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Giordano Bruno on Copernican harmony, circular uniformity, and spiral motions

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Despite the considerable wealth of literature on Giordano Bruno (1548-1600), his reading of *De revolutionibus* and controversial adoption of the heliocentric theory as a physical truth, no previous study has specifically investigated Bruno's reception of the principles that were at the root of Copernicus' turn.[1] In the wake of the recent scholarly emphasis on circular uniformity and the period-distance relation as motivations for Copernicus' turn to the heliocentric order, the questions raised by this paper concern first of all Bruno's knowledge of these principles, the ways he understood them and their relevance for his cosmological theory.

Copernicus regarded having established the order of the planets on safe grounds as his main achievement. He thought that heliocentrism, while sacrificing the earth's centrality and immobility, the cosmological primacy of the diurnal motion and the Aristotelian theory of natural places, reconciled physics and astronomy, since the sun's central position allowed for a planetary arrangement that was coherent with the principle that celestial motions are circular, or a

[1] Among the many studies that address the relation between Bruno and Copernicus, interested readers may find useful Alexandre KOYRÉ, *From the Closed World to the Infinite Universe*, Baltimore, Johns Hopkins Press, 1957; Paul-Henri MICHEL, *The Cosmology of Giordano Bruno*, London, Methuen, 1973 (1st ed. in French, 1962); Alfonso INGEGNO, *Cosmologia e filosofia nel pensiero di Giordano Bruno*, Florence, La Nuova Italia, 1978; Ernan MCMULLIN, "Bruno and Copernicus", *Isis*, 78, 1978, pp. 55-74; Hilary GATTI, *Giordano Bruno and Renaissance Science*, Ithaca, Cornell University Press, 1999. A historiographical survey up until the 1980s is in Rosmary MASPERO, "Scienza e copernicanesimo in Bruno: principali orientamenti della critica dal 1950 ad oggi", *Rivista di storia della filosofia*, 44, 1989, pp. 141-162. Among Miguel Angel Granada's many groundbreaking studies, see "L'interpretazione bruniana di Copernico e la *Narratio prima* di Rheticus", *Rinascimento*, 30, 1990, pp. 343-365; ID., "L'infinité de l'univers et la conception du système solaire chez Giordano Bruno", *Revue des Sciences Philosophiques et Théologiques*, 82, 1998, pp. 243-275; ID., "Aristotle, Copernicus, Bruno: Centrality, the Principle of Movement and the Extension of the Universe", *Studies in History and Philosophy of Science*, 35, 2004, pp. 91-114; and ID., "L'héliocentrisme de Giordano Bruno entre 1584 et 1591: la disposition des planètes inférieures et les mouvements de la Terre", *Bruniana & Campanelliana*, 16, 2010, pp. 31-50. On the issue of Bruno's knowledge and understanding of the relevance of celestial harmony, circular uniformity and the period-distance relation, see also the considerations in Robert WESTMAN, *The Copernican Question: Prognostication, Skepticism, and Celestial Order*, Berkeley, University of California Press, 2011, p. 301, who notes that Bruno "barely hinted at the arguments from harmony and order so heavily emphasized by Copernicus, Rheticus, Rothmann". As a term of comparison, cf. the entry "Armonia" by Pasquale Terracciano in the recent *Giordano Bruno: Parole concetti immagini*, ed. by Michele Ciliberto, 3 vols., Pisa, Edizioni della Normale, 2014, vol. I, pp. 169-171, which focuses on the reception of Neoplatonic philosophical themes, but entirely overlooks Bruno's references to the Copernican harmony.

combination of circular motions, and all have equal linear speed. The circular uniformity of the planetary movements, whose origin was attributed to Pythagoras by Geminus, was formulated by Aristotle's *On the heavens*, and accepted in principle by Ptolemy. The principle that planets move by uniform and circular motions bore the consequence that longer periods of revolutions corresponded to greater circumferences of their orbs/orbits, and therefore greater distances from the centre of motion. Since all planets revolve around the same centre, their periods of revolution allow us to establish their relative order and to estimate their mean distances.[2] In Aristotle, the relation between periods and distances is a derivation of the principle of circular uniformity, which in turn depends on a series of assumptions concerning the sphericity of the universe, the perfection of the spherical shape, the physical unity and simplicity of the celestial regions, its bodies (i.e., composed of ether only) and their motions.[3] Copernicus shares at least some of these points and, crucially, those on sphericity. Since planets are ordered according to their period of revolution, the slowest being the most distant from the sun, he can claim that his astronomical system satisfies the period-distance relation, and therefore corresponds to the ideas of harmony ("harmonia") and commensurability ("sum·metria"), where these are intended in general philosophical terms as the agreement of all parts as a whole.[4]

While it is known that early readers of *De revolutionibus* from the mathematical profession, such as Erasmus Reinhold, Tycho Brahe and Johannes Kepler (to mention the most prominent) clearly comprehended the implications of Copernicus' adherence to circular uniformity and of the significance of the period-distance relation for his attempt at an astronomical reform, natural philosophy seems to have waited until the first decades of the seventeenth century before assimilating the full extent of the heliocentric novelty. Giordano Bruno's philosophy has always been a controversial point in this respect. Sometimes hailed as the frontrunner of a philosophical revolution that will come to fruition in the following century, in other quarters his relevance has raised questions from his uncertain grasp of mathematics, adherence to animistic explanations of natural phenomena, and unconventional style of thinking. This research hopes to provide further

[2] Cf. ARISTOTLE, *On the Heavens*, II, 10, 291a29-291b11; and Ptolemy, *Almagest*, I, 3 and IX, 2 (quoted below ref. 34). My account follows Bernard GOLDSTEIN, "Copernicus and the Origins of His Heliocentric System", *Journal for the History of Astronomy*, 33, 2002, pp. 219–35, and André GODDU, "Reflections on the Origins of Copernicus' Cosmology", *Journal for the History of Astronomy*, 37, 2006, 1, pp. 37-53: 40: "The key principle is that the periods of the planets are longer as their orbs are farther from the centre of motion". Copernicus' axiomatic adoption of circular uniform motion and its relevance for the origin of heliocentrism was previously discussed in Curtis WILSON, "Rheticus, Ravetz, and the 'Necessity' of Copernicus' Innovation", in *The Copernican Achievement*, ed. R. S. Westman, Berkeley, Los Angeles, and London, University of California, 1975, pp. 17-39.

[3] Cf. Pierre PELLEGRIN, "The Argument for the Sphericity of the Universe in Aristotle's *De caelo*: Astronomy and Physics", in *New Perspectives on Aristotle's* De caelo, ed. by A. C. Bowen and C. Wildberg, Leiden and Boston, Brill, 2009, pp. 163-185; and GRANADA, "Aristotle, Copernicus, Bruno" (ref. 1), pp. 93-96.

[4] Cf. the passages from *De revolutionibus* quoted below (ref. 34). On the concept of "symmetria" as "commensurability", and of its import in the history of early Copernicanism, see the extended discussion by Édouard MEHL in this volume.

considerations on the early reception of heliocentrism among natural philosophers in the wake of recent scholarly advances on Copernicus and by reconsidering well known as well as less-explored texts by Bruno.

1. ORDER, PROPORTION AND SYMMETRY IN THE *ASH WEDNESDAY SUPPER*

Giordano Bruno's first writing in support of the Copernican doctrine is the *Cena de le ceneri* (*The Ash Wednesday Supper*), a dialogue in the Italian vernacular published in London in 1584.[5] This is the first instalment of a sextet of works printed between 1584 and 1585, and intended to present Bruno's philosophical ideas to the Italianate audiences of Elizabethan society. The *Cena* and the two following dialogues, *De la causa, principio et uno* (*Cause*, *Principle and Unity*) and *De l'infinito, universo e mondi* (*On the Infinite Universe and Worlds*), form a trilogy dedicated to cosmological and metaphysical arguments. Although there is continuity in genre and subject matter with the previous works, the second trilogy - comprising the *Spaccio de la besta trionfante* (*The Expulsion of the Triumphant Beast*), also published in 1584, the *Cabala del cavallo Pegaseo* (*The Kabbalah of the Horse Pegasus*), and *De gli eroici furori* (*On the Heroic Frenzies*) from 1585 - focuses on political and religious reform, the theory of knowledge and the perfection of the human being.

Copernicus' heliocentric theory holds a central position in the narrative of the *Cena*. Its starting point is an invitation received by Bruno to discuss "his Copernicus and other paradoxes in his new philosophy"[6] at a dinner in the presence of Elizabethan courtiers, Oxford professors and other intellectuals. The events leading up to the dinner and its aftermath are narrated in the five-part dialogue by the philosopher's spokesperson, Teofilo, and three other characters, Smitho, Prudenzio and Frulla. In the first of the five *dialoghi* which form the *Cena*, Teofilo recounts the origin of the supper, held at the initiative of Sir Fulke Greville, who invites Bruno, always referred to as "il Nolano",[7] to attend the supper in his private quarters at Whitehall. After an adventurous journey

[5] Bruno had almost certainly read Copernicus' *De revolutionibus* years before, possibly when he was still in Italy, but this early reading had very little consequence, if any, in previous works. Only the *De umbris idearum*, published in Paris two years before the *Cena*, alludes, very briefly, to the centrality of the Sun and the earth's mobility. Cf. Giordano BRUNO, *De umbris idearum*, in ID., *Opere mnemotecniche*, ed. by Michele Ciliberto, Marco Matteoli, Rita Sturlese, Nicoletta Tirinnanzi, Milano, Adelphi, 2004, pp. 18-20; and GRANADA, "L'interpretazione bruniana di Copernico" (ref. 1), pp. 347-348.

[6] Translated in Giordano BRUNO, *La Cena de le ceneri/ The Ash Wednesday Supper*, edited and translated by Edward A. Gosselin and Lawrence S. Lerner, Hamden (CT), Archon Books, 1977, p. 85. The Italian text is in Giordano BRUNO, *La cena de le ceneri,* in ID., *Opere italiane*, testi critici di G. Aquilecchia, coordinamento generale N. Ordine, 2 vols, Torino, Utet, 2002, I, p. 447 (herafter abbreviated BOI, followed by volume and page numbers).

[7] On the "Nolano" as a Bruno's spokeperson and the rhetoric of the dialogues, cf. above all Eugenio CANONE and Leen SPRUIT, "Rhetoric and Philosophical Discourse in Giordano Bruno's Italian Dialogues", *Poetics Today,* 28, 3,

through London to reach the location of the supper, narrated in the second dialogue, the third and fourth dialogues recount the heated dispute between the philosopher and two Oxford dons named Nundinio and Torquato. The debate is interrupted at the end of the fourth dialogue when the two professors hurriedly leave the scene. In the fifth day of the dialogue, Teofilo expounds with little or no interruption Nolano's cosmology and natural philosophy, starting with two radical consequences of the earth's motions, that is, the decentralization of the physical universe and the uniformity of its substance. The final pages of the *Cena* deal with the physics of the celestial bodies, animism as the cause of their motions, the meaning of gravity and levity, generation and corruption (reframed as eternal vicissitude) and the earth's four motions.[8]

Throughout the *Cena* Bruno wavers between celebrating Copernicus' genius and commenting condescendingly on his limits, between adopting heliocentrism and departing from it. At the beginning of the dialogue, Bruno claims that Copernicus was a mathematical mind rather than a philosophical one, and that he took the original idea of heliocentrism from the ancient Pythagoreans. In turn, Teofilo claims that Nolano holds heliocentrism on the basis of his own principles and observations: "he saw through neither the eyes of Copernicus nor those of Ptolemy".[9] The tension between the defence of Copernicus against the attacks of his opponents and the affirmation of Bruno's own philosophical tenets pervades the dialogue. The initial celebration of the astronomer's genius ("he was a man of deep, developed, diligent and mature genius; a man not second to any astronomer before him") is followed, first, by the exposure of his limitations ("Yet, Copernicus did not go much further [away from the common and vulgar philosophy] because being more a student of mathematics than nature, he could not plumb and probe into matters to the extent that he could completely uproot unsuitable and empty principles") and then by the glorification of the Nolan philosophy, entrusted with a salvific mission to restore truth against the errors of the Aristotelians.[10] Later on, in the third dialogue Bruno defends the interpretation of heliocentrism as a physical reality against the Oxford professors' attempt to read it as a mere mathematical hypothesis

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2007, pp. 363-391: 376ff. Other recent assessments are by Henning S. HUFNAGEL, *Ein Stück von jeder Wissenschaft. Gattunghybridisierung, Argumentation und Erkenntnis in Giordano Brunos italienischen Dialogen*, Stuttgart, Franz Steiner Verlag, 2009, pp. 69-102; Steffen SCHNEIDER, "Writing after Copernicus: Epistemology and Poetics in Giordano Bruno's *Ash Wednesday Supper*", and Sergius KODERA, "Timid Mathematicians vs. Daring Explorers of the Infinite Cosmos: Giordano Bruno, Literary Self-Fashioning and *De revolutionibus orbium coelestium*", in Wolfgang Neuber, Thomas Rahn and Claus Zittel, eds, *The making of Copernicus*. *Early Modern Transformations of a Scientist and his Science*, Leiden, Brill, 2015, pp. 131-154, and 229-250, respectively.

[8] A wide-ranging account of Bruno's cosmology in the *Cena* can be found in Miguel Angel GRANADA, "Introducción", in Giordano BRUNO, *La cena de las Cenizas*, traducción, introducción y notas de Miguel Á. Granada, Madrid, Editorial Tecnos, 2015, which also accounts for my reading of Bruno's interpretation of the Copernican planetary order, and Omodeo's study of Bruno's reception of Copernicus' motions of the earth: Pietro Daniel OMODEO, "Giordano Bruno and Nicolaus Copernicus: The Motions of the Earth and the *Ash Wednesday Supper*", *Nuncius*, 24, 2009, pp. 35-59.

[9] BRUNO, *The Ash Wednesday Supper* (ref. 6), p. 85 (BOI I, 447).

