The Impact of the Platonic Distance–Period Relationship on Martianus Capella's Astronomy

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Introduction

The order of the planets was one of the most challenging and pressing questions in the study of cosmology from antiquity up to early modernity. Nicolaus Copernicus (1473-1543) unraveled the actual structure of the solar system, adopting an ancient astronomical principle, the distance-period relationship (i.e., the planets with larger orbits have more extended periods of revolution), first formulated by Plato (429 [?]-347 B.C.E.). Modern scholars construed Copernicus' heliostatic cosmology as the first consistent implementation of the abovementioned principle. But this is inaccurate. In this paper, contrary to scholarly belief, I argue that Martianus Capella's (fl. c. 410-420) geoheliocentric system consistently implemented a basic form of the distance-period relationship for the order of the planets by grouping those celestial bodies that did not conform with the distance-period relationship in order to solve the *forma mundi* problem (i.e., the order of the planets), just like Copernicus eleven centuries later.

The paper is divided into two sections. The first section offers a brief overview of Plato's research agenda concerning the foundation of *forma mundi* under the concept of one natural bond and his formulation of the distance-period relationship. Plato's metaphysical reflections concerning cosmology set the stage for a philosophically legitimate solution to the *forma mundi* problem. The second section illustrates Plato's influence over Capella's adoption of a geoheliocentric system and how the Capellan system consistently implemented the distance-period relationship.

Keywords: Ancient Astronomy; Distance-Period Relationship; *Forma Mundi* Problem; Geoheliocentric System; Martianus Capella; Medieval Astronomy; Nicolaus Copernicus; Plato.

I. Plato's Declaration of a Unified Cosmos and the Distance–Period Relationship

At the beginning of the 20th century, Pierre Duhem,[1] interpreting Simplicius' *Aristotelis Quatuor Libros De Coelo Commentaria*,[2] introduced the notorious dogma of "saving the phenomena" (σώζειν τὰ φαινόμενα),[3] which became the orthodox outlook concerning Plato and the subsequent Hellenistic astronomy. According to Duhem's general epistemological position, the whole purpose of science is inextricably linked to the production of mathematical contrivances (models) which delineate everything that humans observe. This idea of science is a form of instrumentalism postulating, in Paul Feyerabend's words, that "even a theory that is wholly correct does not describe anything but serves as an instrument for the prediction of the

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[1] See P. Duhem, *ΣΩΖΕΙΝ ΤΑ ΦΑΙΝΟΜΕΝΑ: Essai sur la notion de théorie physique de Platon à Galilée* (Annales de philosophie chrétienne, 79/156 (ser. 4, V1), 1908), 113-138, 277-302, 352-377, 482-514, 576-592; idem, *Le système du monde: Histoire des doctrines cosmologiques de Platon à Copernic*, vol. 1 (Paris: A. Hermann, 1913), 94-95; cf. idem, *The Aim and Structure of Physical Theory*, trans. P. Weiner (Princeton, NJ: Princeton University Press, [1914] 1954).

[2] According to Simplicius: "καὶ πρῶτος τῶν Ἑλλήνων Εὔδοξος ὁ Κνίδιος, ὡς Εὔδημός τε ἐν τῷ δευτέρῳ τῆς Ἀστρολογικῆς ἱστορίας ἀπεμνημόνευσε καὶ Σωσιγένης παρὰ Εὐδήμου τοῦτο λαβών, ἅψασθαι λέγεται τῶν τοιούτων ὑποθέσεων Πλάτωνος, ὥς φησι Σωσιγένης, πρόβλημα τοῦτο ποιησαμένου τοῖς περὶ ταῦτα ἐσπουδακόσι, τίνων ὑποτεθεισῶν ὁμαλῶν καὶ τεταγμένων κινήσεων διασωθῇ τὰ περὶ τὰς κινήσεις τῶν πλανωμένων φαινόμενα" ("And, as Eudemus recorded in the second book of his astronomical history (and Sosigenes took this over from Eudemus), Eudoxus of Cnidus is said to be the first of the Hellenes to have made use of such hypotheses, Plato (as Sosigenes says) having created this problem for those who had concerned themselves with these things: on what hypotheses of uniform and ordered motions could the phenomena concerning the motions of the planets be preserved?"); Simplicius, *On Aristotle On the Heavens* 2.10-14, trans. I. Mueller (London: Bloomsbury Publishing PLC, 2014), II: 12, 292b10.

[3] Mittelstrass, as Lloyd correctly noted, has illuminated the ambiguities of the 'saving the phenomena;' see J. Mittelstrass, *Die Rettung der Phänomene* (Berlin: De Gruyter, 1962), ch. IV; cf. G. E. R. Lloyd, "Saving the Appearances," *Classical Quarterly* 28 (1978): 221.

facts that constitute its empirical content."[4] More elaborate and erudite studies have demonstrated the inaccuracy of Duhem's astronomical instrumentalism.[5]

At the opposite end of Duhem's "saving the phenomena" instrumentalist dogma is the so-called "pure, ideal, or *a priori*" interpretation of Plato's astronomy and cosmology,[6] which, from my point of view, agrees with the overall spirit of the *Republic*, *Timaeus,* and *Laws*. Although a coherent interpretation of Plato's particular views concerning cosmology cannot be straightforward, since he entertained different opinions in different works,[7] I think this is not the case from his general epistemological and metaphysical standpoint: Plato adopted a specific philosophical research agenda to study astronomy and cosmology.

Due to his Pythagoreanism, the crucial aspect of Plato's cosmology is mathematics which is the essential expression of God's omnibenevolent handiwork. Plato's God, already called in *Republic* 530a as "Demiurge" (Δημιουργός: Craftsman),[8] wanted everything to be good (ἀγαθόν).

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[4] P. Feyerabend, "Realism and Instrumentalism: Comments on the logic of Factual Support," in *The Critical Approach to Science and Philosophy*, edited by M. Bunge (New York, 1964), 280; quoted in A. Musgrave, "The Myth of Astronomical Instrumentalism," in *Beyond Reason*, edited by G. Munévar, Boston Studies in the Philosophy of Science, vol. 132, (Dordrecht: Springer, 1991), 243.

