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HERACLIDES AND HELIOCENTRISM: TEXTS, DIAGRAMS, AND INTERPRETATIONS

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For over a century Heraclides of Pontus (4th century B.C.) has stood with Aristarchus of Samos (3rd century B.C.) as one of the ancient precursors of Copernicus. Heraclides is supposed to have advanced not only a hypothesis that the Earth rotates on its axis once a day but also the idea that the Sun as easily as the Earth may be a centre of planetary motion. There is, however, a very simple historical difficulty with this widely assumed view of Heraclides's planetary doctrines. Whereas Copernicus knew of Aristarchus's heliocentrical hypothesis,[1] neither Copernicus nor Kepler nor anyone else before the nineteenth century put forth the name of Heraclides as an ancient heliocentrist.[2] In an earlier study I have shown that the texts of Vitruvius, Pliny the Elder, and most especially Macrobius do not preserve any sort of Sun-centred or circumsolar path for either of the planets Mercury and Venus, while there is in the writing of Martianus Capella an unambiguous circumsolar theory for these two inner planets, which Martianus does not ascribe to any authority.[3] The Capellan theory was recognized by Copernicus and Kepler and all writers on the subject of heliocentrism since the Renaissance. Where then does the name of Heraclides come from?

Only two sources have ever been cited to support the connection of Heraclides's name with a heliocentrical motion. These are Simplicius's commentary on Aristotle's *Physics* and Calcidius's commentary on Plato's *Timaeus*. I deal below with both, the first more briefly, the second in full detail. For any serious attempt to find a line of thought from late Antiquity through the Middle Ages to Copernicus, the text of Calcidius has been the crucial foundation. What I propose to show is that Calcidius's commentary (and incidentally Simplicius's work as well) offers no ground whatever for attributing to Heraclides of Pontus an idea of circumsolar orbits for Mercury and Venus. This idea came into the Middle Ages only through Martianus Capella. No matter what authorities the medievals later looked back to for this notion, Heraclides and the Heraclidean conception identified by Calcidius were never among these sources. We simply have no basis for assigning the idea to any writer in the Latin tradition before Martianus Capella, and Heraclides disappears from the picture completely. His name should also be removed from all the modern textbook accounts erroneously associating this circumsolar pattern with a Greek of the fourth century before the Christian era.

The name of Aristarchus was likewise not connected with heliocentrism in the Middle Ages, but his widespread recognition in Antiquity and his rediscovery in the Renaissance have secured his position as a forerunner of Copernicus. While no one seriously claims that the medievals knew Aristarchus as a heliocentrist,

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there has been a curve of development in the fortunes of Heraclides in this regard, with his medieval influence strongly supported by the long chapter in 1915 by Pierre Duhem concerning "the system of Heraclides in the Middle Ages". Parallelling Duhem's account, the general understanding of Heraclidean astronomy by classicists and historians of ancient Greek thought until recently appears in Dick's history of early Greek astronomy, wherein Heraclides is the progenitor not simply of a hypothesis that the Earth has a diurnal rotation but also of the hypothesis that the planets Mercury and Venus circle the Sun rather than the Earth as centre.[4]

Two ancient texts connect Heraclides of Pontus with supposedly heliocentrical notions.[5] Simplicius's commentary on Aristotle's *Physics* II, 2, includes a selection via Alexander of Aphrodisias from Geminus's epitome of Posidonius's lost *Meteorology*, in which a Heraclidean doctrine appears in the context of philosophical discussion of hypotheses meant to "save the phenomena".[6] Calcidius's commentary on Plato's *Timaeus* 38D mentions a teaching of Heraclides about the apparent motion of Venus with respect to the Sun, arguably a circumsolar motion.[7] While Gottschalk has recently discussed both texts with full reference to the previous studies on the question, each text can use any further illumination conceivable, as neither text is clearly unambiguous about some kind of heliocentric motion.[8]

1. *Simplicius's Testimony*

The first text, from Simplicius's commentary on the *Physics*, was a source appealed to by writers in the late nineteenth century to show that a follower of Plato with some sort of Pythagorean stimulus had conceived and argued for a Copernican sort of system, with moving Earth and fixed central Sun.[9] The passage runs as follows:

> Alexander carefully quotes a certain explanation by Geminus taken from his summary of the *Meteorologica* of Posidonius. Geminus's comment, which is inspired by the views of Aristotle, is as follows: "It is the business of physical inquiry to consider the substance of the heaven and the stars, their force and quality, their coming into being and their destruction, nay, it is in position even to prove the facts about their size, shape, and arrangement; astronomy, on the other hand, does not attempt to speak of anything of this kind, but proves the arrangement of the heavenly bodies by considerations based on the view that the heaven is a real κόσμος, and further, it tells us of the shapes and sizes and distances of the Earth, Sun, and Moon, and of eclipses and conjunctions of the stars, as well as of the quality and extent of their movements. Accordingly, as it is connected with the investigation of quantity, size, and quality of form or shape, it naturally stood in need, in this way, of arithmetic and geometry. The things, then, of which alone astronomy claims to give an account it is able to establish by means of arithmetic and geometry. Now in many cases the astronomer and the physicist will propose to prove the same point, e.g.,

that the Sun, is of great size or that the Earth is spherical, but they will not proceed by the same road. The physicist will prove each fact by considerations of essence or substance, of force, of its being better that things should be as they are, or of coming into being and change; the astronomer will prove them by the properties of figures or magnitudes, or by the amount of movement and the time that is appropriate to it. Again, the physicist will in many cases reach the cause by looking to creative force; but the astronomer, when he proves facts from external conditions, is not qualified to judge of the cause, as when, for instance, he declares the Earth or the stars to be spherical; sometimes he does not even desire to ascertain the cause, as when he discourses about an eclipse; at other times he invents by way of hypothesis, and states certain expedients by the assumption of which the phenomena will be saved. For example, why do the Sun, the Moon, and the planets appear to move irregularly? If we suppose that their orbits are eccentric or that the stars revolve on epicycles their apparent irregularity will be accounted for (σωθήσεται), but it will be necessary to explain further in how many ways it is possible for these phenomena to come about, so that the study of planets comes to resemble a science of possible causes. For this reason we actually find a person like Heraclides of Pontus coming forward and saying that the apparent irregularity connected with the Sun can be explained even if the Earth is moved in a certain way and the Sun stays still in a certain way. For it is not at all the business of the astronomer to know what is naturally at rest and which things are in movement, but taking as a hypothesis that certain bodies are at rest and others in motion, he asks with which hypotheses the appearances in the sky are most in accord. But he must go to the physicist for his first principles, namely that the movements of the stars are simple, uniform and ordered, and by means of these principles he will then prove that the rhythmic motion of all alike is in circles, some being turned in parallel circles, others in oblique circles." Such is the account given by Geminus, or Posidonius in Geminus, of the distinction between physics and astronomy, wherein the commentator is inspired by the views of Aristotle.[10]

Simplicius has included in this passage a number of interrelated yet distinct elements. The beginning lays out the genealogy of the long quotation from Alexander of Aphrodisias, which is at the same time quoted from Geminus, who in turn seems to have taken part of his statement verbatim from Posidonius's now lost *Meteorologica*.[11] The overall concern in the quotation from Geminus is the nature of explanations of events in the heavens. Whereas the physicist knows and reasons from first principles, taking into account the nature of celestial bodies, the astronomer reasons solely by the use of arithmetic and geometry in a manner to show mathematical order in the heavens. Astronomers are not, by virtue of their calling, able to judge the actual cause but only to provide a mathematical explanation which accounts for, or saves, the appearances of an event. Geminus's statement then focuses more sharply on the character of astronomical hypotheses, pointing out their inventive and expedient attributes. To clarify and emphasize this aspect the example of apparent irregularity in the motions of the Sun, the Moon, and the planets is introduced and Geminus here draws his argument and probably his words from Posidonius.[12]

This example leads to the mention of Heraclides of Pontus, but Heraclides is not invoked as a hypothesizer regarding the Sun, the Moon, and the planets. Heraclides speaks here only of the Sun and the Earth, and his proposal is a very specific subheading under the kinds of hypotheses that Geminus brings forth concerning the apparent irregularities of solar, lunar, and other planetary motions. Eccentric orbits and epicycles as alternatives for explaining the same appearances come first in Geminus's account. But these alternatives, well known in his time, do not exhaust the hypothetical constructions available to astronomers. In fact, a survey of "in how many ways it is *possible* [my emphasis] for these phenomena to come about" in order to create "a science of possible causes" is the special concern of the astronomer. It is because of this interest in possible explanation rather than philosophically commendable explanation that the extravagant notion of Heraclides of Pontus must be mentioned, according to Posidonius. The prefixed "we actually find a person like Heraclides of Pontus coming forward and saying" is meant to show the philosophical disparagement, and perhaps even outrage, that Posidonius directed at the idea proposed by Heraclides, since, as a philosopher, he should have known better.[13] The quotation returns to the more general level of the relative natures of astronomical and physical explanations immediately after presenting Heraclides's hypothesis, and no further explanation of the content of that hypothesis appears either here or elsewhere in Simplicius's commentary on the *Physics*.

The precise meaning of Heraclides's hypothetical proposal, obviously cited as an extreme concept and not as a recommendation for working astronomers,[14] can best be approached through the recent account by Gottschalk. Addressing first the questions of manuscript readings, corruptions and emendations, Gottschalk reviews the evidence and numerous criticisms, concluding that, whatever acceptable correction is proposed, there is no avoiding the facts that Heraclides's name is a genuine part of the text and that the idea is his while the quotation is from Posidonius.[15] More thorny is the question of identifying the specific hypothesis attributed to Heraclides. Here Gottschalk refers to the interpretations of Schiaparelli, Martin, and others and then concludes very shrewdly that much more astronomy has been read into the passage, "the apparent irregularity connected with the Sun can be explained even if the Earth is moved in a certain way and the Sun stays still in a certain way", than is warranted.[16] Gottschalk argues,

> When writing these lines, Posidonius was not interested in the details of this or any other theory. He knew that Heraclides tried to account for some of the apparent movements of the Sun by assigning some kind of rotation to the Earth, and this was enough for his purpose. The whole sentence is nothing more than a rhetorical flourish; it would be unsafe to

draw any conclusion from it which is not corroborated by other evidence. But apart from this fragment we have no reasons to believe that Heraclides ever advanced a heliocentric theory.[17]

The core of Gottschalk's conclusion, which identifies Posidonius's phrasing of the Heraclidean hypothesis as a rhetorical flourish, is quite useful for explaining the lack of specificity in Posidonius. However, this does not justify equating the Heraclidean hypothesis here with the well-known suggestion by Heraclides that the Earth may be considered to rotate on its axis once a day. To begin with, such rotation explains no irregularity specifically connected with the Sun. While attempts to link Heraclides to heliocentrism here are anachronistic, there is no reason to ignore the meaning that can be found by appealing to the mathematical astronomy of Heraclides's time, the Eudoxan theory of homocentric spheres.[18] While Simplicius's text does not refer to Eudoxus's model, we should at least consider its possible application here. Having no reason to believe that Heraclides was an astronomer or creator of an astronomical system and many reasons to consider him as a philosopher and rhetorician, we should look for the already existing elements that he could employ to make the sort of shocking hypothesis to which Posidonius referred.

