Sunrise in Greece[1]

By Gordon H. Clark[2]

In antiquity the study of astronomy was motivated by a desire to answer four questions. And the progress of astronomical theory was directed by the attempt to make the four answers consistent.

The first question is: What makes day and night? To say that the sun revolves about the earth in a regular period of twenty-four hours is simple enough. But a second question complicates the situation. Why do the stars return to their position in less than twenty-four hours? Of course they may revolve in complete independence of the sun in a shorter time. Complete independence, however, is the least desirable hypothesis. A third question is: Why do not the planets and the sun return to their positions as the stars do? And, lastly, why does not the sun rise at the same place everyday?

It is to be observed that these questions are simple and obvious to nearly anyone. Their answers, however, are not so quickly forthcoming.

In Greek philosophy the first to answer these questions was Anaximander, who lived and wrote about 550 B.C. His theory posits a vortex about the earth as a center. The earth itself rotates slowly and the heavenly bodies revolve quickly. That the heavenly bodies are conceived as rings of fire, hidden from view except at one aperture, does not affect the general result for astronomy. It is rather to be noted that the earth is at the center of the system and that it rotates. This combination, necessary in a vortex theory, is somewhat peculiar in antiquity since those philosophers who made the earth move, generally denied that it was at the center, and those who insisted that it was at the center ordinarily denied it motion.

1 Read before ΣΠΣ, Honorary Physics Society, May 19th, 1937.

2 Transcribed and edited by Hiram R. Diaz III. Editorial changes are explained in the Editorial Appendix (p.8).

There are at least two objections which rendered the vortex theory unsatisfactory. In the first place, it does not well explain the regular retrogressions of the planets. To be sure, the universal fluid may contain eddies which affect only the planets, but this is a complication which if possible should be avoided in the interests of simplicity. A second difficulty was Anaximander's own discovery of the obliquity of the ecliptic. If you should stir vigorously the tea and tea leaves in your cup, you would soon discover how difficult it is to get some leaves revolving on a plane inclined 23° to the plane of the other orbits. But although the discovery of this obliquity is attributed to Anaximander, our fragments give us no evidence that he changed his vortex theory to accommodate his discovery.

The next important development in astronomy was made by the Pythagoreans. They assumed that the earth revolved about a central fire. This central fire was not the sun, for the sun, like the earth and other planets, also revolved about the central fire and reflected its light. To explain why we on earth never see the central fire, they assumed the equality of the earth's periods of rotation and anti-rotation. Night and day, then, could be explained by the much greater velocity of the sun, though as a matter of fact Aristotle reports that night and day are accounted for by the earth's revolution about the central fire. The awkwardness of Aristotle's expression here must be attributed either to incomplete statement, to a mistake, to differences within the Pythagorean school, or to the inaccuracy of other source materials. The central fire theory, however, allows an explanation of the greater frequency of lunar eclipses over solar eclipses by assuming between the fire and the earth other unseen bodies which could cast a shadow on the moon but not on the more distant sun. This theory also saves the motion of the moon, simply by giving it a lesser velocity than that of the sun; but the retrogression of the planets, that is, the fact that sometimes they travel faster and sometimes slower than the sun, receives no explanation. The obliquity of the ecliptic may not be made impossible on this scheme, but there is no apparent simplicity possible. And simplicity is highly desirable. In fact, so highly desirable that the problem of ancient astronomy can be formulated as follows: What circular and perfectly regular motions must one assume to save the planetary appearances? This formulation of the problem is so eloquent that it could be expected only after considerable reflection on astronomical phenomena. It is therefore necessary next to turn to Plato who both offered several theories himself and who also stimulated speculation on the part of capable students.

