

The Italic School in Astronomy: From Pythagoras to Archimedes

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Abstract: It is argued that it has not yet been able to value the historical, philosophical and epistemological travail, represented by the fifth and fourth centuries BC of the ancient Greek world, which preceded the highest scientific heritage, represented by the so-called golden age of Euclid, Archimedes and Apollonius, III-II century BC. Well, it is believed that with our complex concept of tradition of thought within which we insert not only epistemological concepts but also philosophical principles, historical and social frameworks, in stasis or in strong movement, processed by us, it is possible better interpret that happy moment of scientific constructions of the third and second century BC, as a result of the valorization of the deep travail and serious battle that preceded it between the fourth and fifth century BC. It is investigated in particular in our paper the development of astronomical thought between the fifth and fourth centuries BC, in the ancient Greek thought, and at last a particular presumed criticism by Archimedes in his *Sandreckoner* to Aristarchus.

Key words: Scientific theories, Traditions of thought.

1. Introduction: The Italic and Ionic Traditions of Thought

There has been in recent years a reevaluation of the so-called Hellenistic science thanks to more sophisticated instruments of historical research as well as of shrewder epistemological tools.

The fifth and fourth centuries BC of the ancient Greek world have been marked by a very sharp conflict, characterized by its production of thought, unfortunately almost all been lost, but not valued, we believe due to limited historiographical paradigms, so those golden centuries of the third and second century BC seem to have been shown as if by magic, thanks to genes, already of <scientific training>. I am thinking in particular of L. Russo's book "The Forgotten Revolution" [1].

The role of tradition on the structure of science has been recognized by Kuhn with his concept of paradigm

which is nothing but what he calls the convergent thinking. Under normal conditions, given historically, the scientist for Kuhn is not an innovator but a solver of puzzles within the existing scientific tradition [2]. The role of tradition at the same time it has been recognized by Kuhn in the scientific change or scientific revolutions with his concept of essential tension [3]. The revolutionary scientist to undermine a system of knowledge, historically given, must fully possess it to recognize the anomalous and limitations. The concept of tradition in Kuhn applies both during the period of normal science and in the period of revolutionary science. It is short, ambiguous and vague.

In order to eliminate some ambiguity and vagueness of Kuhn's concept of tradition we must recognize that the scientific fact is doubly charged with theory, because this on the one part derives from a way of thinking about the structure of science and on the other part by a system of political-religious power and cultural domain, which are welded the way said before. To be reinterpreted it needs to be liberated from the two constraints of a scientific tradition and a system of

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political, social and cultural power [4-13].

Two traditions of thought are facing, in ancient Greece, in astronomy, the Pythagorean- Democritean tradition (from now PDT), or otherwise called Italic, and the Platonic-Aristotelian tradition (from now PAT) otherwise called Ionic, this distinction handed down to us by doxographer Laertius, III century BC, which we insert within our broader and more articulated distinction. In particular, we examine their clash in astronomy, from the VI, V, IV century BC to the III and II-IV century BC, in which mature scientific constructions are elaborated, and of which we hold a lot of documents.

Within these complex historiographical categories we think that theories arise to explain and predict sensible phenomena, in our case, now the celestial phenomena, but that they are influenced by external, philosophical, religious, ethnic, etc., extra-theoretical factors as well as by socio-historical changes, which strongly influence and orient them. Theories in short are never neutral.

Italics as well as Ionic of the sixth, fifth and fourth century. a. C. inherit from the Egyptian and Chaldean culture a great harvest of astronomical observations, which enrich and clarify with more rigorous observations and measurements.

But what were or what are the physical celestial phenomena to explain? Any of us can see, thanks to our senses of sight, the birth (East) and sunset (west) of the sun, with the succession of day and night. As anyone, to a more attentive observation, may observe that the succession of the seasons is related to the position occupied by the sun along the ecliptic (it is the apparent circle that the sun describes across the heaven through the constellations of the fixed stars or zodiac).