[10] Cf. the famous self-celebration in *ibidem*, pp. 86ff. (BOI I, 450-456).

in the wake of Osiander's *Ad lectorem*. Translating into Italian long passages of Osiander's address, Bruno, who does not know the name of its author, infers that the letter is spurious by comparing its content with Copernicus' dedication to the Pope, which supports the natural-philosophical value of heliocentrism ("he [performs] the task not only of a mathematician who supposes, but also of a physician who demonstrates, the movement of the earth").[11] Soon after the successful defence of Copernicus from the attacks of Aristotle's supporters, Bruno proclaims his philosophical autonomy from the astronomer. His belief in heliocentrism is based on solid philosophical arguments and not on the authority of Copernicus or of anybody else.[12]

These episodes prefigure the final dispute with the Aristotelian pedants in the fourth dialogue, where the Copernican planetary order is compared side-by-side with geocentrism. After having discussed the accommodation of science and Scripture, the Aristotelian Torquato draws a diagram representing the geocentric cosmos on the one side, and the Copernican on the other. An illustration in the *Cena* seems to reproduce the diagram drawn by Torquato (fig. 1), but there are several inconsistencies between text and illustration. In the text Torquato is said to use short captions to flag differences between the heliocentric and the geocentric models. Near the last sphere, he wrote "sphera inmobilis fixarum" on the heliocentric side and "octava sphera mobilis" on the geocentric side, where the dichotomy between "mobile" and "immobile" implies the attribution of the diurnal motion to the Earth and the immobility of the last final sphere that follows from it. Crucially, the text of the *Cena* adds that Torquato wrote "Sol" and "Terra" at the centre of each side of the diagram, and on the Copernican side, near the third circle, he drew an epicycle whose centre is occupied by the Earth's globe and the word "Terra".[13] None of these words appear in the printed illustration. In addition, a large dot representing the earth's globe appears on the circumference of the epicycle opposite the moon's astrological sign. In his reply, Bruno challenges Torquato on the position of earth, claiming that its motion takes place on the same epicycle as the moon, and that this is also Copernicus' opinion. A copy of *De revolutionibus* is brought in, and the Aristotelians are shown a passage from Book I, chapter 10, where it says (in Bruno's Italian translation) "la terra e la luna essere contenute come da medesmo epiciclo".[14] After consultation among themselves, the

[11] *Ibidem*, p. 139. Cf. Michel Pierre LERNER, "Note sur Giordano Bruno traducteur de l'*Ad lectorem* du *De revolutionibus*", *Bruniana & Campanelliana*, 18, 2012, pp. 529-536.

[12] *Ibidem*. On the sources of this passage, see Dilwyn KNOX, "Ficino, Copernicus and Bruno on the Motion of the Earth", *Bruniana & Campanelliana*, 5, 1999, 2, pp. 333-366: 339, 352ff.

[13] I have dealt more extensively with Bruno's diagram in Dario TESSICINI, *I dintorni dell'infinito: Giordano Bruno e l'astronomia alla fine del Cinquecento*, Pisa-Rome, F. Serra editore, 2007, cap. 1. See also WESTMAN, *The Copernican Question* (ref. 1), pp. 301-305; GATTI, *Giordano Bruno* (ref. 1), pp. 60-71; and EADEM, "Giordano Bruno's Copernican Diagrams", *Filosofsky vestnik*, 25, 2, 2004, pp. 25-50; GRANADA, "Introducción" (ref. 8), pp. clxxx-ccvi.

[14] Cf. with Nicolaus COPERNICUS, *De revolutionibus orbium caelestium*, in ID., *Gesamtausgabe*, II: *De revolutionibus Kritischer Text*, hrsg. von H. M. Nobis, B. Sticker, Hildesheim, Gerstenberg, 1984, p. 20: "quartum in ordine annua revolutio locum obtinet, in quo terram cum orbe lunari tanquam epicyclo contineri diximus". In order to explain Bruno's misunderstanding, Paul R. BLUM, *Giordano Bruno: An Introduction*, Amsterdam, Rodopi, 2012, pp.

two Oxford professors decide to leave the scene, a course of action that is interpreted by the other guests as if the two were embarrassed by their error, while in fact any reader can easily verify that the text of *De revolutionibus* is in their favour rather than not.

The conclusion of the debate is certainly the most puzzling episode of the *Cena*, as it appears to be based on the false assumption that Copernicus supported the co-epicyclical motion of the earth and the moon. From the point of view of the narrative of the dialogue, Teofilo can claim that the protagonist of his tale, the philosopher "Nolano", won the argument against the Oxford Aristotelians. The host and his guests apologise for the incivility of the two academics and lament the state of philosophical and scientific culture in their country.[15] The fourth dialogue ends with Smitho inviting Teofilo to come back again the next day so that he can expound Nolano's natural philosophy. In this way, the end of the fourth dialogue marks a watershed between the discussion of the Copernican astronomy and the full account of Bruno's "new philosophy" in the last part of the *Cena*, or between the "dawn" of the Copernican awakening from darkness and the full daylight of the "filosofia nolana".

Some of the difficulties of Bruno's text can be untangled by looking closer at the meaning Bruno attributes to the heliocentric theory. In the *Cena* and other works, Bruno reads heliocentrism as an ancient truth rediscovered and revived by Copernicus.[16] This paradigmatic rediscovery of ancient wisdom circulated widely among supporters and critics of Copernicus of the sixteenth and seventeenth centuries, no doubt also thanks to the suggestions included in *De revolutionibus*, which gave substance to the claim of the rebirth of ancient Pythagoreanism *in corpore copernicano*.[17] The *Cena*'s approach to the Copernican theory is functional both for the debate between Nolano and the

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31-32, supposes that the copy of *De revolutionibus* brought in during the supper may have been a manuscript. Suggestive as it may be, there is no evidence this may be the case. Furthermore, Bruno's precise knowledge and translation of Osiander's letter, which was added to the text at the time of its printing, points towards Bruno's use of a printed edition.

[15] BRUNO, *The Ash Wednesday Supper* (ref. 6), p. 193 (BOI I, 542).

[16] *Ibidem*, p. 86: "although almost destitute of vital reasons, [Copernicus] took up again those despised and rusty fragments that he was able to get from the hands of antiquity, refurbished them, and assembled and fastened them together again with his mathematical more than natural reasoning. In this way he brought the cause [i.e., heliocentrism], which had been ridiculed, despised and vilified, to be honored, praised, [to be] more credible than its opposite [i.e., geocentrism]" (BOI I, 449).

[17] On Copernicus' Pythagoreanism, see Bronisław BILIŃSKI, *Il Pitagorismo di Niccolò Copernico*, Wrocław: Polskiej Akademii Nauk, 1977. Giovanni Maria Tolosani, one of the earliest critics of Copernicus, framed heliocentrism as a revival of the ancient Pythagoreans in order to use Aristotle's arguments against it: see WESTMAN, *Copernican Question* (ref. 1), pp. 196-197. For Copernicus' supporters, cf. Thomas DIGGES, *A Perfit Description of the Caelestiall Orbes according to the most aunciente doctrine of the Pythagoreans, latelye reuiued by Copernicus and by Geometricall Demonstrations approued*, London, Th. Marsh, 1576, and Miguel Angel GRANADA, "Thomas Digges, Giordano Bruno e il Copernicanesimo in Inghilterra", in Michele CILIBERTO, and Nicholas MANN, eds. *Giordano Bruno, 1583–1585: The English Experience/L'esperienza inglese*, Florence, L. S. Olschki, 1997, pp. 125-156. On Renaissance pythagoreanism cf. Christiane L. JOOST-GAUGIER, *Pythagoras and Renaissance Europe: Finding Heaven*, Cambridge, Cambridge University Press, 2009, pp. 133-142, and above all Michael J. B. ALLEN, "Pythagoras in the early Renaissance", in Carl A. HUFFMAN, ed., *A History of Pythagoreanism*, Cambridge, Cambridge University Press, 2014, pp. 435-453.

Aristotelians, and to Bruno's own interpretation of the heliocentric order of the planets. In the first respect, Copernicus' rediscovery of the ancient truth provides valuable ammunition against the arguments *ex authoritate* of the Aristotelian professors.[18] More importantly, though, the Pythagorean cosmology provides Bruno a framework to interpret not only the earth's motion and displacement from the centre of the cosmos, but also the relative positions of the Sun, the earth and the moon.

In Aristotle (*On the heavens*, II, 13-14) and in his commentators, Bruno found that the Pythagoreans thought the earth to be "one of the planets" ("unus planetarum"), and that it revolves around a central fire, a celestial body different from the Sun, once per day.[19] Alongside the earth, the moon, the sun and the central fire, the Pythagoreans placed yet another celestial body, which they called "counter-earth" (it would become "antichtona" in medieval Latin sources). The counter-earth is located between the earth and the central fire. As it lies constantly on the opposite side of the earth, it is invisible to earthly observers.[20] This cosmological system was attributed by sources better informed than Aristotle to Philolaus of Croton, a contemporary of Socrates who was sometimes accused of breaching the Pythagorean vow of secrecy and who may have influenced Plato. Strictly speaking, Philolaus' system is not heliocentric but heliokinetic and "hestiocentric", as the sun orbits like a planet above the earth and around a central fire located at the centre of the cosmos.

Later interpreters of the Pythagorean cosmology, readers and commentators of Aristotle, will bring Philolaus' theory closer to a heliocentric system. The sixth-century Neoplatonist Simplicius of Cilicia in his commentary to *On the heavens* claimed that the earth and the counter-earth revolved on the same circle (similar to the earth and the moon in Bruno's diagram). This theory is reported in reference to a lost work by Aristotle on the Pythagoreans, in which the earth, as "unus planetarum", moves around the central fire together with its counter-planet, the "antichtona". In turn, the central fire is provided with a "virtus conditiva" which propagates from the centre of the cosmos, nourishes our earth and balances its coldness.[21] In an attempt to reconcile the Pythagorean doctrine with Aristotle, later commentators stressed the identification of the counter-earth with the moon and of the central fire with the sun and, concurrently, located the moon/counter-earth on the same circle as

[18] Cf. the juxtaposition of Aristotle and Ptolemy, supported by the pedants, against Pythagoras and Plato in BRUNO, *The Ash Wednesday Supper* (ref. 6), p. 188 (BOI I, 537).

[19] ARISTOTLE, *On the Heavens*, II, 13 293a15-25.

[20] A detailed account of Philolaus' cosmology, from which mine is based, is Daniel W. GRAHAM, *Philolaus*, in HUFFMAN, ed., *A History of Pythagoreanism* (ref. 17), pp. 46-68: 56-60.

[21] Cf. SIMPLICIUS, *Commentaria in quatuor libros de Coelo*, Venice, H. Scotus, 1584, f. 151, comm. 47: "Terram autem tanquam unum astrorum existentem moveri circa medium, et eam quae ad solem habitudinem noctem et diem facere. Antichtona autem mota circa medium et sequens terram. Hoc non videtur nobis, eo quod interiacet nobis semper terrae corpus […] Qui autem sincerius ista callent, ignem quidem in medio dicunt conditivam virtutem ex medio totam terram alentem, et quod infrigiditatum ipsius est recreantem […] Antichtonam autem lunam vocabant Pythagorici".

our own earth. Averroes is the first one to attribute to the Pythagoreans the idea that the counter-earth is "another earth […] moving on the same circle and with the same motions as our own earth".[22] He is followed by Albert the Great, who in his commentary to *On the heavens* reports, echoing Averroes, that "on the same circle as our earth, but diametrically opposed to it, the Pythagoreans affirmed there is another earth that they called *antictona*". The interposition of the counter-earth between the sun and the moon is the cause of their eclipses. And just as our earth has a counter-earth, each planet has a counter-planet, a planetary companion (as Bruno would say in his later works), which revolves with the other one on the same circle but at the opposite end of its diameter.[23]

Key to the understanding of how the counter-earth helps to explain Bruno's interpretation of the Copernican motions in the *Cena* is the transmutation of the hestiocentric cosmos into a heliocentric one through the identification of Philolaus' counter-earth and central fire with the sun and the moon. In Bruno's works we find both. The sun and the central fire are one and the same in *De immenso* with explicit reference to the Pythagoreans and against other interpretations of the Pythagorean sacred fire placed at the centre of the earth.[24] In the Italian dialogues, the term "antictona" stands for the moon in conjunction with its motions relative to the earth. In *De l'infinito* the motions of earth and moon are mutually linked by alternate movements and positions with respect to the sun.[25] While one moves away the other comes closer, and vice versa. Similarly, the

[22] AVERROES, *In de caelo*, in *Aristotelis Opera cum Averrois commentariis*, Venetiis, apud Iunctas, 1562-1574, 15 vols, reprint Frankfurt am Main, Minerva, 1962, vol. v, l. ii, comm. 75, 148M-149A; comm. 72, f. 157 A-B, "Quidam enim dicentes autem quod terra non est in medio, dicunt quod movetur circa medium, sicut stella. [...] Deinde dicunt quod terra movetur circa medium cum altera terra, quae ei opponitur. Et apparet ex hoc, quod faciunt al- teram terram oppositam, et quod ipsi opinabantur quod in circulo, super quem movetur terra, est altera terra opposita isti, et quod movetur motu aequali ei".

[23] Cf. ALBERTI MAGNI, *De caelo et mundo*, ed. P. Hossfeld, in ID., *Opera omnia*, B. Geyer praeside [W. KÜBEL], Monasteri Westfalorum, Aschendorff, 1955-1993, t. V, pars I, lib. II, tract. 4, p. 179, 181: "Dicebant etiam, quod movetur circulariter circa centrum, in quo est ignis, et revolvitur secundum motum diurnum. [...] Et per diametrum in eodem circulo in quo movetur terra nostra, dixerunt esse aliam terram oppositam diametraliter huic terrae in qua nos habitamus, quam vocaverunt antygyon, et huius causa fuerunt eclipses solis et lunae, quas ex opacitate illius terrae motae ante solem et lunam dixerunt provenire, et eclipses, quae proveniunt habitantibus in antygyon, dixerunt proveni- re ex motu nostrae terrae. [...] Nec dixerunt tantum unicam esse terram, sed multas et omnes illas circa medium huius mundi moveri. Sed quia una semper movetur sub altera, ideo una occultatur ab altera".

[24] Cf. Giordano BRUNO, *De innumerabilibus, immenso et infigurabili* (henceforth *De immenso*)*,* in *Jordani Bruni Nolani Opera latine conscripta,* ed. F. Fiorentino et al., 3 vols, 8 parts, Florence-Naples, Morano, 1879-1891 (henceforth abbreviated as BOL, followed by volume and page numbers), vol. I, t. ii, p. 8: "Et multa mentiuntur philosophi, garrire cupientes sub titulo sententiae Pythagoricorum quam nunquam capiunt, *ut ubi ille ignem in centro constituit, id est, solem medium planetarum*, adducunt quidam ignem in medio Telluris, Vestae sacrum, et fabulas augent arcanas quibus in praecedentibus libris ferculasse volumus" (my emphasis).

