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Copernicus in the Cultural Debates of the Renaissance

Reception, Legacy, Transformation

PIETRO DANIEL OMODEO

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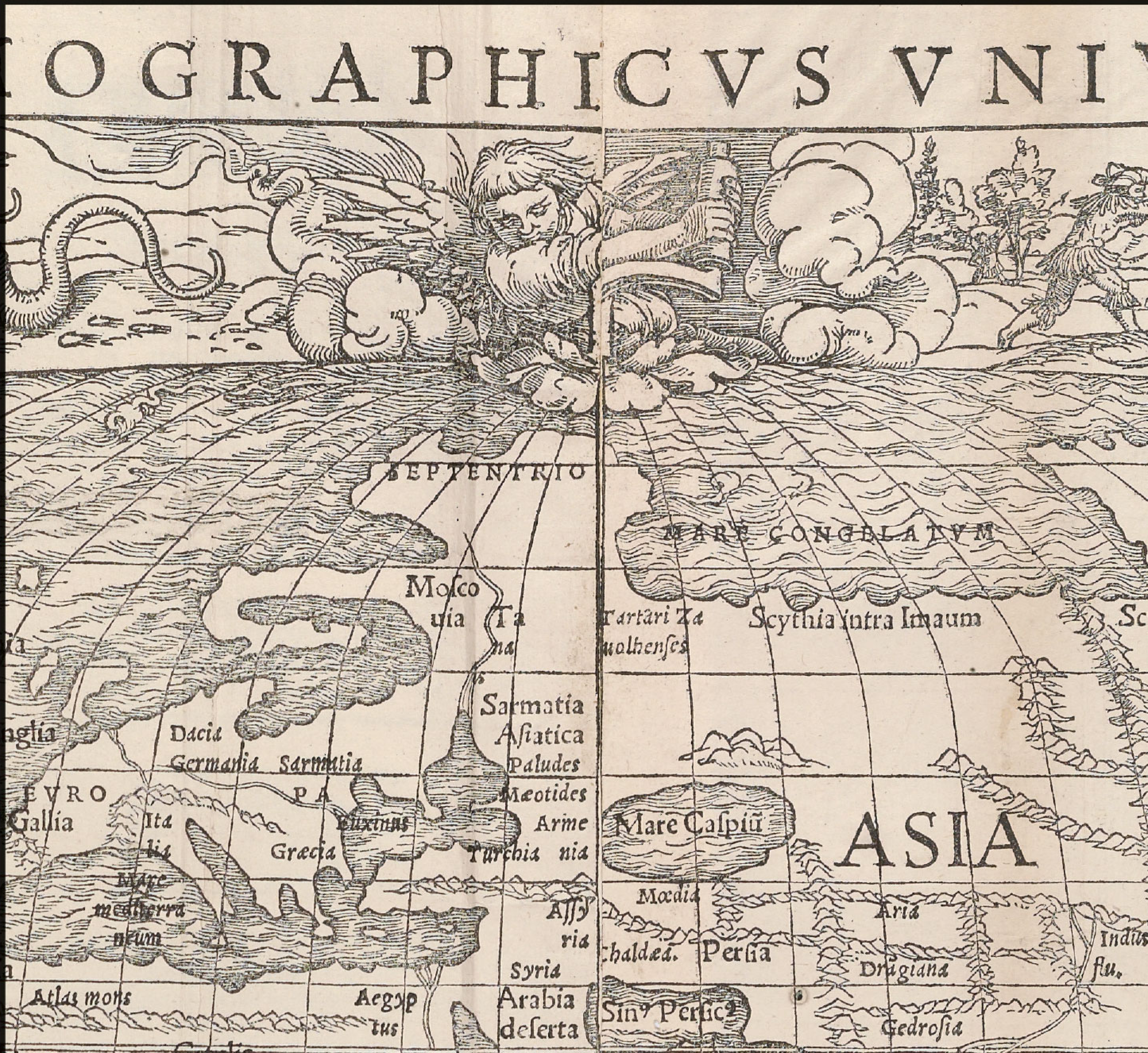

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Reception, Legacy, Transformation

By

Pietro Daniel Omodeo

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List of Illustrations

List of Abbreviations of Journals and Reference Books

ADB	*Allgemeine Deutsche Biographie*
AIMSS	*Annali dell'Istituto e Museo di Storia della Scienza di Firenze*
B&C	*Bruniana & Campanelliana*
BJHS	*The British Journal for the History of Science*
BOL	Bruno, *Opere latine conscripta*
BP	*Bibliografia Polska*
DBI	*Dizionario biografico degli Italiani*
DNB	*Dictionary of National Biography*
EN	Galileo, *Opere: Edizione nazionale*
ESM	*Early Science and Medicine*
FP	*La France Protestante* (reprint Génève, 2004)
GA	Copernicus, *Gesamtausgabe*
Gal.	*Galilaeana. Journal of Galilean Studies*
GCFI	*Giornale critico della filosofia italiana*
JHA	*Journal for the History of Astronomy*
JHI	*Journal of the History of Ideas*
JWCI	*Journal of the Warburg and Courtauld Institutes*
KGW	Kepler, *Gesammelte Werke* (München, 1937–)
MBW	Melanchtons *Briefwechsel* (Stuttgart-Bad Cannstatt, 1977–)
MFCG	*Mitteilungen und Forschungsbeiträge der Cusanus-Gesellschaft*
NDB	*Neue Deutsche Biographie*
Nunc.	*Nuncius. Journal of the History of Science*
ODNB	*Oxford Dictionary of National Biography*
PAPS	*Proceedings of the American Philosophical Society*
PSB	*Polski Słownik Biographiczny*
RSF	*Rivista di storia della filosofia*
SHPS	*Studies in History and Philosophy of Science*
TAPS	*Transactions of the American Philosophical Society*
VA	*Vistas in Astronomy*
Zedler	Johann Heinrich Zedler, *Grosses vollständiges Universal-Lexicon*

Other Abbreviations

app.	appendix
coll.	library or archive classification/shelf-mark/call number
n.	number
fn.	footnote
th.	thesis
s.v.	*sub voce*

Introduction

In his famous *Advis pour dresser une bibliothèque* (*Advice on Establishing a Library*, 1627), the Paris Librarian Gabriel Naudé included Nicholas Copernicus among the authors that a good furnished library ought to include, notwithstanding the fact that the Catholic Church had prohibited any support for the physical reality of the heliocentric system since 1616. Naudé insisted that Copernicus, followed by Kepler and Galileo, had thoroughly changed astronomy (*Copernic, Kepler et Galilaeus ont tout changé l'astronomie*).[1] Contrary to the views of Roman censorship and projects aiming at "selective libraries," such as that of the Jesuit Antonio Possevino, Naudé argued that all those who innovated (*innové*) our knowledge (*és Sciences*) or modified any respect of it (*changé quelque chose*) merit a place in a good library, even though they cast doubt on ideas that were held for irrefutable by the ancients and those who followed them uncritically.[2] He even listed Copernicus among scientific innovators who brought precious novelties (*Est quoque cunctarum novitas gratissima rerum*).[3] In a rather libertine *esprit*, Naudé did not exclude from his ideal library all "heresiarchs," like Luther, Melanchthon and Calvin, arguing that wrong opinions should be transmitted as well, at least in order to rebut them.[4] He also encouraged the acquisition of "rare" books, for which reason he mentioned the Copernican philosopher and heretic Giordano Bruno along with Girolamo Cardano and Pietro Pomponazzi.[5] More in general, Naudé encouraged the dissemination of the "Moderns," including Averroists (such as Zabarella, Achillini, and Nifo), Montaigne, Charron and Bacon, since only a "pedant" could deny the value of their works.[6] Thus, all "innovators" deserve a special place in the pantheon of culture. These are the "Novators who build upon new principles or else reestablish those of the ancients, Empedocles, Epicurus, Philolaus, Pythagoras, and Democritus, for philosophy."[7] Apart maybe from Empedocles, the philosophers on whom Naudé judges the *novateurs* to base their new philosophies are directly or indirectly relevant for the natural debates hinging on Copernicus during the Renaissance. In fact, Pythagoras and Philolaus were

1 Naudé, *Advis*, 42.
2 Ibid.
3 Ibid., 43. The quotation is from Ovid.
4 Ibid., 46–48.
5 Ibid., 45.
6 Ibid., 56–57.
7 Ibid., 65. Cf. Engl. ed., 41.

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generally seen as ancient supporters of the heliocentric model and the atomists were treated in connection with Copernicus in many intellectual circles.

Naudé's perspective offers a synthesis of a widespread image of Copernicus at the beginning of the seventeenth century, that is, an image resulting from the debates that I am going to reconstruct in this book on the early reception of Copernicus. With Naudé, Copernicus potentially enters as a protagonist of the *Querelle des Anciens et des Modernes*. This image accords with one of the most widespread representations of Copernicus, if not the historical *cliché* concerning his person and work. However, the present research on the reception, presence, influence and transformation of Copernicus in the scientific and cultural debates of the Renaissance aims to reconstruct how differently his person and his work were perceived in different moments and in different environments throughout the sixteenth century.

Copernicus's achievement as an astronomer who profoundly changed his discipline occurred in an exceptional period of transition in the European history, when natural investigation flourished and rapidly developed in many fields with unprecedented impetus. This age of "Renaissance" paved the way for crucial scientific, philosophical and cultural developments, not last the scientific habitus, celebrated in later centuries as a unique trait of modernity *tout court*. Yet, it is undeniable that the medieval roots are no less important to understand the epoch than the new prospects it disclosed. What's more, humanists and Renaissance scholars tended to conceive of their activity as a commitment to the rebirth of classical Antiquity, a fact that accounts for the constant entanglement of innovation and tradition that so distinguishes their age.

As I intend to show, this profound ambiguity also affects Copernicus and his reception. Much like many works of those times, his *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*, 1543), and the discussions it provoked, were marked by an inner tension between *new* and *old*, i.e., in this case, by the exploration of new conceptual worlds, on the one hand, and the hope and declared intention to reestablish some ancient and almost mythical wisdom, on the other. Thus, I am going to assess the multifariousness of the cultural environment in which Copernicus lived and was received, and more precisely of the "century" that began with the first circulation of his ideas, at the outset of the sixteenth century, and ended about 1616 with the Catholic interdiction of the heliocentric system.

Fifty years ago, Thomas Kuhn had very much in mind the effects produced by Copernicus when he published his theory of scientific revolutions, according to which scientific advancement is a discontinuous process in which apparently stable systems of knowledge, or, as he called them, "paradigms," are undermined by challenging problems that cannot be solved within a given framework and inevitably lead to conceptual upheavals. Kuhn's most famous work on historical epistemology, *The Structure of Scientific Revolutions* (1962), was preceded in fact by a monograph on Copernicus, unambiguously entitled *The Copernican Revolution* (1957). Its main thesis was that the heliocentric system was from the very beginning destined to disrupt the coherent but unsatisfactory worldview constructed on the pillars of Ptolemaic astronomy, Aristotelian natural philosophy and Biblical exegesis.

The tie between "Copernican Revolution" and "Scientific Revolution" was not new in Kuhn's times: Alexander Koyré had already proposed it in influential works such as *Études galiléennes* (*Galileo Studies*, 1939) and *From the Closed World to the Infinite Universe* (1957), where inertial dynamics, cosmological infinity, and the geometrical and uniform conception of space were presented as the direct offspring of Copernican astronomy, since they presumably stemmed from unsolved problems raised by Copernicus's planetary theory. Hence, Koyré deemed the so-called Scientific Revolution, from Galileo to Newton via Descartes, to be, in its core, an "astronomical revolution," as the title of another book of his goes: *La révolution astronomique* (*The Astronomical Revolution*, 1961).

Albeit questionable, the opinion that modern science emerged in radical opposition to traditional views on nature, and that Copernicus played a fundamental role in it, is probably as old as the idea of modernity. Immanuel Kant presented his transcendental philosophy, which can be regarded as both the coronation and the conclusion of the Enlightenment, as a "Copernican revolution." He contended that his project of reversing the relation between subject and object in the theory of knowledge could be compared to Copernicus's substitution of geocentrism for heliocentrism in astronomy. In the introduction to the second edition of the *Kritik der reinen Vernunft* (*Critique of Pure Reason*, 1787), he claimed that natural knowledge had just undergone a conceptual revolution bringing physics to its definitive scientific form thanks to authors like Galileo and Copernicus. Addressing this "schnell vorgegangene Revolution der Denkart" (sudden revolution in the way of thinking), Kant made reference to Francis Bacon as well, who was one of the intellectual heroes of the Enlightenment.[8]

Yet, in modern imagery, the opposition between "progressive Copernicans" and "conservative" Aristotelian-Ptolemaic scholars does not stem exclusively from a modernist commitment like Bacon's to a *new method* pitting empiricism and technology against the obscure "superstitions" (and metaphysics) of

8 Kant, *Kritik*, 18, and *Critique*, 18.

the Middle Ages. The opposition between Copernicus, on the modern side of the historical watershed, and Ptolemy and Aristotle, on the other, owed very much, *ex negativo*, to the cultural policy of Counter-Reformation Rome, especially to tragic episodes of intolerance like the execution of the Copernican philosopher Bruno in 1600, the prohibition of the heliocentric system in 1616, and Galileo's Inquisitorial trial and abjuration of the Copernican system in 1633. We will discuss in detail the historical and theoretical contradictions entailed in the idea of an "Aristotelian-Ptolemaic system" as well as by the *aut-aut* opposition between geocentrism and heliocentrism in the sixteenth century. In a way, this interpretation was crystallized by Galileo's *Dialogo sopra i due massimi sistemi del mondo* (*Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican*, 1632) as the conflict between Copernican versus Aristotelian-Ptolemaic cosmology, which later took the shape, in the consciousness of many Europeans, of an irredeemable conflict between *science* and *religion*.

For these many reasons, a reflection on Copernicus and his achievement cannot be disentangled from wide historical, cultural and philosophical considerations. Of course, we shall avoid the one-sided temptations of big-picture narratives seeking for an artificial unity in the reception of Copernicus, as has often been the case in the scholarship. In fact, as Owen Gingerich's *Census of Copernicus' De Revolutionibus* (2002) has demonstrated, the interests and interpretations of the readers of Copernicus's work in the sixteenth and seventeenth centuries cannot be limited to cosmology, or the general hypotheses of planetary theory. The motivations to read *De revolutionibus* in Copernicus's century were the most varied. For instance, Gingerich and Robert Westman have shown the centrality of geometrical modeling and computation of the ephemerides rather than terrestrial motion for the majority of German mathematicians working under the influence of Philip Melanchthon.

Although the idea of a pluralist reception of Copernicus has gradually emerged in the Copernican studies, there is a continuing trend to seek all-encompassing interpretations of Copernicus's achievement and its effects. This enduring tendency appears most vividly in Westman's recent presentation of the *Copernican Question* (2011) as an "astrological question," in which the motivations of Copernicus and his early readers are brought back to prognostication. Although the relevance of astrology for Renaissance science is undeniable, the reduction of post-Copernican astronomy to an astrological enterprise is very dubious, as we shall see while treating, in this book, a variety of issues that invested Copernican astronomy without concerning astrology. Additionally, scholars treating Copernicus within the history of philosophy have inclined toward his insertion into some "-ism," for instance "Platonism" or “Aristotelianism.” Curiously enough, the vogue to compare Copernicus with some authoritative classical forerunners began back in the Renaissance, when he was often mentioned as “another Ptolemy” for his mathematical skills, and called “the Pythagorean” for his cosmology.

In this study, I will remain as close as possible to the perspectives documented by historical sources. As Miguel Angel Granada and Rienk Vermij have shown in seminal studies on early modern astronomy, only an “empirically-grounded research” can free history of science from the illusions of historical teleology. I share their opinion that the history of knowledge shall not depart, acritically and ahistorically, from present knowledge about nature and current assumptions, but should rather try to understand the natural conceptions of the past in their contextual dimension. For his inimitable historical sensitivity, along the same lines, I would also like to mention here the earlier scholar Ludwik Antoni Birkenmajer, whose *Mikołaj Kopernik* (1900) still offers, after more than one hundred years, precious historical and philosophical suggestions, always based on thorough knowledge of original and rare sources.

Concerning the intellectual tools employed in this research, I owe much, at least *idealiter*, to the prominent Renaissance scholar Eugenio Garin, whose concepts of *cultura scientifica* and *cultura filosofica* are also useful for the treatment of Renaissance astronomy. Following Antonio Gramsci’s reflections on culture, Garin did not restrict the history of knowledge (philosophical or scientific) to a technical history or to a product of internal debates among experts. In his historical overviews, he showed that one ought to go beyond the realm of the “philosophy of the philosophers,” in our case the “astronomy of the mathematicians and astronomers,” and look at wider interconnections. In particular, I will focus on the “scientific culture” of the *intellettuali* participating in the “higher” production of culture. Garin called intellectuals those influential people who express dominant conceptions in the fields of philosophy, literature, the arts, and even politics. Furthermore, according to this Gramscian reflection, there is a “philosophy of the masses” to be taken into account, which is crystallized in the language, folklore, popular beliefs and, above all, religion. These remarks are relevant to investigations on the image and the influence of Copernicus during the sixteenth century and beyond. Although *De revolutionibus* was explicitly presented as a work for mathematicians, it underwent a gradual dissemination from restricted circles of specialists to other fields of culture. Eventually, it was brought to the attention of the masses, when the rejection of Copernicus’s system became a matter of faith even addressed in public from the pulpit of the Church. Hence, the scriptural-theological attacks on Copernicus or religious apologies for his theory during the sixteenth century are indications of his “public reception” or, rather, “popular dissemination.”

In order to grasp the cultural meaning of science in its historical development, literary sources can be useful as well. Remarkably, the first echoes of the heliocentric theory printed in Italy, France and England appeared in vernacular, precisely in Anton Francesco Doni's *I Marmi* (*The Marbles*, Venice, 1552–1553), Robert Recorde's *The Castle of Knowledge* (London, 1556), and Pontus de Tyard's *L'Univers* (*The Universe*, Lyon, 1557).

Due to the interconnections of different aspects of culture, the Renaissance development of astronomy shall be treated as a process of mutual influences among the three main levels of knowledge production and transmission: technical, cultural and social. In this study I will focus on the *astronomical culture*, that is, I will present a historical investigation guided by the assumption that science is a multi-layered cultural phenomenon in which the contents of science, their historical form and social conditions are indissolubly interwoven. In particular, Renaissance astronomical culture results from interactions among several factors, such as the advancement of empirical knowledge, the materials and conceptual instruments available (for instance, philosophical and mathematical), natural philosophy, epistemology, theology, literature as well as material culture, and the political, social, institutional, and confessional environments of scientific production.

Another essential lesson from Garin was the centrality of sources for any historical reconstruction. Again: loyalty to sources and authors means keeping interpretations and sources in constant dialogue so as to avoid the distortion of data to fit some grand narrative. Garin never deemed it necessary to translate the sources on which his investigations rested, but rather quoted them extensively in their original language, very often Latin. In my opinion, he was motivated to do so by a profound respect for his readers. He communicated to them the passion for an investigation in constant contact with original documents and, what is more important, he encouraged new generations of scholars learning from him to cultivate the study of the classical languages without which early European history is neither possible nor conceivable. This is particularly true, of course, for the Renaissance. Times have changed, though. Therefore, according to new academic standards—which are no longer those of Birkenmajer or Garin—I will quote the original sources from English translations that are already extant (from time to time correcting them, when I deem it necessary), or I will translate them from Latin, Italian, German, and French into English. I will make the original sources available to scholars separately, on the web. In the transcription of passages, I have generally revised punctuation, accents and capital letters according to common standards. I have corrected gross misprints and as a rule I have replaced the abbreviations and the symbols with the full text. In the translation into English I have generally preferred intelligibility to literalism, that is, I have chosen to translate freely, so as to respect, as much as possible, the meaning rather than the letter of the words.

This investigation on Copernicus in his century will concentrate on *debates*, broad cultural discussions hinging on key problems that were perceived as particularly important at special moments and places. For instance, the Renaissance debate on the status of astronomy was intense and concerned philosophers as well as mathematicians. Furthermore, the issue of the relation between revelation and nature, or between exegesis and natural science, ran through the most diverse areas of European culture. Debates involved actors who often belonged to different disciplinary fields and environments. One famous debate of the seventeenth century, for instance, on the Moderns and the Ancients, cannot be restricted to a special disciplinary field, since it involved history as well as the theory of art, philosophy and technology. The agenda of such debates changed over the years and could vary depending on different geographical, linguistic, confessional environments or existing scholarly networks. Copernicus's work, as we shall see, was variously embedded in Renaissance debates such as those mentioned, and thus was interpreted and assessed differently depending on contexts and complexes of problems.

I would like to stress that *debates* include *scientific controversies* without being reducible to them. The epistemological relevance of scientific controversies as a constitutive basis for science and scientific development has emerged especially in the last years. According to Gideon Freudenthal's definition, a scientific controversy is "a persistent antagonistic discussion over a disagreement concerning a substantial scientific issue that is not resolvable by standard means of the discipline involved."[9] "Debates" are more general. They constitute the background of special controversies and gravitate around key ideas. An issue that was debated in connection with Copernican astronomy is, for instance, the problem of the relation between astronomy and physics, involving philosophers, mathematicians, and theologians. Another example was the collective reflection about the impact of the heliocentric model on imagery, involving poets, astronomers, philosophers and laymen, for instance aristocrats interested in scientific matters and letters. One might also treat terrestrial motion and solar centrality and immobility as key themes for cultural debate. Still, as already stated, heliocentrism does not provide the full understanding of the presence, dissemination and influence of Copernicus. A hint at the complexity of the reception of his system is the fact that, during the Renaissance, the heliocentric model was not perceived as simply "Copernican" but rather as "Pythagorean"—with all the implications of a reference to that ancient

9 Freudenthal, "Rational Controversy," 126.

philosophical school to which the most varied theories were attached, ranging from mathematical epistemology to metempsychosis.

In this connection, it is important to dispel a widespread myth concerning the reception of Copernicus. Although his ideas, especially the cosmological views, were often compared to geographical discoveries (indeed, this is the way in which Copernicus and his pupil Rheticus presented heliocentrism and terrestrial motion in some passages), the analogy between astronomy and geography can be misleading, since it might convey the wrong and quasi-religious idea of heliocentrism as a truth to be revealed to humankind and disseminated in the same way as explorers of lands yet unknown to the Europeans reported about their discoveries, thereby modifying and enriching traditional geography (and most significantly that of Ptolemy). Copernicus did not really do anything to avoid this and even encouraged, at the beginning of *De revolutionibus*, the association between Amerigo Vespucci's *mundus novus* and his own innovative world system. Moreover, he compared his worldview to a secret to be cautiously revealed to the initiated, much as the Pythagoreans taught their doctrines only to the adepts. However, the dissemination of Copernicus's views cannot be convincingly presented as a process in which a "discovery" overcame all obstacles in its path and rebutted objections based on prejudices or obstinacy by winning all conceivable disputes and bringing forward arguments stronger than those of opponents. By contrast, Copernicus's astronomy underwent a process of profound transformation at the end of which his planetary theory maintained only some of its initial features, but was modified substantially with regard to its details and its natural and physical premises. In fact, the "Copernicanisms" of Bruno, Kepler, Galileo, and Descartes are not simply vindications of Copernicus's astronomy. Rather, these authors put forward new and very different viewpoints that owe to *De revolutionibus* certain salient ideas, mainly heliocentrism and terrestrial motion, while rejecting almost everything else: Copernicus's geometrical models for the planets, the number and characteristics of terrestrial motions, the form of the universe, the number of worlds, the laws of motion, and, in general, the concept of nature and science.

As Hartmut Böhme recently stressed in his reflections about the dynamics of cultural evolution, all forms of reception and of knowledge transfer entail by necessity transformation. These are "complex processes of change occurring between a reference realm and a reception realm [...]. Thereby, the appropriation act does not only modify the receiving culture but also, and especially, constitutes the reference culture."[10] The potentialities of Copernicus's work

10 Böhme, *Transformation*, 39 (own translation).

were only disclosed by the decisions, commitments, commentaries, and interpretations, even criticisms, of those who came after him. From a historical perspective, it does not only matter to establish what debates and controversies originated from Copernicus. It is also relevant to consider how and why the person, the work and the ideas of Copernicus were embedded in different discourses. Natural debates about heavenly matter, atomism, and space infinity, as well as ethical concerns about human dignity and freedom, could not reasonably stem from Copernican astronomy. The fact that an assessment of Copernicus became part of such debates might be the fruit of historical contingencies. Nonetheless, those contingencies forged the image of Copernicus and the subsequent judgment about his work.

A study on the *transformations* of Copernicus in his century is to a great extent an investigation of the historical appearance of "Copernicanism" as a commitment in favor of a worldview—or rather worldviews—including astronomical, epistemological, natural, cultural, ethical and religious connotations. "Copernicanism" is no explanation, it is the *explanandum*. Only after 1616 (and 1633), siding with the Copernican "cause" meant supporting heliocentrism (at times also cosmological infinity), mostly a mathematical approach to nature, certainly the criticism of tradition, stressing intellectual freedom from doctrinarian dogma and opposing the religious and cultural line of Rome. In this book, I will investigate the period that preceded those developments. I will thus focus on the processes of dissemination, reception, appropriation and transformation of Copernicus as resulting from the cultural debates that were either triggered by his work or produced new evaluations of it.

In the first chapter of this book, I reconstruct the main lines of *reception*. It is an overview of the dissemination of Copernicus's ideas before and after the publication of *De revolutionibus*, up to 1616. In the subsequent chapters, from two to eight, I will go into closer detail, focusing on particular issues linked to Copernican astronomy. To this aim, I deem it expedient to organize my analyses around certain themes, crucial for understanding Renaissance astronomy and science. These are the following: the epistemology underlying astronomy, mathematics and natural philosophy (chapters two and six), computation and astrological prediction (chapter three), cosmology and space conceptions (chapter four), physics (chapter five), theology and biblical exegesis (chapter seven), anthropology and ethics, and literary imagery (chapter eight).

Contrary to the majority of treatments of Copernicus and his reception, the goal of this book is not to look for a unifying principle accounting for the genesis, the circulation and the influence of *De revolutionibus* and its author. It rather seeks to convey the sense of the richness of Copernicus's work, which is mirrored by the plurality of the readers' interests, the prism of their interpretations and the variety of debates that involved it, directly or indirectly. I believe that the stature of an author lies not in the coherence of his views and that such consistency is mostly a projection of the desires of later interpreters, critics and followers. Plurality is stronger evidence of scientific and cultural significance than unity of interpretation. To put it more clearly, this research does not depart from the idea of a "Copernican revolution" to arrive at any "Copernicanism;" rather, it assumes that "Copernicanism" is a historical product that has been very useful for narratives on the "Copernican revolution" but remains, in the end, one among many assessments of Copernicus that emerged in history. I will thus consider the "Copernican question" as a plurality of questions that, in the long run, profoundly changed science, epistemology, natural philosophy, theology and even literature.

CHAPTER 1

Copernicus between 1514 and 1616: An Overview

1 Copernicus's Connection

The 1st of May 1514 is the first ascertained date of the circulation of Copernicus's planetary theory. On that day, the Cracovian physician, historian and geographer Maciej of Miechów recorded in the catalogue of his library an essay presenting the unusual doctrine of the motion of the Earth and the immobility of the Sun: "A quire of six leaves (*sexternus*) of a theory asserting that the Earth moves whereas the Sun is at rest."[1] This entry refers almost undoubtedly to the first presentation of Copernicus's astronomical conception, a manuscript generally known as *De hypothesibus motuum coelestium commentariolus* (*Brief Commentary on the Hypotheses of Heavenly Movements*), only three copies of which, as far as we know, have been preserved up to the present day.[2]

Nicholas Copernicus was then a canon of the Chapter of Frombork in Varmia. Although he lived in an apparently isolated Baltic region subject to the King of Poland, he and his close friends kept up correspondence with many scholars in different countries, in the Polish capital Cracow, Germany, Italy, Switzerland and Flanders. Their network facilitated the first propagation of Copernicus's views even before the completion and publication of his major work, *De revolutionibus orbium coelestium* (*The Revolutions of the Heavenly Spheres*), printed in Nuremberg in 1543. In the thirty years between the *Commentariolus* and the publication of his mature and extended work on mathematical astronomy, he keenly attended to the recording of astronomical data and to the improvement of astronomical parameters and geometrical models.[3] Notably, one can trace a first reception of Copernicus, however limited, already in this period.

With its university, humanist milieu and court, Copernicus owed his cultural background to Cracow. He studied liberal arts at Jagellonian University between 1491 and 1495, and maintained academic contacts there throughout

1 Biskup, *Regesta*, 63–64, n. 91. Cf. L.A. Birkenmajer, *Kopernik*, chap. 3, 70–88, and Swerdlow, "Derivation," 431.

2 Cf. Biskup, *Regesta*, 50, n. 55: Nationalbibliothek of Vienna (manuscript 10530), Kungliga Vetenskapsakademiens Bibliotek of Stockholm (Ms Copernicus) and University Library of Aberdeen, Special Collections Centre (πf 521 Cop2[2]).

3 Cf. Swerdlow-Neugebauer, *Mathematical Astronomy*, 64–72.

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his life.[4] Therefore, Cracow played a significant role both in his formation and in the establishment of his fame even during his own lifetime. As a student he was able to benefit from a consolidated tradition in astronomy. According to Hartmann Schedel's *Liber chronicarum* (*Book of Chronicles*, 1493), no German university could compare to Cracow in this discipline: "The study of astronomy flourishes [...] and nowhere in Germany can one find it more eminent than here."[5] Later, Copernicus maintained correspondence with the cartographer and historian Bernard Wapowski, to whom he addressed, on 3 June 1524, a letter on the motion of the fixed stars in which he criticized Johannes Werner's *De motu octavae sphaerae* (*The Motion of the Eighth Sphere*).[6] Given the friendly relations between Copernicus and Wapowski, it is plausible that he was the person who received the copy of *Commentariolus* registered in Maciej of Miechów's library.[7] Wapowski acted as a mediator and promoter of Copernicus on another occasion, shortly before his death. In 1535, in fact, he sent to Sigismund Herberstein in Vienna an almanac of his friend's which was derived from his new astronomical tables.[8]

Copernicus was already appreciated for his astronomical talent in Italy as well, where he continued his studies. He attended courses in law and medicine between 1496 and 1503 at Bologna, Padua and Ferrara, where he eventually graduated in canon law.[9] In Bologna, he was appointed by the mathematician Domenico Maria Novara as a collaborator and a witness of astronomical observations (*adiutor et testis observationum*).[10] Some of the records from that period are registered in *De revolutionibus*.[11] According to the report of his pupil Rheticus, Copernicus also held some public lectures on astronomy in Rome around 1500.[12] After he returned to Poland (1503), the Bishop of Fossombrone

4 Cf. Biskup, *Regesta*, 36, n. 21 (for the immatriculation). On Copernicus and the University of Cracow: Birkenmajer, *Stromata*, 50–141, Poulle, "Activité astronomique," Czartoryski, "École astronomique," and Knoll, "Arts Faculty."

5 Schedel, *Liber chronicarum*, f. 269r. On the Polish scientific tradition before Copernicus, cf. A. Birkenmajer, *Études*. See also Goddu, *Copernicus, passim* and Markowski, "Astronomie als Leitwissenschaft."

6 Cf. Rosen, *Three Copernican Treatises*.

7 Cf. Hugonnard-Roche, *Introductions*, 32.

8 Biskup, *Regesta*, 155–56, n. 345. On Wapowski see also BP 32 (1938), *s.v.*

9 Ibid. 44, n. 42. On Copernicus in Italy see, among others, Poppi, "Filosofia della natura," Biliński, "Periodo padovano," and, for Bologna, Westman, *Copernican Question*, 76 ff., chap. 3.

10 GA VIII/1, 6.

11 Biliński, *Alcune considerazioni*, 50–53, and Bonoli, *Pronostici*.

12 GA VIII/1, 6; Biskup, *Regesta*, 42, n. 36.

Paul of Middelburg, as the president of a commission deputized to implement the calendar reform at the Lateran Council (1512–1517), consulted him on this matter.[13] Middelburg noted in his *Secundum compendium correctionis calendarii* (*Second Summary of the Calendar Correction*, 1516) that Copernicus had answered his appeal, but his letter is now lost.[14] In any case, this reform would remain an unresolved issue until the introduction of the Gregorian calendar in 1582. Some years after the Council, the Cardinal of Capua and papal secretary Nicolaus Schönberg asked Copernicus for a copy of his astronomical manuscripts in a letter dated 1 November 1536 and later printed in the opening of *De revolutionibus*. Schönberg guaranteed his patronage to the *nova mundi ratio*, that is, the planetary theory "that the Earth moves; that the Sun occupies the lowest, and thus the central, place of the universe; [and] that the eighth heaven remains perpetually motionless and fixed."[15] These facts show that Copernicus's mathematical talent as well as the principal features of his cosmology were already known and even appreciated by exponents of the Roman curia in the first decades of the sixteenth century.

When he returned to Poland to fulfill his duties as a canon of Frombork, Copernicus maintained constant diplomatic relations, even during war, with Ducal Prussia, a region that almost entirely surrounded Varmia. Between 1520 and 1521 he faced an invasion of Varmia by the troops of the aggressive neighbor. In 1522, the Grand Master of the Teutonic Order ruling that country, Albrecht of Hohenzollern, was persuaded by the Nuremberg preacher Andreas Osiander and by Martin Luther to embrace the Reformation and to convert his territory into a hereditary duchy, a decision that strained the already uneasy relations with the Catholic Kingdom of Poland. Notably, Copernicus was not at all on bad terms with the Duke of Prussia, despite his loyalty to the King and the Pope. In particular, he energetically devoted himself to the civil project of standardizing the coinage for the regions of Varmia, Royal Prussia and Ducal Prussia—on which subject he wrote most importantly the treatise *Monetae cudendae ratio* (*On the Coinage of Money*, 1528). Moreover, he and his closest friends took up a rather tolerant attitude toward the Reformation. In turn, Duke Albrecht supported Copernicus's pupil Rheticus and was the dedicatee of the first tables derived from Copernicus's parameters, the *Prutenicae tabulae* (*Prussian Tables*, 1551) of the Wittenberg Professor Erasmus Reinhold.[16]

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13 Cf. Copernicus, *Revolutions*, 5–6. See also Marzi, *Questione*.

14 Cf. Rosen, "Was Copernicus' Revolutions Approved?," 531, fn. 3.

15 Copernicus, *Revolutions*, XVII.

16 Westman, *Copernican Question*, 144–47.

The humanist environment of Varmia comprised a group of admirers of Erasmus of Rotterdam: Tiedemann Giese, Alexander Scultetus, Feliks Reich and Achacy Trenck.[17] Giese, canon of Varmia (since 1502–1504) and later Bishop of Chełmno (1538) and Varmia (1548), warmly supported Copernicus's research and prompted the publication of *De revolutionibus*.[18] He also depicted himself as a "pupil" of Erasmus and declared that he would rather renounce "fire and bread" than his books.[19] He entered into correspondence with the famous humanist and submitted to him some theological writings. It is possible that Erasmus was informed of Copernicus's planetary conception. This is witnessed at least indirectly by the *Epistolae ad naturam pertinentes* (*Epistles on Nature*, Cracow, 1615) by the Cracovian mathematician Johannes Broscius: "I saw the still unprinted *Apology* (*Hyperaspisten*) for Nicholas Copernicus by the Bishop of Chełmno Tiedemann Giese in which Tiedemann himself mentions Erasmus of Rotterdam's rather temperate opinion on Copernicus."[20] Copernicus shared Giese's attitude toward religion and encouraged the publication of his irenic theological writing *Anthelogikon*: "Nicholas Copernicus—his friend stated—prompted the publication of those trifles of mine."[21] Giese was also in contact with the leading Lutheran humanist Philip Melanchthon. He sent to him his syncretistic *De regno Christi*, a compendium of anti-scholastic Christian philosophy that displeased both Wittenberg and the emerging Polish Counter-Reformation for its intention to keep an equidistant position between the two struggling parties.[22]

The tolerant atmosphere of Varmia was subverted in 1538 by the arrival of an intransigent bishop, Jan Dantyszek, whose election had been opposed by Copernicus's circle. Dantyszek was a strenuous enemy of the Reformation and an advocate of ecclesiastical discipline.[23] For instance, he severely contrasted the moral laxity of the chapter, where many canons lived in concubinage. Copernicus was even forced to renounce his housekeeper Anna Schillings. Dantyszek most fiercely attacked Alexander Scultetus, a friend of Copernicus and Giese. He quarreled with him about the appointment of Stanisław Hozjusz

17 Borawska, *Giese*, 318. See also Jasiński, *Kopernik* and Hallyn, "Copernic et Erasme."

18 GA VIII/1, Rheticus, *Encomium Prussiae*.

19 Cf. Borawska, *Giese*, in particular chap. "Giese a reformacja i reformatorzy," 303 ff.

20 Cf. Hooykaas, *Rheticus' Treatise*, 26, fn. 45. See also Biskup, *Regesta*, 157, n. 348 and 160, n. 358.

21 Kempfi, "O dwu edycjach," 422.

22 See Prowe, *Coppernicus*, vol. I/2, 167–87, chap. "Coppernicus und sein Freundes-Kreis in ihrer Stellung zur Reformation."

23 Cf. Prowe, *Coppernicus*, vol. I/2, chap. 7, "Coppernicus und Dantiscus," 326–71. See also PSB 3 (1938), *s.v.*

as a canon, a later bulwark of the Polish Counter-Reformation. Scultetus, accused of concubinage and heresy, had to flee abroad, to Rome, where he was eventually exculpated after three years' imprisonment in Castel Sant'Angelo (1541–1544). As it was impossible to return home because of the tensions with Dantyszek, he stayed in Rome and published a universal chronology, *Chronographia sive Annales omnium fere regum, principum ac potentatum ab orbe condito usque ad annum 1545* (*Chronography or Annals of Almost All Kings, Princes and Dominions from the Beginning of the World to 1545*, 1545), in which "Nicholas Copernicus, Canon of Varmia, Astrologer" was also included among the *clari viri* of all epochs.[24] Despite the frictions with Copernicus, Dantyszek contributed to the dissemination of his renown, in particular through his correspondence with the Flemish mathematician and physician Reiner Gemma Frisius, professor at Louvain.[25] The two had met in 1531, when Dantyszek came to Flanders in the retinue of Charles V as ambassador of the King of Poland and took Gemma Frisius under his protection.[26]

2 Platonizing Humanists

A European network of humanists played a major role in the early dissemination of Copernicus's cosmology in the philosophical framework of Platonizing Pythagoreanism. Copernicus himself trumpeted the Pythagorean origins of his planetary theory, and his conception was long thought to be inspired by the doctrines of that ancient school.[27] To reconstruct this network, it is convenient to refer back to Schönberg's letter to Copernicus. In 1536, this Roman Cardinal stated that the Polish astronomer was widely known and esteemed, relating how "some years ago word reached me concerning your proficiency, of which everybody constantly spoke. At that time I began to have a very high regard for you." He added that he praised Copernicus's talent with "our contemporaries among whom you enjoy such great prestige,"[28] probably referring

24 Scultetus, *Chronographia*, 163. See also Prowe, *Coppernicus*, vol. I/2, 346–62 and Borawska, *Giese*, 325 ff.

25 GA VI/1; Biskup, *Regesta*, 198, n. 468, 198–99, n. 469, 209, n. 492, 210, n. 495. See also Van Ortroy, *Bio-Bibliographie*, Hallyn, *Gemma Frisius*, McColley, "Early Friend" and Gingerich, *Annotated Census*, 147.