While the sphere of the heaven of the fixed stars, so called because the stars do not appear to change their relative distances in the course of time, seems to run about every 24 h inside its axis passing through the center of the earth, from east to west, the sun, as well as to move along with them, seems to move along the

ecliptic in the opposite direction, from west to east, up to return to its point of departure, compared to a star in the heaven of the fixed stars, after about a year. The apparent motion of the sun, therefore, is composed by its daily motion, the circle route from east to west, due to the rotation of the heaven of the fixed stars, and by a contemporary slow moving eastward along the ecliptic.

This also appears to be inclined with respect to the celestial equator of 23° and $30'$. More systematic observations also show that not all stars are the same; some, although they move in harmony with the heaven of the fixed stars to the west and in an easterly direction in harmony with the sun, according to their own times, however, seem then to move compared to others, with irregular motions, because sometimes advancing eastwards, sometimes relegated to the west, slowing their speed but increasing their brightness and then to continue their journey, increasing their speed.

For their irregular motions these stars were named by the ancient Greeks planets (from the ancient Greek language *planetà* = wandering). It seems that the name "planet" for these stars was first coined by Democritus (V-IV BC). The earth seems flat in the first approximation, but other phenomena carefully observed and studied instead demonstrate that it is spherical.

It is said that Pythagoras, Italic, (VI-V century BC) was the first to recognize that Hesperus and Phosphorus, the morning star and the evening star, are the same star, that he was the first to observe the planets move in separate orbits, inclined to the celestial equator, and that he was the first to be aware of the inclination of the zodiacal circle which Enopides of Chios (about 500-430 BC) has claimed to himself.

Aetius still testifies that Alcmaeon of Croton, Italic, (VI BC) and the mathematicians discovered that the planets travel a path opposite to that of the fixed stars, that is, from west to east [14].

Many *sofòì*, so called at that time (Democritus was nicknamed *sofia* = wisdom) go to study at the Chaldean and Egyptian priests. According to the documents, we

can say that these impress the science of astronomy a leap in quality.

They want to explain within a specific theoretical and mathematical model all the observed facts and for this they build theories. But we also noted that these are not built in a neutral way. Only in the Italic or Pythagorean tradition, which assigned a role to rationality and its mathematical constructs, one could say soon the sphericity of the Earth, thanks to a careful consideration of the observed facts.

For Thales, Anaximenes, and Heraclitus, Ionic, according to our distinction above, the Earth was flat.

However, only a strong rationalist tradition, not linked to the political and religious tradition, could lead to the affirmation of the universe as infinite, as will do precisely the PDT, with Democritus, and that it is homogeneous from the point of material view, since there is no distinction between incorruptible heaven and corruptible Earth. Where finally the PDT expressed its rationalism and critical ruthlessness was in the construction of audacious theories in the explanation of the observed facts, which we have already mentioned above.

It is true that the alternation of day and night can be explained by the rotation of the sun around the earth, from east to west, but it is also true that it can be explained by the rotation of the Earth around itself, the sun standing still, from west to east in about 24 h. It is true that the changing of the seasons can be explained by the circular motion of the sun along the ecliptic and by inclination of this respect to the celestial equator, but it is also true that it can be explained by the revolution of the Earth, in about a year, around the sun and by the inclination of its axis with respect to the celestial equator.

Certainly the second rational explanation required a greater rational boldness, to be thought and established, not only because it went against the evidence of the senses, but also because it went against established and inveterate cultural customs, laden with religious and political significances.

Well inside the PDT one will dare assert that the Earth revolves around not only to itself, in about 24 h, but it also turns around the sun, in about a year. In fact Ecfantus and Ictas of Syracuse (fifth century BC), Pythagoreans, were the first who dared to assert the earth's rotation around itself from west to east. Cicero testifies that Ictas of Syracuse believes, according to Theophrastus, that the heaven, the sun, the moon, the stars, and finally all the superior things are immobile, and that nothing moves except the Earth; turning and rotating around its axis with extreme speed, it ensures all the effects which would occur if, remaining motionless the Earth, the heaven was moving itself [15].