The Sun's motion, which is what Heraclides proposed to explain in part, was divided by Eudoxus into three parts, each of which a single sphere in a tripartite complex would describe.[19] The outermost sphere accounted for diurnal motion with an east-to-west rotation every twenty-four hours on the equatorial axis. The middle sphere, inclined to the outer, rotated very slowly on the axis on the ecliptic in a west-to-east direction. The third, innermost sphere, on whose equator the Sun itself was fixed rotated annually from west to east around an axis inclined slightly to that of the second sphere. While the angle assigned by Eudoxus is unknown, later writers assumed it to be $\frac{1}{2}^{\circ}$. Thus the third sphere gave a hypothetical (and imaginary) small latitudinal motion to the Sun in the zodiac, while the second sphere turned the nodes of the solar orbit very slowly in the same direction along the ecliptic. The sum of the rotational motions of the second and third spheres equalled a tropical year.

Viewed from the Earth at the centre of these concentric spheres, what could Heraclides have supposed to be an "irregularity connected with the Sun"? Nothing if not the movement of the second sphere, which has a period that is neither daily nor annual. If this does not satisfy the meaning of anomaly, then we are reasonably driven one small step further to the homocentric spheres of Callippus, a younger contemporary of Heraclides, who added two spheres to the Eudoxan model with the effect of these spheres being a modification in the solar longitudinal motion to explain the variations in the lengths of seasons, according to Eudemus as reported by Simplicius.[20] Here we have a solar anomalous motion explained in the astronomical terms of Heraclides's time. More to the point, his claim, according to Posidonius, to give an account of such a motion by a motion of the Earth is fully in accord with both the words of Posidonius and the notion of a centrally fixed Earth.

We have no justification for the assumption that Heraclides intended to explain only the most obvious of motions with his claim. On the contrary, his statement that a motion of the Sun "in a certain way" can be transformed into a motion of the Earth "in a certain way" — exactly the same word (πως) was repeated by Posidonius — allows emphasis to three points. First, no motion other than rotational is intended for the hypothetical attribution to the Earth. Second, the motion is a specific one, drawn from current theory. Third, the attributed motion need not be an addition to some previously named motion, such as diurnal rotation. Heraclides's meaning now becomes clear. Just as we have already heard him propose as a hypothesis that diurnal rotation of the sphere of fixed stars can be translated into diurnal rotation of the Earth, so we are now challenged to imagine a very different translation from the spheres for the Sun to the sphere of the Earth. The motion transferred is not to be added to some other motion already attributed to the Earth, since Heraclides nowhere is said to have created a system, but simply to be given to an immobile central Earth. In short, Posidonius has referred to an extension by Heraclides of his famous diurnal rotation hypothesis, an application of the same line of relativistic reasoning to only one other motion of the Sun, abstracted from all others, even though such a hypothesis would in no way please physicists, who are best able to determine the principles for a true system of astronomy. And of course, in any such relativistic transfer of motion from the spheres to the centre there is no possibility of a heliocentric motion of any kind for the Earth.

2. *Calcidius's Testimony*

The second text in which Heraclides's name appears and which has been interpreted to make him a heliocentrist of sorts comes from the fourth century A.D. Calcidius's commentary on Plato's *Timaeus* 38D remains as the only ancient text that might justify the claim that Heraclides put the planets Mercury and Venus (and *perhaps* Mars, Jupiter and Saturn) in orbits around the Sun rather than centred on the Earth. According to this interpretation the Earth remains fixed while the Sun, carrying planets as satellites, revolves around the Earth. Gottschalk defends vigorously the limited version of this reading of Calcidius, that is, that Mercury and Venus but no other planets circle the Sun as centre according to Heraclides of Pontus.[21] The defence is insufficient as we shall now see.

Calcidius's presentation covers five sections, Paragraphs 108–12, in his commentary. Before immersing ourselves in the details of these paragraphs, let us consider the overall pattern of argument here. Paragraph 108 summarizes Plato with respect to the two planets, Mercury and Venus, which constantly accompany the Sun and are seen variously ahead of and behind the Sun within fixed limits of elongation from it. Paragraph 109 points out that these motions of Mercury and Venus have two possible explanations; one is according to *contrarios motus*, the other by means of *contrariam vim*. The paragraph ends with the requirement that the circles of the Sun, Mercury and Venus have *una medietas atque punctum unum*, and this requirement is made only with reference to the latter explanation (*contrariam vim*). Paragraph 110, at the beginning of which Heraclides's name appears, is an explication of the second alternative alone, and this account continues into Paragraph 111. The phrase *una medietas et unum punctum* appearing in 110 can only describe a homocentric system, which is necessary to explain the shifting back and forth to either side of the Sun by Mercury and Venus. At the very end of 111 a new geometrical element, a circle tangent to two radii from the Earth, enters the picture as a means to clearer understanding. The introduction of this tangent circle is supposed to enhance the clarity of our understanding, because the mention of this circle begins Calcidius's preferred alternative. At this point, the beginning of 112, we are taken into an explanation of the first option (*contrarios motus*) presented in 109. This is the epicyclical account, which uses the "clearer" circle introduced at the end of 111. Calcidius does not associate Heraclides with the epicyclical explanation, which appears only in the first half of 109 and then again in 112. Calcidius's text runs as follows:

> **[c.108]** "Then [the deity] arranged the lights of Venus and Mercury", Plato says, "in a motion agreeing with the solar path but circulating with a tendency contrary to it [the Sun]; whereby it happens that these planets alternately limit each other and are limited by each other". Why he says that these planets are equal in speed he reveals when he claims that the course is completed by all of them in the space of a year, but so that going now slower now quicker they at times contain the Sun and at times are bounded by it.
>
> **[c.109]** Plato says that these lights [of Mercury and Venus] have a force contrary (*contrariam vim*) [to the Sun], which various persons understand in different ways. Some hold that this contrariety arises because the Sun, while naturally travelling always from east to west with the whole of the heavens, nevertheless traverses its own epicycle (*epicyclum*) in the space of a year. The rotation of this epicycle is opposed to that of the heavens, and Lucifer and Mercury always perform movements contrary (*contrarios motus*) to the rotation of the heavens. Others propose that there is a contrary force (*contrariam vim*) in these two planets, for Mercury and Lucifer enclose the advance of the Sun and then, slowing down, have the Sun enclose them, since they have their risings and settings, their appearances and occultations, sometimes in the morning, sometimes in the evening, at times ahead of and at times behind [the Sun]; thus they appear nearly always to accompany the Sun. This happens because there is one middle and one centre (*una medietas atque punctum unum*) as much for the Sun's circle as for any other of these planets.
>
> **[c.110]** Accordingly when Heraclides of Pontus drew the circles of Lucifer and of the Sun and gave the two circles one centre and middle (*unum punctum atque unam medietatem*), he positioned Lucifer sometimes ahead of (*superior*) and sometimes behind (*inferior*) the Sun. In fact he said that the Sun, Moon, Lucifer, and all the planets, wherever any of them may be, are located by a line passing from the centre of the Earth through the centre of the planet. Therefore there will be one straight line leading from

the middle of the Earth to the Sun, and two other straight lines 50° to the right and to the left of the Sun, viz. 100° apart. Of these the line to the east intersects Lucifer when Lucifer stands farthest from the Sun and close to the eastern regions, whence it receives the name Hesper, as it appears towards the east at evening after sunset; the other line, to the west [of the Sun, intersects Lucifer] when Lucifer stands farthest from the Sun to the west, which is why it is called Lucifer. For it is clear that it is called Hesper when it is seen to the east [of the Sun] after sunset and Lucifer when it goes down before the Sun and in turn at the end of the night rises before the Sun.
[c.111] Therefore let the centre of the Earth and of the heavens be at X; [let there be] the zodiacal circle, on which are ABΓ, and let AB and BΓ each be an arc of 50° and along the line XB let the centre of the Sun be at K. Thus line XKB will locate the Sun at B [on the zodiacal circle], and let this same line be moved the same amount as the Sun, about 1° per day, and likewise let those lines XA and XΓ be separated [constantly from XB] by 50°.[22] Next let XA be the line to the east and XΓ be the line to the west, the latter setting and rising before the Sun, the former setting and rising after the Sun. Thus the line XA must locate Lucifer at A as Hesper when this planet has withdrawn to its maximum from the Sun, while the line XΓ locates the same planet as Lucifer at Γ early in the morning. All this will be made clearer (*Hoc autem fiet apertius*), if a circle is drawn through the line XKB and is tangent to (*contingat*) the two lines XA and XΓ, which locate the extent of Lucifer's elongation from the Sun.
[c.112] Indeed Plato and all who have examined this matter quite diligently affirm how much higher than that of the Sun is the *globus* of Lucifer, which is bounded by the letters ΔEZH and touches the line XA at E and XΓ at H.[23] Wherefore, when Lucifer travelling its own *circulus* comes to E, it will seem to be at A, farthest away from the Sun, that is by the full 50°, in the east just at daybreak, inasmuch as the Sun appears nowhere other than at B. Further on, when Lucifer is at H, it will seem to be far out at Γ, more remote from the Sun, and to the West by exactly the same 50°. When it is under either Δ or Z, there is no doubt that it appears nearest the Sun and passes once a great distance from the Earth under Δ, another time closer and nearest to the Earth in Z. Now under quite diligent observation it has been noted that when at maximum elongation, whether at rising or at setting, the same planet will take 584 days to return to that point, whether E or H, at which it was before. Given that the same planet in the same number of days covers its whole *circulus* ΔEZH, the major segment of its course, HΔE, from rising to setting, is covered in 448 days. The minor and lower segment, EZH, takes the remaining 136 days, since passage through the maximum interval from setting to rising is done in this number of days, as a common observation of the ancients made known.[24]

Having seen both an outline of the contents of these Paragraphs 108–12 and a translation thereof, let us discuss further certain crucial parts of Calcidius's text.

The latter half of 108, as translated, simply lays out what it is that Plato describes, while the opening sentence of 109 ties the Platonic view to the phrase *contrariam vim*. In explicating this view in the second part of 109, Calcidius describes the phenomena only as appearances preceding or following the Sun, not as results of epicyclic motion, which is explicitly linked to the prior alternative. The second alternative, explained by a contrary force rather than a regularly contrary motion, places the cause of the retrograde motion of Mercury and Venus in the bodies, and perhaps souls, of the planets instead of placing the cause in a continuous geometrical pattern, which the planet follows in unchanging fashion. Then at the close of 109 Calcidius claims that the contrary-force alternative is explained within the context of a system of concentric circles. The final sentence of 109 sets the circle of the Sun in parallel with those of Mercury and Venus, indicating that the three planetary orbits are all of the same sort, with no suggestion that they are epicycles.[25] In fact, pursuing the point already made about the organization of the successive sections, we should be surprised to encounter epicycles here, for Calcidius is giving his extended account of the Platonic theory, the second of his two alternatives, which is directly contrasted to a theory built upon an epicyclical explanation, viz. the first alternative. Therefore the phrase "one middle and one centre" in the last sentence of 109 must refer to the single centre of the concentric planetary orbits in a non-epicyclic planetary system. The apparent reiteration in the conjoined use of *medietas* (middle) and *punctum* (centre) is a conjunction which emphasizes both universal symmetry and geometrical centrality; *punctum* and *medietas* appear together in this sense elsewhere in Calcidius's commentary.[26]