[5] See, e.g., G. E. R. Lloyd, "Saving the Appearances," 202-222; A. Musgrave, "The Myth of Astronomical Instrumentalism," 243-280; cf. Ivor Bulmer-Thomas, "Plato's Astronomy," *The Classical Quarterly* 34, no. 1 (1984): 107-12; A. Gregory, *Plato's Philosophy of Science* (London: Bristol Classical Press, 2001), 93-100. For Plato's use of hypotheses, see H. H. Benson, *Clitophon's Challenge: Dialectic in Plato's Meno, Phaedo, and Republic* (Oxford: Oxford University Press, 2015), 183-207; Y. Kanayama, "The Methodology of the Second Voyage and the Proof of the Soul's Indestructibility in Plato's Phaedo," *Oxford Studies in Ancient Philosophy* 18 (2000): 41-100.

[6] For convenience, I follow Gregory's and Mourelatos', among others, distinctions; see A. Gregory, *Plato's Philosophy of Science*, 58; A. P. D. Mourelatos, "Plato's «Real Astronomy»: Republic 527d-531d," in *Science and the Sciences in Plato*, edited by J. P. Anton (New York: Caravan Books, 1980), 34-36.

[7] See, e.g., the eternal cosmos in *Timaeus* versus the myth of the *Politicus* (269a-c and 273b ff.) and the passage 529d ff. of the *Republic*; the free-floating Earth in *Phaedo* (108e ff.) and *Timaeus* (33d and 34a) in contrast to an Earth turning on a pivot in *Republic* (616b ff.) and *Politicus* (270a); the cosmos as a non-living entity in *Republic* (616c ff.) versus the cosmos as a living entity in *Timaeus* (e.g., 36e). See A. Gregory, *Plato's Philosophy of Science*, 101-123.

[8] A rather humble characterization since manual labor was considered inferior in Plato's time; see, e.g., G. Vlastos,

It is of great interest that, according to John Cooper, the substance or nature of the good-itself is conceived in explicitly mathematical terms: a complex, ordered whole whose orderliness is due to the mathematical relationships among its parts.[9] In *Timaeus* 30a, we are told that God found everything in a state of turmoil, moving in a discordant (πλημμελῶς) and chaotic (ἀτάκτως) manner, so he led it from chaos (ἀταξίας) to order (τάξιν), which he regarded as in all ways better.[10] The divine artisan imposed order on the pre-existing disorder (i.e., formless material) using mathematics and harmony to sustain a well-functioning and unified whole:

> Εἰκὼ δ' ἐπενόει κινητόν τινα αἰῶνος ποιῆσαι, καὶ διακοσμῶν ἅμα οὐρανὸν ποιεῖ μένοντος αἰῶνος ἐν ἑνὶ κατ' ἀριθμὸν ἰοῦσαν αἰώνιον εἰκόνα, τοῦτον ὃν δὴ χρόνον ὠνομάκαμεν.
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> *Timaeus* 37d
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> [The Demiurge] intended to create a movable image of eternity, and at the same time as ordering the heavens, he made from the eternity that resides in unity an eternal image moving according to number, that which we have called time.[11]

In *Laws* 966d-968a, Plato repeats that the mathematical structure of the cosmos has been established by divine intervention. But what about the mathematical content of the above-mentioned unified whole and the method through which we can unravel the divine architectural plan? As Alexander Mourelatos has rightly argued, Plato viewed the heavens as a

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Plato's Universe (Las Vegas: Parmenides Publishing, 2006), 26-27.

[9] J. M. Cooper, "The Psychology of Justice in Plato," *American Philosophical Quarterly* 14, 2 (1977): 155.

[10] *Timaeus* 30a; translation from Plato, *Timaeus and Critias*, trans. R. Waterfield (Oxford: Oxford University Press, 2008), 18.

[11] *Timaeus* 37d; as quoted in A. Gregory, *Plato's Philosophy of Science*, 107.

diagram (see *Republic* 527d-531d). Consequently, a real astronomer might fill the diagram of the heavens with circles and radii. Then assuming some intelligible intermediate connection between comparable periods and radii, a real astronomer may be able to reduce the system of *symmetriai* he seeks to one involving the radii, or some parameters of the radii, or perhaps, some geometrical construction based on the radii.[12] Plato considers the correlation between the planetary periods and their radii to be of the utmost importance and is highly critical to those who have not investigated those matters.[13] Indeed, Plato defined the universe's *symmetria* as a unified whole governed by mathematical relationships.[14] The order of the planets (the structure and form of the world: *forma mundi*) must follow a law-like relationship.[15] There must be *one* natural bond that necessarily links together all the heavenly bodies. Plato clearly stated the concept of oneness in *Laws* 822a and 898a-b too. Moreover, in *Epinomis* 991d-992a, we read:

> Ὁ δὲ τρόπος ὅδε· ἀνάγκη γὰρ τό γε τοσοῦτον φράζειν· πᾶν διάγραμμα ἀριθμοῦ τε σύστημα καὶ ἁρμονίας σύστασιν ἅπασαν τῆς τε τῶν ἄστρων περιφορᾶς τὴν ὁμολογίαν οὖσαν μίαν ἁπάντων ἀναφανῆναι δεῖ τῷ κατὰ τρόπον μανθάνοντι,

[12] A. P. D. Mourelatos, "Plato's «Real Astronomy»: *Republic* 527d-531d," 56.

[13] See *Timaeus* 39c ff.

[14] *Timaeus* 30a, 32b-c, 47a-c, 90b-d; cf. *Laws* 897c, 898a-b, 966d-968a, *Epinomis* 991d-922a, and *Republic* 527d-531d; see also M. Vesel, *Copernicus: Platonist Astronomer-Philosopher, Cosmic Order, the Movement of the Earth, and the Scientific Revolution* (Bern: Peter Lang, 2014), 330-338; M. Burnyeat, "Plato on Why Mathematics is Good for the Soul" in *Mathematics and Necessity: Essays in the History of Philosophy*, edited by T. Smiley (Oxford: Oxford University Press, 2001), 56-81.

[15] See, e.g., the introduction in Plato, *Timaeus, and Critias*, trans. R. Waterfield, xxii-xxviii; cf. A. Gregory, *Plato's Philosophy of Science*, 115-118.