26 Hallyn, *Gemma Frisius*, 12–13 and 157. See chap. 3,1 and 3,2.

27 Biliński, *Pitagorismo*. For general considerations on the Platonic influences on Copernicus see: De Pace, *Copernico e la fondazione*.

28 Copernicus, *Revolutions*, XVII.

to the prelates and canons of Varmia and Prussia and their common acquaintances in Cracow. Schönberg had cultivated relations with Poland since 1518, when he participated in the wedding of King Sigismund I Jagiellon with the Italian aristocrat Bona Sforza. On that occasion he may have heard about Copernicus's views, which were known to Maciej of Miechów and Wapowski. In 1518, Schönberg visited Varmia and was warmly received at the chapter of Frombork.[29] It is likely that he also met Copernicus in person.[30]

News of the Copernican doctrine reached Rome in 1533, where Schönberg's secretary-to-be (beginning in 1535), the Orientalist Johann Albrecht Widmanstadt (or Widmanstetter), presented the heliocentric theory to Pope Clemens VII and to distinguished members of the curia (Cardinal Franciotto Orsini and Cardinal Giovanni Salviati, the Bishop of Viterbo Giampietro Grassi and the papal physician Matteo Corte).[31] The Pontiff, who was a learned man of the family de' Medici, welcomed the original ideas and presented the reporter a copy of Alexander of Aphrodisias's *De sensu et sensibili*. Inside that precious Greek codex, Widmanstadt noted the circumstance and the reason for that present, namely the exposition of Copernicus's heliocentric theory.[32]

Widmanstadt's twofold interest in cosmology and Oriental studies was not unprecedented, as the same mingling is displayed by one of his teachers, the Hebraist and geographer Sebastian Münster, remembered as someone who pursued the *veritas hebraica* and empirical geographical research at the same time.[33] Münster had become a professor of theology in Basel in 1538 and collaborated with his stepson, the printer Heinrich Petri, who published the second edition of *De Revolutionibus* (1566). Sebastian Münster was the author of a map of the world displaying the motion of the Earth. It was printed in an anthology of exploration reports in the West as well as in the East, *Novus Orbis* (*New World*, 1532), collected by his colleague and friend Simon Grynaeus, professor of Greek at Basel. The world map, *Typus cosmographicus universalis*, accompanied by an introduction by Sebastian Münster himself, displayed a couple of angels pulling two huge handles on the poles of the Earth to produce its daily rotation (see figure 1).[34] This map bears witness to the circulation of alternative

29 Cf. Biskup, *Regesta*, in particular 88, n. 167.

30 See L.A. Birkenmajer, *Kopernik*, chap. XXV, "Mikołaj Schomberg i Jan Albert Widmanstadt," 533–45. Cf. also Walz, "Lebensgeschichte."

31 Zinner, *Entstehung*, 227–28.

32 Tiraboschi, "Memoria," 350. Cf. also Biskup, *Regesta*, 153, n. 339.

33 McLean, *Cosmographia*, 43. Cf. L.A. Birkenmajer, *Kopernik, passim*, Burmeister, *Münster* and ADB 42 (1897), *s.v.* ("Widmanstetter").

34 Grynaeus, *Novus Orbis*; cf. Rosen, *Copernicus and his successors*, 172–92. Münster's map and introduction were excluded from the subsequent German edition (Grynaeus, *Die New Welt*, Strasbourg, 1534).

FIGURE 1 *Sebastian Münster's Universal Map with the Earth in rotation about its axis*
COURTESY OF THE DIBNER LIBRARY OF THE HISTORY OF SCIENCE AND TECHNOLOGY AT THE SMITHSONIAN INSTITUTION LIBRARIES (WASHINGTON, DC, USA).

cosmologies with the Earth in motion before the publication of Copernicus's major work in 1543. Perhaps Sebastian Münster was informed about it, since he was well acquainted with Widmanstadt. He significantly maintained a correspondence with him at least until 1547, that is, long after the presentation of heliocentrism to the Roman Curia.[35] He could also have had some contacts in Cracow, as Maciej of Miechów's *Tractatus de duabus Sarmatiis, Asiana et Europeana* (*Treatise on the Two Sarmatias, the Asian One and the European One*, 1517) was the only source on Russia in his *Cosmographia*.[36] Later, he probably met Copernicus's pupil Rheticus, when the latter came to Basel in 1547. Their acquaintance is suggested by their interest in mathematics and geography, Sebastian Münster's contact with Rheticus's friend Gasser, and his employment of Rheticus's map of Prussia in the *Cosmographia*.[37]

35 Burmeister, *Münster*, 147.
36 Münster, *Cosmographia*, f. 8v. A new edition of the *Tractatus* by Maciej of Miechów was included in Gryneus, *Novus orbis*. Cf. BP 22 (1908), *s.v.*
37 For the common mathematical interests, see Burmeister, *Rhetikus*, vol. 1, 98–99; for

Sebastian Münster's and Widmanstadt's cosmological doctrines grew out of an environment strongly characterized by Pythagoreanism and Oriental studies. This is also the case for the learned scholar Celio Calcagnini of Ferrara, Latin translator of Plutarch's *De Iside et Osiride* (*On Isis and Osiris*), and a supporter of terrestrial motion in *Quod Coelum stet, Terra autem moveatur* (*That the Heaven Stands Still whereas the Earth Moves*). He wrote this essay around 1518–1519, while he was traveling through Central Europe as a secretary of Cardinal Ippolito d'Este.[38] Whether, when and how he heard of Copernicus's ideas is not clear. It is, however, clear that he cultivated relations with Poland: like Schönberg, he participated in the wedding of Sigismund and Bona in Cracow, in 1518 and, on that occasion, he received the honorific title of the *szlachta*, viz. the Polish aristocracy. He also traveled up the river Dnepr and later described Eastern European customs in *De moribus Scytharum* (*On the Customs of the Scythians*). Needless to say, his anthropological and geographic interests corresponded with those of Sebastian Münster and Maciej of Miechów.

Calcagnini's essay on terrestrial motion was published posthumously by Hieronymus Froben in *Opera aliquot* (*Selected Works*, 1544). At that time the Swiss town of Basel was already prepared for cosmological novelties. It was a vibrant intellectual center, where the irenic humanism of Erasmus as well as the Reformation took root and the Copernican system and related cosmological and philosophical views were accepted favorably. Besides Sebastian Münster and Calcagnini, the humanist, geographer and astronomer Jacob Ziegler, who met Calcagnini in Hungary in 1517, also published an astronomical commentary on the second book of Pliny's *Natural history* (issued by Heinrich Petri in Basel in 1531). In this book, however, he attached the doctrine of terrestrial motion to Cusanus instead of Copernicus.[39] In Basel ten years later the Calvinist Robert Winter printed the second edition of Rheticus's *Narratio prima* (*First Report*) on *De revolutionibus*. Calcagnini's *Opera aliquot* (1544) was next. A few years later, Heinrich Petri published three fundamental philosophical-cosmological works in rapid succession: Cusanus's *Opera* (*Complete Works*, 1565), the second edition of Copernicus's *De revolutionibus* and a new edition of Rheticus's *Narratio prima* (together in 1566).[40]

Gasser, see Münster, *Cosmographia*, f. 8*v*, and for the map of Prussia, see Horn, "Münster's Map," 66–73.

38 DBI 16 (1973), *s.v.*, and L.A. Birkennajer, "Solpha i Calcagnini," in idem, *Kopernik*, 480–91.

39 Ziegler, *Commentarius*, 49.

40 See Benzig, *Buchdrucker* and Heitz, *Basler Büchermarken*. For a reconstruction of the milieu of sixteenth-century printers in Basel: Perini, *Vita*.

3 Rheticus and the Printing of *De revolutionibus*

The importance of Georg Joachim Rheticus for the dissemination and affirmation of Copernicus's theories can hardly be overestimated.[41] This mathematician and physician studied at Wittenberg under Johann Volmar, who had attended the University of Cracow beginning in 1498/99—and, thus, might have been informed about Copernicus's research through common acquaintances.[42] Upon the latter's death, Rheticus took over his professorship beginning in 1537.[43] In 1539, he visited Copernicus accompanied by his assistant, the student of mathematics Heinrich Zell of Cologne. Rheticus, who was to become Copernicus's only pupil, soon undertook the task of writing a first report about his innovative theories, presumably under his supervision: the *Narratio prima* (Gdańsk, 1540). The publication of this introduction to Copernicus's astronomy prepared the publication of *De revolutionibus*, partly supervised by Rheticus himself.

Rheticus was native of Feldkirch, in Voralberg, a region then called "Rhetia" (hence his toponymic). He studied liberal arts in Zwingli's Zurich along with the naturalist Konrad Gesner, who would later mention him in *Bibliotheca universalis* (*Universal Library*, 1545).[44] It seems that they lost touch with each other after the university, for it is otherwise difficult to explain Gesner's confused understanding of Copernicus's planetary theory, which he reduced to the axial rotation of the Earth: "Nicholas Copernicus of Toruń, Canon of Varmia, has recently written some books *On the Revolutions*, in which it is claimed that the Earth goes round whilst the Heaven stands still. They have been printed in Nuremberg, in 1543, as a folio. Georg Joachim Rheticus had published a *Report* [*Narratio*] on these books before."[45]

Rheticus completed his studies at Wittenberg, where Melanchthon encouraged his inclination toward mathematics and supported his candidacy for one of the two chairs of mathematics to be awarded in 1536.[46] In 1538, Rheticus left for a study tour that led him to Nuremberg, where he met the editor Johannes Petreius, the theologian Osiander, and the astronomer and geographer Johannes Schöner, who had access to valuable astronomical

41 Burmeister, *Rheticus* and Danielson, *First Copernican*.

42 Cf. Kathe, *Wittenberger philosophische Fakultät*, 69 and 114.

43 Burmeister, *Rheticus*, vol. 1, 28.

44 Gesner, *Bibliotheca*, 269.

45 Ibid., 518.

46 Rheticus's Letter to Heinrich Widnauer (13 August 1542), in Burmeister, *Rhetikus*, vol. 3, 49–51.

manuscripts by Johannes Regiomontanus, Bernard Walther, and Johannes Werner.[47] Among other things, Schöner had published an introduction to cosmography, *Opusculum geographicum* (*Geographical Booklet*, 1533), composed of an astronomical part concerning spherical astronomy and a geographical one on the various continents. The first part also included, as chapter two, Regiomontanus's discussion of terrestrial motion ("An Terra moveatur an quiescat, Ioannis de Monte Regio disputatio"). Even though Regiomontanus rejected this thesis, nonetheless he offered in that section a synthetic overview of the Ptolemaic arguments against terrestrial motion. He argued, moreover, that the elements are in constant motion although the Earth itself always occupies the center and does not turn about its axis.[48] Those pages may have served as a basis for further reflections for both Schöner and Rheticus.

Rheticus then visited Peter Apian in Ingolstadt, and the philologist Joachim Camerarius in Tübingen.[49] Finally, he headed for Frombork in May 1539, attracted by the fame of Copernicus. The latter and Giese welcomed the young scholar warmly. Rheticus presented the Polish astronomer with some valuable scientific volumes, including Regiomontanus's *De triangulis* (*On Triangles*, 1533) and Witelo's *Optics* (1535) in Petreius's edition.[50] It was probably the high quality of these printings that convinced Copernicus to entrust Rheticus with the manuscript of *De revolutionibus* and Petreius with its printing. In Varmia, Rheticus also completed a map of Prussia, which Copernicus himself had begun and which was later published by Rheticus's assistant Zell (Nuremberg, 1542).[51]

Rheticus's *Narratio prima* achieved a fair degree of success, judging from its circulation and the numerous editions: four in the sixteenth century alone. Even before printing was concluded, Andreas Aurifaber, a university friend of Rheticus then in Gdańsk, sent the first printed sheets of the treatise (not those concerning heliocentrism) to Melanchthon. Aurifaber was also the compiler of an almanac based on Copernicus's values, which appeared in Gdańsk in 1540.[52]

Another copy of the *Narratio prima* reached the Louvain Professor Gemma Frisius, who commented in a letter to Dantyszek (20 July 1541) in Varmia: "Urania seems to have established a new residence there."[53] Additionally, Giese

47 For Schöner cf. NDB 23 (2007), *s.v.*, and Prowe, *Coppernicus*, vol. I/2, 406–25.

48 Schöner, *Opusculum geographicum*, ff. A3*r*–A4*r*.

49 On Apian's silence on Copernicus see Wattenberg, *Apianus*, 62–65.

50 Cf. Prowe, *Coppernicus*, vol. I/2, 406–25.

51 Horn, "Karte."

52 Green, "First Copernican Astrologer" and Kremer, "Calculating."

53 Danielson, "Gasser," 459.

sent the *Narratio prima* directly to Albrecht of Hohenzollern in Königsberg on 23 April 1540,[54] and Rheticus to Achilles Pirmin Gasser, a physician of Feldkirch who had first introduced him, when he was a young man, into astronomy, astrology and medicine.

Gasser immediately became an adherent of the new cosmology and forwarded a copy of Rheticus's report, together with an enthusiastic letter, to his correspondent Georg Vögeli, a mathematician and physician in Constance (Feldkirch, 1540):[55]

> Although this book [Rheticus's *Narratio prima*] does not agree with the traditional approach, although it contrasts with the Scholastic theories in more than one point and, although it can be judged heretical (as the monks would say), nonetheless it evidently leads to the restoration of a new and true astronomy, undoubtedly even to its rebirth, especially in that it bears evident statements on issues on which not only very learned mathematicians, but also eminent philosophers discussed at length all over the world with great efforts, as you know.

Gasser supported the publication of the second edition of the *Narratio prima*, printed by Winter in Basel in 1541. A hymn by Vögeli, inserted as an epigram at the beginning of the book, pointed out that Copernicus's planetary theory can be grasped only by a cultivated elite: "But let us set envy aside! These things will be approved by few people indeed. Suffice it if they are approved by learned men." The *Narratio prima* was then reprinted in Basel in 1566 together with Copernicus's *De revolutionibus*, and in Tübingen in 1596 as an appendix to Kepler's *Mysterium cosmographicum*.

Back in Wittenberg, Rheticus gave classes on astronomy relying upon Ptolemy's *Almagest* and al-Farghani's *Rudimenta astronomica*. It cannot be ruled out that he related the Copernican novelties to his students, presenting them as a development from classical astronomy, for this was his tendency at that time. In Wittenberg in 1542, for instance, he edited Copernicus's work on trigonometry, *De lateribus et angulis triangulorum* (*On the Sides and Angles of Triangles*), and ensured the mathematician and theologian Georg Hartmann of Nuremberg that his master was working in the wake of Ptolemy: "My very learned master Nicholas Copernicus has written on trigonometry in a very erudite way, while he is expounding Ptolemy and working on the traditional

54 Burmeister, *Rheticus*, I, 47.

55 Idem, *Gasser*, III, 50–55, 51.

theory of motions."[56] Many of Rheticus's students at Wittenberg would later distinguish themselves and have brilliant academic careers. Among them, let us mention Caspar Peucer, future professor of mathematics at Wittenberg and Matthias Lauterwalt, member of the Faculty of Arts beginning in 1550.[57]

Copernicus was initially reluctant to publish *De revolutionibus*, as he himself acknowledged, but he was finally convinced by his friend Giese and presumably also Rheticus.[58] The latter consigned the book's manuscript to Petreius at the end of 1542 but could not supervise the edition up to its completion, as he had to fulfill his academic duties. He entrusted another, the theologian Andreas Osiander, with the last phase of the printing. In this manner, the publication of *De revolutionibus* was executed in 1543 and, according to legend, Copernicus received a copy of it on his deathbed.

As to Osiander, he was a rather cautious promoter of Copernicus's theories. In fact, he introduced a deceptive anonymous preamble (*Ad lectorem, De hypothesibus huius operis*) which asserted the conjectural character of all astronomical hypotheses and limited their purpose to the correct calculation of celestial motions. He questioned the physical and natural validity of Copernicus's theory, because he thought that these reservations could safeguard the new cosmology, and especially terrestrial motion, from the criticism of Aristotelians and theologians whose doctrines the Copernican cosmology undermined.[59] He had already explained his viewpoint to Rheticus and Copernicus in some letters;[60] nonetheless his intrusion stimulated an angry reaction by Giese, who wrote a letter of reclamation to the Nuremberg Senate and one to Rheticus (Lubawa, 26 July 1543) in which he claimed to share his discontent toward Petreius's impiety and bad faith.[61] He blamed the author of the introduction—whoever he might be—for discrediting Copernicus's work. He demanded justice and the restoration of truth, but his denunciation produced no concrete results.

Gasser, the aforementioned early teacher and friend of Rheticus, was one of the first to read *De revolutionibus*. He received a copy directly from Johannes Petreius with his handwritten dedication. Gasser read and made a few notes in

56 Burmeister, *Rhetikus*, vol. 3, 45 ff.

57 Westman, "Melanchthon circle," 171 and idem, "Three Responses."

58 GA VIII/1, Rheticus, *Encomium Prussiae*. See Zimmerman, "Publikation."

59 Cf. Lerner-Segonds, "Sur un 'avertissement' célèbre."

60 Letter to Rheticus (Nuremberg, 20 April 1541) and to Copernicus (20 April 1540), in Osiander. *Gesamtausgabe*, 333–38.

61 GA VI/1, 357–60, n. 194. Cf. Burmeister, *Rhetikus*, vol. 3, 54–59.

it, showing that he sided with a realist interpretation of the planetary theory.[62] Moreover, in his preface to Petrus Peregrinus of Maricourt's *De magnete* (1558), he hinted at a magnetic explanation for the rotation of the Earth.[63]

4 The Network of German Mathematicians

De revolutionibus was directed principally to a readership of mathematicians. This is clear already from the frontispiece presenting the motto of Plato's Academy "Let none ignorant of geometry enter." Although it cannot be assumed that this epigraph was chosen by Copernicus directly, it nonetheless expresses his intention to "write mathematical things for mathematicians," as he claimed in the dedicatory letter to Paul III. Many of the first mathematicians who read Copernicus's work did not consider the heliocentric system to be his principal achievement. Instead, they were interested in technical aspects, like corrected parameters and geometrical models supported by observation, as well as in providing a synthesis of the whole discipline as put forward in *De revolutionibus*. Apart from the planetary system, this work did in fact address debated issues of mathematical astronomy such as the difference between the rate of the tropical year and the sidereal one, the theory of the Moon and the Sun, planetary rates and trigonometry, as well as the possibility of renouncing the Ptolemaic equant in planetary modeling. The earliest German readers of *De revolutionibus* confronted these issues attentively and were not particularly concerned about defending the physical reality of Copernicus's planetary model.[64]

The network of mathematicians at German Protestant universities played a decisive role in the first circulation of *De revolutionibus*.[65] Their principally geometry-focused and computational reading—usually referred to in the history of astronomy as the "Wittenberg interpretation"[66]—was perhaps induced by Martin Luther's disagreement with terrestrial motion and Philip Melanchthon's rejection of this theory in the textbook *Initia doctrinae physicae* (*Introduction to Physics*), which he co-authored with the professor of

62 Gingerich, *Annotated Census*, 108–10.

63 Gasser, "Praefatio," ff. B2v–B3r. Cf. Burmeister, *Gasser*, 72–80.

64 The reasons for this particular line of reception will be discussed in detail in the next chapter.

65 See Westman, *Copernican Question*, 160–64.

66 Westman, "Melanchthon Circle."

natural philosophy Paul Eber and first printed in 1549.[67] In the 1566 edition of Luther's table talks, *Tischreden*, the editor Aurifaber reported his opposition to a new astronomer (*novus quidam astrologus*), whom he designated in 1539 as a "fool" (*Narr*) seeking to distort the entire art of astronomy (*die ganze Kunst Astronomie umkehren*).[68] Yet despite these theological and physical reservations, Melanchthon supported two astronomers who greatly contributed to Copernicus's reputation, albeit in a very different manner: Rheticus and Erasmus Reinhold, who were both appointed as professors of mathematics at Wittenberg, doubtlessly upon his recommendation.

Reinhold's astronomical tables *Prutenicae tabulae* (1551) made it relatively easy to employ the parameters of *De revolutionibus* for practical purposes and the compilation of ephemerides. Their success disseminated the name of Copernicus among those who were primarily concerned with practical astronomy, such as astrologers, physicians and geographers who made constant use of astronomical tables and ephemerides.[69] Among those who followed Reinhold and continued his work, one can mention Frisius's pupil Johannes Stadius in Flanders (*Ephemerides novae et exactae*, 1556 and later editions), Magini in Bologna (*Ephemerides Coelestium motuum … secundum Copernici hypotheses, Prutenicosque canones*, 1582 and later editions) and the Florentine theologian and astrologer in Lyon Francesco Giuntini (in *Speculum Astrologiae, universam mathematicam scientiam*, 1581).

The list of the successful followers of Reinhold is quite long. The prestige of Wittenberg University permitted his pupils to advance in their careers and occupy chairs of mathematics in other Reformed Universities organized according to Melanchthon's *curriculum studiorum*. This fact guaranteed Copernicus's astronomy an appreciable propagation.[70] First Reinhold, in his manuscript papers, and then his successor at Wittenberg and Melanchthon's son-in-law Caspar Peucer attempted to bring Copernican parameters back to a geocentric framework and in this way reconcile astronomical hypotheses

67 Wohlwill, "Melanchthon und Copernicus," Thüringer, "Eber," and Meinel, "Certa deus," and Bauer, *Melanchthon*, 371–76.

68 Luther, *Tischreden*, vol. 1, 419. Although in 1539 Copernicus's work had not yet been printed, his hypotheses were already circulating in Europe through a wide network of humanists and mathematicians. Therefore, I do not endorse Lerner's interpretation of Luther's words as a reference to Calcagnini rather than Copernicus (idem, "Der Narr"). What is more, by the time the *Tischreden* were published, readers would obviously connect Luther's negative judgment with Copernicus's theory.

69 Gingerich, "The Role of Erasmus Reinhold," and Savoie, "Diffusion."

70 Westman, "Melanchthon circle," 171.

and physics.[71] Brahe's Denmark can be regarded as "one of the last bastions of Philippism," that is of Melanchthon's school, and can be included in this geocentric line of reception of Copernican astronomy.[72]

Relative to planetary geometries, one of Copernicus's most appreciated achievements lay in the intention to eliminate the equant, a geometrical device of Ptolemy's that disrespected what was called the *axioma astronomicum*, that is, the commonly accepted assumption that circular celestial motions are uniform around their centers.[73] Although this "axiom" was not universally accepted, as some astronomers preferred to maintain the equant (as was the case for the Italian mathematician Magini),[74] uniform circular motion was considered to be fundamental by Reinhold and many other early readers of Copernicus, until Johannes Kepler, at the beginning of the seventeenth century, reassessed the geometry of planetary paths by introducing elliptical orbits and definitively renouncing the principle of uniform circular motion.[75]

5 Italy

In Italy, the first witnesses of the circulation of Copernicus's work are to be found in literature. The first document is a work by Anton Francesco Doni, a Florentine *poligrafo*, printer and writer working in the wake of Pietro Aretino.[76] It is entitled *Ragionamenti diversi fatti ai marmi di Fiorenza* (*Different Reasonings Made at the Marble* [*Stairs*] *of Florence*, Venice, 1552–1553), or *I Marmi*. It is a disorderly and heterogeneous collection of dialogues, tales, remarks and poems, presented as conversations (*ragionamenti*) that are imagined to take place among Florentines on the marble stairs of the city's cathedral. The first *ragionamento* is a paradoxical astronomical discussion based on the Copernican novelties. Carafulla and Ghetto, common people designated as "pazzi" (fools), discuss the motions of the Earth. The former seeks to defend the bizarre thesis that "The Sun does not turn. We do. The Earth is the one

71 Barker, "*Hypotyposes.*" Omodeo-Tupikova, "Post-Copernican Reception." See chap. 2.

72 Christianson, "Copernicus and the Lutherans," 10.

73 Swerdlow pointed out Copernicus's inconsistent application of this principle: Swerdlow-Neugebauer, *Mathematical Astronomy*, 290. See also Savoie, "Diffusion."

74 On Magini's considerations on planetary models after Kepler's *Astronomia nova*, see Voelkel-Gingerich, "Magini's 'Keplerian' Tables."

75 Cf. Gingerich, *Annotated Census*, 97–98 and 105 for Reinhold's annotations on the so-called *axioma astronomicum* of planetary uniform and circular motion.

76 DBI 41 (1992). For the context, see Aquilecchia, "Aretino," Grendler, *Critics*, and Quondam, "Letteratura in tipografia."

that turns. Do you not know that the sky is called the firmament [the immovable heavens]?"[77] Ghetto asks: "Hence, is the Sun always immobile, [while] the Moon and the [wandering] stars as well as we come back to the same place turning around?" "Messer sì" is Carafulla's positive answer.[78] This passage clearly refers to solar immobility and centrality opposed to lunar, terrestrial and planetary circular motion. Doni likely refers to a heliocentric model. This is confirmed by another passage in which Carafulla links terrestrial motion to seasonal changes: "In winter the terrestrial globe turns under one part of the heavens, in spring under another one and so on from time to time."[79] This is a heliocentric treatment of the annual transit of the Earth below the zodiacal signs, indicated as different "parts of the heavens."

A series of extravagant arguments are brought forward in the dialogue. Ghetto reports, for instance, the opinion of two friars, *frate* Alberto del Carmine and *fra* Mauro d'Ogni Santi, who reject terrestrial motion. This could be a reference to certain theological reservations as to the reality of the Copernican system, but Carafulla does not expand on this. He rather asserts, contrary to a well-known Aristotelian thesis, that, if the Earth were not in motion, the elements (earth, water, air, fire) would mix together and the Earth would collapse. He contends that motion has the function of keeping the elements separated and avoid confusion and destruction. Carafulla's reasoning goes so far as to argue that earthquakes are tremors resulting from the constant motion of the Earth. For the same reason, he argues, things fall down and perish with time.[80] The ocean tides are further evidence of terrestrial motion.[81] This intuition was to be revived at the University in Pisa by Professor Andrea Cesalpino in his *Peripateticae quaestiones* III,5 (*Peripatetic Questions*, 1571), which were to stimulate Galileo's Copernican speculations on the origin of the tides.[82]

Furthermore, on Doni's account, the circular form of the Earth and its motion make it difficult for human beings to stand on feet. The argument *semiserio* is that terrestrial motion accounts for children's having to learn to stand. Since they are not used to terrestrial conditions, they are forced to always move in

77 Doni, *Marmi*, 16.

78 Ibid., 17.

79 Ibid., 19.

80 Ibid.

81 Ibid., 17. On account of this issue, Boffito ("Doni precursore") compared Doni to Galileo, but the connection between terrestrial motion and the tides is also present in other authors, for instance Leonardo da Vinci (see Renn-Damerow, *Equilibrium Controversy*, 56–57).

82 Omodeo, "Riflessioni sul moto terrestre."

order to maintain a precarious balance.[83] Doni's treatment of the Copernican theory of terrestrial motion is assuredly ironic; nonetheless, his dialogue is an important witness of a very early dissemination of that idea, even outside the academic and ecclesiastic environments.

At Italian universities, Copernicus's tables and theory spread slowly and comparatively late. At the University of Padua the renowned astronomer Giuseppe Moletti never abandoned the *Alfonsine Tables*, upon which his *Tabulae gregorianae* of 1580 still relied. The chair of mathematics was not occupied by a convinced adherent to Copernicus's system until 1592, when Galileo succeeded Moletti.[84] At Bologna, the mathematician and geographer Giovanni Antonio Magini encouraged the employment of Copernican tables in a university with a strong tradition in astronomy.[85] In 1582, he printed the *Ephemerides coelestium motuum* for the years 1581–1620, computed in accordance with Copernicus's hypotheses, Reinhold's parameters, and the new calendar introduced by Pope Gregory XIII, as one can read in the subtitle: "secundum Copernici hypotheses, Prutenicosque canones, atque iuxta Gregorianam anni correctionem." These ephemerides were an editorial success, as witnessed by the large number of revised and augmented editions. It is noteworthy that the author gradually abandoned his initial enthusiasm for Copernicus's "hypotheses." For instance, the subtitle of the *Ephemerides* of 1609 for the years up to 1630 presents a slight but significant variation: the computations are no longer in accordance "with Copernicus's hypotheses" but, more modestly, "with Copernicus's observations" (*secundum Copernici observationes*). It is the signal of a modification in the author's attitude toward hypotheses, the main reason being his admiration for Brahe's geo-heliocentric vision of the world, which he accepted with some modifications.[86]

The years of the Gregorian calendar reform were generally marked by an opening to Copernican parameters in Catholic Italy. An example of an interpretation of Copernicus that was accurate but impervious to his cosmology was that of Egnazio Danti, mathematician and cartographer of the Grand Duke of Tuscany. His work revealed excellent knowledge of the theory of three terrestrial motions presented in *De revolutionibus*, which were described with precision. Yet he rejected the motion of the Earth, whose mention served only to illustrate the variety of cosmological opinions:[87]

83 Doni, *Marmi*, 17.

84 See Proverbio, "Giuntini," 42–44.

85 For insight into Bologna's astronomical and astrological tradition, see Bonoli, *Pronostici*.

86 Betti, "Copernicanesimo" and Peruzzi, "Critica."

87 Danti, *Annotazioni*, 12–13.

> Others asserting that the heavens are only eight wanted to defend [the assumption] that the eighth heaven does not move except for one motion, precisely the daily motion. In order to account for the motion of a degree every one hundred years [i.e. the precession of the equinoxes] and the trepidation, they asserted that the Earth itself moves in this manner about the poles of the zodiac from east to west, of one degree every hundred years. Moreover, [they assumed that], while it moves in this manner, it also accomplishes the trepidation from north to south. Copernicus follows this opinion. In fact, he moves the Earth and locates the Sun at the center of the world. Above the Sun, instead of the heaven of the Moon, he posits that of Mercury and then that of Venus. Above that, he posits the Earth in the Sun's sphere, and attaches to it three motions. The first one is the daily motion, the second is that of one degree every hundred years and the third is the declination. About the Earth, in a little circle, he locates the Moon which, turning around the Earth in twenty seven days and a third, is sometimes conjuncted and sometimes opposite to the Sun. After that, the heavens of Mars, Jupiter and Saturn follow. He ascribes to them the usual periods. Above the planets, he posits the eighth sphere, which he calls place of the world, where the other heavens turn. Furthermore, somebody posited the Earth at the center of the world—where it really is—and assumed that it turns in twenty-four hours about its center. The falsity of these opinions is so evident that it is not necessary to bring forward any proofs.

The doctrinal and political polemics aroused by the calendar reform, completed by the Jesuit mathematician Christoph Clavius and promulgated by Gregory XIII with the Bull *Inter gravissimas* on 24 February 1582, brought astronomical issues outside the circle of mathematicians and learned people. Moreover, with the reform of Gregory XIII, the Catholic Church affirmed its authority in the resolution of scientific questions, creating the conditions for the condemnation of the Copernican hypotheses in 1616.

Clavius, author of the Gregorian reform, participated in numerous debates and arguments. Within his order, he defended the dignity and autonomy of mathematics against its belittlement by Benito Pereyra, who had questioned the certainty of mathematics and its scientific status, and had affirmed its subordination to metaphysics.[88] On another front, he was also involved in

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88 Cf. Romano, *Contre-réforme mathématique*. For the *questio de certitudine mathematicarum*, see De Pace, *Matematiche e il mondo*. On Clavius's promotion of mathematical studies

the strong dispute with Protestant denigrators of the calendar reform.[89] His main adversary in this case was Michael Mästlin, Kepler's teacher and author of *a Bericht von der allgemainen... Jarrechnung oder Kalender* (*Report on the Universal... Annual Computation or Calendar*, 1583), republished in 1584 as *Notwendiges und gründtliches Bedennckhen von dem Römischen Kalender* (*Necessary and In-Depth Consideration of the Roman Calendar*)[90] along with a series of pamphlets in which he condemned not only the "deformed calendar" (*der von Bapsts deformierte Kalender*) but also the Papacy in general, as an institution of the Antichrist. In reply to these writings and to an *Examen* compiled by Mästlin in 1586,[91] Clavius wrote an apology for the new Roman calendar, *Novi Calendarii Romani Apologia*, in which the name and surname of his adversary were indicated in the title: *Adversus Michaelem Maestlinum Geppingensem, in Tubingensi Academia Mathematicum*.

Clavius's position on Copernicus was not hostile so far as parameters were concerned. In his commentary on Sacrobosco's *Sphaera*, Clavius cited Copernicus among the principal authors of astronomical tables, next to Alfonso, Regiomontanus, Bianchini and also Reinhold (in reference to the *Prutenicae tabulae*). He also mentioned him among the most important *auctores disciplinae*. The separation of astronomical parameters from cosmology in Clavius's reading of Copernicus is clear in the chapter "The Earth is immobile" (*Terram esse immobilem*). For Clavius, the authority of the Scriptures, in addition to the usual physical arguments, counted against the Pythagorean-Copernican doctrine, since they supported terrestrial immobility.[92] Clavius's appraisal of Copernicus concerned rather the calculation of the period of the solar and lunar cycles and the accurate measurement of the difference between the tropical and the sidereal year, and thus of the exact period of the precession of the equinoxes.[93] Indeed, chapter I,6 of the *Apologia*, entitled "On the rate of the anomaly of the equinoxes, and the inequality of the years according to Copernicus's theory [*doctrina*]," dealt with the Copernican doctrine of irregularity of the precession (a doctrine that was erroneous in some aspects but generally considered valid at the time), arriving at the demonstration of the perfection of the new calendar (*calendarium novum esse perfectum*),

at the Jesuit Collegio Romano, see Baldini, "Academy of Mathematics." On Pereyra, see Blum, "Pererius."

89 Cf. L. Osiander, *Bedencken*. See Maiello, *Storia del calendario*.

90 Mästlin et al., *Notwendige und gründtliche Bedennckhen*.

91 Mästlin, *Alterum examen*.

92 Clavius, *Novi calendarii Romani apologia*, f. a 4*r*.

93 Cf. Lattis, *Between Copernicus and Galileo*, 163–73.

even though in 20,000 years there would be a certain deviation with respect to the *Prutenicae tabulae* (nonetheless a margin of error considered acceptable). Hence, it is clear that the discussions about Copernicus at the time of the Gregorian calendar were kept extraneous from the confessional divisions. On the other hand, Clavius's extremely influential commentary to Sacrobosco conveyed geostatic and geocentric arguments that were irreconcilable with the acceptance of the Copernican hypotheses from a physical viewpoint.[94]

Some attention to the Copernican hypotheses can also be found in the writings of one of the protagonists of the "Italian Renaissance of mathematics," Federico Commandino. His famous Venetian edition of Archimedes's *Opera* (1558) also included the *Arenarius* (*The Sand Reckoner*), in which Archimedes discussed the dimensions of the universe according to the heliocentric hypotheses of Aristarchus. Archimedes's mention and admiration for Aristarchus was a sufficient reason, according to Commandino, to publish the only extant work of the ancient astronomer on the dimensions and the distances of the Sun and the Moon. Although Commandino omitted the name of Copernicus in the introduction to Aristarchus's *De magnitudinibus et distantiis Solis et Lunae* (*On the Magnitudes and the Distances of the Sun and the Moon*, 1572), he underscored the originality of the latter's heliocentric astronomical hypotheses. In this context, he argued that, if the "divine Archimedes" considered them worthy of consideration, they must have been convincingly demonstrated, no matter what the common people might think about them.[95]

Concerning the interest for the physical aspects of the Copernican system in Italy, one should mention the mathematician and physicist Giovanni Battista Benedetti, who had been "court mathematician and philosopher" to the Dukes of Savoy in Turin since 1567 and whose considerations on the falling bodies and on mechanics have been often considered in connection with the birth of mathematical physics and Galileo's science.[96] Between 1580 and 1581 he was involved in a quarrel with a certain Benedetto Altavilla of Vicenza concerning the reliability of ephemerides and astrological prognostication. On that occasion, Benedetti defended both astrology and the validity of the Copernican tables. His cosmological views are scattered in *Diversarum speculationum*

94 Ibid., chap. 5.

95 Aristarchus, *De magnitudinibus*, f. +3*r*–*v*. See Omodeo, "Archimede e Aristarco."

96 DBI 8 (1966), *s.v.*, Bordiga, *Benedetti*, Roero, "Benedetti," Bertoloni Meli, *Thinking, passim*. On the environment: Mamino, "Scienziati." See also Renn-Damerow: *Equilibrium Controversy*, and Renn-Omodeo, "Del Monte's Controversy." Benedetti and Galileo also shared the title as "court mathematicians and philosophers," in Turin and Florence respectively: Biagioli, "Social status," 49–50.

mathematicarum et physicarum liber (*Various Speculations on Mathematics and Physics*, 1585), in which he supported heliocentrism and space infinity. Instead of the material spheres of the Aristotelian tradition, he assumed that planets move through air following a providential design. The central Sun warms them through its light. He also revised basic concepts of physics such as "motion," "place" and "time," in the framework of a "Pythagorean" mathematical approach to nature. Moreover, he supported the existence of void, as a condition for motion, and an anti-Aristotelian *impetus* dynamics aimed at explaining physical phenomena on a ship-like moving Earth. According to this dynamics, objects partake of terrestrial rotation; therefore, a falling body moves contemporaneously downward and westward together with our globe. This apparently simple assumption was at odds with Aristotelian natural philosophy, which assumed that a body cannot be simultaneously moved in two directions, circular and linear.[97]

The natural philosopher Francesco Patrizi, a correspondent of Benedetti, deserves mention as well. Even though he did not support Copernicus's planetary theory, he sided with a conception of space that had great influence on the subsequent history of science. In his *Pancosmia*, which is part of his *Nova de universi philosophia* (*New Philosophy of the Universe*, 1591), he advocated the homogeneity and continuity of universal space. This is a three-dimensional absolute space, which subsists independently and prior to all bodies and expands *ad infinitum* beyond the sphere of the fixed stars.[98]

6 France

The first reactions to Copernicus in France, like in Italy, are to be found in some literary and rhetorical works. Omer Talon was apparently the first Frenchman to mention Copernicus, in his commented edition of Cicero's *Academicae quaestiones* (Paris, 1550).[99] He was the "lifelong associate" of the Calvinist philosopher Pierre de la Ramée (Latinized as *Petrus Ramus*)—together, they undertook a radical reform of logic and rhetoric, which they attempted to fusion into a single and simplified discipline.[100] The members of the *Pléiade*

97 For Benedetti's cosmology see: Di Bono "Astronomia copernicana," Seidengart, *Dieu*, 125–29, and Omodeo, "Cosmologia."