If the close of 109 is meant to elaborate the non-epicyclical picture, then the opening of 110, which uses precisely the same vocabulary when referring to the orbits, or circles, of Venus and the Sun as having one and the same centre (*unum punctum atque unam medietatem*), entails the assumption of concentric circles for Venus and the Sun around the Earth. This is quite in accord with Plato, whose system is still being explained here by Calcidius, and it is quite consonant with the astronomy of homocentric spheres, dominant at the time of Heraclides of Pontus, whose name is invoked in the opening of 110. Further confirmation of the geocentric sense of these circles of Venus and the Sun comes with the interpretation of the two words, *superior* and *inferior*, relating the successive positions of Venus to the Sun. These two positions are exactly what Calcidius proceeds to explain in the remainder of 110. Setting the boundaries of Venus's elongation from the Sun by drawing radii from the central Earth at fixed intervals to each side of the Sun, Calcidius locates the planet Venus, respectively, ahead of the Sun (*superior*) in order to rise the next morning ahead of it, and again behind the Sun (*inferior*) when Venus is called Hesper and sets after the Sun. The whole of 110 deals with the appearances of Venus and the Sun, not the radial distances of these two planets with respect to the Earth. Hence Mercury does not enter into the discussion, since it is so much less in evidence than Venus for observers of the skies. Over fifty years ago A. E. Taylor interpreted this passage of Calcidius in a similar manner, followed recently by

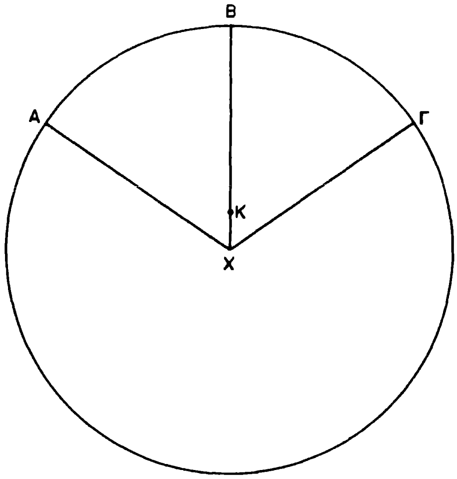
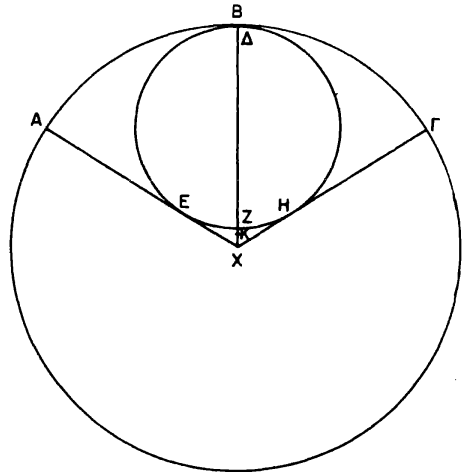


FIG. 1.



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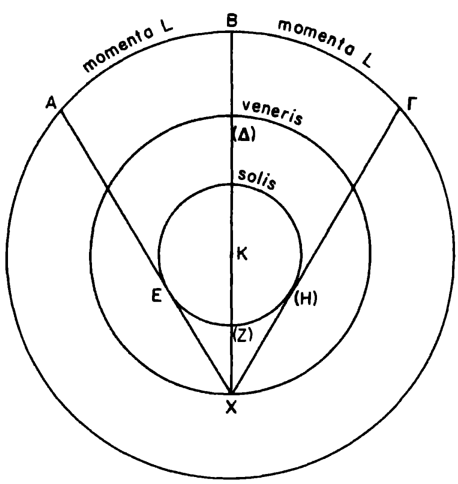

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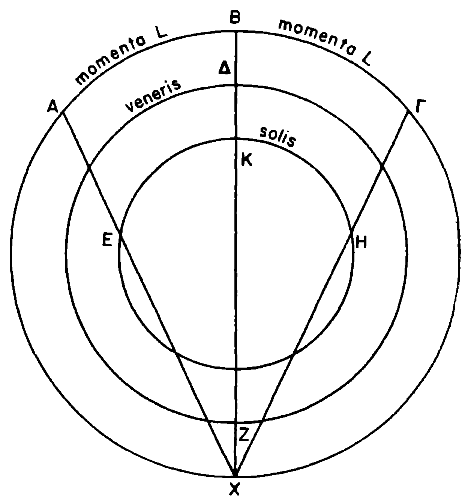

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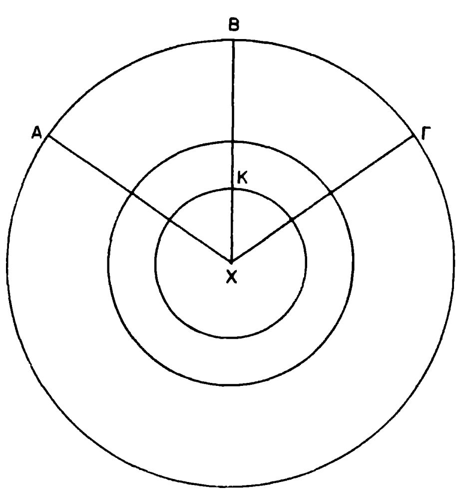

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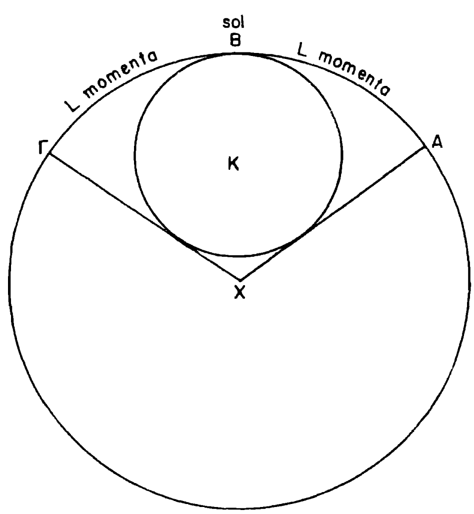

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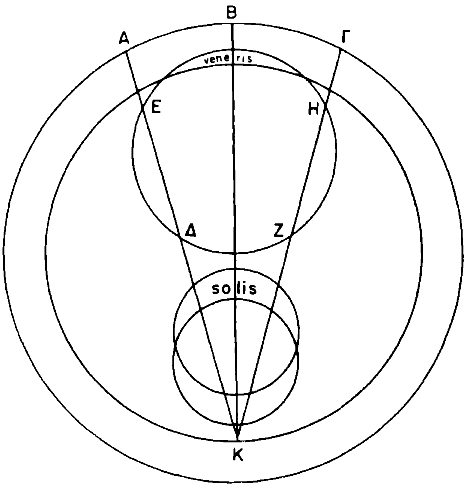

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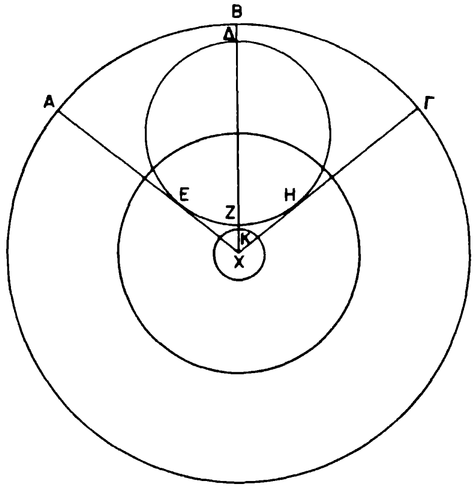

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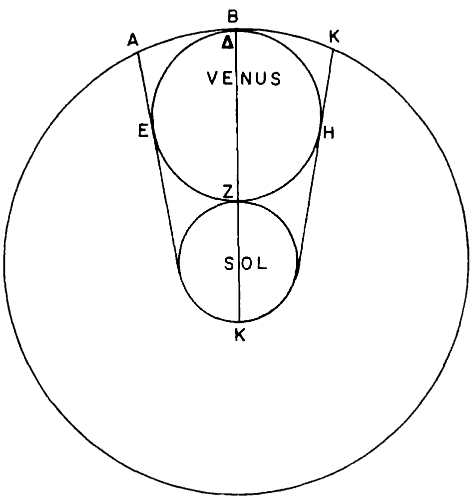

FIG. 9(a).

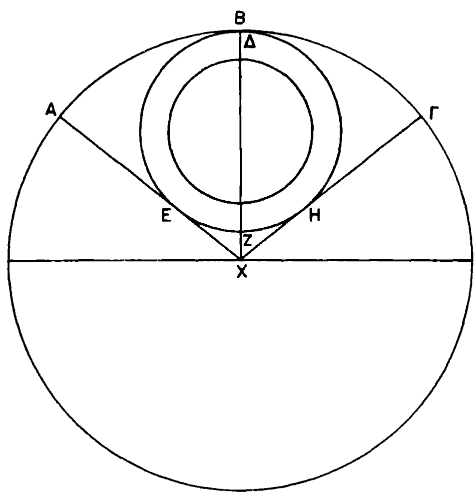

FIG. 9(b).

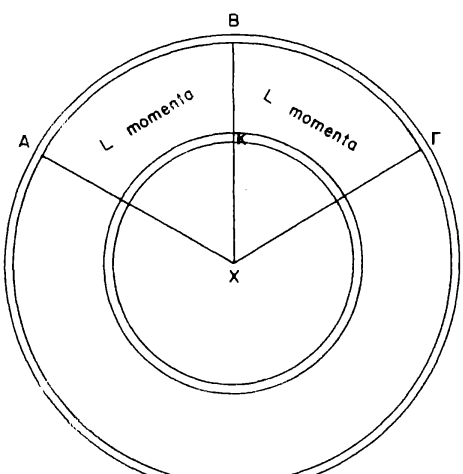

FIG. 10(a).

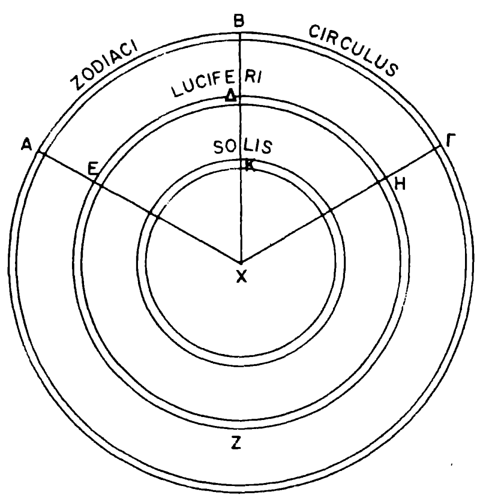

FIG. 10(b).

Godfrey Evans.[27] A useful technical addendum has been offered by Otto Neugebauer, who notes that the Greek originals for *superior* and *inferior* in spherical astronomy, for example in Theodosius of Bithynia (1st century B.C.) and his scholiasts, mean "before" and "behind" in relation to the solstices.[28] In sum, there is no reason other than belief in an anachronistic connection of Heraclides with a limited heliocentrism to justify a circumsolar interpretation of Venus's path in this text by Calcidius.

As for the reason why Heraclides's name should appear here at all, we can only hypothesize. However, it is worth noting that the concentric and geocentric pattern of Venus and the Sun, along with the radial lines from the Earth to each of the planets, can be construed as part of a discussion which shows that the relative positions of the planets as seen from the Earth do not change when we suppose the Earth to rotate diurnally at the centre. If such a Heraclidean elaboration of the famous diurnal-rotation hypothesis existed, then Calcidius has simply lifted part of it in order to describe the apparent motions of Venus (and Mercury by implication) in the Platonic explanation of the varying longitudinal positions, caused by intrinsic contrary force (*contrariam vim*), of the two planets with respect to the Sun.

