THE CULTURAL RELEVANCE OF ASTRONOMY IN CLASSICAL ANTIQUITY

Roberto de Andrade Martins

Abstract: Nowadays we understand 'astronomy' as the study of celestial bodies. However, astronomical knowledge in classical Greece and Rome cannot be reduced to the study of the sky. Of course, it did include the study of stars and planets, but this knowledge was intimately linked to many other subjects, such as religion, geography, meteorology, mythology, medicine, etc. Acquaintance with many celestial phenomena and the constellations and their lore was part of ancient culture. Remove from the classical Antiquity its astronomical knowledge, and many of its features and activities would become impossible or meaningless. Astronomy was deeply implanted in ancient culture, as will be shown in this paper, and that was the reason underlying its very high status in Antiquity.
Keywords: Greek astronomy; Roman astronomy; astrology; cultural astronomy; history of astronomy

1. INTRODUCTION

Nowadays, astronomy is a serious concern solely for astronomers. A few non-astronomers have an intellectual curiosity for astronomical knowledge, but modern astronomy has no direct influence on the life of most people. If astronomical knowledge just disappeared tomorrow, this would have negligible impact on everyday activities. The situation was completely different, however, in the Greek and Roman worlds.

MARTINS, Roberto de Andrade. *Studies in History and Philosophy of Science II*. Extrema: Quamcumque Editum, 2021.

This paper will show how deep was the influence of celestial knowledge in many fields of ancient culture – agriculture, navigation, religion, geography, medicine, meteorology, astrology, time measurement and other subjects.[1] Acquaintance with many celestial phenomena and the constellations and their lore was part of ancient culture. Remove from the classical Antiquity its astronomical knowledge, and many of its features and activities would become impossible or meaningless.

For understanding the cultural relevance of astronomy in the classical culture it is necessary to realize that its focus was not planetary theory, as one might think after consulting a few works on the history of astronomy. We are the heirs of the "Copernican revolution" and for that reason we usually think that the main astronomical question was whether the Earth is the unmoving center of the universe or an ordinary planet moving around the Sun. All extant histories of astronomy were written after Copernicus, and they have an unquestionable Whig style. Copernicus' contribution was a change in the understanding of the motion of the planets, and introduced the motion of the Earth itself; therefore – that is the Whig catch – the history of astronomy should be the account of the ideas about those two subjects. However, the study of planetary theory was just a small part of astronomy, before the Copernican revolution; and the very meaning of the old astronomical culture is absent in most recent accounts.

The astronomical status of the Earth and the motion of the planets was not the heart of Greek and Roman astronomy. Its core was the study of the stars and constellations, of the Sun, and the Moon. At a time when people spent much time in open spaces and artificial lighting was feeble, knowledge of the stars

[1] This paper and its sequel (the next essay in this volume) were written for presentation at the conference *Oxford Scientiae 2016: Disciplines of knowing in the early modern world* – St Anne's College, University of Oxford, 5-7 July 2016. It was circulated at that time, but it had not been published until now.

and the constellations, the apparent motion of the Sun and the study of the shadows it produces, the variable duration of the day and night during the year, the phases of the Moon and other conspicuous phenomena were well known. The motion of the planets, on the other hand, was not described in the oldest extant Greek astronomical works. Notice that the Moon moves around the Earth both in geocentric and heliocentric astronomies; and the apparent motion of the stars and of the Sun is much easier to understand from the point of view of a geocentric theory, which can deal with all its phenomena.

However, astronomy in Antiquity cannot be reduced to the study of the sky, because of its intimate relationship with many other subjects, such as religion, geography, meteorology, mythology, medicine, etc. Astronomy was deeply implanted in ancient culture, as will be shown in this paper. That was the reason underlying its very high status in Antiquity – and that was lost during the early modern period, as will be pointed out in a next paper.[2]

2. THE ROLES OF ASTRONOMY IN CLASSICAL ANTIQUITY

Since Antiquity, astronomy was regarded as a central component of the human culture[3]. In Aeschylus' *Prometheus Bound*, the main character thus describes the very birth of mankind:

> First of all, though they had eyes to see, they saw to no avail; they had ears, but they did not understand; but, just as shapes in dreams, throughout their length of days, without purpose they wrought all things in confusion. They had

[2] MARTINS, Roberto de Andrade. The transformation of astronomical culture in the seventeenth century, in this volume.

[3] This paper will only address the European case. Of course, in other regions of the world, astronomy was also an integral part of culture, since Antiquity or Pre-History. See, for instance, Kelley & Milone (2011) for a survey of early astronomy in other cultures.

> neither knowledge of houses built of bricks and turned to face the sun nor yet of work in wood; but dwelt beneath the ground like swarming ants, in sunless caves. They had no sign either of winter or of flowery spring or of fruitful summer, on which they could depend but managed everything without judgment, until I taught them to discern the risings of the stars and their settings, which are difficult to distinguish. Yes, and numbers, too, chiefest of sciences, I invented for them, and the combining of letters, creative mother of the Muses' arts, with which to hold all things in memory. I, too, first brought brute beasts beneath the yoke to be subject to the collar and the pack-saddle, so that they might bear in men's stead their heaviest burdens; and to the chariot I harnessed horses and made them obedient to the rein, to be an image of wealth and luxury. It was I and no one else who invented the mariner's flaxen-winged car that roams the sea. (Aeschylus, *Prometheus Bound*, 447-468)

In Aeschylus' account, the basic astronomical knowledge of the stars, their risings and settings, and the signs of the seasons, together with mathematics, writing and the basic techniques, were taught by Prometheus to the brutes who became the early human tribe.

3. HESIOD'S YEAR

Some of the relevant traits of astronomy in the early Greek culture appear in Hesiod's *Works and Days* (Ἔργα καὶ Ἡμέραι). In this poem, the year – an astronomical concept – and its seasons and phenomena are described by the appearance of specific stars or constellations, and by solar events, such as the solstices. The knowledge of those phenomena was essential, in agriculture.

> When the Pleiades, daughters of Atlas, are rising [late in May], begin your harvest, and your ploughing when they are going to set [in November]. Forty nights and days they are hidden and appear again as the year moves round, when first you sharpen your sickle. (Hesiod, *Works and Days*, 383-387)

Notice that the Pleiades were described as the daughters of Atlas; they were not just a set of stars; they had a mythological meaning – as any other astronomical entity. A thorough acquaintance with the sky required the knowledge of mythology, and vice-versa. The Greeks identified stars with heroes and heroines who were translated to the sky by the gods. A lost work attributed to Hesiod, with the title *Astronomia*, described the myths associated to the stars and other heavenly bodies. The earliest known work on this subject was written by Eratosthenes, in the third century BCE (Davidson, 2007, p. 206).

The very concept of time and its divisions was a consequence of the study of the sky. The division of the year among the Greek obeyed the phenomena of two different astronomical bodies: the Sun and the Moon. The months began at new Moon, usually regarded as the first appearance of the lunar crescent. The mean lunar cycle takes about 29.5 days, therefore the months were either 30 or 29 days long; the year had 12, and sometimes 13 lunar months (James, 1998, p. 184). The calendar varied from city to city, beginning at different times, in each case (Gawlinski, 2016, vol. 1, pp. 891, 898). Instead of a calendar with months and days, it was more useful, in ancient Greece, to use tables of the main astronomical phenomena (appearances and disappearances of stars) that occurred in the yearly cycle. Those tables were called *parapegma*; they were, of course, the same for all Greek cities. They also included weather predictions (James, 1998, p. 190).

For Hesiod, spring begins with the late rising of Arcturus (about 24 February of our calendar), two months after the winter solstice; the beginning of winter corresponds to the setting of the Pleiades, or the early setting of the Hyades or Orion (early November). The time for harvest is given by the early rising of the Pleiades (about 19 May), threshing time by the early rise of Orion (9 July), and vintage time by the early rising of Arcturus

(18 September). He was acquainted with the solstices, but did not refer to the equinoxes (Heath, 1913, pp. 10-11).

The production of wine, the sacred drink of Dionysus, was also regulated by the stars:

> But when Orion and Sirius are come into mid-heaven, and rosy-fingered Dawn sees Arcturus [in September], then cut off all the grape-clusters, Perses, and bring them home. Show them to the Sun ten days and ten nights: then cover them over for five, and on the sixth day draw off into vessels the gifts of joyful Dionysus. But when the Pleiades and Hyades and strong Orion begin to set [the end of October], then remember to plough in season: and so, the completed year will fitly pass beneath the earth. (Hesiod, *Works and Days*, 609-617)

The adequate time for cutting wood was also related to astronomical phenomena:

> When the piercing power and sultry heat of the Sun abate, and almighty Zeus sends the autumn rains [in October], and men's flesh comes to feel far easier – for then the Dog Star [Sirius] passes over the heads of men, who are born to misery, only a little while by day and takes greater share of night – then, when it showers its leaves to the ground and stops sprouting, the wood you cut with your axe is least liable to worm. (Hesiod, *Works and Days*, 414-422)

Of course, this entails that every artisan who used wood in his work – the carpenter, architect, shipbuilders, and the persons who built furniture, wagons and other implements – all of them had to know and obey the rhythm of nature, written on the stars.

The appearance of the Dog Star (Sirius) was regarded as ominous. Euripedes' play *Iphigenia at Aulis* begins with Agamemnon's sighting of this star just before dawn, therefore associating the sacrifice of his daughter to a particularly hot and unhealthy time of the year, and to the rise of the Etesian wind (Davidson, 2007, p. 206).

Along the year, the duration of the days and nights keep varying – long nights in winter, long days in summer – and many features of everyday life should be adjusted to those changes – including the diet of men and animals:

> In this season [Winter] let your oxen have half their usual food, but let your man have more; for the long nights decrease their needs [of the animals]. Keep the habit of regulating nourishment during the whole year according to the length of days and nights, until the Earth, the mother of all, bears again her various fruit. (Hesiod, *Works and Days*, 559-563)

Not only plants, but also animals, obey the influences of the sky and appear at definite times of the year:

> When Zeus has finished sixty wintry days after the solstice [in February], then the star Arcturus leaves the holy stream of Ocean and first rises brilliant at dusk. After him the shrilly wailing daughter of Pandion, the swallow, appears to men when spring is just beginning. Before she comes, prune the vines, for it is best so. But when the house-carrier [the snail] climbs up the plants from the earth to escape the Pleiades [in the middle of May], then it is no longer the season for digging vineyards, but to whet your sickles and rouse up your slaves. (Hesiod, *Works and Days*, 564-575)
>
> But when the artichoke flowers [in June], and the chirping grass-hopper sits in a tree and pours down his shrill song continually from under his wings in the season of wearisome heat, then goats are plumpest and wine sweetest; women are most wanton, but men are feeblest, because Sirius parches head and knees and the skin is dry through heat. (Hesiod, *Works and Days*, 582-588)

Notice that the whole annual drama is directly connected with the Greek gods; and we should not regard the Earth or the Ocean as mere geographical names.