98 See Rossi, "Negazione," Rosen, "Patrizi," Vasoli, "Patrizi," and Seidengart, *Dieu*, 116–24.

99 Pantin, *Poésie*, 28–29. See also ibid., fn. 18.

100 Cf. Mack, *History of Renaissance Rhetoric*, chap. 7. See also Popkin, *History of Scepticism*, 28–30.

were also familiar with *De revolutionibus*, although they probably limited their interest to its first book.[101] Another document of an early literary reception of Copernicus in France is the cosmological dialogue by the man of letters Pontus de Tyard, *L'Univers ou Discours des parties, et de la nature du monde* (*The Universe or Discourse on the Parts ant the Nature of the World*). It appeared for the first time in Lyon in 1557 and was revised, augmented and reprinted in Paris in 1578, with a dedication to King Henry III of France. The title was changed to *Deux discours de la nature du monde et de ses parties: A sçavoir le premier Curieux traittant des choses materielles et le second Curieux des choses intellectuelles* (*Two Discourses on the Nature of the World and Its Parts: The First Curieux on Material Things and the Second Curieux on Intellectual Things*). In the first part of this work, *Premier Curieux*, Tyard referred to Copernicus's solar observations and his determination of the dimensions of the Sun and the Moon.[102] Moreover, he referred to the paradoxical hypothesis of Aristarchus: "And he has revived that ancient assumption, or rather paradox."[103] Although he was undecided on the heliocentric theory (*vraye ou non que soit sa disposition*), he praised Copernicus's ingenuity and the accuracy of his observations. He expressly supported only the daily rotation of the "law part of the Universe," which is subjected to continuous changes.[104] Tyard regarded astronomy as an incomplete discipline and Copernicus's system as a noteworthy proposal. In particular, he appreciated the gnoseological consequences of the heliocentric hypothesis, precisely to remind scholars that senses and common opinions are labile and untrustworthy: "In order to correct the disorder concerning the demonstration of celestial appearances, the so-called phenomena, this good and very learned Copernicus demonstrated in a very subtle way that the vulgar opinion does not entail any truth as a necessary consequence of its authority. By contrast, [the truth] can sometimes descend from dubious, suspicious or even false assumptions."[105]

De la Ramée, the leading figure of the *Collège Royal* in Paris from the 1550s up to his death in 1572, addressed Copernican astronomy as well. He appreciated the Copernican tables[106] and Rheticus's trigonometry, although he openly declared his disagreement with the "vain and cumbersome" doctrine of terrestrial motion:[107]

101 Ibid. See also Céard, "Introduction."
102 Tyard, *Premier Curieux*, 88–89 and 93.
103 Ibid., 157.
104 Ibid., 159.
105 Ibid.
106 Ramée, *Scholae physicae*, IV,14, 123.
107 Idem, *Scholae mathematicae*, II,47.

> If only Copernicus had addressed the edification of astronomy without hypotheses! In fact, it would have been much easier for him to trace an astronomy in accordance with the truth of heavenly bodies than [to make] such a gigantic effort to move the Earth, forcing us to look at and speculate on the immovable stars from a moving Earth.

De la Ramée challenged astronomers to develop an astronomy without hypotheses (*sine hypothesibus*) which he regarded as a restoration of Babylonian astronomy.[108] Moreover, Jean Pena, appointed as royal lecturer of mathematics upon de la Ramée's recommendation in 1555, sustained cosmological views that became quite controversial among astronomers. In the preface to his Latin edition of Euclid's *Optica* (Paris, 1557), he refuted Aristotle's theory that the heavens are incorruptible and ethereal. He suggested instead that their matter is air or, more precisely, an aerial element and principle of life (*aer anima plenum*). This is probably a hint at the Stoic *pneuma*, a spiritual fiery and airy element pervading the universe.[109] Concerning the order of the planets, he reaffirmed the Capellan geo-heliocentric system in which only the inferior planets rotate about the Sun. Additionally, he rejected the annual revolution of the Earth (probably due to the absence of stellar parallax) and its daily rotation, but he ascribed to the Earth a slow motion accounting for the alleged irregularities of the precession of the equinoxes.[110]

Pena died in 1558 and de la Ramée in 1572, in the St. Bartholomew's Day Massacre. After them, the Italian philosopher Giordano Bruno became a royal lecturer in Paris. There, he published a book on the art of memory, *De umbris idearum* (*On the Shadows of Ideas*, 1582), in which he expressed for the first time his adherence to Copernicus's heliocentric system. Another Paris professor of mathematics interested in Copernican planetary theory was David Sainclair (in post in 1599–1629), who owned a copy of *De revolutionibus* and taught at the Cambrai College in 1607–1608. He was possibly the editor of an anthology of cosmological excerpts from *De revolutionibus* published in Paris in 1612 as *Sphaera Nicolai Copernici, seu systema mundi secundum Copernicum* (*Copernicus's Sphere or the System of the World according to Copernicus*).[111]

In France, *De revolutionibus* also attracted the attention of astrologers concerned about the accuracy of celestial predictions. Significant from the point of view of the reception of Copernican astronomical tables is the astrological work by the German mathematician Johannes Offusius, who lived in Paris

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108 Cf. Jardine-Segonds: "Challenge," Rosen, "Ramus-Rethicus," and FP 7, *s.v.* Cf. chap. 2,10.

109 See Barker, "Stoic contributions."

110 Cf. Granada, *Sfere*, 3–46.

111 Lerner, "Copernicus in Paris."

beginning in the 1550s. He was the first one to undertake a revision of astrological influences in accordance with the project of a reform of Ptolemy's *Tetrabiblos*, relying on revised planetary distances in accordance with *De revolutionibus*. In the posthumous *De divina astrorum facultate* (*On the Divine Power of Heavenly Bodies*, 1570), which he may have completed by 1557, Offusius considered the advantages of the Capellan planetary arrangement. Yet he refrained from accepting terrestrial motion.[112]

Several scholars considered Copernicus to be an astrologer, deriving this conviction from Rheticus's assertion in the *Narratio prima* that the motion of the eccentricity of the Sun was the celestial cause of the rise and decline of human empires.[113] It was commonly accepted that this theory stemmed from Copernicus himself. Francesco Giuntini, a Florentine theologian, mathematician and astrologer who lived in Lyon, shared this opinion, as documented by his *Commentary* of Sacrobosco. He was the renowned author of a remarkable astronomical and astrological *corpus* that included some tables derived from Reinhold and Copernicus.[114]

The attribution to Copernicus of an astrological political theory was strengthened by the political thinker Jean Bodin, who, however, rejected the validity of the dependency of public human affairs on astrology. In *Les six livres de la république* (*Six Books on the Republic*, 1576), he confirmed his aversion to Copernicus, ascribing to him two "errors": that the Earth is moved and that this motion produces astrological effects. He further refuted the theory of terrestrial motion in *Universae naturae theatrum* (*Theater of the Whole Nature*, 1596).[115] The enduring anti-astrological criticism of Copernicus by political thinkers is witnessed by Pietro Andrea Canoniero's rejection of the (allegedly) Copernican theory of the astrological causes of the decline of the states in *Dell'introduzione alla politica alla ragion di stato et alla pratica del buon governo* (*Introduction to Politics, Raison d'État and Practice of Good Government*, 1614).[116] On the opposite front, the eschatologist Guillaume Postel used Copernicus to predict the combustion and end of the world as a consequence of the diminution of the Sun's distance from the Earth.[117]

112 Westman, *Copernican question*, 185–90 and Gingerich-Dobrzycki, "The Master."

113 In fact, in Copernicus's theory the center of planetary revolutions is not exactly the Sun but a point very close to it.

114 Proverbio, "Giuntini." Cf. also DBI 57 (2001), *s.v.* and Omodeo, "Fato."

115 Bodin, *Theatrum*, 580–83, and idem, *Six livres*, IV,2. Cf. Blair, *Theater*.

116 Canoniero, *Introduzzione*, 616.

117 Thorndike, *History of Magic*, vol. 5, chap. 18, and Poulle, "Postel."

7 Spain and Flanders

In Spain, Copernicus attracted the attention of the geographers of the *Casa de Contratación* of Seville, who were interested in astronomy for practical purposes. Significantly, one of the few extant copies of *De revolutionibus* preserved in Spain belonged to Alonso and/or Jerónimo Chaves, father and son, who one after the other held the chair of cosmography and navigation.[118] Philip II of Spain owned another copy, perhaps the same one that his father Charles V had received as early as 1543.[119] Moreover, in the Academy of Mathematics (1582–1634) founded by Philip II, Copernicus's astronomy was well known and appreciated.[120]

In Spanish Flanders, the mathematician, instrument maker, cosmographer and physician Reiner Gemma Frisius, a pupil of the German geographer Peter Apian, introduced Copernicus's astronomy to his country and the Netherlands. As already said, he maintained an epistolary correspondence with the Bishop of Varmia, Dantyszek. Gemma Frisius was not only an attentive reader of *De revolutionibus*, interested in its computational aspects and in Copernicus's descriptions of astronomical instruments and trigonometry, but also an advocate of the physical reality of Copernicus's system.

He taught the geographer Gerhard Kremer, better known as Mercator, the Flemish ephemerist Johannes Stadius and the English polymath John Dee. Stadius became famous for his Copernican ephemerides, *Ephemerides novae et exactae*, published in Cologne in 1556 with a dedication to Philip II of Spain whose majesty he compared to that of the Sun, the cosmological emperor of the world.[121] In a vehement letter (*Epistola de operis commendatione*) published in the opening of these ephemerides, Stadius's master Gemma Frisius expressed his preference for the Copernican system and stressed the contribution of his pupil's work to the affirmation of Copernicus's worldview.[122]

By contrast, the attitude toward the heliocentric astronomy of Frisius's most famous student, Mercator, seems to have been rather skeptical. At least this is what emerges from his teaching and publications—for instance his classes on mathematics and cosmography, delivered at the Gymnasium of Duisburg between 1559 and 1562, and published by his son Bartholomaeus as *Breves in*

118 Cf. Gingerich, *Annotated Census*, 205.
119 Vernet, "Copernicus in Spain," 273.
120 Ibid., 274–75.
121 Stadius, *Ephemerides*, f. A2v.
122 Hallyn, *Gemma Frisius*, chap. 9, 193–212. See chap. 3, 1–3,3.

sphaeram meditatiunculae (*Brief Meditations on the Sphere*, 1563).[123] There he illustrated a geocentric world system without any reference to the Copernican alternative. Nor did Mercator write about Copernicus in his major work, the *Atlas* of 1595.[124] In spite of the fact that he owned a copy of *De revolutionibus*, his interest in astronomy was probably limited to the extent to which it could support cosmography, for which the choice between an Earth-centered or a Sun-centered system does not matter. For instance, for his celestial globe of 1551, he used Copernicus's star catalogue as well as the Copernican rate of the precession of the equinoxes to compute stellar coordinates for the year 1550.[125]

To our present knowledge, Mercator only expanded on cosmological considerations once, in a letter of 1573, to his correspondent Johannes Vivianus. It was accompanied by a drawing, a *Typus universitatis*, presenting a scheme of "the universe according to the classification and order of its parts."[126] According to these sources, Mercator believed that the universe is composed of a series of spheres, centered on a *nihil* (nothing) out of which Creation originated, and framed in a triangle expressing the Holy Trinity. The elementary sphere, the celestial one and the empyreal are located in between. The most interesting feature, as far as planetary theory is concerned, is the Capellan representation of the orbs of Mercury and Venus, which, in fact, encircle the Sun.[127]

Rather different was the attitude of Reiner Gemma Frisius's son, Cornelius, an eclectic physician and natural philosopher. In his *De arte cyclognomica* (*The Cyclognomic Art*, 1569), he tried to develop a universal doctrine bringing together Hippocrates, Plato, Galen and Aristotle in a syncretistic spirit typical of neo-Platonic supporters of the *prisca philosophia*, i.e., the idea of the fundamental unity of the major doctrines from Antiquity based on the oneness of truth. In this work, which was dedicated to Philip II of Spain, he drew on the theme of the macrocosmic correspondence of man. Even though his primary concern was metaphysical and symbolic, he took into account Copernican cosmology as well. After discussing at length the Sun's metaphysical excellence as the worldly image of God, Cornelius Gemma remarked that this preeminence could suit the Ptolemaic planetary model as well as the heliocentric solution by the "very illustrious Nicholas Copernicus" (*Nic. Copernicus, vir*

123 Thiele, "*Breves in sphaeram meditatiuncolae.*"

124 Vanpaemel, "Mercator," and Gingerich, *Annotated Census*, 290–93.

125 Dekker-van der Krogt, *Globes*, 263–64.

126 The letter and the drawing went lost in the Second World War, but copies had already been printed at the beginning of the twentieth century. Cf. Averdunk and Müller-Reinhard, *Mercator*, and Vermij, "Typus universitatis."

127 Vermij, "Typus universitatis."

clarissimus).[128] In another passage, dealing with the celestial sphere, Cornelius Gemma asserted that the Copernican *ratio* concerning the worldly revolution (*Revolutio mundi iuxta Copernicum*) was in much better agreement with the heavens, as Reinhold, Rheticus and Stadius demonstrated.[129] This remark was followed by a heliocentric diagram (*Sphaera revolutionum D*[*omini*] *N*[*icolai*] *Copernici*), a Copernican poem (*Alma de mundo cum Mens infusa caleret*) and reference to the correspondence between the revolution of the terrestrial eccentricity and the succession of monarchies.[130]

Quite original was the position of the Dutch Catholic Albert van Leewen (or *Albertus Leoninus*), author of a "Copernican" treatise, *Theoria motuum coelestium, referens doctrinam et calculum Copernici, ad mobilitatem Solis, eamque sequentes hypotheses, cum nova de motu ipsius Terrae sententia et hypothesi* (*Theory of Celestial Motions Referring Copernicus's Theory and Computation to the Sun's Motion, and the Hypotheses Descending from That, along with a New Statement and Hypothesis about the Motion of the Same Earth*, Cologne, 1578). He rejected the heliocentric hypothesis but picked up on other elements of *De revolutionibus*: first, its lunar theory; second, the theory of the variation of the Sun's apogees; and third, the theory accounting for the precession of the equinoxes and the variation of the ecliptic's inclination. Hence, the only motion that Leoninus ascribed to the Earth was the third Copernican one. He deemed Copernican astronomy to be relevant for the calendar reform, in which he posited his hope for a reconciliation of Catholics and Protestants.[131]

8 England and Scotland

Copernican astronomy reached England quickly. A first appreciation of *De revolutionibus* both for its mathematical and its physical-cosmological aspects is included in the elementary introduction to astronomy *The Castle of Knowledge* (1556), a dialogue between a scholar and his master written by the mathematician and physician Robert Recorde.[132] Hence, in England, as in Italy and France, the first response to the Copernican planetary challenge was printed in vernacular, in the form of a dialogue. In the fourth treatise of *The Castle of Knowledge*, the master points to the fact that it is common opinion that

128 C. Gemma, *De arte*, 54.

129 Ibid., 121.

130 Ibid., 122–23. Cf. chap. 8,17.

131 Cf. Vermij, "Albertus Leoninus."

132 Cf. Johnson, *Astronomical Thought*.

the Earth does not move. "Yet—the pupil remarks—sometime it chaunceth, that the opinion most generally received, is not moste true."[133] In fact, the master replies, illustrious man taught that the Earth moves. In Antiquity, for instance, "not only Eraclides Ponticus, a great Philosopher, and two great clerkes of Pythagoras schole, Philolaus and Ecphantus [...], but also Nicias Syracusius, and Aristarchus Samius, seeme with strong arguments to approve it."[134] Copernicus is then mentioned as the restorer of those ancient views, but his doctrine is deemed to be too complex to be taught in an introductory manual of astronomy for students:[135]

> Master: That is trulye to be gathered: how bee it, Copernicus a man of greate learninge, of muche experience, and of wonderfull diligence in observation, hathe renewed the opinion of Aristarchus Samius, and affirmeth that the earthe not only moveth circularlye about his owne centre, but also may be, yea and is, continually out of the precise centre of the world 38 houndreth thousand miles: but because the understanding of that controversy dependeth of profounder knowledge then in this Introduction may be uttered conveniently, I will let it passe tyll some other time.
>
> Scholar: Nay syr in good faith, I desire not to heare such vaine phantasies, so farre againste common reason, and repugnante to the consente of all the learned multitude of Wryters, and therefore lette it passe for ever, and a daye longer.

In Recorde's times, another English mathematician, John Field, published in London two ephemerides based on Reinhold's Copernican tables: in 1556, for the following year, and in 1558, for the years 1558–1560.[136] The famous mathematician and magician John Dee wrote an introduction to Field's ephemerides of 1556, in which he pointed out Copernicus's mathematical talent. However, he did not discuss his theories (*cuius de hypothesibus nunc non est disserendi locus*) nor did he not embrace heliocentrism, at least not in his *Propedeumata aphoristica* of 1558.[137] As to Field, he probably adhered to the new hypotheses. In his prefatory words, he declared, in fact, his fidelity (*secutus sum*) to

133 Recorde, *Castle*, 164.
134 Ibid.
135 Ibid., 165.
136 DNB 6 (1917), *s.v.*
137 Heilbron, *Dee on Astronomy*.

"N[icholas] Copernicus and Erasmus Reinhold, whose works are based and founded on true, certain and sincere demonstrations."[138]

Evidence of an early treatment of the physical and cosmological aspects of Copernicus's theory in England is Thomas Digges's *A Perfit Description of the Caelestial Orbes according to the most aunciente doctrine of the Pythagoreans, latelye revived by Copernicus and by Geometricall Demonstrations approved* (in his father Leonard Digges's *Prognostication*, 1576) which is mainly a paraphrase of the cosmological chapters of *De revolutionibus* I,10, on the order of the celestial spheres, and I, 7–8, against Ptolemy's and Aristotle's arguments against terrestrial motion. Digges proposed an indefinite enlargement of the heaven of the fixed stars, which cannot be explicitly found in Copernicus's text. In several passages and in a renowned diagram of the heliocentric system, he presented and represented the realm of the fixed stars as unbounded.[139] This suggested to his readers that heliocentrism and cosmological infinity were tied together. In any case there is no doubt that a heliocentric scheme significantly enlarged the dimensions of the universe compared to geocentrism, as a consequence of the absence of detectable parallax—a fact that had already been recognized in antiquity by Archimedes.[140] Digges's diagram later served as a model for the figure of the solar system in William Gilbert's *De mundo nostro sublunari philosophia nova* (*New Philosophy Concerning Our Sublunary World*, published posthumously in Amsterdam, 1651).[141] Most likely, Digges derived the idea of an indefinite space mainly from Marcellus Palingenius Stellatus's popular moral-cosmological poem *Zodiacus vitae* (*The Zodiac of Life*), first printed in Venice around 1536 and translated into English and printed in London as early as the 1560s. The *Zodiacus* proposed an infinite space filled with divine light beyond the outermost sphere of the stars (of a geocentric world).[142] Yet, it seems that Digges did not abandon the idea of a center of the universe, in his case the Sun. In fact, he ascribed infinity exclusively to the sphere of the stars as God's abode. This is remarkable, as the concept of a cosmological center seems to be inconsistent with that of a "boundless sphere." As Cusanus stressed in *De docta ignorantia*, in an infinite universe, every point can be considered to be at its center and on its circumference at the same time. By contrast, the

138 Field, *Ephemeris anni 1557*, f. A3*r*. Cf. Russel, "Copernican System," 192.

139 Johnson-Larkey, "Digges," Johnson, *Astronomical Thought*, Hooykaas, "Thomas Digges' Puritanism," and Granada, "Thomas Digges." See also Seidengart, *Dieu*, 132–41.

140 Cf. Archimedes, *Sand Reckoner* and Dijksterhuis, *Archimedes*, 360–73, chap. XII, "The Sand-Reckoner."

141 Gatti, *Bruno and Renaissance Science*, 96–98.

142 Koyré, *From the Closed World*, Bacchelli, "Note," Granada, "Palingenio."

author of the *Zodiacus*, and later Patrizi, assumed an infinite space that is not homogeneous as to its physical structure, that is, qualitatively differentiated, in a manner that looks similar to Digges's approach.

Cosmological infinity was reassessed few years later by Bruno, who came to England in 1583 as a guest of the French ambassador Michel de Castelneau. He taught some classes at Oxford University but they were abruptly interrupted with scandal: "He [Bruno]—noted the Canterbury Bishop-to-be George Abbot—undertooke among very many other matters to set on foote the opinion of Copernicus, that the Earth did goe round and the heavens did stand still; whereas in truth it was his owne head which rather did run round, and his braines did not stand still."[143] Not discouraged, Bruno reaffirmed his views in a series of philosophical dialogues in Italian that appeared in London between 1584 and 1585.[144] The first of them, *La cena delle Ceneri* (*The Ash Wednesday Supper*), was an apology for Copernicus's planetary system and a discussion of its reconciliation with terrestrial physics.[145] In the subsequent *De l'infinito universo e mondi* (*On the Infinite Universe and Worlds*), Bruno abandoned the hierarchical conception of reality still at work in the *Zodiacus vitae* and in Digges's booklet for an infinite number of Copernican systems (which he later called "synodi ex mundis") in an infinite homogeneous space. He collected ontological arguments in favor of his conception of the universe in the *De la causa principio et uno* (*On the Cause, Principle and One*), and stressed the ethical and religious ties of his new worldview in the so-called ethical dialogues (*Spaccio de la bestia trionfante*, *Cabala del cavallo pegaseo* and *De gli eroici furori*), advocating in particular the restoration of a civil ethics and a natural religion contrary to asceticism. It has been noted that the infinity of the universe later became a standard feature of the English reading of *De revolutionibus*, in spite of Copernicus's reticence about the dimensions of the universe.[146]

Bruno later propagated his views in Paris and in Germany as well. His contribution to the Copernican debate concerned the philosophical framework, cosmology and natural philosophy (in particular, the reassessment of atomism), and the anthropological and ethical implications of a new worldview.[147] The relevance of Bruno for the reception of Copernicus is witnessed by the

143 Aquilecchia, "Tre schede," and Sturlese, "Le fonti." See also Ciliberto, "Fra filosofia e teologia."

144 Providera, "Charlewood."

145 Koyré, *From the Closed World*, 54, and Aquilecchia, "La cena."

146 Cf. Gatti, *Bruno and Renaissance Science*.

147 On Bruno's post-Copernican cosmology I will limit myself to mentioning a few secondary sources: Michel, *Cosmologie*, Védrine, *Conception*, Ingegno, *Cosmologia*,

fact that their names were frequently coupled at the beginning of the seventeenth century. The natural philosopher and theologian Tommaso Campanella would confuse their conceptions,[148] and Kepler was to regard Bruno as the unacknowledged source of Galileo's views in his *Dissertatio cum Nuncio Sidereo* (*Conversation with Galileo's Sidereal Messenger*, 1610). A passage of Robert Burton's letter to the reader in *The Anatomy of Melancholy*, explaining the author's pseudonym "Democritus junior," stresses the close connection between Copernicus and Bruno, according to a common opinion of the day:[149]

> And first of the name of Democritus; lest any man by reason of it should be deceived, expecting a pasquil, a satire, some ridiculous treatise (as I myself should have done), some prodigious tenent, or paradox of the Earth's motion, of infinite worlds, *in infinito vacuo, ex fortuita atomorum collisione*, in an infinite waste, so caused by an accidental collision of motes in the Sun, all which Democritus held, Epicurus and their master Leucippus of old maintained, and are lately revived by Copernicus, Brunus, and some others.

Additionally, I would like to mention those scholars who made possible the scientific transfer across German-speaking countries and Great Britain. The Greek scholar and mathematician Henry Savile traveled through Europe and brought back to England a copy of *De revolutionibus*, which he annotated extensively, and a copy of Copernicus's letter to Wapowski on the eighth sphere. He eventually funded the "Savilian professorships" of astronomy and geometry at Oxford.[150] The Scotsman John Craig, who had studied in Wittenberg and Königsberg and taught in Frankfurt on Oder, returned to Great Britain as a physician to James VI of Scotland and I of England and kept in contact with scholars in continental Europe.[151] Duncan Liddel of Aberdeen, who studied under Craig, was a member of the humanist circle of Wrocław and was professor of mathematics at Rostock and Helmstedt, returned to Aberdeen in 1607 and endowed a chair of mathematics at Marischal College in 1613.[152] The University Library of Aberdeen preserves two annotated copies

Tessicini, *Dintorni*, Granada, "Synodi," idem, "Héliocentrisme," and Omodeo, "Bruno and Nicolaus Copernicus."

148 Campanella, *Cosmologia*, 88.

149 Burton, *Anatomy*, 15.

150 Gingerich, *Annotated Census*, 258.

151 Mosley, "Brahe and Craig."

152 Omodeo, "*Iter* europeo."

of *De revolutionibus* that belonged to him, one of which contains his transcription of the *Commentariolus*.[153]

Another influential British scholar was the English Royal Physician William Gilbert, author of the successful treatise on magnetism *De magnete, magneticisque corporibus, et de magno magnete Tellure, Physiologia nova* (*New Physical Theory of the Lodestone, the Magnetic Bodies and the Great Lodestone Earth*, 1600). Among other things, he presented the Earth as a lodestone set in spontaneous rotation.[154] To be precise, he addressed in the sixth book the motions linked with the terrestrial axis; asserted "the probability of the daily magnetic revolution of the Earth against the ancient opinion of a primum mobile" (VI,3); and indicated some axial motion as the sources of the precession of the equinoxes (VI,8). It is controversial whether he accepted the annual rotation but, if so, he denied the necessity of an explanation of its constant parallelism relative to the ecliptic, contrary to Copernicus (VI,2 "Magneticus axis Telluris invariabilis permanet"). He also expanded on the annual rotation and cosmological aspects of Bruno's treatment of Copernicus's system, in the manuscript *De mundo* (published posthumously in Amsterdam, in 1651) a copy of which was also owned by Francis Bacon.[155]

In continental Europe, Gilbert's magnetism stimulated Kepler's search for a causal explanation of planetary motions. His theses were considered attentively by Galileo as well. In England, they spread along with those of Copernicus.[156] The so-called "Northumberland circle," a group of men of science and letters attached to the "Wizard Earl" Henry Percy of Northumberland, brought together Copernicanism and atomism, an empirical and mathematical approach to nature, Renaissance naturalism and anti-Aristotelianism.[157] Among its affiliates, the most noteworthy are perhaps the mathematician and natural philosopher Thomas Harriot—who has been called an "English Galileo"[158]—and the Epicurean and Lullist philosopher Nicholas Hill. The first was familiar with Walter Raleigh, for whom he fulfilled the famous *A Brief and True Report on the New Found Land of Virginia* (1588). His amazing

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153 Gingerich, *Annotated Census*, 264–67. See also: Dobrzycki, "Aberdeen Copy" and Dobrzycki-Szczucki, "Transmission."

154 Henry, "Animism."

155 Boas, "Bacon and Gilbert." For the opposed reactions to Gilbert's Copernican commitment among his English colleagues interested in magnetism see Gatti, *Bruno and Renaissance Science*, 86–98.

156 Jones, *Ancients*, 62–84, chap. 4, "The Gilbert Tradition." See also Pumfrey, "Selenographia."

157 Kargon, *Atomism*.

158 Schemmel, *English Galileo*.

manuscripts, which show an intense scientific activity approaching the contemporary research of Galileo, remained unpublished.[159] As far as his natural and cosmological convictions were concerned, he was an atomist and a supporter of the infinity of the universe. Notably, his reflections on the *maximum* and the *minimum* bear witness to an attentive reading of Bruno.[160] As to Hill, he was the author of an apology of Epicureanism, *Philosophia Epicurea* (1601), which also included arguments in favor of the motion of the Earth and many others in favor of its magnetism.[161] For his ideas he was later censured by Marin Mersenne in *L'impiété des déistes, athées et libertins du temps* (*The Impiety of Deists, Atheists and Libertines of Today*, 1624) together with Bruno and Vanini. Like the ancient atomitsts, Hill asserted the boundlessness of the universe as well as the plurality of worlds.[162]

9 Central European Circles and Courts

In the history of the reception of Copernicus some central European Renaissance circles and courts deserve particular mention as extra-academic places where cultural and philosophical aspects of *De revolutionibus* were discussed with a free-minded attitude. In Wrocław (the German "Breslau"), at the crossroads of Cracow, Prague, Vienna and Wittenberg, the Italo-Hungarian man of letters Andreas Dudith-Sbardellati and his humanist circle were interested in mathematical astronomy along with the criticism of astrology.[163] This linking of post-Copernican astronomy with ethical concerns is quite original. In this environment, the rejection of superstition elicited a confrontation with mathematical astronomy, contrary to the attitude of many astrologers who sought in *De revolutionibus* and in the derived tables the basis for reliable prognostications. In the 1580s, Dudith offered his hospitality to young British scholars who were on a study tour through Europe and would bring knowledge of mathematics and Copernicus to their homeland: the Englishmen Henry Neville,

159 ODNB 25 (2004), *s.v.*

160 Fox, *Harriot*. Cf. Henry, "Harriot and Atomism."

161 Hill, *Philosophia Epicurea*, 155–57. Cf. ODNB 27 (2004), *s.v.*, and Plastina, "Nicholas Hill."

162 Some considerations on Harriot and Hill can be found in Ricci, *Fortuna*, 49–79. For an overview of English science in that period, see also Hill, *Intellectual Origins*, in particular 15–76, chap. 2, "London Science and Medicine," and 118–200, chap. 4, "Raleigh: Science, History and Politics."

163 Costil, *Dudith*, Vasoli, "Dudith-Sbardellati," and Caccamo, *Eretici*. As documents of the anti-astrological polemics of this group of scholars: Dudith, *Commentriolus* and Erastus *et alii*, *De cometis*.

Henry Savile, Robert Sidney (brother of the Elizabethan court poet Philip and pupil of the mathematician Thomas Harriot)[164] as well as the Scotsmen John Craig and Duncan Liddel. Another member of this group, Paul Wittich, was a brilliant Wrocław mathematician who frequented many German universities and courts (Leipzig, Wittenberg, Prague, Altdorf, Frankfurt on Oder, Uraniborg, Kassel and Vienna). He analyzed alternative geometrical models of planetary motions that would eventually influence the geo-heliocentric theory of Brahe.[165] Dudith hinted at Wittich's planetary arrangement in a letter to Neville of 7 August 1581:[166]

> Please, prompt in a more insistent way and stimulate more forcefully Savile to elaborate something for me on the obscure passages of the ancient mathematicians and to compare Copernicus with the ancients or perhaps to express his preference for Wittich.

Kassel became another important center for the discussion on Copernicus. From the 1560s, Landgrave Wilhelm IV's generous support of astronomy made his court an attractive center for mathematicians.[167] He himself was fond of astronomy, recorded observations of heavenly phenomena and appointed capable mathematicians in the 1580s, including the astronomer Christoph Rothmann and the instrument builder Jost Bürgi.[168] Wilhelm IV was respected and admired by most German mathematicians of his age and was the dedicatee of several astronomical publications, for instance Peucer's *Hypotheses* (Wittenberg, 1571). Among the numerous mathematicians who visited him it is worth mentioning Brahe (in 1575), Wittich (in 1584) and Nicolaus Raimarus Ursus (between 1586–1587), who became imperial mathematician in Prague in 1591. Apart from mathematical astronomy, the natural consequences of the new planetary theories, the structure of the world, its dimensions and its matter were also freely debated at Kassel, as witnessed by the manuscripts of Rothmann and his correspondence with Brahe (who published it in Denmark in 1596).[169] Moreover, Ursus accomplished for Bürgi the first German

164 Cf. Hill, *Intellectual Origins*, 125.

165 Gingerich-Westman, "Wittich Connection."

166 Costil, *Dudith*, 444.

167 Hamel, *Astronomische Forschungen* and Granada *et alii, Christoph Rothmanns Handbuch*. On German courts and science, cf. Moran, "German Prince-Practitioners."

168 Cf. Gaulke, "First European Observatory."

169 Launert, *Reimers*, idem *Reimers Ursus*, and Granada, *Debate cosmológico*.

translation of Copernicus's major work, *Von den revolutionibus*, while he was residing in Kassel.[170]

A major center of post-Copernican astronomical research was the Danish island of Hven, which Brahe obtained as a fief from the King of Denmark Frederik II and transformed into "the center of the Danish Renaissance,"[171] an observatory, alchemical laboratory, academy and court. He built there the castle observatory of Uraniborg and the detached basement observatory of Stjerneborg, equipped with spectacular and precise astronomical instruments, an alchemical laboratory and a printing press. A team of craftsmen and scientists worked there recording data for the improvement of astronomical parameters. Astronomers and aristocrats came from all over Northern Europe to visit this marvelous island. Information about it was included in the *Atlas* of the Dutch geographer Willem Blaeu, along with a note on the scientific activities that took place there under Brahe's supervision.[172]

The network of contacts of the "Lord of Uraniborg," scientific and non, is impressive. He had been familiar with German academies since his student years in Copenhagen, Leipzig, Wittenberg and Rostock. Moreover, he had traveled extensively in his youth. He contributed to the construction of astronomical instruments in Basel along with the Dutch humanist Hugo Blotius, later imperial librarian in Prague. He met the astrologer Cyprianus Leowitz in Bavaria, the geographer Philip Apian in Ingolstadt, the humanists Hieronymus Wolf and Paul Heinzel in Augsburg and later, in the same town, the imperial physician Thaddeus Hayek, with whom he established a long-lasting friendship. He also visited Erasmus Reinhold, son of the same name of the author of the *Prutenicae tabulae*, in Saalfeld, as well as Wolfgang Scultetus and Caspar Peucer in Wittenberg. In Augsburg in 1570, he met the French philosopher Pierre de la Ramée, who urged him to develop astronomy "without hypotheses." Brahe regarded that program as foolish, but other astronomers, for instance Rheticus, Rothmann and Kepler, took it up as a challenge to improve their discipline.[173] Brahe was also in Kassel in 1575, where he met Wilhelm IV. He could thus count on a wide scientific network to exchange data and information, and to discuss his theories.

In 1599, Brahe left his country after a quarrel with the king and moved to Prague, where he was welcomed by the magnificent supporter of the arts and

170 GA III/3; Hamel, *Astronomische Forschungen*.

171 Zeeberg, "Alchemy, Astrology," 997. Cf. also idem, "Science," and "Alchemy of Love."

172 Blaeu, *Novus Atlas*, f. 7*v*. Dreyer, *Brahe*, Christianson, *On Tycho's Island*, Thoren, *Lord*, and Mosley, *Bearing the Heavens*.

173 See Jardine-Segonds, "Challenge."

sciences Rudolph II. There, he appointed one of the most promising astronomers of that age as his assistant, the fervent Copernican Johannes Kepler, who was to become the imperial astronomer. Rudolf II's patronage attracted many other mathematicians, astrologers and philosophers, among them the imperial mathematician Ursus, the John Dee and Giordano Bruno, whose conception of a boundless homogeneous universe inhabited by infinite solar systems was still vigorously debated in Prague at the beginning of the seventeenth century, as witnessed by Kepler and others.[174]

The court of Braunschweig-Wolfenbüttel was another flourishing center of the German Renaissance, thanks to Duke Heinrich Julius, a well-educated patron of the arts and later adviser of Rudolf II in Prague. Heinrich Julius, as a rector and protector of the University of Helmstedt, acquired valuable cosmologers for his *Studium*: besides Bruno, also the Rostock mathematician Magnus Pegel and the Scottish mathematician and physician Duncan Liddel. Pegel supported innovative natural views against the well-established Aristotelian finite and ethereal conception of the heavens: the so-called Capellan planetary system (a geocentric system in which only Mercury and Venus encircle the Sun), the elementary composition of the skies, the existence of void, and the infinity of space beyond the fixed stars.[175] Although he was no supporter of Copernicus's planetary theory, his opinions show his participation in the debate on the structure and nature of the universe that originated from a physical and not merely mathematical consideration of astronomy. By contrast, Bruno developed his cosmology from Copernican premises. He completed his so-called Latin poems (*De triplici minimo et mensura, De monade* and *De immenso*) in Helmstedt, publishing them in Frankfurt on Main in 1591 with a dedication to Duke Heinrich Julius. In these writings he expounded his view of the infinite universe, in which Copernicus's heliocentric system was multiplied *ad infinitum* by assigning to each star a court of planets. Moreover, he offered a philosophical foundation to this cosmology, based mainly on the so-called "principle of plenitude."[176] This posits that the infinite power of God must necessarily yield an infinite universe. The last of the scholars mentioned above, Liddel, taught mathematics and astronomy at Helmstedt from 1591 to 1600. He considered himself a Pythagorean and introduced to Helmstedt (as to Rostock before) the teaching of the heliocentric and geo-heliocentric hypoth-

174 On Dee, see Sherman, *Dee*, 8–9. On Kepler, see Granada, "Kepler and Bruno," and Omodeo, "Astronomia, filosofia e teologia."

175 On Pegel: ADB 25 (1887), Biegel, "Pegel," Omodeo, "Disputazioni." On Capella: Eastwood, *Ordering*.

176 Cf. Lovejoy, *Great Chain of Being* and Granada, "Rifiuto della distinzione."

eses, which he presented primarily from a mathematical perspective, avoiding discussion about their physical tenability.[177]

As a sign of the interest in Copernicus's work among German scholars, one can mention the circulation of the *Commentariolus* as a precious rarity. The imperial physician Thaddeus Hayek owned a copy of the *Commentariolus* which he passed on to Brahe around 1575. Later, in the second part of his *Astronomiae instauratae progymnasmata*, Brahe mentioned Copernicus's manuscript and hinted at the provenance of his own copy and of those that he sent to other astronomers:[178]

> The most distinguished man Thaddeus Hayek, who is very close [*coniunctissimus*] to me for a lasting [*diutina*] friendship, gave me once in Regensburg that manuscript [Copernicus's small treatise on his own hypotheses]; I myself transmitted it later to some other mathematicians in Germany. I mention these [facts] in order to inform those who will receive that piece of writing [*scriptum*] about its provenance.

Dudith-Sbardellati, who was also familiar with Hayek, received the *Commentariolus* from Paul Wittich in Wrocław, in 1589. He regarded it as an abridgment (*epitomen*) or an enlightening introduction to *De revolutionibus*, as he wrote to the Altdorf professor of mathematics Johannes Praetorius (1537–1616) on 12 February 1589:[179]

> Wittich said that the *Epitome* of Copernicus was written by the author himself; he received it from his uncle, a well known physician and mathematician of this city [Wrocław], Master Balthasar [Sartorius] whose many letters to Rheticus you were able to see at Rheticus's house. I am surprised that Rheticus did not show us this *Epitome*, which the doctor [Sartorius] is likely to have received from him; the book was never printed; written in Wittich's hand, it is in quarto; it has 14 folios whose so-called gatherings [*arcus*] are four.

