles and eccentric circles, which was enriched and expanded by Hipparchos (ca. 190-120 B.C.) and Ptolemy (A.D. 87-150).

However, the current of thought denying geocentricity had not died out. Thus, Aristarchos of Samos (310-230 B.C.) was the first astronomer to put forward a heliocentric astronomical theory in an explicit and unquestionable manner (Heath, 1932; Noack, 1992). Archimedes wrote about him:

His hypotheses are that the fixed stars and the sun remain unmoved, that the earth revolves about the sun in the circumference of a circle, the sun lying in the middle of the orbit ... (*Psammites*, I. 4-7; see Figure 1).

Nevertheless, the striking hypothesis advanced by Aristarchus met with great hostility in Athens and—with the sole exception of Seleucos of Seleucia, who espoused it vividly more than a century later—does not seem to have created any solid following (Heath, 1913: 305-307; Lloyd, 1973: 57-58; 1984, 276; 1991: 367 n.40; Noack, 1992: 4).

It seems, therefore, that throughout the history of ancient Greek astronomy theories supporting a geocentric

or a heliocentric (or at least a ‘fire-centred’) world co-existed in opposition to each other at any one time (Thales vs. Pythagoras, Oinopides of Chios vs. Philolaos, Apollonios of Perge vs. Aristarchos of Samos, Hipparchos vs. Seleucos). Nevertheless, the geocentric view of the Universe prevailed throughout Hellenistic and Roman times (Figure 2), whereas the heliocentric view was abandoned, only to be rediscovered by Copernicus in the sixteenth century.

The reasons why geocentrism prevailed are complex, but in the following two sections we will explore two of what might have been among the main reasons:

- a) heliocentrism, as the true system of the world, was conceived from a purely philosophical point of view; it co-existed with geocentrism, but it was obscured and carefully hidden from the predominant religious beliefs from fear of persecution for impiety; and
- b) geocentrism, cleverly conceived as the Earth-centred celestial sphere, explained in a convincing manner the motions of the celestial bodies, and aided in the determination of calendric time (especially prior to Eudoxos, who is largely responsible for turning astronomy into a mathematical science—see Goldstein and Bowen, 1983), as well as in the prediction of weather phenomena by means of the risings and settings of the fixed stars or constellations, something that heliocentricity could not help with.

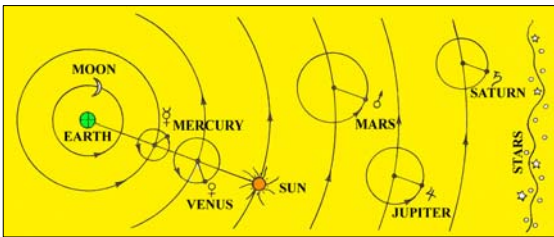


Figure 2: The geocentric system of Ptolemy.

2 IMPIETY (ASEBEIA) AND ANCIENT GREEK ASTRONOMY

In the previous section, it was mentioned that the heliocentric theory of Aristarchos of Samos met with strong opposition in Athens. Indeed, Athens does not seem to have been as tolerant and open-minded with regard to deviant religious actions and opinions, as some romantic views about Athenian democracy want us to believe (Cohen, 1991: 211, 215; Dodds, 1951: 189-190, 201 n.63; Garnsey, 1984; Price, 1999: 67 f.). As the most important city of the Greek world, Athens became a great intellectual centre in the second half of the fifth century B.C. It attracted many philosophers and sophists, who formed part of the so-called ‘Enlightenment’ movement, which drew its origins in mid-sixth century B.C. Ionia (Xenophanes, Heracleitos). Especially, Pericles attracted around him a circle of intellectuals, the most eminent among whom was Anaxagoras, who introduced Ionian philosophy into Athens. The free, rational thinking of all these intellectuals about the gods and the world was a great challenge to traditional Athenian religion. It brought about atheism and it was checked by a series of trials (Derenne, 1930; Dodds, 1951: 179-206; Garland, 1994: 97-102). Between 432 B.C. and the end of the fourth century B.C., a series of philosophers, including astronomers, were prosecuted for impiety because of their ‘blasphemous’ beliefs (Table 1), besides other

people (intellectuals or not). As Dodds (1966: 189) commented: “The Great Age of Enlightenment was also, like our own time, an Age of Persecution.” Impiety (*asebeia*) referred both to sacrilegious actions and to the expression of scandalous beliefs concerning the gods (Cohen, 1991: 203-217; Derenne, 1930: 9-12, 217-245; Price, 1999: 82). It was considered a major crime and it was punished by death or perpetual exile.