And yet Aetius testifies that Heraclides of Pontus (fourth century BC) and Ecfantus the Pythagorean make the earth move not for progressive motion, but rotational, as a wheel mounted on an axis around its center, from west to east. And finally Simplicius testifies that Heraclides of Pontus thought he had saved the phenomena assuming that the Earth was in the center and moved in a circle, and that the skies were at rest [16].

But already Philolaus of Croton, Pythagorean and Italic (fifth century BC), had dared to undermine the Earth from its central place to put the fire, the hearth of the universe, around which the ten bodies, which are the Anti-hearth, the Earth, the Moon, the Sun, the five planets (Mercury, Venus, Mars, Jupiter and Saturn) and the sphere of the fixed stars of heaven move. The Anti-hearth always remains invisible to us, because, lying between us and the central focus, it also performs its period of revolution in 24 h and is moving in the same plane of the equator.

The next step was made by Aristarchus of Samos, who lived in the third century BC, which placed, according to the testimonies of Archimedes and Plutarch, in the center of the cosmos no longer the hearth, but the sun. According to Plutarch Aristarchus was accused of impiety for his hypothesis.

If not everything in the PDT, it can be said pure

theory (but how to separate the theory or better the Italic theories from posterior, Platonic and Neo-Platonic, Aristotelian and neo-Aristotelian, intentional and unintentional intrusions!), it is true that these bold and fruitful theoretical hypotheses in ancient times were strongly opposed and fought, as well as their creators, in the name of religious convictions and customary beliefs, and why not, for not confessed, but also sometimes manifestly declared, social and political reasons.

A society, rigidly divided into classes, like the old one, but the same can be said of the Middle Ages, poorly tolerates an infinite universe without a privileged center, around which everything revolves, as well as a homogeneous universe, from the material point of view, in which are less natural hierarchies, between a noble heaven, because it is the seat of the immortals, and a non-noble Hearth, because it is the seat of the corruption and change.

A natural, closed and hierarchical, universe, is functional to hierarchies of class, as sanctioned by nature itself. Where the natural constraints of diversity for birth have ceased, a strong social mobility through the creation of new rich and new classes less tied to the custom, to the traditional costume, because uprooted from their origins as the men of Ionia and the Italics, in continuous emigrations, here, between the VI, V and IV century BC, has been created the historical, extra-theoretical conditions because philosophical and scientific theories in astronomy, more open, more open-minded, more dynamic, more secular, less tied to traditional cults and myths, were born, were established, and were widespread.

That's why Anaxagoras of Clazomenae (fifth century BC), a citizen of Ionia, was forced to flee from Athens, because he was accused of impiety. Anaxagoras, since he said that the sun was a burning stone, was sentenced to death by Athenians [17].

And yet Protagoras of Abdera (fifth century BC) of Democritean tradition, is forced to flee from Athens, as he also was accused of impiety, and even the works of

Democritus they want to burn (those of Protagoras will be burned in the agora) and a conspiracy of silence was weaved on his person and his works and yet, as we remembered, Aristarchus is accused by Cleanthes, head of the Stoic school, school in Athens (third century BC) of Platonic and Aristotelian tradition, for the umpteenth time, of impiety.

Plutarch in his account of military disaster of Syracuse, because of the terror of his general for the eclipses, recounts that Scientists and astrologers as they were called were not frowned upon by the common people, because they reduced the divine work in the world to natural and irrational causes, to unpredictable forces and to an absolute determinism, as Protagoras was exiled for this reason, as Anaxagoras avoided for a short the prison thanks to the intervention of Pericles. And he concludes his account by writing that only later the radiant glory of Plato, coming out of his life no less by having he subordinated physical laws to divine and transcendent principles, swept away the suspicion by which these studies were surrounded and opened to sciences a way to spread among all men [18].