Praetorius had been a guest of Dudith in Cracow between 1569 and 1571 and had probably helped him to understand the technicalities of planetary astronomy. In the letter in question, Dudith was disappointed by the fact that he had

177 Omodeo, "Sixteenth Century Professors" and "*Iter* europeo."

178 Brahe, *Opera*, vol. 2, 428.

179 Dobrzycki-Szczucki, "Transmission," 26–27.

not received the manuscript earlier, directly from Rheticus in Cracow.[180] After disappearing from sight since the seventeenth century, the *Commentariolus* was rediscovered around 1878 by the German historian of science Maximilian Curtze, who published it as Copernicus's commentary "über sein Buch *De Revolutionibus*."[181] Like his Renaissance forerunners, Curtze considered it to be an abridgment of the author's most famous work.[182]

10 The Physical-Cosmological Turn

In the mid-1580s astronomers and philosophers began an intense debate on general astronomical hypotheses and on their physical implications, in particular on the order of planetary circles, on the dimensions of the universe and on the matter of the heavens. According to tradition, these issues pertained to natural philosophy, or *physica*. Copernicus's theory of terrestrial motion was at odds with the Aristotelian doctrines, which distinguished between a "corruptible" sublunary realm (the globe of the Earth with its four elements: earth, water, air, fire) and a celestial realm, inalterable except for motion. This distinction would lose meaning if the Earth, quoting Cusanus's prophetic words, was regarded as a "noble star" (*stella nobilis*) traveling through the heavens like other planets.[183] Moreover, opponents of terrestrial motion argued its centrality and immobility from the observable vertical falling of bodies toward its center, which they considered to be both the geometrical and the gravitational center of the universe. Aristotle distinguished between the downward and upward rectilinear motions of the terrestrial elements (in accordance with his "doctrine of natural places") and the circular and uniform motion of

180 Dudith lived in Cracow between 1562 and 1576, and Rheticus between 1554 and 1574 (Burmeister, *Rhetikus*, Costil, *Dudith*). In his correspondence, Dudith mentioned the latter for the first time in a letter to Catherine of Austria, Queen of Poland (Lublin, 27–29 Jun. 1566), in which he presented Rheticus as an astrologer and spiritist (Dudith, *Epistulae*, vol. 1, 323 n. 137). From Dudith's correspondence with Joachim Camerarius, Konrad Dasypodius and Hayek, it appears that he later became familiar with Rheticus, despite the fact that he disapproved of his commitment to Paracelsian medicine. See in particular the following letters (also for reference to Praetorius), in Dudith, *Epistulae*, vol. 2: 226, 228, 238, 251, 272, 275, and 287.

181 Curtze, "*Commentariolus*."

182 Actually, the *Commentariolus* is prior to *De revolutionibus*, as scholars established by considering the differences between the geometrical models employed in the two works. Cf. Swerdlow, "Derivation," Wilson "Rheticus," Hugonnard-Roche, *Introductions*.

183 Cusanus, *De docta ignorantia* II, 12.

celestial spheres. The "physical-cosmological turn" of the 1580s was prepared by extraordinary celestial apparitions, such as a nova in Cassiopeia in 1572 and various comets (1577, 1580, 1582 and 1585). Measurements forced these phenomena to be placed outside the terrestrial atmosphere, and this statement of fact undermined confidence in the Aristotelian teaching of the incorruptibility of material heavenly spheres, triggering new questions concerning the "nature" of the heavens.[184]

1588 was a decisive year in the history of post-Copernican astronomy, seeing the concomitant publication of three books tackling the "physical problem" of astronomy: Ursus's *Fundamentum astronomicum* (*Astronomical Foundation*, in Strasbourg), Brahe's *De mundi aetherei recentioribus phaenomenis* (*On the Most Recent Phenomena in the Ethereal World*, in Uraniborg) and Bruno's *Camoeracensis acrotismus* (*Proclamation at the College of Cambrai*, in Wittenberg).[185] These authors used planetary hypotheses to challenge traditional cosmology and the authority of Aristotle in "physics." The publications of Ursus and Brahe proposed slightly different geo-heliocentric models that safeguarded the mathematical requirement to "save the phenomena" and the Aristotelian doctrine of natural places along with traditional explanations of motion. In both cases the Earth was put back at the center of the universe and encircled by the Sun, Moon and fixed stars, whereas the circular paths of the other planets were centered on the Sun in accordance with Copernicus. According to Brahe, the cosmic centrality of the Earth accounted for the downward fall of bodies and related physical phenomena, and was compatible with the letter of the Bible. He presented his hybrid system, a kind of "inverted Copernican hypothesis,"[186] as an alternative to both Copernicus and Ptolemy. While he considered the Earth to be at rest, Ursus rejected only its annual revolution but adhered to its axial rotation to account for the apparent daily motion of the heavenly sphere. Moreover, neither Brahe nor Ursus remained entirely true to Aristotelian celestial physics.[187] In addition, Ursus opened up unconventional physical perspectives in the cosmological section of the *Fundamentum* titled "Theses astronomicae: de mundo ac mundanorum corporum motibus, deque novis hypothesibus" ("Astronomical Theses: On the World and the Motions of Worldly Bodies, and on New Hypotheses"). Among others, he was inclined to accept a region of fixed stars extending up indefinitely, and

184 Cf. Granada, "Novelties."

185 Granada, *Debate cosmológico*. Blum, *Bruno*, 73 explains the translation of "acrotismus" as "proclamation."

186 Barker-Goldstein, "Role," 387.

187 See Schofield, *Tychonic and Semi-Tychonic World Systems*.

surmised that the distance of the stars from the Earth could be different and their number be infinite.[188]

In the *Fundamentum astronomicum*, Ursus reported that he had "discovered" his geo-heliocentric model between 1585 and 1586.[189] According to his report, he had already presented it to the Landgrave during his stay in Hesse-Kassel between 1586 and 1587. Bürgi, for whom he translated *De revolutionibus* into German, had even realized a brass model of that planetary system. Brahe immediately started a quarrel with Ursus on the authorship of the geo-heliocentric model and accused his rival of plagiarism, adducing that he had certainly peeked at his manuscripts during a stay on Hven in 1584.[190]

To be fair, the possibility of a "geocentric conversion" of Copernicus's parameters and even a duplication of the centers of planetary revolutions had been discussed in Germany for many years. A geocentric arrangement of Copernicus's model for the precession of the equinoxes and the millenarian motions of the heavens had been proposed by the Wittenberg theologian and mathematician Peucer on the advice of Reinhold.[191] Paul Wittich of Wrocław also proposed a geo-heliocentric model, at least for the inferior planets (Capellan system), as emerges from his manuscripts.[192] The same system was also presented in a less known publication: *Universi seu mundi diatyposis* (*The Order of the Universe or World*, 1586) by the aforementioned Pegel of Rostock.[193]

All these elements trace a lively circulation of ideas in the German-speaking world. Wittenberg, Kassel, Uraniborg, Rostock, Strasbourg are some junctions of the intricate central and northern European network (Reformed Universities, central European courts and circles). In this context, one also ought to mention Rothmann, the court mathematician of Wilhelm IV in Kassel, who started up a correspondence with Brahe about heated cosmological issues, such as the physical and biblical acceptability of Copernican astronomy, the motion of the Earth and the matter of the heavens.[194]

In contrast to Ursus and Brahe, Bruno's *Acrotismus* openly advocated a Copernicus-inspired cosmology with anti-Aristotelian elements derived from neo-Platonism (or, as is often said, "Hermeticism"), Cusanus's ontology,

188 Ursus, *Fundamentum*, ff. 37*r*–38*v*. See Granada, *Sfere*, app. 5.

189 Ursus, *Fundamentum*, f. 37*r*.

190 Cf. Rosen, *Three Imperial Mathematicians*, Jardine, *Birth*, and Jardine-Segonds, *Guerre des astronomes*.

191 Peucer, *Hypotheses*, f. X4v.

192 Cf. Gingerich-Westman, "Wittich Connection."

193 Omodeo, "Disputazioni."

194 Barker-Goldstein, "Role" Granada, *Sfere*, and idem, "Defence of the Movement."

and atomism. The *Acrotismus* was published in Wittenberg, where Bruno had taught philosophy for two years, and was a reassessment of 120 theses (*articuli*) printed in Paris in 1586 in defense of cosmological infinity, the eternity of the world, the atomistic structure of matter, and the existence of physical void. Brahe, who owned a copy of the *Acrotismus*, did not appreciate it, probably due to the lack of mathematics in the treatment of astronomical issues and to the idea of space infinity. On the frontispiece he annotated some mocking words about the philosopher of Nola: "Nullanus nullus et nihil/ Conveniunt rebus nomina saepe suis" ("Nullanus-nobody-nothing: things often fit to their names").[195]

11 Heliocentrism between Two Centuries: Kepler and Galileo

The end of the sixteenth century was marked by the publication of Kepler's *Mysterium cosmographicum* (*The Secret of the Universe*, 1596), a momentous attempt to affirm the heliocentric outlook.[196] It marked its author, at that time a young professor of mathematics at the *Stiftschule* of Graz, as one of the most promising and innovative scholars of his time. After a season marked by observational campaigns and empirical research based on perfecting astronomical instruments and data records—as was the case with Wilhelm IV, Brahe and Kepler's teacher Michael Mästlin—Kepler reversed the method of his predecessors. He proposed an a priori justification of planetary astronomy, which he considered to be the "rediscovery" of the secret geometry beyond the cosmos. Through a skillful intersection of the planetary spheres and the five regular solids (the "Platonic solids"), he accounted for the distances of the planets and for their number, six instead of seven as in the Ptolemaic system (in which also the Moon was a planet). He was convinced that he could unveil the mystery of Creation, that is to say, God's archetypal project underlying the universe, a geometrical scheme that, according to him, was already known to the Pythagoreans. What is more, his astronomical treatise was directed toward the unification of mathematical and physical astronomy, a project fulfilled by the publication of the *Astronomia nova* (*New Astronomy*) in 1609.[197] It this later work, he managed to interweave heliocentric planetary theory and its physical

195 Cf. Sturlese, *Su Bruno e Tycho*.

196 See chap. 6.

197 See, among others, Beer, *Kepler*, Koyré, *Astronomical Revolution*, Jardine, *Birth*, Hallyn, *Structure poétique*, Stephenson, *Kepler's Physical Astronomy*, Gingerich, *Eye*, Schwaetzer, "*Si nulla*," Martens, *Kepler's Philosophy*, Voelkel, *Composition*, and Bucciantini, *Galileo e Keplero*.

explanation so deeply that they could be not separated without rejecting the work in its entirety.[198]

In the preface to the *Mysterium*, Kepler reported that he had been initiated in Copernican astronomy by Mästlin at Tübingen,[199] who, however, had refrained from heliocentric claims in his publications. Still, his master found Kepler's astronomical work so convincing, despite its unconventional approach, that he felt confident to openly declare his adherence to a "realistic Copernicanism." Despite the preference earlier accorded to recording data and carefully deriving parameters, Mästlin appreciated Kepler's rationalism so much that he undertook to publish the *Mysterium*. It eventually appeared together with a new edition of Rheticus's *Narratio prima* and a short essay with calculations of planetary distances compiled by Mästlin himself. In the letter to the reader (*Candido lectori*), Mästlin extolled his pupil's a priori explanation of God's cosmological design. He in fact considered this to be the decisive argument in favor of Copernicus's hypotheses.[200]

Along with Kepler's *Mysterium* and *Astronomia nova*, another milestone in the history of early modern astronomy was the *Sidereus nuncius* (*Sidereal Messenger*, 1610) by the Italian mathematician and physicist Galileo Galilei. This was the first printed report of telescopic observation of the heavens and communicated a series of new discoveries: the irregular surface of the Moon, new planets—to be precise, four satellites of Jupiter named "Medicean" in honor of the Grand Dukes of Tuscany—and new visible stars. Observations such as those of an irregular lunar surface and, later, of the sunspots, provided evidence of the elemental (corruptible) nature of heavenly matter in opposition to Aristotle's teachings. Moreover, the phases of Venus, observed just after the publication of *Sidereus nuncius*, provided proof that this planet circled around the Sun. In the dedicatory epistle to Cosimo II de'Medici, Galileo openly declared his adherence to the Copernican system, but the relevance of the new observations for undermining the ancient cosmology can be better illustrated by a passage in a letter of 1 January 1611 to the Florentine ambassador in Prague Giuliano de'Medici and Kepler, informing them about the phases of Venus:[201]

> From this remarkable experience we derive a sensible and certain demonstration concerning two important issues which were until now

198 Voelkel, "Legal Contingencies," 52.

199 Kepler, "Prefatio ad lectorem," in KGW vol. 1, 9–14. For Mästlin, cf. Betsch-Hamel, *Zwischen Copernicus und Kepler*.

200 Mästlin, "Candido Lectori," ibid. 82.

201 Galileo's letter to Giuliano de'Medici in Prague (Florence, 1 January 1611), EN vol. 10, 11–12.

> undecided among the most intelligent scholars. On the one hand, all planets are obscure according to their nature (since Mercury appears like Venus); on the other hand, Venus necessarily revolves around the Sun, like Mercury and all other planets, which was believed by the Pythagoreans, Copernicus, Kepler and myself but not yet supported by sensible evidence as is now the case with Venus and Mercury. Mr. Kepler and other Copernicans can be proud that they thought and philosophized correctly, although we were considered (and we will be considered again in future) to be less intelligent and almost foolish by all philosophers *in libris*.

Galileo made clear his intention to strengthen the Copernican cause. Heliocentrism could provide the cosmological framework for his discoveries and for the mathematical physics he was developing. In the same years, Harriot was performing physical and astronomical research that yielded results close to those of Galileo. The English scientist made independent telescopic observations of the heavens and interpreted the existence of Jupiter's satellites as confirmation of Bruno's infinite, homogeneous universe.[202]

At the beginning of the seventeenth century many Dutch scholars, too, favored the Copernican planetary system. Simon Stevin defended the daily and annual motion of the Earth in the cosmological section of his *Wisconstige gedachtenissen* (*Mathematical Thoughts*) of 1605–1608.[203] Moreover, the geographer Willem Blaeu of Amsterdam was favorable to the Copernican model despite his admiration for Brahe (whom he had visited personally in Hven), and even built a heliocentric sphere around 1630. A special case is the professor of mathematics at Leiden Nicolaus Mulerius, who brought out a new edition of *De revolutionibus* entitled *Astronomia instaurata* (*Restored Astronomy*, 1617), although he was not convinced of the physical reality of Copernicus's planetary system.[204]

12 Geo-Heliocentrism and Copernican Hypotheses

Kepler's celestial physics and Galileo's telescopic discoveries (and mechanics) heralded a new phase of the reception of Copernicus and, in more general terms, of scientific research. They initiated the age of Descartes, Huygens, Hevelius, Halley and Newton. Kepler's *Astronomia nova* and Galileo's *Sidereus*

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202 Ricci, *Fortuna*, 76.

203 Dijksterhuis, *Stevin*.

204 See Vermij, *Calvinist Copernicans*. GA VIII/1, Mulerius, *Notae breves ad libros Revolutionum Copernici* and *Thesaurus Observationum Copernici*.

nuncius were a watershed in the reception of Copernicus. Their almost simultaneous publication between 1609 and 1610 could thus be regarded as the epilogue of the reception of Copernicus "in his century." Nonetheless, if we take into account the momentous historical relevance of the theological attacks against heliocentrism in the 1610s we are forced to slightly postpone the end of this early reception of *De revolutionibus* and take another date as the turning point.

Geo-heliocentric planetary models proliferated at least from the mid-1580s. These hybrid models seemed to overcome the physical problems of the heliocentric theory, issues pertaining to the fall of bodies and nature of the heavens: how is it possible that a body falls straight downward if the Earth moves? What about the distinction between terrestrial elements and incorruptible heavens if our globe is a planet among others? Why is there no detectable parallax of the stars if the Earth rotates about the Sun? In his correspondence with Rothmann, Brahe listed these and other problems with the Copernican system, yielding examples and arguments that later would be found on the agenda of Galileo's heliocentric reassessment of physics in the *Dialogo sopra i due massimi sistemi del mondo* (*Dialogue Concerning the Two Chief World Systems*, 1632).[205]

Brahe's and Ursus's models (both published in 1588) are only two examples, certainly more relevant than others, but not isolated. Two authors already mentioned, Pena in Paris (1557) and Pegel in Rostock (1586), proposed the Capellan model with Mercury and Venus rotating around the Sun in an otherwise geocentric system. Patrizi, in the *Nova de universis Philosophia* (*New Philosophy on Universal Things*, 1591), was one of the first to confront Brahe's system, which he regarded as one of the three major planetary systems along with heliocentrism and homocentrism (the Aristotelian model of concentric spheres centered on the Earth). For his part, he denied the centrality of the Sun (either in the Copernican or in the Tychonic version) but accepted the daily axial rotation of the Earth. Moreover, he rejected material celestial spheres and considered planets to be self-moving fiery bodies.[206]

Magini independently developed a geo-heliocentric system in his *Novae coelestium orbium theoricae congruentes cum observationibus N. Copernici* (*New Theories of the Celestial Spheres in Accordance with the Observations of N[icholas] Copernicus*, 1589). In his opinion, this was a necessary reassessment of Copernicus who, so Magini, had irrefutably demonstrated that the inferior planets turn about the Sun. The German ephemerist David Tost, Latinized as

205 Bucciantini, *Galileo e Keplero*, 63.

206 Bleuel, "Introduzione." On the Platonic and censorial environment of Patrizi's work: Perosa, "Cultura."

Origanus, professor at Frankfurt on Oder, also supported the geo-heliocentric model, but in another variant. He assumed Brahe's orbits (with the intersection of the circle of Mars and the Sun) but ascribed a daily motion to the Earth in accordance with Ursus. He further underpinned his model through magnetic arguments, which he derived from Gilbert and combined with a vitalistic conception of nature.[207] The same pattern was then followed by Brahe's pupil and professor at Copenhagen Christian Sørensen, known as Longomontanus, in his *Astronomia Danica* (*Danish Astronomy*, 1622).[208]

In the history of the reception of Copernicus, the development of geo-heliocentric systems is relevant for two principal reasons. On the one hand, it can be regarded as part of a wider debate inaugurated by *De revolutionibus*, in which advocates of geo-heliocentrism could regard Martianus Capella's *De nuptiis Philologiae et Mercurii* (*The Marriage of Philology and Mercury*), composed in the fifth century of our era, as an authoritative precedent. On the other hand, their objections forced the followers of Copernicus's system to seek physical arguments more convincing than those presented in the first book of *De revolutionibus*. If the debate is restricted to the possibility of terrestrial motion, Brahe's "physical arguments" could be associated with those of Ptolemy, as Galileo did by reducing the clash of the various hypotheses to a confrontation between Ptolemy and Copernicus. It should be further noted that geo-heliocentrists adduced cosmological and natural remarks that exerted great influence on the astronomical debate in general. A perspicuous example is the fluidity of the heavens, which Brahe demonstrated on the basis of his observations of comets, but also for reasons linked to his general hypotheses (namely, the intersection of the circle of Mars with that of the Sun).[209]

The historical relevance of geo-heliocentrism also lies in its great diffusion in the seventeenth century. In certain environments it even became a standard view, as was the case in Leiden at the end of the sixteenth and the beginning of the seventeenth century. As Rienk Vermij pointed out, the local university was particularly receptive to the cosmological aspects of Copernicus's and Brahe's works: Janus Dousa Filius, in the *Rerum coelestium liber* (*Book on Heavenly Matters*) of 1591, advocated the Capellan system, which he considered to be a

207 Origanus, *Ephemerides Brandeburgicae*, epistle dedicatory, f. b2*r*, 121–22 and 132–33. Cf. Omodeo, "Origanus's planetary system."

208 Longomontanus, *Astronomia, pars altera*, I,1, 161. On Longomontanus and the Copenhagen University in those years, see Moesgaard, "How Copernicanism." For early seventeenth-century debates on terrestrial motion see Siebert, *Große kosmologische Kontroverse*, 111–22.

209 Cf. Granada, *Sfere* and "Did Tycho."

doctrine of the Egyptians and the Pythagoreans; Johannes Lucius Pontanus followed Brahe, whom he knew personally, and ascribed the Capellan system to Macrobius, of whose work he was an editor (Leiden, 1597); the renowned jurist Huig van Groot (Latinized as *Grotius*) would later take into consideration the details of the geo-heliocentric hypotheses in his new edition of Capella; and Willebrord Snellius (Snel van Royen) was inclined toward the doctrine of terrestrial motion, which he never approved without reservation.[210]

Another ground of dissemination for geo-heliocentrism were the schools of the Jesuits, although Christopher Clavius, who was the most authoritative sixteenth-century mathematician of the order, always refused a confrontation with Brahe. Only in the last years of his life, after Galileo's telescopic observations, did Clavius become more open to new hypotheses: "Under present conditions, astronomers ought to consider how celestial spheres shall be ordered in order to account for these phenomena."[211] These words could be interpreted in different ways, but were taken by many as an invitation to accept Brahe's model. This was the case for the Milanese mathematician Cristoforo Borri who, in the manuscript *De astrologia universa* (*On Universal Astronomy*), reported that he abandoned Ptolemy in 1605 for Copernicus's mathematics, but was never satisfied with his physics. For this reason he eventually embraced Brahe's system. Christopher Scheiner, well known for his observations of the sunspots, also approved of Brahe's approach. The mathematician Giuseppe Biancani of Bologna, who studied under Clavius in Rome between 1599 and 1600, adopted the same model along with Kepler's elliptic planetary orbits, whereas Giovan Battista Riccioli, around the mid-seventeenth century, developed a semi-Tychonic model according to which the inferior planets and Mars were heliocentric, while the two outermost planets remained geocentric like the Moon and the Sun.

13 The Difficult Reconciliation between Copernicus and the Sacred Scripture

The problem of reconciling the doctrine of terrestrial motion and solar centrality and immobility with the Holy Scripture worried the readers of Copernicus

210 See Vermij, *Calvinist Copernicans, passim.*

211 Cf. Lerner, "Entrée de Tycho Brahe," 164 and Lattis, *Between Copernicus and Galileo*, chap. 7, especially 180–83. For Clavius see also: Romano, *Contre-réforme mathématique*, Giard, *Jésuites*, and Casanovas, "Copernicus and the Gregorian Calendar Reform." See also Strano-Truffa, "Brahe Cosmologist."

from the beginning.[212] In fact, a literal interpretation of the Bible seemed contrary to the main hypotheses of *De revolutionibus*. In particular, one reads in Joshua 10:12–14 that once God stopped the Sun in the middle of the heavens to ensure the Hebrews a complete military victory over their enemies. Moreover, one could read in 2 *Kings* 20:8–11 and *Isaiah* 38:8 about Isaiah's miracle of the sundial of Ahaz, consisting in producing a backward motion of the Sun in its daily motion and a corresponding variation in the shadow of the dial. Luther had already affirmed the incompatibility between the doctrine of terrestrial motion and Joshua's miracle in a table talk delivered on 4 June 1539 and recorded by his pupils. Copernicus was aware of the scriptural difficulties entailed in his planetary theory, but limited himself to dissociating from a theological discussion on astronomical matters and mocked Lactantius, a respected Father of the Church, for asserting that the Earth is flat on the basis of the Bible.[213] Certainly, Copernicus considered it convenient to dedicate *De revolutionibus* to Pope Paul III and to ask his protection against the "bite" of calumniators in the dedicatory epistle. Among his closest friends, Giese and Rheticus faced the scriptural issue in two apologies for the new cosmology, only one of which is still extant: Rheticus's writing known as *De Terrae motu et Scriptura Sacra* (*Terrestrial Motion and Sacred Scripture*).[214] It embraced the exegetic principle that the Bible accommodates the understanding of the vulgar, refers to common sense and does not address philosophical or natural matters, its aim being the salvation of the souls and not the exposition of astronomy. A similar position would be adopted by those followers of Copernicus who gave a realistic interpretation of his planetary hypotheses, as for instance Galileo and the Calabrian Carmelite Paolo Antonio Foscarini in his theological defense of Copernicus, *Lettera sopra l'opinione de' Pitagorici e del Copernico* (*Letter on the Opinion of the Pythagoreans and of Copernicus*, 1615).[215] Both were reprimanded for this reason by the Inquisitor Cardinal Bellarmino in a letter to Foscarini dated 15 April 1615. The principle of accommodation was also reaffirmed by the Calabrian theologian and philosopher Tommaso Campanella in his apology for the Galilean approach to nature, the *Apologia pro Galilaeo*, written in 1616 but published only in 1622 in Frankfurt on Main.[216]

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212 See chap. 7.

213 GA II, 5.

214 Hooykaas, *Rheticus' Treatise*.

215 DBI 49 (1997), *s.v.*, Caroti, "Sostenitore napoletano," Boaga, "Annotazioni," and Ponzio, *Copernicanesimo e Teologia*.

216 Firpo, "Campanella e Galileo," Ernst, *Campanella*, Corsano, "Campanella e Galileo," idem, "Campanella e Copernico," Ingegno, "Galileo, Bruno, Campanella," Lerner, "Introduzione," idem, "Campanella lecteur."

Those who considered it possible to reconcile Copernicus and the Sacred Script tended to interpret problematic passages, as they said, "relative to us and according to appearance" (*respectu nostri et secundum apparentiam*) and principally justified their exegetical stance with the help of Augustine. It should be added that Calvin, although he did not accept the heliocentric cosmology, proposed a biblical exegesis based on the principle of accommodation that permitted *de facto* to accept the Copernican system with no theological inconvenience.[217] By contrast, a realist reading of Copernicus considering heliocentrism as the physical structure of the planetary system was not compatible with the literal interpretation of several Biblical passages that prevailed among Lutheran and Catholic theologians of the sixteenth century.

Not only Luther and Melanchthon, but also exponents of the Roman curia reacted badly to *De revolutionibus*. The Dominican friar Bartolomeo Spina, in his role as *Maestro di Sacro Palazzo* in Rome, criticized Copernicus's theory and conceived a response, which he was prevented from writing by his death in 1547.[218] The task of refuting Copernicus was then overtaken by a Dominican brother of Spina's, Giovanni Maria Tolosani, who completed a refutation of Copernicus's hypotheses, *De coelo supremo immobili et Terra infima stabili, ceterisque coelis et elementis intermediis mobilibus* (*On the Immobility of the Outermost Heaven, the Stability of the Earth, Lowest in Position, and the Mobility of the Other Intermediate Heavens and Elements*). Yet this treatise remained unpublished until the twentieth century, as a consequence of its author's death in 1549.[219] In his reply to Copernicus, Tolosani argued that the Ptolemaic-Aristotelian geocentric worldview was philosophically right and respected the Bible, whereas Copernicus's system was at odds with revelation and nature. Against the background of this theological culture, the attempt by the Spanish Augustinian Diego Zuñiga to found Copernicus's theory on the Bible in a commentary to Job appears quite isolated. His *In Iob commentaria* first appeared in Toledo, in 1584, but was already completed by 1579, judging by the license to print.[220]

The gradual acceptance of the heliocentric system among astronomers provoked a stronger interest in the scriptural problem. In fact, theological reservations, doubts and criticism concerned only the cosmological-philosophical aspects of *De revolutionibus*, which questioned established interpretations of the Bible. Kepler and Galileo had to address these. The former defended

217 Cf. Granada, "Rothmann e la 'teoria,'" 799. See also Rosen, "Calvin's Attitude."

218 Granada, "Tolosani" and Lerner, "Aux origines."

219 Garin, "A proposito."

220 Arámburu Cendoya, "Zúñiga."

Copernicus from attacks based on the Scriptures in the introduction to the *Astronomia nova*, arguing that the Bible is written for the vulgar. Additionally, he remarked that the principle of authority is valid in theology but not in philosophical debates, where the best arguments shall prevail. Galileo presented a similar point of view in a letter to his friend the Benedictine friar Benedetto Castelli (21 December 1613) and in its later reworking, a letter to the Grand Duchess Christina (1615). Galileo relied on the principle of accommodation and even argued that natural explanations are not arbitrary, whereas there is a certain degree of freedom in the Biblical exegesis of passages concerning natural issues and astronomy.[221]

14 Copernicus before and after 1616

The culmination of the long debate on Copernicus and the Bible was the Catholic condemnation of 1616 and the persecution of Galileo a few years later. On 24 February 1616 three fathers rejected the centrality and immobility of the Sun alongside the motion of the Earth at a session of the Holy Office. Heliocentric views were said to be "foolish and absurd in philosophy and formally heretical," whereas terrestrial motion was banned as false and "at least erroneous in faith."[222] On 5 March the Sacred Congregation of the Index decreed that the theory of the immobility of the Sun and the motion of the Earth was contrary to faith. As a consequence, all books teaching the dangerous "doctrine of the Pythagoreans" were censured or prohibited. Thus, the Catholic Church suspended Copernicus's *De revolutionibus* and Zuñiga's *In Iob commentaria* "donec corrigantur," and condemned Foscarini's *Lettera*.[223]

In the history of the reception of Copernicus, the censure of 1616 marked a hiatus between a period when the cosmological ideas of *De revolutionibus* were discussed more freely and a phase when the astronomical issue was given an unprecedented confessional and philosophical dimension. Although the decree of 5 March 1616 did not explicitly define Copernicus's teaching as heretical—a qualification which had been attached only to the immobility of the Sun by the theological referees on 24 February—after that date the Copernican worldview could not be endorsed by those who wanted to remain

221 EN, 283. Cf. chap. 7,10 and 7,12.

222 Galileo, *Documenti*, 99–100.

223 Ibid., 102–03.

within the Catholic Church.[224] Galileo and his fellows, the members of the *Accademia dei Lincei*, were struck by the condemnation.[225]

Cardinal Caetani and the referee of the Congregation of the Index Francesco Ingoli applied themselves to the "correction" of *De revolutionibus*, which was completed by 1620. Although Ingoli did not agree with heliocentrism, he was well aware of the impossibility of eliminating and correcting all statements on terrestrial motion without suppressing the book almost entirely. Hence, he limited himself to the censure and modification of the passages which presented this theory assertively (*assertive*) and not duly hypothetically (*hypothetice*).[226] This moderation is apparent only. In fact, Catholic persecution of a realist reading of Copernicus was rigorous. The Barnabite Redento Baranzano, then at Annecy in Savoy and later in France, defended the Copernican system, also from a theological perspective, in his *Uranoscopia, seu de coelo* (*Uranoscopy, or on Heaven*, 1617). For this reason he was rebuked by the authorities of his order and had to exculpate himself by writing the treatise *Nova de motu Terrae Copernicaeo iuxta Summi Pontificis mentem disputatio* (*Disputation on the Copernican Motion of the Earth in Accordance with the Supreme Pontiff*, 1618), in which he rejected the reality of the Copernican model.[227]

Galileo's auto-censure in the famous *Dialogo* is also revealing of the repressive atmosphere of those years. The author, despite his convictions, pretended to attach equal validity to Copernicus and Ptolemy and to consider the heliocentric theory as a merely mathematical device for the sake of astronomical prediction. "Some years ago, in Rome, it was published a salutiferous edict—Galileo noted in the introduction to the "judicious reader"—which, in order to obviate the dangerous scandals of the present age, imposed an opportune silence upon the Pythagorean opinion of the mobility of the Earth."[228] He then stated:[229]

> I have presented the Copernican [perspective] in this discourse, proceeding upon an hypothesis purely mathematical; striving by every artifice to represent it superior not to that of the immobility of the Earth absolutely but as it is defended by some who, claiming to profess the peripatetic

224 Cf. Camerota, *Galilei*, 310, and Brandmüller-Greipl, *Copernico, Galilei*, in particular 21–60, chap. 2 and 3. See also Heilbron, "Censorship."

225 Bucciantini, "Reazioni alla condanna."

226 Lerner, "Copernic suspendu" and Bucciantini, *Contro Galileo*.

227 DBI 5 (1963), *s.v.*

228 Galileo, *Dialogue*, 5.

229 Ibid. 6.

> doctrine, retain of it no more than the name, and are content, foregoing the old ways, to adore shadows, not philosophizing with their own intelligence but with the sole remembrance of a few principles badly understood.

Galileo pretended to dissociate from a realistic commitment on Copernicus's system at the end of his dialogue as well, by introducing a skeptical argument presented by the Peripatetic *persona dialogans* Simplicio. As one reads, natural things cannot be known with absolute certitude, according to "a solid doctrine that I once received from a most learned and eminent person, and to which there can be no answer." Hence, the manner in which the omnipotent and wise God chooses to realize natural phenomena are mysterious and beyond the understanding of human intellect.[230] The "very eminent" person at whom Galileo hinted was none less than Pope Urban VIII, who was profoundly offended to notice his opinions reported by the naive Simplicio. Shortly after the publication of the dialogue the aged Galileo was forced by the Inquisition to abjure the heliocentric theory. He appeared before his judges, the Cardinals of the Congregation, on 22 June 1633 in the convent of Santa Maria sopra Minerva in Rome, knelt down and abjured the theory of terrestrial motion and solar immobility at the center of the cosmos. He was then sentenced to jail—he was consequently kept under house arrest in the villa of Arcetri in Tuscany until his death—and was prevented from publishing any new books.[231] All of the European *respubblica litterarum* was struck by the intransigent violence of Rome in censuring one of the most admired and illustrious scholars of the time.

From 1616 onward, theological arguments became an integral part of the debate on *De revolutionibus* and strongly conditioned not only Catholics, but also Protestants and authors living and publishing in Protestant countries. The French philosopher René Descartes was shocked by the condemnation of Galileo and declared to his correspondent Mersenne his intention to keep secret his post-Copernican cosmology.[232] In the Calvinist Netherlands, the minister Philip Lansbergen sought to unify heliocentrism and Christian philosophy. He even wrote an apology of Copernicus in Dutch, *Bedenckingen*, in 1629, and his

230 Ibid., 471.

231 The studies on Galileo's trial are countless. Let me mention only: De Santillana, *Crime*, Morpurgo-Tagliabue, *Processi*, Blackwell, *Galileo, Bellarmine*, Baldini, *Legem*, Bucciantini, *Contro Galileo*, Blackwell, *Behind the Scenes*, and the numerous biographies on Galileo (e.g. Camerota, *Galilei*, Festa, *Galileo*, Wootton, *Galileo*, and Heilbron, *Galileo*).

232 Descartes to Mersenne (Deventer, late November 1633), in *Œuvres*, vol. 1, 270–73.

astronomical tables *Tabulae motuum coelestium perpetuae* (*Perpetual Tables of Celestial Motions*, 1632) competed for a while with those of Kepler.[233] The issue of the theological acceptability of Copernicus was discussed intensively among Protestants and was even vehemently attacked along with Cartesianism by some theologians, like Gijsbert Voet in the Netherlands, who did not accept a non-literal interpretation of scriptural passages concerning the Sun and the Earth. Yet, the decentralized character of the Protestant churches made the affirmation of a unitary perspective concerning the accommodation of heliocentrism to the Bible impossible. As a result, various opinions could coexist. For instance, the religious *Schwärmer* Abraham von Franckenberg published *Oculus sidereus* (*Sidereal Eye*, 1644), a reappraisal of the Copernican system combined with Brunian infinitism and unorthodox religious ideas inspired by Jacob Böhme. His friend Johannes Hevelius, the famous author of the *Selenographia* (1647), may have shared some of his unconventional religious and natural ideas.

Moreover, Protestant exegesis left theologians considerable freedom. While Copernican books became clandestine in Catholic countries, Copernicus's cosmology was able to circulate and slowly affirm itself in Protestant areas, so that the Inquisition's condemnation soon appeared as a form of obscurantism. A Latin translation of Galileo's *Dialogo* was reprinted by the Elseviers in Leiden as early as 1635, under the title of *Systema cosmicum*, along with Kepler's introduction to *Astronomia nova*, a translation of Foscarini's *Lettera* and an excerpt of Zuñiga's *In Iob commentaria*.[234] It is remarkable that the Catholic censure arrived exactly when the common but essentially independent efforts of Galileo and Kepler were leading to a reinforcement of the Copernican approach among learned scholars. This untimely condemnation shows that the debate in those years no longer concerned the planetary theory in itself, but the relation between natural science and religion in general.[235]

The discussion of Copernicus in seventeenth-century France was then characterized by formal adherence to the Roman censures but developed much more freely. Heliocentrism was discussed and even defended, albeit with some caution. In Paris, Pierre Gassendi, himself a keen supporter of Copernicus's system, and several authors published apologies of the heliocentric planetary model in different forms. In the preface of an incomplete work, *Exercitationes adversus Aristotelicos* (*Exercitations against the Aristotelians*, 1624), he announced that he intended to defend terrestrial

233 Vermij, *Calvinist Copernicans* and idem, "Putting the Earth."
234 Cf. Vermij, *Calvinist Copernicans*, 242 and 247.
235 Garin, "Il 'caso' Galileo," 7.

mobility, solar immobility, alongside with Epicurean theses, such as atomism, the existence of void and the plurality of worlds.[236] Among French scholars, Ismael Boulliau first published his pro-Copernican astronomical work *Dissertationis de vero systemate mundi libri IV* (*Four Books Discussing the True System of the World*, Amsterdam, 1639) under the pseudonym of *Philolaus* and only later printed under his own name a huge book entitled *Astronomia Philolaica* (*Philolaic Astronomy*, Paris, 1645). Moreover, Gilles Personne de Roberval issued a book pretending to provide a Latin translation from the Arab of a non-existent work by Aristarchus of Samos, *De mundi systemate, partibus et motibus eiusdem libellus* (*Booklet on the True System of the World, Its Parts and Motion*, Paris, 1644), also reedited by Mersenne in his *Novarum observationum physico-mathematicarum … tomus III* (*Third Volume.… of New Physical-Mathematical Observations*, Paris, 1647).[237]

15 Summary of the Main Lines of the Early Reception of Copernicus

It may be helpful to summarize this overview of the most significant actors, environments and networks of the first reception of Copernicus from 1514 up to circa 1616. Different issues, concerns and interpretations emerged at different stages of this process. As the first stage of this reception one could indicate the self-representation of Copernicus, that is to say, the manner in which he presented himself and his work, and conceived of his astronomical research and achievements. From this perspective, his environment is particularly relevant. Copernicus was part of an Erasmian humanist network with international ties. In particular, Platonizing learned men with interests in mathematics, geography and Oriental studies and acquainted with Plato's *Timaeus* and Cusanus's *Docta ignorantia* were inclined to accept an innovative cosmology with the Earth in motion. This was the case with Schönberg, Widmanstadt and the *sodalitas Basiliensis*. Therefore an early propagation of Copernicus's views was made possible precisely thanks to a network of mainly anti-scholastic humanists. An important center was Basel, where the second and the third editions of Rheticus's *Narratio prima* (1541 and 1566) as well as the second edition of *De revolutionibus* appeared (1566), together with other philosophical works relevant for cosmology such as Calcagnini's *Opera aliquot* (1544) and Cusanus's *Opera* (1565).