All these impiety trials started with the introduction of the famous law or decree of Diopeithes (432 B.C.), which stated that “... public accusation should be laid against persons who did not believe in gods or who taught doctrines regarding the heavens.” (Plutarch, *Pericles*, 32. 1). This decree was especially designed by the seer Diopeithes to eliminate his main rival, the philosopher and astronomer Anaxagoras. As a professional seer, Diopeithes was fighting for the preservation of the traditional religious beliefs, since his own craft assumed that the sky was replete with divine omens (Derenne, 1930: 19-24; Garland, 1992: 139-141, 205f.; 1996: 94; MacDowell, 1978: 200-201). Anaxagoras was prosecuted “... for saying that the sun is a stone and the moon is made of earth.” (Plato, *Apology*, 26d). This was a very shocking idea indeed, given that ancient Greek religion (like any ancient religion) regarded the heavenly bodies and the heavens themselves as gods (Vegetti, 1995: 277f.; Vernant, 1974: 104-112; 1983: 197). Thus, Plato, arguing against the atheists about the existence of gods, says that

... all the Greeks and barbarians, under all conditions of adversity and prosperity, directed [their prayers] to [the sun and the moon], not as though they were not gods, but as though they most certainly were gods beyond the shadow of any doubt. (Plato, *Laws*, 887e).

And Aristotle writes on this subject:

Our forefathers in the most remote ages have handed down to their posterity a tradition, in the form of a myth, that [the heavenly] bodies are gods, and that the divine encloses the whole of nature. (Aristotle, *Metaphysics*, 12, 8).

Anaxagoras appears therefore to have been prosecuted, because he dared reduce the celestial divinities into stones and earth (Derenne, 1930: 23-25), although some of his contemporaries saw the case as a direct consequence of his friendship with Pericles (Derenne, 1930: 23-25; Plutarch, *Pericles*, 32). Eventually, Anaxagoras was not executed, but fled Athens with the assistance of Pericles (Derenne, 1930: 39-41; Plutarch, *Pericles*, 32).

Around 416 B.C., Protagoras, the sophist, was brought to trial for impiety, accused for his impious book *On the Gods*, as well as most probably for his astronomical theories. Protagoras escaped death, either because he was banished or because he fled before his trial. After his exile or escape, all the copies of his book were burnt in the public square, the *agora* (Derenne, 1930: 46-55)—this was the first public burning of a book in history!

In a significant passage, Plutarch talks about Anaxagoras and Protagoras, as proof of the Athenians’ aversion towards natural philosophers and astronomers:

The first man to put in writing the clearest and boldest of all doctrines about the changing phases of the moon was Anaxagoras. But he was no ancient authority, nor

was his doctrine well-known, but it was still under seal of secrecy and circulated among a few people only, who received it with a certain caution, rather than with implicit confidence. For there was widespread intolerance of natural scientists and “star-gazers”, as they were called at the time, on the grounds that they reduced the divine to irrational causes, blind forces and necessary incidents. Hence it was that Protagoras was banished and Anaxagoras cast in prison and rescued with difficulty by Pericles, and Socrates, though he had nothing whatever to do with such matters, nevertheless lost his life, because of philosophy. (Plutarch, *Nicias*, 23, 2-3).

The memory of Anaxagoras’ trial must have been still very vivid in Athens in 399 B.C., the time of the most famous impiety trial, that of Socrates (Cohen 1991: 213-215; Derenne, 1930; Stone, 1989). Prosecuted “... for not believing in the gods of the city-state, but in other new divinities ...” (Plato, *Apology*, 24b; cf. Diogenes Laertius 2. 40), the philosopher, in his defense, refuses to be associated with the astronomers “... because those who hear them think that men who investigate these matters do not even believe in gods.” (Plato, *Apology*, 18c), thereby disclaiming any knowledge of astronomy attributed to him by Aristophanes in the *Clouds* (423 B.C.); a little later in his apology, Socrates denies that he is a complete atheist and affirms that he does “... believe that the sun and the moon are gods, like all the other people do ...”, unlike Anaxagoras, implying that the astronomers’ beliefs do support the accusation of impiety (Plato, *Apology*, 26d).

Xenophon expresses even more clearly the opinion of Socrates about Anaxagoras and the astronomers, in general, as reckless atheists (talking about *hybris*), when he declares that

With regard to the phenomena of the heavens, [Socrates] disapproved strongly of attempts to work out the machinery by which the god operates them; he believed that their secrets could not be discovered by man, and that any attempt to search out what the gods had not chosen to reveal must be displeasing to them. He said that he who meddles with these matters runs the risk of losing his sanity as completely as Anaxagoras, who took an insane pride in his explanation of the divine machinery ... When [Anaxagoras] pronounced the sun to be a red-hot stone, he ignored the fact that a stone in fire neither glows nor lasts long, whereas the sun-god shines with unequalled brilliance for ever. (Xenophon, *Memorabilia*, IV, 7, 6f.; see also Liritzis, 2003).

