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GIORDANO BRUNO'S COPERNICAN DIAGRAMS

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The study of Giordano Bruno's Copernicanism has a long and distinguished history, going back to the nineteenth century and continuing until the present day. It has involved a number of prestigious scholars, both historians of science and historians of philosophy, such as Paul-Henri Michel, Alexandre Koyré, Hélène Vedrine, Thomas Kuhn and Robert Westman, among many others[1]. This notable body of comment on Bruno as one of the major Copernican philosophers of the sixteenth century will be taken as given, and mention will be made of the details of his reading of the *De revolutionibus* only when necessary to the development of our subject. This intends to be a comment on the way in which Bruno attempted to pilot a recalcitrant sixteenth-century public, convinced of the falsity of the Copernican hypothesis except within a strictly mathematical formulation of it, towards a realist acceptance of the heliocentric principle, together with much else that Copernicus himself would not have been prepared to accept. It was precisely this realist helio-

[1] Serious consideration of Bruno's Copernicanism starts with Domenico Berti's pages in *Copernico e le vicende del sistema copernicano in Italia,* Paravia, Rome 1876, pp. 76–92. For the twentieth century comments listed above, see Alexander Koyré, *From the Closed World to the Infinite Universe,* Johns Hopkins University Press, Baltimore 1957; Thomas Kuhn, *The Copernican Revolution: Planetary Astronomy in the Development of Western Thought,* University of Harvard Press, Cambridge (Mass) 1957; Paul-Henri Michel, *The Cosmology of Giordano Bruno,* Cornell University Press, Ithaca (NY) [1962] 1973; Hélène Vedrine, *La conception de la nature chez Giordano Bruno,* J. Vrin, Paris 1967; Robert Westman, "Magical Reform and Astronomical Reform: the Yates Thesis Reconsidered", in *Hermeticism and the Scientific Revolution,* University of California Press, Los Angeles 1977. More recently, Bruno's Copernicanism has been reconsidered by, among others, E. McMullin, "Bruno and Copernicus", in *Isis,* (78/1987); J. Seidengart, "La cosmolgie infinitiste de Giordano Bruno" in *Infini des mathématiciens, Infini des philosophes,* F. Monnayeur (Ed.), Belin, Paris 1992, and R.G. Mendoza, *The Acentric Labyrinth: Giordano Bruno's Prelude to Contemporary Cosmology,* Element Books, Shaftesbury 1995. See also the relevant chapters in Hilary Gatti, *Giordano Bruno and Renaissance Science,* Cornell University Press, Ithaca (NY) 1999.

centric stand, however, shared by only a small handful of his contemporaries, which involved Bruno in the attempt to visualise a new world picture; for he left to others the task of calculating more precisely the movements of the heavenly bodies. At the same time as he praised Copernicus publicly as one of the most audacious and innovative minds of all times, he also chided him for being "too much of a mathematician, and not enough of a natural philosopher"[2].

Bruno did not make the mistake of identifying Copernicus himself with the famous anonymous preface to the *De revolutionibus* written by Andreas Osiander, which advised use of the astronomical system proposed in the volume only in terms of a mathematical hypothesis. Indeed he was the first to declare publicly that Copernicus himself could not possibly have written that preface, although he seems not to have known who the true author was. But Bruno did think that Copernicus himself had not stood out strongly enough in defence of the realist nature of his own proposal. Bruno saw himself as assuming Copernicus's mantle in so far as he accepted the difficult challenge of making people see the world in its new shape, not just mathematically but physically. For Bruno, who was a philosopher not an astronomer, the new universe was the place we have to live in, and he hoped that it would be possible to live better there than in the world people had thought they were living in before. This was made all the more difficult by the fact that Bruno also extended the Copernican hypothesis to infinite dimensions, proposing not a unique universe with a single sun at its centre but an infinite world inhabited by an infinite number of solar systems. For, as Michel-Pierre Lerner has recently once again underlined, Bruno was among the first to develop a radical criticism of the finite cosmology delimited by the so-called planetary spheres. These were supposed to carry the planets round in their harmonious circles in a crystalline quintessence of Aristotelian origin: for Bruno, they were pure fictions with no physical basis at all[3]. Bruno's own cosmology derives from Epicurus and Lucretius rather than Aristotle. Space becomes an infinite envelope filled by a tenuous ether which pervades it in all its parts. Visualising our own solar system in Copernican terms thus meant for Bruno not visualising the universe as such, but visualising only a small speck of it floating within an im-

[2] The quotation is from Dialogue 1 of *La cena de le ceneri (The Ash Wednesday Supper).* All references to Bruno's Italian dialogues are to the texts prepared by Giovanni Aquilecchia in *Opere italiane di Giordano Bruno,* 2 vols., Nuccio Ordine (Ed.), UTET, Turin 2002. For the above quotation, see vol. 1, p. 449. All translations from Bruno's works in this paper are mine.

[3] See Michel-Pierre Lerner, *Le monde des sphères,* 2 vols., Les belles Lettres, Paris 1996–97, vol. 2 : *La fin du cosmos classique,* pp. 157–166.

mense and infinitely populated whole. Although to-day we have become used to seeing the earth as a minute, hardly visible point within immense vistas of space and time, such an idea at the end of the sixteenth and beginning of the seventeenth centuries appeared overwhelmingly unfamiliar and strange. Even those who had made the effort to accomodate their minds to the new Copernican system, such as Johannes Kepler, found Bruno's overall cosmological picture totally unacceptable. Kepler referred to it as Bruno's "innumerabilities", expressing concern for his friend Johann Matthaüs Wacker von Wackenfels's "deep admiration for that dreadful philosophy"[4]. On the other hand, it was precisely Bruno's conceptual leap towards the idea of an infinite universe which lead Alexandre Koyré to exclaim, four hundred years later:

> On reste confondu devant la hardiesse, et le radicalisme de la pensée de Bruno, qui opère une transformation – révolution véritable – de l'image traditionelle du monde et de la réalité physique.[5]

The Physically Real

To be sure, the criterion of scientific realism which inspired Koyré's outburst of praise for Bruno's conceptual leap into infinite space appears now as part of the "traditional" view of the so-called "scientific revolution". Proponents of the more recent historiographical criteria of contingency and scientific sociology, or social constructivism, would be quick to brand it as suspect "for want of a right reason constituted by nature"[6]. It would overrun the bounds of this paper to enter into our contemporary debate concerning the respective claims of a logical system of reasoning based on a coherent concept of scientific objectivity, and the idea of science as "a form of intellectual

[4] Johannes Kepler, *Conversation with the Sidereal Messenger recently sent to Mankind by Galileo Galilei* [Daniel Sedesanus, Prague 1610]. Translated with an Introduction and Notes by Edward Rosen, Johnson Reprint Corp., New York 1965, p. 37.

[5] Alexandre Koyré, *Etudes galiléennes,* 2 vols., Hermann, Paris 1939–40, vol. 1, p.141.

[6] The quotation, which is from Hobbes, is used by S. Shapin and S. Schaffer to question the whole concept of scientific realism. See their much discussed volume, *Leviathan and the Air-Pump,* Princeton University Press, Princeton 1985. Previous philosophical discussion concerning the problem of scientific realism had included, B.C. Van Fraasen, *The Scientific Image,* Oxford University Press, Oxford 1980, and Ian Hacking, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science,* Cambridge University Press, Cambridge 1983. For a synthesis of this discussion, see W.H. Newton-Smith, "Realism", in *The Routledge Companion to the History of Modern Science,* R.C. Olby et al. (Eds.), Routledge, London and New York 1990, pp. 181–195.

ecology rather than of inductive logic"[7]. It is worth pointing out, however, that Bruno himself, placed at the very beginning of what still continues to be called "the scientific revolution", was aware of precisely this problem, and discussed it openly in his cosmological dialogues. In the remarkable second dialogue of his major cosmological work in Italian, *La cena de le ceneri* or *The Ash Wednesday Supper,* written and published in London in 1584, Bruno pictures himself as "the Nolan philosopher" (he was born in Nola, near Naples) and sees himself as undertaking a night-time journey which will eventually lead him to the rooms of Sir Fulke Greville where the supper and the cosmological discussion were held. Travelling in an ancient creaking boat down the Thames, followed by an adventurous walk through the muddy streets of the still crowded city – metaphors of a world still enclosed within the gradually disintegrating structure of the traditional Aristotelian-Ptolomaic universe – Bruno notes how on the way he cannot avoid meeting with "a princely palace here, there a wooded plain with a glimpse of the sky lit by the morning sun"[8]. The dialogue continues by offering a wealth of further information about the London of the day: how the unfriendly English servants dress and behave, the affectations and at times the arrogant behaviour of Bruno's aristocratic hosts, how wine at table was drunk out of a communal cup (complete with only half-hidden references to the Protestant transformations of the rituals of the Catholic mass). Such was the social context in which a cosmological discussion based on Bruno's reading of Copernicus's *De revolutionibus* was held on the evening of Ash Wednesday, 1584, in the rooms of Sir Fulke Greville, friend and future biographer of Sir Philip Sidney whom Bruno praises in his work as one of the most brilliant minds of his time. Bruno is aware that all this cannot but affect the way in which Copernicus's book was being read and discussed in London on that momentous evening.