236 Wilson, *Epicureanism*, 25.

237 On Mersenne's attitude toward the Copernican system, see Hine, "Mersenne and Copernicanism."

Thanks to Rheticus, Reinhold and their followers, *De revolutionibus* circulated through the Lutheran universities linked to Wittenberg. As a consequence of natural as well as alleged theological inconsistencies in Copernicus's theory, Protestant mathematicians focused primarily on the technical aspects and the computational part of Copernicus's work. I shall refer to this reception phase as mathematical. It was marked by the publication and great diffusion of Reinhold's *Prutenicae tabulae* beyond the German borders, in England, Flanders and later also in France, Italy and Spain. This mainly geometrical and ephemeristic reception of Copernicus's astronomy with the mediation of Reinhold is common not only to the German Reformed Universities, but also to all those who were interested in the predictive part of astronomy for whatever reason. Among these one ought to list geographers, practitioners, physicians and astrologers.

A further stage of the Copernican debate concentrated on cosmological and natural aspects, as well as the physical implications of the motion of the Earth. The debate on such issues is well exemplified by the philosophical dialogues that Bruno published in London in 1584 and 1585 and in the subsequent works he published in the German empire (Wittenberg, Prague, Frankfurt on Main). His infinitist cosmology became only one of many different natural and planetary approaches, albeit a particularly relevant one, among which I have mentioned those of Brahe, Ursus, Rothmann and Pegel. Different planetary systems (variants of the geo-heliocentric and the Capellan models) and various theories on space and celestial matter proliferated at this stage. As to the reassessment of terrestrial physics, Benedetti deserves particular mention, as the connection between Copernicanism and mathematical studies on mechanics prepared Galileo's work.

In the years between the end of the sixteenth century and the beginning of the seventeenth, Kepler's and Galileo's parallel efforts made the Copernican planetary system more acceptable as they demonstrated the untenability of the Ptolemaic system (this was in particular the result of Galileo's telescopic observations) and began to develop a post-Copernican celestial and terrestrial mathematical physics. One can thus consider the publication of Kepler's *Astronomia nova* in 1609 and Galileo's *Sidereus nuncius* in the subsequent year as a watershed in the history of astronomy, as they opened new research perspectives that superseded the science of the first readers of Copernicus.

The difficult reconciliation of Copernicus with the Bible became a heated and delicate issue as a collateral effect of the development of the cosmological and physical, that is to say, the affirmation of a realistic reading of Copernicus and of natural philosophies at odds with the ancient geocentric worldview, which seemed in better agreement with the Bible. The censure of the "Pythagorean doctrine" by the Roman Church in 1616 marked a turning point in the reception of Copernicus, because a realistic reading of *De revolutionibus* was prohibited in Catholic countries, as demonstrated by the severity of the condemnation of Galileo in 1633. This produced, on the one hand, the large-scale affirmation of geo-heliocentric systems among Jesuit scholars and, on the other hand, a confessionalization of science. For these reasons, 1616 can be conveniently taken as the closing date of the first reception of Copernicus.

CHAPTER 2

Astronomy at the Crossroads of Mathematics, Natural Philosophy and Epistemology

In the history of Renaissance astronomy, the relation between epistemology and the development of geometric models accounting for celestial motions (the *theorica planetarum*) is an intricate issue, all the more since the development of new planetary models before and after Copernicus cannot be separated completely and clearly from natural and theological concerns. This chapter aims to clarify the different aspects of this problem by focusing, first, on the epistemological background of the mathematical reception of Copernicus, and, second, on the relation between the mathematical side of astronomy and the physical (or "natural philosophical") one.

1 A Split Reception of Copernicus

At the beginning of the last century, Pierre Duhem pointed out the epistemological dimension of modern astronomy in a book that has become a classic of the history of science, *ΣΩΖΕΙΝ ΤΑ ΦΑΙΝΟΜΕΝΑ: Essai sur la notion de théorie physique de Platon à Galilée* (*To Save the Phenomena: An Essay on the Idea of Physical Theory from Plato to Galileo*, 1908). There, he claimed that the theoretical concern about the limits and the legitimacy of scientific theories originated from a millenarian tension between a physical (or natural philosophical) approach to astronomy, on the one hand, and a mathematical one, on the other. However, some prejudices distorted Duhem's narrative: the assumption that a strong conventionalism was the only viable epistemology,[1] a militant ecclesiastical Catholicism[2] as well as a certain French chauvinism.[3] Nonetheless, his

1 Duhem, *To Save*, 117: "Despite Kepler and Galileo, we believe today, with Osiander and Bellarmine, that hypotheses of physics are mere mathematical contrivances devised for the purpose of saving the phaenomena." On the shortcomings of Duhem's narrative, cf. Clavelin, *Galilée*, 63–68 and Kokowski, *Copernicus's Originality*, 211–17.

2 Ibid., 100: "Kepler was a Protestant, *but* deeply religious" (emphasis is ours); and 113: "The physicists of our day [...] have been compelled to acknowledge and proclaim that logic sides with Osiander, Bellarmine, and Urban VIII, not with Kepler and Galileo."

3 Ibid., 60: "Between 1300 and 1500 the University of Paris taught a doctrine of physical method which far surpassed in truth and profundity all that was going to be said on this subject until the middle of the nineteenth century."

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essays had the merit of underscoring the intermediary position of astronomy among mathematics, natural philosophy and epistemology. He extensively discussed the conceptions of Copernicus, as well as those of his immediate forerunners and of his followers. In spite of the fact that Copernicus was no conventionalist, Duhem claimed that his German followers, thanks to Osiander's anonymous preface, were led to a "correct" approach to science: "Astronomical hypotheses are simply devices for saving the phenomena; provided they serve this end, they need not be true nor even likely."[4] Duhem asserted that conventionalism was especially well received at Wittenberg: "The view on hypotheses professed by the Wittenberg astronomers [Reinhold and Peucer] in the middle of the sixteenth century appears to us quite homogeneous; they all supported the doctrine of Osiander formulated in his celebrated preface. The testimony of Melanchthon will show us presently that at this university the theologians thought exactly as astronomers."[5] By contrast, Copernicus and Rheticus were "victims" of the "realist prejudice," since they believed that "a good astronomical system [...is] built on hypotheses that have their foundation [*qui ont leur fondement*] in the very nature of things."[6] The same approach was followed "illogically" by Bruno, Galileo and Kepler, in spite of the recommendations of "enlightened" epistemologists like Osiander, Urban VIII and Bellarmino.

Since Duhem, the network of German scholars has always played an important role in the narrative of Renaissance astronomy in general, and of Copernicus's reception in particular. Lynn Thorndike designated that academic network "the circle of Melanchthon" in the fifth volume of his monumental *History of Magic and Experimental Science* (1941).[7] As a matter of fact, the contribution to Renaissance astronomy by Wittenberg professors of mathematics was momentous in spite of their different characters and conceptions of astronomy. Protestant mathematicians benefited from the anti-Scholastic culture promoted by Luther and Melanchthon, which permitted them to diverge from the medieval tradition of philosophy. Melanchthon advocated a restoration of Aristotle's thought in its pure form where this was necessary for teaching, especially of the *physica*.[8]

Several classic textbooks were reissued under the auspices of Melanchthon, who embellished them with eloquent introductions, as was the case with Euclid and Sacrobosco. The introduction to Sacrobosco's *Sphaera* was a letter to Simon Grynaeus (Wittenberg, August 1531) stressing the pedagogical value

4 Ibid., 92.

5 Ibid., 77–78.

6 Ibid., 65 (translation revised). Cf. Duhem, *ΣΩΖΕΙΝ*, 77.

7 Thorndike, *History of Magic*, vol. 5, 378. Cf. Brosseder, *Im Bann*, 11–17.

8 Kathe, *Wittenberger philosophische Fakultät*, vol. 2, and Moran, "Universe," 4.

of astronomy and the religious significance of the study of this discipline, especially in connection with astrology.[9] Melanchthon also composed an introduction to Sacrobosco's *Computus ecclesiasticus* (Wittenberg, August 1538) on the Christian calendar, in the form of a letter to his friend (*amico suo*) Achilles Pirmin Gasser, himself a friend and correspondent of Copernicus's pupil Rheticus. In this epistle, he ascribed to Rheticus the suggestion to integrate the teaching of the *Sphera* with that of the *Computus*.[10] These textbooks were often bound together with others on related subjects as miscellanea. For instance, the volume 50 MA 17401 of the *Staatsbibliothek zu Berlin* contains Sacrobosco's *Sphaera* and *Computus* with Melanchthon's prefaces, some *Quaestiones novae in libellum de Sphaera* (*New Questions Concerning the Booklet on the Sphere*, 1550), Johannes Honter's *Rudimentorum cosmographicorum … libri III cum tabellis Geographicis elegantissimis* (*Three Books of Cosmographic Elements with Very Elegant Geographic Tables*, 1552), and some other short texts of astronomical relevance, including some *loci communes*, that is, passages on astronomy derived from literary works.[11]

Melanchthon's preface to Peuerbach's *Theoricae novae planetarum* was reissued several times, also in Reinhold's edition. In this preface, a letter to Grynaeus written in 1535, Melanchthon reaffirmed the cultural importance of mathematics, even its relevance for civil order, and the validity of astrology. His support for this discipline culminated with his and Joachim Camerarius's translation of Ptolemy's *Quadripartitum*. Melanchthon highly praised and recommended this book because he firmly believed that its study could bring astrology back to its original purity.[12]

Melanchthon's support for mathematics strengthened the teaching of astronomy in the centers that adhered to his academic reform. Copernicus's astronomy was also able to spread within the network of Lutheran institutions connected to Wittenberg, like Leipzig, Rostock, Frankfurt on Oder, and Helmstedt.[13] Robert Westman reassessed the relevance of Wittenberg scholars and their connection for the reception of Copernicus in an influential essay of 1975, "The Melanchthon Circle, Rheticus and the Wittenberg Interpretation of

9 Sacrobosco, *Libellus de sphaera,* f. A3*r*. Cf. Pantin, "Lettre de Melanchthon."

10 Idem, *De anni ratione*.

11 On Melanchton's introductions to mathematical works and his ties to the mathematicians of his age, see Reich, "Melanchton im Dialog."

12 Ptolemy, *De praedicationibus*, 8. Cf. Caroti, "Melanchthon's Astrology."

13 Cf. Baumgart-Hammerstein, *Beiträge*, and Bauer, *Melanchthon*. See also Omodeo, "German and European Network."

the Copernican Theory."[14] The expression "Wittenberg interpretation" designates a split reception of Copernicus, according to which German astronomers focused on technicalities, heavenly parameters and geometrical modelings, neglecting the cosmological issue. Westman highlighted that this approach permitted certain aspects of Copernicus's work to be deepened, although it did not imply a general acceptance of his daring planetary theory.

Later, Barker and Goldstein questioned the Duhemian claim that astronomers linked to Wittenberg could be regarded as conventionalist. In fact, the general disaffection toward the heliocentric system by those mathematicians did not stem from any lack of interest in the real structure of the world or in physical issues related to astronomy.[15] Actually, the Wittenberg reception is characterized by an emphasis on certain features of Copernicus's theory that are not merely computational, for instance geometrical models deseigned in accordance with the astronomical principle, or *axioma astronomicum*, that planetary motions shall be uniformly circular about their centers or, rather, result from the composition of circular uniform motions. The request for such modeling was essentially natural philosophical. Even though Copernicus was not consistent with his own claims and did not banish Ptolemy's equant from the entire planetary theory due to computational constraints,[16] his epicyclic models, accounting for planetary motions with an approximation reasonably close to that of the *Almagest*, opened up the possibility of replacing the equant theory, at least in principle.[17] Additionally, many German mathematicians shared the conviction that Copernicus's devices could be transferred to a physically acceptable geocentric framework. As we shall see, their attempts to elaborate a geocentric translation were not in themselves a mere utilitarian intention to "save the phenomena."[18] Rather, the efforts to receive *De revolutionibus* without renouncing geocentrism might be regarded as revealing a group of "geocentric and geostatic realists."[19]

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14 Although in his most recent volume on the "Copernican Question" astrology is presented as the *fil rouge* traversing Renaissance astronomy in its entirety, prognostication did not yet play a central interpretative role in the 1975 essay.

15 Barker-Goldstein, "Realism." For a criticism of Duhem's interpretation of ancient astronomy, see Lloyd, "Saving the Appearances."

16 Swerdlow-Neugebauer, *Mathematical Astronomy*, 289 ff. and Savoie, "Diffusion."

17 Cf. Gingerich, *Book*, 263–65, app. 1, "From Equant to Epicyclet."

18 Westman, "Melanchthon Circle," 167. See also idem, *Copernican Question*, 160–64.

19 Barker-Goldstein, in "Realism," 253, call them "perpetually frustated realists."

2 Copernicus Presents Himself as a Mathematician

The epistemological question about the status of astronomy during the Renaissance was, at least initially, the problem of defining the boundaries between different disciplines. In Copernicus's time, Ptolemy was the main source of mathematical astronomy, while Aristotle constituted the basis for natural philosophy, especially in the university curricula. This separation presupposed a hierarchy of knowledge according to which the mathematical treatment had a lower status and always had to be traced back to its physical foundations. The tension between the Ptolemaic and the Aristotelian approach, however, led to frictions between philosophers and mathematicians who were not willing to restrict their practice to computation, regardless of physical reality.[20]

When Copernicus stated his disciplinary affiliation, he declared himself a mathematician, that is, a follower of Ptolemy in the technical tradition of astronomy, to which his immediate forerunners Peuerbach and Regiomontanus belonged as well. Rheticus stressed this legacy in the conclusion of the *Narratio prima*: "For him [Copernicus] there is nothing better or more important than walking in the footsteps of Ptolemy."[21] This assertion shall not be regarded as merely rhetorical, considering that Copernicus's adherence to the model of the *Almagest* is mirrored even by the inner structure of the *De revolutionibus*, which closely followed the Ptolemaic example. Copernicus was also explicit about his intended readership: in the prefatory epistle to Pope Paul III, he claimed that mathematical books, like his own, were written exclusively for mathematicians (*mathemata mathematicis scribuntur*).[22] This means that his theories were directed to learned mathematicians or, at least, to scholars adequately trained in this field. There is no doubt, furthermore, that the disciplinary distinction between mathematics and physics strongly influenced the reception of his work. In actual fact, mathematicians were his principal early readers, estimators and disseminators—especially in Germany, where the study of mathematical astronomy and related disciplines flourished (e.g. the so-called *cosmographia*).

It should be further remarked that Copernicus's planetary model questioned the separation between mathematical and physical astronomy and the subordination of the first to the second. Ptolemy, in the first book of the *Almagest*,

20 Cf. Barker, "Reality of Peurbach's Orbs."

21 Rosen, *Three Copernican Treatises*, 186.

22 GA II, 6. Rosen restricts the meaning of this expression in his translation of Copernicus, *Revolutions*, 5: "Astronomy is written for astronomers."

had already affirmed the superiority of mathematics over the other two speculative disciplines, theology and physics, due to the reliability and certitude of mathematical demonstrations:[23]

> The first two divisions of theoretical philosophy should rather be called guesswork than knowledge, theology because of its completely invisible and ungraspable nature, physics because of the unstable and unclear nature of matter; hence there is no hope that philosophers will ever be agreed about them; and that only mathematics can provide sure and unshakable knowledge to its devotees, provided one approaches it rigorously. For its kind of proof proceeds by indisputable methods, namely arithmetic and geometry.

What is more, Copernicus's "real" model of the world, radically different from the Aristotelian, was elaborated and justified in mathematical terms and was supported by no causal explanation in the Aristotelian sense.[24] Thus, *De revolutionibus* elicited further reflections on the epistemological status of astronomy and its "hypotheses." No reader of Copernicus could avoid facing this issue.

3 Cosmology and Mathematics in Copernicus's *Commentariolus*

According to Copernicus, general planetary hypotheses are a bridge between mathematics and physics. This was the claim in the brief historical introduction to the *Commentariolus*. There, he presented heliocentrism as a satisfactory answer to the theoretical tension between the Aristotelian and Ptolemaic conceptions of the heavens. Astronomers, he wrote, always tried to explain planetary motions as the product of uniform circular motions:[25]

> I understand that our predecessors assumed a large number of celestial spheres principally in order to account for the apparent motion of the planets through uniform motion, for it seemed highly unreasonable that a heavenly body should not always move uniformly in a perfectly circular figure.

23 Ptolemy, *Almagest*, 36.

24 This aspect is treated extensively by De Pace, *Copernico e la fondazione*.

25 Swerdlow, "Derivation," 433.

In *De coelo*, Aristotle highlighted the antiquity of the basic cosmological principles of the circularity and eternity of the celestial motions (II,1), their spherical figure (II,4), and their simplicity and uniformity (II,5–6). In the *Hypotyposis* (Ὑποτύποσις τῶν ἀστρονομικῶν ὑποθέσεων, or *Draft of Astronomical Hypotheses*), the neo-Platonic philosopher Proclus (fifth century AD) required astronomers to reduce all heavenly phenomena to regular circular motions in spite of the apparent irregularities.[26] He even listed those irregularities, for which astronomy should account. Among them, the changing velocity of heavenly bodies (I,11), their retrogradations (I,13), the variation of their perceived dimensions (I,18), and planetary order (I,23). However, contrary to Aristotle, Proclus did not claim that the hidden regularity of heavenly phenomena could be sought in concentric planetary spheres.

Following Aristotle, in *Commentariolus*, Copernicus traced the principle of uniform circularity back to Eudoxus of Cnidus and Callippus of Cyzicus, who, according to ancient reports, sought to reduce all celestial phenomena to the displacements of concentric spheres (*concentrici circuli*). Copernicus maintained that they had to fail for two reasons: the scarce predictive power of their theory, and its disagreement with observation, especially the variation in planetary dimensions and distances, a fact for which concentric spheres could not account.

Copernicus added that other ancient astronomers dismissed the concentric system for an explanation through eccentrics and epicycles (*per eccentricos et epicyclos*). This refers to the Ptolemaic modeling of planetary motions through combinations of "eccentric deferents," primary circles not precisely centered on the Earth, and secondary circles transported by them, called "epicycles." In addition, Ptolemy introduced the "equant." This was a point set symmetrically opposite to the Earth's center on the continuation of the diametrical line connecting the Earth to its eccentricity. According to this model, planets supposedly rotate with uniform angular speed around the equant—excellent representations of Ptolemy's theory can be found in any edition of Peuerbach's *Theoricae planetarum* (see figure 2). Deferents modeled the average period of planetary revolutions, whereas their eccentricity, together with the uniform angular motion about the equant, accounted for the apparent variation in speed over the year. The epicycle, a "second anomaly" to the longitude theories, accounted for retrograde motions resulting—in a Copernican perspective—from the annual revolution of the Earth. Moreover, the fact that the superior and the inferior planets reach the center of their apparent retrograde arcs when

26 Proclus, *Hypotyposis* (I,7–9), 6–7.

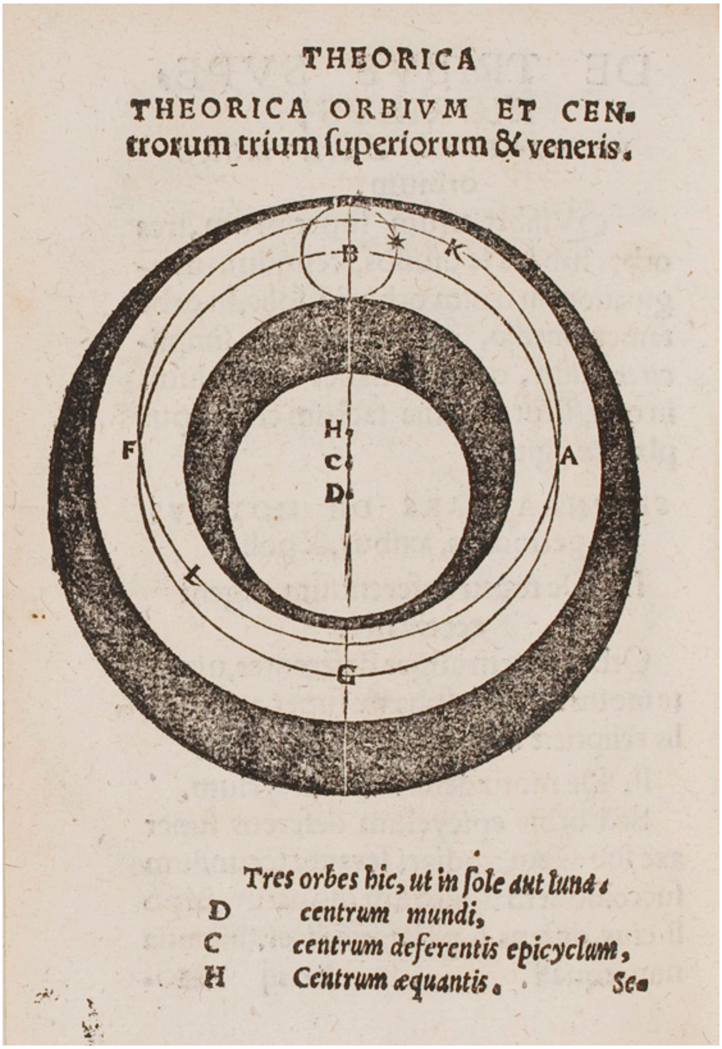

FIGURE 2 *A diagram from an edition of Peurbach's* Theoricae novae planetarum *displaying the main devices of Ptolemaic astronomy (deferent, epicycle, equant point) for the modeling of planetary motions*
COURTESY OF THE HERZOG AUGUST LIBRARY (WOLFENBÜTTEL, GERMANY).

they are in opposition and in conjunction to the Sun, respectively, remained an oddity for Ptolemy's astronomy.

According to the declarations in the *Commentariolus*, Copernicus's investigation was originally stimulated by the dilemma of whether to accept mathematical precision at the expense of the uniformity of celestial motions, or to save this principle at the expense of accuracy and agreement with observation.

"I often pondered—Copernicus declared—whether perhaps a more reasonable model composed of circles could be found from which every apparent irregularity would follow while everything in itself moved uniformly, just as the principle of perfect motion requires."[27] He offered a solution based on seven *petitiones*, which he called also "axioms." These postulated a heliocentric and geokinetic planetary system, as well as an enlargement of the sphere of the fixed stars to account for the absence of stellar parallax or the fact that any horizon always bisects the starry heaven into halves.[28]

Still, Copernicus's planetary theory exhibited clear advantages in terms of intelligibility and simplicity. It permitted to easily account for retrograde planetary motions and to rigorously establish the order and the distances of the planets. In fact, the heliocentric circle of the Earth about the Sun substituted the epicycles producing the retrograde motions of the superior planets and the deferents of the inferior planets.[29] Furthermore, the dimensions of planetary orbs could be determined by considering their periods of revolution and the circle of the Earth about the Sun. In this case Copernicus applied an Aristotelian ordering principle concerning the relation between distances and periods: if planets, as he assumed, have equal linear speed, they can be conveniently ordered within a heliocentric scheme. As Owen Gingerich put it, "what Copernicus had achieved was a linked system in which all the distances were locked into place relative to a common measure, the Earth-Sun distance, which provided the yardstick for the entire system."[30] As a result, the order of the planets, a controversial issue of ancient cosmology, could be established with certainty, by relating planetary periods and distances.[31] Recently, Bernard Goldstein and Anna De Pace, followed by Westman, reasserted the priority of the heliocentric thesis over geometrical modeling. Even though this interpretation does not match Copernicus's own declarations in *Commentariolus*, it is supported in *De revolutionibus* I,10.[32]

27 Ibid., 435–36.

28 For Copernicus's postulates, cf. ibid., 436.

29 For the inferior planets, their circle about the mean Sun replaced a Ptolemic epicycle: cf. Swerdlow-Neugebauer, *Mathematical astronomy*, chap. 5,4, 369ff. Cf. Swerdlow, "Kuhn's First Scientific Revolution," 106–11.

30 Gingerich, *Book*, 54. See also idem, "Crisis."

31 According to De Pace, *Copernico e la fondazione*, Copernicus's *argumentum magnum* in favor of his system was that "of symmetry," derived from the relation between planetary distances and periods.

32 Goldstein, "Copernicus and the Origin." Cf. De Pace, *Copernico e la fondazione*, and Westman, *Copernican Question*, 55–61.

Copernicus's claim that he could bring astronomy back to circular regularity thanks to his heliocentric arrangement, however, is rather puzzling. In fact, the heliocentric scheme accounts essentially for the retrograde motions of the planets, but not for circular uniformity. Therefore, historians of science, in search of the source of Copernicus's conception, the origins of his planetary models and the development of his theory, debated at length whether there is a necessary relation between the heliocentric model and the principle of uniform circular motion.

Copernicus introduced a combination of two epicycles, a "biepicyclic" or "epicycl-epicyclic" scheme in order to eliminate non-uniform planetary motions. As this solution could also suit a geocentric model, Noel Swerdlow thus concluded that the heliocentric theory "really has nothing to do with the principle of uniform circular motion that started Copernicus's investigations in the first place."[33] According to him, Copernicus developed the heliocentric system independently from the *axioma*, while investigating a replacement model for Ptolemy's second anomaly. Contrary to the claim of *Commentariolus*, Copernicus's solution originated from a reworking of Regiomontanus's *Epytoma* (Book 12), where a geometrical equivalent to Ptolemy's second anomaly is expounded.

Swerdlow's skepticism about the credibility of Copernicus's account of his path of discovery and his motivations has been questioned, among others, by Curtis Wilson. It is possible that Copernicus first adopted the biepicyclic model to replace the equant and then found it convenient to substitute the epicycles of the second anomaly with the terrestrial orbit around the Sun. In fact, the straightforward substitution of the equant with a double epicycle would have led to an extremely cumbersome mechanism.[34] Copernicus might have opted for the heliocentric model for its intrinsic simplicity. Hence, the principle of uniform circular motion, together with the belief in the harmonic structure of the world, really could have guided him toward the heliocentric hypothesis, albeit indirectly.

To sum up this scholarly controversy, respect for the *axioma astronomicum* has either no relation (Swerdlow) or only an indirect relation (Wilson) to the heliocentric scheme. Although Wilson's learned reconstruction might be right,

33 Swerdlow, "Derivation," 425.

34 Wilson "Rheticus," 32–34, in particular 34: "Whether Copernicus's thought actually followed this exact course must remain a matter of conjecture [. . .] but the conjecture is at least in accord with his explicit insistence that it was the violation of the principle of uniform motion in Ptolemy's use of the equant that 'gave us occasion to consider the mobility of the Earth.' "

the link between the cosmological principle of uniform circular motion and the geokinetic model is, in fact, by no means self-evident. This discussion concerns not only the modern historians of science investigating Copernicus's motivations and path of discovery. In fact, it is very likely that early readers of the *Commentariolus* and of *De revolutionibus*, who were familiar with the physical-astronomical problems raised by Copernicus, had already evaluated the relevance of the axiom on uniform and circular motion and the existence of a relationship between this principle and heliocentrism. One can go even further and assume that the very essence of the "split" Wittenberg reception consisted in separating these two issues: the agreement about the necessity to eliminate the first Ptolemaic anomaly, on the one hand, and the substitution of the second anomaly of superior planets for the annual rotation of the Earth, on the other. Moreover, Copernicus's surprising claim in the *Commentariolus*, that heliocentrism could solve all physical problems, cannot be treated as an exclusively technical problem. Rather, it should be considered against the background of the astronomical and philosophical culture of the Renaissance. In order to clarify all these aspects, it is worthwhile to recount the Averroist debate on the status of astronomy and the reconciliation of mathematical hypotheses and physical assumptions that took place in Italy during the years Copernicus was studying there.

4 A Clash of Authorities: Averroist Criticism of Mathematical Astronomy

The conflict between Ptolemy's mathematical models and Aristotle's cosmology, addressed by Copernicus at the beginning of the *Commentariolus*, was widely debated by fifteenth-century Italian Averroists. According to them, the twelfth-century Iberian philosopher Ibn Rushd (Averroes) pointed out the differences between the two *auctoritates* in his commentaries on Aristotle's *De coelo* and *Metaphysics*. He sided with Aristotle and strongly criticized Ptolemy's mathematical models: "These […] motions supposed by Ptolemy rely on two principles that are inconvenient to natural science, that is to say eccentrics and epicycles, both of which are false."[35] According to Aristotle, in fact, the circular uniformity of celestial motions should bear evidence to the perfection of the heavens. His cosmological model, derived from predecessors like Callippus and Eudoxus, was a mechanism of concentric spheres centered on the Earth. The stars were attached to the outermost sphere and transported around the

35 Averroes, *Commentum Magnum* (II 62,54–57), 394. Cf. Shank, *Mechanical Thinking*.

poles of the world. The highest sphere, said *primum mobile* (first movable), communicated the daily motion to all spheres underneath: to the "oblique circle" of the ecliptic and the zodiac, and to a series of material spheres on which planets (including the Sun and Moon) were attached.

In some cases, Ibn Rushd corrected Aristotle through Ptolemy, showing a certain independence from his master. For instance, one reads that Ptolemy calculated that the Sun moves faster than Mercury and Venus, even though its sphere is supposed to be higher. This violated the Aristotelian assumption that the outermost planetary spheres have a period of revolution which increases with their distance from the Earth. In the case of Mercury, Venus and the Sun, Ibn Rushd preferred to adjust Aristotle's theory: "It is not inconvenient that the motion of the Sun is faster than the motion of Mercury and Venus, although it is higher, because the abundance of its power is greater than their power."[36] Yet, apart from details, Ibn Rushd embraced the Aristotelian outlook and maintained that the philosophical explanation is superior to the mathematical.[37] He thus explicitly declared that it was necessary to develop a new astronomy departing from the models of the *Almagest*.[38]

His criticism of mathematical astronomy was adopted by Alessandro Achillini, who was professor of philosophy and medicine at the University of Bologna when Copernicus studied there.[39] In 1498, Achillini published *De orbibus* ("On the Orbs"), an outline of cosmology and celestial physics, later included in his *Opera Omnia* (1545). The author denied the existence of eccentrics and epicycles in the section entitled "Utrum eccentrici et epicicli sint ponendi" ("Whether Eccentrics and Epicyles Should be Posited"). He derived his cosmological views from Aristotle, to whom he referred simply as "philosophus," and from Ibn Rushd. Assumptions like "the center of the world is one" (*unum est centrum mundi*) and "the skies are not perforated" (*caeli non sunt perforati*, in the sense that they cannot be perforated by an epicycle), were irreconcilable with the existence of Ptolemy's devices. Commenting on a diagram displaying an eccentric orb tangent to a concentric sphere from the inside (see figure 3),[40] Achillini remarked that the motion of the eccentric would be

36 Ibid. (II 58,85–87), 385.

37 Ptolemy discussed physical aspects of planetary theory in a treatise, *Planetary Hypotheses*, which was not received in Europe and circulated only in the Islamic world. Cf. Goldstein, "Arabic Version," and Lerner, *Monde*, vol. 1, 70–81.

38 Averroes, *Aristotelis Stagiritae Opera*, f. 329*v* (*Comm. Metaph.* XII 45). Cf. Kren, "Homocentric Astronomy."

39 Nardi, "Achillini," Lohr, *Latin Aristotle*, 5–6, Goddu, *Copernicus*, chap. 7,7, "Achillini."

40 Ibid., f. 29*r*.


ficiei alicuius eēt punctum exterioris superficiei corporis. ¶ Corollarium corpora quæ mathematici uocāt epiciclos sub excentrici significatione comprehe[n]duntur, siue conuaua ponantur, siue non. ad propositum tam[en] n[on] st quod intra superficiem excentrici simpliciter & secu[n]dum quid tam concauam q̄ conuexam centrum mundi contineri, siue in medio earum uel alterius, siue non, & tunc excluditur epiciclus. ¶ Mathematicorū tamen imaginatiōi propinquius accedēdo in plana sup̄ficie proijciantur, dato pūcto a. ī plana superficie circa ipsum describantur duo circuli, unus maior altero, ipsis undiq; æq̄liter distantibus, parallelli.n.sunt. sit maior.e.f.g. tunc erit linea continuans.e.b. diameter comprehendens spisitudinem sphæræ cuius circulus sit b.h.e.i. Distantia enim circulorum nobis spisitudinem sphæræ indicabit. & si a.sit cētrum mundi, tunc designatum corpus concentricum est. Si autem a.non sit centrum mundi, tunc corpus designatum est excentricū simpliciter, et cū corporibus cælestibus excentricum simpliciter applicatur, à mathematicis noīatur deferēs su. corpus planetæ. Circulus aūt b.h.e.i. corp̄ibus cælestibus applicatus designat epiciclū. ¶ Quod si ītra circulum b.c.d. describimus circulū cō tingentē circulū b.c.d. in puncto exempli gratia b. claudē tē tamē in se a. centrum, tūc indicabit nobis excentricum secundum quid. Et talium excentricorum secundum quid ponunt unum extra deferens, aliud uero intra. & semper grossior pars unius directe supponitur uel supponitur tenuiori parti alterius, & per ista tanq̄ p̄ simpliciores hypotheses apparētias cælestes saluant, sine uacuo, penetratione corporum, rarefactione & condensatione, diuisione, & absq; corpore replēte uacuum. ¶ Contra quos ponitur hæc con

FIGURE 3 *Achillini's sketchy images of Ptolemaic astronomical models in* De orbibus, *first published in Bologna, in 1498*

COURTESY OF THE DIBNER LIBRARY OF THE HISTORY OF SCIENCE AND TECHNOLOGY AT THE SMITHSONIAN INSTITUTION LIBRARIES (WASHINGTON, DC, USA).

possible only if there was *vacuum* in the concentric structure of the world but, since nature abhors void, Ptolemy's astronomy was untenable. His conclusion was that mathematicians founded astronomy on uncertain principles.[41]

Achillini demanded a strictly concentric model for planetary motions. He argued that the *terra* (earth) as the gravitational center of the earthly element and the cosmological center, which is the *Terra* (Earth) as the globe at the center of the world, can be distinguished only from a logical point of view, but not in reality. The necessity to combine physical and mathematical astronomy meant, from an Aristotelian perspective, that the latter approach should be subordinated to the former. Theology was not excluded from Achillini's treatment. The central books of *De orbibus* (II and III) addressed such issues as God's intelligence and the rationality underlying the worldly order. He raised a series of questions (*dubia*) concerning God and superior intelligences which he deemed to be relevant for astronomy, for instance "God is unbegotten and incorruptible" (*Deus est ingenerabilis et incorruptibilis*), "God cannot be augmented nor diminished" (*Deus non est augmentabilis neque diminuibilis*), "Interposed intelligences are unbegotten and incorruptible" (*Intelligentiae mediae sunt ingenerabiles et incorruptibiles*) and so on. It is thus evident that for Achillini the question about the status of astronomical explanations was essentially a matter of establishing the hierarchy of different disciplines: mathematics, physics and even theology.

5 Fracastoro's Homocentrism

At the beginning of the sixteenth century, some scholars from the School of Padua tried to reconcile planetary geometries and physical reality in the spirit of Aristotle (and perhaps of Achillini).[42] The physician and philosopher Girolamo Fracastoro of Verona wrote a treatise on this issue, *Homocentrica sive de stellis* (*Homocentrics or on the Stars*), which began circulating in the 1530s and was eventually published in Venice in 1538. Fracastoro is known as a universal Renaissance mind, who wrote on a great number of different subjects ranging from medicine to mathematics, astronomy, physics, geography and botany. He was also appreciated as a poet, author of the *Syphilis sive de morbo gallico* (*Syphilis, or French Deasease*, 1530).

41 Ibid.

42 On the School of Padua: Randall, *School of Padua*, Nardi, *Saggi*, Olivieri, *Aristotelismo veneto* and Poppi, *Introduzione all'aristotelismo*.

His *Homocentrica* was an attempt to reintroduce the concentric spheres of Eudoxus and Callippus.[43] In fact, the author modeled planetary geometries in accordance with widely accepted natural principles derived from Aristotle. Copernicus probably knew him, since Fracastoro was professor of logic at Padua when he was a student there. The *Homocentrica* was not an isolated publication, as it appeared almost simultaneously with other two books propounding a revival of homocentric cosmology: al-Bitruji's *Planetarum theorica phisicis* [*sic.*] *rationibus probata* (*Planetary Theory Physically Demonstrated*, Venice, 1531) and Giovan Battista Amico's *De Motibus corporum coelestium iuxta principia peripatetica, sine eccentricis et epicyclis* (*The Motions of Celestial Bodies in Accordance with the Peripatetic Principles, without Eccentrics and Epicycles*, Venice, 1536 and Paris, 1549).

It should be recounted that al-Bitruji (known as "*Alpetragius*" in Latin), was a Spanish contemporary of Ibn Rushd who tried to correct Ptolemy by bringing astronomy back to an Aristotelian physics, that is, to construct a planetary system of concentric spheres in agreement with the phenomena. He thus dismissed eccentrics and epicycles, worked out the details of his planetary model and asserted the superiority of natural philosophy over mathematical astronomy. His book on heavenly motions, also known in the Middle Ages as *De motibus caelorum* (*The Motions of the Heavens*) in Michael Scot's translation, had a great impact in Europe.[44] Like Kepler many centuries later, but from a very different perspective, he claimed that his conception unveiled the cosmographic mystery of creation:[45]

> I remained for long time dubious [about Ptolemy's geometrical models] and I refused to go on reading the book [*Almagest*] until God gave me the grace of an inspiration coming from Him—since it could not but come from Him. He woke me from my torpor and freed me from deviation, so that I discovered that which, in my assessment, did not occur to the mind of anybody dealing with this issue [...]. In fact, God decided to reveal His miracle and uncover the astronomical mystery of His heavens [only to me]. At that point, I was revealed the truth about His astronomy and the holiness of the quantities of its motions, which I shall expose in the following. I will explain the apparent irregularities and their causes,

43 For the first dissemination of Fracastoro's cosmology in manuscript form, see Di Bono, *Sfere*, 70.

44 Cf. Carmody's introduction to al-Bitruji, *De motibus*. For the historical context of medieval homocentric astronomy, see Panti, *Moti*.

45 Al-Bitruji, *De motibus*, 77–78.

> although [this means that] I will claim that Ptolemy did not describe things as they are in actual fact.