The tradition of including astronomical information in poetry was later reproduced in the Roman culture by Ovid (*Fasti*) and

Virgil (*Georgics*), for instance (James, 1998, p. 18). Columella's work on farming (1st century CE) also included detailed astronomical information.

Sailors should also be aware of the adequate winds and sailing times, according to the signs of the sky:

> But if desire for uncomfortable sea-faring seizes you; when the Pleiades plunge into the misty sea [end of October or beginning of November] to escape Orion's rude strength, then truly gales of all kinds rage. Then keep ships no longer on the sparkling sea, but bethink you to till the land as I bid you. Haul up your ship upon the land and pack it closely with stones all around to keep off the power of the winds which blow damply, and draw out the bilge-plug so that the rain of heaven may not rot it. (Hesiod, *Works and Days*, 618-626)

> Fifty days after the solstice [July-August], when the season of wearisome heat is come to an end, is the right time for me to go sailing. Then you will not wreck your ship, nor will the sea destroy the sailors, unless Poseidon the Earth-Shaker be set upon it, or Zeus, the king of the deathless gods, wish to slay them; for the issues of good and evil alike are with them. At that time the winds are steady, and the sea is harmless. (Hesiod, *Works and Days*, 663-670)

Of course, the will of Zeus, Poseidon and the other gods is unpredictable; but those who are acquainted with the language of the heaven can choose adequate times for their undertakings: "Mark the days which come from Zeus, duly telling your slaves of them, and that the thirtieth day of the month is best for one to look over the work and to deal out supplies. For these are days which come from Zeus the all-wise, when men discern aright" (Hesiod, *Works and Days*, 765-768).

The relation between the celestial phenomena and weather changes was regarded as one of cause and effect, according to Aristotle and most Greek authors, although some later authors – such as Geminus – denied this interpretation (James, 1998, p. 200).

Each day of the Moon cycle may be suitable or inadequate for different activities:

> To begin with, the first, the fourth, and the seventh [days after the New Moon] – on which Leto bare Apollo with the blade of gold – each is a holy day. The eighth and the ninth, two days at least of the waxing month, are especially good for the works of man. Also, the eleventh and twelfth are both excellent, alike for shearing sheep and for reaping the kindly fruits; but the twelfth is much better than the eleventh, for on it the airy-swinging spider spins its web in full day, and then the wise one [the ant] gathers her pile. On that day woman should set up her loom and get forward with her work. (Hesiod, *Works and Days*, 770-779)

In Hesiod's time the month was not divided in weeks, but in three parts of ten days each – the waxing, the midmonth, and the waning (James, 1998, p. 5).

4. RELIGIOUS FESTIVALS AND THE STARS

Time in Greece was not an abstract entity, but meant the cycles of the phenomena involving the stars, the Sun and the Moon (Davidson, 2007, p. 204). In Plato's Laws, the Athenian suggests the inclusion of astronomy in the education of the ideal city to ensure "the proper ordering of days into monthly periods, and of months into a year, so that times, sacrifices, and feasts may each be assigned their due position, according to nature [*kata physin*]" (Plato, *Laws*, 809d, *apud* Davidson, 2007, p. 206).

The Moon lies at the core of Greek calendars, resembling the calendars of Mesopotamia and Assyria; the evening sighting of the new moon's crescent was the sign of a new month (Hannah, 2005, p. 27). In the Sumerian calendars, the names of the months were derived from the agricultural activities and seasonal phenomena associated to those periods of the year. In Greece, the months were named either after gods who were honored in those months, or after associated religious festivals that took

place in them. The specific names of the months varied, however, from city to city (Scullion, 2007, p. 190). There was a festival dedicated to Helios (the Sun god) in the summer solstice, and another to Cronos at the spring equinox. The Olympic festival was held every fifty moons; it began at the second full moon after the summer solstice. Many of the festivals coincided with the full moon, that is, the middle of the lunar month (Davidson, 2007, pp. 204-205). In general, it was the Moon that ruled the religious calendar and the festivals (Bouché-Leclercq, 1899, p. 45).

The lunar month was divided in three decades (an Egyptian influence); they did not use the seven-day week (Hannah, 2005, p. 87). As the time from one new moon to the following one is about 29.5 days, the division of the month in three decades was convenient: ten days of waxing, the intermediary ten days around the full moon, and ten days of waning, which were counted backwards in Athens, beginning from 9 – the numbers diminishing as the moon vanishes. There were monthly festivals that occurred at fixed days, such as Artemis' festival on day 6 (Davidson, 2007, p. 210).

The "new year" of each Greek city, associated to some relevant astronomical event (usually the solstices or equinoxes), was the time when annual magistrates or sacred officials took up office, and when new citizens were admitted. It was not just a single day, but "a much longer period, often marked by rituals of cleansing and renewal, veiling and unveiling, passing on secrets, absence and return, by festivals of disorder or of suspension of norms, and of rebirth, festivals which often looked back to the foundation of the city and/or to the start of a new divine order" (Davidson, 2007, p. 209).

The mysteries of Demeter and Kore were a central part of Greek religion. Demeter was the goddess of the harvest, who presided over grains (especially the cereals) and the fertility of the earth; she also presided over the sacred law, and the cycle of life and death. She and her daughter Kore (called Persephone in the underworld, after she was abducted by Hades) were the

central figures of the Eleusinian Mysteries. Their Athens festival was held every year from the 15th to the 23rd of the month of Boedromion, roughly corresponding to September and the beginning of Autumn. In the evening of the 21st the initiates entered the sanctuary and took part in the secret rite (Clinton, 2007, p. 345).

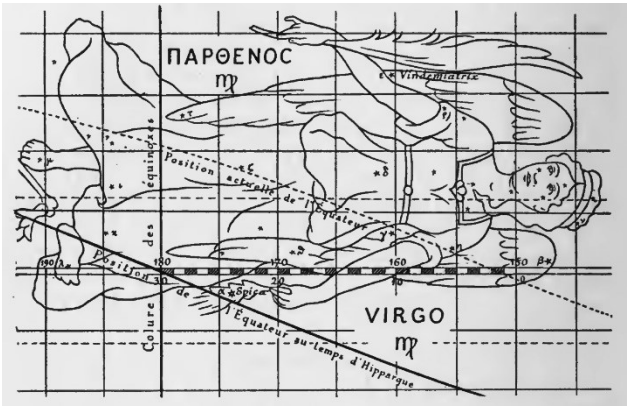

Fig. 1. An old representation of the Virgo constellation (Bouché-Leclercq, 1899, p. 140)

There is both a lunar and a solar symbolism behind the time of the festival. The 21st day of the lunar month was the first of the waning decade, meaning the beginning of the disappearance of the Moon. The myth of Kore was deeply related to her disappearance and the search by her mother in the underworld – with a symbolism related to the "death" of the seeds in the ground, before the crops are born. The festival was held when the Sun was in the sign of Virgo, represented by a woman holding a wheat ear (Spica) (Fig. 1); and the cereals were intimately related to Demeter (Bouché-Leclercq, 1899, p. 139; Hard, 2015, p. x). According to the Geminus' *Parapegma*, the 24th day after the Sun enters Virgo is the time when the Wheat-Ear of the Virgin rises (its morning rising); and it rains (Evans, 1998, p. 199). Of course, the solar phenomenon (the rise of Spica) will usually occur at a day different from the lunar

phenomenon (the 21st day of the lunar month), but they both happen around the same period of the year.

5. THE DIRECTIONS OF SPACE

Some knowledge of astronomy was also essential for sailors, because the North direction was identified by means of the stars, at a time when the magnetic compass was unknown:

> Gladly then did goodly Odysseus spread his sail to the breeze; and he sat and guided his raft skillfully with the steering-oar, nor did sleep fall upon his eyelids, as he watched the Pleiades, and late-setting Bootes, and the Bear[4], which men also call the Wain, which ever circles where it is and watches Orion, and alone has no part in the baths of Ocean. For Calypso, the beautiful goddess had bidden him to keep this star on the left hand as he sailed over the sea. (Homer, *Odyssey*, V.268-277)

Orientation, on the earth or at the sea, needed astronomical knowledge. The circumpolar stars were the best guides for finding the north, during the night. The Sun can also be used to find the four cardinal points, using a *gnomon*, but it is necessary to know that it does not rise exactly at the East and does not set exactly at the West, except for two days in each year (the equinoxes). Acquaintance with the annual motion of the Sun was necessary to understand this.

In several ancient civilizations, temples and other important buildings – such as palaces – were built following astronomical orientation. In the late 19th century, Francis Cranmer Penrose and Joseph Norman Lockyer claimed that several Greek temples exhibited relevant astronomical alignments, related to the Sun and to the rising of some stars (Kelley & Milone, 2011, p. 240). This is, however, a controversial issue. Greek temples were not erected following the four cardinal directions, and hitherto there

[4] During Homer's time, the name "Bear" likely included all the stars the move around the north celestial pole (Tannery, 1893, p. 7).

is no general clear interpretation of their alignment. However, in some cases it is possible that their orientation was related to specific appearances related to the Sun, the Moon and stars (Salt, 2009).

6. ARATOS' PHAINOMENA

The deep relation between heavenly phenomena and practical human interests is displayed not only in the early poetic productions but also in the Greek technical literature that developed from the fourth century BCE onwards. Eudoxos of Cnidos (ca. 408-355 BCE), who was a pupil of Plato and contemporaneous of Aristotle, is famous for his mathematical explanation of the motion of the planets using homocentric spheres. However, he did also compose a work on the visible celestial phenomena (now lost, as all his other books), that was rendered into verses in the third century BCE by Aratos of Solis (ca. 315-240 BCE). His poem begins by invoking Zeus:

> From Zeus let us begin; him do we mortals never leave unnamed; full of Zeus are all the streets and all the market-places of men; full is the sea and the havens thereof; always we all have need of Zeus. For we are also his offspring; and he in his kindness unto men giveth favorable signs and wakened the people to work, reminding them of livelihood. He tells what time the soil is best for the labor of the ox and for the mattock, and what time the seasons are favorable both for the planting of trees and for casting all manner of seeds. For himself it was who set the signs in heaven, and marked out the constellations, and for the year devised what stars chiefly should give to men right signs of the seasons, to the end that all things might grow unfailingly. (Aratos, *Phainomena*, 1-13)

This preamble and other parts of the poem were strongly influenced by the Stoic doctrine that the cosmos is governed from within by the divine reason that pervades it (Hard, 2015, p. xx).