3. *Diagrams for the Calcidius Text: A Modern Reconstruction*

In Paragraph 111 Calcidius proceeds quite deliberately to describe a diagram for the Platonic explanation of the appearances of Venus with respect to the Sun. This diagram must be considered in comparison with the description to be found in 112. Upon further examination it will become evident that 112 gives an epicyclical account by making use of one new circle added according to the instructions at the end of 111. That is, both 111 and 112 use the same basic configuration of lines and points, differing only in the addition of a circle, allowing Calcidius to return to the first alternative posed in 109, which he obviously prefers, the explanation by appeal to *contrarios motus*, or epicycles. The diagrams in the manuscripts, and certainly those chosen for the most recent critical edition,[29] are quite corrupt and require reconstruction in a manner unlike any yet proposed.

The diagram described in 111 is remarkably spare when reconstructed from the text. The essentials come to no more than this: the zodiacal circle, the central Earth, the Sun at an unspecified point along a radius from Earth to zodiac, and two radii to the zodiac at constant intervals of 50° to either side of that intersecting the Sun (Figure 1). Remarkable about this description is the absence of any mention of an orbital circle either for the Sun or for Venus, from which we can only conclude that the sole purpose of the diagram is to show the bounded elongation of Venus as an appearance against the background of the zodiac. The only motions or distances to which Calcidius refers are at angles or along arcs with reference to the centre, the Earth. Radial distances are nowhere mentioned in 111, as Figure 1 shows. As explained above, it is only the final sentence, introducing a new element into the diagram in preparation for a new account in 112, that the suggestion of a location for Venus emerges. The new element, a tangent circle, appears in our Figure 2.

The diagram described and used in 112 is fully represented by Figure 2. Once again the spareness of its elements is noteworthy. In fact, it is exactly the same diagram as that contrived in 111, except for the added circle ΔEZH. Once again there is no circular path prescribed for the Sun. The location of the Sun, K, is quite clearly not specified as the centre of the circle for Venus. There is no discussion of the appearances of retrogradation or stations, only the points of maximum elongation and of conjunction with the Sun and the time intervals involved. In other words, 112 explains the same appearances as 111 by using the added circle ΔEZH, which represents the epicycle of Venus, the basis for an account of the *contrarios motus* of the planet. Calcidius concludes this segment (Paragraphs 109–12) of his account with his own preferred explanation, via an epicycle, for the appearances of Venus.

Certain features of Figure 2 must be noted. From the description it is not completely clear that the point K is closer to the centre X than is Z. As for the name given to ΔEZH, *circulus* is used here, not *epicyclus*, but the meaning is "epicycle". We must therefore ask whether the *globus* of Venus is in reference to the planet itself or to a circle on which it travels. Calcidius says that the *globus* of Venus is higher than that of the Sun. The meaning of *globus* here is not at all clear. In principle it may mean the body of the planet, the orbit of the planet, or the epicycle of the planet. Calcidius's usage elsewhere, however, makes the last of these unlikely. In the whole of his commentary on planetary astronomy (Paragraphs 56–118), *globus* is used 28 times. At 5 points the word definitely means a physical body, such as the body of the Earth and the body of the Sun.[30] At 19 points *globus* means either the sphere of the fixed stars or the orbital sphere of a planet or the orbital circle of a planet.[31] At 3 points Calcidius uses *globus* either in apposition to *epicyclus* or to help explain *epicyclus*, but in each of these uses the epicyclical meaning of *globus* is given by the presence of *epicyclus* in the same sentence.[32] This leaves us with the one place where *globus* is used uncertainly, in 112.

Given the larger context of 110–12, concerned with explaining in two ways the appearances of bounded elongation, as well as Calcidius's tendency to simplify an explanation to the barest elements, the meaning of *globus* here seems to be the planet itself. Surely when he says that the *globus* of Venus is, according to Plato, higher than that of the Sun, Calcidius is referring to planetary order and means either the body of the planet or its orbit, but not its epicycle. With a choice between planetary orbit or body, we would invite confusion by understanding "orbit of Venus ... bounded by the letters ΔEZH" at the point in question. We are left with the choice of "planetary body". The *circulus* introduced initially for the planet Venus in Paragraph 111 reappears explicitly in the second sentence of 112 as Venus's *proprius circulus*, that is, its epicycle.

One definite textual corruption occurs where the edited text shows two lines KA and KΓ touching the circle ΔEZH at points E and H respectively.[33] This must be emended to refer to the two lines XA and XΓ, not KA and KΓ, for many reasons, most obviously because the explanation of bounded elongation makes no sense using lines projected from the Sun and tangent to the epicycle of Venus. As a matter of appearances these lines must originate at the Earth, already placed at point X.

Before turning to the problems posed by the diagrams that appear with Paragraphs 110–12 in the manuscripts, we must face one more difficulty arising in the text. In 109 Calcidius describes the first, or epicyclical, account by referring not only to epicycles for Mercury and Venus but also quite explicitly to an epicycle (*epicyclus*) of the Sun. The shift from 109 to 110 is marked by an omission thereafter of the planet Mercury and also by no further mention of a solar epicycle. Indeed, the sense of the descriptions in 110–12 requires that the Sun be fixed at a point on the radius XB (*non nisi ubi est B littera*) in order to preserve the value of 50° for the maximum elongation of Venus. It would appear that in 109 Calcidius has in mind the utility of an epicycle to explain solar anomalous motion, but that in 112 he omits any such solar epicycle as a complicating and unnecessary factor in an explanation of the appearance of elongation of Venus from the Sun. For the appearances of Venus (in Paragraph 112) an epicycle for that planet alone will suffice. And the centre of Venus's epicycle need only be on the same radius as is the Sun, not centred on the Sun itself. What must be recognized here is, first, that Calcidius introduces only the minimum needed to explain the appearance of bounded elongation and, second, that he is not concerned to provide a geometrical model drawn from a more technical manual of astronomy. Instead he simply constructs a single epicyclic circle and never even bothers to specify the location of its centre in relation to the Sun, since such specification is irrelevant to his limited purpose. All that is relevant is the location of the epicyclic circle with respect to a radius passing from the Earth's centre through the Sun, which radius must bisect the circle.

4. *Diagrams in the Calcidius Manuscripts: Paragraphs 110–11*

As soon as we look at the manuscript diagrams we are struck by the misfit of extant figures with preserved text. The diagrams, whether those chosen by Waszink and Jensen for the modern critical edition[34] or any of the other variants in the manuscripts, must be interpreted in one of two ways, either as corruptions of the originals in Calcidius's commentary or as inventions of a time later than Calcidius in order to provide replacements for the diagrams. The first thing these manuscript diagrams force us to do is to return to the text of 110–11 and consider adding further elements to Figure 1, which is a reconstruction based solely on 111. While the text appears to begin construction of a diagram at the beginning of 111, the manuscript diagrams overwhelmingly, though not unanimously, record a fundamental design of three concentric circles (Figures 3–4). The significant variations in this design include the location of points X and K as well as the positioning of the lines XA and XΓ, but the basic pattern of three concentric circles is remarkably stable. Since two of these three circles, which do *not* appear to include the tangent circle introduced at the end of 111, are unmentioned in 111, we must look in the previous section for them. Within the enclosing zodiacal circle we can identify two more concentric circles as the two circles that "Heraclides of Pontus drew [as] the circles of Lucifer and of the Sun" at the beginning of 110; they have, according to Calcidius, "one and the same centre and middle" (Figure 5). As we see in the subsequent description in 110–11, there is no need for these two planetary orbits in order to make the point intended by Calcidius. Therefore it is quite uncertain whether or not they were part of the original diagram. They can have been added later to satisfy the concern of readers and copyists that the two circles mentioned in 110 find a place in the diagram for 111.

The various manuscript diagrams for 110–11 have been studied and interpreted primarily by van der Waerden[35] and van der Tak.[36] These interpretations as well as the diagrams themselves now require full consideration. A general rule must, however, be set down as a precondition for discussing the relationships of text and diagrams. The rule gives precedence to text over diagram in attempting to reestablish the original form of an image, even though there is some flexibility in the rule. The manuscripts involved in this investigation number 57 at the most, that is, those manuscripts which include the text of Calcidius's Paragraphs 109–12. Of these I have examined all but one.[37] Of the 56 consulted only six have no diagrams at all for these sections of Calcidius. Among the 50 manuscripts with diagrams the distribution by century is as follows:[38]

s. IX: 2; s. X: 3; s. XI: 19; s. XII: 8; s. XIII: 3; s. XIV: 2; s. XV: 13

This enumeration gives ready testimony to the rapid rise in interest in Calcidius's explication of Plato in the eleventh century with continuing but notably diminished interest in the twelfth. This development is thrown even more into relief by a count of manuscripts of the *Timaeus* alone, without the commentary. With a total of six manuscripts surviving from the ninth through eleventh centuries, the *Timaeus* appears independent of Calcidius's work in 43 manuscripts during the twelfth century. The coincidence of this rapid increase with a notable decline in new manuscripts of Calcidius's commentary suggests that the commentary was valued only as an introduction to Platonic cosmology and had largely served its purpose by the twelfth century, when scholars turned to the *Timaeus* itself and produced new commentaries on it. This general development will be seen in our discussion of the diagrams to Calcidius's Paragraphs 110–12, where the problem of reconstructing the original diagrams cannot be solved without a simultaneous consideration of the problem of identifying new diagrams, added to the manuscripts as replacements for older unsatisfactory ones.

In essays of 1944 and 1951, van der Waerden divided the Calcidius diagrams, based on 15 manuscripts,[39] into three groups. (Groups I, II, and III are shown in Figures 3, 4 and 6 respectively.) His classification began, however, with an exclusion of both the text and the diagrams for Paragraph 112, focusing instead on 110–11 and the first diagram of the pair normally found in the manuscripts. This decision on his part was due to a concern to identify only the Heraclidean doctrine, and he does not discuss 109 and 112 at all in this regard.[40] (His discussion elsewhere of 112 will be reviewed below.) Van der Waerden's Group III diagrams (Figure 6) are essentially the same as our Figure 2,[41] and he concluded that this group of manuscript drawings derived from a clever medieval scribe ("ein kluger Schreiber") who reconstructed this figure from the text. Van der Waerden reached his own conclusion from these facts: (1) the Group III design had only two circles and lacked the letters ΔEZH; (2) this group of diagrams has no apparent relationship to the diagrams of Group I and II.[42] With regard to the first, it should be said (a) that the letters ΔEZH *are* in the diagram in many manuscripts, but not those he consulted, and (b) that it begs the question to object that the diagram has only two circles, since this is not ruled out by the text. With regard to van der Waerden's second reason, it remains to be seen precisely what relationship exists between the groups. His use of only 15 of the 50 manuscripts with diagrams is partly responsible for the inconclusiveness of his results.

With regard to Group III (Figure 6), van der Tak followed van der Waerden's classification but concluded that this diagram type was indeed the original Calcidian figure and passed through a series of corruptions in three further stages that produced the results found in Groups I–II (Figures 3–4).[43] The sequence of three stages, according to van der Tak, can be described as a progressive sinking of point X from the centre towards the periphery, accompanied by the insertion of another concentric circle within the diagram (from Figure 6 to 3 to 4). Both authors, in studying the diagrams, have considered the tangent circle introduced only at the end of Paragraph 111 to be an integral part of the explanation of the supposedly Heraclidean position throughout 110–11. Since that is not the case, and the tangent circle is brought in only for use in 112 — the numbering is foreign to the manuscripts and is no more than a modern convenience — we must begin at the beginning in order to gain a better sense of what can be learned from the manuscript diagrams.