Anaxagoras and his astronomical doctrine was also attacked by Plato, who alludes to him in his *Laws*, when he makes the Athenian say:

But as to our younger generation and their wisdom, I cannot let them off when they do mischief. For do but mark the effect of their words: when you and I argue for the existence of the Gods, and produce the sun, moon, stars, and earth, claiming for them a divine being, if we would listen to the aforesaid philosophers we should say that they are earth and stones only, which can have no care at all of human affairs, and that all religion is a cooking up of words and a make-believe. (*Laws*, 886e).

Immediately afterwards, Plato declares such philosophers to be “... unholy men ... impiously disposed ...” (*Laws*, 887a), and therefore people who would be liable to “... be punished with death ...” by the impiety

law of his ideal State (*Laws*, 910c-d; Cohen, 1991: 216-217; Derenne, 1930: 248-252).⁵

The disapproval and distrust of the astronomers (and their supporters) on religious grounds was widespread in Classical Athens (Dodds, 1951: 201 n64). In the *Laws* (967a), Plato writes that people “... imagine that those who study [the heavenly bodies] in astronomy ... become atheists through observing ... that all things come into being by necessary forces ...” And he continues:

... all that moves in the heavens appeared to them to be full of stones, earth and many other soulless bodies ... These were the views which ... caused them many charges of atheism and much antipathy, and which also incited the poets to abuse them by likening philosophers to ‘dogs howling at the moon. (*Laws*, 967c).

The famous orator Gorgias, in his display speech on the power of rhetoric, said:

To understand that persuasion, when added to speech, is wont also to impress the soul as it wishes, one must study: first, the words of Astronomers who, substituting opinion for opinion, taking away one but creating another, make what is incredible and unclear seem true to the eyes of opinion ... (*Gorgias Encomium of Helen*, 13; Sprague, 1972: 50-54).

Table 1: Impiety trials against philosophers in ancient Athens.*

Date (BC)	Name	Accusation	Verdict
432	Anaxagoras	For saying that the Sun is a stone and the Moon is made of earth.	Death
ca. 416	Protagoras	For his impious book <i>On the Gods</i> and for his astronomical theories.	Death or exile
399	Socrates	(Amongst others) ‘For not believing in the gods of the city-state, but in other new divinities.’	Death
323	Aristotle	For giving divine status to his father-in-law Hermias, thereby introducing new gods. ⁴	(Fled before trial.)
317-307	Stilpon	For claiming that Athena of Phidias is not a god.	Exile
317-307	Theodoros	For claiming that a high-priest of the Eleusinian Mysteries was impious.	Exile
316	Theophrastos	Unknown	Acquitted for lack of evidence

* Sources: Bruyn (1995) and Derenne (1930), where all the references to the ancient texts are cited.

Even more vehemently, the tragedian Euripides declared:

Has not the man ... who apprehends god cast far away the crooked deceits of those who observe the heavens? Their poisonous tongue, although it possesses no way of

knowing, talks at random of invisible things. (Derenne, 1930: 24; Nauck, 1964: Frag. 913).

And Eupolis, in his comedy *Kolakes* (421 B.C.), made fun of Protagoras in these words: "... that man, who boasts like a criminal about celestial phenomena, while eating the things that come from the earth." (Diels 1907, Volume II: 530, 14-16).

About one hundred and fifty years after the trial of Anaxagoras, ca. 286 B.C., the astronomer Aristarchos of Samos, the proponent of the revolutionary heliocentric theory, living in Athens, appears to have been accused of impiety by the head of the Stoic school at Athens, Cleanthes (Derenne, 1930: 215; Heath, 1913: 304; Lloyd, 1973: 58; 1991: 157 n.46; Noack, 1992: 4), who even wrote a book entitled *Against Aristarchos* (Diogenes Laertios, 7, 174). In the words of Plutarch:

Cleanthes thought that the Greeks ought to lay an action for impiety against Aristarchos the Samian on the ground that he was disturbing the Hearth of the Universe [i.e. the Earth], because he sought to save the appearances by assuming that the heaven is at rest while the earth is revolving along the ecliptic and at the same time is rotating about its own axis. (Plutarch, *On the Face in the Orb of the Moon*, 6, 923a).