Nevertheless, having dealt with such "preliminaries" in the first two dialogues of the *Supper,* in the third dialogue, where the cosmological discussion properly begins, Bruno does call upon a criterion of physical objectivity in his defence of the Copernican astronomy. He does this in the first place by mounting a bitterly ironic attack on the writer of the anonymous preface, whom he brands as an unfaithful doorkeeper of Copernicus's new edifice. This in itself is clearly a metaphor pregnant with important meanings; for an

[7] See Stephen Toulmin, "From Logical Systems to Conceptual Populations", in *Boston Studies in the Philosophy of Science,* (8/1971), R.C. Buck and R.S. Cohen (Eds.), pp. 552–64. For a balanced discussion of the recent debate concerning scientific realism, see H. Floris Cohen, *The Scientific Revolution: a Historiographical Enquiry,* Chicago University Press, Chicago and London 1994, pp. 230–36.

[8] See the *Argomento del secondo dialogo,* in *La cena de le ceneri,* op. cit., p. 434.

edifice must have its mathematical co-ordinates, but it is evidently in the first place a physical construction. Although "set" within a definable social, geographical and historical landscape, nevertheless an edifice constitutes an autonomous architectonic structure within which its inhabitants live, move and create their world. There is clearly a sense in which a physical edifice is more "real" than the mathematical calculations which have served to create it or than the social and historical context within which it has been built. Bruno's choice of metaphor, at the very beginning of the discussion of Copernicus's book which the final three dialogues of *The Ash Wednesday Supper* narrate, is thus a conceptually appropriate one with which to define the complex but nevertheless "realist" terms in which, as the Nolan philosopher, he intends to conduct the debate.

Robert Westman, in what he has called the "Wittenberg interpretation" of Copernicanism in the sixteenth century, has demonstrated how rare were the early attempts to read the new astronomy in realist terms, in the Protestant parts of Europe as well as in the Catholic ones. He includes Bruno among the very few Copernican realists active in sixteenth century Europe[9]. Undoubtedly, given the fact that the discussion narrated by Bruno in the *Supper* took place in London, and that he wrote about it and published his work in that city, the most important precedent to Bruno's realist stand was that of Thomas Digges. First published in 1576, and presented somewhat slyly as a mere addition to his father's completely traditional work on astrology, in particular in its practical application to weather forecasting, *A Prognostication Everlastinge,* Digges's few Copernican pages are partly direct translation from book I of *De revolutionibus*, and partly stringent comment on their implications. Unlike Bruno, Digges does all he can to avoid underlining the "revolutionary" nature of the Copernican proposal. In so far as he also sees it as opening out the universe to possibly infinite dimensions, he proclaims his entirely traditional acceptance of the four elemental spheres reaching as far as the moon, surrounded by a crystalline semi-divine substance identifiable as Aristotle's quintessence. Thus, for Digges there is only one solar system, not an infinite number as Bruno would proclaim. So Digges saw no need for his readers to be alarmed by the new astronomy, and he precedes his Copernican pages with the picture of a ship sailing in calm waters: presumably a tranquilizing message to Sir Edward Fines, the Lord High Admiral, to whom the book, in his father's name, is dedicated. Within this overall strategy of underplaying the innovative aspects of his own pages, it is entirely character-

[9] See Robert Westman, "The Melancthon Circle, Rheticus, and the Wittenberg Interpretation of the CopernicanTheory", in *Isis,* (66/1975).

istic of Digges that he should give his key punch for a realist reading of the heliocentric proposal almost in a throw-away aside. It is not clear how many of his English readers (for Digges was writing in English rather than in Latin, as his father had done before him) understood the literally world-shattering implications of his claim:

> Copernicus mente not as some have fondly excused him to deliver these grounds of the Earthes mobility onely as Mathematicall principles, fayned and not as Philosophicall truly averred.[10]

Bruno himself, on the other hand, had already discovered that even in England the waters of Copernican discussion tended to be remarkably agitated, and not tranquil at all. By the time Sir Fulke Greville invited him to supper to discuss his reading of Copernicus as well as other "paradoxes" of his new philosophy, Bruno had already been publicly derided by the Oxford dons after his attempts to explain the Copernican astronomy in lectures at the university given during the summer of 1583[11]. His own ship diagram in *The Ash Wednesday Supper* depicts stormy waters, in the course of being stirred up to further tempests by a chubby-cheeked north wind. Nevertheless, Bruno's ship image may be, and frequently has been, compared with Digges's ship in so far as both authors are concerned to argue that the impetus of a ship's movement would be "impressed" on a weight dropped from the mast, which would therefore fall vertically to the foot of the mast and not be left behind by the moving ship. This argument was already known and discussed in the middle-ages, although in an Aristotelian-Ptolemaic context. It was repeatedly used in early Copernican discussion, up to and including Galileo, to contradict the anti-Copernican objection that a moving earth would leave all the clouds and the birds behind[12]. Bruno never mentions Digges in his work (an example followed by Galileo, who never mentions Bruno, to Kepler's surprise and concern); but it seems more than likely that Bruno at least knew of Digges's work. For Digges was a pupil of John Dee, who also taught math-

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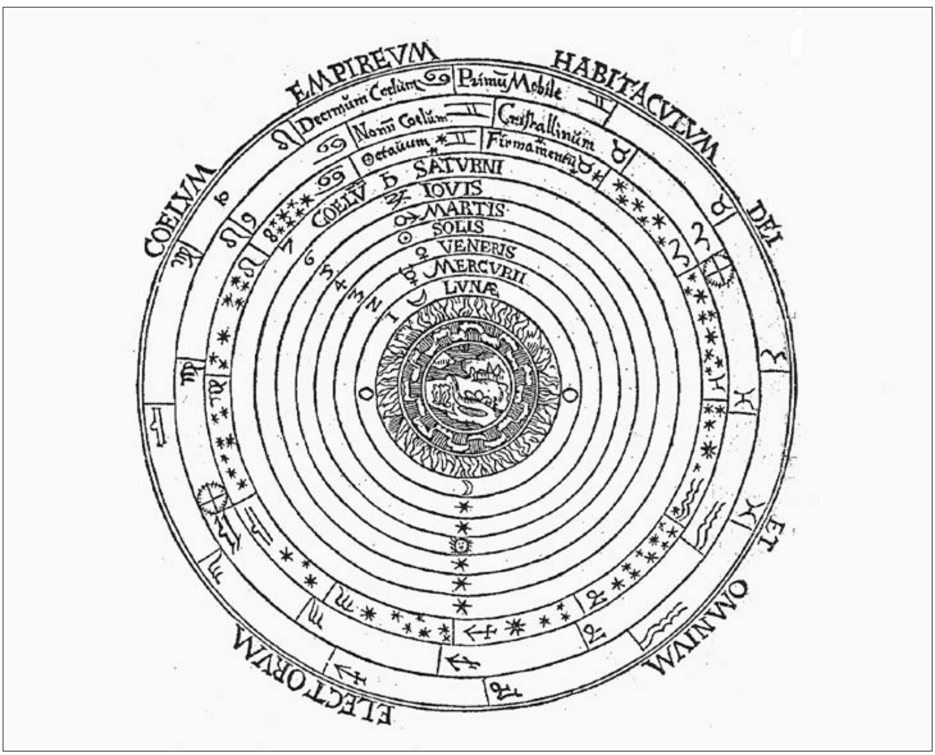
[10] Leonard Digges, *A Prognostication everlastinge … lately corrected and augmented byThomas Digges, his sonne,* Thomas Marsh, London 1576, fol. Mi, r and v.

[11] This episode, although much discussed and the subject of many conjectures, remains obscure in so far as the texts of Bruno's lectures have not survived. For the known documents, see Giovanni Aquilecchia, "Giordano Bruno at Oxford", in *Giordano Bruno, 1583–1585: The English Experience,* M. Ciliberto and N. Mann (Eds.), Olschki, Florence 1997.

[12] See D. Massa, "Giordano Bruno and the Top-Sail experiment" in *Annals of Science,* (30/1973); Robert Westman, "Magical Reform and Astronomical Reform", op. cit., and G. Aquilecchia, "I 'Massimi sistemi' di Galileo e la 'Cena' di Bruno", in *Nuncius: Annali di Storia della Scienza,* (X/1995), pp. 485–496.