Of the 50 manuscripts with diagrams, three, from the eleventh and twelfth centuries,[44] do not fit neatly into any of the three groups set out by van der Waerden and van der Tak. Group I (Figure 3), as delineated by these two investigators, has as its primary characteristics: three concentric circles, a vertical XB running from X at the bottom of the second circle through the common centrepoint to B at the top of the outer circle, two lines inclined from X to A and Γ on the outer circle to the left and right respectively of B. All other characteristics are inconsistent, although van der Tak tried to specify more.[45] There are 15 manuscripts in Group I.[46]

Group II (Figure 4), found in 27 manuscripts,[47] has three characteristics mentioned by van der Tak: the three concentric circles have relatively wider radii than in most cases with Group I; X lies on the outer circle, with the line XB making a complete diameter across the three circles; at least two of the letters ΔEZH appear (but this does not differ significantly from Group I).[48] Of some interest is the placing of K, supposed to locate the Sun, which appears distinctly above the centre and usually quite close to the inner, solar circle in 20 of the 27 diagrams in this group. Five of the others have K at the centre.[49] The placement of the letters ΔEZH in Group II is more haphazard, with the letters put in more than one circle in 21 examples. As van der Tak noted, the large majority of diagrams here have the lines XA and XΓ cutting the inner circle rather than tangent to it. Only six have the lines tangent, while two more have these lines almost but not quite touching the inner circle.[50]

Group III (Figure 6) contains ten manuscripts. Of these, only five comprise a completely separate group, without apparent influence of the Group II diagrams.[51] One manuscript contains both Group I and III diagrams at the appropriate location.[52] Four manuscripts have diagrams for Groups II and III at the same place.[53] The overall appearance of the Group III diagrams is rather suspect, giving only weak support for van der Tak's hypothesis that these represent the original for Paragraphs 110–11.

The proposed purity, or originality, of the Group III diagram (Figure 6) can be assessed partly by comparing the members of this group. According to Waszink's *stemma codicum*[54] Paris 6280 (P3) and Paris 7188 (P9) should have similar diagrams, but they are not even faintly alike, unless we consider the marginal diagrams added to P3 by a later scribe for Paragraph 112[55] to be somehow related to the diagram included within the text of 111 in P9. But such an assumption would be highly tendentious. Again, Paris 6280 (P3) and Reginensis 1308 (Reg 6) are sisters, derived from the same exemplar, and yet Reg 6, a member of Group II, does not possess the Group III diagram found marginally in P3. Some further diversity in other diagrams across the two manuscripts should suggest caution about concluding too much from the groupings of van der Waerden and van der Tak. There is only one point in the stemma where we can test with reasonable confidence whether or not a Group III diagram has come from the original. This is possible in the Y group of manuscripts, where Wien 443 (U1) is preceded by Bamberg M.V.15 (Ba) and followed by Köln 192 (Col 1), München 6365 (M3), and Reginensis 1861 (Reg 8). It turns out that Ba, Col 1, M3, and Reg 8 are all Group II and quite similar, with no suggestion of the Group III diagram that appears in the intermediate U1, which is, in turn, lacking in any sign of a Group II diagram. The diagram for Paragraphs 110–11 in U1 rather clearly derives from an independent scribe, like van der Waerden's "clever copyist", quite possibly in response to a manuscript (U1) that had been copied with spaces for the diagrams but without inclusion of the diagrams themselves.

If we review the dates for all the manuscripts discussed, we can see that the Group I and II diagrams (Figures 3 and 4) are found as early as the ninth and tenth centuries while all Group III diagrams (Figure 6) appear in eleventh- and twelfth-century manuscripts or later copies. Group I has fifteen entries with three from the ninth/tenth centuries; Group III, with ten entries, remains limited to the eleventh century and later. A fair conclusion would be that the invention of the Group III diagram for Paragraphs 110–11 occurred early in the eleventh century, or a bit before, and was simply reconstructed from the text.[56]

If the conclusion for an eleventh-century inventor of the Group III design seems less than credible, consider briefly a closely related parallel. One of the manuscripts in Group III, Leiden BPL 64 (s. XI), has a thoroughly unique addition to the text of Plato's *Timaeus* 38D. Inserted into the textual space where the orbits of Mercury, Venus, and the Sun are described is a diagram of these orbits taken directly from the manuscripts of Martianus Capella, where this diagram had travelled since its invention in the ninth century.[57] In no other extant manuscript of Plato's *Timaeus* before the twelfth century[58] is there an astronomical diagram inserted into Plato's text, yet the copyist has done so, clearly in the spirit of innovation, in this manuscript. The same manuscript, of course, also contains two instructive pairs of diagrams for Paragraphs 110–11 and Paragraph 112. For 110–11 we find within the same textual space both a typical Group II diagram and a Group III diagram. Again, on the following page, for 112, we find in the textual space both an example of an extremely common, traditional diagram accompanied by another diagram, almost identical to the Group III sort used for 110–11.[59] The rather straightforward conclusion to be drawn here is that the diagrams represent unusually careful thought on the part of the copyist, or director of copying, for this whole manuscript, and the pair of diagrams in each of the two relevant Calcidian locations shows (a) the traditional diagram in the manuscript from which copy is made and (b) a new diagram constructed from the text as an improvement over that found in the exemplar. The inventiveness of the manuscript's copyist and the novel character of the Group III diagram are both exemplified here in Leiden BPL 64.

There is an interesting difference between the Group III diagrams (along with others they influence) and the other two groups taken together. In those manuscripts where a Group I or II diagram (Figures 3, 4) appears without the company of an example from Group III, the inner circle is almost always labelled "sol" or "solis",[60] and there is no other reference to the Sun. It is as if the emphasis in these diagrams is on the circle of the Sun, not on the apparent position of the Sun as seen along the zodiac from X. On the other hand, throughout the Group III diagrams (Figure 6) there is a placing of "sol" along the zodiac at the point B, where the Sun's appearance is projected. Here the diagram clearly emphasizes observed appearance, as does the text. However, in every manuscript having either a Group I or II diagram accompanying one in Group III, the "sol" at B in the Group III design has caused the copyist to insert a "sol" at B in the Group I or II figure as well. This occurs in five manuscripts.[61] The intent seems to have been to carry this stronger emphasis on observed appearances over to the older diagram from the new diagram. Such a conclusion would seem to be reinforced by the consistent absence of the "sol" at point B in all 34 other Group I and II figures.

Van der Tak's interpretation of Groups I and II was that the point X had begun at the centre of the zodiacal circle with only the solar circle inside and tangent to the radii from X. Then, he hypothesized, the point X sank progressively lower until it reached the lowest point of the zodiacal circle, while a second internal circle was added for Venus. If the Group III diagrams (Figure 6) represented the Calcidian original most closely, van der Tak's hypothesis would be persuasive, but the manuscript evidence indicates that Group III is a medieval reconstruction from the text, just as van der Waerden had supposed though on insufficient grounds. In this case, a new accounting for the forms of Group I and II is required, and van der Waerden's hypothesis on this matter is quite unacceptable.[62] Solely because of Greek lettering in the diagram, he proposed that the two forms had developed from a tradition in the astronomical text of Adrastus, before Calcidius. Van der Waerden then proposed that the Calcidian figure, representing Heraclides's astronomy, contained a central point X, two radii XA and XΓ, and *two* concentric circles for the epicycles of Venus and the Sun between these two radii. An interpretation of Groups I and II much more in accord with the positive evidence we have, rather than with the absence of evidence, is that the point X was initially central, the two concentric circles for Venus and the Sun were just as they are in the manuscripts, and the radii XA and XΓ extended 50° to either side of the vertical radius XB, on which K was located. In other words, our Figure 5. This would indeed have the point X dropping to successive planetary circles from the centre as progressive corruption of the diagram occurred. But it would not make those circles epicycles. The most likely source of the corruption would be from confusion with the diagram for Paragraph 112, which did contain an epicyclic circle for Venus.

5. *Diagrams in the Calcidius Manuscripts: Paragraph 112*

In turning to Paragraph 112 and its diagrams (Figure 7 and variants), which will help understand the various states of diagrams for 110–11, we need to recall that Group III diagrams, which contain the tangent circle (or epicycle), were reconstructed for 110–11. Why an epicycle, if our argument for only geocentric and concentric circles is appropriate for the text of 110–11? This query should remind us that 111 is adequately described by Figure 1, since the closing introduction of an epicycle is an entry into 112. Reference back from 111 to 110 would make the figure include geocentric circles for Venus and the Sun as in Figure 5. Reading both 111 and 112 together without 110 would produce a combined diagram like Figure 2, which is also Figure 6 in essence, or the Group III diagram. This means that, unlike Groups I and II, meant to illustrate 110–11 but not 112, Group III was meant to illustrate 111 and 112 without any reference back to the solar and Venusian orbits mentioned in 110. As a composite for 111–12, Group III should be able to replace all other diagrams at this point in Calcidius's commentary, and the details of the manuscripts support this prediction.

In the five manuscripts with Group III alone to illustrate 111, there exists one more diagram to illustrate 112. This figure is of precisely the same form as the Group III diagram for 111, with only a few changes in lettering to accord with the text of 112. In other words, where we find Group III (Figure 6) introduced as a new diagram for 111, the same sort of diagram is considered proper for 112 (*cf.* our Figure 2). Furthermore, the same state of affairs exists in the manuscripts having combinations of Group III with either Group I or II diagrams for 110–11. In Group I the sole example is Reginensis 1114, of the fourteenth century, where there exists a Group III diagram within the textual space along with the traditional diagrams for both 110–11 and 112 (Figure 7).[63] The labelling is different in the two Group III diagrams here in order to accord with the labels indicated in the successive texts, but the same form of diagram is used for both 111 and 112. Again, this common diagram is the form given in our

Figure 2. In the combinations of Group II and Group III for 110–11, the same results appear for the diagrams illustrating 112. Every manuscript — there are four — shows a combination of Group II and Group III followed by a combination of the traditional diagram for 112 (Figure 7) with a Group III design (Figure 6).[64] Here again the same conclusion prevails as before: the medieval invention of the Group III diagram was understood to be suitable for both 111 and 112, just as our own reconstruction in Figure 2 is easily understood to serve economically for both 111–12, even though the epicycle is needed only for 112.

If both a modern and a medieval reconstruction of diagrams for the texts of 111 and 112 agree that the same diagram can serve for both, we must return to the traditional form of the diagrams for 112 and inquire about the relationship of this figure to the figures (Group I–II) for 110–11. Certain elements universally present in the traditional diagram for 112 (Figure 7) require recognition and interpretation. Figure 7 is clearly degenerate in many ways and not all variations signify something that leads to understanding of the origin of such a design. For instance, some examples have point K on the outer circle; some have the upper of the two small intersecting circles arranged so that it touches the large circle for Venus; some have only one rather than two small circles inside and at the bottom of the enclosing band. What appear to be the fundamental elements in this diagram are: an enclosing zodiacal circle; a large epicycle for Venus carried on a circle concentric with the zodiacal circle; a vertical "radius" of the zodiacal circle, on which is carried the centre of the epicycle for Venus and another two-circle element for the Sun; two intersecting circles for the Sun, one of which is larger than the other, with the centre of the two-circle unit below the midpoint of Venus's epicycle and above the lower end of the radius; two radii 50° to either side of the vertical radius and tangent to the epicycle of Venus. The lettering is problematical, but, given what happened in the corruption of the diagram for 110–11, the rest of the arrangement for 112 seems to be reasonably clear except for the exact size and position of the two-circle unit for the Sun. The interpretation of this part of the design for 112 cannot be certain and requires further consideration.