By moving the Hearth of the Cosmos from its central location Aristarchos dared upset the tranquility of the Olympian gods. He claimed that the Earth was not the great goddess of the hearth, Hestia, the sister of Zeus (the master and king of the Universe, the incarnation of justice and order; see Vernant, 1974: 104-114), she who, according to the general belief, is enthroned immobile at the centre of the world and of the 'House of the Gods' (Plato, *Phaedrus*, 247a; Dicks, 1970: 114-115; Heath, 1913: 304; Lloyd, 1973: 58; Vernant, 1983: 128, 159-161, 188-189, 195-196), but it was a mass, which, like the other planets, turned around the Sun. Aristarchos ventured to explain in a mechanical manner phenomena that were regarded by everybody as the work of divinities. It is to him that the Platonist philosopher Dercyllides (first century A.D.) alluded, when he announced that

... we must suppose the Earth, the Hearth of the House of the Gods, according to Plato, to remain fixed, and the planets with the whole embracing heaven to move, and reject with abhorrence the view of those who have brought to rest the things which move and set in motion the things which by their nature and position are unmoved, such a supposition being contrary to the hypotheses of mathematics. (Theon of Smyrna, *Mathematical Knowledge Useful for the Reading of Plato*, iii 34; see also Heath, 1913: 304; Hiller, 1878: 200, lines 7-12).

It is worth noting here that although Dercyllides reacts with horror to an attempt to put the Earth in motion, he also says that it is contrary to the hypotheses of the mathematicians; so it seems that not only religious feeling, but also the mathematicians themselves were opposed to the idea. This, however, does not alter our basic hypothesis. Indeed, by placing the Earth at the centre of the cosmos, the mathematicians and astronomers could explain the seasons, the movements of the planets Venus and Mars, weather phenomena and other celestial parameters made by observations. And this could have been independent of their potential philosophical view that the Sun is at the centre (see Section 3 below).

Having, no doubt, scandalized the public opinion and facing the death penalty, Aristarchos had no option but to flee Athens and never come back (see also, Christianidis et al., 2002).

Impiety trials were the violent reaction of the community of the Greek city-state or *polis*, which felt its integrity to be under threat. In the absence of any dogma or any organized priesthood in ancient Greek religion, it was the city-state itself, i.e. the citizen body or *demos*, that undertook to prosecute and punish those who were 'impiously disposed'. In addition, in Athens, like in all Greek cities, the cult community was identified with the citizen body and the cult guaranteed the unity of the citizens, of the state. As Louis Gernet put it, the city-state considered itself to be "... a concrete and living entity under the sure protection of the gods, who would not abandon it, as long as it did not abandon them." (Gernet and Boulanger, 1932: 295).

Religion and the state being inextricably linked in ancient Greece, any crime against religion was considered as an attack against the whole of the citizen body, against the security of the state, i.e. as a crime of high treason. This is why attacks by the philosophers and natural scientists on traditional religious beliefs and on the sacred 'ancestral customs' (*ta patria*), were seen by the community as seriously undermining the social order, the stability of the *polis*, and were severely punished (Bruit Zaidman and Schmitt Pantel, 1992: 11-15; Derenne, 1930: 247-267; Dover, 1974: 246-254; Garland, 1994: 25-26, 88-89, 97-102; 1996; Vegetti, 1995; Sakellariou, 1999: 15, 274-276; Price, 1999: 67-88; Mikalson, 2005: 181-184).

Given the nature of the evidence at our disposal, we have concentrated so far on the religious values of Classical Athens, the best-documented city of Greek antiquity. The evidence regarding impiety laws in the rest of the Greek world is much more scattered both in time and space, and we are not in a position to know whether the fear of prosecution for impiety actually applied to, say Rhodes, at the time of Hipparchos, around 120 B.C., or Alexandria, at the time of Ptolemy, around A.D. 150.

As far as pre-classical times are concerned, textual evidence going back to the sixth century B.C., to the time of the first Presocratic philosophers (Thales, Anaximander and Anaximenes), suggests that there was already religious intolerance and talk about impiety not only in Athens, where, at the time of Solon (594 B.C.), it was considered that "... piety resided ... in the absolute respect of the customs handed down by the ancestors ...", as mentioned by Isocrates (*Areopageticus*, 29-30; Derenne, 1930: 235-236; Mikalson, 2005: 183), but also elsewhere in Greece: the first appearance of the word 'impiety' (*asebeia*) is in a poem by Theognis of Megara (ca. 580 or 545 B.C.): "Respect and fear the gods. This keeps a man from doing or saying anything that is impious." (Theognis, lines 1179-80, to his friend Cynos; Garland, 1992: 138; Mikalson, 2005: 188), while a fable by Aesop (ca. 620-560 B.C.), from Samos, describes how a sorceress was condemned to death "... for making innovations in religion." (Aesop, *The Sorceress*; Derenne, 1930: 232-233; Temple 1998: 72, no. 91)—even though it is a fable, it might reflect the existence of a law prohibiting innovative religious practices already at that period. It