In *Homocentrica*, Fracastoro followed in this Arabic predecessor's footsteps. He considered astronomy to be a "mixed discipline," since it is in part mathematical and in part physical.[46] It derived from mathematics its demonstrative rigor: "As it relies on mathematics, it develops from very certain [principles] for the most part."[47] On the other hand, it should include nothing in disagreement with the principles of natural philosophy. In other words, it should be based on Aristotelian physics. Perfect circular motion, Fracastoro wrote, is a sign of divine wisdom. Hence, it is an indispensable principle, as one reads in the dedicatory letter to Pope Paul III:[48]

> You are aware that all professional astronomers always had great difficulties to provide the causes of heavenly phenomena. In fact, there were two ways of explanation, one through the so-called homocentric orbs, and the other through the so-called eccentrics, but both presented specific difficulties and obstacles. In fact, one could not account for the appearances by employing the homocentric spheres. On the other hand, even if eccentrics seemed to provide better demonstrations, nonetheless they treated those divine bodies in an unjust and quite impious way, by assigning them a place and a figure that are not fit at all to the heavens. For these reasons, we admit the shortcomings of Eudoxus, among the ancients, and also Callippus, as they sought a homocentric explanation. By contrast, Hipparchus was one of the first who preferred to assume the eccentric orbs [...], and was followed by Ptolemy of Philea and, after him, by almost everybody.

Since nature does not admit eccentrics and epicycles, these devices should be banished from the science of the heavens: "No philosopher could be found so far who dared to pose monstrous spheres amid those divine and most perfect [celestial] bodies."[49] Fracastoro reassessed the opposition between philosophy and astronomy or, more accurately, between Peripatetic physics and Ptolemaic astronomy. Repeating a well-known *topos* that can also be found in Copernicus's *Commentariolus*, he mentioned Callippus as the opponent of

46 Fracastoro, *Homocentrica*, f. 3*v*.

47 Ibid., f. 3*r*.

48 Ibid., ff. 1*r*–*v*.

49 Ibid., f. 1*v*.

Ptolemy, and pitted Aristotelian philosophers against idle *ratiocinatores*, or calculators.

Fracastoro's system consists of 79 spheres. According to him, stars do not move autonomously or freely in space. Rather, they are transported by spheres moved by one motion each. He supposed that superior ones communicate their virtue to the inferior ones, but are not affected by the motion of those below. A homocentric explanation should even account for the back and forth motion called *trepidation*, accounting for alleged irregularities in the precession of the equinoxes.[50] He explained that daily and annual rotation, precession and *trepidatio*, the motions of the starry heaven called *Aplane* sphere, are produced by the interplay of five spheres arranged so as to account for all appearances.

6 Amico on Celestial Motions

Amico's *De motibus corporum coelestium* (*On the Motions of Heavenly Bodies*) also aimed to dispel the conflict between *astrologi* and *philosophi*. Amico, too, sought a physical astronomy: "Not one of so many philosophers has so far put forward principles capable of explaining all those [celestial] phenomena [*effectus*] by means of homocentric orbs."[51] According to him, the quintessence material out of which the heavens are made only allows simple motions: perfectly circular displacements around a unique cosmic center. Thus, he was forced to substitute the "principle of economy," according to which celestial orbs should be reduced to a minimum number, with a sort of "natural principle," according to which astronomical theories should be above all compatible with natural philosophy:[52]

> That what astronomers say against natural philosophers is nothing; in fact, they claim that one shall not multiply the spheres [*orbes*], if one can explain all heavenly phenomena [*ea omnia … quae circa sydera apparent*] through a lesser number of spheres. On the contrary, one should rather multiply the spheres, instead of introducing spheres that nature by no means admits.

50 Di Bono, "Copernicus, Amico, Fracastoro."

51 Amico, *De motibus*, 134.

52 Ibid., 149.

His motto was: "Trace the phenomena back to their causes" (*Conspecta ad proprias causas referenda sunt*). Science shall begin with a clarification of its philosophical principles (*Primo autem praemittit supposita, mox rem ipsam aggreditur*).[53]

Amico's main assumptions concerning the interactions of the celestial spheres are similar to Fracastoro's. In chapter seven of his treatise, Amico stated that all spheres have only one motion around their axis, which they communicate to the inferior ones. Changes in the velocity of a sphere as well as planets' retrogradations should be described as the effect of a back-and-forth motion communicated by a superior sphere. Like Fracastoro, he even presented a homocentric model accounting for the *trepidatio*.[54]

Since Ptolemy's epicycles conveniently accounted for the changing brightness and dimensions of planets (consequences of their varying distances), Amico and Fracastoro could not avoid this issue and had to provide a homocentric explanation for these phenomena. In *Commentariolus*, Copernicus saw the homocentric solution as insufficient precisely because he deemed it incapable of accounting for the variation in the planets' apparent dimensions, whereas heliocentrism made the reasons intelligible. Italian homocentrists proposed, as an *ad hoc* solution, the presence of an inhomogeneous medium between the Earth and the celestial bodies, producing changes in their appearances. Fracastoro, for instance, surmised the existence of a material sphere of inhomogeneous density beneath the Moon as the cause of its varying dimensions and of the different durations of eclipses. Amico proposed a similar thesis to explain the variation in the dimensions of the solar disc.[55]

As a student at Padua and a learned scholar, Copernicus should have been well informed about the Averroist criticism of Ptolemaic models. The publication of the theories of Amico and, above all, of Fracastoro provided examples of the application of the homocentric principle to mathematical astronomy. As a consequence, the discussion on the concentricity of celestial spheres did not remain restricted to the Aristotelian and Averroistic exegesis accomplished by natural philosophers such as Achillini. Rather, it became relevant for mathematicians as well. Accordingly, Copernicus's perspective shifted from a rather "historical, diachronic" treatment of homocentric astronomy in the *Commentariolus* to a "systematic, synchronic one" in *De revolutionibus*. In this later work, he was forced to acknowledge that homocentrism still had

53 Ibid., 139.

54 For the mechanism of reciprocation producing these effects see Di Bono, ibid., 81–82 and 113–15.

55 Amico, *De motibus*, 172–75.

the dignity of a theoretical alternative in the astronomical and mathematical debates of his age. Copernicus's acquaintance with the works of his Paduan contemporaries is witnessed in particular by the substitution of the expression *circuli concentrici* (used in *Commentariolus*) for *circuli homocentri* (in *De revolutionibus*) following Amico's and Fracastoro's terminology.[56]

Copernicus mentioned al-Bitruji and Ibn Rushd in *De revolutionibus* I,10 concerning the order of the planets.[57] Additionally, Rheticus celebrated his master's achievement with reference to the Aristotelian and Averroist debate on the heavens. He even repeated the claim of the *Commentariolus* that Copernicus's theory had successfully overcome the breach between mathematical and physical astronomy.[58]

> You [Schöner] are not unacquainted with the importance to astronomers of hypotheses or theories, and with the difference between a mathematician and a physicist. Hence you agree, I feel, that the results to which the observations and the evidence of the heavens itself lead us again and again must be accepted, and that every difficulty must be faced and overcome with God as our guide and mathematics and tireless study as our companions. Accordingly, anyone who declares that he must be mindful of the highest and principal end of astronomy will be grateful with us to my teacher and will consider as applicable to himself Aristotle's remark: "When anyone shall succeed in finding proofs of greater precision, gratitude will be due to him for the discovery." The examples of Callippus and Aristotle assure us that, in the effort to ascertain the causes of the phenomena, astronomy must be revised as unequal motions of the heavenly bodies are encountered. Hence I may hope that Ibn Rushd, who played the role of the severe Aristarchus to Ptolemy, would not receive the hypotheses of my teacher harshly, if only he would examine natural philosophy patiently.

Given the intensity of the Averroist debate of those years, this mention of Callippus, Aristotle, and Ibn Rushd referred not only to the "astronomical axiom" of uniform circular motion, but to a wider set of philosophical problems. The issue at stake was the reconciliation of astronomy and physics. According to Rheticus and his master Copernicus, mathematical and geometrical demonstrations should precede physics. As I shall discuss in more detail in chapter

56 Granada-Tessicini, "Copernicus and Fracastoro," 449.

57 GA II, 17–8. However, the references are possibly indirect.

58 Rosen, *Three Copernican Treatises,* 140–41. Cf. Rheticus, *Narratio* in GA VIII/1, 21.

five, Copernicus's challenge was to accord physics to astronomy and not *vice versa*. As far as epistemological issues were concerned, for him, as well as for al-Bitruji, Fracastoro and Amico, it was a problem of principles and of disciplinary hierarchy: the rejection or the reaffirmation of the preeminence of physics over mathematics, and the choice between a mathematical approach to nature and a causal one.

7 Osiander's Theological Instructions

Copernicus's requirement to respect the *axioma astronomicum* encountered a broad consensus on the part of his early readers familiar with the natural and epistemological problems it entailed.[59] Before tackling the theoretical concerns of German mathematicians belonging to the so-called Wittenberg connection, I shall consider Osiander, for the epistemological importance allotted to his opinions by historians of science after Duhem. The point of view of this Lutheran theologian emerged even before the publication of *De revolutionibus*. In a letter to Rheticus written on 13 March 1540, he praised Copernicus's emendation of astronomy, saying that it would bring back to light the wisdom of ancient Egypt.[60] He even asked Rheticus to introduce him to his master: "Again and again I ask you that, in the same manner in which you offer to me your friendship, you make the effort to win for me the friendship of that man [Copernicus]."[61] It seems that only later, perhaps after reading the *Narratio prima*, was Osiander informed about the new hypotheses and conceived some reservations. In 1541, in fact, he warned Copernicus and his pupil to be careful and to adhere to a certain conventionalism concerning hypotheses, in order to avoid the criticism of Scholastic Aristotelians and Biblical exegetes.[62]

In the anonymous preface to the reader of *De revolutionibus*, Osiander clarified that the task of astronomy is to "devise hypotheses" (*confingere hypotheses*) and "correctly calculate" (*recte calculari*).[63] He explained that natural knowledge begins with accurate records of astronomical data. Astronomers choose

59 Cf. Gingerich, *Annotated Census*, 269.

60 Osiander to Rheticus (Nuremberg, 13 March 1540), in Osiander, *Gesamtausgabe*, vol. 7, 278–80.

61 Ibid., 280.

62 Cf. ibid., Osiander to Copernicus (Nuremberg, 20 April 1541), 333–36, and to Rheticus (Nuremberg, 20 April 1541), 337–38.

63 Copernicus, *Revolutions*, XVI. Cf. Osiander, *Gesamtausgabe*, vol. 7, 556–68, "Vorrede zu Copernicus, *De revolutionibus*."

hypotheses depending on the advantages they offer to computation. Economy is the only criterion in this choice, because the real principles of nature are unattainable to men. Hence, according to him, astronomy follows solely utilitarian and computational criteria.[64]

> For it is the duty of an astronomer to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain the true causes, he will adopt whatever suppositions enable the motions to be computed correctly from the principles of geometry for the future as well as for the past.

Correspondence to reality, or even plausibility, does not matter to astronomers dealing with hypotheses. They should value only the accurate computation of heavenly motions, whereas philosophers strive for likelihood. Truth itself can only be revealed: "Neither of them [the astronomer and the philosopher] will understand or state anything certain, unless it has been divinely revealed to him."[65]

Osiander establishes a hierarchy of the different approaches to truth. Faith has primacy over both mathematical astronomy and philosophy (or physics). Mathematics is the lowest level of knowledge, since it is limited to usefulness; philosophy is superior, because it aims at reasonableness and likelihood; theology, based on revelation, is sovereign over all paths to knowledge. It should be noted that Duhem was not right to treat this view as conventionalist in the twentieth-century sense of the term. Osiander, in fact, assumed that truth is essentially a theological matter and, as a theologian, he endorsed no conventionalist perspective at all. His attitude toward astronomy was more skeptical than conventionalist, aiming at the preservation of theological and metaphysical truths deemed to be superior to those gained through natural knowledge. Therefore, his introduction to *De revolutionibus* can be read as instructions for theologians on how to deal with Copernicus's planetary system (and to neglect it)—and maybe also to astronomers, on how to avoid conflicts with natural philosophers and theologians.

It should be further remarked that it is unlikely that Osiander, as an editor of *De revolutionibus*, intended to discredit the book. He rather tried to protect it from criticism through a sharp distinction between the fields of competence of theologians, philosophers and mathematicians. As far as Copernicus's

64 Ibid.

65 Ibid.

hypotheses are concerned, he asserted that they were as worthy as those of the ancients. They brought together simplicity of explanation and richness of observation. Still, he reassessed his fundamental skepticism: "So far as hypotheses are concerned, let no one expect anything certain from astronomy, which cannot furnish it, lest he accept as the truth ideas conceived for another purpose, and depart from this study a greater fool than when he entered it."[66] This was Osiander's conclusion.

Although his perspective entailed a profound disillusion as to the reliability of science, in actual fact, it offered some advantages to natural investigation: asserting the indifference of mathematical theories to the (theological) truth freed astronomers from theological intrusion. Yet, Osiander's preface was not respectful of Copernicus, who did not conceive of hypotheses as mere surmises, but rather as corresponding to reality. Moreover, Osiander's theological perspective did not give mathematicians any means to better understand their discipline and method, but only a possible strategy to avoid quarrels with colleagues from other fields or clerics. Thus, although Osiander's metaphysical and theological concerns and skepticism on natural issues might have helped German readers of Copernicus to escape conflicts, his epistemology must nonetheless have been regarded as superfluous by mathematicians who adopted Copernican geometrical models in a non-heliocentric framework. In fact, as we have said, a conventionalist epistemology could not serve as the foundation for a program of translating Copernicus into a geocentric model, which, by contrast, presupposes a strong realist understanding of astronomical theory. In other words, in a context in which the centrality of the Earth was not abandoned, Osiander's methodological precaution—to "use" Copernicus but not to consider heliocentric hypotheses as "true"—was pointless, since no traditional natural or theological convictions were under threat. We shall therefore abandon the Duhemian myth of the importance of Osiander's conventionalism for the simple reason that he was no conventionalist, but rather a fideist skeptic, and, second, because his indications were of no use to mathematicians testing geocentric translations of Copernicus.

8 Melanchthon's Approach to Nature

Rather than to Osiander's concerns, we shall better look to Philip Melanchthon's conception of astronomy and nature, since this learned humanist and theologian had a greater and more enduring influence on German culture. As I will

66 Ibid.

argue, their conceptions of astronomy and natural knowledge were very different, if not opposite. Melanchthon's initial condemnation of Copernicus's planetary theory is well known in the history of the reception of Copernicus. In a letter of 1541 to Burchard Mithoff, physician to Philip of Hesse, Melanchthon blamed Copernicus, "that Sarmatian astronomer, who sets the Earth in motion and fixes the Sun" (*ille Sarmaticus Astronomus, qui movet Terram et figit Solem*) and even proposed political measures to wipe out his subversive ideas: "Without question, wise rulers should suppress intellectual immodesty" (*Profecto sapientes gubernatores deberent ingegnorum petulantiam cohercere*).[67] Such an aversion tinged with contempt also emerges from the *Initia doctrinae physicae*, which appeared in 1549 as a textbook of natural philosophy.[68] In this treatise, written together with the natural philosopher Paul Eber, Melanchthon not only rejected the *paradoxon* of Aristarchus of Samos.[69] He even pointed out the conflict of the heliocentric doctrine with the Holy Script and accused Copernicus of presenting a bizarre cosmology only to exhibit his wit. In the manuscript version of the *Initia*, which is preserved in the City Library (*Stadtbibliothek*) of Nuremberg, Melanchthon used even ruder words to reprimand Copernicus.[70] However, in that textbook, Melanchthon reported some observations and calculations from *De revolutionibus* as data of "the most recent astronomers," or as explicitly derived from Copernicus.[71]

Emil Wohlwill hypothesized that the anti-Copernican passages of the *Initia* date back to a period before 1545. Later, Melanchthon's judgment softened.[72] Evidence of this fact are the corrections in the 1550 edition of the *Initia*, where all references to Copernicus's vain ostentation of wit were eliminated. The "absurdas sententias" of 1549 became generic "talia" and the study of Copernicus's "paradoxical" doctrines was no longer prohibited for specialists, but only for young students, the *iuniores*. Thus, in 1550 Melanchthon was more tolerant toward the new astronomy. His main concern was now didactical; Aristarchus's theory should be kept for scholarly discussion and should not be presented to the youth:[73]

67 Melanchthon to Mithobius (16 October 1541).

68 Thüringer, "Eber," and Bauer, *Melanchthon*, 371–76.

69 Cf. Wohlwill, "Melanchthon und Copernicus."

70 See Thüringer, "Eber," especially 316 and 319–320 (transcription from the Nuremberg manuscript).

71 Cf. ibid.

72 Ibid.

73 Melanchthon, *Initia* (1563), f. 31*v*.

> Although subtle practitioners [*artifices*] take into consideration many [different theories] in order to exercise their intellects, nonetheless the youth should know that they [the practicioners] do not dare to affirm such theories. In their first education, [students] shall appreciate theories [*sententias*] transmitted with the shared consensus of the practitioners, which are minimally absurd. If [students] grasp that truth is manifested by God, they will embrace this [truth] with reverence and be satisfied with it.

In accordance with this intention to banish Copernicus's theories from university teaching, Melanchthon expunged all references to *De revolutionibus* and positive remarks on details—e.g. those concerning the theory of Mercury and Venus—from later editions of the *Initia*.

The *Initia* is fundamental to grasping Melanchthon's conception of nature.[74] It also includes important epistemological remarks. It is therefore convenient to consider the relevant sections (we will refer to the later, revised version of the *Initia*) and to assess how Melanchthon's perspective could have affected the reception of Copernicus in a Lutheran environment. In the dedicatory letter from 1549, to Michael Meienburg, he wrote:[75]

> This entire [worldly] theater [that includes] the heavens, luminaries, stars, air, water, earth, plants, animals and other worldly bodies was built with so much art, [it was made] so wonderful in its form [*specie*], figure, harmonious motions, efficacious forces, [and] sympathy, [and] was so well ordered [in its parts] that it is an illustrious witness of God [as its] Creator. And the man was located in this splendid house and was given an insight [*noticia*] of God and virtue, so that, by often watching and rising his eyes to contemplate the order of nature [*rerum ordine*], he could recognize that God exists and His eternal mind—artifice of this entire world [*totius huius operis*]—is wise, good, true, just, charitable, pure, [and] free. [Man could moreover see] that [God] is present in this creation of His, preserves the creation [*res conditas*], its established order and, without question, protects [it]. [God reveals that He] punishes atrocious crimes with atrocious punishments in this life, not only in order to defend the human commonwealth, but also to remind us of Himself. Once we acknowledge that He is just, true, charitable, [and] pure, we

74 See Meinel, "Certa deus."

75 Melanchthon, *Initia*, ff. *2*r*–*v*.

> distinguish Him from unjust, false and obscene natures, and apprehend that we should conform our habits to His will.

Thus, Melanchthon embeds natural science in a theological framework. Nature reveals to the eyes of a contemplating human being the excellence, wisdom, power and benignity of its Creator. It is the manifestation of a providential "law" in which ethics interconnects with natural philosophy, astronomy and medicine.[76]

Although the cultural influence of Aristotelianism had been significantly reduced and completely banished from theology by Luther, according to Melanchthon, Aristotle remained the main source for physics nonetheless. This discipline encompassed all natural knowledge, including mathematics and medicine.[77] Moreover, Aristotelian physics was seen as a bulwark against the impious doctrines of Democritus, the Epicureans, Stoics and Skeptics.[78]

While Osiander separated the certitude of faith from the uncertainty of science, Melanchthon deemed God the judge of the validity of human knowledge: "God wants some arts governing life and even somehow revealing Him to be certain and stable."[79] He discussed this issue in the first book of the *Initia*, entitled "Is there any certainty in physics [*doctrina physica*]?" There, he proposed three criteria (κριτήρια) to judge the reliability of human knowledge: 1. the principles (*principia*) on which it relies, 2. the shareability of the experiences which are at its basis (*universalis experientia*) and 3. its logical consistency (*intellectus consequentiae*).[80] Melanchthon also offered examples of physical certainty, some of which were relevant to Copernican astronomy: the Aristotelian theory of the elements, the deduction of worldly finitude from the daily motion of the stars and the impossibility of vacuum. Here follows the first part of Melanchthon's argumentation:[81]

> Experience manifestly shows that inferior bodies have different qualities and different motions. Fire entails warmth whereas earth and water entail coldness, and these qualities are mutually discordant. The heavens are moved in a circle, whereas the elements in straight lines: light bodies upward and heavy ones downward. The natural philosopher [*physicus*]

76 Cf. Wels, "Melanchthons Anthropologie."

77 Melanchthon, *Initia* (1563), f. *3*r*.

78 Ibid., f. *6*v*.

79 Ibid., f. 6*r*.

80 Ibid.

81 Ibid., f. 6*v*.

> adds to that the principles. For instance, when he wants to demonstrate that the dimensions of the world cannot be sized by our eyes and still it is finite, he begins from this principle: "No infinite body is moved in circle." It is evident that the heavens are moved in a circle in a small time, that is, twenty-four hours. Hence, they are not infinite. The major premise is derived from the principles. An infinite distance cannot be covered in a finite time. In the case of an infinite diameter revolving, it is impossible to get back to the same point. Thus, the following conclusion is true and certain: "The heavens are no infinite body."

These examples and some other certitudes (e.g. "in natura nullum vacuum") should prove that physics is trustworthy; many natural matters are known with certainty, although the knowledge of the world can be only partial. The fact that much is still unknown is a quantitative and not a qualitative limit: "One must acknowledge that many things are certain, even though nature has not been investigated in all its parts."[82]

Melanchthon tackled the heliocentric problem, without mentioning Copernicus, in the chapter entitled "De mundo" (*The World*), in particular in the section "What Is the Motion of the World?" One reads that the world, or rather its outermost celestial sphere, moves in a circle. As already mentioned, Melanchthon noted that some thinkers, in particular Aristarchus of Samos, supported a different point of view. In fact, they believed that the Earth moves:[83]

> Yet, somebody holds that the Earth is moved and denies that the eighth sphere and the Sun are moved, while they attribute motion to the other celestial orbs, since they locate the Earth among the celestial bodies. There is a still extant book by Archimedes, the *Sand Reckoner*, where it is recounted that Aristarchus of Samos proposed this paradox: that the Sun rests and the Earth is carried around the Sun.

This passage is followed by the aforementioned warning to prevent students from learning paradoxical theories and to stick to traditional geocentrism. Melanchthon expanded there on scriptural passages confirming that the Sun moves and the Earth is at rest. Not content with this, he also presented a list of philosophical arguments against terrestrial motion derived from Aristotle.

To sum up, Melanchthon's conception of science was very different from Osiander's. He admitted no skepticism and no separation of natural certainty

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82 Ibid., f. 7*v*.

83 Ibid., f. 31*r*–*v*.

from revealed truth, since theology should underpin all natural investigation. Melanchthon's dislike of heliocentrism, as has often been argued, especially by Westman, may have determined the refusal of most "Wittenberg mathematicians" to abandon geocentrism. Yet, this did not prevent them from studying Copernicus or, in the special case of Rheticus, even from embracing the new planetary hypotheses as the real structure of the planetary system.

9 Rheticus's Early "Realism"

Rheticus is often mentioned as a resolute opponent of Osiander as far as hypotheses are concerned, since he supported a realist acceptance of the heliocentric system and, therefore, no two actors in the Renaissance debate on astronomy are apparently further apart than they. Revelatory of Rheticus's perspective is the way in which he presents the motion of the Earth as conveniently accounting for retrogradations and the varying distances of the planets:[84]

> To Venus and Mercury, however, he [Copernicus] assigns an eccentric on an eccentric. The planets are each year observed as direct, stationary, retrograde, near to and remote from the Earth, etc. These phenomena, besides being ascribed to the planets, can be explained, as my teacher shows, by a regular motion of the spherical Earth; that is, by having the Sun occupy the center of the universe, while the Earth revolves instead of the Sun on the eccentric, which it has pleased him to name the great circle. Indeed, there is something divine in the circumstance that a sure understanding of celestial phenomena must depend on the regular and uniform motions of the terrestrial globe alone.

In the section entitled "The Principal Reasons Why We Must Abandon the Hypotheses of the Ancient Astronomers," Rheticus presents the main advantages of Copernicus's hypotheses over geocentrism. They first permit several celestial phenomena to be treated with more accuracy, beginning with the precession of the equinoxes and the variation of the inclination of the ecliptic, which depend on the irregularities of the so-called "librations" linked with the third terrestrial motion. Moreover, terrestrial motion accounts for the relation of the eccentricities of the Sun and other planets. He adds that geocentrism cannot conveniently account for Mars's appearances nor for Venus's and Mercury's closeness to the Sun: "Venus and Mars do not recede from the

84 Rheticus, *The Narratio Prima*, 135–36.

Sun further than fixed, ordained limits because their paths encircle the Sun."[85] Additionally, Copernicus accorded his theory to the axiom of uniform circular motion, and heliocentric theory is in accordance with the principle of economy: "Nature does nothing without purpose."[86] Rheticus resorts to the metaphor of God the clockmaker:[87]

> Since we see that this one motion of the Earth satisfies an almost infinite number of appearances, should we not attribute to God, the Creator of nature, that skill which we observe in the common makers of clocks? For they carefully avoid inserting in the mechanism any superfluous wheel or any part whose function could be served better by another with a slight change of position.

Apart from economy, Copernicus employs a "principle of order" that can be traced back to the Pythagorean doctrine of cosmological harmony. Poetical images from antiquity employed by Renaissance neo-Platonic thinkers, for instance that of the Sun as a "governor of nature, and king" ceased to be mere commonplaces and attained the dignity of cosmological truths.[88] Between the image of a wandering ruler and that of an emperor firmly sitting on his throne, Copernicus chose the second option and supported it through mathematical demonstrations. Only this *ratio*, so Rheticus, could support the doctrine of universal harmony:[89]

> [Copernicus] saw that by his hypotheses the efficient cause of the uniform motion of the Sun could be geometrically deduced and proved. Hence the mean motion of the Sun would necessarily be perceived in all the motions and appearances of the other planets in a definite manner, as appears in each of them. Thus the assumption of the motion of the Earth on an eccentric provides a sure theory of celestial phenomena, in which no change should be made without at the same time re-establishing the entire system, as would be fitting, once more on proper ground.

Rheticus sought to legitimize his and his master's views by tracing them back to the Pythagorean school. In his dedicatory letter to Copernicus's *De lateribus*

85 Ibid., 136.
86 Ibid., 137.
87 Ibid., 137–38.
88 Ibid., 139.
89 Ibid.

et angulis triangulorum … libellus (*Booklet on the Sides and Angles of Triangles*, Wittenbeg, 1542), to the Nuremberg mathematician and theologian Georg Hartmann, he opposed Pythagoras to vulgar people incapable of hearing the music of the heavens and appreciating the liberal arts, especially mathematics (*bonas artes* and *numerorum doctrinam*):[90]

> Even after [the arts] have been restored, it certainly appears to [the minds of] the people that which Pythagoras said, according to tradition, about the harmony of heavenly motions. He said, in fact, that they produce very sweet sounds but, since people cannot hear them due to habit [of hearing them], they are as deaf and, therefore, they neither hear nor look after the study of the divinely restored arts. […] If there were no enumeration of the years in history, religion and the market, how much darkness would there be in life!

As to the status of hypotheses, the conclusion of the *Narratio prima* is a resolute affirmation of the correspondence between Copernicus's mathematical model and physical reality:[91]

> Just as soon as I have read the entire work of my teacher with sufficient application, I shall begin to fulfill the second part of my promise. I hope that both will be more acceptable to you, because you will see clearly that when the observations of scholars have been set forth, the hypotheses of my teacher agree so well with the phenomena that they can be mutually interchanged, like a good definition and the thing defined.

10 The Elder Rheticus and Pierre de la Ramée against the Astronomical Axiom

Rheticus later abandoned the favorable and admired opinion of Ptolemy which he expressed as a young man in the *Narratio prima*. In August 1568, in a letter from Cracow to Pierre de la Ramée, royal lecturer in Paris, he referred to his addressee's hostility toward Euclid, and stated that his own aversion to

90 Reticus's dedicatory letter to Georg Hartmann, in Copernicus, *De lateribus et angulis*. Cf. Burmeister, *Rhetikus*, vol. 3, 45–49, 46.

91 Rheticus, *The Narratio Prima*, 186.

Ptolemy was even stronger.[92] He even changed the Latin title of the *Almagest*, *Magnae constructiones* (great constructions), into *Maximas destructiones* (greatest destructions). This shift in his opinion about Ptolemy possibly reveals a change of opinion about the epistemological status of hypotheses.

In 1563, de la Ramée wrote to Rheticus about his project to reform the liberal arts. Arithmetic and geometry should rely on logic (actually, on an anti-Aristotelian dialectical method based on dichotomies). As to astronomy, he needed the help of a specialist capable of reforming the discipline in accordance with his philosophical guidelines. Specifically, he envisaged a science "without hypotheses," that is to say, a purely computational art renouncing geometrical models. According to him, hypotheses corrupted astronomy's purity (*disciplina tam involuta tamque perplexa hypothesibus*). Thus, he prompted Rheticus (of whom he knew the *Canon doctrinae triangulorum* printed in 1551 and 1565) to develop a computational astronomy independent of the "schools of Pythagoras and Jabir." This meant a rejection of the principal hypotheses, that is, those of Copernicus (Pythagoras) and those of the Islamic followers of Ptolemy (Jabir). De la Ramée accused the Pythagoreans of having introduced epicycles and eccentrics, which he deemed to be useless. As to Copernicus, he appreciated Reinhold's tables but rejected the geokinetic hypothesis as cumbersome and useless.[93]

The "prejudice" of hypotheses derived, so de la Ramée, from two erroneous premises: first, that an astronomy deprived of geometrical models could not account for heavenly phenomena and, second, that only such models could ensure exact predictions. On this point, de la Ramée reproached Proclus for writing, in *Hypotyposis*, that celestial irregularities are contrary to divine providence, thus supporting the principle that heavenly motions are uniform and circular. By contrast, he regarded heavenly irregularities as a matter of fact: "In my assessment, you will succeed [in reforming astronomy], if, avoiding all hypotheses, you will render astronomy as simple as nature itself made the essence of the heavenly bodies."[94] De la Ramée proposed to substitute planetary theory for a *historia*, that is, a record of the heavenly phenomena, including all planetary irregularities and retrogradations. On this basis one could calculate heavenly recurrences and forecast future positions. This should be enough for the purposes of astronomy. On the other hand, natural or cosmological

92 For Rheticus's letter to de la Ramée of 1568, see Burmeister, *Rhetikus*, vol. 3, 187 ff.

93 Ramée, *Scholae physicae* IV,14, 123 and idem, *Scholae mathematicae* II, 47. Cf. chap. 1,6.

94 For de la Ramée's letter to Rheticus (Paris, 23 August 1563), see Burmeister, *Rhetikus*, vol. 3, 173–81, 174.

considerations should be avoided. Given these premises, he urged Rheticus to develop an astronomy in accordance with "natural simplicity":[95]

> I would like you to embrace this case and to bring out of your treasure reasons that will persuade us with necessary demonstrations [...] that astronomy can rely on exclusively arithmetical and geometrical elements and principles and that it can perfectly subsist without any hypotheses.

De la Ramée intended to restore the astronomy of the Babylonians, the Egyptians and the Greeks before Plato. In his assessment, not only the "Pythagorean" epicycles and eccentrics, but also the cosmology of concentric spheres of Eudoxus, Callippus and Aristotle should be dismissed. Accordingly, de la Ramée apporved the theses of the anonymous introduction to *De revolutionibus*, which he mistakenly attributed to Rheticus: "If I am not wrong, in your prefatory letter to Copernicus you show through the epicycle of Venus that the hypotheses of epicycles and eccentrics are false and absurd devices."[96]

Brahe, who met de la Ramée in Augsburg in 1570, disdained this program of a computational astronomy deprived of geometrical hypotheses. Indeed, he considered it to descend from ignorance. Rheticus was more open to the challenge of the French philosopher, even though he declined his invitation to Paris. In the letter to de la Ramée of 1568, he declared himself favorable to a conventionalist use of the term "hypothesis," contrary to earlier statements in the *Narratio prima*. On this occasion, he wrote that he was trying to get rid of hypotheses. He added that he was completing astronomical tables of irregular heavenly motions which could be used as ephemerides,[97] and that he also wanted to restore Egyptian astronomy thanks to an obelisk that he erected in Cracow and probably intended to use as a gnomon. He furthermore agreed with de la Ramée on the necessity of a science based on empirical evidence instead of authority: "I am also working on a new philosophical approach to nature which is based only on the observation of nature and renounces all ancient writings."[98]

It should be remarked that it is difficult to completely grasp Rheticus's epistemology in his late years on the basis of only these few letters. One could even suppose that he dissimulated the divergences between his conceptions and those of de la Ramée, and that he rejected only those hypotheses that he

95 Ibid., 175.

96 Ibid.

97 Ibid.

98 Rheticus to de la Ramée (Cracow, 1568) in Burmeister, *Rhetikus*, vol. 3, 187–90, 188.

deemed to be in disagreement with nature, like Kepler did in the *Astronomia nova* of 1609. It is, however, important to stress that epistemological reflections accompanied Rheticus over the years and suggest that he might have changed his mind on this, shifting from Melanchthonian realism to Ramist conventionalism.

11 Facts and Reasons in Astronomy according to Melanchthon and Reinhold

Let us now return to Wittenberg. In 1542, while Rheticus was completing the edition of Copernicus's major work in Nuremberg and was moving to Leipzig to occupy the chair of higher mathematics (beginning in that year), Reinhold published an edition of Peuerbach's *Theoricae novae planetarum*. This textbook was issued as part of the Melanchthonian program of a humanist and Lutheran reformation of university curricula. Its preface was a letter from Melanchthon himself, written to the editor Grynaeus for a previous edition of Peuerbach (Wittenberg, 1535). Reinhold's new edition appeared between the publication of the *Narratio prima* and *De revolutionibus*; it deserves our consideration because it contained several epistemological remarks by Reinhold as well as by Melanchthon.

Melanchthon's prefatory letter begins with an analogy between present political and religious conflicts and the Peloponnesian wars that troubled ancient Greece. At that time, the oracle required from the Delians a cubic altar for Apollo double the size of the one that already existed. This would appease the gods and bring back peace to the country. The citizens thus consulted Plato, who not only offered them the solution of the geometrical problem, but also unveiled the hidden message of the oracle: only philosophy could bring harmony and peace to men. The love of knowledge, he said, would erase ambition and greed, and foster peace and moderation. Melanchthon revived Plato's warning and addressed it to his German contemporaries: philosophy and mathematics should elevate men and wipe out religious conflicts.[99] Melanchthon thus encouraged the teaching of mathematics and supported new editions of basic textbooks for the university curricula in that discipline, among them Sacrobosco's *Sphera*, Euclid's *Elementa* and Peuerbach's *Theoricae* as well as Ptolemy's astrological treatise *Quadripartitum*.

As far as planetary astronomy was concerned, Melanchthon remained with geocentrism. His explicit address to astronomers to be "prudent" should be

99 Melanchthon to Grynaeus, in Reinhold, *Theoricae novae*, ff. 6*r*–13*r*, ff. 6*v*–7*r*.

interpreted in the theological meaning to bear in mind God's Providence.[100] In particular, he praised the pedagogical clarity of Peuerbach's introduction to astronomy: "Peuerbach summarized Ptolemy's theory on the motions of all heavenly spheres in a very prudent manner, so as to disclose to students the entrance to fruitful disputations."[101] With regard to the epistemological issue, Melanchthon held the *Theoricae* to be a mere treatment of "facts" or, as he called them in Greek, τὸ ὅτι—an expression corresponding to the Latin *quia*. The teaching of the *quia* relying on Peuerbach should awaken in the students the desire to investigate the διότι as well, that is, the deeper reasons or causes (in Latin, *propter quid*) of astronomical phenomena. These reasons, as we know from the *Initia*, are physical and theological.

As usual for him, in his prefatory letter Melanchthon also pointed out the theological relevance of astronomy. In his opinion, knowledge of celestial harmonies strengthens faith and morality, because it reveals God's wisdom. Plato correctly taught that God "geometrizes." The regularities of nature are the signs (*vestigia*) of Providence, contrary to the Epicureans and their doctrine of natural *casualitas*.[102] The emphasis on Providence behind astronomy was connected, in Melanchthon's eyes, to the *pars divinatrix* of astronomy: astrology, to which he accorded great importance, as documented, among many other writings, by his and Camerarius's translation of the *Quadripartitum*.[103] The capability to interpret celestial signs, he argued, is essential for medicine, economy and government. Furthermore, the anticipated knowledge of misfortune permits man to take precautions or, at least, to implore God's mercy: "Often God, appeased by pious prayers, mitigated the violence of the fates."[104]

Reinhold was interested in astrology, too. As one reads in the dedicatory epistle of the *Theoricae* to Albrecht of Prussia, solar eclipses signal war, plague and other misfortunes. Reinhold added, in accordance with Rheticus's *Narratio prima*, that the decline of empires and civilizations should be preceded by exceptional celestial phenomena, as was the case with the Peloponnesian War. It is in this astrological context that Reinhold mentioned Copernicus as a providential reformer of astronomical tables:[105]

100 Ibid., f. 11*r*.

101 Ibid.

102 Ibid., f. 7*v*.

103 Ptolemy, *De predicationibus*.

104 Reinhold, *Theoricae novae*, f. 9*r*.

105 Ibid., f. A8*r*.

> I very much rejoiced at hearing that a very learned man, who collected many observations through a long practice, has undertaken the emendation of the [astronomical] tables, which I strongly wish that he could accomplish. In fact, although the great upheavals [*conversio*] of all empires hampers human undertakings, nonetheless it is inconvenient for a generous mind to neglect the virtue and study, especially because we fear the impending barbarism, and the struggle to transmit the most good and useful arts to posterity has become harder.

Human limits are such, so Reinhold, that we cannot completely grasp celestial harmonies, hence we are forced to resort to geometrical models in order to explain heavenly phenomena.

Reinhold added the natural consideration that planets move thanks to an intrinsic principle or *vis insita* that maintains them on their trajectories according to a divine project:[106]

> Even though those seven lucid and beautiful [heavenly] bodies perhaps have, instead of those spheres [*sine huiusmodi orbibus*], an inner force [*vis insita*] thanks to God—so that everything preserves its own way and perpetual harmony according to varying and irregular motions—nevertheless it is difficult for us to understand and to trace the course of that, so to say, irregular harmony without recourse to numerous orbs, at least as much as reason is concerned [*rationabiliter*].

Reinhold here questioned the existence of the material spheres of the Aristotelians. Although he stated that the main concern of astronomy was "to save the phenomena" (*apparentiae salvari*), nonetheless he held that astronomers could not avoid taking into account natural questions such as the matter of the heavens and the causes of motion.