With regard to the diagram that originally appeared in Calcidius's account, we can bring to bear the following conclusions, which have already been advanced in our interpretation. Figure 8 is our reconstruction of the diagram for 112. (1) The last sentence of 111 says "a circle" but does not specify the centre of the circle, other than placing it on XB, nor the planet for which it is intended. This is the beginning of Calcidius's epicyclical explanation. (2) The first sentence of 112 refers to Plato and others, the *globus* of the Sun, the *globus* of Venus, and the fact that Venus's *globus* touches XA and XΓ. (3) Despite ambiguity the best meaning for *globus* here is the body of the planet. (4) The second sentence of 112 uses *circulus* for the epicycle of Venus, which is said to travel on its *circulus* and to encounter E and H on opposite sides of the vertical while meeting Δ and Z along the vertical. A bit later in 112, ΔEZH is called the *circulus* of the planet. (5) In 112 the Sun is explicitly restricted to the visual point B, not to various positions on a solar epicycle. (6) If we assume that Calcidius composed a diagram for this text, we must assume the diagram did not include a solar epicycle (Figure 8). But this interim conclusion, based on the text, not the diagrams, appears to fly directly in the face of the evidence we can derive from the surviving diagrams. Since medieval manuscript diagrams often have a life of their own, this evidence should be assessed for what it tells us about these diagrams themselves, not necessarily about the original text or even the original diagrams.

The two-circle unit for the Sun in the extant manuscript diagrams (Figure 7) seems most likely to be a degenerate solar epicycle. Some late medieval students of this figure for 112 concluded the same, presumably because of their familiarity with epicyclical models, and in two fifteenth-century manuscripts the two circles were separated, one being moved down to centre on K and the other being placed next to ΔEZH, the epicycle for Venus, so the design would seem to show the two epicycles tangent to XA(KA) and XΓ(KΓ) and centred on the overextended radius XB(KB).[65] Why is the solar epicycle in the design at all? Our answer is that only two alternatives are plausible. Either the solar epicycle was added after the text and diagrams were completed as a result of misunderstanding — perhaps after corruption of the text, which we know occurred in the labelling of the radii as KA and KΓ, and perhaps even in late Antiquity, through an assumption that completely epicyclical astronomy was intended in 112. Or the solar epicycle was in the original diagram, because the whole diagram was adopted from another work. However, this latter alternative is unlikely, because (a) the text of Calcidius is explicit and prescribes a simpler diagram, and (b) it would be odd to adopt a diagram from a pre-existing text and then fail to describe it correctly when using it.

6. *Divergent Manuscript Diagrams for Paragraphs 110–12*

In concluding our study of the manuscript diagrams for Calcidius's text of Paragraphs 110–12, we should review briefly the three manuscripts omitted from previous consideration, as they do not fit any of the three groups used above. One contains an incomplete diagram for 110–11 and the most common form for 112; it tells us nothing new except, perhaps, about some confusion of the scribe in the face of a corrupt diagram for 110–11.[66] A much more interesting set of figures is found in the margin of the British Library ms. Roy. 12.B.XXII, f. 33v, from the early twelfth century. In a vertical sequence of five designs, added to a text requiring a number of emendations, the uppermost diagram is exactly like our Figure 1, for c. 111, with the exception that K is located midway from X to B. The second in the sequence shows the same diagram with a large unlabelled added circle, passing through the points XAΓ; this unlabelled circle follows the directions at the end of 111 to add a circle to the first diagram.[67] The third diagram (Figure 9 (a)) is an illustration of 112 and seems to be an attempt to improve the traditional diagram by eliminating one circle from the pattern for Venus and one circle from the two-circle unit for the Sun. The fourth figure (Figure 9 (b)) presents a small mystery. Either it is a thorough innovation in diagramming 112, or it is a reversion to and revision of the manuscript figures for 110–11; an argument can be made for either choice, and there is no basis other than personal preferences for deciding. If the latter, then we have here a modification of the Group III diagrams, adding an inner concentric circle for the epicycle of the Sun. If the former, we have a placement of the solar epicycle in direct contradiction to the text as edited. However, this manuscript page carries a corrupt phrasing which would allow ambiguity in locating the Sun, or its epicycle, with respect to Venus. The text here can be read to say that Venus's *globus* is larger than that of the Sun, thus allowing *globus* to mean epicycle and suggesting that one epicycle contain the other.[68] In any case, the diagram appears in the upper semicircle and not spread across the full zodiacal circle. The last of the five figures in vertical sequence is no more than an example of the Group II diagram, perhaps representing the image found in the exemplar, but there is no way to confirm or reject such a hypothesis.[69] These manuscript diagrams show once more the innovative and reforming tendencies of the eleventh- and early twelfth-century students of Calcidius's commentary.

The last of the three manuscripts with unclassified diagrams presents a tantalizing prospect. Paris 10195, of the eleventh century, is the sole survivor from one of four lines of manuscripts descendant from the important Γ group of texts of Calcidius's commentary. At the two spaces in the text for diagrams to 110–11 and 112 we find figures with concentric circles only, no epicycles. The design for 110–11, or conceivably 111 alone, has concentric bands for the zodiac and the orbit of the Sun with radii XA and XΓ marking the limits of Venus's elongation from XKB (Figure 10 (a)). The design for 112 takes the same form and adds a concentric band for Venus, between the Sun and the zodiac, and places the letters ΔEZH around this intermediate band (Figure 10 (b)), ignoring the fact that such a circle for Venus neither helps explain bounded elongation nor fits the textual prescription that Venus be closer to the Earth at Z than at Δ — unless, of course, the Earth is meant to be eccentric in the cosmos and with respect to the zodiac, an extremely unlikely intention in this diagram. One of the interesting elements in this figure is its retention of X for the origin of the lines to ABΓ, which makes much more sense than the accompanying text, which makes K the origin of the tangent lines. The two diagrams in this manuscript are clearly related, with the second no more than a modification of the first by an addition of a labelled circle for Venus. This close relationship plus the adherence to concentric planetary orbits rather than epicycles exhibits once more, and in a different way, the ability and intent of eleventh-century students of Calcidius to devise figures more satisfactory to them than the thoroughly corrupt forms we have observed in the manuscript traditions for 110–11 and 112. In both cases the diagrams which were reformed by eleventh- and twelfth-century scholars are so far from the originals that we cannot use the manuscript diagrams alone to reconstruct the originals. Those manuscript diagrams which make more sense than Groups I and II are medieval reforms, not hints of a surviving tradition. The same lesson holds for diagrams for 112. Despite its imperfections, the textual tradition remains our best source for reconstructing what Calcidius had in mind.

7. *Calcidius, His Sources, and Heraclides*

The question of Calcidius's source for his teachings in Paragraphs 109–12 is one which has been discussed elsewhere, though perhaps not fully enough and surely not with enough precision to illuminate the significance of his reference to Heraclides of Pontus. Waszink's edition notes that Theon of Smyrna or, even more likely, Adrastus was the source for the contents of these four paragraphs, though no argument appears to support this claim. The most relevant discussion, encapsulating all pertinent claims, regarding the source for Calcidius's text is an article by Hiller, who reasoned that Calcidius used only Adrastus, not Theon, as his source for astronomical excerpts.[70] What Hiller argued most strongly is (1) that wherever Calcidius might appear to have used Theon, Adrastus is more likely the source, and (2) that Theon was not used for some accounts where his explanation would, in fact, have been of value to Calcidius. The conclusions to be drawn from Hiller, therefore, are that Adrastus was the author used by Calcidius for the materials we can trace in Theon, and that we have no certainty of the source for the materials not found in Theon. Theon himself, we know, cited Adrastus extensively and was especially interested in astronomy.[71] If we follow Hiller, Calcidius would therefore seem either not to have had Theon at hand or else to have chosen Adrastus for greater simplicity or perhaps for a preferred doctrinal orientation. However, we do not know what Adrastus's commentary on the *Timaeus* contained except where there is explicit testimony in other works, and it is just this limitation which makes any attribution of Calcidius's Paragraphs 109–12 to Adrastus so hazardous. There is no independent attribution of this material in Antiquity to Adrastus. The most Hiller could do was to follow Martin in remarking that the use of Greek lettering in the propositions (only 111–12 it should be noticed) indicated a Greek source. From this Hiller inferred that Adrastus was here again the source excerpted by Calcidius.[72]

Two simple points must be made. First, it would seem excessive to claim that a knowledge of the Greek alphabet and use of Greek letters in geometrical diagrams *c.* A.D. 400 by Calcidius shows that he used a Greek source at such points. Surely we would not argue thus for modern writers. Second, the absence of any further evidence for a source of Calcidius's 109–12 allows the presumption that these sections, while repeating some information that can be found in Theon,[73] were either a composition by Calcidius himself or an extract from another, unknown source. In sum, we cannot say where these sections came from. Most assuredly we do not know the source of the reference in 110 to Heraclides of Pontus.[74]

Plato's *Timaeus* gives no authority either to epicyclic or eccentric paths for Mercury and Venus. Cornford and Taylor agree that Plato gave a separate geocentric circle each to Mercury, Venus, and the Sun.[75] Plato's *Republic* 616 D-E agrees with this allocation of separate geocentric orbits to the three planets. Theon of Smyrna said that Plato *seemed* to prefer the epicyclical hypothesis over the eccentrical in explaining planetary motion,[76] but this statement is, of course, an invocation of Plato's name coupled with an extravagant interpretation of his words. More appropriately Theon might have said that, in his opinion, Plato would have preferred the epicycle had he been apprised of the two alternatives. Calcidius does not claim anything like Theon regarding Pluto. In fact, Plato is invoked by Calcidius only for the order of the planets (Paragraph 112) in the midst of Calcidius's account of his own preferred alternative, the epicyclical, for explaining the appearance of the bounded elongation of Venus. If we look carefully at Calcidius's wording in 108–9 we find that he clearly did not associate Plato with the epicyclical account, for Calcidius equated Plato's doctrine at the beginning of 109 with the non-epicyclical explanation, that which referred to a *contrariam vim* of Mercury and Venus.[77]

The name of Heraclides of Pontus appears in the course of Calcidius's discussion of the first (the Platonic) alternative in explaining the appearances of Venus's bounded elongation. Both text and context exclude the possibility that some sort of heliocentric path was supposed by Heraclides for the planet Venus. Even the diagrams exclude this possibility whether we use our own reconstruction from the text (Figure 1) or a medieval reconstruction of the conjoined texts of 111–12 (Figure 6) or the corrupt figures found in the extant manuscripts (Figures 3–4) or even a sympathetic attempt to clarify these corrupt surviving figures (as in Figure 5). The only place where epicyclic motion, apparently not around the Sun, is proposed for Venus in Calcidius's text is in 112, where Heraclides of Pontus not only has no place but is excluded by his attachment to the alternative explanation.

Nowhere in the ancient literature mentioning Heraclides of Pontus is there a clear reference to his support for any kind of heliocentrical planetary motion. Even more to the point, in none of the places where we find Heraclides's well known proposal of the hypothesis of Earth's diurnal rotation do we find any suggestion of some further revolutionary idea such as heliocentric motion for any of the planets. The conclusion should be clear — modern proposals for an ancient Heraclidean heliocentrism have come from post-Copernican expectations rather than from a dispassionate reading of the texts.