The main part of Aratos' work describes the stars and their successive appearances in the sky. He only mentions the planets to dismiss their study:

> Mixed with them are five other stars [planets], in no way like them, that whirl all through the twelve figures [of the Zodiac]. Not by looking at other stars could you mark the paths of these, since all move about. Long are the periods of their revolutions, and very far apart the signs of their conjunctions. Of them I have no longer confidence: may I be competent to tell of the circles of the fixed stars and the signs in heaven. (Aratos, *Phainomena*, 454-461)

We find a similar view in Xenophon's description of Socrates' attitude towards astronomy:

> He bid them also to become experienced in studying the stars – in this too, however, up to the point of being able to judge the time of night, month, and year, for the sake of traveling, sailing, and guarding, and as for the other things that are done by night or by month or by year to have marks to use in distinguishing the periods of the things mentioned. And he said that these things were easy to learn from night hunters and ship pilots as well as many other whose concern it is to know them. But he turned them strongly away from learning astronomy as far as knowing also the beings that do not keep to the same path of revolution, both the planets and the unstable stars [comets], or exhausting themselves by seeking their distances from the earth, their paths and the causes of these things. For he said that he did not see any benefit in these things either (and yet even in these he was not uninstructed), and he said that they too were sufficient to exhaust the life of a human being and to hinder one from many beneficial things. (Xenophon, *Memorabilia*, IV.7.4-5)

The oldest surviving Greek works on mathematical astronomy were written by Autolycos of Pitane, about 320 BCE (James, 1998, p. 21). They do not analyze the motion of the

planets – their subject is the rotation of the sphere of the stars, and the rising and setting of constellations – that is, the mathematical treatment of the same subject covered by Aratos' work.

Indeed, the Greek word ἄστρων (*astron*) was generally applied to the Sun, the Moon and to the constellations, not to an isolated star of to the planets, which were not a concern for the early Hellenic αστρονομία (Tannery, 1893, p. 4). Plato, in the *Republic*, also emphasizes the practical side of astronomy when discussing the useful sciences that should be studied:

> [Socrates:] "Shall we set down astronomy as a third [after arithmetic and geometry], or do you dissent?" "I certainly agree," he [Glaucon] said; "for quickness of perception about the seasons and the courses of the months and the years is serviceable, not only to agriculture and navigation, but still more to the military art". (Plato, *Republic* VII, 527d)

Aratos' poem includes technical information – such as the celestial axis and poles –, mythological aspects and practical uses of astronomical knowledge, such as the use of the two Bears to guide the sailors:

> They [the stars], all alike, many though they be and other star in other path, are drawn across the heavens always through all time continually. But the Axis shifts not a whit, but unchanging is forever fixed, and in the midst, it holds the earth in equipoise, and wheels the heaven itself around[5]. On either side the Axis ends in two Poles, but thereof the one is not seen, whereas the other faces us in the north high above the ocean. Encompassing it two Bears [Ursa Major and Minor] wheel together – wherefore they are also called the Wains. Now they ever hold their heads each toward the flank of the other, and are borne along always shoulder-wise, turned alternate on their shoulders. If, indeed, the tale be true, from

[5] The idea of a spherical rotating heaven was probably introduced in Greek thought by Pythagoras.

> Crete they by the will of mighty Zeus entered up into heaven, for that when in olden days he played as a child in fragrant Dicton, near the hill of Ida, they set him in a cave and nurtured him for the space of a year, what time the Dictaean Curetes were deceiving Cronus. Now the one [of the two Bears] men call by name Cynosura [Ursa Minor] and the other Helice [Ursa Major]. It is by Helice that the Achaeans on the sea divine which way to steer their ships, but in the other the Phoenicians put their trust when they cross the sea. But Helice, appearing large at earliest night, is bright and easy to mark; but the other is small, yet better for sailors: for in a smaller orbit wheel all her stars. By her guidance, then, the men of Sidon steer the straightest course. (Aratos, *Phainomena*, 19-44)

Some of the Greeks ascribed the discovery of the spherical form of the Earth to Pythagoras (sixth century BCE), others to Parmenides (fifth century BCE). According to Sulpicius Gallus, Thales of Miletus was the first to represent the heavens with a sphere (James, 1998, pp. 47, 90). The cosmological view of the Greeks, with a spherical universe with the Earth at its center, entailed a sense of order and aesthetic beauty associated to the very concept of κόσμος (Taub, 2003, p. 13).

It is likely that Aratos' *Phainomena* soon became a standard textbook, and it was supplemented by commentaries and additional works. The understanding of Aratos' work required a knowledge of the constellations, that were probably studied using celestial globes and charts (Hard, 2015, p. xxii).

7. ASTRONOMY AND METEOROLOGY

A very important part of Aratos' work is the description of the relations between the weather and the heavenly signs. This was a very important subject to be studied by sailors, for instance:

> Those twelve signs of the Zodiac are sufficient to tell the limits of the night. But they to mark the great year – the season

> to plough and sow the fallow field and the season to plant the tree – are already revealed of Zeus and set on every side. Yea, and on the sea, too, many a sailor has marked the coming of the stormy tempest, remembering either dread Arcturus or other stars that draw from ocean in the morning twilight or at the first fall of night. (Aratos, *Phainomena*, 740-747)

In the Odyssey and the Iliad, the meteorological phenomena are often linked to gods. Zeus is "cloud gatherer", and Athena both sends and stalls winds (Taub, 2003, p. 5). However, the ancient practice of using the risings and settings of stars to mark out the seasons and to predict weather phenomena was based on ideas that the motions of the heavens are related to terrestrial effects, particularly weather (Taub, 2003, p. 8). Some of the weather signs were related to the Moon:

> Scan first the horns on either side the Moon. For with varying hue from time to time the evening paints her and of different shape are her horns at different times as the Moon is waxing – one form on the third day and other on the fourth. From them thou canst learn touching the month that is begun[6]. If she is slender and clear about the third day, she heralds calm: if slender and very ruddy, wind; but if thick and with blunted horns she shows but a feeble light on the third and fourth night, her beams are blunted by the South wind or imminent rain. If on the third night neither horn nod forward or lean backward, if vertical they curve their tips on either side, winds from the West will follow that night. But if still with vertical crescent she brings the fourth day too, she gives warning of gathering storm. If her upper horn nod forward, expect thou the North wind, but if it leans backward, the South. But when on the third day a complete halo, blushing red, encircles her, she foretells storm and, the fierier her blush, the fiercer the tempest. (Aratos, *Phainomena*, 778-799)

[6] The Greek month began on the New Moon.

A similar account of the relation between the astronomical signs and weather occurs in a work ascribed to Theophrastos (Tannery, 1893, p. 17).

The Greeks preferred not to sail during the stormy winter months. The best conditions for sailing were from late May to mid-September, that is, after the rising of the Pleiades to the rising of Arcturus (Irby, 2016, v. 1, p. 861). The four main winds of the Greek tradition, mentioned by Homer and other ancient authors, were Boreas (from the North), predominant in winter, bringing fine weather, but strong and violent; Notos (from the South), a dangerous, stormy wind associated to late summer and autumn storms; Zephyros (from the West), bringing spring and early summer breezes; and Euros (from the East) (Bunbury, 1879, vol. 1, p. 36; Daremberg, 1885, p. 329). In ancient Greek mythology, they were regarded as wind gods; in the Odyssey, they are horses kept in the stables of the storm god Aeolus. During the year, each of those main winds was announced by specific constellations:

> Beneath the head of Helice are the Twins [Gemini]; beneath her waist is the Crab [Cancer]; beneath her hind feet the Lion [Leo] brightly shines. There is the Sun's hottest summer path. Then the fields are seen bereft of corn-ears, when first the Sun comes together with the Lion. Then the roaring Etesian winds[7] fall swooping on the vast deep, and voyaging is no longer seasonable for oars. Then let broad-beamed ships be my choice, and let steersmen hold the helm into the wind. (Aratos, *Phainomena*, 147-156)

8. MEASUREMENT OF TIME

Astronomy also had a fundamental role in the measurement of the parts of the day. Instead of dividing the time between one midnight and the next one into twenty-four equal parts, as we do, the Greeks divided the time between sunrise and sunset in

[7] The name "etesian" is related to ἔτος, year. The Etesian winds are the strong North winds.

twelve hours which changed their length through the year; and night was also divided in twelve hours (Evans, 1998, p. 95). The Egyptians were probably the first people to divide the night in 12 parts, as this was recorded since 2150 BCE (Hannah, 2005, p. 87).

Since it depended on sunrise and sunset, the measurement of time was directly related to the motion of the Sun. There were several ways of measuring times smaller than a day – such as water clocks (clepsydrae) and other devices; but since the hour was defined as the 12th part of the bright part of the day (between sunrise and sunset), the most useful and precise clocks of Antiquity used during daytime were sundials. For all practical uses, no other instrument could provide an adequate measure of time, because only sundials provided variable hours, smaller during the winter and larger during the summer.

According to Herodotus, the division of the duration of the day in 12 parts, the device for observing the shadow of the Sun (the *gnomon*) and the first spherical sundial (the *polos*) were imported by the Greeks from Babylon (Tannery, 1887, p. 82). The *gnomon* can be used to find the equinoxes, the obliquity of the ecliptic, the height of the celestial pole (and, therefore, the geographical latitude). Some ancient sources ascribe to Anaximander of Miletus (c. 610-546 BCE) the erection of a *gnomon* in Lacedaemon; and to Aristarchus of Samos the construction of a plane sundial, that requires advanced mathematical analysis of the motion of the Sun (*ibid*., pp. 82-83). The design of a plane sundial is a very complicated subject. Besides ascertaining the cardinal directions, it requires knowledge of the latitude of the place where it is built, and uses a set of complex geometrical procedures.