[25] Cf. *De l'infinito*'s English translation in Dorothea SINGER, *Giordano Bruno: His life and thought. With Annotated Translation of His Work,* On the Infinite Universe and Worlds, New York, Schuman, 1950, p. 371: "Thus from one to another cause, little by little, from season to season, our most frigid globe is heated by the sun, now from this side, now from that, now on this part of her surface, now on that; and through certain vicissitudes she now yeldeth and anon claimeth place from the neighbouring earth which we name the moon, so that now one, now the other body is respectively further from or nearer the sun: wherefore the moon is named by Timaeus and other Pythagoreans the counter-earth" (BOI, II 159). Cf. Giordano BRUNO, *On the Heroic Frenzies*, ed. by I. Rowland and E. Canone, Toronto, University of Toronto Press, 2013, p. 177: "he [the frenzied hero] claims to conform himself to the moon that always

earth and the moon take turns heat themselves by exposing one of their sides to the sun while the other cools down. This understanding of the earth's and moon's motions is part of Bruno's vitalistic conception of the universe, whereby the changing positions of stars and planets are functional to their self-preservation by means of mutual exchange of heat, from stars to planets, and of cold and humid exhalations from planets to stars.[26] The antithesis between the earth and the moon in the cosmological diagram is thus only partial, as it relates to their motions, while their physical qualities are entirely similar and in fact mutually dependant. The moon is another earth as much as the earth is another moon. The analogy is then extended to the entire universe: just as the earth is one of the planets, each planet is another earth. 'Earths' ("terre"/ "terrae") is Bruno's denomination for planets and, conversely, each star, being similar to our sun, is called "sole"/ "sol".[27]

Taking a more comprehensive look at the diagram of the *Cena,* with the exception of the earth and the moon, the order of the planets follows the Copernican arrangement in *De revolutionibus* I, 10. On the heliocentric side of the illustration, Mercury and Venus are appropriately located under the sun, while the three superior planets follow their traditional order (Mars, Jupiter and Venus), common to both Copernicus and Ptolemy. However, important innovations by Copernicus are not mentioned, including the elimination of the equant points, or the replacement of the planets' yearly epicyclical motion with the earth's annual orbit, and its consequences for the explanation of retrograde motion. On the other side, though, significant references are made to the observed size of the planets, and to the proportion between planetary motions and the earth.[28] The first issue concerns the search for observational evidence of the earth's motion. If the earth revolves around the sun, then observed planetary sizes should vary in relation to their geocentric distances. This means that in theory the diameters of the celestial bodies should be smaller or larger depending on their distance from Earth.[29] This aspect allows Bruno to frame the debate over the planetary order

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shines so brightly, and is so beautiful – or at least he claims that he is unlike that anti-earth that stands between our Earth and the Sun in its variability to our eyes, but he is like it in absorbing an unchanging portion of the Sun's radiance". In this case too, Bruno stresses the vitalistic aspect of the 'antictona' rather than the dynamical role as counter-planet of the earth.

[26] On Bruno's universal animism and organicism, see above all MICHEL, *The Cosmology of Giordano Bruno* (ref. 1), pp. 250-268; and Miguel Angel GRANADA, "Giordano Bruno et 'le banquet de Zeus chez les Éthiopiens': la transformation de la doctrine stoïcienne des exhalaisons humides de la terre dans la conception brunienne des systèmes solaires", *Bruniana & Campanelliana*, 3, 1997, pp. 185-207.

[27] Bruno is not isolated in interpreting the Pythagorean counter-earth and central fire as Pythagorean names for the moon and the sun. The same semantic translation will be made in the early seventeenth century by both supporters and enemies of heliocentrism, such Tommaso Campanella in the *Apologia pro Galilaeo*, Giulio Cesare La Galla on the opposite side of the debate on Galileo's novelties, and by Johannes Kepler in various of his works including the *Apologia pro Tychonis,* the *Harmonice Mundi*, the *Epitome* and in his unpublished German translation with commentary of the second book of *On the Heavens*. On this aspect, see TESSICINI, *I dintorni dell'infinito* (ref. 13), pp 50-57.

[28] Cf. BOI, I, 530.

[29] In practice, only celestial bodies near to earth would display any sensible variation. Telescopic observations will allow Galileo to detect the variations of the diameters of Mars and Venus and use the evidence in support of heliocentrism. Cf. Albert VAN HELDEN, *Measuring the Universe: Cosmic Dimensions from Aristarchus to Halley*,

around questions concerning the size of planetary diameters. In the midst of the debate, the argument used by Nolano to counter Torquato's drawing of the Copernican diagram is that the earth's motion on a concentric circle would not produce the observed variations in the sun's diameter. Hence, the earth's position on an epicycle is argued on account of these variations.[30] Similarly, the discussion over the planetary order is prompted by Torquato's question concerning whether the diameter of Mars would change if the earth were in motion. Teofilo replies that Nolano promptly answered this question positively, which in turn leads to Torquato's question on the second issue: "He suddenly asked about the relationship ["proporzione"] of the motions of the planets and the earth".[31]

The relationship, or "proportion", of the planetary motions and the earth, as Bruno phrases it, resonates with what Copernicus considered the aim and principal achievement of his work. Torquato's question is allusive to (at least) one passage of *De revolutionibus*, where it is explained that the motion of the earth allows us to connect, or "bring together", all planetary motions according to one single principle, and that all motions follow from it, as well as the order and the magnitudes of the celestial bodies. The end result has cosmological relevance, as the whole heavens are thus bound together so closely that nothing can be shifted around without disrupting the other parts and the universe as a whole.[32] The nature of this relation is explained by Copernicus as a principle of commensurability, or "symmetria", of times and distances, brought together by the annual motion of Earth as the common measure. Following a long tradition, Copernicus believed that in a finite spherical universe celestial bodies can only move by uniform circular motions – where circularity allows for the combination of singular circular motions, and uniformity stands for the constant linear velocity of the celestial bodies. As a necessary consequence, planets moving closer to the centre of the cosmos complete their circles in less time than planets orbiting farther away: the closer the planet to the centre, the shorter its period of revolution. Once the periods of all planets are known, through regular observation of their motions, the duration of their revolutions

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Chicago, Chicago University Press, 1985, pp. 72-74, and ID., "The Telescope and Cosmic Dimensions", in René TATON, Curtis WILSON, eds., *Planetary Astronomy from the Renaissance to the Rise of Astrophysics. Part A: Tycho Brahe to Newton*, Cambridge, Cambridge University Press, 1989, pp. 106-118.

[30] Cf. Nolano's reaction to Torquato's locating the earth on a concentric deferent in BRUNO, *The Ash Wednesday Supper* (ref. 6), p. 192: "For even the greatest ass in the world knows that from that place [if the earth is located on the concentric deferent] the diameter of the sun would always appear the same; and many other conclusions which would be impossible to verify" (BOI, I 540-541).

[31] *Ibidem*, p. 183 (BOI, I 530: "[Torquato] Dimandò subito della proporzione dei moti degli pianeti e la terra").

[32] Cf. Nicolaus COPERNICUS, *De revolutionibus*, *Praefatio*, in Anna DE PACE, *Niccolò Copernico e la fondazione del cosmo eliocentrico con testo, traduzione e commentario del libro I de* Le Rivoluzioni Celesti, Milano, Bruno Mondadori, 2009, p. 252: "Atque ita ego positis motibus, quos terrae infra in opere tribuo, multa & longa observatione tandem repperi, quod si reliquorum syderum errantium motus, ad terrae circulationem conferantur, & supputentur pro cuiusque syderis revolutione, non modo illorum phaenomena inde sequantur, sed & syderum atque orbium omnium ordines, magnitudines, *et coelum ipsum ita connectantur, ut in nulla sui parte possit transponi aliquid, sine reliquarum partium, ac totius universitatis confusione*" (my emphasis).

becomes their ordering principle.[33] Copernicus' concern with a planetary order that complied with the period-distance relation, and his success at arranging planets from the fastest to the slowest revolution, thanks to the introduction of the earth's motion, led him to the conviction that heliocentrism restored the harmony and symmetry of the cosmos.[34]

On the heels of the discussion on the variation of planetary diameters, and with the discussion on the planetary order in sight, Torquato's question on the proportion of the planetary motions and that of the earth brings the discussion in this part of the *Cena* very close to the motivation for Copernicus' heliocentrism. The answer follows suit. Despite having vindicated the autonomy of his arguments in support of heliocentrism, when it comes to the central tenet of heliocentrism, Nolano states that he stands by Copernicus and his idea of order as symmetry/commensurability. In his words:

> He [Nolano] replied, instead, that he had come there neither to lecture nor to teach, but to answer; that the symmetry, order, and measure of the celestial motions are assumed as they are and had been understood both by ancients and modern men; that he did not dispute them on this, and had no case against the mathematicians with which to deprive them of their measurements and theories, which he endorsed and believed; but that his interest was directed towards the nature and verification of the cause of these motions.[35]

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[33] Cf. GOLDSTEIN, "Copernicus and the Origins of His Heliocentric System" (ref. 1), pp. 221, 226-228; and, with a different emphasis on the nexus of problems faced by Copernicus, GODDU, "Reflections on the origins of Copernicus' cosmology" (ref. 1).

[34] Cf. the well-known passages in COPERNICUS, *De revolutionibus* (ref. 32), *Praefatio*, p. 251: "Rem quoque praecipuam, hoc est mundi formam ac partium eius certam symmetriam, non potuerunt invenire, vel ex illis colligere"; I, 10, p. 277: "Invenimus igitur sub hac ordinatione admirandam mundi symmetriam: ac certum harmoniae nexum motus et magnitudinis orbium: qualis alio modo reperiri non potest"; and a fundamental yet less quoted passage from Book V, chapter 1 in Nicolaus COPERNICUS, *De revolutionibus orbium caelestium libri V*, Norimbergae, apud Ioh. Petreium, 1543, f. 133v: "Aggredimur modo quinque errantium stellarum motus, *quorum orbium ordinem & magnitudines ipsa terrae mobilitas consensu mirabili, ac certa symmetria connectit*, ut primo libro summatim recensuimus, dum ostenderemus, quod orbes ipsi non circa terram, sed magis circa Solem centra sua haberent." (Nicholas COPERNICUS, *On the Revolutions*, translation and commentary by E. Rosen, Baltimore and London, The Johns Hopkins Press, 1992, p. 227: "Now I tackle the motions of the five planets. *The order and size of their spheres are connected with remarkable agreement and precise symmetry by the earth's motions*, as I indicated generally in Book I [ch. 9], when I showed that the centers of these spheres are not near the earth, but rather near the sun.") My emphasis stresses the reference to the passage from I, 10, quoted in note 32. Cf. this passage with Ptolemy's programmatic statements in *Almagest*, I, 2 and 3. See *Ptolemy's Almagest*, translated and annotated by G. J. Toomer, Princeton University Press, Princeton 1998, I, 2-3, p. 38: "the heaven is spherical in shape, and moves as a sphere [...]. What chiefly led them [the ancients] to the concept of a sphere was the revolution of the ever-visible stars, which was observed to be circular, and always taking place about one centre, the same [for all]. For by necessity that point became [for them] the pole of the heavenly sphere: those stars which were closer to it revolved on smaller circles, those that were farther away described circles ever greater in proportion to their distance"; and in IX, 2 (*ibid.*, p. 420): "Now it is our purpose to demonstrate for the five planets, just as we did for the sun and moon, that all their apparent anomalies can be represented by uniform circular motions, since these are proper to the nature of divine beings, while disorder and non-uniformity are alien [to such beings]. Then it is right that we should think success in such a purpose a great thing, and truly the proper end of the mathematical part of theoretical philosophy".

[35] BRUNO, *The Ash Wednesday Supper* (ref. 6), pp. 183-184 (BOI, I 530: "Anzi rispose che lui non era andato per leggere né per insegnare, ma per rispondere; e che la simmetria, ordine e misura de moti celesti si presuppone tal qual'è, et è stata conosciuta da antichi e moderni; e che lui non disputa circa questo, e non è per litigare contra gli matematici per togliere le lor misure e teorie, alle quali sottoscrive e crede: ma il suo scopo versa circa la natura e verificazione del soggetto di questi moti").

The wording of the answer refers, quite unequivocally in my opinion, to the Copernican claim that the cosmological order and proportion of its parts ("ordine" and "simmetria") was restored through the adoption of an astronomical system that conformed to principles of proportion, that is, one where there was a "misura" ("proportion") between mean periods of motions and their relative distances. Bruno does not comment on any of the implications of the Copernican harmony, and seems to consider the interlaced issues of proportion, symmetry and order uncontroversial or, at least, not a matter he is ready to discuss with neither Torquato nor Nundinio, despite the fact that the very order of the planets is under discussion in this part of the fourth dialogue. Beyond the general reference to the "ancient and modern men", Teofilo avoids a thorough discussion on account that it would be lengthy and that both parties agree on the "quantity and quality of the motions". A likely interpretation is that Bruno refers to observational data (i.e., their "quantity"), and notes that circular uniformity and the period-distance relation (i.e., the "quality" of the motions) are widely agreed principles. At this stage of the debate, he sees no point in discussing a topic over which there is no substantial disagreement with the two Aristotelian professors – or at least so he claims. Evidently, he prefers to concentrate on the topic of the earth's motions, as it is clear from what follows in the dialogue.

There is, however, at least another question unanswered by the passage, that is, how could an idea of harmony ultimately dependent on a spherical universe, such as Copernicus', coexist with a shapeless infinite universe, where circular motions are no more necessary than rectilinear or composite ones? In the Italian dialogues, and the *Cena* in particular, Bruno seems unconcerned about the issue. Harmony, order and symmetry have little relevance in his arguments, and when they are mentioned their coherence with Bruno's infinitist cosmology is never called into question, notwithstanding some cases where the harmony of the universe is related to circular uniformity and the period-distance relation (as will be shown below), and despite cosmological harmony being closely linked to the revival, or rediscovery, of the ancient Pythagorean wisdom which, in turn, was associated with heliocentrism. One of these instances occurs in the first pages of the fifth dialogue of the *Cena*.