Now the interpretation of Plato is difficult because when he was not certain of his theories, he often put them in the form of myth. The astronomical myth in the *Phaedo* is so vague that virtually the only conclusion to be drawn from it is that Plato was dissatisfied with previous theories. Apparently referring to previous attempts to use the diameter of the earth as the astronomical unit, he writes: "The earth is itself neither in size nor in other respects such as it is supposed to be by those who habitually discourse about it."[3] He does, however, place his stamp of approval on Anaximander's locating the earth at the center and on the reason for the earth's remaining there: "If the earth is round and in the middle of the heavens, it needs neither air nor any other force to keep it from falling… for a body which is in equipoise and is placed in the center of something homogeneous cannot change its inclination in any direction."[4] More than this in the way of positive astronomical statement the myth does not supply.

3 *Phaedo,* 108c.

4 *Phaedo,* 109a.

Some years later, Plato appends another myth to the *Republic* in which he ventures a little further. A straight pillar of light is stretched across the whole heaven and earth. Its extremities are fastened by chains to the sky, and this light binds the sky together. What Plato means by the pillar of light is not certain; but in spite of its being pulled *straight* the most plausible suggestion is that it represents the Milky Way. Although difficulties of interpretation remain, it may be thought that the observer is completely outside the universe looking down in the plane of the Milky Way and, therefore, seeing it only as a straight line.

"To the extremities is fastened the Distaff of Necessity,"[5] by means of which all the revolutions of the universe are kept up. On the Distaff is a series of concentric wheels, which may best be pictured as a series of eight concentric spheres cut in half so that their rims or edges present a plane to the eye. Fitting closely together, they form a solid disc embracing the shaft. The rims are of different breadths. The outermost rim is the broadest, the rim next to the outermost is the narrowest. Now obviously the rims are connected with the planets in some way. They cannot be the planets themselves because, aside from the fact that no planet completely encircles the earth, these rims are in contact and the planets are not. The most plausible suggestion is that the breadth of the rims represents the distances between the planets. Not only are other assumptions improbable, but an astronomical theory ought to mention these distances and this is a fairly natural way of doing so. The positive result of this assumption is that Saturn and Jupiter are the nearest together of any two bodies. The distance between Jupiter and Mars is a little greater. The distance between Venus and the Sun is exceeded only by the distance from Saturn to the stars. The colors of the rim are also given. The stars are varicolored. The sun is the most brilliant; the moon gets its color from the reflect light of the sun. Saturn and Mercury have a deeper color than the others. Jupiter is the palest; Mars is red and Venus is almost as pale as Jupiter.

Further, and now we come to the motions of the planets, the Distaff as a whole has a uniform rotation causing day and night. But the seven inner circles rotate slowly in the opposite sense. The moon is quickest. The Sun, Venus, and Mercury are next in velocity and their velocities are equal. Mars revolves more slowly; Jupiter still more slowly, and Saturn is the slowest of all.

5 *Republic,* Book X, 616c.

This arrangement means that the attempt to explain planetary motion by a simple vortex is abandoned. The stars may have a single daily motion; but the planets present us with a combination of two motions. First, the outer heaven carries them around every day; and second, they have a notion of their own from west to east. The introduction of the composite motion of the planets is the first important point here; a second is the strong suggestion that Plato is describing not exactly the heavens themselves but a model of them, an orrery, perhaps the first one ever made. The reason for supposing Plato to be the original inventor of the orrery are briefly as follows: Plato is always talking of models. No good workman undertakes a problem without a model. All through the dialogues, models are stressed. A second way of stating the same reason is that the verbal description of the planetary motions taxes the most lively imagination; and if Plato was deficient in visual imagery as an obscure passage in the *Theaetetus* can possibly indicate, the need of a model becomes even more imperative. A third reason is that the myth in the *Republic* goes on to describe certain accoutrements of these concentric whorls which are more easily understood as fanciful decorations on a new invention rather than as positive astronomical observations. For example, there is a siren sitting on each rim uttering a single note and the eight notes form a harmony. The three fates which sit around the concentric rims, particularly Lachesis who interferes with the motions of the planets in an insufficiently defined manner, may represent unexplained perturbations, but may also represent them by appearing in person on the orrery. And finally, it is a well attested historical fact that within two centuries there was a marvelously perfect orrery, made by Aristarchus of Samos, and his perfect model did not spring complete from his unaided head. A visit to a good planetarium will convince one that these models developed bit by bit, and two hundred years is not too long to allow for Aristarchus' results.