During the night, the measurement of time employed the observation of the stars. In each night, six signs of the Zodiac rise and set; hence, the appearance or disappearance of each sign corresponds to two hours. To ascertain the time, it was necessary both to observe the rising zodiacal sign on the eastern horizon; and to know the current sign of the Sun (Evans, 1998, p. 95).

The beginning of the night corresponded to the rising of the sign opposite to the one occupied by the Sun, and so on. From the fifth century BCE on, the information about the position of the Sun would be known to the average person; in some towns, *parapegmata* (public calendars) displayed the current place of the Sun in the Zodiac, along with other information (Evans, 1998, p. 98)

9. ASTRAL MYTHOLOGY

The sky was regarded by several ancient civilizations – including the Greek one – as a sacred space. The Pythagoreans held that the heavenly bodies are divine, moved by the ethereal soul which informs the universe and is akin to man's soul; Plato regarded the stars are visible gods (Cumont, 1912, p. 39).

We have remarked that a few stars and constellations had already names and mythological meaning in the early Greek culture, as seen in the works of Homer and Hesiod. Most astral myths were developed, however, after the fifth century BCE, flourishing later in the Hellenistic period. Sophocles and Euripedes are cited as sources for the myths related to the constellations of the Perseus-Andromeda group, and Pherecydes for the mythology of the Hyades and Ariadne's crown, for instance (Hard, 2015, pp. xiv-xv). In a few centuries, the splendid figures set in the heavenly sacred space were identified with people, creatures and things from myth and legend. They had been placed or depicted in the sky, usually by gods, in a process called *katasterismos*.

In Aratos' *Phainomena* we can find the names and a description of symbolic imagens covering the sky, including almost all the constellations of Ptolemy's later catalogue (Bouché-Leclercq, 1899, p. 62). His source was Eudoxos' fourth century work, and therefore at this time there was a definite identification of the observable stars. However, Aratos was not especially interested in myths – he describes only a few stories concerning the constellations, his main interest being their positions, risings and settings. Not much later than Aratos,

Eratosthenes (ca. 276-194 BCE) wrote a lost astronomical work, called *Katasterismoi*, that was probably the most complete early collection of myths related to the stars, besides describing the stars in each constellation (Hard, 2015, pp. xvii-xviii). In many cases, astral lore was intimately linked to the influences associated to each constellation or star. We have remarked that the Dog Star (Sirius) brought strong heat; Eratosthenes presented a myth for the Dog Star that explained this characteristic (Hard, 2015, p. 117).

The content of Eratosthenes' work is known through a Latin manual of astronomy ascribed to Gaius Julius Hyginus (ca. 64 BCE-17 CE), the *Astronomia*, or *Poeticon astronomicon*. It contains the basic (non-mathematical) ancient astronomical knowledge, but was mostly devoted to star myths, often with variants and alternative stories (Hard, 2015, pp. xvii; xxvi-xxvii). This canon of astral mythology became part of the general Hellenistic and Roman cultures. Educated people would be expected to have a broad knowledge of astronomy and of the celestial myths.

10. MEDICINE AND THE STARS

Another realm of human concern that was related to the heaven, in the ancient Greek culture, was medicine. In Plato's *Symposium*, Eryximachus (a physician) explained the relevance of equilibrium between the opposite powers for health, and its relation with the influences of the stars that bring the different seasons:

> Thus, in music and medicine and every other affair, whether human or divine, we must be on the watch as far as may be for either sort of love; for both are there. Note how even the system of the yearly seasons is full of these two forces; how the qualities I mentioned just now, heat and cold, drought and moisture, when brought together by the orderly Love, and taking on a temperate harmony as they mingle, become bearers of ripe fertility and health to men and animals and plants, and are guilty of no wrong. But when the wanton-

> spirited Love gains the ascendant in the seasons of the year, great destruction and wrong does he wreak. For at these junctures are wont to arise pestilences and many other varieties of disease in beasts and herbs; likewise hoar-frosts, hails, and mildews, which spring from mutual encroachments and disturbances in such love-connections as are studied in relation to the motions of the stars and the yearly seasons by what we term astronomy. So further, all sacrifices and ceremonies controlled by divination, namely, all means of communion between gods and men, are only concerned with either the preservation or the cure of love. (Plato, *Symposium*, 187e-188c)

The relation between health, the seasons and winds brought by the stars is discussed at length in the treatise *On airs, waters, and places* of the Hippocratic corpus.

> Whoever would study medicine aright must learn of the following subjects. First, he must consider the effect of each of the seasons of the year and the differences between them. Secondly, he must study the warm and cold winds, both those which are common to every country and those peculiar to a particular locality. [...] With the passage of time and the change of the seasons, he would know what epidemics to expect, both in the summer and in the winter, and what particular disadvantages threatened an individual who changed his mode of life. Being familiar with the progress of the seasons and the dates of rising and setting of the stars, he could foretell the progress of the year. Thus, he would know what changes to expect in the weather and not only would he enjoy good health himself for the most part but he would be very successful in the practice or medicine. (Hippocrates, *On airs, waters, and places*, 1-2)

This treatise is full of specific predictions, such as these:

> And respecting the seasons, one may judge whether the year will prove sickly or healthy from the following observations. If the appearances connected with the rising and

setting stars be as they should be; if there be rains in autumn; if the winter be mild, neither very tepid nor unseasonably cold, and if in spring the rains be seasonable, and so also in summer, the year is likely to prove healthy. But if the winter be dry and northerly, and the spring showery and southerly, the summer will necessarily be of a febrile character, and give rise to ophthalmies and dysenteries. For when suffocating heat sets in all of a sudden, while the earth is moistened by the vernal showers, and by the south wind, the heat is necessarily doubled from the earth, which is thus soaked by rain and heated by a burning sun, while, at the same time, men's bellies are not in an orderly state, nor the brain properly dried; for it is impossible, after such a spring, but that the body and its flesh must be loaded with humors, so that very acute fevers will attack all, but especially those of a phlegmatic constitution. Dysenteries are also likely to occur to women and those of a very humid temperament. And if at the rising of the Dog star rain and wintery storms supervene, and if the etesian winds blow, there is reason to hope that these diseases will cease, and that the autumn will be healthy; but if not, it is likely to be a fatal season to children and women, but least of all to old men; and that convalescents will pass into quartans, and from quartans into dropsies; but if the winter be southerly, showery and mild, but the spring northerly, dry, and of a wintry character, in the first place women who happen to be with child, and whose accouchement should take place in spring, are apt to miscarry; and such as bring forth, have feeble and sickly children, so that they either die presently or are tender, feeble, and sickly, if they live. Such is the case with the women. The others are subject to dysenteries and dry ophthalmies, and some have catarrhs beginning in the head and descending to the lungs. Men of a phlegmatic temperament are likely to have dysenteries; and women, also, from the humidity of their nature, the phlegm descending downwards from the brain; those who are bilious, too, have dry ophthalmies from the heat and dryness of their flesh; the aged, too, have catarrhs from their flabbiness and melting of the veins, so that some of them die suddenly and some

> become paralytic on the right side or the left. (Hippocrates, *On airs, waters, and places*, 10)

The Hippocratic treatise *On Regimen* presents a simple division of the year, not unlike our modern one: "I divide the year into four parts, which most people know best: winter, spring, summer, autumn. And winter lasts from the setting of the Pleiades until the spring equinox; spring, from the spring equinox until the rising of the Pleiades; summer from the Pleiades until the rising of Arcturus; and autumn from Arcturus until the setting of the Pleiades" (Hulskamp, 2011, pp. 151-152)[8]. According to Hippocrates, epidemics were brought by particular weather conditions related to the seasons of the year. For instance:

> In Thasus, a little before and during the season of Arcturus, there were frequent and great rains, with northerly winds. About the equinox, and till the setting of the Pleiades, there were a few southerly rains: the winter northerly and parched, cold, with great winds and snow. Great storms about the equinox, the spring northerly, dryness, rains few and cold. About the summer solstice, scanty rains, and great cold until near the season of the Dog-star. After the Dog-days, until the season of Arcturus, the summer hot, great droughts, not in intervals, but continued and severe: no rain; the Etesian winds blew; about the season of Arcturus southerly rains until the equinox. In this state of things, during winter, paraplegia set in, and attacked many, and some died speedily; and otherwise the disease prevailed much in an epidemical form, but persons remained free from all other diseases. Early in the spring, ardent fevers commenced and continued through the summer until the equinox. Those then that were attacked immediately after the commencement of the spring and summer, for the most part recovered, and but few of them died. But when the autumn and the rains had set in, they were of a fatal character,

[8] The first recorded Greek observation of the summer solstice was made in 432 BCE by Meton and Euctemon (James, 1998, p. 20).

> and the greater part then died. (Hippocrates, *Of the Epidemics*, I.2.7-8)

Besides the general effects of the weather, *On airs, waters, and places* also states that some specific days of the year are particularly dangerous:

> Whoever studies and observes these things may be able to foresee most of the effects which will result from the changes of the seasons; and one ought to be particularly guarded during the greatest changes of the seasons, and neither willingly give medicines, nor apply the cautery to the belly, nor make incisions there until ten or more days be past. Now, the greatest and most dangerous are the two solstices, and especially the summer, and also the two equinoxes, but especially the autumnal. One ought also to be guarded about the rising of the stars, especially of the Dog star, then of Arcturus, and then the setting of the Pleiades; for diseases are especially apt to prove critical in those days, and some prove fatal, some pass off, and all others change to another form and another constitution. (Hippocrates, *On airs, waters, and places*, 11)

The crisis of a disease is a decisive moment: either the disease overcomes the patient, of the patient overcomes the disease, or the disease changes into something completely different (Hulskamp, 2011, p. 158). The Hippocratic doctrine of critical days was closely similar to the astrologers' beliefs. It accepted that there were specific days or hours that were of crucial significance in determining the outcome of an illness. This doctrine was later developed in Galen's medical astrology (Nutton, 2013, p. 275).

11. MAN, THE MICROCOSM

The deeper relation between the heavens and the human body was expressed as the view, ascribed to Democritus, that the individual is a *mikros kosmos*; and this analogy between man

and the cosmos appears in the Hippocratic treatise *On Regimen.* That work establishes relations between the appearance of stars, the seasons, the weather and its effect on the body, and the adjustments of regimen required at each time. It also uses astronomical phenomena in *diagnosis*, *prognosis* and treatment of diseases (*prodianosis*) (Hulskamp, 2011, pp. 163-164).