> Now, Heraclitus, Epicurus, Pythagoras, Parmenides and Melissus understood this point concerning bodies in the ethereal region, as the fragments we possess make manifest to us. In [these fragments] one can see they recognized an infinite space, an infinite region, infinite matter, an infinite capacity for innumerable worlds similar to this one, rounding their circles as the earth rounds its own. And this is the reason why they were formerly called *ethera*, that is runners, messengers, ambassadors, nuncios of the One Highest, who, *with musical*

harmony, tune the order of the constitution of the universe, the living mirror of the Infinite Deity (my emphasis).[36]

Here, the nature and motions of the celestial bodies in the infinite universe are outlined according to Pythagorean literary suggestions, or rather their "fragments", in the very same way as Copernicus had restored heliocentrism from the scattered fragments he found in Aristotle and other authors. On this occasion, the object of the rediscovery is the distinction of the celestial bodies between fiery and watery, and forming innumerable worlds within an infinite region. They complete their circles in a similar way as the earth completes its own orbit, and all together they form an ensemble whose musical harmony corresponds ("contemprano") to the order of nature, which is in turn "the living mirror of the infinite deity". In this case two central concepts of Bruno's cosmology, the uniformity of the universe and its infinity, coexist with the harmony of the circular motions.

2. Celestial Harmony in the Italian Dialogues

The other Italian dialogues reinforce and in one case expand on the *Cena de le ceneri*. *De l'infinito universo et mondi,* the third in the cosmological trilogy, provides a thorough examination of the concept of infinity with long sections devoted to the rebuttal of Aristotle's arguments against it. In the third *dialogo*, Bruno discusses at some length the "proportion" of the planetary motions, although in this case he uses a terminology different from the *Cena*. But before addressing *De l'infinito*, and in order to provide some context for it, I will briefly sample other references to the harmony of the universe, noting in the first place that these are not limited to the cosmological dialogues, but are also occasional presences in the second trilogy of dialogues. In these cases, the harmony of the universe is usually intended as a manifestation of cosmological order through the music of the celestial spheres, or the consonance and proportion of the celestial motions. This is a recognizable motif of the Neoplatonic and Pythagorean philosophies, not necessarily associated with heliocentrism, and indeed often reconciled with a geocentric cosmos.[37] Bruno deals with the

[36] *Ibidem*, p. 206. Cf the relevant passage in BOI, I 547: "che con musicale armonia contemprano l'ordine della constitution della natura".

[37] According to Andrew Hicks, "Pythagoras and Pythagoreanism in Late Antiquity and the Middle Ages", in Huffman, *A History of Pythagoreanism* (ref. 17), pp. 416-434: 432-434, this is a view that originates in late-antique and medieval Neoplatonism, whereby the world-soul manifests itself through the 'harmomy of the spheres', i. e., in the intervallic (harmonic) series of planetary distances. This theory of cosmic harmony, which was separate from Aristotle's account of Pythagorean cosmology in *On the Heavens* and *Metaphysics*, found its way to the Renaissance through the works of authors like Macrobius, Calcidius, Boethius and Martianus Capella. For other outlooks on Pythagorean revival, see in this volume the chapters by E. Mehl and Jonathan Regier.

theme from a literary point of view more than in a strictly philosophical or cosmological manner. In the *Cabala del cavallo pegaseo*, for instance, the reference to harmony appears in the dedication of the work, and in a passage dealing with the book's value as a gift.[38] The theme – the act of a book dedication as gift-giving – is a literary commonplace that Bruno adapts to the satirical tone of the dialogue. Should the fictional dedicatee decide to get rid of the book, and find that there is some worth in it for mathematics, he should give it to a "cosmographer" so that he could use the content as a "type of megacosmos" in which the "concordance and harmony" of the two types of motion in the cosmos, rectilinear and circular, depend on an intrinsic soul as a principle of motion. Moving on to *De gli eroici furori*, the *Argomento e allegoria del quinto dialogo* provides a cosmological description different from the *Cabala* in literary style but similar in the terminology relative to the harmony and connection of the parts. In this section, Bruno introduces the subject of the fifth dialogue of the second part, which brings the entire work to a conclusion under the allegorical tale of nine blind men who regain their sight on the shores of the River Thames. Their celebratory singing is compared with the harmony of the nine spheres, where this is intended as deriving from their order and interconnection:

> At last we contemplate the harmony and consonance of all the spheres, intelligences, Muses, and instruments together, where heaven, the movement of the worlds, the works of nature, the discourses of intellect, the mind's contemplation, the decrees of divine providence, together celebrate the lofty and magnificent alternation that equals the lower waters with the higher, exchanges night for day, and day for night, so that divinity is in all things, so that everything is capable of everything, and the infinite goodness conveys itself endlessly to all things in their full measure.[39]

Only in *De l'infinito*, published in the same year as the *Cena*, does Bruno depart from this traditional and rather unspecific view of celestial harmony. This dialogue, entirely dedicated to the physical theory of the infinite universe, includes some relevant considerations on Bruno's view of the period-distance relationship. The issue is prompted by a question on the preservation of life in the infinite universe:

[38] BRUNO, *Cabala del cavallo pegaseo*, BOI, II 411-412: "Se finalmente vi par ch'abbia del matematico, fatene grazia ad un cosmografo perché gli vada rependo e salticchiando tra il polo artico et antartico de una di queste sfere armillari, alle quali non men comodamente potrà dar il moto continuo, ch'abbia possuto donar l'infuso mercurio a quella d'Archimede, ad esser più efficacemente tipo del megacosmo, in cui da l'anima intrinseca pende la concordanza et armonia del moto retto e circolare".

[39] BRUNO, *On the Heroic Frenzies* (ref. 25), p. 31 (BOI II, 47-49). On blinded love, and this section of the *Furori*, cf. Giovanni AQUILECCHIA, "Componenti teatrali nei dialoghi italiani di Bruno", *Bruniana & Campanelliana*, 5, 1999, 2, pp. 265-276: 267-268.

> ELP. How then wouldst thou maintain that all these bodies, however far from the centre, that is from the sun, can nevertheless participate in the vital heat thereof? - PHIL. Because the further they are from the sun, the larger is the circle of their orbit around it; and the greater their orbit, the more slowly they accomplish their journey round the sun; the more slowly they move, the more they resist the hot flaming rays of the sun. - ELP. You maintain then that though so distant from the sun, these bodies can derive therefrom all the heat that they need. Because, spinning around the sun, they can derive not only as much heat but more still if it were needed; since by the more rapid spin around her own centre such part of the convexity of the earth as hath not been sufficiently heated is the more quickly turned to a position to receive heat; while from the slower progress around the fiery central body, she stayeth to receive more firmly the impression therefrom, and thus she will receive fiercer flaming rays.[40]

This is an important passage, as it lays the foundation for a natural-philosophical (i.e., animistic, and "biocosmological") interpretation of one of the basic tenets at the root of the Copernican theory. Not by chance, the same concepts, almost in the same terms, will be reiterated in *De immenso*. In the first section of the passage, Bruno (through Filoteo) links the distance of the planets from the centre of motion to the size of the circle they revolve on, thus implicating a relation between distance and period of revolution ("the further they are from the sun... the larger is the circle of their orbit... the more slowly they accomplish their journey"). To this relation, which echoes Copernicus' formulation in *De revolutionibus*, I, 10 ("revolutionum suarum [i.e., the planets] magnitudinem... quae longius distant tarde ferri videntur")[41], Bruno adds a further term which concerns the physical properties of the celestial bodies, that is, that their resistance to heat is commensurate with the time their bodies are exposed to the sun. In fact, Elpino's second intervention overlooks the issue of planetary order, and conceptualizes the period-distance relation in physical and natural-philosophical terms. The relation of period and distance is conceived within a physical and naturalistic conception of the celestial motions, namely, that the period-distance relation exists so as to balance the quantity of heat received by the planets. Slower, more distant planets are more resistant than swifter planets to the heat of the solar rays since their surfaces are exposed longer to the sun's heat. Thus, in the passage above the period-distance relation is comprised within a vitalistic cosmology: the universe appears as a homogeneous organism composed of mixtures of the four elements, whose interplay is facilitated by the exchange of materials in the form of exhalations. This exchange maintains balance and life in the universe. Seen from this point of view, the period-distance relation is not purely a geometrical property of circular

[40] The translation is from SINGER, *Giordano Bruno* (ref. 25), p. 305 (BOI, II 90-91); and cf. also *De immenso*, V, 2 (BOL I, ii), pp. 121-125 for a reprise of these considerations.

[41] COPERNICUS, *De revolutionibus* (ref. 32), I, 10, p. 272: "Errantium vero seriem penes revolutionum suarum magnitudinem accipere voluisse priscos philosophos, assumpta ratione, quod aequali celeritate delatorum quae longius distant tardius ferri videntur".

motions (as in Copernicus), but a self-regulating mechanism that keeps the celestial bodies at the right distance from each other.

The examination of the Italian dialogues, and particularly of the passage from *De l'infinito*, reveals Bruno's reception of the period-distance relation and, to some extent, its role in the ordering of the planets, although this does not translate into an endorsement of its centrality for the astronomical validity and intellectual viability of heliocentrism. In fact, while on the one hand Bruno claims in the *Cena* that his version of heliocentrism is not at odds with the harmony, symmetry and proportional arrangement of the planets, on the other hand he evades any discussion of Copernicus' conception of harmony, whose constitutive principle – the period-distance relation – is reconsidered within a vitalistic conception of the mutual relations between celestial bodies in *De l'infinito*.

3. The Latin Works: Planetary Motions and Symmetry

Bruno continues to discuss cosmological themes in the works published after he left London at the end of 1585. The nature of the infinite universe, the concepts of space and void, the movement of the celestial bodies, the uniformity of celestial and terrestrial matter, the elements and the concepts of gravity and levity, the universal soul and other topics are discussed in the *Centum et viginti articuli de natura et mundo* (Paris, 1586) and the *Camoeracensis acrotismus* (Wittenberg, 1588), while the arrangement of the planetary order is the focus of the final section of a short treatise that Bruno dedicates to Emperor Rudolph II, the *Articuli centum et sexaginta adversus huius tempestatis mathematicos atque philosophos* (Prague, 1588).[42] The content of the latter work draws largely on the previous one and presents Bruno's infinitist cosmology as an alternative to Aristotelian physics and natural philosophy. The last of the 160 "articuli" is particularly relevant, as it introduces new considerations on planetary physics and motions. A cosmological diagram (fig. 2) representing the motions of the four inferior planets (earth, moon, Mercury and Venus) and of the sun introduces some variants to the arrangement in the *Cena.* These variants follow from the earth-moon model of the Italian dialogue, as Mercury and Venus form a planet and counter-planet couple revolving on the same circle similarly to the earth and the moon. In the caption to the diagram, Bruno calls them

[42] For Bruno's works between 1586 and 1591, cf. Saverio Ricci, *Giordano Bruno nell'Europa del Cinquecento*, Rome, Salerno, 2000, chapter 6. The *Centum et viginti articuli* are published in Giordano Bruno, *Centoventi articoli sulla natura e sull'universo contro i peripatetici/ Centum et viginti articuli de natura et mundo adversus Peripateticos*, ed by. E. Canone, Pisa-Rome, Fabrizio Serra editore, 2007. On the *Acrotismus*, see Id., *Acrotismo cameracense. Le spiegazioni degli articoli di fisica contro i Peripatetici*, ed by. B. Amato, Pisa-Rome, Fabrizio Serra editore 2009; and Miguel Angel Granada, *El debate cosmológico en 1588: Bruno, Brahe, Rothmann, Ursus, Röslin*, Naples, Bibliopolis, 1996.

"antichtoni mundi seu tellures", which implies the extension of the Pythagorean concept of counter-earth to other planets (or "tellures"). The text of the *Articuli* states that "Mercury and Venus are in the same circle with the earth and the moon". The two planets form an "aggregatum" diametrically opposed to the one formed by the earth and the moon on their respective circle – or epicycle, should a Ptolemaic terminology be assumed in this case. Both 'congregations' of planets move isochronally in one year around the sun. In turn, the sun appears to move around a small circle (CDEF) at the centre of the planets.[43] This motion does not appear in a later diagram from the cosmological poem *De immenso* (Frankfurt, 1591; fig. 3), although Bruno continues to hold the idea of the sun's orbit. In *De immenso*, however, the earth-moon model is applied universally to all planets. Each planet is thus provided with a "counterplanet" or, as Bruno now calls it, with a "companion" ("consors"), although the nature of this relation tends to be developed more in physical than in geometrical terms.[44] This scheme departs substantially from Copernican astronomy and to some extent seems to be a step back from it, as it reintroduces the annual motions of Venus and Mercury, which were mooted by the earth's orbit in *De revolutionibus*.

The works published by Bruno between his stay in Paris in 1586 and the first part of his travels in Protestant countries mark a different phase from the Italian dialogues. In these and in the later works, Bruno aims to communicate his philosophy to the continental Latinate audiences of French and German universities and courts. The headings of the *Articuli de natura et mundo* are quite explicit in this sense, as its contents are "a Nolano in principibus Europae Achademiis propositi".[45] At the same time, Bruno continues to refine his thought, his cosmology in particular, as witnessed by changes to the planetary order, or by the introduction of new concepts such as the "aggregatum" of planets whose movements around a star are bound together. In these same works Bruno introduces the idea of the "synodus ex mundis" (or "synodus mundorum"), which indicates, with a word resonant of religious terminology, the fundamental cosmological unity of the universe, endlessly repeated and made up of planetary bodies (including comets) arranged around a star which, in turn, moves around its own axis and/or on a small orbit.[46] At the same time, in the works

[43] BRUNO, *Articuli adversus mathematicos,* art. 160 (BOL I, iii, 76): "Mercurius et Venus in eodem sunt circulo cum tellure atque luna. Hoc enim ex hisce duobus astris aggregatum unum, quod circa solem aeque annuo motu circumfertur, diametraliter (intermediante sole) opponitur aggregato ex duobus illis astris, quae aequis passibus annuum conficiendo circulum incedunt".

[44] BRUNO, *De immenso*, II, 9 (BOL I, i, 290-291): "Ast veluti Tellus cum Luna est, Mercuriusque/ Cum Venere adnexus, quo currant passibus aequis;/ Non aliter fortasse Jovi, Marti, ac Seniori [Saturni],/ Consortes natura dedit, qui tempore certo,/ aut raro, aut oculis nunquam sunt lumina nostris"; and III, 10 (BOL I, i, 397). Cf. TESSICINI, *Dintorni dell'infinito* (ref. 13), pp. 74-78 for a discussion of the issue, also with reference to the question of the relative positions of the "counterplanets". A more recent appraisal is in GRANADA, "Introducción" (ref. 8), pp. cxc-ccvi.