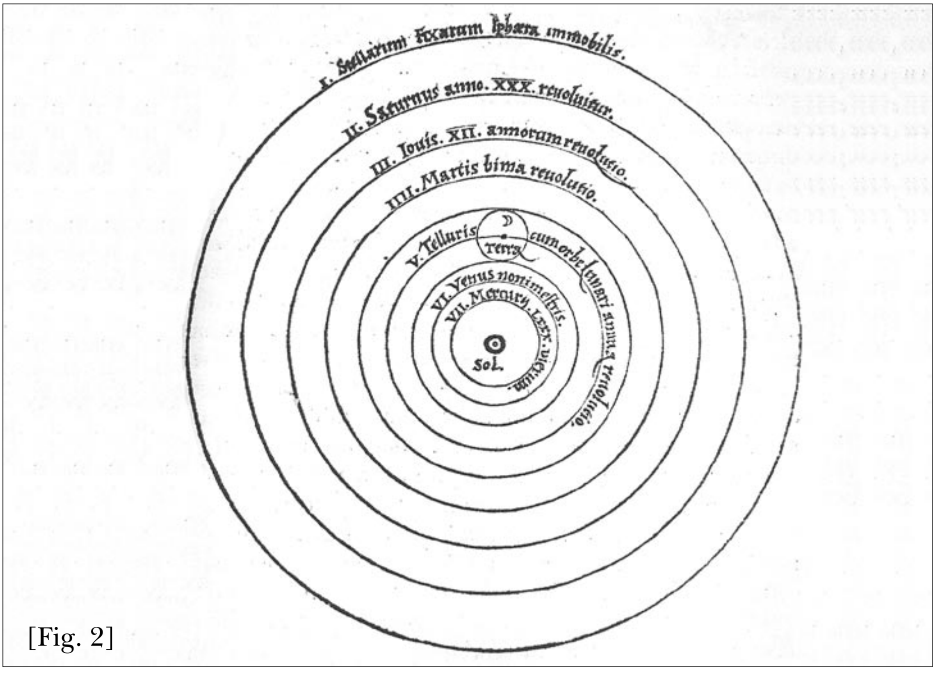
ematics to Sir Philip Sidney and whose remarkable library, which contained Copernicus's *De revolutionibus,* was the occasion of a meeting with Sidney and his entourage after a state visit to Oxford in which Bruno is known to have participated[13]. Although Bruno, unless unaided by a friend, would not have been able to read Digges's English text, he could certainly have contemplated his well-known Copernican picture of the universe, and may have had it in mind when preparing his own rather different Copernican picture to illustrate the text of the fourth dialogue of *The Ash Wednesday Supper.*

Copernican realism, already a characteristic (if constantly underplayed) of Copernicus himself and of Digges, and a defining one of Bruno's readings of his astronomy, caused problems of visualisation from the very beginning. It decreed the sudden superfluity of a centuries-long tradition of illustrations of the Aristotelian-Ptolemaic universe, which had assumed a notable aesthetic as well as scientific dimension (see fig. 1 from the cosmological work of Peter Apian, 1524).

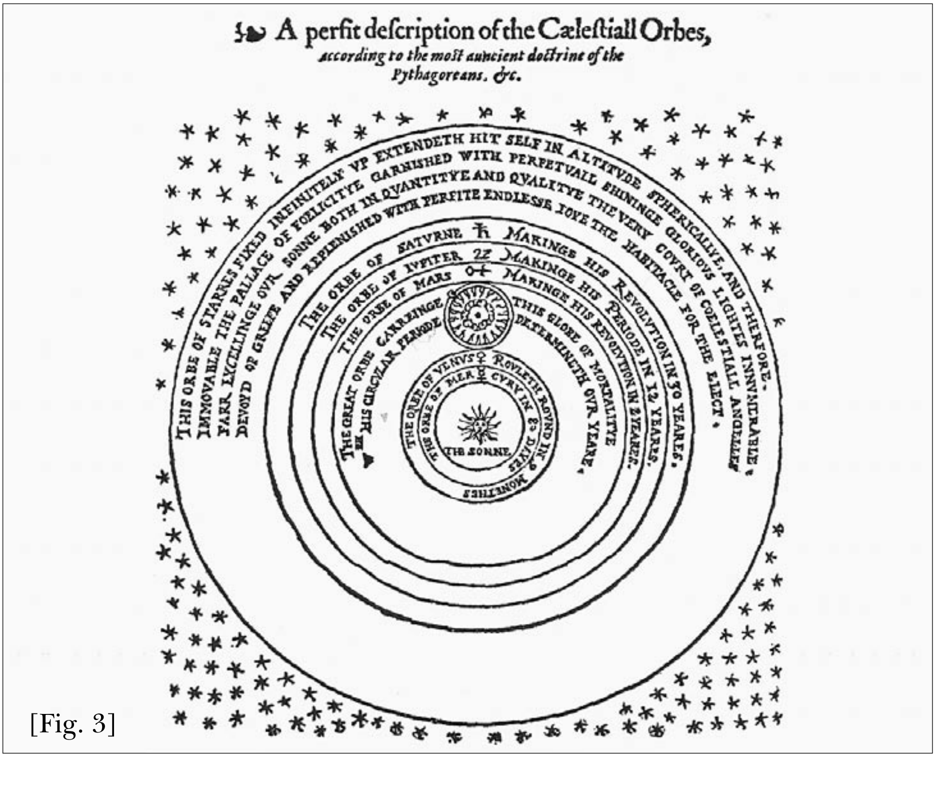


[Fig. 1]

[13] See *John Dee's Library Catalogue,* J. Roberts and A.G. Watson (Eds.), Bibliographical Society, London 1990, n. 220.


I. Stellarum Fixarum sphaera immobilis.
II. Saturnus anno. XXX. reuoluitur.
III. Iouis. XII. annorum reuolutio.
IIII. Martis bima reuolutio.
V. Telluris cum orbe lunari annua reuolutio
Terra
VI. Venus nonimestris.
VII. Mercurius. LXXX. dierum.
Sol.

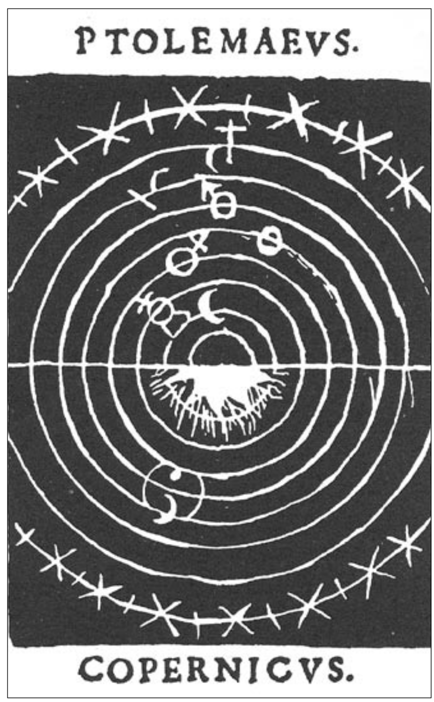
[Fig. 2]


A perfit description of the Cælestiall Orbes,
according to the most auncient doctrine of the Pythagoreans, &c.
THIS ORBE OF STARRES FIXED INFINITELY VP EXTENDETH HIT SELF IN ALTITVDE SPHERICALLYE, AND THEREFORE IMMOVABLE THE PALLACE OF FOELICITYE GARNISHED WITH PERPETVALL SHININGE GLORIOUS LIGHTES INNVMERABLE, FARR EXCELLINGE OVR SONNE BOTH IN QVANTITYE AND QVALITYE THE VERY COVRT OF COELESTIALL ANGELLES, DEVOYD OF GREEFE AND REPLENISHED WITH PERFITE ENDLESSE IOYE THE HABITACLE FOR THE ELECT.
THE ORBE OF SATVRNE MAKINGE HIS REVOLVTION IN 30 YEARES.
THE ORBE OF IVPITER MAKINGE HIS PERIODE IN 12 YEARES.
THE ORBE OF MARS MAKINGE HIS REVOLVTION IN 2 YEARES.
THE GREAT ORBE CARRIENGE THIS GLOBE OF MORTALITYE HIS CIRCVLAR PERIODE DETERMINETH OVR YEARE.
THE ORBE OF VENVS ROVLETH ROVND IN 9 MONETHES
THE ORBE OF MERCVRY IN 80 DAYES
THE SONNE

[Fig. 3]

The task of drawing a new and unfamiliar image of a now heliocentric cosmology was by no means simple; and Edward Rosen has drawn attention to the fact that difficulties arose at once, with relation to the illustration to be included in first editions of the *De revolutionibus.* Copernicus's own diagram was rejected and one (possibly by Rheticus) included which was to be the cause of perplexities and misunderstandings throughout the sixteenth century (see fig. 2)[14]. Digges's Copernican diagram is virtually the same as that in the *De revolutionibus*, except for the suggestion of an infinite number of stars stretching out beyond a unique astronomical system of a heliocentric kind (see fig. 3).