The structure of the human body is related to the Earth and the universe, "a copy of the whole, the small after the manner of the great, and the great after the manner of the small" (Hippocrates, *Regimen* I.10, *apud* Hulskamp, 2011, p. 164). The belly is like the sea, the stomach and the lungs correspond to the earth; the peritoneum is associated to the Moon, the stars to the peripheral circuit close to the skin, the Sun to the intermediate circuit – probably the heart – where the hottest and strongest fire is located and the soul moves. Health problems can be diagnosed by dreams related to the several parts of the universe. Problems associated to the stars indicate that the outer bodily circuit has been affected, and it should be purged outward, through the skin; when it concerns the Moon, there is something wrong in the hollow parts of the body, and purgation should be directed inward; when the problem is related to the Sun, purgation in both directions should take place (Hulskamp, 2011, p. 166).

> Whenever a heavenly body appears to fall away from its orbit, should it be pure and bright, and the motion towards the east, it is a sign of health. For whenever a pure substance in the body is secreted from the circuit in the natural motion from west to east, it is right and proper. In fact, secretions into the belly and substances disgorged into the flesh all fall away from the circuit. But whenever a heavenly body seems to be dark and dull, and to move towards the west, or into the sea, or into the earth, or upwards, disease is indicated. When the motion is upwards, it means fluxes of the head; when into the sea, diseases of the bowels; when into the earth, most usually tumors growing in the flesh. In such cases it is beneficial to reduce food by one-third and to take an emetic, to be followed

> by a gradual increase of food for five days, the normal diet being resumed in another five. Another emetic should be followed by the same gradual increase. Whenever a heavenly body seems to settle on you, if it be pure and moist, it indicates health, because what descends from the ether on to the person is pure, and the soul too sees it in its true character as it entered the body. But should the heavenly body be dark, impure and not transparent, it indicates disease caused neither by surfeit nor by depletion, but by the entrance of something from without. It is beneficial in this case to take sharp runs on the round track, that there may be as little melting of the body as possible, and that by breathing as rapidly as possible the patient may secrete the foreign body. After these runs let there be sharp walks. Diet to be soft and light for four days. (Hippocrates, *Regimen*, IV.89; Hippocrates, 1959, pp. 433-435)

12. GEOGRAPHY AND ASTRONOMY

Some ancient technical developments, such as the study of geography and the manufacture of maps, also required astronomical knowledge.

Homer did not mention the four cardinal points; he vaguely referred to those directions as “towards the dawn and the Sun” (east) and “to darkness” (west); and he also mentioned the four main winds, Boreas, Notos, Zephyros and Euros (corresponding to north, south, west and east), without stating their directions (Bunbury, 1879, vol. 1, pp. 35-36, 77).

By the fourth century BCE, Greek philosophers and astronomers accepted that the Earth was a sphere at rest in the middle of a finite universe, and that the fixed stars were bound to a sphere that rotates uniformly around a fixed axis (James, 1998, pp. 19-20). This seemingly simple geometrical view of the universe allowed the Greek to develop sophisticated theories of the motion of the stars, and also a mathematical geography grounded upon the observation of the sky.

Nowadays, the use of a magnetic compass for ascertaining the geographical directions is so common that we forget that this

instrument was unknown in Europe before the 12th century and that before that time the concept of the cardinal directions was an astronomical one. The geographical directions were defined in Antiquity by taking into account the structure of the sky: the north and south poles were the extremities of the axis of the celestial sphere, and the north-south direction could be ascertained either by the observation of the night sky (the circumpolar stars) or during daytime by the study of the motion of the Sun, with the use of a *gnomon*, possibly introduced in Greece by Anaximander (Bunbury, 1879, vol. 1, p. 122). This was known by all educated people, in Antiquity.

One of the earliest arguments for the spherical form of the Earth was that different constellations could be observed from different geographical places. At first, this was a qualitative observation made by travelers, but Theodosius of Bithynia (2nd century BCE) wrote a work *On geographical places*, where he discussed the appearances of the stars as seen from different places, taking into account the spherical shapes of the sky and the Earth (James, 1998, p. 24).

The ascertaining of the geographical position of a place on the spherical Earth depends on the determination of its latitude and longitude. The observed angular height of the North celestial pole, relative to the horizon, varies depending on the geographical position of the observer, due to the spherical shape of the Earth. This observable angle allowed the determination of the latitude of the observer on the Earth. It could also be ascertained by the study of the shadows produced by the Sun – especially during the equinoxes or the solstices (Bunbury, 1879, vol. 1, p. 632). So, latitude was ascertained by astronomical observations. It was much more difficult to find the geographical longitudes. Sometimes it was found by direct evaluation of distances and by computing the angular distance between the corresponding meridians. It was possible, however, to evaluate large longitude differences by the timing of lunar eclipses, as described by Hipparchus (Bunbury, 1879, vol. 1, p. 633).

Nowadays, we think about the meridians and the parallel circles (equator, tropics and polar circles) as imaginary lines upon the surface of the Earth. However, both their early definitions and the method of finding them were astronomical. The meridians were the circles of the heavenly sphere that passed by the celestial poles. The equator was the circle drawn in the sky by the Sun during the equinoctial days. The tropics were the circles described by the Sun during the solstices. According to Plutarch (*De Placitis Philosophorum* 2.12 and 3.14; see Strabo, 1917, vol. 1, p. 361), Thales and Pythagoras defined those circles and divided the heaven in five zones (Bunbury, 1879, vol. 1, p. 120). The corresponding circles and divisions of the Earth came afterwards, and were defined relative to the celestial ones. Poseidonius ascribed the later division to Parmenides (Strabo, *Geography*, II.2; see Strabo, 1917, vol. 1, p. 361; Bunbury, 1879, vol. 1, p. 125). The surface of the Earth was later divided in seven narrower parallel bands, the "climes" (κλίματα), perhaps by Eratosthenes, or Hipparchus (Shcheglov, 2006).

The lengths of daytime and night vary, depending on the time of the year and the latitude of the observation place[9]. The largest difference occurs during the solstices. The person who first established the ratio of the durations of day and night and latitude is unknown; but it was used by Hypsicles in Alexandria, in the second century BCE (Kelley & Milone, 2011, p. 89). Theodosius of Bithynia (2nd century BCE), in his work *On days and nights*, developed advanced computations on the duration of days and nights, and their relation to the geographical latitude (Tannery, 1893, p. 42).

The phenomenon of variation of the length of days and nights was strikingly observed by the famous traveler Pytheas of Massalia (fourth century BCE) who sailed from the

[9] According to the older definition of the hour, every day and every night had exactly 12 hours. The astronomers introduced an artificial hour, by dividing the time between two successive midnights into 24 parts. Using this new definition of hour, the durations of day and night may be different.

Mediterranean to Iberia and the Keltic territory, and then to British islands, measuring the latitudes of the places he reached, up to the northern tip of Scotland. He also reached land to the north of Scotland, perhaps on the Norwegian coast (Roller, 2006, p. 69-75). He may be the first Mediterranean to see and to describe the summer night of high latitudes, where the Sun shines dimly all night, moving from west to east.

Pytheas described that the tides of the ocean increased as the Moon became full, and decreased as it waned (Bunbury, 1879, vol. 1, p. 600). This is not a correct description, but it is one of the earliest accounts of the relation between the tides and the Moon, that were later described by Aetius, Stobaeus, Posidonius, Pliny the Elder and Ptolemy; it was incorporated in the popular lore, establishing one additional important influence of the celestial bodies.

13. ASTROLOGY

Since the time of Hesiod, the Greeks accepted several types of celestial influence upon the Earth. This is the main concept supporting astrology. However, the idea of predicting the life of an individual by the study of the celestial configuration at the moment of his birth (genethlialogy) did not exist among the Greeks, at that time. This approach to astrology appeared in Babylon around the fifth century BCE – the earliest known horoscope being from 410 BCE (Beck, 2007, pp. 13-14). Babylonian horoscopes described the position of the ascendant sign of the Zodiac – that is, the one that is rising at east, as viewed from the place where the person is born –, the positions of the Sun, the Moon and, sometimes, of the planets. The earliest Babylonian horoscopes only contained a description of the sky, without interpretation (Barton, 1994, p. 14). Others provided an explanation of the astrological influences, such as this example, from 235 BCE:

> Year 77 [of the Seleucid Era, month] Siman, [from?] the 4th [day until? some? time?] in the last part of the night off?]

> the fifth [day], Aristocrates was born. That day, Moon in Leo. Sun in 12;30° in Gemini. The Moon set its face from the middle towards the top; [the relevant omen reads:] 'If, from the middle towards the top, it [i.e., the Moon] sets its face, [there will ensue] destruction.' Jupiter [...] in 18º Sagittarius. The place of Jupiter [means]: [his life? will be] regular, well; he will become rich, he will grow old, [his] days will be numerous [literally, long]. Venus in 4º Taurus. The place of Venus [means]: Wherever he may go, it will be favorable [for him]; he will have sons and daughters. Mercury in Gemini with the Sun. The place of Mercury [means]: the brave one will be first in rank, he will be more important than his brothers, [...] Saturn; 6º Cancer. Mars: 24º Cancer […] the 22nd and 23rd of each month [...] (Barton, 1994, p. 16-17)

In Greece, up to Socrates' time, the planets had been neglected because of their irregular motion; they were neither described nor received individual names (Barton, 1994, p. 21). Plato, however, was already paying attention to them, and in the *Timaeus* he regarded them as divine beings – as was the case in Babylon (Barton, 1994, p. 22). The main character of this Platonic dialogue, called *Timaeus*, was a Pythagorean; and the followers of Pythagoras held that the heavenly bodies are divine, moved by the ethereal soul which informs the universe and is akin to man's soul (Cumont, 1912, p. 39). Some authors find in Plato's *Timaeus* a philosophical inspiration for the development of Greek astrology, since it describes all the fixed and moving stars, and even the Earth, as "living and immortal gods", endowed with body and soul; and that the Demiurgue ordered them to continue the work of fashioning the world and the mortal beings – including men and their souls (Bouché-Leclercq, 1899, pp. 21-22). Contemplation of the heaven produced not only aesthetic emotions, it was the motivation of the powerful belief in a good, rational and powerful deities that produced order (Cumont, 1909, pp. 264-265).