[45] Cf. Eugenio Canone's introduction in BRUNO, *Centoventi articoli* (ref. 43), p. xix.

[46] On the *synodi* as the cosmological unit forming the basic structure of the infinite universe, cf. *De immenso*, III, IV (BOL I, i, 344). See also the identification of comets and rarely seen planets in the same chapter. Cf. Miguel A. GRANADA, "Synodus ex mundis", in Eugenio CANONE and Germana ERNST, eds. *Enciclopedia Bruniana & Campanelliana*, Rome, Fabrizio Serra Editore, 2010, pp. 142-154.

from this period Copernicus and *De revolutionibus* are mentioned only occasionally, although the consequences of Bruno's adoption of heliocentrism are ever present. Copernicus' name appears again in the *Oratio valedictoria* of 1588, Bruno's final tribute to the University of Wittenberg. In this case, the famous astronomer features among the founders of the German "house of wisdom" together with Albert the Great, Nicholas of Cusa ("non Pythagorico par, sed Pythagorico longe superius"), Paracelsus and a group of enlightened princely patrons of astronomy. Following in the wake of the *Cena*, Bruno praises the divine intellect of Copernicus for his mathematical skills. He is described as a physicist only incidentally ("obiter"), and yet just two of his chapters are valued more than all books by Aristotle and his followers.[47]

Bruno's major publication from this period is a trilogy of works, published in Frankfurt in 1591, which comprises *De immenso* and *De monade et mensura*, bound together, and *De triplici minimo*, printed separately. Although commonly referred to as "poems" (particularly as scientific, didactic and/or philosophical poems), all three works belong to the genre of the prosimeter. This is a mixed mode of writing which alternates between prose and verse, with various possibilities as per the relations between poetry and prose. The prosimeter has a distinguished literary history from late antique and medieval examples such as Boethius, Martianus Capella and Dante to works chronologically closer to Bruno, such as Sannazzaro's *Arcadia*. In Bruno's own take on the genre, each chapter of his three works is a unit formed by a poetical component followed by a section in prose that expands on the content of the former.

The Latin trilogy is conceived as a *summa* of Bruno's philosophy in Latin aimed at learned audiences of continental Europe.[48] The dedicatory letter to Duke Heinrich Julius of Braunschweig, the *Epistola dedicatoria et clavis*, outlines the meaning of his "triple gift", that is, the philosophical programme that underpins the three works.[49] In *De minimo,* "doctrine, erudition and learning provide an understanding of the first elements" (i.e., the atoms); in *De monade, "*revelation, faith and divination apprehend the foundations or traces of imaginations, opinions and experiences"; *De immenso* provides "safe and irrefutable demonstrations of the arrangement of the worlds, the unity of the infinite universe governed by one principle and on the natural order".[50] Senses prevail in the

[47] Cf. BRUNO, *Oratio valedictoria* (BOL, I, i, p. 17): "Copernicum etiam qualis putatis esse nedum mathematicum, sed (quod est mirum) obiter physicum? Plus ille invenitur intellexisse in duobus capitibus quam Aristoteles, et omnes Peripatetici in universa eorum naturali contemplatione."

[48] Cf. Eugenio CANONE, "Introduzione", in Giordano BRUNO, *Poemi filosofici latini. De triplici minimo et mensura. De monade, numero et figura. De innumerabilibus, immenso et infigurabili*. Ristampa anastatica delle cinquecentine, a cura di E. Canone, La Spezia, Agorà edizioni, 2000, p. xi-xl; and S. RICCI, *Giordano Bruno* (ref. 42), pp. 432-452: 435: "In versi lucreziani, commentati in capitoli in prosa, il Nolano produce un'ampia sintesi della filosofia naturale che ha esposto nei Dialoghi italiani, affiancata dalla geometria degli *Articuli* dedicati a Rodolfo II, e dalla rassegna delle tradizioni esoteriche avviata nelle opere di Helmstedt".

[49] Cf. BRUNO*, De immenso*, *Epistola dedicatoria et clavis* (BOL I, i, pp. 196): "Triplex igitur ex arca exiguitatis meae depromptum munus (ibi, ter Maxime princeps) offero".

[50] *Ibidem.*

first one, words in the second, and beings ("res") in the third. Senses, words and beings are in turn mutually related, as are the sciences that encompass them: mathematics, metaphysics and physics.[51]

De immenso is the work where Bruno reconsiders Copernicus, his planetary order, the motions of the planets, as well as the principles that govern their arrangement and mutual relations. After introducing the metaphysical arguments in support of an infinite physical space in the first book, and refuting Aristotle's objections in the second one, the ten chapters of the third book deal with the uniformity of space, the physics of the celestial bodies, their motions and arrangement in the infinite universe. The earth's position in the universe is discussed in chapter 2: since the universe is infinite, the earth cannot be at its centre more than any other celestial body. As an extension of the concept that our Earth is a planet, all planets are similar to ours, and they are innumerable.[52] Since planets do not emit light like stars, the more distant ones are invisible to an observer from Earth, while others, including comets, that Bruno considers permanent bodies, may become visible to us only at times.[53] These and other considerations are not new in Bruno's works. In many parts, *De immenso* draws on ideas, text and illustrations that were deployed in earlier works, the Italian dialogues in particular. Yet there are also significant differences and new considerations that Bruno freshly develops, and a relevant portion of them concern cosmological themes. In this way, Bruno's infinitist cosmology appears less an extension of Copernicus' heliocentrism, albeit a radical one, as compared to the *Cena*, and is more safely anchored in the metaphysical and natural-philosophical principles and arguments of *De immenso*, Book I.

At several points in the central chapters of Book III, Bruno attacks, dismisses or denies the possibility of a harmonical or 'symmetrical' (the word used most often) arrangement of the celestial bodies in connection with their perfection or the regularity of their motions. Bruno's arguments are firmly based on the infinity and the uniformity of physical space, the core of his cosmology, as they are posited at the beginning of Book I and throughout Book III, although the correlation of uniform circular motion, cosmological symmetry and Copernican astronomy is unique in *De immenso*. In *De immenso* III, 5 the arguments for the centrality of the earth based on the physical properties of the primary elements, such as the gravity and density of the earth, are revisited and rejected with reference to the Italian dialogues.[54] This discussion includes the idea that the Earth is an animal, and therefore that its motions are not performed along perfect geometrical paths as evidenced by the

[51] *Ibidem*, p. 198.

[52] *De immenso*, III, 2 (BOL I, i, pp. 324-325): "Ut lunae tellus, telluri lunam vicissim/ Sint coelum ..."

[53] *Ibidem*. Cf. GRANADA, "Giordano Bruno et 'le banquet de Zeus" (ref. 26); MICHEL, *The cosmology of Giordano Bruno* (ref. 1), pp. 260-265.

[54] Cf. the references to the *Ash Wednesday Supper* and *On the infinite*, in Felice TOCCO, *Le opere latine di Giordano Bruno esposte e confrontate con le italiane*, Florence, Le Monnier, 1890, p. 244-245.

observation of the relative movements of the earth and the sun that never return to the same place.[55] A spiral or 'helical' motion seems more suitable to Bruno, and this idea will be explored further in the following chapter (III, 6), which extends the discussion of the irregular paths to all celestial bodies. It is in this chapter that Bruno stresses with particular strength the unbridgeable distance between the infinite universe and the geometrical harmony of the spherical cosmos. Bruno introduces the argument in the wake of the topic that ends the previous chapter, that is, the earth's motions (including his own autobiographical recollection of a pre-Copernican geokinetic system[56]).

Chapter 6 opens with a discussion of the geometrical irregularity of the earth's and of every other celestial motion, in opposition to the "regula" according to which motions are performed along circular lines and with uniform motion:

> For now I leave to others to judge to what extent this knowledge may help us to understand that rule (which is in fact nothing). Do we not see that that motion, continuous and regular, in fact, the very same measure and term of comparison for every period, time and motion, not extensible or remissible, is completely dissolved? Just as that self-evident motion came from a very unskilled and speculative philosopher and was accepted by a blind crowd and bestowed with divine immutability, so now, endorsed by faith, authority and custom, does it flee from that eighth sphere, which is perceptible to them (I mean, through the subject of time), to the imaginary ninth sphere.[57]

The "rule" is intended here as the uniform ("continuous and regular") motion performed by the fixed stars, that is, the outermost and simple revolution of the heavens on which all other motions depend and are measured according to a tradition stemming from Aristotle. In fact, Bruno's passage recalls Aristotle's own arguments in *On the heavens* Book II, chapter 4:

> the locomotion of the heavens is the measure of movements due to it alone being continuous and regular and everlasting, and if in each class the smallest member is the measure, and if the quickest movement is the shortest, it is clear that the movement of the heavens will be the quickest of all movements. [58]

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[55] Cf. *De immenso*, III, 5 (BOL I, i, pp. 357-358).

[56] Cf. GATTI, *Giordano Bruno and Renaissance Science* (ref. 1), pp. 34-39.

[57] *De immenso*, III, 6 (BOL I, i, 364): "Quantum vero interea haec scientia faciat ad comprehensionem ejus (quae nulla est) regulae, aliis relinquo judicandum. An non videmus motum illum, quem continuum regularem, immo et mensuram ipsam atque regularem omnis durationis, temporis, atque motus non intensibilen, non remissibilem, in nihilum evanuisse? Ille tanquam per se manifestus editus est ab inexpertissimo abstractissimeque perito philosopho, et a coecorum multitudine acceptatus et cum divinitatis ipsius invariabilitate concelebris: nunc in fide, et authoritate, et usu creditus, ab octava illa ipsis sensibili sphaera aufugit (temporis inquam ab illo subjecto) ad imaginariam nonam sphaeram".

[58] ARISTOTLE, *On the Heavens*, edited and transl. by S. Leggatt, Warminster, Aris & Phillips, 1995, II, 4, 287a23-30. Cf. also ID., *Physics*, transl. by P. H. Wicksteed and F. M. Cornford, Cambridge, 2 vols, Harvard University Press, 1948, vol. 2, VIII, 9, 265b8: "It is rotation (of the farthest heavenly sphere) that is the measure (in time) of all movements, wherefore it must be primary, for it is by primary in their kind that all things are standardized or measured. And again it is because rotation is primary that it is the measure of all other kinds of movement or change".

Since astronomers found that the fixed stars do not perform their diurnal motion in exactly 24 hours but have a minimal delay (which results in the precession of the equinoxes), the perfect motion was reassigned to a ninth sphere, or even to a tenth or eleventh sphere when astronomers found further 'irregularities' or departures from the perfect 24-hour motion of the fixed stars. These spheres did not transport any celestial bodies (and thus Bruno alludes to their invisibility due to their lack of association with a celestial body) and bore the sole function of performing the 'regulatory' 24-hour primary motion of the universe. In the wake of other critical responses to the theoretical nature of geocentric astronomy and the unnecessary proliferation of celestial spheres, Bruno entirely rejects the existence of the "regula", which vanishes the moment the diurnal motion is attributed to the earth's axial rotation, as in the Copernican theory.[59] However, the above passage entails a criticism of the *locus* of the primary uniform motion of the universe (the "measure and term of comparison" for the other motions), as well as the very existence of circular motion in the universe.

The possibility that a planet or a star moves according to circular uniformity is undermined by the physical homogeneity of the universe. Bruno posits that the physical universe is formed by the four primary elements that are commonly considered to form the terrestrial region only. In this case, Bruno turns the Aristotelian theory of the elements against Aristotle himself, extending part of terrestrial physics to the celestial bodies. As a consequence, Bruno can argue that celestial bodies are not simple, but mixed, and thus their motions are not simple (as Aristotle wanted), but mixed as well, that is, not solely circular, but a composite of both circular and rectilinear. From this point of view, the elemental composition of the universe and of the bodies within it removes the possibility of the existence of perfect circular motion. Bruno sums up this argument in these terms:

> Simple and regular motion cannot be attributed to celestial bodies, so that we easily conclude – and this is evident to Aristotle as well as anybody else – that simple motion can only exist in simple bodies.[60]

The implication is that since for Bruno celestial bodies are not simple but compounds of the primary elements, their motions cannot be simple, that is, perfectly circular (and possibly uniform)

[59] Cf. Copernicus's criticism of the proliferation of spheres, and the presentation of the earth's motion as a solution, in *De revolutionibus*, III, 1 (ref. 34), f. 63v. Similarly, in Thomas DIGGES, *A Perfit Description* (ref. 17), pp 86-87: "The first and highest of all is the immoveable sphere of fixed stars, containing itself and all the Rest, and therefore fixed as the place universal of Rest, whereunto the motions and positions of all inferior spheres are to be compared. For albeit sundry Astrologians finding alteration in the declination and Longitude of stars, have thought that the same also should have his motion peculiar: Yet Copernicus by the motions of the earth saveth all, and utterly cutteth off the ninth and tenth spheres, which, contrary to all sense, the maintainers of the earth's stability have been compelled to imagine".

[60] *De immenso*, III, 6 (BOL, I, i, p. 365): "Motus illum semplicem atque regularem in astris non dari posse inde facillime concludimus quod et Aristoteli et omnibus tanquam manifestum supponitur, motum simplicem non nisi in corporis simplicis esse posse."

because they obey the same laws that regulate the motions of terrestrial bodies. In turn, their mixed bodies produce compound motions that are neither circular nor straight.[61] This argument leads back to the "simple" and "regular" primary motion of the Aristotelian universe, and to the premise of the spherical shape of the universe, both of which are rejected by Bruno.[62] As stated above, the diurnal motion is performed by the earth, whose motions are directed by its soul. This fundamental change redesigns celestial physics, since the "physical and metaphysical motors" of the Aristotelian philosophy are "destroyed, and in their place the true face of nature, wisdom and virtue returns. And this mover, without any geometrical rule ("regula"), without circles, restores the true aspect of things".[63]

This line of argument takes Bruno far from the idea of harmony and symmetry supported by Copernicus, an idea whose roots are found in the spherical cosmos and in its nexus with circular uniform motion. Contrary to the Italian dialogues, *De immenso* contains explicit rejections of the idea of cosmological perfection based on sphericity and circular uniformity. Harmony and symmetry are now framed as intellectual artefacts. The two terms do not correspond to any real relation between beings in the universe, but are fabrications that serve the purpose of hiding the true face of nature (in this case, the real motions of the planets). There is no common geometrical measure, no need to find new circles and add them to the old ones "in order to adapt the order of nature to your symmetries".[64] There is no exact "norm" that unites the motion of the celestial bodies, nor do their motions return twice to the same path: their irregularities cannot be reduced to circular uniformity, and thus to an idea of harmony that is rooted in geometry (or in geometrical dynamics, as in the period-distance relationship): "orbits and revolutions are irregular, and therefore there cannot be a circle around a central point".[65] As circular motions do not exist in nature, the astronomers' efforts to save the anomalies of the celestial motions by way of combinations of circles are inadequate, an attempt to save from failure the principle of circularity. Bruno condemns the attempt to use circle-based models to explain phenomena that defy circularity and, consequently, the possibility that a "commensurable" (i.e., "symmetrical") cosmological system

[61] On the details of these motions see Dilwyn KNOX, "Bruno's Doctrine of Gravity, Levity and Natural Circular Motion", *Physis*, n.s., 38, 2001, pp. 171-209.