> ἀναφανήσεται δέ, ἄν, ὃ λέγομεν, ὀρθῶς τις εἰς ἓν βλέπων μανθάνῃ· δεσμὸς γὰρ πεφυκὼς πάντων τούτων εἷς ἀναφανήσεται διανοουμένοις.
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> *Epinomis* 991d-992a
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> The way [i.e., the right method] is this –for it is necessary to explain it thus far: every diagram, and system of number, and every combination of harmony, and the agreement of the revolution of the stars must be made manifest as one through all to him who learns properly, and will be made manifest if, as we say, a man learns aright by keeping his gaze on unity; for it will be manifest to us, as we reflect, that *there is one bond naturally uniting all these things*.[16]

Within the field of astronomy, the theme of unity, or oneness, is of paramount metaphysical importance. Consider, for example, a pair of spectacles. Our attention is naturally drawn to the unity of the two lenses as a single pair, rather than to the individual lenses that comprise it. Only when one lens is absent does our focus shift to the realization that there were two. Similarly, numbers are only germane when contemplating the multiplicity of a collection and the combination of its constituent parts. As such, numbers are fundamentally linked to multiplicity from a philosophical standpoint. However, when an assemblage is truly unified, the number of its components fades into irrelevance, as it exists as a seamless, harmonious whole. Thus, unity stands as the essential attribute of ordered wholes.

Consequently, Plato, establishing the philosophical agenda for the foundation of the structure or form of the cosmos (*forma mundi*), envisioned an astronomy that settles the relative positions of the planets under one principle (unity) involving the periods of the

[16] *Epinomis* 991d-992a (emphasis mine); slightly modified translation from Plato, *Charmides, Alcibiades 1 & 2, Hipparchus, The Lovers, Theages, Minos, Epinomis*, trans. W. R. M. Lamb, Loeb Classical Library No. 201 (Cambridge, Massachusetts: Harvard University Press, 1927), 485; see A. Gregory, *Plato's Philosophy of Science*, 88-90.

planets with their radii. The question is whether or not Plato took the next important step in proposing such an astronomical principle. I think that the question is best answered in the affirmative since in *Timaeus* 38e-39a he writes:

> Ἐπειδὴ δὲ οὖν εἰς τὴν ἑαυτῷ πρέπουσαν ἕκαστον ἀφίκετο φορὰν τῶν ὅσα ἔδει συναπεργάζεσθαι χρόνον, δεσμοῖς τε ἐμψύχοις σώματα δεθέντα ζῷα ἐγεννήθη τό τε προσταχθὲν ἔμαθεν, κατὰ δὴ τὴν θατέρου φορὰν πλαγίαν οὖσαν, διὰ τῆς ταὐτοῦ φορᾶς ἰούσης τε καὶ κρατουμένης, τὸ μὲν μείζονα αὐτῶν, τὸ δ' ἐλάττω κύκλον ἰόν, θᾶττον μὲν τὰ τὸν ἐλάττω, τὰ δὲ τὸν μείζω βραδύτερον περιῄειν.
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> *Timaeus* 38e-39a
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> When all the heavenly bodies whose shared task it was to produce time had attained their appropriate movements, and when they had been generated as living beings, their bodies fastened with bonds of soul, and when each of them had understood its instructions, they began to revolve in conformity with the oblique movement of difference,[17] which crosses the movement of identity[18] and is subject to it. *Their circles ranged from larger to smaller, and those with smaller circles revolved faster than those with larger circles which revolve more slowly*.[19]

To my knowledge, this is the first time in the history of astronomy that we found the formulation of the so-called "distance-period relationship"[20] (i.e., the farther the orbit of a

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[17] I.e., the orbit of the celestial bodies across the ecliptic.

[18] I.e., the diurnal rotation of the fixed stars.

[19] *Timaeus* 38e-39a; modified translation from Plato, *Timaeus and Critias*, trans. R. Waterfield, 27; emphasis mine.

[20] Plato seems to insinuate the distance-period relationship in *Republic* 617a-b. Aristotle adopted the same principle in *De Caelo* 291a29-34, where he says: "Περὶ δὲ τῆς τάξεως αὐτῶν, ὃν μὲν τρόπον ἕκαστα κεῖται τῷ τὰ μὲν εἶναι πρότερα τὰ δ' ὕστερα, καὶ πῶς ἔχει πρὸς ἄλληλα τοῖς ἀποστήμασιν, ἐκ τῶν περὶ ἀστρολογίαν θεωρείσθω· λέγεται γὰρ ἱκανῶς. Συμβαίνει δὲ κατὰ λόγον γίγνεσθαι τὰς ἑκάστου κινήσεις τοῖς ἀποστήμασι τῷ τὰς μὲν εἶναι θάττους τὰς δὲ

planet is from the center of its motion, the longer its period of revolution is[21]). Adopting a geocentric cosmology, Plato implemented well enough the distance-period relationship to explain the trajectories of Mars, Jupiter, and Saturn. According to their sidereal periods, Saturn was the outermost planet (completing the ecliptic in 30 years), immediately below Jupiter (in 12 years), followed by Mars (in 2 years). As far as the Moon was concerned, it was easy to see that its sphere was the one closest to Earth because the Moon has a lunar month period. According to an observer on Earth, Mercury, Venus, and the Sun complete the ecliptic in a solar year (on average).[22] Such an observation put forward a severe problem concerning the consistent implementation of the astronomical principle in question. If one follows the distance-period relationship, then, *prima facie*, these bodies should have the same distance from the Earth, which would have been considered quite problematic for both astronomical and physical reasons. Another peculiar aspect was the relationship of Mercury and Venus to the Sun because they can only be in conjunction[23] with and never in opposition[24] to it.

Therefore, Plato, assuming that the orbital periods become increasingly faster as the orbits become smaller, did not know where to place Mercury, Venus, and the Sun. I do not know how much Plato relied on this principle, but it seems that he did not want to abandon it since he

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βραδυτέρας" ("The questions of their order, their relative positions before or behind each other, and their distances from one another, may best be studied in astronomical writings, where they are adequately discussed. One characteristic is that their movements are faster or slower according to their distances"); Aristotle, *On the Heavens*, trans. W. K. C. Guthrie, Loeb Classical Library No. 338 (Cambridge, Massachusetts: Harvard University Press, 1939), II: 10, 291a29-34.

[21] For a critical discussion concerning the distance-period relationship, see B. R. Goldstein, "Copernicus and the Origin of his Heliocentric System," *Journal for the History of Astronomy* 33, 3 (2002): 219-235; esp. 220.

[22] Plato recognized the common period of those celestial bodies in *Timaeus* 38d; cf. *Republic*, 617a-b.

[23] I.e., the Sun and planet have the exact ecliptic longitude.