In Dialogue 4 of *The Ash Wednesday Supper*, the published diagram in *De revolutionibus* appears at the centre of the heated Copernican discussion between Theophilus, the mouthpiece of Bruno himself, and Torquato, one of the two bejewelled and conservative Oxford dons called in by Sir Fulke Greville to defend the traditional cosmology at his supper party. The problem raised by Bruno has been often considered both puerile and mistaken by commentators, especially by those anxious to further Frances Yates's Hermetical and magical reading of Bruno's works, which denies any scientific value to his Copernicanism at all[15]. In fact, Bruno's argument is both justified and not altogether incorrect. Torquato, as Bruno points out, bases his anti-Copernican comments on Rheticus's diagram rather than on a serious reading of Copernicus's text, thus failing to understand that if the orbit of the earth around the sun is seen as perfectly circular, then the sun has to be slightly off-centre for the system to be valid. Otherwise, as Bruno puts it, the diameter of the sun would appear constant throughout the year. Another solution to this problem, put



[Fig. 4]

[14] See Copernicus, *De revolutionibus (On the Revolutions),* Jerzy Dobrsycki (Ed.), comment by Edward Rosen, Macmillan, London 1978, p. 359, note 21.

[15] See Frances Yates, *Giordano Bruno and the Hermetic Tradition,* Routledge and Kegan Paul, London 1964.

forward by Copernicus himself only in book III of *De revolutionibus,* is to keep the sun at the geometrical centre of the system and put the earth on an epicycle, which is the solution adopted by Bruno in his own Copernican diagram in *The Ash Wednesday Supper* (see fig. 4).

Bruno's visualisation of the new sun-earth relationship, although very schematic, is thus quite correct: more correct than that suggested by the *De revolutionibus* diagram, and indeed by that of Digges[16]. It is interesting to note, however, that Digges, in a previous Latin work of 1573, *Alae seu scalae mathematicae,* written together with John Dee, had already made a number of references to Copernicanism in Latin. This work could well have been read by Bruno, as in it Digges raises the same questions that Bruno is discussing here: that is, the necessity of introducing either epicycles or eccentrics to guarantee the apparent changes in the sun's diameter[17]. Bruno, furthermore, goes on to make a mistake himself, by putting the moon on the same epicycle as the earth, whereas Copernicus (in bk. III) puts it on a second epicycle centred on the revolving earth. These were still early Copernican times, and mistakes in reading the new cosmology were many. Both Kepler and Galileo made their own seriously mistaken conjectures, raising the whole question of "Copernican mistakes" which are themselves an interesting, and ultimately not unfruitful, aspect of his reception. Where Bruno leaves Digges far behind, although in written text rather than in illustration, is in his attempt to visualise an entirely homogeneous and infinite universe, no longer characterised by those elemental spheres which are still so clearly depicted by Digges in his diagram (see fig. 3) as still dominant in the earth-moon orbit of his newly Copernican world.

Waiting for the Telescope

> Advances in engraving techniques, and in particular the detail made possible by copper-plate, meant that illustrations could match the most disparate subjects. Maps, plans, structural and logical diagrams, mathematical figures, drawings of machines and cog wheels, reproductions of animal or plant species, and synoptic tables invaded the printed page, clarifying, qualifying and completing it… The image acquired a philosophical role, and the ensuing redefinition in figures and signs of the totality of knowledge would play its part in the development of a new conception of man and the cosmos.

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[16] For Bruno's use of bk. III of *De revolutionibus* in this context, see my chapter on "Reading Copernicus" in *Giordano Bruno and Renaissance Science,* op. cit., pp. 43–77.

[17] See Thomas Digges, *Alae seu scalae mathematicae, quibus visibilium remotissima Caelorum Theatra conoscendi,* Thomas Marsh, London 1573, fols. Aiir-Aiiiv.

This eloquent passage written by Luce Giard on illustrations in texts of the early modern period defines the context in which discussion of Bruno's illustrations, cosmological and otherwise, should be examined[18]. Much recent discussion of the problem of visualisation of astronomical objects, however, has concentrated on the hiatus between the pre- and the post-telescopic age. The advent of telescopic observation with Galileo, it is argued, raised a whole series of new optical issues, including those relating to the degree of accuracy of scientific instruments themselves. A systematic programme of observations of the moon, for example, was not carried out until well after Galileo's death, and even then not without numerous problems interfering relating to sightings of discs created by the telescope itself[19].

It is known that telescopes were already being made and discussed in Bruno's time. Bruno himself would undoubtedly have known about them from the work on natural magic of his fellow Neapolitan, Giovan Battista della Porta, which was also known to Kepler, and possibly also from the works of Leonard and Thomas Digges[20]. Both Della Porta and the Digges, however, only discuss in their works the use of telescopes for terrestial observation, particularly in the field of navigation. Modern comentators have tended to deduce from this that visualisation of the new astronomy only started with Galileo. The pre-telescopic age appears relegated by this discussion to a kind of meaningless limbo, as if from Copernicus himself the reception of his theory had jumped to the momentous event expressed by Galileo's succinct comment of 1610: "But forsaking terrestial observations, I turned to celestial ones"[21].

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[18] See Luce Giard, "Remapping knowledge, reshaping institutions", in *Science, Culture and Popular Belief in Renaissance Europe,* Stephen Pumphrey, Paolo L. Rossi, Maurice Slawinski (Eds.), Manchester University Press, Manchester 1991, pp. 19–47: 29–31.

[19] See Mary G. Winkler and Albert Van Helden, "Representing the Heavens: Galileo and Visual Astronomy", in *Isis,* (83/1992), pp. 195–217; Mary G. Winkler and Albert Van Helden, "Johannes Hevelius and the Visual Language of Astronomy", in *Renaissance and Revolution: Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe,* J.V. Field and Frank A.J.L. James (Eds.), Cambridge University Press, Cambridge 1993, pp. 97–116, and Isabelle Pantin, "L'illustration des livres d'astronomie à la renaissance : l'evolution d'une discipline à travers ses images", in *Immagini per conoscere: dal Rinascimento alla Rivoluzione Scientifica,* Fabrizio Meroi and Claudio Pogliano (Eds.), Olschki, Florence 2001.

[20] See Albert Van Helden, "The Invention of the Telescope", in *Transactions of the American Philosophical Society,* (67, pt. 4/1977), and for a claim that the telescope was invented in England by Leonard Digges, see C.A. Ronan, "The Origins of the Reflecting Telescope", in the *Journal of the British Astronomical Association,* (101/1991), pp. 335–342.

[21] Galileo Galilei, *The Starry Messenger* [1610], translated with an Introduction and Notes by Stillman Drake, Doubleday, New York 1957, p. 28.

Nobody was more critical of such an approach to the new astronomy than Kepler himself. For Kepler formulated his theory of the elliptical orbit of Mars on the basis of observations made with the naked eye. Furthermore he wrote his famous *Dissertatio* on Galileo's discovery of the moons of Jupiter, shortly after it had been published in the *Sidereus nuncius,* before having obtained a telescope with which to observe them for himself. There is a curious note of disdain in Kepler's disparagement of Galileo's ability to make his own telescope. Kepler himself is not able, he assures his public, to work with his hands; but soon someone will lend him a telescope and then he will see Galileo's new moons himself[22]. To his credit, Kepler never doubts the authenticity of Galileo's discovery, as Galileo's ecclesiastical enemies went on doing until well after his trial and house imprisonment at Velletri. Kepler's instinctive trust in Galileo's observational skill throws a deep shadow over Galileo's own mistrust, indeed total silence, with respect to Kepler's momentous discovery of elliptical orbits. It was Galileo himself who was largely responsable for the assumption, made by so many scholars to-day, that serious visualisation of the Copernican theory began only with telescopic observation of the new pattern in the skies.

A major claim made by Kepler in his *Dissertatio* is that a number of post-Copernican theories and discoveries formulated before Galileo's observations of the moons of Jupiter made that discovery conceptually possible. He thinks that Galileo should have recognised their importance in his text. And if Kepler's main concern is to insist on the importance of his own theories and discoveries, he also includes Bruno in this context. For Bruno had formulated a clear distinction between bodies such as suns and stars which generate their light from within, and moons or earths which are illuminated from without. Kepler agrees with Bruno that it is necessary to move beyond the purely visual outlook of the new system provided by Copernicus himself, and to pass from the facts to the causes[23]. This had become imperative to the natural philosopher of the time, as the new system virtually banished from the cosmological picture the traditional Aristotelian "prime mover", which had set the Ptolemaic celestial system in motion in the first place (see fig. 1). Copernicus himself, as well as an early Copernican such as Thomas Digges, had fleetingly referred to the neo-Platonic concept of elemental motion put forward, in an Aristotelian cosmological context, by Marsilio Ficino. Recently studied by Dilwyn Knox, this doctrine sees gravity and levity as causes of ce-

[22] See Kepler, *Conversation with the Sidereal Messenger,* op. cit.