[62] Cf. *De immenso*, III, 6 (BOL I, i, p. 365): "Quod vero ad motus, quos in suo universo contemplantur Peripatetici, atque consimili farina insaginati astronomi, si aliquis unus regularis atque simplex est, is maxime est diurnus, quapropter cum irregularitatem vidissent in suo illo stellifero contra aristotelicas suppositiones et positiones, egressi sunt ad motus diurni primum subjectum coelum superius, quasi motus illus principium a circumferentia esset petendum omnino, etiam ubi quispiam infinitum dixerit universum".

[63] *Ibidem*: "En ubi dii illi metaphysicique motores, quorum interitu, vultus tum naturae tum sophiae tum virtutis, omnis redit".

[64] Cf. *ibidem*: "Et hic motor, nullis geometriae regulis, nullis circulis eundem rebus vultum restituit, sed semper omnia innovaturus in gyrum spiralem et hunc, quem nullo etiam geometrico canone possis satis assequi, compellit ire. Quid ergo opus est circulos circulis, orbes orbibus apponere, quasi veritatem aliquando geometricam adsequuturus, et non tuam ineptiam naturae, sed naturae ordinem ad tuas symmetria aptaturus aliquando?"

[65] *Ibidem*: "Irregulariter recursus seu revolutiones fieri, nullum consequenter circulum circa medium esse posse."

could emerge from the combination of parts that are not "symmetrical": "there is no error or deviation that our experts don't want to save with geometrical arguments so that the symmetrical can be constituted from what defies measure".[66] Bruno's discussion of the Copernican theory in the last chapters of *De immenso* follows from the rejection of the principles that are at its origin, while in the *Cena*, as seen above, it is the exact opposite. There, Bruno declares his theory as not consistent with the harmony and symmetry of the cosmos.

4. COPERNICUS RECONSIDERED (*DE IMMENSO*, BOOK III, 9-10)

The discussion of *De revolutionibus* and celestial motion in the two final chapters of *De immenso*, Book III, should be examined in view of the arguments posited in the previous sections, where circularity of motion and celestial harmony were dealt with in critical terms. *De immenso*, III, 9, is introduced by the celebration of Copernicus' divine intellect. This is a familiar narrative for Bruno. It appears in previous works (*Cena* and *Oratio valedictoria*) and recalls a literary trope from George Joachim Rheticus' *Narratio prima*.[67] In the following part of the chapter, criticism of the Aristotelian philosophy leads Bruno to take into consideration some tenets of Pythagoras and of Neoplatonism. A group of philosophers (Timaeus, Pythagoras, Icetas and 'Aegesias': Bruno takes them from Ficino) are indicated as early supporters of the earth's movement, so that heliocentrism is connected to an ancient philosophical tradition alternative to Aristotle.[68] In the prose section, long passages from the first book of *De revolutionibus* are appropriated and commented by Bruno in a fashion not dissimilar to the one used in the *Cena* when Osiander's letter was translated into Italian and sections of the text discussed by the interlocutors of the dialogue. In this case, however, different literary strategies are used. At times the text reads as if it were a dialogue, where the voices of the characters (Bruno, who now speaks in first person, and Copernicus) are signposted to the reader by the use of appropriate *verba dicendi*. At other times, the boundaries between the two are less identifiable, as Bruno's text appropriates passages from Copernicus and combines them with his own through a selective method. Briefly consider two extracts from *De immenso*, III, 9. The first one is distinctly dialogic:

> [Bruno:] Heic quibus te verbis divinis ille tuus Genius incitarit, *ego referam*. [Copernicus:] "Hominis philosophi cogitationes a vulgi iudicio sunt remotae propterea quod illius studium sit in rebus omnibus inquirere veritatem

[66] *Ibidem*, p. 366: "ut de ametro symmetrum constituant".
[67] Cf. GRANADA, "L'interpretazione bruniana" (ref. 1).
[68] KNOX, "Ficino, Copernicus and Bruno (ref. 12), pp. 340-342, 352-355.

per se"; [B.] cui istud mercenarium et ignobile etiam sub philosophiae titulo recepta mendacia anteponit; […] *At tu. Inquiebas …*[69]

Shortly after, Copernicus' dedication to the Pope is summarised as a list of points, variously interspersed with Bruno's own considerations. Simonetta Bassi has aptly compared Bruno's approach to the text of *De revolutionibus* to intarsia inlays expertly assembled together, such as in the case below, where Copernicus' famous sentence "mathemata mathematicis scribuntur" and appeal to the Pope are juxtaposed with Bruno's own text and concepts:

Octavo, "nam mathematica mathematicis scribuntur, quibus et hi nostri labores si non fallit opinio, a reipublicae ecclesiasticae fine abhorrere non videbuntur"; ideoque, doctissimorum et prudentissimorum iudicio et authoritate fretus, futurum arbitror ut a calumniarum fine immunis maneam et illaesus, licet si in proverbio: "non est remedium adversus sychophantae morsum".[70]

In the second case, Bruno omits the reference to the Pope, which may have been outdated and out of place in a work dedicated to a Protestant prince, and adds the proverb from Erasmus' *Adagia* that was quoted by Copernicus a few lines beforehand. The final effect is that the meaning of the original text departs from Copernicus' intentions, who sought papal protection against the attacks of the "mataiologoi"; Bruno now turns the text on common ignorance.

Heliocentrism, the earth's motion and celestial harmony are present as well in the first part of *De immenso*, III, 9. The chapter's prose reproduces the entire section of *De revolutionibus*' dedication dealing with the uncertainty of astronomers over the planetary models and the following passage on the cosmological symmetry ("mundi forma ac partium ejus certa symmetria"). Bruno's interventions on this point are minimal. [71] Similarly, the second part of the prose of III, 9, dedicated to the earth's motion, revisits in its entirety and with minimal linguistic variants the text and the illustrations of *De revolutionibus*, I, 11, that is, the chapter where Copernicus deals with the three

[69] Italics and inverted commas are mine: the text within inverted commas is adopted with small variations from COPERNICUS, *De revolutionibus* (ref. 32), p. 249: "Et quamvis sciam, hominis philosophi cogitationes esse remotas a iudicio vulgi, propterea quod illius studium sit veritatem omnibus in rebus, quatenus id a Deo rationi humanae permissum est, inquirere, tamen alienas prorsus a rectitudine opiniones fugiendas censeo." On Bruno's variants to Copernicus' text and more in general on his strategy in the first section of this chapter, cf. the remarks by Simonetta BASSI, "Il Copernico di Bruno", in ID., *L'incanto del pensiero: studi e ricerche su Giordano Bruno,* Rome, Edizioni di Storia e Letteratura, 2014, pp. 128-129.

[70] *Ibidem* (my emphasis). Cf. COPERNICUS, *De revolutionibus*, (ref. 32), p. 253: "Mathemata mathematicis scribuntur quibus & hi nostri labores, si me non fallit opinio, videbuntur etiam Reipublicae ecclesiasticae conducere aliquid, cuius principatum tua Sanctitas nunc tenet". The proverb at the end of the sentence comes from Erasmus, *Adagia*, 2.6.29 "Non inest remedium adversus sycophantae morsum".

[71] Cf. *De immenso*, III, 9 (BOL I, i, pp. 383-384): "Secundo, quia non est illis ratio cur propter varium indagandi motum mihi improperent, ubi *in constituendis motibus tum solis et lunae, ut dictum est, tum aliarum quinque errantium* [the text follows, with small variants, the *Praefatio* until "videntur contravenire": cf. COPERNICUS, *De revolutionibus* (ref. 32), pp. 250-251]. Tertio, quia *rem praecipuam, idest, mundi formam ac partium ejus certam simmetriam non potuerunt invenire, vel ex illis colligere* ... [continues to "procul dubio verificarentur", *ibidem*, p. 251].

motions of earth.[72] The only significant variation is that Bruno breaks the chapter up in three paragraphs with individual titles ("Definitio triplicis Terrae motus per Copernicum"; "Demonstratio triplicis motus" – similar to the title of the original "De triplici motu telluris demonstratio"; "Quod non omnino aequales sint motus centri et inclinationis").

The final two chapters in the third book of *De immenso* are inextricably linked together, as the second one provides a critical analysis of Copernicus' motions for the earth as expounded in the previous one. In fact, the second and final sections of *De immenso*, III, 9, can only be considered in relation to the following chapter, where Bruno's interpretation of Copernicus' motions for the earth represents yet another controversial point of his cosmological theory. Instead of three motions of the earth, as with *De revolutionibus* – diurnal on its axis, annual around the sun, and declination motion –, the *Cena de le ceneri* considers four motions, the first two of which roughly correspond to the first two Copernican motions. Bruno's third motion, or 'hemispherical', is the precession of the equinoxes, which Copernicus solved by positing a small difference between the periods of the second and third motions. As for the fourth motion Bruno posits a shift of the earth's pole in order to account for the trepidation of the fixed stars.[73] Differently, *De immenso* considers two motions only in relation to Copernicus, the diurnal and the annual. He also rejects Copernicus' "motus declinationis" (which Bruno calls "inflexio" or "inclinatio convertibilis"),[74] and reconsiders his own fourth motion independently from Copernicus.

Furthermore, while discussing the earth's motions Bruno gradually shifts the attention to the planets closer to earth. After the critique of the third motion, Bruno extends the discussion to the moon, Mercury, and Venus. As the earth performs an annual revolution around the sun, so every other planet does as well, including the moon and the two inferior planets (fig. 3).[75] That this arrangement of four planets (earth and moon, Mercury and Venus) on two orbs is an extension of the model of the *Cena* is explicitly indicated by Bruno, who refers to Copernicus' arrangement of the earth and moon interpreted according to the text and illustration of the *Cena*, that is, as per their

[72] Cf. *De immenso*, III, 9 (BOL I, i, pp. 385-389)

[73] On Bruno's reception of Copernicus' terrestrial motions in the *Cena*, see OMODEO, "Giordano Bruno and Nicolaus Copernicus" (ref. 8). This groundbreaking article revises previous scholarly knowledge (Tocco and Schiaparelli, Michel, Ingegno, and Gatti) in light of newly found sources used by Bruno (Peurbach's *Theoricae novae planetarum*).

[74] Cf. *De immenso*, III, 10 (BOL I, i, p. 393): "Satis enim Tellus assequitur finem suum variandorum temporum, et mensurae lucis ac tenebrarum, calidi atque frigidi, si cum motu diurno componat obliquum circa solem circuitum absque tertio illo motu". See INGEGNO, *Cosmologia e filosofia* (ref. 1), pp. 67-70.

[75] *De immenso*, III, 10 (BOL I, i, p. 394): "Mihi vero longe magis naturae consentaneum videtur, ut Tellus, ultra motum diurnum, quo proprii aequinoctialis circulum describit, pro secundo annuo motu, eodem ordine ab occasu ad ortum aequinoctialem terat nostri seculi lineam; [...] Sicut et judicamus planetarum reliquorum singulos immobilem habendo axem ad sibi constitutos polares circulos, quos axis extremitatibus delineent; annuos circa solem medium percurrere circuitus; quod manifeste in luna comperiri potest." The annual motions of the planets around their stars are further enquired in *De immenso*, V, 8 (BOL I, ii, pp. 144-145).

common annual motion around the same epicycle.[76] From this point of view, the planetary model discussed at the end of the chapter (and of *De immenso,* Book III) seems to be recomprised within a genealogical relation with Copernican heliocentrism. This relation is explicitly acknowledged and based on the assumption that the arrangement of the motions of Mercury and Venus, as well as the earth and the moon, derives from the Copernican theory mediated and revisited through Neoplatonic and Pythagorean sources, which are also present in this chapter.

However, looking more closely at Bruno's final argument, it becomes clear that *De immenso* departs from Copernicus further than the *Cena*, and not only on the mutual positions of the four inferior planets. The final section of *De immenso* III, 10 appeals to astronomers, alerting them of the existence of a physical argument according to which planetary motions are not circular or based on a combination of circles, but that they take the form of "spirae". After all, the "spira" is better suited to represent planetary motion because it is more consonant with nature:

> In turn, do Earth and Mercury seem to be less elongated from the sun? Therefore, Venus (K) and the moon (M) are farther away from the sun, as we show in this diagram [fig. 4] according to a rather confused and concise argument, since it is not easy for us to reach a satisfactory arrangement given the proliferation of circles or (as it is really in agreement with nature) spirals. [...] Let it suffice to have shown such an argument to the most expert astronomers so that they can investigate themselves better than I can. [77]

No more details are provided at this stage, but, as seen above, Bruno mentioned "spiral" (or "helical") motions earlier on in *De immenso*, and in fact in another previous work as well. The reference at the end of *De immenso*, III, 10 thus comes at the end of an argument that develops from the central chapters of the third book in *De immenso*. The argument comes to a conclusion at the end of the final chapter. In fact, no other discussion of the spiral motions is present in *De immenso* beyond the third book.

5. Spiral motions and cosmological harmony

[76] *Ibidem*, p. 396: "Sunt ergo mihi quattuor haec astra tanquam in duobus orbibus computata, quemadmodum Copernicus ex Luna et tellure non sine laudabili ratione constituit, haud quidem respectu habito ad discontinuitatem et absolutionem, quam habent inter se, atque minores ad solem habitudines: sed ad continuitatem, nempe socialem concurrentiam quam annuo motu habent circa solem".