[24] I.e., the Sun and planet are precisely 180° apart in the sky.

ordered the outer planets and the Moon accordingly. In the end, he possibly believed that Mercury and Venus were between the Sun and Mars (Fig. 1).[25] Francis Cornford rightly argues that Plato gave an independent geocentric orbit for each of the aforementioned heavenly bodies.[26] By attempting to unravel the order of the planets, Plato created a cosmological problem instead, the *forma mundi* problem, since he did not consistently implement the astronomical principle he came up with. Plato made, however, a crucial contribution to its solution, since he paved the way –maybe unintentionally– for an astronomy that a) combines the periods of the planets with their radii with the adoption of the distance-period relationship and b) consistently implements the principle mentioned above.

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[25] See *Republic*, 617a-b: "αὐτῶν δὲ τούτων [δηλαδή τῶν κύκλων] τάχιστα μὲν ἰέναι τὸν ὄγδοον, δευτέρους δὲ καὶ ἅμα ἀλλήλοις τόν τε ἕβδομον καὶ ἕκτον καὶ πέμπτον: [τὸν] τρίτον δὲ φορᾷ ἰέναι, ὡς σφίσι φαίνεσθαι, ἐπανακυκλούμενον τὸν τέταρτον, τέταρτον δὲ τὸν τρίτον καὶ πέμπτον τὸν δεύτερον" (Of these inner circles number eight [i.e., the Moon] turns fastest, followed by numbers seven, six and five, [i.e., the Sun, Mercury and Venus] which all travel at the same speed. Third in the speed of its counterrotation, as it appeared to them, was the fourth whorl [i.e., Mars]. Fourth was number three [i.e., Jupiter], and fifth number two [i.e., Saturn]); modified translation from Plato, *The Republic*, trans. T. Griffith (Cambridge: Cambridge University Press, 2000), 340; cf. *Timaeus* 36d and 38d. See also D. R. Dicks, *Early Greek Astronomy to Aristotle* (New York: Cornell University Press, 1985), 186.

[26] F. M. Cornford, *Plato's Cosmology: The Timaeus of Plato* (Indianapolis: Hackett Publishing Company, Inc, 1937), 105, n. 2.

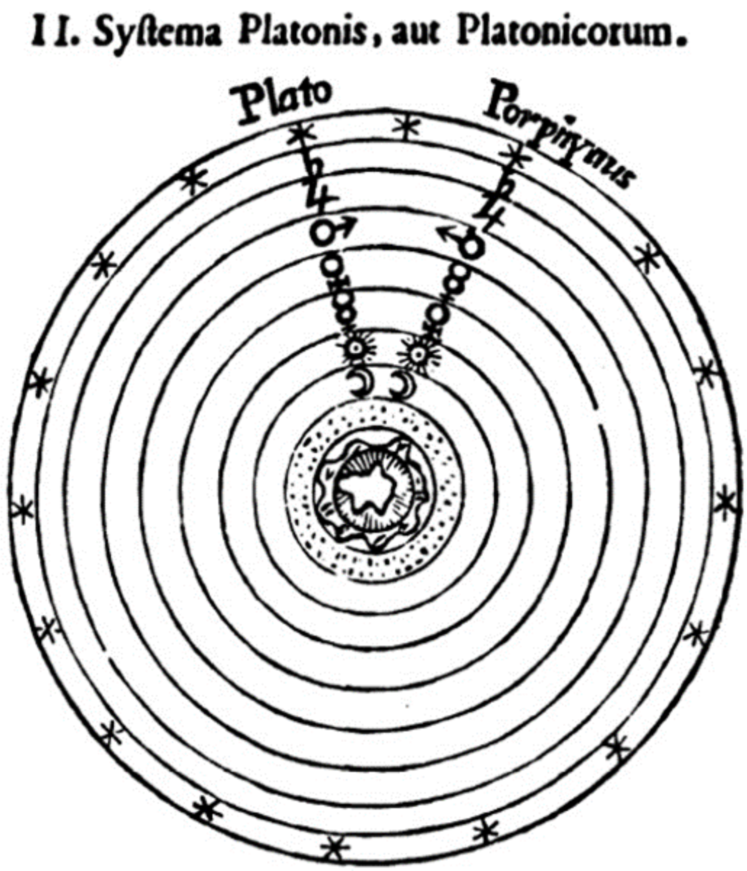

Figure 1. The order of the planets according to Plato and the Neoplatonists (Riccioli, *Almagestum novum*, Bologna, 1651).

With humility due to our epistemic limitations acknowledged by Timaeus at the very beginning of his speech (*Timaeus* 27c), Plato set the stage for the subsequent astronomy. This stage was not an instrumentalist one, as Duhem claimed. On the contrary, Plato praised the divine craftsmanship of the Geometer-God and tried to discover the blueprint of his mind. Plato focused on a mathematical explanation of celestial motions while, at the same time, he did not neglect observation.[27]

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[27] See *Timaeus* 47a-c; see also A. Gregory, *Plato's Philosophy of Science*, 58-64; G. Vlastos, *Plato's Universe*, 50; I. Bulmer-Thomas, "Plato's Astronomy," 107-12.

After this preliminary discussion, we will now turn our attention to Martianus Capella's *De nuptiis Philologiae et Mercurii* (*On the Marriage of Philology and Mercury*; hereafter *De nuptiis*) since, in this work, one can detect the vast influence Plato exerted over Capella's adoption of a geoheliocentric system.

II. The Geoheliocentric System and the Distance–Period Relationship

Martianus Capella –or Martianus Minneus Felix Capella– was a Latin writer in the early Middle Ages and the founder of the seven liberal arts (*artes liberales*), which were established in the Middle Ages as *Trivium* (Grammar, Dialectic/Logic, and Rhetoric) and *Quadrivium* (Geometry, Arithmetic, Astronomy and Harmony/Music).[28] One of his most important contributions to astronomy/cosmology is that he adopted heliocentric orbits for the inner planets (Mercury and Venus).[29] But what was Capella's reasoning behind this decision?

Plato profoundly influenced Capella, as is evident from Capella's references to *Timaeus* in his work *De nuptiis*.[30] The book on astronomy (hereafter *De Astronomia*) is the shortest in *De nuptiis* but perhaps the best-elaborated of the *Quadrivium*. The genuine interest lies in the

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[28] See W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts* (New York & London: Columbia University Press, 1971), 21-27; J. Willis, *Martianus Capella and his early commentators*, Doctoral thesis (London: University of London 1952), 1-15.