[23] For a comment on Kepler's multiple references to Bruno in this text, see L. Simoni Varanini, "La *Dissertatio cum Nuncio Sidereo* fra Galileo e Bruno", in *Bruniana e campanelliana,* (IX-1/2003), pp. 207–215.

lestial motion, within a conceptual context still founded on the theory of the four elemental spheres as the primary constituents of matter up to the planetary sphere of the moon[24]. However, Bruno repudiated the elemental spheres just as he repudiated the planetary spheres of Aristotelian fame. Serious speculation about the universal causes of the heavenly motions within the new cosmology thus may be seen as starting with Bruno; even if Kepler prefers his own unique world based on his more mathematical idea of a universe divided among the five Platonic solids. Galileo, for his part, had little time to spare for Kepler's mystical neo-Platonism, and in his later *Dialogue concerning the two chief world systems* preferred to refer to William Gilbert's magnetical explanation of the causes of celestial motions[25]. Kepler himself also knew and admired Gilbert's *De magnete,* which had been published in 1600, the year of Bruno's death. Nevertheless, in his *Conversation* with Galileo, it is through multiple references to Bruno's natural philosophy that Kepler establishes the principle that a new, universally valid cause of the celestial motions was necessary to make sense of Copernicus's theory at all.

Bruno's own solution, already put forward in *The Ash Wednesday Supper* and never abandoned, was based on a thermodynamic concept of the play between the contrary forces of cold and heat. Its root lay in the anti-Aristotelian natural philosophy of Bernardino Telesio, whom Bruno greatly admired[26]. Telesio saw the whole universe as moved throughout by the active principles of heat and cold, even if he himself never abandoned the Aristotelian, finite cosmology. Telesio's thermodynamic doctrine of planetary movement, however, did defy the traditional idea of elemental spheres, for the contrary forces of heat and cold were seen as dominant throughout his still finite and geocentric universe. Kepler was probably thinking of Bruno's enthusiastic adoption of this concept when he criticised Bruno for "talking in generalities". However, a careful reading of Bruno's *De immenso et innumerabilibus* of 1591 shows that he did attempt to specify his thermodynamic theory of planetary motion by supplying it with a mathematical formulation. He does this through the use of a diagram whose importance seems to have escaped the notice of his commentators (see fig. 5).

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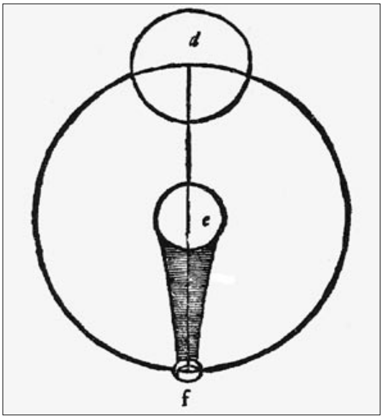
[24] See Dilwyn Knox, "Ficino, Copernicus and Bruno on the Motion of the Earth", in *Bruniana e campanelliana,* (V- 2/1999), pp. 333–66, and *Physis,* (38/2001), pp. 171–209.

[25] Galileo Galilei, *Dialogue Concerning the Two Chief World Systems,* Stillman Drake (Ed.), California University Press, Berkeley and Los Angeles 1953, pp. 400–411.

[26] On Bruno and Telesius, see Giovanni Aquilecchia, "Ramo, Patrizi, e Telesio nella prospettiva di Giordano Bruno" and "Ancora su Bruno e Telesio", in *Schede bruniane,* Vecchiarelli, Manziana 1993, and Hilary Gatti, "Telesio, Giordano Bruno e Thomas Harriot", in *Accademia cosentina: Atti 1991–2,* Accademia Cosentina, Cosenza 1994.



[Fig. 5]

Bruno's text claims that in the infinite universe, if considered infinitely, nothing can be said either to act or to be acted upon. But if considered in terms of the finite bodies within it, then they do act and are acted upon. He goes on to consider how, in a general sense, action of one body on another decreases with respect to increase in the distance between them. For example, the fire e heats point f according to the distance e–f. If the fire d is four times as hot as e, it will heat e according to the distance d-e four times as much as e heats f, but it will heat f only twice as much because it needs to travel twice the distance to reach it. Thus Bruno is introducing a mathematical idea of the ratio of distance to intensity to measure the amounts of heat by which the hot bodies (stars or suns) attract the cold ones (earths or moons) into their orbit. The argument goes on to consider Aristotle's (puerile) claim that if the universe were infinite and the heat of an ethereal fire were of infinite intensity, then there would be no chance of the earth withstanding such heat: therefore all bodies must be contained within a finite world. Bruno's final claim is that Aristotle would have been right if the elements were confined, as Aristotle thought, to separate spheres, and therefore fire, in its own sphere, were pure. As we have seen, however, for Bruno there are no elemental spheres, just as there are no planetary spheres, but only an infinite universe filled with a universal ether. In this universe, in all its parts, Bruno claimed that fire is always united in some degree to humidity, creating an atmosphere in which all the celestial bodies, including the so-called "fixed stars", can move and survive[27]. As we shall see later on, Bruno's thermodynamic theory of celestial motion got him into difficulties when he had to consider the movements of moons about cold planets. For the moment, however, it is enough to notice that he is already thinking in terms of a universally valid cause of the movements of stars and planets within heliocentric systems, which can be expressed by a mathematical formulation. Kepler was surely right to note that Bruno's published discussions of

[27] An anastatic reprint of the first edition of Bruno's *De immenso* [1591] may be consulted in Giordano Bruno, *Poemi filosofici latini,* ed. Eugenio Canone, Agora, La Spezia 2000, pp. 399–907. For this diagram and its textual explication, see pp. 490–92. There is no English translation of this text, but an Italian translation is in Giordano Bruno, *Opere latine,* translated and edited by Carlo Monti, UTET, Turin 1980. For this diagram and its textual explication, see pp. 493–94.

the heliocentric astronomy constitute a development in the reception of the Copernican revolution which Galileo should not have ignored[28].

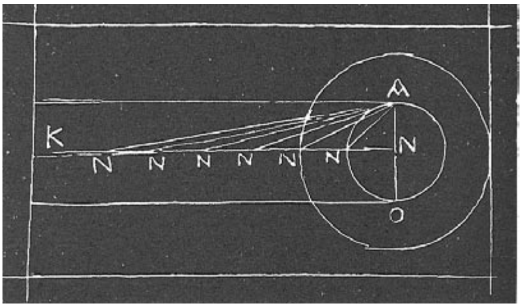
Bruno's diagram also shows that the visualisation of the new celestial problems was an important moment of pre-telescopic thought about the new astronomy. Two more of his Copernican diagrams may be mentioned here, although these have already attracted the attention of commentators. Both come from the Copernican discussion in the earlier *Ash Wednesday Supper*. In that work Bruno makes a considerable use of optics to justify the new astronomy. He makes no mention of his sources; but it has been supposed by his commentators that he had been reading the work of Jean Pena. Before arriving in London, Bruno had been living and lecturing in Paris, where Pena's optical writings, which already apply optics to a discussion of the Copernican theory, were well known[29]. Bruno's reasoning in *The Ash Wednesday Supper* may also have been influenced by the *Optics* of Ibn Al-Haytham (Alhazen), an Arabic mathematician and astronomer who originated from Iraq and was active in Cairo in the first half of the eleventh century. A Latin translation of his work, known as the *Perspectiva*, was published in 1572 by Freidrich Risner in Basle, and widely used by the natural philosophers of the period. The Ninth Earl of Northumberland, who owned one of the most important contemporary collections of Bruno's texts, attributed the change of his life from a frivolous courtier to a dedicated natural philosopher to a reading of this work of Alhazen[30]. In bk. III, chap. 7, Alhazen considers "The Ways in which Sight Errs in Inference", and writes that "by looking at a fixed star and a planet at the same time sight will not perceive the difference between their distances, but rather perceive them both in the same plane despite the great difference between their distances". These, and similar optical arguments, were used by Bruno to justify not only the astronomy of heliocentric systems but also his

[28] For a recent, detailed comparison of Bruno's cosmology with that of Galileo, see Arcangelo Rossi, "Bruno, Copernico e Galilei", in *Physis* (XXXVIII/2001), pp. 283–303.

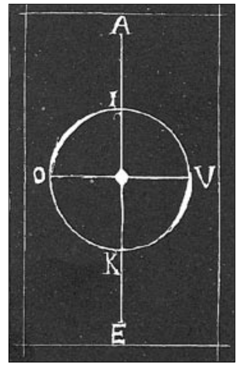
[29] For the importance of Pena's application of optics to the new Copernican astronomy, see W.G.L. Randles, *The Unmaking of the Medieval Christian Cosmos,* Ashgate, Aldershot 1999, chap. 3: "The Challenge of Applied Optics", pp. 58–79. Bruno's possible use of Pena's optical theories has been considered by M. R. Sturlese Pagnoni, "Su Bruno e Tycho Brahe", in *Rinascimento* (25/1994).

[30] For an English translation of this text, see Alhazen [Ibn Al-Haytham], *Optics,* ed. I. Sabra, The Warburg Institute, London 1989. For Northumberland's claim, see his essay on "Love", first published by Frances Yates in *A Study of 'Love's Labour's Lost',* Cambridge University Press, Cambridge 1936, pp. 206–11. On the importance of Alhazen's optics in renaissance thought, see J.V. Field, *The Invention of Infinity,* Blackwell, Oxford 1997. For Northumberland as a reader of Bruno, see Hilary Gatti, "Giordano Bruno: the Texts in the Library of the Ninth Earl of Northumberland", in *The Journal of the Warburg and Courtauld Institutes* (46/1983).

theory of an infinite universe. Two of his best known Copernican diagrams in *The Ash Wednesday Supper* (see figs. 6 and 7) are of some importance in his discussion of his new picture of the universe.