The earliest Greek names of the planets were merely descriptive of their visible characteristics (e.g., Mars was the

"fiery star", because of its red color). After the fourth century BCE the five known planets were named after Greek gods: they became the stars of Hermes, Aphrodite, Ares, Zeus, Kronos, probably because of Babylonian influence (Cumont, 1912, pp. 45-46). Notice that the Sun and the Moon were associated to Helios and Selene, which were secondary deities in the Greek pantheon.

Plato's pupil Eudoxus of Cnidus (408-355 BCE), after travelling to Egypt and Anatolia, acquiring new mathematical and astronomical skills, attempted to explain and predict their motions, using homocentric spheres. According to Seneca, Eudoxus was the first to bring the table of planetary motions from Egypt to Greece (Bouché-Leclercq, 1899, p. 63). Aristotle (384-322 BCE) was strongly influenced by this approach. The Aristotelian approach to the heavens was very different from Plato's; however, his philosophy also had a strong influence in later astrology, because of his theory of the four elements and the four main qualities (dry/moist, hot/cold) that was used by Ptolemy and other authors to explain the astral influences (Bouché-Leclercq, 1899, p. 25).

A third important philosophical influence on Greek astrology was the Stoicism of Zeno of Citium (ca. 334-262 BCE). According to the Stoics, man is a microcosm, the image and abridgement of the world. The stars were regarded as living gods, higher than man. The astral gods had the power and the will of interfering on terrestrial affairs. They acted by universal sympathy on their destiny, also sending signs that can be understood by human beings. This led the Stoics to accept all types of divination, including astrology, because of their religious and philosophical principles (Bouché-Leclercq, 1899, pp. 28-31). After Alexander, the combination of Babylonian religious influences with Stoic philosophy produced a very influent astral religion, which flowered with Posidonius of Apameia (ca. 135-51 BCE) and maintained a strong impact during the Hellenistic and Roman periods (Cumont, 1909, pp. 256-257).

Once this basic philosophy of astrology was accepted, the symbolic meanings of each sign of the Zodiac acquired a new function, acting upon the human beings under their influence. The association between the planets and Greek gods established another important way to interpret the astral influences related to the personal characteristics (including physical, psychological and gender peculiarities) of each deity (Bouché-Leclercq, 1899, pp. 67, 89-101, 132).

The study of the motion of the planets was highly complex, and was studied only by the mathematicians. However, some broad acquaintance with the planets and their main phenomena and influences soon became part of the Greek culture. The analysis of the motion of the stars and planets for drawing horoscopes required the development of an approach that was much more detailed and precise than the one known to former astronomers. Hypsicles (ca. 190-120 BCE) was probably the first Greek author who introduced the Babylonian division of the circle in 360 degrees (and also the day in 360 parts) to develop a more accurate analysis of the celestial motions (Bulmer-Thomas, 1972). Genethlialogy probably migrated from Babylon to the Greek world together with mathematical astronomy[10], and it was fully established in the Hellenistic culture in the second century BCE, at the time of Hipparchus (fl. 150-125 BCE) (Beck, 2007, pp. 15-16). The oldest surviving Greek horoscope was produced on 72 BCE (Barton, 1994, p. 16).

Several ancient astrological manuals were produced from the first century CE onwards, both in Hellenistic Greece and in the Roman Empire (Beck, 2007, p. 39). Some of the best known were written by Marcus Manilius (first century), Ptolemy

[10] However, according to Cicero, Eudoxus (possibly the first Greek mathematical astronomer) rejected prophecies based on the day of birth, that is, horoscopes (Barton, 1994, p. 22). The names of two Chaldean astrologers who brought the Babylonian knowledge to the Greek world are known: Berosus (ca. 280 BCE) and Soudines (ca. 238 BCE) (Cumont, 1912, pp. 56-57).

(second century) and Julius Firmicus Maternus (fourth century CE).

14. THEORY OF MATTER, METALLURGY AND ALCHEMY

The study of stars and planets also became linked to the practical and theoretical study of matter, in Antiquity. This occurred along several different and independent lines.

Aristotle had combined the four elements of Empedocles (fire, air, water, earth) with Hippocrates' doctrine of the four main influences (dry/wet, hot/cold), providing a fundamental connection between them: fire was dry and hot; air, wet and hot; water, wet and cold; and earth, dry and cold. Ptolemy, in his astrological treatise *Tetrabiblos*, associated Aristotle's ideas to several astronomical phenomena (Beck, 2007, p. 59). Each season, produced by the passage of the Sun by a specific set of zodiacal signs, brings a predominance of one of the four main influences. Spring is wet (becoming hot), summer is hot (becoming dry), autumn is dry (becoming cold), winter is cold (becoming wet). Therefore, those seasons (and the corresponding signs of the zodiac) were respectively associated to the elements air, fire, earth and water.

Another correlation was established by Marcus Manilius, who divided the twelve signs in four groups according to the trine aspect, establishing the following associations (Beck, 2007, p. 60):

- The triangle of fire (hot, dry, male): Aries, Leo, Sagittarius
- The triangle of earth (cold, dry, female): Taurus, Virgo, Capricorn
- The triangle of air (hot, wet, male): Gemini, Libra, Aquarius
- The triangle of water (cold, wet, female): Cancer, Scorpius, Pisces

Ptolemy did not associate the elements to the planets, but described their associations with the four qualities. The active power of the Sun is to heat and, to a certain degree, to dry; that of the Moon, to humidify, but it has a moderate heating power;

Saturn's quality is to cool and, moderately, to dry; that of Mars, to dry and to burn; Jupiter has a temperate active force: it heats and humidifies; Venus is similar to Jupiter, but she warms moderately and chiefly humidifies; Mercury sometimes dries and sometimes humidifies, and changes quickly from one to the other (Ptolemy, *Tetrabiblos* I.4; Ptolemy, 1940, pp. 35-39).

The four basic qualities and the four elements were also related by Ptolemy to other quaternities: the four main winds, the four cardinal directions, the four ages of mankind that had been formerly identified by the Pythagoreans: childhood, like spring; youth, like summer; adulthood, like autumn; and old age, like winter (Beck, 2007, p. 59). Galen (ca. 129-200 CE), who lived in the same period as Ptolemy, improved the Hippocratic analysis of the qualities and bodily humors, creating a new medical theory that included a typology of human physical constitutions and temperaments: sanguine (with predominance of blood), melancholic (black bile), choleric (yellow bile) and phlegmatic (phlegm). This medical theory was not born from astrology, but it was soon linked to celestial influences:

> For in general Saturn causes his subjects to have cold bellies, increases the phlegm, makes them rheumatic, meagre, weak, jaundiced, and prone to dysentery, coughing, raising, colic, and elephantiasis; the females he makes also subject to diseases of the womb. Mars causes men to spit blood, makes them melancholy, weakens their lungs, and causes the itch or scurvy; and furthermore, he causes them to be constantly irritated by cutting or cautery of the secret parts because of fistulas, hemorrhoids, or tumors, or also burning ulcers, or eating sores; he is apt to afflict women furthermore with miscarriages, embryotomies, or corrosive diseases. (Ptolemy, *Tetrabiblos*, 3.12; Ptolemy, 1940, pp. 327-329)

A completely different tradition, with strong Babylonian influence, established relations between the planets, their gods, and seven metals. Both in Mesopotamia and in Egypt, gold was

related to the Sun god and was supposed to have life-giving properties; and silver was the metal of the Moon god Sin (Forbes, 1950, pp. 86, 177). Those associations were also accepted in ancient Greece, together with a few others that were not so generally accepted. Aphrodite (and her planet, Venus) was associated to copper, a metal named after the island of Cyprus; and Aphrodite was sometimes called Cypris, because she was born in that island. Besides that, most mirrors were made of bronze, and copper is one of its components. Aphrodite, the beautiful goddess, was associated to mirrors (Cyrino, 2012, pp. 27, 66).

From the second century CE onward, we find an invariable connection in Hellenistic and Roman literature between Sun and gold, Moon and silver, Saturn and lead, Venus and copper, Mars and iron; the later relation between Jupiter and tin, and Mercury and quicksilver, had not been recognized at this time (Lippmann, 1919, p. 217). Those specific identifications between planets, gods and metals were also recognized by the Assyrians (Karpenko, 2003, p. 216).

The lapidary attributed to Damigeron and Evax (perhaps second century BCE), describes stones related to the seven planets and their engraving to produce amulets (Quack, 2001, p. 338). Sometimes, a relation was also established between the planets and precious stones that were placed on a board, to represent them, when casting a horoscope (Evans, 2004):

> A voice comes to you speaking. Let the stars be set upon the board in accordance with [their] nature except for the Sun and the Moon. And let the Sun be golden, the Moon silver, Kronos of obsidian, Ares of reddish onyx, Aphrodite lapis lazuli veined with gold, Hermes turquoise: let Zeus be of stone crystalline; and the horoscope, in accordance with [nature]. (Betz, 1992, p. 312, *apud* Campion, 2012, pp. 157-158)

In the first centuries CE there were many works pointing out relationships between the planets and specific stones, but the

correspondences varied widely (Hall, 2007, pp. 41-54). The relations between the planets, their gods and metals had a strong influence in later alchemy.

15. CONCLUSION: A SYMBOLIC NETWORK

The introduction of the astrological symbolism – especially that related to the planets – gave rise to a complex network of correspondences between different realms. Instead of the dry Aristotelian quaternities, we find in several Hellenistic authors the description of emblematic homologies such as this:

> First, the all-seeing sun, burning fire and intellectual light, instrument of spiritual perception; in a nativity, it means kingship, authority, intelligence, wisdom, beauty, social respect, revelation of the gods, judgement, reputation, action, authority over the people; it means the father, the master, friendship, noble persons, the honor having his portrait made, his statue done, of using a crown, command upon one's country [and over] the places. The parts of the body that it rules: the head, the sense organs, the right eye, the trunk, the heart, the breath, all perceptions, the nerves. Of the goods, it rules gold; of fruits, wheat and barley. It is of the day sect. Its color, like wine; its taste, bitter. (Valens, *Anthologies* I.1; Valens, 1989, p. 27)

In Marcus Manilius' *Astronomica* we find the classical distribution of the parts of the human body to different signs of the Zodiac:

> And just as the human frame is apportioned among the signs, a and the protection they afford, though collectively extending over the whole body, is in addition exercised separately over the limbs allocated among them. The Ram is attached to the head, the Bull to the neck; the arms are reckoned as under the Twins' domain, the breast under the Crab's; the shoulders appeal to you, Nemean [Leo], and to you, Maiden [Virgo], the belly; the Balance attends the loins, and the Scorpion is lord of the groin; the Archer [Sagittarius]

> has bestowed his love upon the thighs, Capricorn upon the knees, whilst the Youth [Aquarius] is protector of the shanks and the Fishes of the feet. So in like manner do different signs lay claim to different lands. (Manilius, *Astronomica* IV.701-710; Manilius, 1977, p. 279)

Those correlations between the human body and the macrocosm, accepted by all later authors, became of utmost importance in astrological medicine (*iatromathematics*), up to Modernity (Beck, 2007, p. 69).