[29] Eastwood argues that Calcidius' commentary offers no ground for attributing to Heraclides of Pontus an idea of circumsolar orbits for Mercury and Venus and that this idea came into the Middle Ages only through Martianus Capella; see B. S. Eastwood, "Heraclides and Heliocentrism: Texts, Diagrams, and Interpretations," *Journal for the History of Astronomy* 23, 4 (1992): 233-260. For the adoption of this doctrine during the Middle Ages see W. Stahl, "To a Better Understanding of Martianus Capella," *Speculum* 40, 1 (1965): 102-115; idem, *Roman Science: Origins, Development, and Influence to the Later Middle Ages* (Wisconsin: Madison, 1962); P. Duhem, *Le système du monde: histoire des doctrines cosmologiques de Platon à Copernic*, I: 24-25, 400-410, II: 70-79, III: 45-60.

[30] For Capella's (neo)platonism, see S. Gersh, *Middle Platonism, and Neoplatonism: The Latin Tradition* (Notre Dame, Indiana: University of Notre Dame Press, 1986), 597-646; I. L. E. Ramelli, 'Martianus Capella,' in *The Encyclopedia of Ancient History*, edited by R. S. Bagnall, K. Brodersen, C. B. Champion, A. Erskine and S. R. Huebner (2012).

second part of *De Astronomia* (§§ 850-887), where Capella develops his theory of the seven planets, mainly not because he adopts a geoheliocentric model *per se*, but for his determination to solve the problem of the structure of the world (*forma mundi*). I believe that Copernicus glorifies Capella in *De Revolutionibus* I, 10 because Capella attempted to solve the riddle of the *forma mundi* by invoking the distance-period relationship.

As we saw in the previous section, the exact positions of the inner planets and the Sun were an embarrassment. Capella inherited the *forma mundi* problem, which had already been perpetuated throughout the ages. Indeed, as Capella mentions in § 858 of *De Astronomia,* some authorities place Mercury's and Venus' orbits above the Moon's orbit[31] while others place the Sun's orbit after the Moon's.[32] Subsequently, there was no consensus among astronomers/natural philosophers regarding the exact positions of the aforementioned celestial bodies. However, the distance-period relationship was faithfully applied regarding the positions of the outer planets (Mars, Jupiter, and Saturn) and the Moon. Capella, while putting Mars, Jupiter, and Saturn in motion around the Earth, exclaims:

> Nam Venus Mercuriusque licet ortus occasusque cotidianos ostendant, tamen eorum circuli terras omnino non ambiunt, sed circa Solem laxiore ambitu circulantur. denique circulorum suorum centron in Sole constituunt.
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> *De nuptiis Philologiae et Mercurii* VIII, § 857

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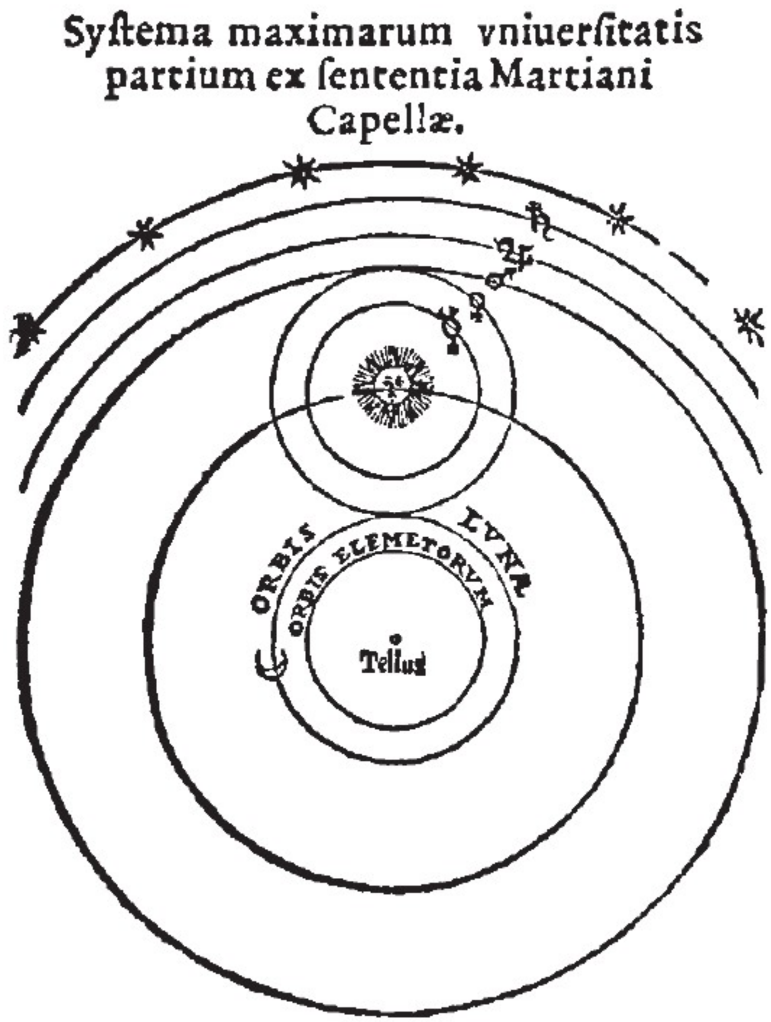
[31] Claudius Ptolemy made, for example, that choice; see C. Ptolemaei, *Claudii Ptolemaei Opera Quae Exstant Omnia, Syntaxis Mathematica*, edited by J. L. Heiberg (Leipzig: vols. 1.1 and 1.2, 1898-1903), Θ': α'; cf. B. R. Goldstein, "The Arabic Version of Ptolemy's Planetary Hypotheses," *Transactions of the American Philosophical Society* 57, 4 (1967).

[32] M. Capella, *De nuptiis Philologiae et Mercurii*, edited by James Willis (Leipzig: B.G. Teubner Verlagsgesellschaft, 1983), VIII. § 858; see W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts*, 333.

> Now Venus and Mercury, although they have daily risings and settings, do not travel about the Earth at all; rather, they encircle the Sun in wider revolutions. The center of their orbits is set in the Sun.[33]

The above passage constitutes Capella's undisputed belief in heliocentric orbits for the inner planets. Therefore, by placing the Earth in the center, the order of the planets as accepted by Capella is as follows: Moon, Sun along with Mercury and Venus as a single system, Mars, Jupiter, and Saturn (Fig. 2).