Moreover, Reinhold expanded on the epistemological distinction between τὸ ὅτι and διότι. He regarded Peuerbach's *Theoricae* as a treatise on τὸ ὅτι, because it dealt exclusively with the "form" and the connection of astronomical motions. Reinhold believed, however, that astronomy should go beyond that. He himself was completing a book dealing with the διότι. According to his declarations, he conceived of it as a continuation of Regiomontanus's *Epitome*. It seems therefore that, on his advice, Ptolemy and Regiomontanus, not Aristotle, could provide an adequate philosophical basis for planetary theory. This hint is remarkable on Reinhold's part, because it shows that he attached

106 Ibid., f. 15*r*.

to "facts" and "reasons" a different meaning than Melanchthon, who sought the foundation of astronomy in physical "causes" in the Aristotelian sense. By contrast, the kind of foundation that Reinhold could expect from Ptolemy and Regiomontanus was not "physical" in the Peripatetic sense. To make his point, Reinhold paralleled the relationship between the *Theoricae* and the work of Ptolemy (and Regiomontanus) to the relationship between the moral precepts of Cato or Isocrates and the "demonstrations" of Aristotle, that is, the derivation of moral precepts from principles:[107]

> There are two ways of teaching. The first one only presents the τὸ ὅτι of the art, that is to say, it presents some naked and brief precepts, or statements or rules without [explaining their] causes or demonstrations. In the moral teaching, these are called παραινετικός, for instance Cato, Isocrates and the like. The other [way of teaching] also shows the διότι, that is, it concerns not only statements and rules, but also the accurate investigation of the causes, as well as the consideration of the effects and the demonstrations. This is the way Aristotle teaches ethics, since he almost always intends to ground his theses [*dogmata*] on solid arguments [*firmis probationibus*]. In the same manner, the *Almagest* and Regiomontanus's *Epitome* explain the διότι of astronomical motions and phenomena. To be honest, this introduction [Peuerbach's *Theoricae novae planetarum*] entails almost only the τὸ ὅτι of the art.

The most original aspect of Reinhold's epistemology rests on the conviction that to found a planetary theory does not mean abandoning the mathematical treatment of the problem for a natural philosophical one. Quite on the contrary, geometrical "hypotheses," conceived as preliminary theses of mathematical astronomy, have a foundational validity.

12 Reinhold's Astronomy and Copernicus

Reinhold's *Theoricae* of 1542 document his opinion on Copernicus. In the dedicatory letter, he called the latter a *doctissimus* reformer of astronomical tables and, in another place, extolled him as the one who emended Ptolemy's lunar theory.[108] Additionally, he called the Sun "prince and moderator," as well as the *choragus* to whose motion all other planetary rates are tuned.

107 Ibid., f. 16*v*.

108 Ibid., f. 19*r*.

These expressions emphasized the importance of solar theory for planetary astronomy in general, but clearly increased their significance from the point of view of heliocentric astronomy:[109]

> As relates to the first question [why Peuerbach proceeds from the solar theory], my answer is the following. Even though other scholars bring forward many reasons for this beginning, Peuerbach, in my opinion, merely follows Ptolemy as the best model of a practitioner [*artifex*] in this art. As is well known, Ptolemy exhausts the theory of the primum mobile in the first two books [of the *Almagest*] and then immediately moves on to the treatment of solar motion [for two reasons]: first, because we measure all planetary motions and periods from the Solar period, which determines our year; second, because the treatment [*disputationes*] of all the different [heavenly motions] cannot be grasped without a preliminary acquaintance with the motion of the Sun, which all [celestial bodies] revere as their prince and god. Therefore, they accord their travels [*cursos*] to its rule [*norma*]. In the same manner, lunar theory directly follows the solar theory in accordance with Ptolemy.

Later, in the *Prutenicae tabulae* of 1551, Reinhold explicitly celebrated Copernicus, calling him an "Atlas" and a "Ptolemaeus alter." In the preface ("Praefatio autoris in prutenicos canones"), Reinhold reported on the state of the art and remarked that many imperfections had been emended by Copernicus thanks to his observations and theories:[110]

> We should be very thankful to the illustrious Nicholas Copernicus because he generously shared with other scholars his observations, which he carried out for many years, at night, through very diligent work, and because he restored and brought back to light the nearly lost planetary theory [*motuum doctrina*] with the publication of his work *On the Revolutions*.

Reinhold's opinion on Copernicus is synthesized in the following comment: "all his geometries, as the [product] of the highest practitioner [*artifex*], are so perfect and plainly worked out, that I can hardly imagine that anything better in this entire theoretical field could be ever conceived."[111] He deemed Copernicus's models to be perfect, despite some inaccuracies concerning heavenly rates and

109 Ibid., f. 20*r*.

110 Reinhold, *Prutenicae tabulae*, f. b2*v*.

111 Ibid.

the difficulty in the employment of his tables. For instance, in the *praeceptum* number three concerning planetary computation ("De accomodatione temporis ad usum calculi aequalium motuum, tum iuxta Alphonsinarum rationem, quam Copernici"), Reinhold explained that the time of reference for calculations is not clearly indicated in Copernicus's tables, and this fact makes their utilization difficult.[112] The *Prutenicae tabulae* should overcome this difficulty and be easy to consult.

In the dedicatory epistle to Albrecht of Prussia, Reinhold stated that he derived his tables from Copernicus although he took into account earlier authors, as well:[113]

> I am confident that the practitioners [*artifices*] will appreciate my intentions [*voluntas*], the extent [*magnitudo*] of my effort and the work itself. In fact, they know that the old tables are not in agreement with the phenomena anymore and an emendation is necessary. The complexity of this task can be judged by the fact that no one, in so many centuries, was able to calculate completely exact tables. Copernicus, the very learned man that we could call another Atlas or another Ptolemy, provided the demonstrations and the causes of the [heavenly] motions relative to the observations he could collect, in a very erudite way. Still, he escaped the work of constructing new tables to the extent that computations derived from his canons do not even agree with the observations on which this work is based. Thus, I undertook the task to compare Copernicus's observations with those of Ptolemy and Hipparchus, so that I could build new [celestial] tables, whose employment I will explain in the following. I will later expand on the causes and sources in another work.

The "other work" (*aliud opus*) announced here never appeared: it was to have been a commentary of *De revolutionibus*, which was also mentioned in the imperial concession of printing privileges attached to the tables as *Eruditus commentarius in totum opus Revolutionum Nicolai Copernici* (*Learned Commentary on the Entire Work of Nicholas Copernicus on the Revolutions*). Although Reinhold did not accomplish it, an unfinished manuscript is preserved in the *Staatsbibliothek* of Berlin. It is entitled *Commentarius in opus Revolutionum Copernici* and has been published in volume VIII/1 of Copernicus's *Gesamtausgabe*.

112 Ibid., f. Ee3*r*.

113 Ibid., f. a4*r*.

Reinhold's handwritten papers, as Aleksander Birkenmajer remarked, contain an attempt at a geocentric translation of Copernicus.[114] In his uncompleted commentary on *De Revolutionibus*, Reinhold referred to this arrangement as "our own hypotheses" (*novae hypotheses nostrae*) in a passage on Jupiter's theory. In his model, the Copernican locations of the Earth and the Sun are inverted so that the terrestrial orb about the center becomes the solar orb.[115] This geocentric remodeling of Jupiter could be extended to the other planets. This handwritten annotation, albeit brief and somehow elliptic, documents the fact that Reinhold's approach to astronomy was far from merely conventionalist and computational, since he took into consideration the problem of the accordance between mathematical models and physical reality. Moreover, his attempt at a geocentric revision of Copernicus provided a line of research that would be followed by many German mathematicians up to Brahe.

Another indication that Reinhold adhered to the centrality of the Earth is his commented and illustrated Greek and Latin edition of the first book of the *Almagest* (1549). The chapters that are most averse to heliocentrism contain no hint from Reinhold about the shortcomings of Ptolemy's line of argumentation from the point of view of *De revolutionibus*. Chapter IV, "That the Earth is Located in the Middle of the Heavens," was embellished with many diagrams and σχόλια, that is, commentaries, in which Reinhold omitted any mention of the Copernican theory. In a σχόλιον to chapter six against terrestrial motion, "That the Earth is Not Moved of Local Motion, or Change of Place," he revised the traditional argument of gravity, the tendency (*impetus*) of the elements to reach their natural place: "According to Ptolemy, there is no necessity to search for a reason why heavy bodies move to the middle. In fact, nature is universally made in such a way that things sharing a kindred nature reach out to the same place through an inner tendency [*proprio et nativo impetu*]."[116] As to the thesis of an axial rotation of the Earth, he attributed it to "Nicias Syracusius," and regarded it as an unviable doctrine.[117]

Apart from physics, theological concerns might also have inspired Reinhold's views. Astronomy, he wrote, is a divine science, thanks to which men can admire the Providence of God as a ruler of the world. A Melanchthonian accent in Reinhold's treatment is the conviction that the contemplation of heavenly

114 Birkenmajer, "*Commentaire* inédit."

115 Cf. GA VIII/1, 296. For an analysis, cf. Omodeo-Tupikova, "Post-Copernian Reception," 236–38.

116 Reinhold, *Ptolemaei Mathematicae constructionis liber*, f. 19*v*.

117 Ibid., f. 20*v*. Cf. Omodeo and Tupikova, "Post-Copernian Reception."

harmonies can lead to a refutation of Epicurean atomism and reinforce trust in God's Providence.[118]

Reinhold compared his tables to the technical and engineering products of mathematical expertise. In his eyes, astronomical tables pertained to practical mathematics. He equated them to the surprising "geometrical machines" designed since antiquity for civil and military purposes.[119] Reinhold concluded the dedicatory letter of the *Tabulae* with a complaint about the fragility of all human endeavors. Nevertheless, he hoped that his astronomical tables could survive the centuries.[120]

13 Epistemological Remarks on Reinhold's Terminology

The second part of the *Prutenicae tabulae* (entitled "Logistice scrupulorum astronomicorum") contained the explanations, or *canones*, of how to use the tables in order to calculate the positions of heavenly bodies. Reinhold noted that astronomy, unlike astrology, should be limited to the treatment of the *ratio* and *numerus* of celestial motions. It relies on arithmetic and geometry as its two *organa* (instruments, or auxiliary sciences). Geometry has two astronomical tasks: to find hypotheses consistent with heavenly phenomena and to predict celestial positions using trigonometry (*doctrina triangulorum*). Geometry is thus fundamental for the theoretical as well as for the practical part of the discipline:[121]

> And so geometry most prominently governs both parts of this philosophy, of which, the first, theoretical one accounts for the motions with sure hypotheses, while the second, practical one connects, with admirable skill and purposefulness, stellar motions and numbers or, the other way round, [moves] from those [numbers] to [the observation] with accurate instruments.

According to Reinhold's scientific terminology, "apparent motions" (*motus adparentes*) are the irregularities for which astronomical hypotheses should account. Moreover, the *motus adparens* is the same as the *motus verus* or "true motion." It appears from the fifteenth "principle [*praeceptum*] for the compu-

118 Reinhold, *Prutenicae tabulae*, ff. a3*r*–*v*.

119 Ibid., f. a4*v*.

120 Ibid.

121 Ibid., "Logistice," f. 1*v*. See also ibid., f. Aa1*v*.

tation of heavenly motions," which is entitled "On the Computation of the True or Apparent [*veri sive adparentis motus*] Motion of the Sun," and the 35th on the apparent positions of planets, "On the Composition of a Canon of the True Daily Motion [*veri motus diarii*] of One of these Five [Planets]." In Reinhold's terminology, the adjective "real" refers not to uniform circular motions but to the "phenomena." Hence, he does not oppose "apparent" and "real" in the way a "realist" supporter of Copernicus's planetary system could oppose the "apparent motion of the Sun around the Earth" and its "real" immobility in a heliocentric framework.

Furthermore, the apparent motion, *sive verus*, is opposed to the *motus aequalis*. This "equal motion" is the mean motion of a planet (*motus medius*), calculated for given periods of time (years, months, days). As "real" planetary motions are not uniform, but sometimes accelerated and sometimes slowing down (not to speak of retrogradations), there is a gulf between the *motus aequalis* and the *motus adparens*. The "true" motion is the latter. Therefore the *motus aequalis* is an abstraction, an *ens rationis*, as opposed to the effective, real, albeit anomalous, motion of celestial bodies. All of these distinctions are useful for the astronomer, whose method is described as follows:[122]

> In their study [*inquisitio*] of the heavenly motions, astronomers first ascertain the mean or uniform motions, which are fittingly and neatly distributed in equal intervals of time, such as years, months, days, and the parts of the day, that is, the hours. Second, they establish how much shall be added to or subtracted from those equal motions in order to know the place in which a celestial body passes at a determined moment [*hoc aut illo tempore*], without observational efforts, but simply thanks to canons and numbers. This is actually the goal of astronomical computation.

A certain conventionalism in Reinhold's approach to astronomy is undeniable. Geometrical hypotheses are abstractions compared to "concrete" irregular motions, called *adparentes* or "true." Still, this was no conventionalism *à la Duhem*. Rather, it mirrors Reinhold's awareness of the way mathematical models approximate observed reality. A model can be more or less adherent to that for which it accounts. He was sensitive to this issue, of course, since the accordance between theory and observation was the crucial problem and the special task of a compiler of astronomical tables like himself. The degree of correspondence to the celestial phenomena should establish what hypotheses are "closer to" or "further from" truth. His appreciation of Copernicus's *geometrica*

122 Ibid., f. Dd2*r*.

thus has a complex meaning which goes far beyond his acknowledgment of the formal perfection of hypotheses or respect for the *axioma astronomicum*. Since he holds that the preferability of a certain set of geometrical models is not arbitrary from a natural viewpoint, Reinhold proves to be no agnostic conventionalist in Duhem's sense.

It should be underscored that, in Reinhold's case, to call irregular motions "true" is not a naive "phenomenism" (according to which, for instance, if celestial bodies seem to turn about the Earth, this should be accepted as a reality). One could ascribe to him an intermediary position between realism and Osiandrian conventionalism: if a theory is in better agreement with the phenomena, it is "closer to" truth, even though the observed irregularities lead us to conclude that the planets, which might in fact encircle the Sun (for instance, within a geoheliocentric sheme), do not have complete geometrical accuracy. In a passage from the preface to the *Prutenicae tabulae*, he described how he compiled his tables and, indirectly, his path to astronomical investigation:[123]

> Thus, I first gathered the observations of Copernicus, Ptolemy and others, in the most accurate way. Besides the bare observations and the manner of the demonstrations, I did not take anything else from Copernicus. Rather, I constructed anew the canons of uniform motions [*aequalium motuum*], prosthaphaereses, and all the rest, whereby I followed a slightly different approach that I deemed to be the most convenient.

Concerning the physical causes of planetary motions, Reinhold surmised in the *Theoricae* that planets move thanks to an inner force or *vis insita*. As we have already remarked, he possibly adhered to a natural view, close to the Stoic one, according to which celestial bodies are moved by intrinsic impulses and not by external causes, that is, by material spheres. The resulting interactions of planetary motions constitute the unfolding of a providential harmony, which is close to geometrical perfection, although mathematical accuracy cannot be completely achieved by nature.

To sum up, Reinhold's astronomical conception is based on two basic assumptions: first, the fictitious character of celestial orbs, and, second, a "moderate mathematical conventionalism." He, as a compiler of ephemerides, did not ignore the fact that no tables and no theory were perfectly adequate to observation. Hence, he regarded geometrical models as approximations of reality. He deemed them to be necessary in astronomy, although they could not be satisfactory in all respects.

123 Ibid., f. b2*v*.

14 Peucer's Continuation of Reinhold's Program

In 1568, an anonymous publication on cosmological hypotheses appeared in Strasbourg: *Hypotyposes orbium coelestium,* whose rather long title was *Hypotyposes of Celestial Spheres, Usually Called Planetary Theories, in Agreement with the Alfonsine Tables and Copernicus, or Rather with the Prussian* [*Tables*]*: Published for Academic Use*. Konrad Dasypodius, professor of mathematics at the Gymnasium of Strasbourg (*Academia Reipublicae Argentinensis*), composed the dedicatory letter, which was addressed to Landgrave Wilhelm IV of Kassel. Dasypodius is famous as the one who constructed the astronomical clock on the Strasbourg cathedral, between 1572 and 1574, with the support of the blacksmiths (*fabri ferrari*) Isaac and Iosia Habrecht. He was probably the one who decided to embellish that clock with a famous portrait of Copernicus, made by the painter (*pictor*) Tobias Stimmer.[124]

In the dedicatory epistle of the anonymous *Hypotyposes*, Dasypodius reported that he was first shown the manuscript by the editor Theodosius Rihel. Struck by its accuracy and originality, he decided to have it printed. It was a treatise on planetary theory, similar to Peuerbach's but noteworthy for the attempt to bring together Copernicus, Alfonso and Reinhold.[125] The title, *Hypotyposes*, referred to the problem of hypotheses; the Greek term ὑποτύπωσις actually means "model," "example" or "draft." Dasypodius believed its author to be the deceased Professor Reinhold, "whom I would almost call another Ptolemy."[126]

The aim of the work, according to the editor, was to overcome several uncertainties concerning hypotheses:[127]

> Namely, some assert that the heavens are moved by a perpetual movement; by contrast, others argue that it is the Earth that moves, and that the Sun rests in the middle of the world. Some make use of homocentric circles; others posit eccentrics and epicycles, homocentrepicycles and I do not know what other kinds of circles and spheres. The goal is, however, to save the variety and vicissitude of the heavenly motions.

124 Dasypodius, *Heron mechanicus*, ff. F2*v*–F3*v* (on the order for the clock and his collaborators), and f. H2*v* (on the portrait of Copernicus).

125 Cf. Barker, "The *Hypotyposes.*"

126 [Peucer], *Hypotyposes orbium*, f. a4*v*.

127 Ibid., ff. a2*v*–a3*r*.

A few years after this publication, the treatise was reissued in Wittenberg as *Hypotheses astronomicae* with a slightly modified title: *Astronomical Hypotheses, or Planetary Theory Derived from Ptolemy and Other Ancient Doctrines Adapted to the Observations of Nicholas Copernicus and to the Canons of the Motions Established by Him*. This new edition revealed the name of the author: Caspar Peucer, a pupil of Reinhold's and his immediate successor as professor of mathematics at Wittenberg. In the beginning of the new edition, Peucer declared himself unsatisfied with his *Hypotheses*. Yet, since the tract had begun circulating in an anonymous form due to Dasypodius's edition, he felt compelled to reissue it to vindicate his authorship. He modestly regarded it as a contribution to the "restoration" of astronomy and hoped that other scholars could finalize his unfulfilled project.

In spite of Peucer's vindication of authorship, the work also continued circulating anonymously. In 1573, it was even reprinted in Cologne without his name on the title page, but with Dasypodius's dedicatory letter at the beginning. This may hint that Peucer's claim to authorship was not universally accepted or, at least, that doubts concerning the attribution of the work were not immediately dispelled—since this textbook on planetary theory also continued circulating in the anonymous version ascribed to Reinhold.[128] Since the *Hypotheses—or Hypotyposes*—promoted a (partial) geocentric translation of Copernican parameters, its anonymous circulation and its attribution to Reinhold could later strengthen the conviction, shared by many scholars of the time, that geo-heliocentrism was nothing but a prosecution of Reinhold's work. Peucer himself acknowledged that Reinhold had told him that he wished a reform of hypotheses in the spirit of the *Hypotheses astronomicae*.[129]

As one reads in Peucer's introduction to the second edition, he began his career as a professor of mathematics about twenty years earlier, after Reinhold's death, when he took over the vacant chair. In his classes on astronomy, Peucer lectured on optics, Ptolemy's hypotheses and Copernicus's observations and canons, which he probably adapted to a geocentric framework:[130]

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128 In the copy of the 1573 edition preserved at the Dibner Library of the History of Science and Technology in Washington, DC (coll. QB 603 M6D23 1573), Dasypodius's name at the end of the dedicatory letter has been erased, possibly by some reader enraged that Peucer's authorship was not acknowledged. It should be also noticed that Dasypodius was prohibited as a heretic in the Roman Index. See Baldini-Spruit, *Catholic Church*, vol. 1/2, n. 20, pp. 1488 ff.

129 Peucer], *Hypotyposes orbium*, (f. 4*v*).

130 Ibid., (f. 5*v*).

> After optics, I dealt with astronomical hypotheses, deriving them from the doctrine of Ptolemy and his commentators, and adjusted them to Copernicus's observations and canons. In fact, I prefer the latter to the Alfonsine ones for many reasons, although I think that Copernicus's hypotheses should by no means be introduced in the universities [*in Scholas*]. I have intentionally set up another order than that established by others before me. In the introductory class [*in prolegomenis*], I exposed and demonstrated the basic notions [*fundamentum*] of the principal hypotheses in general. Thereafter, it is easy to transfer and apply the general demonstrations to theories [*hypotheses*] of the single planets.

It should be remarked that the word "hypothesis" has two meanings in this passage. It refers to the most general features of planetary theory as well as to geometrical modeling of planetary motions.

Peucer probably never adhered to the geokinetic and heliocentric theory. In 1551, he published a traditionally geocentric introduction to spherical astronomy, *Elementa doctrinae de circulis coelestibus et primo motu* (*Elements of the Theory of Heavenly Circles and the First Motion*), without any claim to originality. It was nonetheless an editorial success as a textbook, judging from the fact that it was reprinted several times. In this work Peucer rigorously adhered to the distinction between the sublunary (or elementary) and the superlunary realms. In accordance with Peripatetic philosophy, he maintained the existence of ethereal spheres transporting planets. As to the Earth, he showed no doubts about its rest and centrality.[131] It should be noted that the *Elementa* were conceived as an elementary textbook; therefore, as Melanchthon wished, it was not supposed to trouble students with Copernicus's planetary theory. Still, Peucer acknowledged the relevance of Copernicus, whom he mentioned as the last great astronomer in a list of predecessors found in the first pages of the *Elementa* of 1551. In later editions, he also added the name of Reinhold, remembered as "my very beloved teacher [*praeceptor*] to be acknowledged with perpetual gratitude."[132] Peucer dedicated the *Hypotheses astronomicae* of 1571, like the preceding, anonymous *Hypotyposes*, to the Landgrave of Hesse-Kassel. In the introduction, he pointed out the problems of astronomy, especially the imprecision of the tables (either Alfonsine or Copernican) and the difficulty of reducing all heavenly motions to regular ones. However, the most remarkable uncertainty regarded hypotheses: "How unsatisfied the specialists [*artifices*] of our century are about the common hypotheses, is witnessed by

131 Peucer, *Elementa doctrinae de circulis* (1551), f. G3*v*.

132 Idem, *Elementa doctrinae de circulis* (1563), f. A7*v*.

their writings."[133] Neither Ptolemy nor Proclus, neither Alfonso nor Peuerbach could perfect astronomy. Even Copernicus's astronomy entailed errors, if not absurdities: "The absurdity of the Copernican [hypotheses] is offensive and far from the truth."[134] Peucer wished that a great astronomer could continue and complete the emendation of astronomy undertaken by Reinhold, whose premature death he regretted. The only living astronomer capable of restoring astronomy who occurred to his mind was old Rheticus, who was then in Cracow.

Concerning the difficult relation between mathematical and physical astronomy, in his *Prolegomena*, Peucer reaffirmed the partition between a mathematical treatment of the heavens and the investigation of causes. The two pillars of astronomy, according to him, are agreement with observation and physical tenability. He moreover indicated four "foundations" upon which astronomy should be built: 1. the φαινόμενα or *apparentia*, that is, observation; 2. the hypotheses, that is, the general cosmological assumptions; 3. geometry, and 4. arithmetic. He defined hypotheses as "those things that are devised and employed through resourceful ingenuity [*artificium ingeniis*] and diligence, and are accorded to the phenomena observed and examined with the most diligent investigation."[135] Hence, for him hypotheses are essentially geometrical abstractions based on observed reality. This idea is asserted most clearly in the following passage, claiming that hypotheses are artificial:[136]

> The inventions and fabrications of the practitioners [*artifices*] are called hypotheses. By describing and distributing thereby certain spheres [*orbes*] in convenient positions and order, they express and demonstrate the precise reason [*tota ratio*] for the apparent irregularity by means of a law, so that, through that anomaly, they can maintain the perpetual and constant regularity [*aequalitas*] of the periods as well as render that anomaly in a determined and well established manner. Hence, these are called hypotheses as [to express the fact] that they are posited and assumed by the practitioners [*ab artificibus*].

However, the usefulness of hypotheses is not limited to computation. They are rather conceived as necessary abstractions from reality and approximations of it.

133 Idem, *Hypotheses astronomicae*, f. X3*r*.
134 Ibid.
135 Ibid., 4.
136 Ibid., 8.

Peucer's treatise deals extensively with two concurring models: the eccentric model (*eccentricus*) and the omocentrepicyclic one (*omocentrepiciclus vel concentricus vehens epicyclum*). Even though there are equivalent geometrical options, Peucer assumes that mathematical explanations are neither completely arbitrary, nor conventional in the sense that they only have to support computation. According to him, planetary theory should respect certain physical requirements and geocentrism. Hypotheses, meaning "general cosmological assumptions," ought to be in agreement with the "fact" that the Earth is *stabilis et firma* at the center of the universe.[137] Thus, Peucer supported no computational conventionalism, but rather a physical reworking of Copernicus.

The unification of Ptolemaic geocentrism and Copernican *canones* leaves unresolved the issue of how the motion of the Sun relates to the motions of the planets. In the section entitled "Analogia motus planetarum ad motum Solis" ("Analogy between the Planetary Motions and the Solar Motion"), Peucer only mentioned the fact that the Sun is the "moderator and ruler" of the planetary system:[138]

> Single planets are connected by their own, firm laws to the Sun's motion, so that the Sun looks like the ruler and governor of all celestial motions, as if it dictates and promulgates to the planets laws that they cannot infringe.

He sought to transfer the Copernican model for precession and trepidation from the Earth to the sphere of the fixed stars. While Copernicus postulated that some librations of the terrestrial axis account for these millenary motions, Peucer brought them back to the eighth sphere, but maintained the geometrical devices and the terminology of *De revolutionibus*:[139]

> In order to account for the ratio of those [fixed stars] one ought to connect to the poles of the equator two reciprocal motions similar to hanging oscillations. In the same sphere, the circles—whose poles are mobile—change their disposition [*mutantur*] according to the ratio of their poles. Hence results, first, a motion changing its inclination between the equinoxial plane and the ecliptic plane, for the back-and-forth libration [*accessu recessuque librato*], depending on which the poles are carried up and down about the angle of the section, as in a straight line. Second,

137 Ibid., 36–37.

138 Ibid., 458.

139 Ibid., 592–93.

> another [motion] is produced, which increases and decreases the precessions of the equinoxes and solstices. Hence results a transversal motion. As a consequence, at times the mean equinoxes and solstices match the real ones, and at times diverge. Of those two motions, the latter, i.e. the precession of the equinoxes, is completed twice in the time in which, so to speak, one obliquity is accomplished. Therefore, Copernicus calls the former motion simple anomaly, and the second, duplicated anomaly.

The expressions "simple anomaly" and "duplicated anomaly"—to indicate the rates for the precession and the variation of the ecliptic inclination, respectively—as well as the term "librationes," are Copernican. Peucer also owes to *De revolutionibus* the so-called "mechanism of reciprocation," that is to say, the combination of circular motions which Copernicus employed in order to produce a back and forth motion of the Earth, with the difference that, in *Hypotheses astronomicae*, this device is attributed to the sphere of the fixed stars.[140]

15 Wittich's Combinatory Games

Paul Wittich of Wrocław was another reader of Copernicus who belonged to the German network of mathematicians sharing Reinhold's and Peucer's interest in the geometrical modeling of planetary motions. His biography and work are obscure in many respects, although he was renowned among his contemporaries as a talented mathematician and was mentioned in laudatory terms by many of them. He was a wandering scholar: a student at Leipzig beginning in 1563 and at Frankfurt on Oder beginning in 1573, a friend of the Scottish mathematicians Craig and Liddel, a member of Dudith-Sbardellati's humanist circle in Wrocław, a correspondent of the imperial physician Hayeck, and an acquaintance of the Landgrave of Kassel. He also visited Brahe, who mentioned him with affection in his correspondence. During his life he did not publish anything. Nonetheless, Gingerich and Westman were able to stress the originality of his contribution to planetary models on the basis of his handwritten drawings and annotations contained in two copies of *De revolutionibus*, one in the *Biblioteca Apostolica Vaticana* and one in the *Bibliothèque de l'Université de Liège*.[141]

140 See Peucer, *Hypotheses astronomicae*, 684, illustration and explanation.

141 Gingerich, *Annotated Census*, and Wittich, *Vatican Annotations*, in Gingerich-Westman, "Wittich Connection," app. 1, 77–140.

In the Vatican copy of *De revolutionibus*, Wittich drew a series of diagrams representing equivalent planetary models. He employed three alternative combinations of circles, two stemming from Copernicus and one of his own invention. Initially (f. 135), he displayed the geometrical equivalence of an epicyclic and an eccentric planetary model, annotating: "In the theory of the three superior planets Copernicus considers two kinds of arrangement [*hypothesis*]: one is the eccentrepicycle, which agrees with calculations and observations, the other is the concentric with an epicycle on an epicycle."[142] It should be remarked that in this passage the term "hypothesis" has a conventionalist meaning. In the Liège copy, Wittich referred to the first geometrical model as *primus modus*, or *eccentrepicyclon*: it consists of an eccentric deferent transporting the planetary epicyle. This device is composed of a total of three circles: the eccentric, the deferent and its epicycle. In the same context, the *secundus modus* is said *concentricum cum epicyclo epycicli*, consisting of a concentric deferent transporting two epicycles whose radii are equal to those of the eccentricity and of the planetary circle, according to the *primus modus*. On folio 197*v* in the Vatican copy, Wittich presents a third equivalent model as his own invention: "This third genre of hypotheses was discovered and developed by myself, relying on Copernicus's hypotheses, on 27 January 1578" (*Haec tertia hypotheseon ratio, inventa atque extructa a me sunt ex D. Copernici hypothesib[us], A[nn]o 78 d[ie] 27 Jan[uarii]*). This is called "eccentr-eccentric." It has a primary circle (corresponding to the deferent of the first and second *modi*), transported by an eccentric circle (corresponding to the planetary epicycle of the other *modi*) whose eccentricity is exactly the same as in the *primus modus*. This model is derived from Copernicus's solar theory. This is why Wittich's *tertia ratio* is followed directly by a representation of the Copernican model for the Sun and by a similar one for the Moon.

A relevant aspect of Wittich's Vatican manuscript is the freedom with which he constructed alternative planetary models by transposing one into another. He drew, one after another, two eccentr-eccentric representations (*tertia ratio*) of the Sun (f. 198*r*) and the Moon (f. 198*v*), followed by some studies on Venus and Mercury (ff. 199*r*–200*r*). He then considered an eccentrepicyclic model (*primus modus*) for the Sun (f. 201*v*) and the Moon (f. 202*r*). An incorrect model for Venus (represented as outside the terrestrial orb, in f. 202*v*) and one for Mercury (f. 203*r*) were the attempts to reduce the theory of the inferior planets to the eccentrepicyclic arrangement (*primus modus*), in the case of Venus,

142 Ibid., 83 (f. 135*r*).

and the eccentreccentrepyciclic one for Mercury (*tertia ratio*).[143] Moreover, Wittich focused on the *secundus modus* with a series of diagrams representing solar theory through a two-epicycle model (ff. 203*v*–204*v* and f. 205*v*). Wittich applied the two-epicycle model to superior planets (f. 205*r*) and to the Moon (f. 206*r*).[144] This was his trial-and-error procedure to test planetary models.

The representation of Venus's *secundus modus*, however inexact, reveals Wittich's special employment of astronomical keywords: "motus verus," "adparens" and "medius." Unlike Reinhold, he uses these termini in accordance with a Copernican terminology. The *motus verus*, or true motion, is the motion of a planet around the Sun. "True" here has the meaning of "describing a structure of reality." The line of the mean motion (*linea moti medii*) joins the Sun to the deferent of a two-epicycle model (*secundus modus*), and the planetary motion as seen from Earth is called "apparent." In this context, "appearance" (and correspondingly "apparent") means "perception," or "subjective representation," as opposed to objectivity. While Reinhold used the adjectives "true" and "apparent" as synonyms, Wittich adopted a post-Copernican terminology: the "apparent motion" is that observed from the Earth (whether stationary or in motion) whereas the "true motion" refers to an objective reality. This opposition between "motion for us" and "motion in itself" comes close to the Platonic separation of appearance and reality, or between empirical and rational.

It should be remarked, moreover, that Wittich's Copernican terminology is embedded in a rather conventionalist framework. This means that, in his combinatorial games, "real" and "apparent" have an abstract meaning: they are *entia rationis* or mental entities. They are epistemological tools that can be employed independently of reality (that is to say, independently of "real reality" and "real appearance"). "Real" and "apparent" are rigorously defined concepts that can be employed for abstract reasoning. In other words, "real" and "apparent" do not have a fixed "physical" meaning, but can be used to designate all possible and equivalent models conceived by the mind of a mathematician, and are model-dependent.

Still, Wittich's combinatory games yielded a physical conclusion. The chain of equivalences ended with a solution in which only one of the

143 Ibid., 108: "The epicycle [of Venus] rides on the Earth's eccentric, rather than on that of Venus; therefore, this model is not strictly parallel to the previous models of this second mode."

144 In f. 206*v* and 207*r* one can find a similar approach to the inferior planets, but this representation based on the *secundus modus* was again mistaken (as in f. 202*v*) because the deferents were represented as outside the Earth. Cf. Gignerich's and Westman's remarks, ibid. 126–27.

alternatives has actual reality. In ff. 207*v* e 208*r*, two diagrams of the superior planets are represented close to each other. The three circles of the *primus modus*, that is, the eccentric (medium-sized circle), deferent (large circle) and epicycle (small circle) are combined in such a way that, in one case, the biggest circle transports the small and the small the medium, and, in the other case, the small one transports the mean and the mean the big one (ff. 207*v*–208*r*, see figure 4). The Sun is at the center of both models, whereas the Earth is represented on an eccentric circle, whose radius corresponds to its orb. Remarkably, Wittich traces an orbit centered on the Earth in the second drawing, although the Sun remains at the center. This suggests that the relation of center to planet can be reversed in order to return to geocentrism. Wittich notably reaches this geocentric solution through consideration of geometrical models freely derived from *De revolutionibus*. Not the cosmology, but the geometry is maintained here, since Copernicus's concentric-epicycl-epicyclic model (*secundus modus*) is preferred to the eccentric model, but applied to a geocentric system.

Wittich was enthusiastic about his invention, as evinced by the title he chose for the diagram in which the trajectory of the Sun encircles the Earth

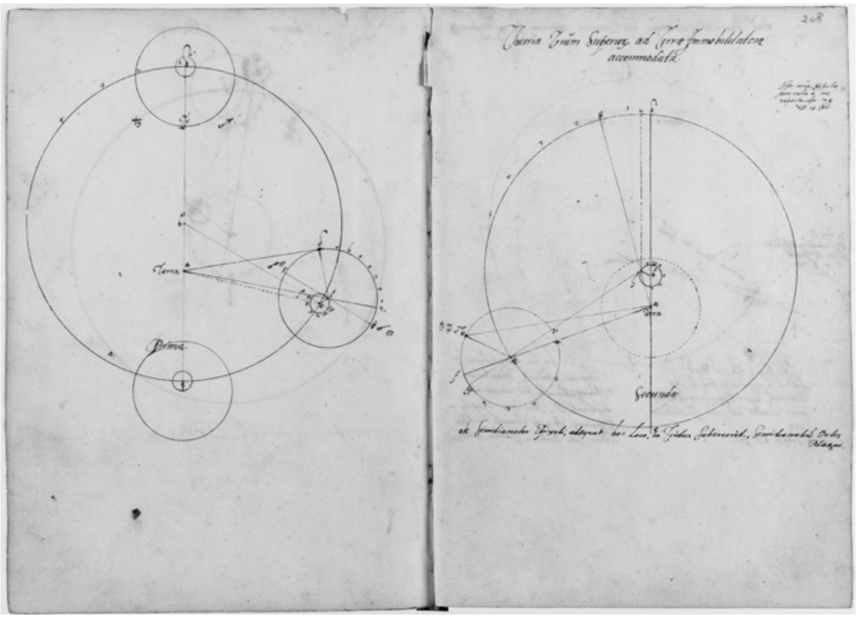

FIGURE 4 *Two diagrams showing epicyclic models developed by Paul Wittich for the external planets, entailed in a copy of Copernicus's* De revolutionibus orbium coelestium
COURTESY OF THE VATICAN LIBRARY.

for the first time: “Theory of the three superior [planets] accorded with the immobility of the Earth” (*Theoria trium superiorum ad Terrae immobilitatem accomodata*). At the lower right he noted the date: “I found this new genre of hypotheses on 13 February 1579” (*Haec nova hypotheseon ratio a me reperta anno [15]79 d[ie] 13 Feb[ruarii]*). A true concern for “reality” emerges in these last pages. A tenable model is now opposed to merely geometrical diagrams. Wittich was glad about the option of a geocentric, or, more accurately, a geoheliocentric translation of Copernicus. The new option was to maintain Copernicus’s geometry while reversing the relation between Earth and Sun. Wittich also adapted inferior planets to the geoheliocentric model. A unique and continuous passage connects ff. 208*v* e 209*r*, where such theory is reworked according to the new hypothesis: “In what manner Copernicus’s theory of the two inferior [planets] can be in agreement with the immobility of the Earth, in accordance with Ptolemy’s words [*ex Ptolemaei sententia*].” As a conclusion (f. 210*v*), Witich drew the image of a cosmos with a central Earth. In this last diagram, the major orbs of the superior planets are centered on it, whereas those of Mercury and Venus are centered on the Sun. It is a return to the Capellan model. The only “physical defect” of this model could be the intersection of the circles of the Sun and Mars. However, given the freedom in treating alternative geometrical models, should we now assume that Wittich still believed in the existence of material spheres?

16 Brahe as the Culmination of the Wittenberg School

As Westman already emphasized in 1975, Brahe’s reading and utilization of Copernicus could be considered as the acme of the Wittenberg reception, because the questions underlying his geoheliocentric planetary model originated from a long debate about how to accept geometrical innovations from *De revolutionibus* without renouncing the centrality and immobility of the Earth.[145] The renowned chapter eight of *De mundi aetherei recentioribus phaenomenis* (1588), in which he presented his geoheliocentric arrangement for the first time, could be regarded as part of the Wittenberg program I have outlined. It deserves special attention since it summarizes the central problems, geometrical, physical, epistemological and even theological, that motivated a non-heliocentric reception of Copernicus.