REFERENCES

1. The standard work on Aristarchus remains Thomas L. Heath, *Aristarchus of Samos, the ancient Copernicus* (Oxford, 1913, repr. 1959); see chap. 18 for Heraclides of Pontus. For Copernicus's awareness that Aristarchus conceived of a mobile Earth, see *Nikolaus Kopernikus Gesamtausgabe*, ed. by Fritz Kubach (Munich, 1944), i, fol. 11v, lines 15–17.
2. Kepler, who made a determined search to find an ancient Platonic school of heliocentrism, was quite ready to discover limited heliocentrism, for Mercury and Venus, in Plato as well as in Vitruvius, Pliny, Macrobius, and Martianus Capella, but never mentioned Heraclides of Pontus. See Kepler's *Apologia contra Ursum* in sect. II of Nicholas Jardine, *The birth of history and philosophy of science* (Cambridge, 1984), and the discussion of Kepler's presumed precursors of Copernicus according to *Apologia contra Ursum*, Part 4, in Bruce Eastwood, "Kepler as historian of science: Precursors of Copernican heliocentrism...", *Proceedings of the American Philosophical Society*, cxxvi (1982), 367–94.
3. *Ibid.*, 373–81, 383–91.
4. Pierre Duhem, *Le système du monde* (Paris, 1915), iii, 44–162; D. R. Dicks, *Early Greek astronomy to Aristotle* (Ithaca, 1970), 136–7, 218–19.
5. Fritz Wehrli (ed.), *Die Schule von Aristoteles. Texte und Kommentar*, vii: *Herakleides Pontikos*

(Basel, 1953), 35–38. 94–101, presents the astronomical fragments and brief commentary. See also *idem*, "Herakleides der Pontiker", *Paulys Realencyclopädie der Altertumswissenschaft*, Suppl. II (1968), 675–86, esp. pp. 685–6. H. B. Gottschalk, *Heraclides of Pontus* (Oxford, 1980), 58–87, discusses very competently the astronomical fragments but I differ with his interpretations of the two crucial texts for any so-called Heraclidean heliocentrism.

6. The text appears in Hermann Diels (ed.), *Commentaria in Aristotelem graeca*, ix: *Simplicii in Aristotelis Physicorum libros quattuor priores commentaria* (Berlin, 1882), 291–2; also in Posidonius, *The fragments*, ed. by L. Edelstein and I. G. Kidd (Cambridge, 1972), 44–45. A translation appears in Heath, *Aristarchus* (ref. 1), 275–6, reprinted in M. R. Cohen and I. E. Drabkin (eds), *A source book in Greek science* (Cambridge, Mass., 1958), 90–91. On 'saving the phenomena' a useful introduction is Jürgen Mittelstrass, *Die Rettung der Phänomene, Ursprung und Geschichte eines antiken Forschungsprinzips* (Berlin, 1962), 140–221, on astronomy; and G. E. R. Lloyd, "Saving the appearances", *Classical quarterly*, n.s. xxviii (1978), 202–22.
7. The text is in J. H. Waszink (ed.), *Timaeus a Calcidio translatus commentarioque instructus* (London, 1962/1975), 156–9 (cc. 108–12). A translation of cc. 109–11 can be found in Gottschalk, *Heraclides* (ref. 5), 69–70.
8. See above, ref. 5.
9. The leading figures in this nineteenth-century group were Giovanni V. Schiaparelli, *I precursori di Copernico nell'antichità* (*Memorie del Reale Istituto Lombardo di Scienze e Lettere*, xii; Milan, 1873), 416–20; *Origine del sistema planetario eliocentrico presso i Greci* (*Memorie del Reale Istituto Lombardo, classe di scienze mathematiche e naturali*, xviii; Milan, 1898), 151–67, under the heading, "The heliocentric planetary system considered as a possible geometrical hypothesis"; and Hermann Staigmüller, "Beiträge zur Geschichte der Naturwissenschaften in Klassischen Altertume", *Programm des königlichen Realgymnasiums in Stuttgart* (Stuttgart, 1899), 33–35 and "Herakleides Pontikos und das heliokentrisches System", *Archiv für Geschichte der Philosophie*, xv (1902), 141–65. Both Schiaparelli and Staigmüller argued vigorously, even over-enthusiastically, that the text in question must assign the hypothesis of a heliocentric mobile Earth to Heraclides. Cautions and alternatives of various sorts were issued by August Böckh, *Untersuchungen über das kosmische System des Platons* (Berlin, 1852), 133–40; Thomas H. Martin, "Mémoires sur l'histoire des hypothèses astronomiques chez les grecs et les romains I, v, 2–4", *Mémoires de l'Institut National de France, Académie des Inscriptions et Belles–lettres*, xxx, Part 2 (1883), 1–43, pp. 25–43; and Paul Tannery, "Sur Héraclide du Pont", *Revue des études grecques*, xii (1899), 307–10.
10. This translation is primarily that of Heath, *Aristarchus* (ref. 1), 275–6, emended in part according to Gottschalk, *Heraclides* (ref. 5), 63, replacing much of lines 20–35 of Heath's p. 276.
11. The closeness of Geminus to Posidonius is of some interest here but remains uncertain. Germaine Aujac's introduction to her edition of Geminus, *Introduction aux phénomènes* (Paris, 1975), p. xxii, bases a reconstructed biography of Geminus on a letter of *c.* 15 B.C. by Dionysius of Halicarnassus to one Cn. Pompeios Geminos, while admitting that her identification of this addressee with our astronomer Geminus is a hypothesis recommended primarily by its lack of explicit contradiction. Otto Neugebauer, *History of ancient mathematical astronomy* (New York, 1975), ii, 579–80, dates Geminus to the first half of the first century A.D., but some latitude exists in the bases for the calculation, placing Geminus's writing (in his later years?) perhaps at the turn of the B.C. – A.D. eras. Aujac puts his *Introduction to the phaenomena* at *c.* 50 B.C., clearly too early. The upshot allows us to consider Geminus as a follower of Posidonius but probably not as one of his students.
12. Posidonius, *The fragments* (ref. 6), 44–45. Ian G. Kidd, "Philosophy and science in Posidonius", *Antike und Abendland*, xxiv (1978), 7–15, p. 11, shows the Posidonian elements, placing astronomy in the service of philosophy rather than in the position of peer.
13. *Ibid.*, II: Kidd paraphrases and partly reiterates the quotation, saying, "You might even have a hypothesis put forward which violates the ἀρχαί or postulates, with a guy (τις) like Heraclides Ponticus assuming the Earth to be in motion in some way".
14. Gottschalk, *Heraclides* (ref. 5), chaps. 1, 7, points to the generally Platonic cast of Heraclides's thought as well as the literary, especially rhetorical, manner in which he presented arguments. Heraclides's polemical attitude is remarked by, among others, Wehrli, *Schule* (ref. 5), 99; Wehrli, "Herakleides" (ref. 5), 685.
15. Gottschalk, *Heraclides* (ref. 5), 64–66.
16. *Ibid.*, 66–69.
17. *Ibid.*, 68–69.

18. J. L. E. Dreyer, *History of the planetary systems from Thales to Kepler* (Cambridge, 1906), 87–107.
19. *Ibid.*, 92–95.
20. Neugebauer, *op. cit.* (ref. 11), 627–8, explains this succinctly. Here I would not agree with Konrad Gaiser, *Platons ungeschriebene Lehre* (Stuggart, 1963), 383–4, in the view that Heraclides has referred to a Eudoxan motion that is equivalent to nutation.
21. Gottschalk, *Heraclides* (ref. 5), 69–82, presents his arguments for this interpretation.
22. The text here (*dividantur in quinquaginta momenta*) is corrupt, as Gottschalk, *Heraclides* (ref. 5), 70, n. 38, following *Commentarius Calcidii*, ed. by Waszink (ref. 7), 157, apparatus *ad lin.* 27, observes. While agreeing on the sense of the passage, I would emend it a bit differently.
23. The text here (ed. by Waszink, 158, line 11) reads KA and KΓ, rather than XA and XΓ, but the text is surely corrupt here as my subsequent analysis of the diagrams will show.
24. See *Commentarius Calcidii*, ed. by Waszink (ref. 7), 156–9 for the Latin texts of cc. 108–12. A translation of c. 112 can be found in B. L. van der Waerden, "The motion of Venus, Mercury and the Sun in early Greek astronomy", *Archive for history of exact sciences*, xxvi (1982), 99–113, p. 103.
25. *Commentarius Calcidii*, ed. by Waszink (ref. 7), 157, lines 3–5: "Quod his usu accidit ex eo quod una medietas atque punctum unum est tam solstitialis circuli quam cuiuslibet alterius stellarum harum."
26. See *ibid.*, 108, line 15 (c. 61); 111, line 14 (c. 64); 127, line 23–128, line 1 (c. 79); 130, lines 8–9 (c. 80); *cf.* 131, line 7 (c. 81), where *punctum* alone describes a geometrical centre in an epicyclic arrangement.
27. Alfred E. Taylor, *A commentary on Plato's Timaeus* (Oxford, 1928), 200–1. Godfrey Evans, "The astronomy of Heraclides Ponticus", *Classical quarterly*, lxiv (1970), 102–11, p. 110; Evans's article proposes (p. 108) three theories in the text of cc. 108–12 of Calcidius, but I find such a proposition quite incredible.
28. Otto Neugebauer, "On the allegedly heliocentric theory of Venus by Heraclides Ponticus", *American journal of philology*, xciii (1972), 600–1.
29. *Commentarius Calcidii*, ed. by Waszink (ref. 7), 158; see p. clxxxx on the source of the published diagrams, a ms. of the tenth century from northern France.
30. In Waszink's edition at 110, line 14; 111, line 17 (globus solis); 128, line 3 (globus solis); 142, line 9; 147, line 3.
31. At 116, line 7; 116, line 11; 119, line 11; 119, line 13; 119, line 15; 121, line 2; 122, line 16; 125, line 16; 127, line 22; 134, line 9; 138, line 12; 145, line 12; 145, line 14; 150, line 17; 151, line 3; 151, line 6; 154, line 7; 159, line 19; 161, line 25. At the three points on p. 119, *globus* = *orbis*. Cicero, *De natura deorum*, II, xviii, 47, defines *globus* as spherical.
32. At 128, line 9; 131, lines 2–3, 131; lines 4–5.
33. See above ref. 23.
34. Diagrams at *Commentarius Calcidii*, ed. by Waszink (ref. 7), 158; also see above, ref. 29.
35. B. L. van der Waerden, "Die Astronomie des Heraklides von Pontos", *Berichte der mathematisch-naturwissenschaftlichen Klasse der sächsischen Akademie der Wissenschaften zu Leipzig*, xcvi (1944), 47–56; *Die Astronomie der Pythagoreer* (*Verhandelingen der Koninklijke Nederlandse Akademie van Wettenschappen Afdeeling Naturkunde*, sect. 1, vol. xx, no. 1; Amsterdam, 1951), 62–73.
36. Johannes G. van der Tak, "Calcidius' illustration of the astronomy of Heracleides of Pontos", *Philologus*, cxvi (1972), 129–36.
37. I have been unable to inspect Napoli Biblioteca Oratoriana ms. XVI.XVIII (A.D. 1507).
38. The dating of the mss. comes with very few exceptions from Waszink's edition (ref. 7), pp. cvii–cxxx.
39. Van der Waerden, "Heraklides" (ref. 35), 52, uses 13 mss.; in *Astronomie der Pythagoreer* (ref. 35), 70, he adds two, from Bamberg and Leiden, to the earlier list.
40. While it is not my concern to dispute van der Waerden's approach point by point, it should be recognized that he has continually argued for a Heraclidean heliocentrism in an extreme form which involves the Earth as well as Mercury and Venus. This position appears in his essays of 1944 and 1951 and can be found in his more recent works: *Das heliozentrische System in der griechischen, persischen und indischen Astronomie* (Zürich, 1970), 51; "On the motion of the planets according to Heraclides of Pontus", *Archives internationales d'histoire des sciences*, xxviii (1978), 167–82. The last of these I consider highly tendentious, arguing for possibilities not historical plausibilities.
41. Van der Waerden, "Heraklides" (ref. 35), 53; *Astronomie* (ref. 35), 71.