[Fig. 6]



[Fig. 7]

In fig. 6, Bruno is concerned to show that a smaller opaque body placed between the eye and a larger luminous body becomes invisible to the eye at great distances. This simple diagram thus supplies him with a conceptual instrument for challenging the Aristotelian doctrine that the sky contains only those bodies which are visible to the eye. Bruno's frequently expresssed conviction that the sky could and undoubtedly did contain numerous bodies which had so far never been seen was probably what Kepler was thinking about when he told Galileo that Bruno was one of those who had helped to prepare the conceptual grounds for his discovery of the moons of Jupiter[31].

In fig. 7, the last of the diagrams in *The Ash Wednesday Supper,* Bruno attempts to visualise the multiple movements of an earth in motion according to the Copernican hypothesis by using the example of a ball thrown into the air. Bruno thinks of the ball as having four different motions, all of them part of one single complex motion. The first and principal one is along the trajectory A-E, the second around its own axis I-K. The third movement consists of an oscillation in the revolution of the moving ball along parts of the circumference which Bruno visualises in his text by dividing it into eight segments. These segments are not indicated in the diagram; and it is not altogether clear what circumference he is referring to. In a recent edition of this text, it has been assumed to refer to a slipping back of the travelling ball along the circumference of the orbit A-E; which would make it correspond to Copernicus's account of the movement known as the precession of the equinoxes. This, however, presupposed an earth still fixed onto precisely those celestial spheres which Bruno, earlier on in this work, had already denied. Alterna-

[31] For Bruno's discussion of this diagram, see *La cena de le ceneri,* op. cit., p. 504.

tively, Bruno's third movement may have corresponded to what was known as axial precession, composed of an oscillation which traced a figure of eight around the two poles of the earth itself. This movement of axial precession, however, could be considered as integrated into Bruno's fourth movement of the ball, visualised as an oblique spin which eventually inverts the positions of O-V. Undoubtedly some obscurity remains in Bruno's account of the third and fourth movements of the ball in the air, largely due to the incomplete nature of his diagram. The important point to be made, however, is that Bruno has understood the principal novelty constituted by the Copernican account of precession of the equinoxes and its accompanying anomalies: that is, that it should be seen as a complex of very slight, long-term variations in the movements of the earth itself, and not of the zodiac or sphere of fixed stars as was the case in the traditional astronomy. Bruno thinks of the four movements of the ball in his figure as roughly corresponding to the Copernican annual movement of the earth around the sun, its daily revolutions around its own axis, added to two of the complex set of long-term anomalies associated in Copernicus's still circular astronomy with the precession of the equinoxes, although Bruno never uses that term. Precession remained extremely complicated in Copernicus's system, as it had been in Ptolemy's, and it was giving rise to heated discussion among more technical experts than Bruno. In any case, Bruno thought that the astronomers were not capable of offering more than mathematical approximations of the movements of the earth and the other planets. His main purpose with the ball image and its accompanying diagram was to catapult his readers into a new adventure in outer space, for ever ousting them from their once comfortably central and immobile earth. In *The Ash Wednesday Supper,* Bruno insists that the multiple motions of the now moving earth are regular and constant, and must be respected as such. If he thought that astronomical calculations were inevitably approximate, that was because of his mistrust of mathematics as the perfect instrument of human prediction, rather than lack of faith in the ordered regularity of the natural world[32].

Work in Progress

Owen Gingerich's *Annotated Census of Copernicus's "De revolutionibus" (Nuremberg, 1543 and Basel, 1566)* contains a description of a copy in the Biblioteca Casanatense in Rome of the 1566 edition with a signature "Brunus

[32] For Bruno's discussion of the earth as a moving ball, see *La cena de le ceneri,* op. cit., pp. 566–68.

Fr[ater] D[ominicanus]", but no annotations by Bruno[33]. This is claimed by Gingerich as "the bold Giordano Bruno signature from the fly-leaf", although Bruno scholars tend to be more cautious. There are, however, some interesting points to be made about this volume. Firstly, it is almost impossible either to attribute it to Bruno, or not to do so, on the basis of the hand-writing of what is not strictly speaking a signature but rather a florid and highly stylized design. Secondly, the book reached Rome from Naples, where it was in the original nucleus of the library belonging to the Spaniard Matias de Casanate (c. 1580–1651), father of the Cardinal Casanatense who brought the collection to Rome. Matias was a high-ranking judicial official, and might have obtained it during the agitation caused by Bruno's trial and execution in Rome in 1600, when the official investigations into Bruno's heresies by the Dominican monastery in Naples became a subject of attention by the inquisition. Thirdly, it has been convincingly shown by Miguel Granada that Bruno must have been reading the 1566 edition, which also contained the *Narratio prima* of Rheticus, passages of which Bruno often transcribes[34]. Fourthly, if this really is Bruno's copy of the *De revolutionibus,* which would not be put on the Index of forbidden books until much later, in 1616, then he was presumably reading Copernicus at a considerably earlier age than commentators have usually supposed. Bruno entered the Dominican monastery in Naples in 1565 at the age of seventeen, and fled north in 1576, at the age of twenty-eight.

Gingerich's *Census* also contains a description of Kepler's annotations to his 1543 copy of the *De revolutionibus,* at present held by the Universitätsbibliothek at Leipzig[35]. These clearly show how sixteenth century and early seventeenth century readings of the Copernican astronomy were in the form of "work in progress" rather than constituting a definitely acquired body of new astronomical knowledge. They also emphasize how a major problem in the ongoing understanding of Copernicus's system concerned the question of where to situate the centre of the new universe. This is the problem raised by Bruno in *The Ash Wednesday Supper.* Also in his case it is correct to speak of "work in progress": in fact it is Bruno himself who, in the fourth dialogue of that work, gives his readers an account of his progressive reactions to the Copernican astronomy. Bruno claims that he had passed through the following

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[33] Owen Gingerich, *An Annotated Census of Copernicus's 'De revolutionibus' (Nuremberg, 1543 and Basel, 1566),* Brill, Leiden 2002, p. 115.

[34] For the history of the Casanatense collection, see Marina Panetta, *La 'Libraria' di Mattia Casanate,* Bulzoni, Rome 1988, where *De revolutionibus* is listed as no. 1263. For Bruno and Rheticus, see Miguel Granada, "L'interpretazione bruniana di Copernico e la *Narratio prima* di Rheticus", in *Rinascimento* (30/1990).

[35] For Kepler's annotations, see Gingerich, *An Annotated Census,* op. cit., pp. 76–80.

stages of growing Copernican conviction: firstly, he considered the new cosmology a mere joke put forward in debate by those who amuse themselves by trying to demonstrate that black is white; secondly, he began wondering why Aristotle had spent so much time in his *De caelo,* bk. II, criticising the heliocentric theory of Pythagoras and his followers; thirdly, in a more mature period of his youth, he began to think of Copernicus's theory as a possibility. Later on (at an unspecified date) came the growing conviction of its certain truth[36].

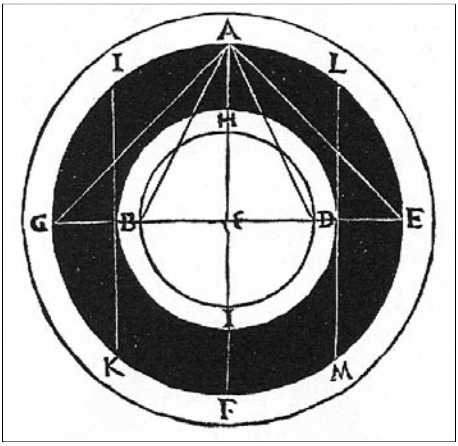
In a page of bk. III, chap. 5, of his later *De immenso,* Bruno harks back to what seems to be the third stage of this story: that is, his growing conviction of the truth of the new theory (see figs. 8 and 9)[37]. Referring to a time "when he was younger", he describes a picture he had formulated in his mind of the following cosmological hypothesis: the sun together with the fixed stars orbits annually around the earth through AF; the earth revolves around its centre at C along the axis HI in its diurnal rotation; the earth does, however, move from the geometrical centre, travelling annually away from the equator of the universe, at times towards the tropical pole E, at times towards the antarctic pole G. The traditional long-term movements of trepidation and oscillation are assured by additional spiralling movements of the earth which expose its surface to the heat or the cold of the poles according to the long-term necessities of its evolution. Bruno illustrates this very schematic cosmological picture with a diagram which he insists represents "the philosophy of the masses", and not his own mature convictions. The question it poses is whether it was possible to maintain a central earth within a compromise solution which took at least some minimal account of the Copernican theory. By 1591, when the *De immenso* was published, such a system had been worked out in much finer technical detail by Tycho Brahe, who had published an account of his own partly-Copernican cosmology in 1588[38]. Brahe, although not explicitly mentioned, is probably being criticised here as over-prudent and "immature" in so far as he failed to step into a fully heliocentric world. Interestingly William Gilbert was aware of this cosmological model of Bruno's "when he was younger" (*cum esset junior).* He commented on it in his posthumously published *De mundo,* adding a diagram of his own. Gilbert criticises the hypothesis for making the earth move in a straight line, "which is not normally attributed to celestial bodies"; although it is probable that Bruno's diagram was not intended to indicate movement in a straight line but rather a small orbit of the

[36] See *La cena de le ceneri,* op. cit., pp. 535–36.