[77] *Ibidem*, pp. 397-398: "Tellus et Mercurius vicissim a corpore solis minore videant elongatione feriare? Hinc vero K Venere inde vero M Luna magis a sole recedentibus, quod in hoc schemate, ut compendiosiore, ita et confusiore ratione designamus quandoquidem neque facile est nobis circulorum multiplicatione vel (ut revera naturae consentaneum) spiralium, felicem compositionem ut possimus adducere [...]: ideo solertioribus Astronomis rei tantae ita monstrasse locum sufficiat, ut ipsi per se ipsos, melius quam ego, indicare possim."

Bruno's first reference to spiral motions, as far as I can ascertain, is in the *Camoeracensis Acrotismus* published in Wittenberg in 1588. The concept is then developed at some length in *De immenso*, Book III, while considerations on the geometric construction and properties of the line are added in *De minimo*. Some of Bruno's arguments on the 'spirals' do not provide enough details, and conceptual difficulties are sometimes marred by obscure expressions. However, the overall intention and function of the spiral motions can be untangled in relation to the critique of the geometrical models used by the astronomers and the rejection of the principle of circular uniformity. Both aspects are developed in the central chapters of *De immenso*, Book III (and occasionally elsewhere) and find their conclusions in *De immenso*, III, 10, that is, together with Bruno's final considerations on Copernicus.[78]

In the *Acrotismus*, non-circular motion is introduced during the discussion on the Aristotelian idea of time (article XXXVIII, *De tempore*). Since Aristotle defines time "mensura motus" in relation to the circularity and regularity of the primary motion of the universe, that is, the diurnal motion of the heavens, celestial motions are a relevant part of this section of the work.[79] Bruno's contention is that the earth's mobility shatters the Aristotelian theory of time, since the diurnal motion is attributed to the earth and thus configured as a particular motion of one of the planets, while other planets perform their "diurnal motions" in different times. This concept is explained with reference to the apparent motions of the planets, introduced by Copernicus to explain both retrograde and annual motions. Thus, since each planet and star performs a rotation on its axis in a particular time, there will be as many "measures" ("regulae") as there are planets and stars, and therefore the 24-hour motion loses its universal significance.[80]

A second point raised with respect to time and celestial motion concerns the geometrical form of the motions themselves: all circular orbits are called "circles" only inappropriately and inaccurately ("nisi usurpato nomine... neque fideliter").[81] The diurnal motion takes place on a "linea

[78] Previous scholars who have dealt with the issue have all underlined this aspect: cf. TOCCO, *Le opere latine* (ref. 54), pp. 245-246; MICHEL, *The Cosmology of Giordano Bruno* (ref. 1), pp. 215-216; Luciana DE BERNART, *Numerus quodammodo infinitus. Per un approccio storico-teorico al dilemma matematico nella filosofia di Giordano Bruno*, Rome, Edizioni di Storia e Letteratura, 2002, pp. 40-42 writes at some length on the spiral in the context of Bruno's possible sources (Cusanus in particular), but does not deal with the import of the concept for Bruno's critique of Aristotle's cosmology and its use in *De immenso*.

[79] Cf. the title of the article, in *Acrotismus camoeracensis*, art. 38 (BOL I, i, p. 143): "Tempus quod est mensura motus, non est in coelo, sed in astris, et primus ille motus, quem concipimus, non est alibi, quam in terra subjective. On Bruno's conception of time in relation to Aristotle's, cf. Miguel A. GRANADA, "El concepto de tiempo en Bruno: tiempos cósmicos y eternidad", in *La filosofia di Giordano Bruno: Problemi ermeneutici e storiografici,* Convegno internazionale, Rome, 23-24 October 1998, ed. by Eugenio Canone, Florence, Olschki, 2003, pp. 85-113: 105-111.

[80] Cf. BRUNO, *Camoerancesis Acrotismus*, art. 38 (BOL I, i, pp. 143-144). Cf. also the references to *De revolutionibus*, I, 5, in ID., *Acrotismo cameracense* (ref. 42), p. 103 note 1.

[81] Cf. ID., *Acrotismus camoeracensis*, art. 38 (BOL I, i, p. 144-145): "Porro revera omnes circuli, qui videntur et verificantur in coelo per nostros astronomos, non sunt nisi usurpato nomine circuli, neque fideliter per circuli canones judicari possunt. Regula igitur motus diurni, sive a sole capitur solo, sive a terram tantum motu, sive ab utroque, sive ab

helica" which defies geometrical laws as well as the possibility of a common measure (i.e., commensurability or "symmetria"). The definition of the 'helix' provided at this point reflects the focus of the text on the diurnal motion and the dichotomy between its interpretation as a common measure, according to Aristotle, and the observation that it does not follow geometrical rules. The defining point of the passage, in contrast with the "regula" of the diurnal motion, is that it is not possible to divide these motions "regulariter". With this word, Bruno means that bodies moving with helical motion cannot move uniformly ("aequalis omnino"), nor according to exact measures ("exacte ad rationem").

This passage can be further illustrated with reference to Aristotle's analysis in *Physics*, V, 4 of the irreconcilable difference between the uniformity and non-uniformity of motion. Aristotle posits that bodies move either uniformly or non-uniformly.[82] In the first case, they move on either a straight or a circular line. Non-uniformity occurs on non-uniform courses, which Aristotle defines as made up of parts that are different from each other. The examples he provides include a line bent back at an angle and the "spiral" ("helix" in the Greek original). The meaning of this distinction is that, while each part of a uniform line, i.e., a circle or a straight line, is formed by equal parts (e.g., arcs with the same radius, or line segments), the parts of non-uniform lines, including the spiral, are unequal, that is, they may comprise both arcs and segments, or arcs with different radii. Non-uniformity is also applied to speed. Motion in which speed is always equal is said to be uniform, while motion from unequal speed is said to be non-uniform. Uniformity of motion only applies to uniform lines. Aristotle rejects the possibility of uniform motion on non-uniform paths since, while uniform and non-uniform belong to the same category, non-uniformity presupposes a smaller degree or quantity of the same category, and therefore, similarly to gravity and levity, where less heavy means a certain quantity of lightness, non-uniformity cannot be said to be a unity or a continuum.[83]

Aristotle's line of argument helps to provide a frame of reference for Bruno's brief considerations on the "linea helica" in the *Acrotismus,* illuminating the comparison between uniform and non-uniform motions and their characterisation in terms of deviation from the perfect regularity of circular uniformity. This aspect is reflected in the finale of *Acrotismus*' articles on time, where the difference between uniform and non-uniform (and therefore between circles and

his, sive ab aliis circuitibus, nulla est prorsus, neque esse potest geometrica: si quippe regulariter dividere lineam helicam non est possibile, et motus supra ea aequalis omnino et exacte ad rationem, non est naturalis".

[82] ARISTOTLE, *Physics*, V, 4, 228b19-30 (ref. 58). The reference to this passage is in Barbara Amato's translation of the *Acrotismus*: see BRUNO, *Acrotismo cameracense* (ref. 42), p. 103 note 4.

[83] Cf. ARISTOTLE, *Physics* (ref. 58), V, 4, 229a1-8: "A movement that is not uniform, then may have a certain unity, in virtue of its continuity in time, though a lesser unity than if it were uniform. An instance would be a movement on a line bent back at an angle. This 'lesser', here as elsewhere, implies an admixture of the contrasted principle. And since any kind of continuous change may be either uniform or not, changes that succeed each other without interval, but are not of like kind, cannot be one and continuous"

'helix') is taken as an exemplification of the divorce between geometry and physics: "The quantity of motion and a uniform geometrical figure never correspond to a uniform physical motion, mass, and figure".[84]

In *De immenso*, Bruno revisits and expands the points made in the *Acrotismus* in connection with the critique of perfect circular motion and the underlying problem of the rapport between physics and its mathematical and geometrical representation. The first reference occurs in *De immenso*, III, 5, where the (apparent) motion of the sun around the earth is said to be a spiral ("solis linea spira est/ Tellurem cingens").[85] Bruno, who tends to use "spira" in *De immenso* more frequently than "helix", claims that tracking the sun's shadow on a sundial does not result in a circular line ("cyclum geometricum") at whose centre we find the earth. However, no mention is made about the fact that the sun's shadow traces a line with the shape of an elongated "8" or "analemma", nor does Bruno provide any detail about its properties and eventual use to explain planetary motion. Rather, his interest is to establish that all celestial motions move along spirals, and that therefore spirals conform to nature better than circles. Bruno develops this point as an argument against the circularity of the celestial motions: since celestial bodies are formed by a mixture of elements ("glomeratio materiei"), their motions cannot be simple and uniform.[86] The further consequence that emerges from these pages is that the regularity of natural phenomena and the order of nature are not undermined by the disappearance of perfect circularity: nature is able to govern itself and the beings within its body according to laws different from mathematics.[87]

More details on the geometrical construction of the spiral are provided in the following chapter. *De immenso*, III, 6 introduces the idea of an eternal spiral motion of the celestial bodies composed of a combination of circular and rectilinear motions, or of unequal circles or spirals.[88] These passages are linked by Bruno to one of the diagrams in the *De minimo*, the "Unio" (fig. 4). This illustration resembles an astronomical model of deferent-epycicle, but the text does not provide any information on how such a geometrical model can explain celestial motion. The figure may perhaps be interpreted as an example of how the combination of circular motions can produce

[84] BRUNO, *Acrotismus*, art. 40 (BOL I, i, p. 150): "Et pro satis comperto habemus, nusquam motus quantitati et figurae geometrice aequali, physice aequalem motum, molem, atque figuram respondere".

[85] *De immenso*, III, 5 (BOL I, i, p. 349). Cf. TOCCO, *Le opere latine* (ref. 54), pp. 245-246 for a reference to Girolamo Fracastoro's *Homocentrica* as a possible source for Brunos' spiral.

[86] *De immenso*, III, 5 (BOL I, i, p. 350): "Spira est in facie, inque ipso spectanda profundo,/ Quam male cyclorum canones aequare laborant,/ Quamlibet ad tempus male cautos fallere suerunt,/ Nec studiis poterit nostris ea spira reponi,/ Naturae quae sit spirae conformis, at inquam/ Nec natura aequa procedit lege reperta/ Per rationis opus numeratoque ordine firme,/ Quam minime patitur glomeratio materiei".

[87] *Ibidem:* "Naturam ipsius moderari lege novantem/ Omnia, ut e quovis quidvis disponat: ob idque stulte disponi res credunt lege mathesis".

[88] *De immenso*, III, 6 (BOL, I, i, p. 366): "Quid spiralis motus compositionem, vel distributionem, vel (ut dicere mavis) divisionem in duos circulos confabricas, si spiralem motum atque lineam non magis possis dicere ex duobus imparibus circulis compositum quam ex duabus (ut et certe longe magis deceret existimare) spiralibus, ut et Aristoteles omnem motum qui non est rectus perfecte et circularis perfecte ex recto circularique compositum affirmat?"

non-circular motions of the sort that Bruno calls 'spirals' or 'helica' – the underlying question being how uniform motions can result in non-uniformity. This reading of the visual evidence is supported by several references to the geometrical construction and properties of the spiral in both *De immenso* and *De minimo*, although Bruno extends the geometrical construction of the spiral to uniform as well as to non-uniform lines. This is the case with *De immenso*, III, 6, where Bruno claims that his "method of proportion" allows us to combine two regular "helicae" or spirals into one, and vice versa to break up one into two.[89]

Bruno's approach originates from his celestial physics. Since celestial bodies have a composite nature, and since (in the wake of Aristotle) only simple substances can have simple motions, celestial motions cannot be simple (simply circular or straight) but a composite of the two. This principle was already introduced in the Italian dialogues, yet, crucially, without reference to spirals.[90] These are in fact two different, although intertwined, issues. The critique of perfect regularity in the physical world is adopted by Bruno in the wake of similar critiques, by Cusanus, for instance, who stressed the approximate rapport between physical beings and geometrical-mathematical beings. In *De docta ignorantia*, this irresoluble difference is at one stage explicitly exemplified by the relation between celestial motions and their relative geometrical models.[91] Similarly, *De immenso* draws on the idea that no material substance conforms to geometrical perfection as exemplified by the impossibility of the existence of perfect circular motion:

> Circular motion does not exist *mathematice* in matter, whatever this may be. Even more so as the Platonists said (and not in the least mistakenly) that no form can perfectly exist in matter, nor a perfect man nor a perfect horse. Nowhere will the geometer find a perfect point or a perfect line, but rather (if he knows) he will not believe they exist, nor will he define them differently from how they are commonly defined. For what concerns [celestial] motions no common measure ["mensura"], nor anything close to it, can be found. The reason for this is that all celestial bodies are constituted by heterogeneous and transmutable parts.[92]

[89] Cf. *De immenso*, III, 6 (BOL I, i, p. 363): "Duas quoque regulares elicas seu spirales in unam regularem componere, unamque regularem in duas dissolvere regulares proportionali novimus methodo".

[90] Cf. BRUNO, *Cena,* BOI, I, p. 507-508: "per che come di corpi naturali nessuno si è verificato semplicemente rotondo, e per conseguenza aver semplicemente centro, cossì anco de moti che noi veggiamo sensibile e fisicamente ne' corpi naturali, non è alcuno che di gran lunga non differisca dal semplicemente circulare e regolare circa qualche centro".

[91] Nicolaus CUSANUS, *On Learned Ignorance/ De docta ignorantia*, transl. by J. Hopkins, A. J. Banning, Minneapolis, 1991 (available at http://jasper-hopkins.info), II, 11, 160, p. 92: "And it is never the case that at two different times [a star or a sphere] is moved in precisely equal ways or that [on these two occasions its motion] describes equal approximate-circles - even if the matter does not seem this way to us"

[92] *De immenso*, III, 6 (BOL I, i, p. 363): "Mathematice enim circularis motus non est in materia, quaecunque et qualiscunque sit, immo neque ullam formam vere in materia esse Platonici dixerunt (et non omnino male), neque hominem verum, neque verum equum. Verum punctum veramque lineam geometra nusquam sua inveniet, quinimo (si sapit) neque esse credat, nisi haec aliter, quam vulgo definita sunt, ille definiat. Quod ad motus ergo attinet eorum nulla, vel quae propius accedat, mensura reperitur: cujus rei causa est quia eterogeneis astra, iisque transmutabilibus omnia constant partibus".