The strongest attack on the philosophical level, or of principles, but absolutely null on the scientific plane, came to the PDT, in astronomy, from Plato and Aristotle.

Declaring themselves champions of tradition and traditional religion, these represent the political and cultural reaction to the PDT. Understanding the danger on the political and social development of a conception of the universe in secular and rationalistic key their role was to express merely a reaction, in a successful attempt then winning, but for external reasons to the theories, to build an alternative tradition.

We read in Aristotle's "Metaphysics" that the ancient thinkers, lived in very remote ages, have handed down to posterity under mythical forms that the heavenly bodies are gods and that deities contains within itself the whole of nature and that other things have been added in later times always in mythical form to inspire among the people persuasion and to induce

him to respect the laws and the common utility [19].

Dreyer writes on Plato that nothing in its various observations on the structure of the universe can make us think that he has devoted much time to explain in detail the celestial motions, because he never goes beyond the simplest and most general facts related to the revolutions of the planets. scientific research was not likely to be much interest in him, because he considered the mathematics inferior to pure philosophy, assuming certain information as self-evident, therefore he classifies the mathematics higher than the mere opinion, but less clear than the real science [20].

Plato's "Timaeus", a composite work of philosophy, astronomy, mathematics, biology, medicine, etc., is projected to assert an animistic as well as a teleological conception of the world as cosmos.

Aristotle's "De caelo" is then a congeries, from the astronomical point of view, of clichés and abstruse and inconclusive arguments, inserted within a conception of the cosmos and of physical science, all based on common sense.

In this work, he argues that the universe is one, finished with a heaven, the supra-lunar world, incorruptible and eternal, and a world, the sublunary world, corruptible and mortal. Read as an example of inconclusive argument, the proof of the existence of the fifth element, the ether, as the element of the celestial world in a passage of Aristotle's "De caelo".

If the circular motion is according to nature for some body, it is clear that among the simple and first bodies there must be one (the ether) which has this property, which, as the fire, moves upward and the earth down, it according to nature moves in a circular motion [21].

The names then for Aristotle do not take their meaning from abstract properties from the physical things, and then composed in theories, but conversely they give meaning to things; it is the case with the name of the fifth element, the ether, used by the ancients, according to Aristotle, to signify the eternity of the heaven. The name thus becomes the proof of the eternity of heaven, because it cannot be used otherwise.

For Aristotle, knowledge is a circle; what the tradition, the common sense with its "words" and theology with its beliefs attest is found by the scientific and philosophical reason and vice versa.

Indeed it cannot profess theories that conflict with these.

For Aristotle it should be convinced of the truth of the ancient doctrines, heritage par excellence of our fathers, according to which there is something immortal and divine. The ancients assigned to the gods the heaven and the upper region, considering them as the only immortal region, and the speech that we now make certifies that the heaven is incorruptible and engendered.

Finally, Aristotle concludes that only in this way we will be able to profess theories which agree with what the oracular science tells us about the divine [22].

Not differently things are for Plato, who refuses any astronomical education which is contrary to the religious beliefs and to the perfection of the heaven. This is what emerges from his "Laws", XXI.

The hardship to the PDT and to theories that it gradually has expressed is continued later by the Platonic and Neo-platonic, Aristotelian and neo-Aristotelian thinkers between the fourth and fifth century AC.

2. The Theory of Eudoxus' Homocentric Spheres (V-IV BC)

A reference apart deserves the theory of Eudoxus' homocentric spheres. This certainly, in the light of what has been supported by us, is to be placed inside the PDT. It is contended, however, that Eudoxus was prompted to develop his theory as a result of the following question posed by Plato to the mathematicians of his time, because of the considerable irregularities in the movement of the planets. It was "what uniform and ordered movements you need to take in order to justify the apparent motion of the planets".