While the *Republic* sets forth the motion of the planets as a combination of two motions, it leaves much to be desired in the way of completeness. To be sure, it is an advance on the vortex theory and on the Pythagorean theory, but it does not show beyond question that such a compound motion explains the appearances. After the writing of the *Republic*, a long time elapsed before Plato again set down much astronomical theory. During this time, there was tremendous activity both in mathematics and astronomy. In geometry, for example, the proofs of the inscription of four of the five regular solids were formulated, and soon after, the fifth proof and the proof that there were no more than five were also discovered. When Plato wrote the *Timaeus,* relatively late in his life, no doubt he thought his astronomy was in the main correct. But so vigorous was the speculation that he soon had to, not merely readjust but, reconstruct the whole system. However, we are getting ahead of the story.

Like the *Republic*, the *Timaeus* places the Earth at the center, and then came the Moon, Sun, Venus, Mercury, Mars, Jupiter, Saturn. The distances between the planets are somehow proportional to the alternating powers of two and three, *viz.* 1, 2, 3, 4, 8, 9, 27. But what these numbers refer to, and what the unit is, have been a matter of dispute. They may refer to the distances between the planets. The view which at first appears plausible is that the numbers are radii and the unit is the radius of the moon's orbit.

Now while it is not necessary to make the *Republic* and the *Timaeus* agree in every particular,
neither is there any reason to make them disagree, and this assumption produces a disagreement. On this assumption, Saturn would be 27 units from the earth and Jupiter 9 [units from the earth]. Then the distance between these two would be 18. And this would be as great as the distance from the Earth to Mars. But in the *Republic*, the rims of Jupiter and Saturn are the narrowest.

Further, the text of the *Timaeus* more naturally refers to the order of the planets from the outside to the center; the numbers more normally refer to the interplanetary distances, and the unit of measurement may well be the distance from Saturn to Jupiter. This, besides being exegetically preferable, harmonizes the *Republic* and the *Timaeus*, and at the same time accounts for the apparent magnitude of the sun and moon in relation to the planets. A little simple arithmetic will show that the planets from Venus to Saturn are fairly near together, but there is a really tremendous gap between the Sun and Venus. Hence, I suggest, Venus appears so much smaller than the Sun.

The Arithmetic

Earth	Radius	Result
Moon	8	8
Sun	8+4	12
Venus	8+4+27	39
Mercury	8+4+27+3	42
Mars	8+4+27+3+9	51
Jupiter	8+4+27+9+3+2	53
Saturn	8+4+27+9+3+2+1	54

More explicitly than in the *Republic*, the stars revolve from east to west in twenty-four hours, and the planets revolve from west to east in various periods. The Sun, Venus, and Mercury have the same period, one year. In the case of Venus and Mercury, retrogression is referred to as a "power contrary to the Sun."[6] This phrase is not mentioned with reference to the other planets because, while they present the same phenomenon and while Mars has the greatest retrogression of all, their distance from the Sun does not lead one at first to connect retrogression and the Sun. It may be inserted here parenthetically that someone, we do not know who, suggested a theory in which, while the earth was the center, Mercury and Venus were satellites of the Sun. Also parenthetically, it may be noted that slight indications lead us to believe that Plato has made another orrery for the *Timaeus*.

6 *Timaeus*, 38D.