is even likely that obedience to the ‘ancestral customs’ was imposed by law in Athens as early as the seventh century B.C.: the first Athenian lawgiver, Draco (621 B.C.), whose harsh legal code punished almost every offence with death, apparently was the first to introduce a law instructing the Athenians “... as a group to honour the gods and local heroes in accordance with the ancestral practices.” (Porphyry, *On Abstinence from Animal Food*, 4.22; Garland, 1992: 138; 1996: 94; Mikalson, 2005: 183).

In view of the tight connection between state and religion in ancient Greece, religious conservatism and intolerance may, in fact, be as old as the eighth century B.C., the time of the formation of the city-state or *polis* (Garnsey, 1984; Sakellariou, 1999: 275).

3 THE GEOCENTRIC VERSUS THE HELIOCENTRIC MODEL FOR ‘SAVING THE PHENOMENA’?

In the previous two Sections we examined the possibility that the heliocentric theory was well known to the ancient Greek philosophers and astronomers, but it was not presented to common people as such due to the generally-accepted religious values. In this Section, we will advance one additional reason why this might have happened, and this is the possibility that it may have satisfied one of the astronomers’ theses, that of ‘saving the phenomena’, which implies on their part an apparent indifference to the real nature of the things that they continuously searched for.

It is likely that putting the geocentric view forward would have also facilitated the reception of the surrounding world in a didactic way, much like in the modern representation of the celestial sphere, where the Earth is at the centre and the Sun makes an apparent orbit on the ‘celestial sphere’ along the zodiac, defining the ecliptic (Figure 3). Thus, in antiquity, the philosophers and astronomers might have used geocentrism for the observation of astronomical phenomena, because it is more easily visualized and provides a much clearer understanding of most every-day phenomena (see below), without necessarily having to sacrifice their heliocentric views. Such an endeavor would not have prevented them from seeking a successful scientific theory, which contained at least some elements of the true nature of the world (Evans and Berggren, 2006: 50; Lloyd, 1978; 1991: 248-277).

The geocentric theory with the irregular movements of the Sun, Moon and planets, is apparent, and the contrast is between those movements and the true circular, orderly, and regular motions in terms of which those irregularities are to be explained (as suggested by Plato). Simplicios (*On Aristotle’s On the Heavens*, 422.3ff., 427.10ff.) points out critically that the astronomers have not demonstrated their hypotheses, and that he is aware of the fact that the same phenomena were sometimes explained by different hypotheses.

A geocentric representation of the Universe could have been justified primarily by the main concern of the Presocratic philosophers and astronomers, from Parmenides onwards, to defend the view of the common people that the world of the senses, of the visible phenomena, has a real dimension, in other words, by their concern ‘to save the appearances’. The Greek expression ‘to save the appearances’ or ‘to save the phenomena’ (*sōzein ta phenomena*) occurs for the first

time in Plutarch (*On the Face in the Orb of the Moon* 6, 923a), but Simplicios attributed it to Plato (*On Aristotle’s On the Heavens*, comments in II.12) (see Evans and Berggren, 2006: 49-50; Goldstein, 1997: 7). ‘Saving the appearances’ patently meant engaging in precise observation, recording and prediction of the apparent movements of the celestial bodies, and striving to explain them, at the same time as attempting to know the real nature and composition of the heavenly bodies. Thus, the importance of any astronomical theory lay in its precise physical interpretation, but also in its prognostic and explanatory ability and its simplicity.

The major achievement of the Presocratic philosophers and astronomers is precisely the effort to interpret the cosmos on the basis of logic, in a rational and abstract way, by rejecting all the supernatural interpretations, which were based on religious or magical beliefs and which prevailed hitherto among the Greeks. Later on, after Plato’s sensible recommendation to apply mathematical methods to the explanation of natural phenomena, this attitude provided the ancient Greek philosophers and astronomers with the power to put forward and use ideal, geometrical models of the Universe, without necessarily believing in their physical existence (Plato, *Republic*, VII, 529-530; Dicks, 1970: 107-108; Farrington, 1963; Lloyd, 1970: 66-79).