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[33] W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts*, 333.

Figure 2. Martianus Capella's geoheliocentric system (Valentin Naboth, *Primarum de coelo et terra institutionum libri tres*, Venice, 1573).

Capella's fundamental motive in formulating this model was the consistent implementation of the distance-period relationship, which is part of the broader spectrum of his Platonic and Neoplatonic influences. Capella repeats the distance-period relationship three times in *De Astronomia*. In paragraph § 852, we read:

> Nam quantum eos retulit diei noctisque rotatio, tantum nituntur diversis compensare temporibus, id est aut mense ut Luna, aut anno ut Sol, aut triginta annis ut Saturnus, et ceteri temporibus attributis pro spatiorum, quae circumeunt, latitudine aut brevitate.
>
> *De nuptiis Philologiae et Mercurii* VIII, § 852
>
> For in varying amounts of time, the planets strive to make up the distance that they are carried backward by a single diurnal rotation: *the Moon in a month, the Sun in a year, Saturn in thirty years, and the others in periods proportional to the amount of space that they traverse.*[34]

In paragraph § 861, Capella, relating the time intervals of completion of the ecliptic to the size of the planetary orbits, poses the following rhetorical question:

> Sed quis dubitet solarem circulum duodecies, quam Lunae est, esse maiorem, cum, quod ilia mense, ille duodecim currat? Martis vero circulus vicies quater potior invenitur, Iovis centies et quadragies, Saturni trecenties tricies et sexies.

[34] Slightly modified translation from ibid, 331; emphasis mine.

De nuptiis Philologiae et Mercurii VIII, § 861

> Will anyone doubt that the Sun's orbit is twelve times as great as the Moon's if the latter completes its orbit in a month and the former in a year? The orbit of Mars is then found to be twenty-four times as great, Jupiter's one hundred and forty-four times as great, and Saturn's three hundred and thirty-six times as great.[35]

Capella restates the distance-period relationship in § 864:

> Quae [Luna] quidem XIII orbis sui partes die nocteque transcurrit, cum pro latitudine circulorum, quos obeunt, eodem interstitio Mars dimidiam, Iuppiter duodecimam unius partis, Saturnus vicesimam octavam unius portionis excurrat.

De nuptiis Philologiae et Mercurii VIII, § 864

> In one day and night, the Moon courses through thirteen degrees of its orbit, *while the other planets, in keeping with the great extent of their orbits*, during the same interval course through the following portions of their orbits: Mars, one-half of a degree; Jupiter, one-twelfth of a degree; and Saturn, one twenty-eight of a degree.[36]

Capella, driven by the periods of the planets, placed the Moon as the nearest celestial body to Earth. He observes that Mercury and Venus complete the ecliptic within about a year and

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[35] Ibid, 335.

[36] Ibid, 336; emphasis mine.

the Sun within a year.[37] Thus, Capella places these three heavenly bodies in a common system centered on the Sun. He did not introduce geocentric orbits for Mercury and Venus, nor has he doubted the position of the Sun, like Ptolemy.[38] Capella applies the astronomical principle formulated by Plato, treating the Sun, Mercury, and Venus, as a common system, due to their periods of revolution.[39] Outside the Sun-Mercury-Venus system, staying true to the distance-period relationship, he places Mars, which completes its orbit in two years, followed by Jupiter in twelve years, followed by Saturn in thirty years. Nevertheless, why does Capella's system constitute an improvement over Plato's or Ptolemy's?

Capella's hybrid system consistently implements the distance-period relationship, by grouping those celestial bodies that complete the ecliptic in one year. Capella calculated the lunar orbit around the Earth as 100 times greater than the Earth's circumference.[40] According to Capella, the distances of the rest of the celestial bodies are multiples of the lunar orbit in conformity with their periods. Since

$$C = 2\pi r$$

where C is the circumference of a circle and r its radius, we can calculate the radius of a given planet's orbit as follows:

$$r = \frac{C}{2\pi}$$

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[37] See M. Capella, *De nuptiis Philologiae et Mercurii*, VIII. § 879 and § 882.

[38] See B. R. Goldstein, "The Arabic Version of Ptolemy's Planetary Hypotheses," 6.

[39] Remarkably, Bruce Eastwood found an 11th-century manuscript of the *Timaeus* in which Capellan diagrams (i.e., circumsolar orbits for Mercury and Venus) are inserted into 39a, where Plato formulated the distance-period relationship; see B. Eastwood, "Plato and Circumsolar Planetary Motion in the Middle Ages," *Archives d'Histoire Doctrinale et Littéraire du Moyen Âge* 60 (1993): 7-26.

[40] M. Capella, *De nuptiis Philologiae et Mercurii*, VIII. § 858; Capella adopted the value of 406,010 stadia for the Earth's circumference, although, in § 596, he gave the correct value of Eratosthenes' estimation (252,000 stadia); cf. W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts*, 223, 333.

Assuming that the lunar orbit equals 1, then the Earth-Moon axis equals 0.16 ($r = \frac{1}{2\pi}$).[41] According to Capella's reasoning, the Sun-Mercury-Venus system lies 1.91 times farther from Earth ($r = \frac{12}{2\pi}$) since these celestial bodies complete the ecliptic within a year (12 months); similarly, Mars' orbit lies 3.82 times farther from Earth ($r = \frac{24}{2\pi}$) with 24 months period or 2 years; Jupiter 22.9 ($r = \frac{144}{2\pi}$) with 144 months period, and Saturn 53.47 ($r = \frac{336}{2\pi}$) with 336 months period.[42] Consequently, if we place those values into a logarithmic scale (Chart 1), we get a straight line because the distance from Earth (in log_{10}(stadia)) grows linearly per unit of time (in log_{10}(months)). Therefore, as one can notice from the chart below, Capella adopted a geoheliocentric model in order to provide a system consistent with the distance-period relationship, and assumed the positions of the planets following an imperfect form of Kepler's harmonic law, i.e.:

$$T \propto a$$

where T is the orbital period and a is the distance from Earth.

[41] The value adopted by Capella for the lunar orbit was either 406,010 stadia multiplied by 100 or 252,000 stadia multiplied by 100. I use the first one since Capella mentioned that value in *De Astronomia*; at any rate, this discrepancy does not affect my argument.

[42] See M. Capella, *De Nuptiis Philologiae et Mercurii*, VIII, § 861 and §§ 879-886.