Referring to "Platonists", Bruno claims that perfect celestial motions are an abstraction of the geometers and that physical reality is made up of heterogeneous parts whose mixture produces composite, "irregular" motions. The topic, however, was not an exclusively Neoplatonic domain; in fact, the above passage draws from Aristotle's *Metaphysics* (III, 2). The focus of the discussion is on the existence of forms and "intermediates, with which they say the mathematical sciences deal". The examples made by Aristotle – and that Bruno reprises literally – are man-himself and horse-itself. In the second part of the passage, Aristotle stresses the hiatus between abstract, geometrical forms and physics, criticising Plato and taking astronomy as an example:

> Not the least absurdity is the doctrine that there are certain entitites apart from those in the sensible universe, and that these are the same as sensible things except in that the former are eternal and the latter perishable. For Platonists say nothing more or less than that there is an absolute Man, and Horse, and Health; in which they closely resemble those who state that there are Gods, but of human form; for as the latter invented nothing more or less than eternal men, so the former simply make the Forms eternal sensibles [...] Nor again, can astronomy be concerned with sensible magnitudes or with this heaven of ours; for as sensible lines are not like those of which the geometrician speaks (since there is nothing sensible which is straight or curved in that sense; the circle touches the rules not at a point, but <along a line> as Protagoras used to say in refuting the geometricians), so the paths and orbits of our heaven [*kinéseis kai elikes tou uranou*] are not like those which astronomy discusses, nor have the symbols [semeìa] of the astronomer the same nature as the stars.[93]

This passage resonates well with Bruno's terms of debate in *De immenso*: no perfect "straight" or "circular" motions are possible in the physical universe since sensible things are of a different nature than geometrical figures. The last lines include a reference to the "helixes" (or "spirals"). In this case, Aristotle uses the term to mean the "sensible" circumvoluted paths of the celestial bodies and to mark their difference from the geometrical descriptors (i.e., the circles) used by the astronomers. Since the references to the Platonists and their theory, including the examples of the absolute man and the absolute horse, are reprised by Bruno, the first part of Aristotle's passage can be considered Bruno's direct source. The context of the second part of the text also

[93] Cf. ARISTOTLE, *Metaphysics,* III, 2, 997b6-13, 997b34-998a6, transl. by H. Tredennick, Cambridge, Mass., Harvard University Press, 1936. W. D. Ross's 1924 translation of the last passage reads "nor are the movements and spiral orbits in the heavens like those of which astronomy treats, nor have geometrical points the same nature as the actual stars" (translation available from the Internet Classics archive at www.classics.mit.edu) . A detailed commentary of this section of *Metaphysics*, focussing in particolar on the discussion of the intermediates between forms and sensibles is by Frans DE HAAS, "Aporiai 3-5" in *Aristotle: Metaphysics* Beta. *Symposium Aristotelicum*, ed. by M. Crubellier and A. Laks, Oxford, Oxford University Press, 2009, pp. 73-104: 89-95. Cf. also the widely-circulating sixteenth-century Latin edition and translation, *Aristotelis Opera cum Averrois commentariis*, Venetiis, apud Iunctas, 1562-1574, 15 vols. (reprint Frankfurt am Main, Minerva Verlag, 1962), vol. IV, f. 44r: "Fingunt enim quod homo in illis substantiis est sicut homo sensibilis hic, et similiter equus, et taurus"; 46r: "Neque etiam scientia stellarum, et coeli istius est corporum sensibilium. Non enim sunt lineae sensibiles, sicut ponis Geometer, sicut ponis Geometer. Nulla enim res rerum sensibilium est linea recta, aut rotunda, sicut ponit Geometer. Circulus enim non tangit mensuram per punctum, sed per lineam, sicut dixit Protagoras in sua redargutione contra Geometras, neque motus coelis, et circulus eius sunt, sicut disponit scientia stellarum, neque conveniunt puncta cum stellis in natura".

seems to be in tune with the passage in *De immenso*, although Bruno may have had to read the Greek text to find the term "helix" he would then use in his own works.

In conclusion, Bruno's definition of the spiral is not geometrically accurate and the explanation of its function is fickle, but the motives for its adoption and, quite temptingly, some possible sources as well are sufficiently clear to help make any final assessment less provisional.

6. Conclusions

I hope that by the end of this study sufficient evidence has been given to show that Bruno's knowledge of heliocentrism and its implications can be extended to circular uniformity, the period-distance relation and celestial harmony. There are strong continuities between the Italian dialogues and the Latin works, but there are also distinctions to be made. In the first instance, Bruno tries to maintain that his own view of the planetary arrangement is not completely at odds with Copernicus, and that the motivations behind it are (to some extent) compatible with those held by the astronomer. Circular uniformity is the subject of a philosophical critique in the *Cena*: physical bodies and measures do not correspond exactly to geometry and mathematics, from which there derives a certain skepticism towards the possibilities of the two disciplines about achieving a sound knowledge. In the Latin works, however, Bruno departs more substantially from both Copernicus' planetary arrangement and his principles of cosmological order. While in the *Cena* the planets were still ordered according to their periods of revolution (the only exception being the earth and the moon, but they were exceptional in *De revolutionibus* as well, since the moon revolved around the earth), the Latin works we have examined present a distinct departure from both the Copernican order of the planets and the principles that inform them, up to the point that, by the end of the Copernican chapters of *De immenso*, Bruno endorses a model for the planetary motions that clearly contradicts Copernicus' principles, as well as the astronomical tradition. In so doing, he brings to fruition a working hypothesis – the "spiral motions" – into which he had begun to enquire only after he left London in 1585.

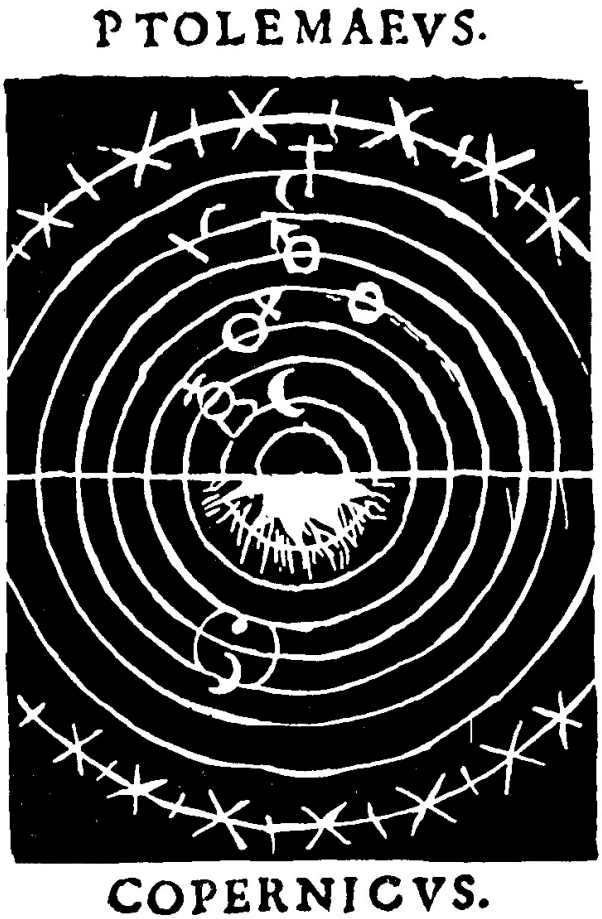

Fig. 1: From G. BRUNO, *Cena de le Ceneri* (1584), dialogo 4, fig. 7.

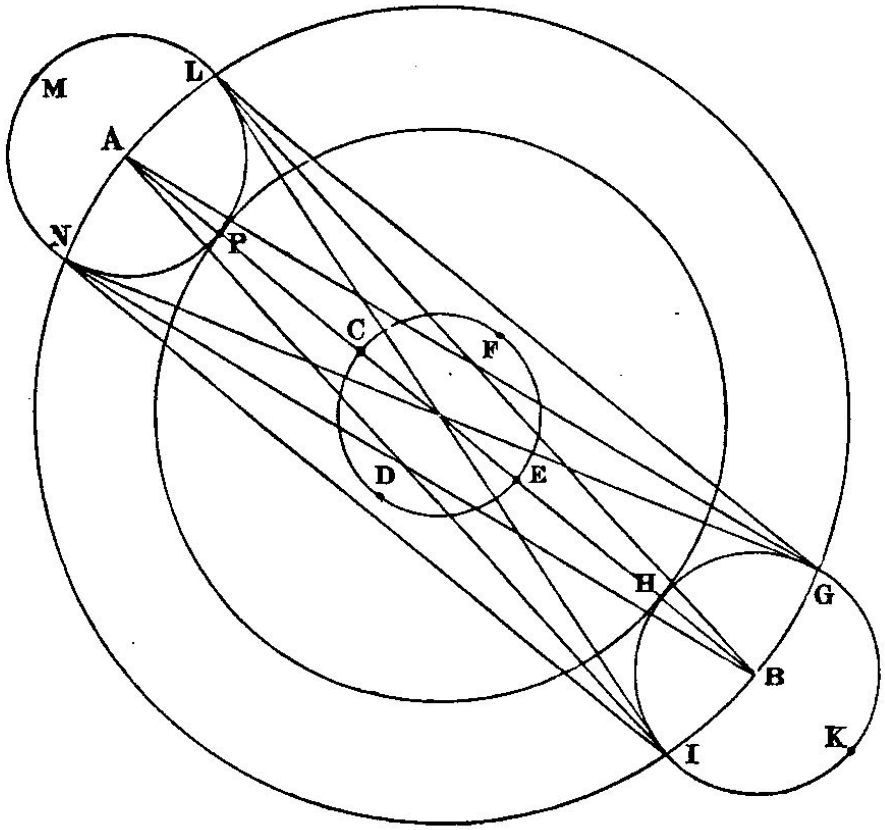

Fig. 2: From G. BRUNO, *Articuli adversus mathematicos* (1588), art. 160. The illustration is taken from the Edizione Nazionale of Bruno's works.

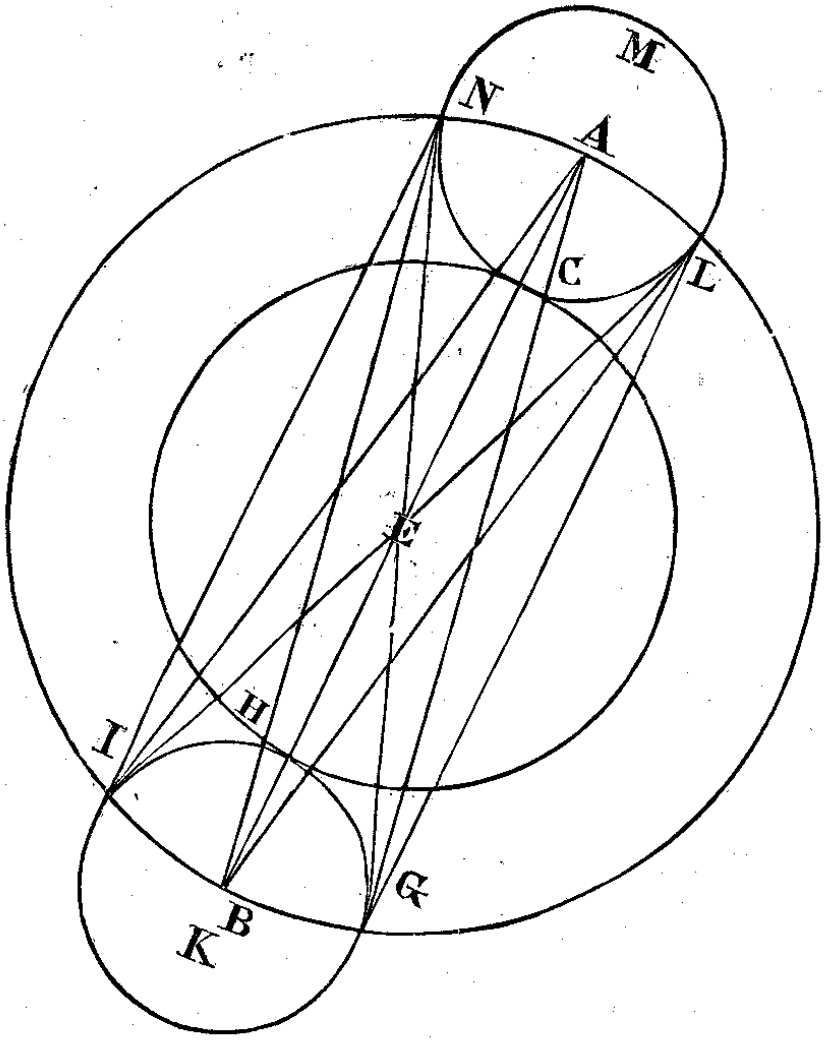

Fig. 3: From G. BRUNO, *De immenso*, III, 10 (1591). Illustration taken from the Edizione Nazionale of Bruno's works.

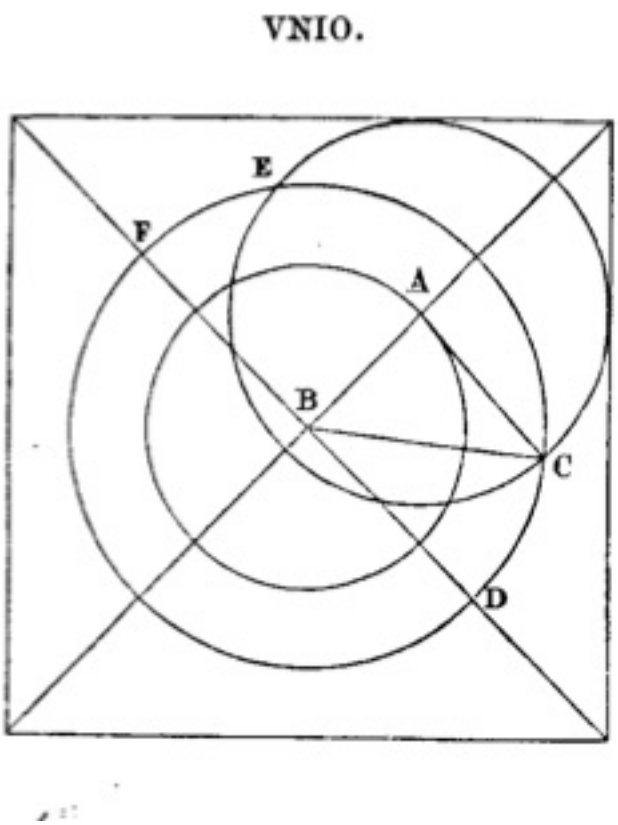

Fig. 4: From G. BRUNO, *De minimo* (1591), I, 8. The illustration is taken from the Edizione Nazionale of Bruno's works.