> According to Ptolemy, medical astrology was first developed in Egypt, and it seems to have been a fairly sophisticated discipline. The physician-astrologer would examine the patient and also cast his nativity, which would give him additional information about the patient's state of health. The stars might tell him about the weak points in the patient's organism, or they might warn him of an impending crisis. If, after having made a prognosis, the physician-astrologer hesitated to choose between two types of treatment, the stars might indicate which one was preferable. (Luck, 2006, p. 416)

Another relevant development was the establishment of relations between the sky and the regions of the Earth. The earliest known Hellenistic author who developed an astrological approach to geography was Serapion (second century BCE), probably a pupil of Hipparchus. He established a relation between the seven geographical climes and the planets that determined the character of nature and man in each of them. His account was reproduced by Nigidius Figulus and influenced Pliny the Elder (Honigmann, 1929, p. 30; cf. Cumont, 1930, p. 231; Sarton, 1930, 272)

Both Ptolemy and Manilius also described the relations between the regions of the Earth and the signs of the Zodiac.

> God has divided the world into portions, distributing it among the individual signs. To each guardian power he has

> given a special region of the world to rule, bestowing also the peoples and mighty cities proper to them, wherein the signs should claim their predominant influences. (Manilius, *Astronomica*, IV.697-700; Manilius, 1977, p. 279)

The ancient astrologers attempted to describe and to explain the character of the people inhabiting each country, by the interpretation of the influences of the planets and signs upon each region – a combination of astral geography and ethnography:

> Of these same countries Britain, (Transalpine) Gaul, Germany, and Bastarnia are in closer familiarity with Aries and Mars. Therefore, for the most part their inhabitants are fiercer, more headstrong, and bestial. But Italy, Apulia, (Cisalpine) Gaul, and Sicily have their familiarity with Leo and the Sun; wherefore these peoples are more masterful, benevolent, and co-operative. Tyrrhenia, Celtica, and Spain are subject to Sagittarius and Jupiter, whence their independence, simplicity, and love of cleanliness. The parts of this quarter which are situated about the center of the inhabited world, Thrace, Macedonia, Illyria, Hellas, Achaia, Crete, and likewise the Cyclades, and the coastal regions of Asia Minor and Cyprus, which are in the south-east portion of the whole quarter, have in addition familiarity with the south-east triangle, Taurus, Virgo, and Capricorn, and its co-rulers Venus, Saturn, and Mercury. As a result, the inhabitants of those countries are brought into conformity with these planets and both in body and soul are of a more mingled constitution. They too have qualities of leadership and are noble and independent, because of Mars; they are liberty-loving and self-governing, democratic and framers of law, through Jupiter; lovers of music and of learning, fond of contests and clean livers, through Venus; social, friendly to strangers, justice-loving, fond of letters, and very effective in eloquence, through Mercury; and they are particularly addicted to the performance of mysteries, because of Venus's occidental aspect. (Ptolemy, *Tetrabiblos* II.3; Ptolemy, 1940, pp. 135-137)

The seven planets were incorporated into time reckoning by the introduction of the week and the weekdays. This was a late innovation in the Roman calendar, introduced in the time of Augustus (first century CE). Before that, the Romans used an eight-day "week", based on the periodicity of *nundinae*, the market days (Hannah, 2005, pp. 102, 141). The names of the weekdays are derived originally from those of the seven planet-gods (including Sun and Moon), beginning with Saturday: Saturn, Sun, Moon, Mars, Mercury, Jupiter and Venus. Each hour of each weekday was associated to a planet, following the Chaldean order of the planets, from the most distant ones to the closest ones (Saturn, Jupiter, Mars, Sun, Venus, Mercury and Moon). The first hour of Saturday was ruled by Saturn; and the following ones by the successive planets (Hannah, 2005, pp. 141-142). According to Cassius Dio (ca. 155–235 CE), the association of the planets with the hours of the day came before and explained their relation with the weekdays:

> The custom, however, of referring the days to the seven stars called planets was instituted by the Egyptians, but is now found among all mankind, though its adoption has been comparatively recent; at any rate the ancient Greeks never understood it, so far as I am aware. But since it is now quite the fashion with mankind generally and even with the Romans themselves, I wish to write briefly of it, telling how and in what way it has been so arranged. […] If you begin at the first hour to count the hours of the day and of the night, assigning the first to Saturn, the next to Jupiter, the third to Mars, the fourth to the Sun, the fifth to Venus, the sixth to Mercury, and the seventh to the Moon, according to the order of the cycles which the Egyptians observe, and if you repeat the process, you will find that the first hour of the following day comes to the Sun. And if you carry on the operation throughout the next twenty-four hours in the same manner as with the others, you will dedicate the first hour of the third day to the Moon, and if you proceed similarly through the rest, each day will receive its appropriate god. This, then, is the

> tradition. (Dio, *Roman history*, 37.18-19; Dio, 1914, vol. 3, pp. 131-133)

The preparation of talismans and other types of magic rituals required the knowledge of the ruling planet-god of each hour of each day.

Oriental influences helped to produce astral religions in the Hellenistic and Roman worlds. Mythra was originally a Persian god, but it also became popular in Greece (Cumont, 1903, pp. 8-9). It was associated to Helios, but his Persian name was never replaced in the liturgy by a translation, as had been the case with the other divinities worshipped in the Mysteries (*ibid*., p. 20). The central iconography of Mythraism was the Tauroctony, in which the divine hero Mythra was shown killing a bull (Taurus), surrounded by other constellational images, including Canis, Hydra, Crater and Corvus (Campion, 2012, p. 158). The obvious astronomical correlations were sometimes expanded by introducing the symbols of the Zodiac, and two youths holding the upright and the inverted torch, that represented the northern and southern paths of the Sun during each half year. The artistic creation of Mythra Tauroctonos was probably a Hellenistic production by a sculptor from Pergamon, in the second century BCE (Cumont, 1903, pp. 24, 124).

The Mythraic mysteries were concerned with the individual salvation, regarded as a return to the celestial world. A similar idea was already extant in Plato's *Timaeus* that described that the individual souls originated in the stars and descended to the Earth, leaving divinity behind, but returning to it after death (Campion, 2012, pp. 153-154). In the mysteries of Mythra, the spiritual ascent to the heavenly realm was represented by an alchemical ladder, described by Origen (ca. 185-254 CE):

> There is a ladder with lofty gates [...] The first gate consists of lead, the second of tin, the third of copper, the fourth of iron, the fifth of a mixture of metals, the sixth of silver, and the seventh of gold. The first gate they assign to Saturn, indicating by lead the slowness of this star; the second to

> Venus, comparing her to the splendor and softness of tin; the third to Jupiter, being firm and solid; the fourth to Mercury, for both Mercury and iron are fit to endure all things, and are money-making and laborious; the fifth to Mars, because, being composed of a mixture of metals, it is varied and unequal; the sixth, of silver, to the Moon; the seventh, of gold, to the Sun, thus imitating the different colors of the two latter. (Origen, *apud* Karpenko, 2003, pp. 216-217)

Notice that the order of the planets, here, is the inverse order of the weekdays. Sunday, over which the Sun presided, was especially holy in Mythra's mysteries (Cumont, 1903, p. 167).

The ladder represented seven steps of initiation in a ritual of spiritual ennoblement; as the soul passes each level (or astronomical sphere) it discards the vices associated with that planet (Campion, 2012, p. 158).

> As the soul traversed these different zones, it rid itself, as one would of garments, of the passions and faculties that it had received in its descent to the earth. It abandoned to the Moon its vital and nutritive energy, to Mercury its desires, to Venus its wicked appetites, to the Sun its intellectual capacities, to Mars its love of war, to Jupiter its ambitious dreams, to Saturn its inclinations. It was naked, stripped of every vice and every sensibility, when it penetrated the eighth heaven to enjoy there, as an essence supreme, and in the eternal light that bathed the gods, beatitude without end. (Cumont, 1903, p. 145)

There is a parallel between this ladder with alchemy, since it presents a series of seven metals, from the lowest (lead) to the highest and most perfect (gold) that became a model for the successive transformations in alchemical theory. This is one of the points where the worlds of esoteric and exoteric alchemy met, and this parallel persisted over the entire period of alchemy. (Karpenko, 2003, p. 217).

Any group of seven things could (and ultimately was) related to the seven planets and their gods, establishing symbolic

relations. So, the seven vowels of the Greek alphabet came to correspond to the seven planetary gods (Luck, 2006, p. 51).

An astrological pharmacology and botany was also developed, especially in the so-called Hermetic tradition. Thessalus (first century CE) wrote a treatise describing the powers of herbs, where he stated that he was transmitting a revelation by Asclepius, that had been taught by Hermes Trismegistus. The treatise named seven herbs associated with the planets and twelve plants related to the signs of the Zodiac (Scarborough, 1991, p. 155). One example:

> First named among the plants of the Sun is the "heliotrope" [attracted to the Sun]; yet there are many kinds of "heliotropes", and of all these most efficacious is the one called chicory. Its juice mixed with oil of roses is an ointment. It is suitable for relieving heartburns, and it releases tertians, quartans, and intermittent fevers, and mixed with an equal part of the oil of unripe olives, it stops headaches. If someone looking toward the sunrise smears on the juice of the chicory, invoking the presence of the [god] Helios, and begs to give him praise, he will be most favored among all men on that day. (Scarborough, 1991, p. 155)

Other examples could be added to illustrate the web of relationships that connected in Antiquity the planets, stars and gods to all features of the physical world, including people, plants, animals, stones, etc. (Campion, 2012, p. 160).

All those instances show that in classical antiquity, astronomy had a strong connection with everyday life and was deeply embedded in the philosophical and religious culture. Although this relationship changed during the Middle Ages, due to both Islamic and Christian influences, astronomy remained of paramount importance in the culture and practical life until the changes brought by the Renaissance.