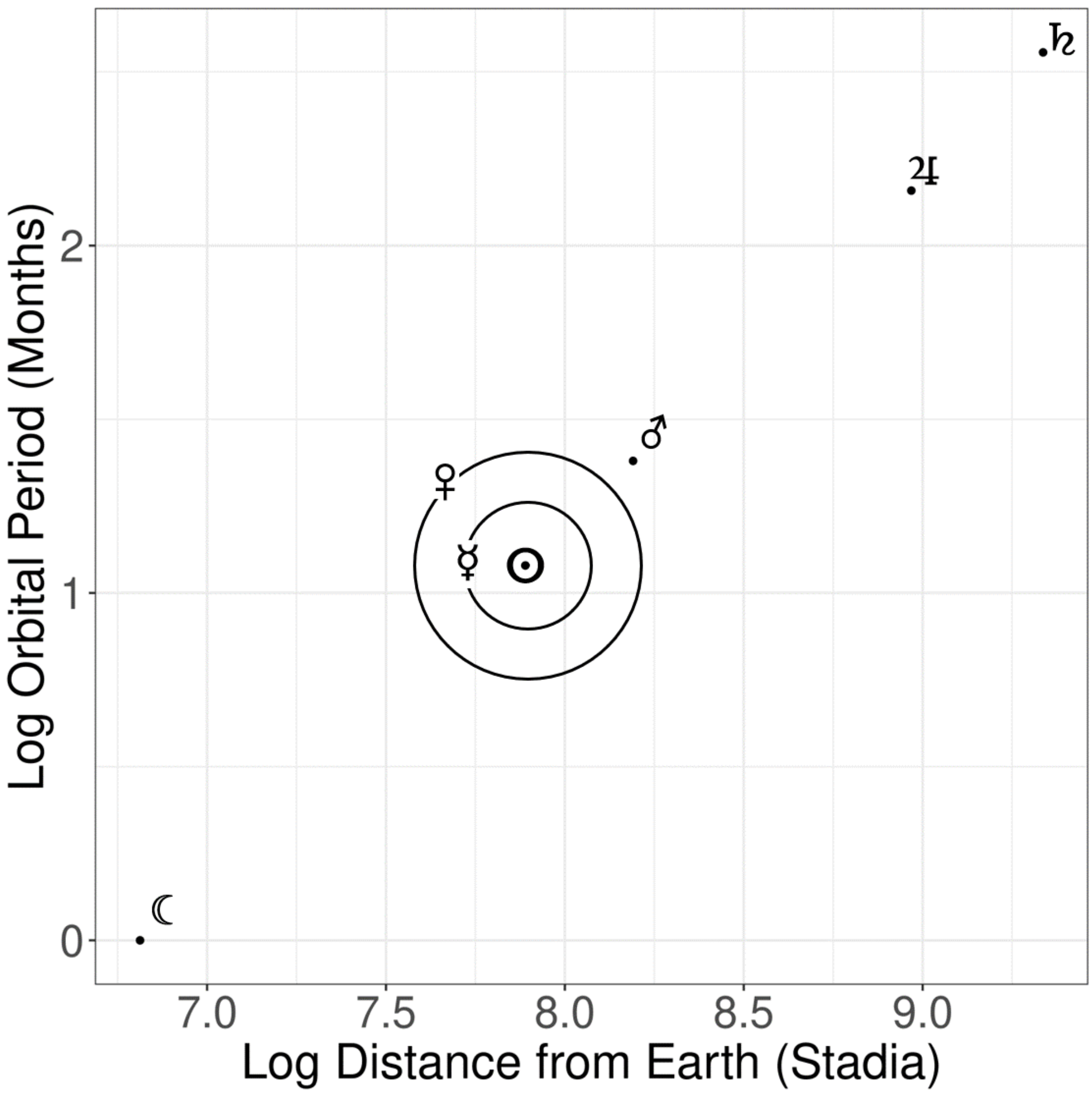

Chart 1. Log_{10} orbital period over Log_{10} distance from Earth according to Martianus Capella. The heliocentric orbits of Mercury and Venus are added for illustrative purposes and are not in scale.

I intentionally ignored the diurnal rotation of the fixed stars, whose sphere lies at the very edge of the cosmos. Capella seems puzzled and even entertains the doctrine of the Peripatetics "that the planets do not move counter to the motion of the celestial sphere but are outdistanced by the speed of the latter and cannot keep up with it" since "the universe could not endure a contrary motion of its parts."[43] Such was Capella's determination to adopt a single natural bond for the order of the planets that he was ready to accept an inverse form of the distance-period relationship. Capella argues that both options are not contrary to his model because "the motion of those bodies (i.e., the planets) is regulated by relationships between themselves."[44] At any rate, the motion of the fixed stars is irrelevant to the order of the planets.

There is a broad consensus among modern scholars that Copernicus' heliostatic cosmology was the first consistent implementation of the distance-period relationship and that this principle could not entirely work in geocentric models. In concluding his influential paper on the origins of Copernicus' system, Bernard Goldstein wrote that "the order of the planetary periods around the Sun conforms to this relationship, but there is no way for it to work in a geocentric world."[45] In a similar spirit, Matjaž Vesel argued that "this principle does not work

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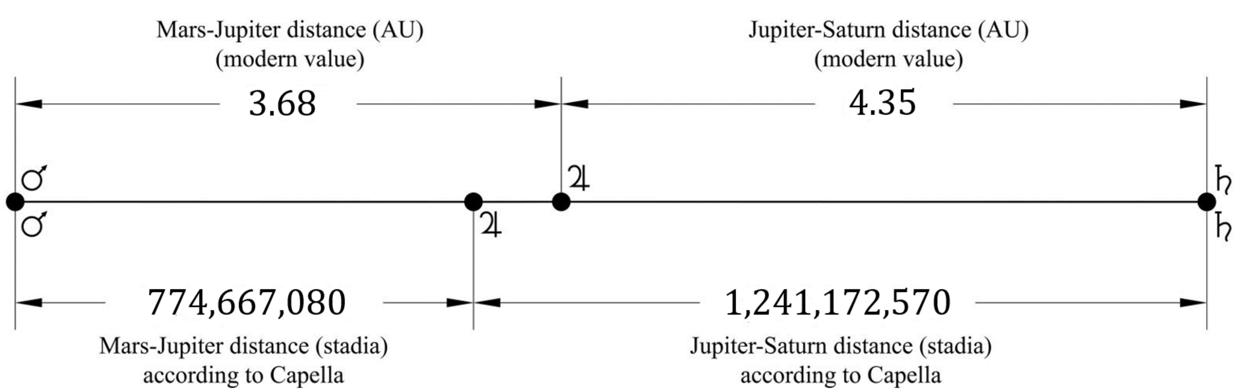
[43] M. Capella, *De Nuptiis Philologiae et Mercurii*, VIII, § 853; W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts*, 332.