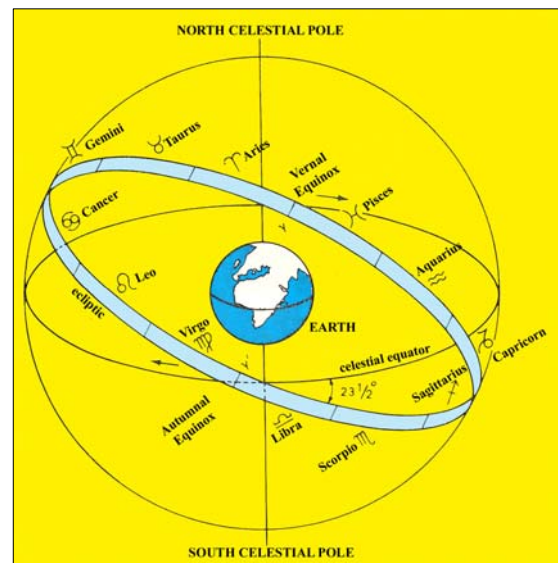


Figure 3: The apparent movement of the Sun round the zodiac circle in one year.

The ancient Greek astronomers’ ideas, in fact, began to blossom when they were applied to the available observational data and a very clear view emerged soon, at least regarding the solar orbit with the solstices and equinoxes defining the four seasons of the solar year. An essential part of this picture was the discovery of the Sun’s apparent circle around the ‘celestial sphere’ each year, denoted by the Sun’s passage through the zodiacal band of constellations, on a tilted plane with respect to the plane of the ‘celestial equator’ (Figures 3 and 4). This discovery is variously attributed by the doxographers to Oinopides of Chios, to the Pythagorean Philolaos or to Pythagoras himself (Diels-Kranz 1951, Volume I: 393-394, no. 41.7). However, it may well go back to Anaximander, since this remarkably

original thinker, who was the first to put forward the hypothesis that the Earth is suspended freely in the Universe, is also the first to be credited with the discovery not only of the solstices, but also of the equinoxes: indeed, if the recognition of the solstices implies no astronomical theory whatsoever, since they can be determined by simple observation alone, it is otherwise for the equinoxes, which presuppose a comparatively advanced level in astronomical thought, i.e. knowledge of a celestial sphere, with the Earth at the centre and with the equator, tropics, and the ecliptic as the Sun's path round the Earth, inclined at an angle to the celestial equator (Dicks, 1966: 31-32).

The concept of the celestial sphere and all that it implied undoubtedly offered an adequate framework, but a lot more theoretical work was needed to correlate the existing observational material with it. This is the reason why Plato urged the astronomers to focus on the theoretical side of their subject and develop a mathematically-based system, which would explain the movements of the visible celestial bodies.

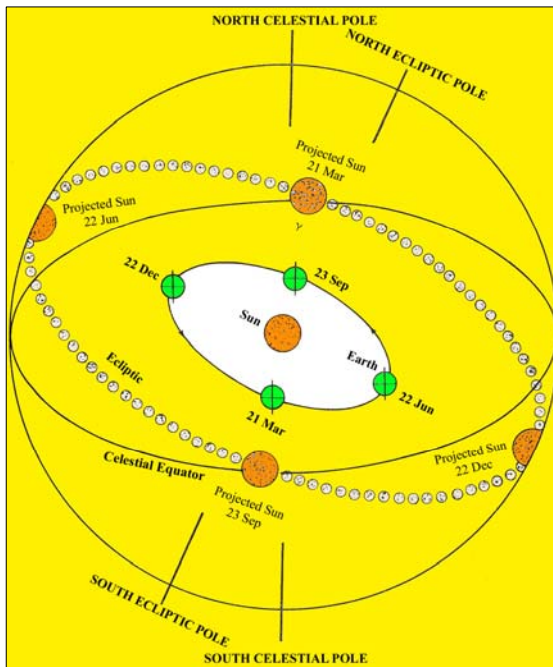


Figure 4: The Sun is at the centre and the Earth moves round the Sun making an internal ellipse in one year. On March 21, the Sun is projected onto the sky at point (y), the opposite part of the Earth's position. As the Earth moves towards June 21, September 23 etc., the Sun seems to move in the opposite part and in the same direction.