42. Van der Waerden, "Heraklides" (ref. 35), 54.
43. Van der Tak, "Calcidius' illustration" (ref. 36), 135, for the three groups of diagrams (Figs 1–3), 136 for the four hypothesized stages of devolution from Group III (similar to our Figure 2). He surveyed 20 manuscripts with diagrams and noted more of the pertinent characteristics than van der Waerden.
44. London BL ms. Roy. 12.B.XXII, f. 33v (s. XII in.); Napoli BN ms. VIII.F.11, ff. 23v–24r (s. XII); Paris BN ms. lat. 10195, ff. 105v–106r (s. XI). I shall return to these three later.
45. He found the lines XA and XΓ always tangents to the inner circle; this is not the case in one example, Vat. Regin. lat. 1114, f. 45v (s. XIV). He said the letters EZH, unexplained by Calcidius, appear; this is not precisely correct in seven examples, of which three have only EH, one has EZ, three have ΔEZH.
46. Bruxelles BR 9625–9626 (s. X), London BL Add. 15293 (s. XI ex.-XII in.), Lyon BM 324 (s. IX), Milano Ambr. I.95 inf. (s. XI ex.), München CLM 13021 (s. XII²–XIII in.), Napoli BN VIII. E.30 (s. XV), Oxford Bodl. Canon. class. lat. 175 (A.D. 1459), Paris BN 2164 (s. XI¹), Paris BN 6281 (s. XII in.), Paris BN 6282 (s. XI m.), Valenciennes BM 293 (s. IX), Vat. lat. 1544 (*c.* 1470), Vat. Barb. 22 (s. XI in.), Vat. Regin. 123 (A.D. 1056), Vat. Regin. 1114 (s. XIV), as well as the earliest printed edition (Paris, 1520).
47. Arezzo BC 431 (s. XV), Bamberg SB M.V.15 (s. XI), Firenze Laur. Plut. 84.24 (s. XV), Firenze Laur. Plut. 89 sup. 51 (s. XI), Firenze BN S. Marco I.IV.28 (s. XI), Firenze BN S. Marco I.IX.40 (s. XII), Köln DB 192 (s. XI), Kraków Jagiel. 529 (s. X), Leiden UB BPL 64 (s. XI), Leipzig UB Rep. I.84 (s. XII ex.–XIII in.), London BL Add. 19968 (s. XI), Milano Ambr. S.14 sup. (A.D. 1454), München CLM 6365 (s. XI), Napoli BN VIII.E.29 (s. XV), Oxford Bodl. Canon. class. lat. 176 (s. XV), Paris BN 6280 (s. XI), Paris BN 6570 (s. XII), Philadelphia U. Penn. 13 (*c.* 1500), Praha SK III.A.13 (s. XIV), Trier Bist. Arch. 28 (s. XII), Vat. Barb. 21 (s. XI), Vat. Chigi E.VI.194 (s. XV), Vat. Regin. 1308 (s. XI in.), Vat. Regin. 1861 (s. XI), Vat. Urb. 203 (s. XV), Wien NB 176 (s. XII), Wolfenbüttel 116 Gud. lat. 2° (s. XI).
48. Though van der Tak did not notice it, the letter Δ of ΔEZH appears very frequently (in 17 mss.).
49. This occurs in Arezzo 431, f. 34v; Leiden BPL 64, f. 85v; Praha III.A.13, f. 99ra; Vat. Barb. 21, f. 59v; Wolfenbüttel 116 Gud. lat. 2°, f. 39v. Paris 6570, f. 21r, has none of the four letters.
50. Of Group II the six with tangents are the Bamberg, Köln, Trier, Leiden, Barberini, and Arezzo mss. The Praha and Wolfenbüttel mss. have the lines XA and XΓ slightly apart from the circle.
51. Cambridge Fitzwilliam Museum McClean 169 (s. XV), Cambridge UL Sidney Sussex 31 (s. XIV), Kraków Jagiel. 665 (s. XV), Paris BN 7188 (s. XII in.), Wien NB 443 (s. XI¹). It should be noted that the two early mss. reverse positions of A and Γ.
52. Vat. Regin. 1114, f. 45v (s. XIV).
53. Leiden BPL 64, f. 85v (s. XI); [Paris 6280, f. 28r (s. XI)]; Paris 6570, f. 2lr (s. XII); [Vat. Chigi E.VI.194, f. 52v (s. XV)]. I enclose Paris 6280 and Chigi E.VI.194 in brackets because in these the Group III diagram is both marginal and joined to a more common version of the diagram for c. 112, making it very likely that this example of a Group III diagram should be ignored in any discussion of the diagrams for cc. 110–11. In Paris 6280 the Group III diagram seems to be intended only for c. 112, and in Chigi, E.VI.194 the Group III diagram, apparently illustrating only c. 112, is almost certainly copied from Paris 6280; van der Tak does not record any of this. He continues to confuse this important point by claiming that Paris 6570 has "two varieties of class III" (p. 132), whereas the second of these is definitely an illustration for c. 112, not c. 111; also, the second is clearly a marginal addition, while the first was apparently intended to accompany the text when it was written.
54. *Commentarius Calcidii*, ed. by Waszink (ref. 7), unnumbered page following p. clxvi.
55. That the marginal diagrams in P3 definitely pertain only to c. 112, not c. 111, seems proven by the position of these marginal diagrams in Ch3 (Chigi E.VI.194), where they are even farther removed from c. 111.
56. This inventiveness of eleventh- (or late tenth)-century scribes with regard to Calcidian diagrams is neither unique nor unusual. The manuscripts of Martianus Capella, Macrobius, Bede, and the Plinian astronomical excerpts all had diagrams added or consciously altered to accord with the sense made by the readers, and such inventiveness appeared especially in the ninth- to eleventh-century period, earlier for some texts than for others.
57. The details of this Capellan diagram are to be discussed in a separate study. In BPL 64 it occurs at f. 46v.
58. There are 28 such mss. of Plato's *Timaeus* before s. XII, including Phillipps 816, once thought

lost, which is now: Austin (U.S.A.), University of Texas, Ransom Humanities Center Library, ms. 29 (the library will not microfilm this manuscript); the *Timaeus* appears at ff. 12r–24r with no diagrams and virtually no glosses.

59. These two pairs of diagrams for 110–11 and 112 appear respectively on ff. 85v–86r.
60. The label is lacking only in Köln 192 and Wolfenbüttel 116 Gud. lat. 2°, both in Group II.
61. Leiden BPL 64, f. 85v; Paris 6280, f. 28r; Paris 6570, f. 21r; Vat. Chigi E.VI.194, f. 52v; Vat. Regin. 1114, f. 45v.
62. The details, conceived in order to advance a Heraclidean heliocentrism, have no support from the diagrams and none I find plausible in the text. See van der Waerden, *Astronomie* (ref. 35), 70–73.
63. Vat. Regin, 1114, ff. 45v–46r.
64. Leiden BPL 64, f. 86r; Paris 6280, f. 28r; Paris 6570, f. 21v; Vat. Chigi E.VI.194, f. 53r. Each of these references is to the page with diagrams for c. 112.
65. This revision appears in Napoli BN VIII.E.30, f. 34v (s. XV), and Vat. lat. 1544, f. 78r (*c.* 1470); both mss. have diagrams for cc. 110–11 in Group I. This revised form also appears in the 1520 Paris edition, f. 33v, and can be conveniently seen in van der Waerden, "The motion of Venus, Mercury, and the Sun..." (ref. 24), 103 (his Fig. 2). Van der Waerden's article is ingenious but fails completely to establish that the theory he has in mind was Plato's or that it would not have come from one of many Hellenistic sources.
66. Napoli BN VIII.F.11, ff. 23v–24r (s. XII).
67. The scribe seems to have followed the defective text for 112 in this ms. in locating the circle. The ms. says that the circle touches A and Γ rather than the lines XA (KA) and XΓ (KΓ).
68. London BL Roy. 12.B.XXII, f. 33v, 5–6: "affirmant aliquanto quam solis esse elacionem luciferi globum qui limitatur notis ΔEZH contingens A...."
69. This ms., R1 in Waszink's stemma, is closely related only to extant mss. with the *Timaeus* alone, not Calcidius's commentary.
70. Edward Hiller, "De Adrasti Peripatetici in Platonis Timaeum commentario", *Rheinisches Museum für Philologie*, N. F. xxvi (1871), 582–9. Followed by Bruno Wladislaus Switalski, *Des Chalcidius Kommentar zu Plato's Timaeus* (Beiträge zur Geschichte der Philosophie des Mittelalters, Bd iii, Heft 6; Münster, 1902), 71–91, who argues that Adrastus and Posidonius, rather than Theon, are Calcidius's sources.
71. G. L. Huxley, "Theon of Smyrna", *Dictionary of scientific biography*, ed. by C. C. Gillispie, xiii (1976), 325–6; and especially Kurt von Fritz, "Theon aus Smyrna", *Realencyclopädie der Altertumswissenschaft*, ser. 2, x (1934), 2067–8, 2071.
72. Hiller, "De Adrasti" (ref. 70), 588–9, with reference explicitly to cc. 107–11 (?!). Martin also remarked that the opinions and wording here are very much like those which Theon derived from Adrastus, but this seems to beg the question when we do not have Adrastus. Jan Hendrik Waszink, *Studien zum Timaioskommentar des Calcidius*, i: *Die erste Hälfte des Kommentars* (Leiden, 1964), 31–33, does not add much strength to Hiller's argument.
73. For example, the 50° elongation of Venus from the Sun: see Theon Smyrnaeus, *Expositio rerum mathematicarum ad legendum Platonem utilium*, ed. by E. Hiller (Leipzig, 1878), 137 (c. 13), 187 (c. 33).
74. Bruno Switalski (*op. cit.* (ref. 70)) argued with insufficient evidence that Posidonius (along with Adrastus) was a source for Calcidius. If we wish to hypothesize on the basis of this unfortunately unsubstantiated claim, we can at least remind ourselves that Posidonius was the author of the reference to Heraclides in the text of Simplicius's commentary on Aristotle's *Physics*. Perhaps Calcidius's reference to Heraclides also derived ultimately from Posidonius (with neither reference being demonstrably heliocentrical)? There is, of course, no way to answer this question.
75. F. M. Cornford, *Plato's cosmology: The Timaeus of Plato* (London, 1937), 105, n. 2; Taylor, *Commentary* (ref. 27), 196, comm. *ad* 38D, 3. Both agree that the text should not contain the τόν, thereby establishing that each of the three planets has an independent geocentric circle. See also Taylor, 154 (*ad* 36D, 3–4), 155 (*ad* 36D, 5–6).
76. Theon, *Expositio*, ed. by Hiller (ref. 73), 188–9 (c. 34).
77. *Commentarius Calcidii*, ed. by Waszink (ref. 7), 156, 19: "Ait [Plato] tamen hos ignes contrariam quoque habere vim."