Note that the testimony is of the neo-Aristotelian

Simplicius! Many historians have taken this as an authentic testimony, thereby giving great credit to Plato in the history of astronomy for having raised first the problem of the planets and thus to have stimulated the scientific research. But according to what we know from the testimony of the strong contrast of Eudoxus with Plato, it seems to us that this testimony is at least to be taken with great caution, because maybe interested, and that it is even to be rejected.

Geminus, Neo-Pythagorean lived in the first century BC, testifies instead, but then we do not know why this is overlooked or even concealed, that the question has been placed inside the Pythagoreans circles of the fifth century BC, that for the first they adopted the circular and uniform motion and they for the first pose the question, that is, as on the basis of this hypothesis to explain the phenomena.

For Geminus the Pythagoreans were the first to deal with this problem and to formulate the hypothesis of a uniform and circular motion for the sun, the moon and the planets. Their conception was that, with regard to the divine and eternal beings, to assume such a mess, so the bodies would move more quickly now, and now even more slowly and would stop in what are called the stations of the planets, is inadmissible. The problem for them is the explanation of appearances once accepted the hypothesis of uniform and circular motion [23].

Eudoxus thought he could explain the observed phenomena concerning the motion of the sun, moon and the planets seemingly irregular, with its geometric-mechanical model, in which each planet was placed over the inner sphere of a system of homocentric spheres (3 for the sun and the moon and 4 for the planets, then 26 in all) connected to one another, rotating at different speeds around different axes.

For example, in the system of spheres which govern the motion of the sun, the external spheres produced the general movement of the sun towards the west, that we observe from sunrise to sunset, the internal sphere in which it is placed produced the slower motion, toward the east, along the ecliptic. The axis of the internal

sphere passes through two diametrically opposite points along the external sphere inclined of an angle of 23° and a half from the celestial north and south poles; the result is that the equator of the internal sphere is found to coincide with the ecliptic along the spheres of the fixed stars.

In the four spheres system, for the planet P, the external spheres produce once again the general motion and the annual motion, while the two internal spheres generate a motion in the form of node, which explains the retrograde motion of the planets.

The planet moving from point 1 to point 1 5 goes in the east direction with a faster motion than its mean motion along the ecliptic, and when it goes from point 5 to point 1 its motion is reversed and it becomes slower, moving toward the west in retrocession.

The curve that the planet describes was called *ippopeda*, because it is crossed by the horses in the riding schools in canter. In analytic geometry, this figure eight-shaped inverted will be called the lemniscate, whose equation is $r^2 = a^2 \cos 2q$.

Aristotle contaminates this wonderful physical-geometric theory, not only making it more complicated, unnecessarily increasing the number of spheres up to 55, but especially by inserting it inside a mystical-theological building, which divinizes the spheres and the motors which move them, up to the first motor, God, who moves all things but that is not moved.

It is here that Aristotle once again closes the circle of knowledge between science, tradition and popular religion, thus creating a holy alliance winning on the other tradition, tending to be secular, rationalist. The passage already quoted from his "Metaphysics", XII, 8, 1074b is placed in fact at the conclusion of his treatment of the celestial spheres.

3. On a Presumed Criticism of Archimedes to Aristarchus

It is customary to say that Galileo, using the telescope, in the observation of celestial phenomena,

was the first who has taken advantage of technical tools for his scientific knowledge of astronomical nature, while, if we are to read Archimedes' "Sandreckoner", we know that in the third century BC this had already made use of technical tools, for his astronomical measurements, or of use of the diopter for the measurement of the apparent diameter of the sun.

Archimedes, as well as an astronomer, is also a very important and authoritative source for the knowledge of astronomical heliocentric hypothesis of Aristarchus, of which he makes use on the solution of his problem to give a number to the spherical universe, imagined filled with grains of sand, choosing the largest universe conceived up to then, that of Aristarchus.