ACKNOWLEDGMENTS

The author is grateful to the São Paulo State Foundation for the Support of Research (FAPESP) and to the Brazilian Council for Scientific and Technological Development (CNPq) for the for the support received during the elaboration of this research.

BIBLIOGRAPHICAL REFERENCES

AESCHYLUS. *Aeschylus. Vol. 1. Prometheus Bound*. Translation by Herbert Weir Smyth. Cambridge, MA: Harvard University Press, 1926.

ARATOS. *Eratosthenes and Hyginus. Constellation myths; with Aratos's Phaenomena*. A new translation by Robin Hard. Oxford: Oxford University Press, 2015.

ARATOS. *The Phenomena and Diosemeia of Aratos*. Translated by John Lamb. London: John W. Parker, 1848.

BARTON, Tamsyn. *Ancient astrology*. London: Routledge, 1994.

BECK, Roger. *A brief history of ancient astrology*. Malden: Blackwell, 2007.

BERRY, William Turner; POOLE, Herbert Edmund. *Annals of printing: a chronological encyclopaedia from the earliest times to 1950*. London: Blandford Press, 1966.

BETZ, Hans Dieter. *The Greek magical papyri in translation, including the Demotic spells.* Chicago: University of Chicago Press, 1992.

BOUCHÉ-LECLERCQ, Auguste. *L'astrologie grecque*. Paris: Ernest Leroux, 1899.

BOUTSIKAS, Efronsyni. *Astronomy and ancient Greek cult. An application of archaeoastronomy to Greek religious architecture, cosmologies and landscapes*. PhD dissertation, School of Archaeology and Ancient History, University of Leicester, 2007.

BOUTSIKAS, Efronsyni. Placing Greek temples: an archaeoastronomical study of the orientation of ancient

Greek religious structures. *Archaeoastronomy*, 21: 4-19, 2007.

BROWNE, C. A. The poem of the philosopher Theophrastos upon the sacred art: a metrical translation with comments upon the history of alchemy. *The Scientific Monthly*, 11 (3): 193-214, 1920.

BULMER-THOMAS, Ivor. Hypsicles. Vol. 6, pp. 616-617, in: GILLISPIE, Charles Coulston (ed.). *Dictionary of scientific biography*. New York: Scribner, 1972.

BUNBURY, Edward Herbert. *A history of ancient geography among the Greeks and Romans: from the earliest ages till the fall of the Roman Empire*. London: John Muray, 1879. 2 vols.

CAMPION, Nicholas. *Astrology and cosmology in the world's religions*. New York: New York University Press, 2012.

CLINTON, Kevin. The mysteries of Demeter and Kore. Pp. 342-356, in: OGDEN, Daniel (ed.). *A companion to Greek religion*. Malden: Blackwell, 2007.

CUMONT, Franz. *The mysteries of Mithra.* Translated from the second revised French edition by Thomas J. McCormack. Chicago: Open Court, 1903.

CUMONT, Franz. Le mysticisme astral dans l'Antiquité. *Bulletin de l'Académie Royale de Belgique*, Classe des Lettres et des Sciences Morales et Politiques, 5: 256-286, 1909.

CUMONT, Franz. *Astrology and religion among the Greeks and Romans*. Translated by J. B. Baker. New York: G. P. Putnam's Sons, 1912.

CUMONT, Franz. [Review] Honigmann (Ernst). Die sieben Klimata und die πόλεις επίσημο. *Revue Belge de Philologie et d'Histoire*, 9 (1): 231, 1930.

CYRINO, Monica S. *Aphrodite.* London: Routledge, 2012.

DAVIDSON, James. Time and Greek religion. Pp. 204-218, in: OGDEN, Daniel (ed.). *A companion to Greek religion*. Malden: Blackwell, 2007.

DIO, Cassius. *Dio's Roman history*. Translation by Earnest Cary. Cambridge, MA: Harvard University Press, 1914-1927. 9 vols.

EVANS, James. *The history and practice of ancient astronomy*. New York: Oxford University Press, 1998.

EVANS, James. The astrologer's apparatus: a picture of professional practice in Greco-Roman Egypt. *Journal for the History of Astronomy*, 35 (118): 1-44, 2004.

EVELYN-WHITE, Hugh G. *Hesiod, the Homeric hymns, and Homerica*. London: William Heinemann, 1914.

FORBES, Robert James. *Metallurgy in Antiquity: a notebook for archaeologists and technologists*. Leiden: Brill, 1950.

GAWLINSKI, Laura. Greek calendars. Vol. 1, pp. 891-905, in: IRBY, Georgia L. (ed.). *A companion to science, technology, and medicine in ancient Greece and Rome*. Chichester: John Wiley & Sons, 2016. 2 vols.

HALL, Judy. *The stone horoscope: evidence for continuity of ancient esoteric tradition and practice*. MA in Cultural Astronomy and Astrology. Bath Spa University, 2007.

HANNAH, Robert. *Greek and Roman calendars: constructions of time in the classical world.* London: Duckworth, 2005.

HARD, Robin. *Constellation myths: with Aratus's Phaenomena*. Oxford: Oxford University Press, 2015.

HEATH, Thomas. *Aristarchus of Samos, the ancient Copernicus. A history of Greek astronomy to Aristarchus*. Oxford: Clarendon Press, 1913.

HOMER. *The Odyssey of Homer done into English prose*. Translated by S. H. Butcher and A. Lang. New York: P. F. Collier & Son, 1914.

HOMER. *The Odyssey*. Translated by Edward McCrorie. Introduction and notes by Richard P. Martin. Baltimore: Johns Hopkins University Press, 2004.

HONIGMANN, Ernst. *Die sieben Klimata und die* πόλεις ἐπίσημοι [poleis episemoi]: *eine Untersuchung zur Geschichte der Geographie und Astrologie im Altertum und Mittelalter*. Heidelberg: Carl Winters, 1929.

HULSKAMP, Maithe A. A. Space and body: uses of Astronomy in Hippocratic medicine. Pp. 149-168, in: BAKER, Patricia A.; NIJDAM, Han; LAND, Karine van't (eds.). *Medicine and space: body, surroundings and borders in Antiquity and the Middle Ages.* Leiden: Brill, 2011.

IRBY, Georgia L. Navigation and the art of sailing. Vol. 1, pp. 854-869, in: IRBY, Georgia L. (ed.). *A companion to science, technology, and medicine in ancient Greece and Rome*. Chichester: John Wiley & Sons, 2016. 2 vols.

KARPENKO, Vladimír. System of metals in alchemy. *Ambix*, 50 (2): 208-230, 2003.

KELLEY, David H.; MILONE, Eugene F. *Exploring ancient skies. A survey of ancient and cultural astronomy*. New York: Springer, 2011.

LIPPMANN, Edmund Oskar von. *Entstehung und Ausbreitung der Alchemie; mit einem Anhange: zur älteren Geschichte der Metalle; ein Beitrag zur Kulturgeschichte.* Berlin: Julius Springer, 1919.

LUCK, Georg. *Arcana mundi: magic and the occult in the Greek and Roman worlds*. 2nd ed. Baltimore: Johns Hopkins University Press, 2006.

MANILIUS, Marcus. *Astronomica*. Ed. and trans. George P. Goold. Cambridge, MA: Harvard University Press, 1977.

NUTTON, Vivian. *Ancient Medicine*. 2nd ed. London: Routledge, 2013

ODOM, Robert L. Vettius Valens and the planetary week. *Andrews University Seminary Studies*, 3 (1): 110-137, 1965.

PLATO. *Plato in twelve volumes*. Vol. 9. Translated by Harold N. Fowler. Cambridge, MA, Harvard University Press; London, William Heinemann Ltd. 1925.

PTOLEMY, Claudius. *Tetrabiblos*. Translation by Frank Egleston Robbins. Cambridge, MA: Harvard University Press, 1940.

QUACK, Joachim Friedrich. Zum ersten astrologischen Lapidar im Steinbuch des Damigeron und Evax. *Philologus. Zeitschrift für antike Literatur und ihre Rezeption*, 145 (2): 337-344, 2001.

ROLLER, Duane W. *Through the Pillars of Herakles: Greco-Roman exploration of the Atlantic.* New York: Routledge, 2006.

SARTON, George. [Review] Die sieben Klimata und die πόλεις ἐπίσημοι by Ernst Honigmann. *Isis*, 14 (1): 270-276, 1930.

SCARBOROUGH, John. The pharmacology of sacred plants, herbs, and roots. Pp. 138-174, in: FARAONE, Christopher A.; OBBINK, Dirk (eds.). *Magika Hiera: ancient Greek magic and religion.* New York: Oxford University Press, 1991.

SCULLION, Scott. Festivals. Pp. 190-203, in: OGDEN, Daniel (ed.). *A companion to Greek religion*. Malden: Blackwell, 2007.

SHCHEGLOV, Dmitry. Eratosthenes' parallel of Rhodes and the history of the system of climata. *Klio*, 88 (2): 351-359, 2006.

SHEPPARD, Harry J. Gnosticism and alchemy. *Ambix*, 4: 86-101, 1957.

SHEPPARD, Harry J. The redemption theme and Hellenistic alchemy. *Ambix*, 7 (1): 42-46, 1959.

SHEPPARD, Harry J. Alchemy: origin or origins? *Ambix*, 17 (2): 69-84, 1970.

STRABO. *The geography of Strabo.* Translation by Horace Leonard Jones. Cambridge, MA: Harvard University Press, 1917-1932. 8 vols.

TANNERY, Paul. *Pour l'histoire de la science Hellène: de Thalès a Empédocle*. Paris: Félix Alcan, 1887.

TANNERY, Paul. *Recherches sur l'histoire de l'astronomie ancienne*. Paris: Gauthier-Villars, 1893.

TAUB, Liba. Meteorology. Vol. 1, pp. 232-246, in: IRBY, Georgia L. (ed.). *A companion to science, technology, and*

medicine in ancient Greece and Rome. Chichester: John Wiley & Sons, 2016. 2 vols.

VALENS, Vetius. *Anthologies, livre I*. Edition, translation and comments by Joëlle-Frédérique Bara. Leiden: Brill, 1989.

Scientiarum Historia et Theoria Studia, volume 3

Roberto de Andrade Martins

Studies in History and Philosophy of Science II

Extrema: Quamcumque Editum, 2021

Summary

Paperback edition: ISBN 978-65-996890-3-1
Kindle edition: ISBN 978-65-996890-4-8

Available at:
https://www.amazon.com/dp/6599689035