The reason for the return, after Aristarchos of Samos, from the heliocentric to the geocentric system—apart from the still existing prejudices and religious beliefs, which set the Earth-Hestia at the centre of the Universe—was the failure of the heliocentric model to 'save the appearances'. More especially, the heliocentric theory failed to account for a number of physical and astronomical considerations. First, it was inconsistent with ordinary experience of motion: if indeed the Earth was subject to daily axial rotation around the Sun, this would have had a serious effect on the movement of heavy objects (since they naturally travel towards the centre of the Earth) or of objects moving through the air, of winds and clouds (since the

Earth would be spinning at incredible rates of speed), whereas no such effects were observed. Second, this theory did not help to explain the apparent absence of stellar parallax (i.e. of any change in the relative positions of the stars as observed from different points of the Earth's orbit), nor did it account for the inequality of the seasons as defined by the solstices and the equinoxes or for the anomalies in the orbits of the celestial bodies, which became obvious as observations improved. Concerning the objection regarding parallax, it is worth mentioning here in particular the Pythagorean attempt to accommodate the phenomenon of lunar parallax, as reported by Aristotle:

For, since the earth is not the centre, but is distant from it by a whole hemisphere of the earth, nothing ... prevents the apparent facts (*τα φαινόμενα*) occurring in the same way when we do not live at the centre as they would were the earth to be at the centre. For even as it is, nothing makes it obvious that we are at a distance of half a diameter from the centre [i.e. on the Earth's surface]. (*On the Heavens*, II. 293b25-30; see also Leggatt, 1995: 255-256).

On the other hand, the model of epicycles and eccentrics, first propounded by Apollonios of Perge and expanded later by Hipparchos and Ptolemy, which assumed a geocentric system, could satisfy with enough accuracy the reconstruction of the celestial phenomena and could compromise with a stationary Earth. Indeed, it was not judged necessary for any mathematical constructions used by astronomical models, such as the model of epicycles and eccentrics or, before it, Eudoxos' model of concentric spheres, to have a physical basis, but rather to be suitable in predicting the planetary positions, (cf. Plato's and Ptolemy's '*hypotheses planōmenōn*'). Astronomy was a mathematical exercise designed to 'save the appearances', to account for the motions of the heavenly bodies by making use of mathematical hypotheses.⁶ The astronomical models aimed at a better estimation of the phenomena connecting the model with the observation. Thus, what counted as phenomena to be saved did not change with time, as Greek astronomy matured. Because of this Ptolemy's model certainly is not matured astronomy, but rather a culmination of astronomy in terms of complex mathematical models.

It is known that the general frame or model adopted finally was that of the celestial sphere with the spherical Earth immobile at the centre. This conception of the Universe proved valuable and long lasting. Even today the model of the celestial sphere is used as a necessary basis for the drawing of sky maps, or in planetaria and with orreries, which by their very nature require the observer to occupy a central position. To ordinary observers on Earth, the stars appear to be attached to the inside of a vast hollow globe, which spins round the Earth from east to west once a day. Although this view is not true—given that the Earth is not at the centre of the Universe, but is only a small-sized planet spinning on its axis in its orbital motion around a brighter than average star in a larger than average galaxy—it could have been useful (and often still is) for astronomers to pretend that this globe, or celestial sphere in the sky, really does exist. Moreover, the cyclic orbit in the heliocentric model does not explain the planetary positions with any accuracy as the geocentric model does.

Indeed, an understanding of most everyday phenomena is made easier if one constructs an image of the ‘celestial sphere’ having the Earth at the centre, whereby the Sun is projected opposite the Earth’s orbit (Figures 3 and 4). Such phenomena include the following:

- 1) The Earth’s revolution around an axis passing through its centre, and turning from east to west, determining day and night.
- 2) The appearance of the Earth as suspended in cosmic space.
- 3) The Earth’s movement around itself and around the Sun.
- 4) The ecliptic and the celestial equator.
- 5) The four seasons of the year.
- 6) Lunar and solar eclipses.
- 7) The ecliptic circle and the zodiacal band of constellations.
- 8) The apparent movement of the Sun through the stars.
- 9) The four solar stands (two equinoxes and two solstices) during a year.
- 10) The precession of the equinoxes.
- 11) The obliquity of the ecliptic, i.e. the 23.5° angle between the plane of the ecliptic and the plane of the celestial equator.
- 12) The determination of the planetary positions at a particular time.

Geocentrism could have also assisted in the fixing of calendric time, as well as in the prediction of weather phenomena by means of the risings and settings of the fixed stars or constellations (Taub, 2003).

Moreover, the brilliant idea of considering a celestial sphere having the Earth at its centre, with the Earth’s poles, as well as lines of latitude and longitude projected on it, would have proved extremely useful to the ancient Greek astronomers themselves, as it is often helpful to astronomers nowadays, because it makes it easier to observe far away celestial bodies by placing them on the surface of the ‘celestial sphere’ and by assuming them to be at an infinite distance.