In doing this he cites measures of diameters of the sun of eminent scientists contemporary to him, as his father Phidias, an astronomer, and the illustrious Eudoxus, choosing the heliocentric hypothesis of Aristarchus, because of which, assuming the earth revolve around the sun and not being visible the phenomenon of parallax, to avoid the refutation of his hypothesis, he is forced to expand greatly the dimensions of the celestial sphere, the home of the fixed stars, up to reduce the earth to a point.

Archimedes wrote in this regard that it is clear that this is impossible; in fact we cannot admit that the center of a sphere, having no magnitude, has some ratio with the surface of this sphere.

He replaces the hypothesis of Aristarchus (hypothesis 1) with his hypothesis (hypothesis 2) or that the ratio of the earth to the cosmos is the same as that of the cosmos to the sphere of the fixed stars [24].

Many have interpreted the passage of Archimedes as a logical-epistemological criticism of Archimedes to Aristarchus, in our opinion improperly. The hypothesis of Aristarchus, being impossible, according to Archimedes, is absurd, so it cannot be the basis of a scientific theory and of a measurement system.

And it is on this that we want particularly to dwell, not before to point out, as Archimedes, quoting Eudoxus, Phidias, and choosing the hypothesis of

Aristarchus, moves into his "Sandreckoner" following the best scientific tradition, the Italic one, which we discussed previously.

Then to the historian Lucio Russo seems that Archimedes did not want to criticize Aristarchus on the physical plane so much as on the mathematical plane, defending the so-called axiom of Archimedes [25].

Russo, in my opinion, does not distinguish between the theoretical and idealizational level, in the construction of scientific theories, and mathematical-physical level in the moment of measurement and their practical use. For Archimedes, as for Italics, the mathematical model does not have to be distinguished from the physical model, but has to be distinguished from idealizational model.

The old Aristotelians and the modern ones, as well as the translators of Archimedes in their blind epistemological empiricism, as they relate only to appearances or measurements, not being able to distinguish precisely in the scientific constructions the idealizational and theoretical level from the level of their physical interpretation or of the measurement, they both interpret the Aristarchus of Archimedes as one anti-Aristarchus.

So Archimedes must explain, already to the Aristotelians of his time, that Aristarchus' point is not a metaphysical, absolute entity, as for Aristotle, but an entity that is defined by a theory, so Democritus could already write that there are great atoms as a world, or that there are entities which, within a theoretical context, behave as if they were a point or element, as these are relative concepts.

In fact Democritus also called atoms with the name of *logoi theorethà* [26].

The hypothesis of Aristarchus does not violate any theory of magnitudes or of Euclid or of Archimedes. Simply Archimedes explains that if on a rational or theoretical or idealizational level, we consider valid the hypothesis of Aristarchus, hypothesis 1, it can be said: Earth's orbit around the sun with respect to the fixed stars of heaven is like a point with respect to the surface

of a sphere.

In the level of appearances or phenomena to be measured we must instead make another assumption, that we have to enunciate as hypothesis 2.

This is the hypothesis that Archimedes advances, which seems correct Aristarchus,, but that then he resumes, as it happens, as a hypothesis, in accordance with the cosmos supposed by Aristarchus, at the end of his work.

If with this one proves that the cosmos, or the earth-sun system, is much larger than that the astrologers of his time sustain, one can theoretically imagine a heaven of the fixed stars much larger, in which the Earth system, the sun can be considered as if it were one point compared to heaven of the fixed stars.

4. Conclusions

In short, we are at the same problem, which I have discussed in my writings. Also here, Archimedes must be freed from the supposed Platonic or Aristotelian influence, in which he is placed by historians, identifying a tradition of thought in which we have to replace him according to the Archimedean texts, well read and interpreted, i.e. in the Italic one.

The ghost of Aristotle, from which it seems that Galileo and Newton and their followers had us freed, come back recursively in the history of science, perhaps for reasons outside of science, which been mentioned.

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