[44] Ibid. Interestingly enough, by comparing the Capellan values for the distances of the outer planets with the modern ones, we can see that Capella's adoption of the distance-period relationship led him to a fair approximation of the relative positions of Mars, Jupiter, and Saturn; see the figure below:



[45] B. R. Goldstein, "Copernicus and the Origin of his Heliocentric System," 231; cf. A. Goddu, "Reflections on the Origin of Copernicus's Cosmology," *Journal for the History of Astronomy*, 37, 1 (2006): 37-53.

fully in geocentric arrangement but reveals its full potential in heliocentric order."[46] Their conclusion, however, concerning geocentric arrangements does not do justice to Capella's system, which, as we saw, consistently implements a form of the distance-period relationship for the order of the planets. The Copernican model adheres to another form of the distance-period relationship, which echoes the later-discovered third law of planetary motion (i.e., $T^2 \propto a^3$) –even though Copernicus was not aware of this law at the time (in fact, neither Capella nor Copernicus knew that the orbital speed of the planets reduces with distance; both held constant speeds and placed the planets according to their periods of revolution). In his famous "U" notes, Copernicus used trigonometry to calculate the relative distances of the planets during maximum elongation and quadrature for the inner and outer planets, respectively.[47]

In agreement with the principle in question as it may be, the Capellan system can be viewed as "odd" because it adopts two centers: one major center (the Earth) and a minor one (the Sun). Capella grouped those celestial bodies that did not conform with the distance-period relationship because he firmly believed this principle was the key to unraveling the actual cosmic order. But bear in mind that Copernicus also grouped the Moon with the Earth for the same reason: the Moon, in the grand scale of his planetary system, did not come in accord with the distance-period relationship.[48] Yet, neither Copernicus nor Capella had any proof that

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[46] M. Vesel, *Copernicus: Platonist Astronomer-Philosopher, Cosmic Order, the Movement of the Earth, and the Scientific Revolution*, 231.

[47] See A. Athanasakis, "Copernicus, Nicolaus," in *Encyclopedia of Renaissance Philosophy*, edited by M. Sgarbi (Cham: Springer, 2021).

[48] That the Moon was the closest celestial body to Earth was known due to the occultations and parallax, but Copernicus had nothing to say about why the Moon revolved around the Earth. My argument focuses on the implementation of the distance-period relationship; see Copernicus, *De Revolutionibus* I, 10; Vesel is correct in saying that Copernicus had nothing much to say about the Earth-Moon grouping; see M. Vesel, *Copernicus: Platonist*

dictated which celestial bodies should be grouped together; rather, they did so in order to support their prior views. Therefore, what is the reason behind assuming that Copernicus' system follows the distance-period relationship and Capella's system does not when both group the celestial bodies to provide a unified cosmology? In my opinion, modern thinking is very much accustomed to the fact that the Moon is not a planet but a natural satellite. But in the eyes of Capella and Copernicus, this was far from the case. The Moon was a full-fledged planet subjected to the same cosmic law, namely the distance-period relationship.

Capella physically justified his system, possibly following Pliny's *Naturalis Historia* II, 69.[49] At the end of *De Astronomia* (§ 887), he espouses the idea that the powerful effect of the Sun's light is responsible for the anomalies in the orbits of all the planets and their stations, retrogradations, and progressions; the light strikes the planets, causing them to rise aloft or to be depressed, or to deviate in latitude or to retrograde. Bruce Eastwood correctly argues that Capella explains the limited elongation of the inner planets as an indication of their distance from the Sun. Due to their proximity to the Sun, Mercury and Venus were "caught" by the solar force in heliocentric orbits, and as they move away, the planets regain their geocentric orbits;[50] so, Mars, for example, is the first among the outer planets to move around the Earth, although due to its proximity to the Sun, it has a longer retrograde arc than Jupiter and Saturn.

Astronomer-Philosopher, Cosmic Order, the Movement of the Earth, and the Scientific Revolution, 229.

[49] See W. Stahl, R. Johnson, E. Burge, *Martianus Capella and the Seven Liberal Arts*, 343-344, nn. 101-107.

[50] B. Eastwood, *Ordering the Heavens: Roman Astronomy and Cosmology in the Carolingian Renaissance*, History of Science and Medicine Library, 4. Medieval and Early Modern Science, 8 (Leiden: Brill, 2007), 291-292.

Conclusion

Like Copernicus many centuries later, Capella put his faith in the distance-period relationship and considered it the key to solving the *forma mundi* problem. Both astronomers had, among others, Plato as their mentor and tried to provide a unified astronomical system. Capella and Copernicus were equally legitimate for their groupings in order to universalize the distance-period relationship for the order of the planets; but for this very reason, it is equally illegitimate to discriminate against one of them for not applying the aforementioned Platonic principle while elevating the other. Although Copernicus' groundbreaking work in the field of astronomy paved the way for significant advancements in the study of celestial mechanics, it is crucial not to overlook the contributions of Martianus Capella. Capella's geoheliocentric system applied a basic form of the distance-period relationship and provided an approximation of the relative positions of the outer planets. This innovative model represents a noteworthy achievement in the field of astronomy, as it marked a significant departure from traditional geocentric cosmologies and anticipated key features of the modern heliocentric system.

Acknowledgments

I express my gratitude to Harvard University and the Center for Hellenic Studies in Greece, through which the current project was pursued. The research work was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the 3rd call for H.F.R.I. Ph.D. Fellowships (Fellowship Number: 5160). I gratefully acknowledge the constructive comments provided by Spyridon Rangos (Professor of Ancient Greek Literature and Philosophy at the University of Patras), Stefanos Papadantonakis (Ph.D. candidate in Biology at the University of Crete), and Konstantinos Karampakakis (Architect Engineer, Technical University of Crete). Finally, I owe a deep debt of gratitude to my supervisor, Georgios Steiris (Professor of Medieval and Renaissance Philosophy at the National and Kapodistrian University of Athens), for his kind support and encouragement.