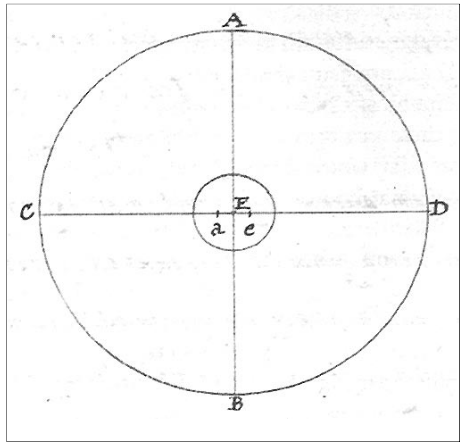
[37] See, *De immenso,* in *Poemi filosofici latini,* op. cit., p. 559. The diagram is at p. 553.

[38] For the importance of 1588 in the development of the new cosmology, see Miguel Granada, *El debate cosmológico en 1588: Bruno, Brahe, Rothmann, Ursus, Röslin,* Bibliopolis, Naples 1996.

earth around the geometrical centre, through BD in Bruno's diagram and ae in Gilbert's [39]. It is not clear whether Gilbert was aware of the ironic stance assumed by Bruno in these pages. Although Gilbert himself was sympathetic to Bruno's cosmological theses, his circle of magnetic philosophers either remained stubbornly Aristotelian in their cosmology, or referred to Tycho Brahe's compromise solution which Bruno could not accept.[40]



[Fig. 8]



[Fig. 9]

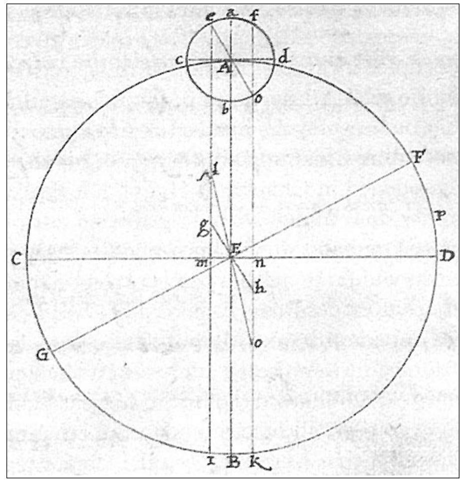
Gilbert's interest in Bruno's cosmological theories did not stop with this diagram. On the very next page, he presents another (by now more fully Copernican) way of visualising the cosmos in terms of Bruno's ideas (*Alius modus iuxta Nol.,* see fig.10)[41]. Gilbert found this new theory in the *De immenso,* bk. III, chap. X[42]. In the pages which interested Gilbert, Bruno appears to be referring to *De revolutionibus,* III, 25, where Copernicus supposes an anomolous heliocentric model in which "the center of the annual revolution be fixed, as though it were the centre of the world, but the sun be moveable by two motions similer and equal to those which we have demonstrated for the center of the eccentric, everything will appear just as before... For then the motion of the centre of the earth would be a perfect and simple motion about the centre of the world, since the two other motions have been granted to the sun". Bruno begins by criticising Copernicus because he does not normally

[39] William Gilbert, *De mundo nostro sublunari philosophia nova,* Ludovicum Elzevirium, Amsterdam 1651, p. 199–200.

[40] See my chapter on "Bruno and the Gilbert Circle", in *Giordano Bruno and Renaissance Science,* op. cit., pp. 86–98.

[41] See Gilbert, *De mundo,* op. cit., pp. 200–01.

[42] See Bruno, *De immenso,* op. cit., pp. 592–93.



[Fig. 10]

make the sun orbit at the centre of the solar system. Further criticism addresses Copernicus's account of precession of the equinoxes, which posited a third movement of the earth as if it was carried around on its planetary sphere and therefore had to slip back gradually on its orbit in order to remain constant[43]. Bruno himself had long maintained that there are no planetary spheres, and that the earth and other planets hang freely in the universal ether. He now sees it as a principle of rotatory planetary motion that the axis remains parallel to itself and in equilibrium, thus rendering superfluous Copernicus's third motion of the earth: a principle which will later on be confirmed both by Gilbert himself and by Galileo. As for the sun, Bruno in these pages, like Copernicus in the passage above, visualises it as moving in an oblique orbit with respect to an earth which travels around the centre of the system on an axis parallel to the equator of the world. The sun must also rotate around itself with a spiralling motion, according to Bruno, as otherwise it would always seem to rise in the same place. Further oscillations of the earth's poles with respect to the zodiac, Bruno notes with admiration, had been introduced by Copernicus to compensate for the traditional slipping back of the zodiac itself which explained, in the Ptolemaic system, the precession of the equinoxes. The lack of any diagram in these pages of the *De immenso* makes Bruno's text arduous reading. Such must have been the impression of Gilbert, whose second Bruno diagram in his *De mundo* illustrates this anomolous heliocentric system described in words by Bruno himself.

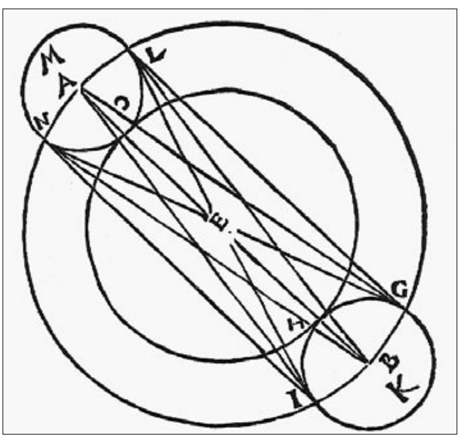
In Gilbert's diagram, which correctly illustrates this page of Bruno's, DFCG represents the colure of the solstitial points, and C and D the poles of the universe. AB is the equator of the universe around which the earth moves annually from west to east. The earth's equator, ab, moves daily around its own axis, also from west to east. The sun describes a small circle limited by the

[43] For what they consider Copernicus's "interesting" alternative model to his usual solar theory, see N.M. Swerdlow and O. Neugebauer, *Mathematical Astronomy in Copernicus's 'De revolutionibus'*, 2 vols., Springer-Verlag, New York-Berlin 1984, p. 159. For Copernicus's account of precession, see N.M. Swerdlow, "On Copernicus' Theory of Precession", in *The Copernican Achievement,* ed. Robert Westman, California University Press, Los Angeles 1975.

equinoctial parallels egi and fhk. If its poles are G and F, the orbit of the sun will pass through g and h, or its two tropical limiting points, although other angulations of the orbit of what seems also here to be a spiralling sun are posited by Gilbert as possible. Bruno himself had further justified this principle as necessary to guarantee the evolution of the planets by supplying them with ever varying quantities of heat and cold. Later on, in Galileo, the idea of a sun which revolves around its own axis would become important to explain the sighting of sun-spots. Surely Bruno was right to consider early Copernicanism as a slow acquisition of new astronomical concepts according to various approaches and reached by travelling along many different paths of thought.

What is right and what is wrong?

Let us now come back to Kepler's mistaken distrust of Bruno's "innumerabilities", expressed to Galileo in his replies to the *Sidereus nuncius*. Kepler points out that Galileo's discovery does not support it because Bruno thought of earths as circling around suns, while Jupiter is a planet, and yet the new moons circle around it[44]. For Kepler this suggested that our own solar system constitutes a unique universe: thus saving him from Bruno's "horrible" idea of a plurality of suns. Kepler's observation, however, carries other implications. It highlights the terms of Bruno's "lunar" mistake in *The Ash Wednesday Supper* (see fig. 3), although Kepler does not mention this specifically. Yet Bruno himself had already realised that his thermodynamic theory of planetary motion did not permit him to put the moon on a further epicycle centred on earth (or an epicycle), as Copernicus had done to save the phenomena; because this would have meant visualising a cold moon as circling around the centre of a cold earth. Why should it do that? For Bruno the moon too must circle around the sun as its centre: the sun becoming thus the fountain of heat and light for the moon in the same degree as for the earth. This precedent in the *Ash Wednesday Supper* should be remembered when considering Bruno's final cosmological diagram in the *De immenso,* bk. 3, chap. X (see fig. 11).



[Fig. 11]

[44] Kepler, *Conversation with the Sidereal Messenger,* op. cit., pp. 11 and 34.