For all the above reasons geocentrism could have apparently won out vis-à-vis heliocentrism. Moreover, the adoption of a geocentric view would have allowed the ancient Greek philosophers and astronomers not only to harmonize their theories with the religious beliefs of their time, but also to facilitate the reception of the surrounding world by the ordinary people so as to ‘save the appearances’, without sacrificing the essence of their ideas. Furthermore, it could have assisted their own observations of the celestial bodies.

4 CONCLUSION

The spherical Universe, apparently implying a belief in the heliocentric system, may have been the prevalent view of the ancient Greek philosophers and astronomers. However, the opposition of such a view to the established religious beliefs, which assumed that the Sun-god circled the Earth-Hearth of the world, and the fear of prosecution for impiety, at least in Athens during the Classical period, may have prevented the promotion of the heliocentric model. Moreover, a model placing the Earth at the centre of the Universe with the Sun revolving around the Earth—much like the modern representation of the celestial sphere—would have ‘saved the appearances’: it would have

explained day and night, the four seasons of the year, the solstices and the equinoxes, the apparent movement of the Sun through the stars and constellations, as well as lunar and solar eclipses, and planetary motions, without exposing the inherent beliefs of the philosophers and astronomers.

5 NOTES

1. This is an expanded version of a paper delivered at the International Conference on “Decoding the Antikythera Mechanism. Science and Technology in Ancient Greece”, which was held in Athens on 30 November-1 December 2006.
2. As opposed to the views attributing the concept of the spherical Universe to Pythagoras or the Pythagorean Philolaos, or even to Oinopides of Chios, at the earliest (e.g. Dicks, 1966: 30; Evans, 1998: 75; see, also, Diels and Kranz, 1951: 393-394, no. 41.7). That Anaximander seems to have already espoused the view of the sphericity of the heavens is supported by his being credited with the determination of the equinoxes, which in itself presupposes the knowledge that the Earth is the central point of a celestial sphere (Dicks, 1966: 32 and *passim*; however, Dicks refuses to ascribe the idea of a spherical cosmos to Anaximander and dismisses it as anachronistic, as opposed to Kahn, 1960: 92-94). For an earlier discussion of the subject, see Heath, 1913: 28-39.
3. A whole series of lenses has been found in archaeological sites in the Aegean world, Troy, Cyprus and the Middle East, dating from the third millennium B.C. to Roman times. The most frequent type of lens (*viz.* with a plano-convex shape), made of rock crystal, has a nominal magnification ranging from $2\times$ to as much as $20\times$ and may well have served as a magnifying or burning glass, an identification which is also supported by ancient literature (Plantzos, 1997: 454; Sines and Sakellarakis, 1987: 191, 193 Figure 3). A case for such lenses having been used in observing the heavens has been made by Temple (2000). On the subject of the observational tools used by ancient Greek astronomers, the prevailing view is that, until the time of Hipparchos (who is known to have used the *dioptra* and the equinoctial armillary), the only sighting aids used were very primitive instruments, such as the *gnomon* or vertical rod (see Lloyd, 1970: 97; 1991: 309). For a more extreme view, in favour of non-instrumental observations, based on the use of body parts, such as the hands, see Rihll, 1999: 69. However, an apparatus as elaborate as the astronomical clock or computer, known as the ‘Antikythera Mechanism’, which appears to have been made at the time of Hipparchus (ca. 120 B.C.) or thereabouts (Edmunds et al., 2006), presupposes a long period of experimentation with astronomical equipment.
4. It is possible that ‘impiety’ was used in the case of Aristotle as a convenient way to persecute him for his connection to Alexander the Great, since the charge was made shortly after Alexander’s death (see e.g. Meyhew, 1996).
5. In fact, according to Momigliano (1978: 188), “... the Athenian prosecutions of the philosophers are the historical precedent – and the paradoxical justification – for the penalization of religious opinions advocated by Plato in the *Laws*. Plato contributed to the notion of heresy in so far as he contributed to the

- idea of intolerance and inquisition.” Similarly, Price (1999: 133-134), writes: “Plato built on the Athenian impiety law ... to formulate his own far more extensive impiety law, which makes him the first political thinker to argue that matters of belief can be criminal offences.”
6. Lloyd (1978; 1991: 248-277) has refuted Duhem’s (1908) instrumentalist view, according to which the models of the Greek astronomers were not intended to represent the true system of the world, by showing that this scholar misunderstood his sources and that all the ancient Greek astronomers of whom we know enough to be able to say anything with confidence were realists. According to our working hypothesis, the seeming realism of the ancient Greek astronomers emerged when they were involved with mathematical models, but while still retaining their philosophical views.
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