But the chief point of interest in the *Timaeus* is the behavior of the earth, for although the earth is at the center, it is in motion. This motion, however, is not, as in Anaximander a rotation in a vortex. In consonance with this, it has nothing to do with the change from day to night. The *Timaeus* has already explained day and night by means of the stellar sphere carrying around with it planets and sun every twenty-four hours. Strange as it may seem, the only motion possible for the earth seems to be rectilinear displacement along the axis of the universe, and if this is the best exegesis, the question arises: What appearances does this new motion save? To this question, several answers have been proposed. First, it may have been intended to account for the relative infrequency of solar eclipses - a problem which had already caused some speculation. Or second, and in a similar vein, it might explain why there is not a total lunar eclipse at every new moon. This latter result can also be combined with a third possibility. Such a rectilinear displacement would account for planetary excursions in latitude. One scholar points out that this would involve excursions for the stars as well; but it may be replied that the stars are so far away from the earth that while the effect is visible in the planets it could not be seen in the stars. And that the stars are vastly farther away than the planets is evidenced by the omission of any reference to the distance between Saturn and the sky. It is, however, to be regretfully noted that the planets do not attain to their maximum excursion at the same time, as a shift of the earth would necessitate. Since, therefore, one cannot assume Plato gave the earth a motion for no reason at all, one must say then either that he has failed to account for excursion or that we have failed to grasp the intended significance.

Apparently, Plato himself considered that he had failed, because Theophrastus, disciple of Aristotle, reports that Plato, in his old age, repented of giving the earth the central position. There is no question that putting the earth off-center involves making the earth revolve about the center. But the change in Plato's theories is farther reaching than the simple statement of Theophrastus might indicate. In the *Laws* - VIII, 822 - Plato himself writes to the effect that every planet has no more than one uniform real motion. On this basis, the apparent motions of the planets must be accounted for by the revolution of the earth about the center. And in Plato's latest work, the *Epinomis*, he states that the outer sphere does not carry the planets around with it from east to west. Let us then ask the question: What results when the earth is put off center, when day and night is referred to the motion of the earth, and when the theory of composite real motions is abandoned? One answer alone is possible. Plato not only produced the first orrery, he also discovered heliocentric astronomy.

This, perhaps, startling conclusion raises the question of why antiquity did not prefer the heliocentric theory. The answer is simply that they were too scientific. To be scientific one must be philosophic, i.e. to conduct an experiment one must allow a theory to set the problem, and the underlying motive in all theory is simplicity. Hence, as before stated, the astronomic problem in antiquity was to save appearances with the fewest *circular* and perfectly regular motions. Simplicity dictates. Before anyone could consider other than circular paths, it had to be demonstrated beyond all doubt that circles were unsatisfactory. That planets move in an ellipse is a proposition which no aesthetic Greek astronomer with an inborn love of simplicity could bring himself to assert of any self-respecting universe.

Editorial Appendix

Transcribing *Sunrise in Greece* was difficult for several reasons. Firstly, this was originally a speech and, therefore, was not as grammatically polished as the majority of Dr. Clark's writings. There are a few places in Dr. Clark's notes where capitalization (the names of the planets) and punctuation (several commas and some question marks) are incorrect. There is also one misspelling ("elipse" on p.7). Secondly, the original documents, likely due to their old age, did not scan well. This required modification of the document's color properties (i.e grayscale levels, brightness, contrast, etc) in order to reconstruct, as best as possible, the time-worn characters on several pages. Thirdly, there were no footnotes in the original. This was likely due to the fact that Dr. Clark was not publishing this in a text. Thus, footnotes have been added in several places to aid the reader. Lastly, the document uses underlining to indicate the titles of Platonic dialogues rather than italics (e.g. "<u>Theaetetus</u>" instead of "*Theaetetus"*). It also uses underlining for emphasis, instead of using italics. The reason for this change was merely a matter of convenience for the modern reader. While underlining and italicizing are, technically, interchangeable means of showing emphasis, italics are more widely used in present day publications.

These changes are minimal but worth mentioning. The original document may be viewed by the reader who wishes to study it alongside this transcription.

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