Bruno says of this diagram that it derives from his conviction that the orbits of Mercury and Venus around the sun cannot really be smaller than those of the earth and the moon, as the astronomers claim[45]. He proposes a system in which the earth A, with the moon now on its epicycle NMLO, revolves around the sun E in direct opposition to Mercury B, which carries Venus on its epicycle IHGK. Although in flagrant disregard of astronomical observation as well as of Copernicus's mathematics, this diagram occurs in a part of Bruno's text devoted to praise of Copernicus as the true hero of the modern world. It reflects Copernicus's conviction, eloquently expressed in his own dedicatory letter of the *De revolutionibus* to Pope Paul III, that a well ordered universe implies uniformity and harmony of the spheres. Undoubtedly the Pythagorean bases of both Copernicus's and Bruno's cosmologies need to be underlined here, as much recent commentary has been doing[46]. Bruno himself refers to both Pythagoras and Plato just before describing this diagram in his text. Nevertheless it was Kepler who understood most clearly the specific technical difficulty which Bruno's thermodynamic theory of planetary movement had led to: if cold planets like the earth fulfill their purpose in the universe by varying on their surface the intensity of heat and light, cold and shadow, through which life evolves on their surface, why should cold moons circle around them at all? Bruno recalls his thermodynamic theory of planetary motion in the opening pages of *De immenso,* bk. 3, chap. X. His attempt to visualise a rudimentary planetary system in this diagram tries to solve the problem which would later be raised by Kepler. It shows how cold planets and the cold moons which revolve around them, by clinging together in epicycles all orbit at harmonious distances around the sun, from which their life-giving energies arise.

Two considerations are in order here. Firstly, Bruno is not addressing in these pages the Hermetic magicians or the neo-Platonic magi (although

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[45] Bruno, *De immenso,* op. cit., pp. 596–98.

[46] For an extended comment on Copernicus's own dedicatory letter, see Robert Westman, "Proof, Poetics and Patronage: Copernicus's Preface to *De revolutionibus*", in *Reappraisals of the Scientific Revolution,* D.C. Lindberg and R.S. Westman (Eds.), Cambridge University Press, Cambridge 1990. See also P.L. Rose, "Universal Harmony in Regiomontanus and Copernicus", in *Avant, avec, après Copernic,* Centre national de la recherche scientifique (Ed.), Blanchard, Paris 1975, pp. 153–163. The Pythagorean and neo-Platonic sources of the new sun-centred cosmology have been discussed by Eugenio Garin, "La rivoluzione copernicana e il mito solare" in *Rinascite e rivoluzioni: movimenti culturali dal XIV al XVIII secolo",* Laterza, Bari 1975, pp. 257–295, and Paolo Casini, "Il mito pitagorico e la rivoluzione astronomica", in *Rivista di filosofia* (85,1/1994). On Bruno's Pythagoreanism, see Dario Tessicini, "'Pianeti consorti': la Terra e la Luna nel diagramma eliocentrico di Giordano Bruno", in *Cosmología, teologia y religión en la obra y en el proceso di Giordano Bruno,* Miguel Granada (Ed.), Universitat de Barcelona, Barcellona 2001, pp. 159–188.

he does do that in other parts of his work). Here, he is explicitly addressing the astronomers. Translated into modern vocabulary, with respect to this rudimentary planetary diagram, Bruno himself admits defeat. He is quite aware that his picture fails to save the phenomena, and therefore that some kind of extension is required to his thermodynamic theory of planetary motion. He tries to turn this into a qualified defeat by pointing out that he at least has a physical theory of planetary motion which postulates a universally valid cause. The empirical problem of saving the phenomena is something which Bruno thinks cannot be solved by simply calculating quantities from the basic observables of time and position. It must be solved within a theoretically acceptable physical framework: a necessity which, in his opinion, Copernicus himself and most of the early post-Copernicans continued to ignore. His own comment on his planetary diagram ends with an appeal to the astronomers to integrate their mathematical skills into a theoretical physics: that, he claims, is all he asks of them in order to be satisfied. Secondly, the frequent use of this diagram by those commentators who are concerned to enclose Bruno's thought entirely within a magical and Hermetic tradition which has nothing to do with a scientific logic is questionable, particularly if it implies (as it frequently does) that serious mistakes in reading Copernicus oust the culprit from any valid tradition of properly scientific thought. Such a premise would clearly present problems with Kepler, given his mistaken attempt to construct a new heliocentric cosmology on the basis of the five Platonic solids, with Galileo who thought he had "proved" the Copernican hypothesis with a mistaken theory of the movements of the tides, as well as with Tycho Brahe who constructed a short-lived compromise cosmology whose conceptual basis was clearly religious and not scientific at all. Furthermore, it is worth reflecting on the fact that one of the earliest formulations of an entirely negative judgement on Bruno's Copernicanism derives from the nineteenth century astronomer Giovanni Virginio Schiaparelli. Appealed to by Felice Tocco, a prestigious nineteenth-century Italian philosopher who was presenting a positive reading of Bruno's Copernicanism as a prelude to Galileo's in a volume which remains essential reading to-day, Tocco found himself in difficulty when the internationally renowned Schiaparelli replied that Bruno's cosmological arguments were obscure, puerile and of no validity at all. Tocco found a clever solution to his problem by continuing to develop in his text a fundamentally positive appreciation of Bruno's cosmological speculation, while relegating to a series of much discussed notes the impatient criticisms of Schiaparelli[47].

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[47] See Felice Tocco, *Le opere latine di Giordano Bruno esposte e confrontate con le italiane,* Le Monnier, Florence 1889. For the letter from Schiaparelli, see the notes at pp. 313–17.

Those commentators who are still to-day using Schiaparelli to eliminate Bruno from the scientific scene may, however, wish to reflect on the fact that Schiaparelli himself perpertrated one of the most colossal and colourful of scientific "mistakes" when he claimed that his telescopic sightings had revealed a regular network of canals on the surface of Mars, which it was "not impossible" to conceive of as constructed by intelligent beings. Schiaparelli's sightings gave rise to more than half a century of fervid Martian speculation. This included the life-long work of Percival Lowell, who built an observatory in California and dedicated his life to what became ultimately a desperate attempt to prove Schiaparelli right. Of course, he may have been; but the Martian probes at present are not pointing in Schiaparelli's direction[48]. Ironically, Schiaparelli may have been thinking about life on Mars because he had been reading the work of the "confused and imprecise" Bruno, whose concept of an infinite universe was based on the postulate that it was a "living" universe in all its parts. It is, in any case, unfortunate that the most recent enthusiast of Schiaparelli's criticisms of Bruno's cosmological speculation is the editor of the important volume recently dedicated to a comment on all Bruno's illustrations and diagrams. Following in Schiaparelli's footsteps has led their editor to take into little or no serious consideration the many diagrams which Bruno uses to illustrate both his atomism and his Copernicanism: two of the most advanced scientific speculations of his day[49].

What is "right" and what is "wrong" is surely not the point which needs to be laboured in studying the early readings of the Copernican astronomy. The historian's task is to address those original minds which responded positively to the overwhelmingly unfamiliar implications of a new theory destined to become the foundation stone of modern cosmological thought. Bruno was among the first to understand that this would be the case: that the centuries-old Aristotelian-Ptolemaic cosmos had suddenly become a thing of the past, and that a new world picture had to be formulated of a radically different kind. His limited grasp of the mathematics of Copernicus's *De revolutionibus* is more than compensated for by his remarkably subtle and daring speculation into its physical and philosophical implications. His extension of the much-enlarged but still finite Copernican universe to infinite dimensions, conceived of as a new infinitistic physics and not only (or even primarily) as

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For a discussion of Bruno's Copernicanism based on a critique of Schiaparelli's remarks, see Alfonso Ingegno, "Bruno, Copernico e i moti della terra" in *Cosmologia e filosofia nel pensiero di Giordano Bruno,* Nuova Italia, Florence 1978, pp. 63–70.

[48] This story is told by F.I. Ordway, "The Legacy of Schiaparelli and Lowell", in *Journal of the British Interplanetary Society* (39/1986), pp. 19–27.

[49] See Giordano Bruno, *Corpus iconographicum,* Mino Gabriele (Ed.), Adelphi, Milan 2001.

a religious intuition, added, less than half a century after the publication of the *De revolutionibus,* another stone to the foundation of the modern world. Furthermore, Bruno's infinite universe incorporated a Copernican heliocentric principle in a "realist" sense: he thought of his infinite number of finite astronomical systems as all centred on suns, seen as the source both of their revolutions and of their life. Bruno knew that his philosophical achievement in his cosmological works depended on the original "revolution" proposed by Copernicus himself. More than once he attributed generous public recognition to Copernicus as the genius whose "light" had ushered in a new era:

> For he had a profound, subtle, keen and mature mind. He was a man not inferior to any of the astronomers who preceded him, unless they are considered in their own time and place. His natural judgement was far superior to that of Ptolemy, Hipparchus, Eudoxus, and all the others who followed them; and this allowed him to free himself from many false axioms of the common philosophy, which – although I hesitate to say so – had made us blind.[50]

[50] See Dialogue 1 of *La cena de le ceneri,* op. cit., pp. 448–49.