Chapter eight of the first part of *De mundi aetherei recentioribus phaenomenis* deals with the location of the comet that appeared in 1577–1578. Having

145 Cf. Westman, “Three Responses.”

already demonstrated in the previous sections that the comet was located above the Moon, Brahe seeks to determine the position (*locus*) of the comet among the planets (*secunda mobilia*). As one reads, this could be established only after obtaining a correct knowledge of the system of the world (*totius mundani systema*), from which planetary distances can be derived. This gives him occasion to introduce the geoheliocentric theory or, as Brahe triumphantly calls it, the "New disposition of the worldly system recently discovered by the author" (*Nova mundani systematis hypotyposis ab autore nuper adinventa*).[146] According to this model, the Earth is stationary at the center, encircled by the Moon, the Sun and the fixed stars, whereas the other planets travel around the Sun. In the introductory passage, this model is presented as a solution to several mathematical, physical and theological difficulties. Epistemology is at stake as well, because hypotheses (or hypotyposes) ought to respect mathematical as well as physical requirements, and shall depict the real structure of the world. The following text could be read as a synthesis of the Wittenberg program:[147]

> I noticed that the old Ptolemaic system [*coelestium orbium distributionem*] [was] not harmonious enough [*concinnam*] and assumed too many epicycles, to account for the relations [*habitudines*] of the planets toward the Sun, for their retrogradations and stationary points as well as their apparent irregularities [*inaequalitatis*] in some parts [of their paths]. [I furthermore noticed] that [this model] was superfluous [*supervacaneam*] and even that those hypotheses were at odds with the first principles of the discipline [*artis*] [that is, astronomy] itself. In fact, they inconveniently assume that the equality of a circular motion could be around a different center than its own or even around the eccentric point of a different [circle] (which is commonly called the "equant"). Moreover, I examined the new theory introduced by the illustrious Copernicus following Aristarchus of Samus (see Archimedes's book for King Gelo of Sicily *On the Number of Sand Grains*). This [model] avoids Ptolemy's superfluous and inconvenient [*dissentaneus*] [devices] quite ingeniously and is perfect from a mathematical point of view. On the other hand, it confers to the body of the Earth (which is large, inert and unfit to motion) a destructive [*dissolutiore*] motion (even threefold) like those of the stars through aether. This [assumption] not only infringes on the principles of physics, but also on the authority of the Holy Scriptures,

146 Brahe, *Opera*, vol. 4, 155.

147 Ibid., 156.

> several passages of which confirm the stability of the Earth (as we shall discuss elsewhere). I will not discuss at present the excessively vast space between the orb of Saturn and the eighth sphere, attributed to the stars as a direct consequence of that vain conception, and other inconveniences connected with these speculations. When I noticed that both hypotheses entailed great absurdities, I began to consider whether I could find another approach to hypotheses [*hypothesium ratio*] which could satisfy the mathematical as well as the physical requirements and avoid theological censures.

In this passage, Brahe first listed Ptolemy's shortcomings. The principal one was the absence of *concinnitas*, which can be translated as "elegance," "grace" or "harmony." It might be a reference to the "symmetry" of Copernicus's system, in which the distances and the periods of planets were interconnected. Second, Brahe accused Ptolemy of employing an excessive number of epicycles to account for planetary retrogradations. Copernicus simplified this anomaly through the circle of the Earth around the Sun. Thirdly, the Ptolemaic models infringed on the first principles of astronomy (*has hypotheses contra ipsa artis prima principia peccare*), since the centers of planetary motions were modeled through eccentrics (and equants), instead of being circular and uniform about their centers. All of these "mistakes," Brahe observed, had been emended by Copernicus thanks to the reassessment of Aristarchus's system. The system of *De revolutionibus*, according to him, was perfect from a mathematical point of view (*nihil contra mathematica principia delinquat*). Nonetheless it was at odds with physics, because the Earth is incapable of moving due to its heaviness. Additionally, Brahe remarked that the Scriptures assert that the Earth is stationary. A further problem of the Copernican system was the excessive distance (*capacitas*) between Saturn and the fixed stars. Brahe claimed that only his system could overcome all Ptolemaic and Copernican flaws at the same time. His planetary theory was satisfactory from all viewpoints: mathematical, physical and biblical.

In spite of Brahe's claims, his solution was not a purely individual discovery, but rather the outcome of a long process, which had begun since the earliest reception of Copernicus by Reinhold. It is no coincidence that geoheliocentric systems were discovered and developed by other scholars independently of Brahe, as was especially the case for his great adversary Ursus, who even anticipated him with the publication of a geoheliocentric planetary model in his *Fundamentum astronomicum*. The shared character of these ideas was clear to the minds of several contemporaries of Brahe, beginning with Rothmann, the court mathematician of Kassel who, after reading *De recentioribus phaenomenis* remarked, in a letter to Brahe of 13 October 1588:[148]

> As to your "new" hypotheses, I do not completely follow you. Actually, I myself, when I was writing my *Astronomical Elements*, positioned first the Moon and then Sun in the same manner about the Earth but [...] in such a way that the centers of the homocentric of the other planets always coincided with the center of the major epicycle of the Sun. In this manner they were transported together by the mean Solar motion on the homocentric of the Sun. Still, I did not consider that to be a new approach [*nova ratio*] but precisely Copernicus's one, apart from the fact that I could treat the matter in the reverse manner by bringing Copernicus's hypotheses back to the solar motion. Moreover, I assumed that also Rheticus and Reinhold considered that same approach. What's more, last year, also our Prince saw to the construction of an αὐτόματον, admirably small but capable of representing all planetary motions. [...] Hence, since you call your [hypotheses] new, please, let me know in your next letter how they can most aptly account for all singular appearances in all respects and how they can be regarded as something more than simply the reverse of the Copernican ones, if none of them is superior to the other from all viewpoints. In fact, if they are equivalent [*si eadem essent*], they do not account for the appearances better than the Copernican ones themselves. If all appearances descend from the Copernican ones, also those [hypotheses of yours] certainly descend from an inversion of them without any significant difference.

Rothmann essentially objected to Brahe that his hypotheses were not new to him and other German scholars: was not it just a reversal of Copernicus's hypotheses, which assuredly was already known to Reinhold and Rheticus? It is clear from Rothmann's words that, in his eyes, to be a follower of Copernicus meant first of all to assume his geometrical models, no matter in what cosmological framework. Moreover, since a geoheliocentric solution did not enhance the predictive capacity of astronomy, why renounce Copernican simplicity for a cumbersome combination of circles?

148 Brahe, *Opera*, vol. 6, 156–57. On the Landgrave's planetarium (or αὐτόματον), cf. Rosen, *Three Imperial Mathematicians*, chap. III, and Mosley, *Bearing the Heavens*, 278–284.

17 Beyond Selective Reading

To clarify the epistemology underlying Renaissance planetary astronomy means, to a great extent, understanding the meaning of the so-called *axioma astronomicum* and the tension between Ptolemaic astronomy and the Averroist-Aristotelian approach to nature. Copernicus tackled this issue and presented his undertaking as the solution to the historical problem of reconciling physical and mathematical astronomy at the beginning of the *Commentariolus*. As we have seen, this was also the main concern of the homocentrists of his age (Fracastoro and Amico) and his early German readers. To summarize, astronomical epistemology can be reduced to a few intertwined issues: first, the question of interdisciplinary ties (among mathematics, physics and, to a certain extent, theology) and the hierarchy of the different forms of knowledge (mathematical, philosophical and revealed); second, the relation between computation and reality; third the meaning of the *axioma astronomicum*; and finally, the geocentric employment of geometrical models resulting from the nesting of uniform circular motions. As these issues were interconnected and they all guided astronomical investigation before and after Copernicus, their analysis helps us understand essential aspects of the reception of *De revolutionibus* from Reinhold to Brahe, and beyond.

The majority of those who dealt with astronomy between the end of the fifteenth century and the beginning of the seventeenth century assumed that astronomical hypotheses should ultimately be accorded to physics. Still, most scholars did not agree about what these imperative physical requirements were. The main one was, as we have seen, the law of uniform and circular motion. This (not only Aristotelian) principle was interpreted and applied differently by different scholars: according to the Averroists, it meant a restoration of the concentric cosmology of Eudoxus, Callippus and, of course, Aristotle. Hence, they criticized (Ptolemaic) astronomers for employing epicycles, eccentrics and, what were deemed to be the worst devices, equants. Copernicus addressed the same problem—the accordance between mathematics and physics—but interpreted it quite differently, restricting it, in the *Commentariolus*, to the elimination of eccentrics and equants and, in *De revolutionibus*, to the rejection of the equant. The heliocentric orb of the Earth, substituting one of the two Ptolemaic anomalies for planetary longitudes, was not directly relevant to reestablish circular and uniform planetary motions. For this reason, Reinhold could extol Copernicus's respect for the *axioma astronomicum* without embracing his planetary system. Instead, he sought a geocentric translation of the Copernican geometrical models. The physical requirements relevant to him (and to most of his followers, beginning with

Peucer) were terrestrial centrality and immobility, as well as the use of geometries for planetary theory. For them, homocentrism was no option.

No German theoretical astronomer, in those years, would really renounce physical tenability for computation. This is true for Reinhold, for his follower Peucer and, of course, for Brahe. As a young man, Rheticus was also convinced of the physical reality of the planetary geometries assumed by the astronomers: in his case, this meant complete adherence to Copernicus's system. Even Wittich, the skillful mathematician from Wrocław who freely tested equivalent planetary models, was glad to figure out a geoheliocentric model combining terrestrial centrality and immobility with the heliocentric orbit of the inferior planets. The only authors who endorsed a computational astronomy renouncing physics were not mathematicians or astronomers, but a theologian and a philosopher: Osiander and de la Ramée. It seems that Rheticus, who had friendly relations with both and has been generally presented as the "most realist" of all German readers of Copernicus, may have embraced the program of a computational astronomy renouncing hypotheses in his later years. Osiander's demand, however, did not stem from an epistemological commitment dependent on astronomical research, or even from a deep awareness about the methods employed by professional mathematicians. Rather, his intention (like that of Bellarmino, many years later) was to assess the indifference of astronomical and natural knowledge in relation to the only reliable truth, which was that revealed by the Sacred Scriptures. As an epistemological requirement, his injunction was useless for astronomers. Furthermore, it was at odds with the views of Melanchthon, whose influence over German mathematicians, *in primis* Reinhold and Peucer, was enormous. Unlike Osiander, Melanchthon asserted the certainty of natural knowledge and the dependency of astronomy on physics, and of physics on theology. Unlike Osiander, he endorsed no skepticism, but promoted the investigation of nature and the study of mathematics as a means to reach God.

Scholars' opinions also diverged about the validity of a mathematical representation of the universe. Following Aristotle, Melanchthon held geometrical models to be *entia rationalia*, that is, abstract representations detached from reality. By contrast, Reinhold was rather Platonic in his idea that natural regularities—those displayed by celestial bodies—were intrinsically mathematical but not perfect. Thus, according to him, nature and knowledge can only approximate mathematical accuracy. As an ephemerist, he was, of course, aware how difficult it was to reach a perfect representation and computation of celestial phenomena.

It seems appropriate to mention here, in conclusion, that echoes of the German mathematical reception of Copernicus can also be traced to late

Renaissance Italy. Bernardino Baldi's assessment of Copernicus, in his *Cronica de matematici* (*Chronicles on the Mathematicians*, a manuscript first printed in 1707),[149] reveals an ambivalent reception of *De revolutionibus*. This mathematician, immersed in the Archimedean purism of Commandino's school and imbued of Roman Catholic Counter-Reformation culture, celebrated *De revolutionibus* as a great Ptolemaic achievement and a very noble book (*nobilissimo libro*), but at the same time he rejected the paradoxical assumption that the Earth could be moved: "On the occasion of the Lateran Council, for the emendation of the calendar, he [Copernicus] wrote his very noble book *On the Revolutions of the Celestial Spheres*, where he followed the false supposition of those who assume the Sun to be immobile, at the center, and the Earth to turn around."[150] As we have seen in this chapter, appreciation for Copernicus's geometries and parameters could be totally separated from the criticism of the geokinetic option.

Almost a century after completion of the *Commentariolus*, Galileo would rebel against the split reception of Copernicus generated by the conflict between mathematical astronomers (*astronomi puri*) and physicists (*astronomi filosofi*). In fact, he advocated the reality of Copernicus's system (*costituzione dell'universo*), presenting heliocentrism as an essential contribution to the restoration of a "true and good philosophy" (*vera e buona filosofia*) capable of overcoming the fractures of the past. In the first of his letters on the sunspots, *Istoria e dimostrazioni intorno alle macchie solari* (*History and Demonstrations Concerning Sunspots*, 1613), he wrote on 4 May 1612:[151]

> Eccentrics [...], deferents, equants, epicycles etc. [were] assumed by pure astronomers in order to make their computations easier, but they should not be considered in the same manner by philosophical astronomers who, besides the concern to save the phenomena at any price, seek to inquire about the true structure of the universe as the highest and most admirable problem, because this structure is [real]—in a unique, true, real and impossibly different way—and it ought to be put before all other scientific questions, as a consequence of its greatness and nobility.

149 The manuscript is preserved at the History of Science Collections of the Oklahoma University Libraries in Norman, Oklahoma (USA) and has been generously been made available on the Internet: http://hos.ou.edu/galleries//16thCentury/Baldi/1596/ (20 August 2011).

150 Baldi, *Cronica*, 120–21.

151 EN, vol. 1, 335–36.

According to Galileo, Copernicus belonged to the group of the philosophical astronomers, those concerned with reality and not only with abstract geometrical models and computation. He vindicated the priority of the cosmological issue over an astronomical investigation limited to the evaluation of geometrical devices. From this perspective, the relevance of Copernicus's achievement lay in the substitution of a Ptolemaic anomaly, through the circle of the Earth about the Sun, rather than in the rejection of the equant or in other partial aspects of the theory that guided the research of many German scholars up to Brahe. According to Galileo, the problem was not only to assert the disciplinary interdependency of mathematical and physical astronomy, but also to establish what, within the mathematical line of reception of Copernicus, was the most relevant innovation. Along with the rejection of any form of computational (rather theological) conventionalism, Galileo pointed out that the fundamental achievement of Copernicus was cosmology.

CHAPTER 3

Beyond Computation: Copernican Ephemerists on Hypotheses, Astrology and Natural Philosophy

It has long been almost a commonplace that sixteenth-century Copernican compilers of tables and ephemerides focused on computation and astronomical prediction and had no marked interest in cosmological and natural issues, that is, in questions related to planetary hypotheses and physics.[1] In the preceding chapter, I already pointed out the weakness of this opinion due to the realist commitment of several German mathematicians. The concern for the "real" planetary order also emerges from the publications on ephemerides by several followers of Reinhold in different countries: Johannes Stadius in Flanders, Francesco Giuntini in France, Giovanni Antonio Magini in Italy and David Origanus in Germany. Besides these schools, I shall consider Reiner Gemma Frisius and Giovanni Battista Benedetti, Renaissance mathematicians who concentrated, among many other things, on computation along with (Copernican) cosmology. All of these scholars accompanied their work on tables and ephemerides with speculations on planetary hypotheses, although they did not necessarily share the same views, especially on terrestrial motion and heliocentrism. The variety of their opinions bears witness to the dimensions of the theoretical and philosophical debate involving scholars who have often been considered to be concerned exclusively with "saving the phenomena." As I will show in the following, in many cases the circulation of tables and ephemerides was intended as a contribution to the debate on hypotheses as well as a means to stress the cultural value of astronomy, both theoretical and practical. As Renaissance ephemerists' work was closely connected with astrological practice, I shall consider this aspect as well.

1 A Premise: Gemma Frisius as a Reader of Copernicus

Valuable evidence of an early reception of the heliocentric system as a physical reality is a letter by Gemma Frisius to his pupil Johannes Stadius. It was printed posthumously as a preface to the latter's *Ephemerides novae et exactae* for the years 1554–1570 (*New and Exact Ephemerides*, 1556). Before I consider this

1 Duhem, *To Save*, chap. 6.

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witness, it would be expedient to introduce Frisius and recount his acquaintance with Copernicus.

Frisius was a Flemish pupil of Peter Apian and a skillful inventor of globes and mathematical instruments. His correspondence shows intense contacts with Varmia, in particular with bishop Dantyszek.[2] As a professor of medicine and mathematics at Leuven (beginning in 1541), he taught outstanding students like Mercator, Stadius and Dee. One of his major scientific contributions was a complete treatment of the principles of triangulation in a *Libellus de locorum describendorum ratione* (*Booklet on How to Describe Places*), which first appeared as an appendix to the Antwerp edition of Apian's *Cosmographicus liber* in 1533, which was to influence famous scholars like Brahe and Snellius.[3]

Thanks to Frisius, Copernicus's work and views spread throughout Flanders and beyond. Notably, references to Copernicus's astronomy can be found in writings on mathematical instruments that are apparently far removed from the theoretical concerns of *De revolutionibus*, as for instance in the treatise *De radio astronomico et geometrico* (*On the Astronomical and Geometrical Staff*, 1545). The *radius* was "an astronomical and geometrical" instrument which served to "measure all the heavens and the Earth," as its inventor claimed. Its purpose was to measure longitudes and latitudes, distances and heights in topography as well as in astronomy.

Frisius celebrated the renewal of sciences in his time, especially that of medicine, which he regarded as an essential part of natural philosophy, and of mathematics (*mathematicae artes*). These disciplines, according to Platonizing neo-Pythagoreanism, should raise man to the cognition of the highest truths (*maximae res*). In *De radio*, Frisius was cautious about the astronomical novelties of those who, in his words, "aimed at, I do not dare say accomplished," the emendation of astronomy. This seems to be a reference to Copernicus. In the same context, Frisius praised the recent advancements of astronomy and did not spare Ptolemy's parameters, whose shortcomings had long since become evident through astronomical observation.[4]

He read and painstakingly annotated the chapters of *De revolutionibus* dealing with trigonometry[5] and referred to Copernicus, together with Euclid and Regiomontanus, for the explanation of the geometrical and trigonometrical properties of his *radius*.[6] In chapter 16, "On the Distances of Stars in the

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2 See GA VI/1, *passim*.

3 Cf. Haasbroek, *Frisius*. For an introduction to Gemma Frisius, see: Hallyn, *Gemma Frisius*.

4 Frisius, *De radio*, f. 4*r*.

5 Gingerich, *Annotated Census*, 146–50.

6 For a eulogy on Copernicus's trigonometry, see Gemma Frisius, *De radio*, ff. 35*v*–36*r*.

Heavens and the Apparent Diameters of the Luminaries (*De stellarum distantiis in coelo et luminarium diametris visis*), the discussion on how to measure the diameters of the Moon and the Sun and their apparent variations offered him the occasion to criticize the homocentric cosmology of the Averroists. A planetary theory in which all celestial bodies are always supposed to be equidistant from the center is simply contrary to observation. Frisius appealed to this evidence (*certissima experientia*) against Aristotelian fictions (*somnia*). He furthermore rejected *ad hoc* conjectures like the existence of an inhomogeneous celestial fluid devised to account for the varying dimensions and brightness of celestial bodies. This remark could be an objection to Fracastoro, who proposed this thesis in the *Homocentrica* (1539).[7] Contrary to the Averroists, Frisius held that epicyles and eccentrics could not be dismissed.

Having accepted this kind of geometrical device, he praised the superiority of Copernicus's solar and lunar theory over Ptolemy's. Concerning the Moon, Frisius resumed Regiomontanus's and Copernicus's criticism of the *Almagest*, whose lunar theory could not accurately account for the variation in the dimensions of that celestial body. In these pages Frisius even called Copernicus a "new Ptolemy" for his improvement of the lunar theory.[8]

As one reads in *De radio*, Frisius intended to avoid the discussion as to whether the Sun is transported by an eccentric or an epicycle, as he was solely interested in the observational fact of its varying distance. This indirectly shows his familiarity with details of *De revolutionibus*. In *De revolutionibus* III,14, Copernicus assumed that the Sun is not precisely at the center of the Earth's circle, because a certain eccentricity should account for the irregularity of its apparent motion, but also explained that there are two geometrically equivalent models, epicyclic and eccentric. Frisius, moreover, pointed out the importance of Copernicus's solar and lunar theory for the exact determination of eclipses, observing, in chapter 17, "On the Magnitude of Eclipses" (*De eclipsium magnitudine*), that this was the only astronomical issue that really fascinates ignorant people.[9]

As to astrology, Frisius was quite cautious. He conceded that stars influence terrestrial events, but was dubious about the extent of this action: "I never believed that human will is subjected to their command."[10] His interest

7 Ibid., ff 29*r*–*v*. See chap. 2,6.

8 Ibid., ff. 28*v*–29*r*. The advantages of the lunar theory of *De revolutionibus* had already been emphasized by Reinhold in his edition of Peuerbach's *Theoricae novae planetarum*, a work that Frisius knew and quoted in *De radio* (cf. ibid., f. 31*r*).

9 Ibid., ff. 29*v*–30*r*.

10 Ibid., f. 4*v*.

in astronomy did not primarily concern astrological application, in contrast to many of his contemporaries—for instance, his son Cornelius, and his pupils Stadius and Dee, who were keenly interested in casting horoscopes and prognostications.

In chapter 19, Frisius explained how to ascertain the positions of planets and comets using his astronomical staff. There, he assessed that Copernicus's emendation of the Martian theory allowed the inaccuracies of the *Alfonsine Tables* to be overcome.[11] In chapter 22, "Longitudes Determined through the Position of the Moon" (*De longitudine locorum per lunae locum*), Frisius determined the longitude of Leuven with respect to Cracow, which is the meridian to which Copernicus referred. This choice documents, once again, his profound respect for the work of the Polish astronomer.

All of these implicit and explicit references show that Frisius had read *De revolutionibus* accurately and extensively. Still, he did not openly declare his position on terrestrial motion in *De radio*. In this book he dealt with astronomical and geographical issues in as much as they pertain to the techniques of observation and measurement. Hence, he focused on those aspects of *De revolutionibus* that were immediately relevant to this topic: observation, the computational reliability of astronomical tables, the computation of ephemerides, and the accuracy of heavenly parameters.

2 Frisius's Cosmological Commitment in Stadius's Ephemerides

Contrary to the circumspection of *De radio*, Frisius openly expressed his adherence to the Copernican system in his letter to Stadius of 1555, published as a preface to Stadius's *Ephemerides novae*. These ephemerides were computed from Reinhold's *Tabulae*, and thus relied indirectly on Copernicus.[12] In his letter, Frisius emphasized that this was a link not only to Copernicus's parameters, but to his hypotheses as well. Frisius encouraged Stadius to publish his "Herculean work," to follow only the truth (ἀλήθεια) and to ignore the slander of his adversaries, perhaps theologians and natural philosophers. In fact, in the *artes*, especially astronomy, only the love for truth shall be taken as a guide.[13]

11 Ibid., ff. 34*r*–*v*.

12 See Gingerich, *Eye*, 194–96, 222–23.

13 Gemma Frisius, "Epistola de operis commendatione" (Leuven, 28 February 1555), in Stadius, *Ephemerides novae*, f. a1*r*.

> But, you will say, whose authority could give so much assurance? Assuredly the queen and just ruler of all the arts: the truth. [. . .] In fact, in this kind of studies [. . .] it could not be obscured or suppressed by any force of wit, by any barking crowd or the malice of poisoning people.

The expression "barking crowd" (*oblatrantium turba*) may have been drawn from Copernicus's letter to Paul III, in which it refers to the theologians ignorant about mathematics.

Frisius is conscious of the difficulties entailed in Copernicus's theory from a scriptural and natural point of view. The new hypotheses, he remarks, could be seen as absurd (παραδοξότατος), and renouncing the *Alfonsine Tables* as daring, because they had been approved by the astronomers of the past (*maiores nostri*). Critics would expect some justification for accepting opinions contrary to an established tradition. Who would be so naive (εὐπειθής), Frisius asks rhetorically, as to accept terrestrial motion in a motionless heaven or to acknowledge the immobility and centrality of the Sun?[14] The answer is preceded by a methodological statement: astronomy should rely on reason rather than tradition, on *veritas* and arguments instead of *auctoritas*. Frisius claims that Aristotle would have approved these principles even though they could be directed against his epigones. In natural philosophy and mathematics, according to Frisius, authority has no cogency and astronomy cannot be grasped by those lacking theoretical insight (ἀθεορητοί), a sense of harmony (ἀμούσοι), and geometrical education (ἀγεωμέτρητοι).[15]

Given the shortcomings of the old astronomical tables, Frisius welcomes Copernicus's correction of astronomical parameters. He declares that Copernicus, a "very ingenious and diligent man" (*vir ingeniosissimus et solertissimus*), emended astronomy by means of observation and demonstration, which are the "infallible bulwarks" of this discipline.[16] He takes into account terrestrial motion as well, in the dense passage that follows:[17]

> There remains the final difficulty concerning the motion of the Earth and the paradox of the Sun at rest in the center of the universe. Those, however, who lack [training] in philosophy and the method of demonstration do not understand the causes or the use of hypotheses. For, in fact, authors do not set up these [hypotheses] as if things must necessarily be

14 Ibid., f. a1*r*.
15 Ibid., f. a1*v*.
16 Ibid., f. a2*r*.
17 Ibid., ff. a2*r*–*v*. This is a revision of Westman's translation in *Copernican Question*, 181–83.

> so and could not be established in some other way. Rather, [the aim is] to obtain a reliable theory [*certa ratio*], avoiding utterly absurd [assumptions] and assuming principles [*exordia*] in agreement with nature, so that [the theory] corresponds to the motions relative to the apparent places of the stars in the heavens, for the future and the past, as well as for the present time. While at first sight Ptolemy's hypotheses may seem more plausible than Copernicus's, the former nevertheless commit rather many absurdities, not only because the stars are assumed to move non-uniformly on their circles, but also because they do not offer causes of the phenomena as evident as those of Copernicus. Ptolemy assumes that the three superior planets (by way of example), are always in perigees of their epicycles when they are achronic or diametrically opposite the Sun. And this is a fact [τὸ ὅτι]. On the other hand, Copernicus's hypotheses [permit to] infer the same fact as a necessary consequence, and provide the causal demonstration [διότι]. And [the Copernican hypotheses] attribute hardly anything absurd to the natural motions, from which one gains a better knowledge of the planetary distances than from the other [hypotheses]. Moreover, if anyone so wishes, he may also transfer to the heavens those motions of the Earth that he posits, except for the first two [axial rotation and annual revolution], and still use the same rules of calculation. Yet, that most learned and prudent man [Copernicus] did not wish that, for the stubborness of such spirits, the entire order of his hypotheses be inverted, but rested content to have posited what would suffice for the true determination [*inventio*] of the phenomena.

According to Frisius, Ptolemy's hypotheses must be substituted for those of Copernicus. These, as one reads, are neither absurd nor contrary to nature, since mathematical and physical arguments could underpin them. Hypotheses, Frisius adds, are necessarily related to nature. According to him, Copernicus's theory unveils the causes (*causae*) of celestial motions, as it not only describes how (τὸ ὅτι) stars move, but also explains why (διότι).

In the final lines of the aforementioned passage on terrestrial motion, Frisius hints at the possibility of transferring some Copernican motions, besides the daily and the annual, from the Earth to the stars. This is a reference to the precession of the equinoxes and its alleged irregularities. Many German mathematicians embraced this translation strategy, for instance Reinhold, Peucer and Wittich, and eventually Brahe. Frisius seems to consider the details of planetary theory to be still open to debate. He even suggests attentively reconsidering what part of the theory is strictly necessary to account for the phenomena.

Frisius concedes that Stadius's tables could be employed regardless of which set of cosmological hypotheses were adhered to. This statement assuredly refers to the fact that, for calculation, the only thing that matters is the accuracy of numerical parameters. As a matter of fact, sixteenth-century astrologers and almanac makers used Copernican and Alfonsine tables interchangeably, or both at the same time, as they were not able to establish the absolute predictive superiority of any one over the others.[18] Nonetheless, as Frisius's introduction demonstrates, ephemerides could be a means to disseminate philosophical and cosmological views. All readers and users of Stadius's book would encounter an apology for Copernicus's planetary theory right at the beginning of the volume.

Frisius's letter closed with the consideration that the publication of these "Copernican" ephemerides would bring eternal glory to their author. The prediction was exaggerated and, in fact, Stadius is not remembered as a major figure in the history of astronomy. Nonetheless, his work met with success and later scholars relied on it. For instance, the professor of mathematics at Frankfurt on Oder David Origanus, whom I will soon consider, presented his widespread ephemerides as a continuation of Stadius's even in his title: *New Ephemerides for 25 Years Beginning with the Year 1595 from Which Those of Johannes Stadius Begin to Be Most Significantly Imprecise* (1599).

3 Stadius and Copernicus

In the *Ephemerides* of 1556, Stadius did not openly declare his cosmological convictions, although Frisius's preface suggests that he did not dislike Copernicus's hypotheses. In the dedicatory epistle to Philip II of Spain, Stadius explained the importance of astronomy through a comparison between political power on Earth and the monarchy of the Sun in the heavens. The Sun, he wrote, is a king on whose authority the perpetual motions of Mars, Jupiter and Saturn depend.[19] This connection between the theory of the superior planets and the Sun is not enough, however, to ascertain Stadius's adherence to Copernicus's system. In fact, the solar theory was already central in Ptolemy's *Almagest*, and the Sun's physical and metaphysical preeminence was a commonplace of Renaissance philosophy:[20]

18 Kremer, "Copernicus among the Astrologers."

19 Stadius, *Ephemerides novae*, f. A2*v*.

20 Ibid., f. A3*r*. See Rabassani, "Analogia platonica."

> O very powerful King [Philip II of Spain], that perpetual harmony of the motions of the Sun and the three superior [planets], entails images of beautiful virtues. As our dukes, princes, leaders and heroes gracefully pay their respects to the King, in the like wise the Sun has of course its servants, the prefects Venus and Mercury. They encircle the Sun with a perpetual law of motion in such a way that sometimes they move toward it, as if they should receive some orders, and sometimes they run back away from it, as if they were sent to explore the dangers of the path.

Superior planets, so Stadius, receive from the Sun orders and force (*mandata et vires*). This could be a reference to a direct influence of the Sun exerted on the planets but, given its metaphorical character, it is difficult to interpret the passage in an unequivocal manner. Yet, Stadius is explicit about the heliocentrism of the inferior planets. Whereas superior planets are represented as dukes and princes, Mercury and Venus are the Sun's servants (*sui satelliti*). The information that the paths of the inferior planets are heliocentric (*circum Solem*) is explicit. By contrast, it is not clear what model Stadius has in mind here for the superior planets. It is even possible that he is referring to the Capellan system rather than the Copernican one. It should be remarked, though, that Stadius mentions Copernicus and Reinhold as those who corrected astronomy: "The theory of [planetary] motions needed to be emended. Copernicus began this project happily and Erasmus Reinhold of Saalfeld completed it."[21] Does this emendation concern only parameters, or hypotheses as well?

In 1560, Stadius published a set of astronomical tables entitled *Tabulae Bergenses* in honor of the Bishop of Liège Robert De Berghes. In the dedicatory letter, Copernicus's astronomy is said to be insuperable (*quo nihil hic orbis vidit aut exquisitius, aut concinnius*). The metaphor of the solar monarchy reappears, but this time the heliocentric disposition of all planets is more likely:[22]

> Admired about the Providence of the Divine Creator and the effective and vigorous presence of Him who manages the movement of those planets with harmony and unity, we worshipped [Him]. We saw that the Sun occupies the middle place, like the mind and eye of the world, and he who is the choragus of this divine theater, leader and prince of the planets, master of the light, illuminating the other [celestial bodies], that which gives the measure of time and the ages. Venus and Mercury always surround it like its assistants at a certain distance. But freer are those

21 Ibid., ff. A5*r*–*v*.

22 Stadius, *Tabulae Bergenses*, f. A2*r*.

> who wander further away: Saturn, Jupiter, and Mars. Still, they receive the splendor of its majesty in the proximity of the Sun […], and they ascend in the north, and descend in the south. And the Sun's course rules the irregularity [*ambiguitas*] of their [apparently] inexplicable motions in a straight way, and explains it.

From this passage it is not evident that Stadius was a realist Copernican rather than a supporter of a partial heliocentric system, namely the Capellan. Still, his teacher's opinion and his own praise of Copernicus's "exquisite and harmonious" astronomy might be revealing of his fuller approval of the heliocentric hypotheses.

In an outline of the history of astronomy (*astronomiae historia*), attached as an introduction, Stadius traces the origins of the discipline back to Adam. He deems it to be a divine science, revealing God's Providence behind the (geometrical) perfection of the heavens. He treats with particular attention the alleged forerunners of Copernicus. One reads that Plato went to Italy to learn from Philolaus that the Earth "moves around a central fire," that Ekphantos, Herakleides Ponticus and Hiketas of Syracuse already set the Earth in motion, and that Aristarchus of Samos anticipated modern heliocentrism.[23] Finally, Copernicus appears as the one who offered a new resolution to the principal problems of astronomy. Stadius claimed that, if anyone, entangled in the bending and winding labyrinth of astronomy, were able to catch the thread offered by Copernicus, in order to escape, then this person would boast immortal glory (*Ecquis in talis labyrinthi flexibus ambagibus implicatus, Nicolao Copernico filum ut sese explicet porrigendi, immortales non habeat glorias?*).

4 Ephemerides and Astrology

Not only did Stadius consider his ephemerides to be a means to propose cosmological views, namely the Copernican system, he also regarded their publication as an occasion to illustrate the cultural and practical meaning of astronomical computation, which was, in his eyes, essentially astrological and medical. Stadius published some medical-astrological remarks as an introduction to his *Ephemerides novae*, entitled *Hermetis Trismegisti Iatromathematica, hoc est medicinae cum mathematica coniunctio, ad Amonem Aegyptium conscripta* (*Hermes Trismegistus's Iatromathematics, That Is, The Unification of Medicine with Mathematics, Written to Amonem the Egyptian*). He regarded

23 Ibid., 11.

ephemerides, as did most of his contemporaries, as the link between theoretical and practical astronomy, that is to say, between the mathematical theory of celestial motions on the one hand, and astrology and medicine on the other. It should be added that physical reality could not be alien to the mind of an astrologer, since he was supposed to deal with the causal effects of heavenly bodies on the Earth.

The interdependency of astronomical computations and astrological prognostication had been a commonplace since antiquity. Francesco Giuntini traced this dichotomy back to Ptolemy: "Ptolemy completely treated all the principles of these [two] parts [of the discipline]: the first [theoretical astronomy] in the *Almagest*—whence all other theories and tables descend—and the second in *Quadripartitum* et *Centiloquium*: to which many ventured to add many things, but not all of them rightly; many of them even wrongly and badly [...]."[24] In his well known commentary on Sacrobosco (*In Sphaeram Ioannis de Sacrobosco*, 1581), the Jesuit mathematician Christopher Clavius presented astrology as the practical part (*pars practica, id est operans et agens*), complementary to the theoretical one (*pars theorica, id est contemplatrix*), in spite of the Catholic aversion to astrology, which led to the prohibition of its practice in 1586.

Several Renaissance astronomers and natural philosophers were inclined toward apocalyptic and eschatological interpretations of heavenly *prodigia*, such as particular conjunctions (Saturn and Jupiter, e.g. in 1524 and 1584), comets (e.g. that of 1577–1578) and supernovas (in 1572 and 1604).[25] The German ephemerist Johannes Stöffler, for one, predicted a deluge in 1524, "setting Europe in fear."[26] The Bohemian ephemerist Cyprianus Leowitz predicted apocalyptical consequences for the conjunction of 1584 in *De coniunctionibus magnis* (*On Great Conjunctions*, 1564).

In this cultural environment, the early reception of Copernicus was permeated by astrological themes. As already remarked, it was Rheticus who first pointed out this link. Bodin harshly criticized Leowitz's predictions in the fourth book of his *De la république* (1576), and extended the anti-astrological polemic to Copernicus, ascribing to him Rheticus's identification of the solar eccentricity with the "Wheel of Fortune." Bodin not only affirmed the independence of politics from astrological determinism, but also attacked the *paradoxon*

24 Giuntini, *Commentaria in Sphaeram*, vol. 1, 3.

25 Cf. Hellman, *Comet* and Granada, "Novelties."

26 Zedler, *s.v.*

of terrestrial motion, considering terrestrial motion to be irreconcilable with astrology, since celestial effects on Earth should depend on celestial motions.[27]

On the other hand, many scholars expected from Copernicus the mathematical precision necessary to cast accurate horoscopes and predictions. Astrology was part of the cultural background of the first German readers and followers of Copernicus. Wittenberg scholars were particularly keen on it. Apart from Melanchthon and Rheticus, Reinhold and Peucer, too, were interested in the practical side of astronomy, and Gasser, who was a pupil of Melanchthon, compiled predictions as well.[28] The proximity of Copernicus's astronomical work and astrological practice in Renaissance culture is confirmed by the editorial line of the Nuremberg printer Heinrich Petri. In 1543, he printed, together with *De revolutionibus*, Girolamo Cardano's *Restitutio temporum et motuum coelestium* (*Restauration of Celestial Times and Motions*, 1543). This work could be perceived as a practical integration of Copernicus, since the Italian physician and mathematician expanded on astrological issues about which Copernicus had preserved a rigorous silence.[29]

5 Some Remarks on Rheticus's Challenge to Pico

It is difficult to establish the extent to which Copernicus practiced and supported astrology, as he did not even hint at this discipline in *De revolutionibus*.[30] He practiced medicine, which, to a large extent, was based on astronomical knowledge, and he did not oppose Rheticus's astrological considerations on the Wheel of Fortune in the section "The Kingdoms of the World [*monarchiae mundi*] Change with the Motion of the Eccentric" of the *Narratio prima*. Rheticus wrote:[31]

> I shall add a prediction. We see that all kingdoms have had their beginnings when the center of the eccentric was at some special point on the small circle. Thus, when the eccentricity of the Sun was at its maximum, the Roman government became a monarchy; as the eccentricity decreased, Rome too declined, as though aging, and then fell. When the

27 Bodin, *Six livres*, IV,2.

28 See Thorndike, *History of Magic*, vol. 5, chap. 17, "The Circle of Melanchthon;" Kusukawa, *Transformation*; and Burmeister, *Gasser, passim*.

29 On Cardano's astrology, cf. Grafton, *Cardano's Cosmos*.

30 Yet, his birth horoscope has been preserved. Biskup, *Regesta*, Figure 22.

31 Rheticus, *The Narratio*, 121–22. Cf. GA VIII/1, 11.

> eccentricity reached the boundary and quadrant of mean value, the Mohammedan faith was established; another great empire came into being and increased very rapidly, like the change in the eccentricity. A hundred years hence, when the eccentricity will be at its minimum, this empire too will complete its period. In our time it is at its pinnacle from which equally swiftly, God willing, it will fall with a mighty crash. We look forward to the coming of our Lord Jesus Christ when the center of the eccentric reaches the other boundary of mean value, for it was in that position at the creation of the world.

Astrology, prognostication, the horoscope of religions and eschatology are interwoven in this passage. The small circle of the solar eccentricity traced by Copernicus corresponds to the *rota fortunae*, the "Wheel of Fortune, by whose turning the kingdoms of the world have their beginnings and vicissitudes."[32] Additionally, Rheticus claimed that Copernicus's "perpetual" astronomy was in agreement with ancient observations and would not fail in the prediction of future phenomena. In his opinion, Copernicus's emendation of astronomy could overcome many anti-astrological arguments brought forward by Pico della Mirandola at the end of the fifteenth century:[33]

> If such an account of the celestial phenomena had existed a little before our time, Pico would have had no opportunity, in his eighth and ninth books, of impugning not merely astrology but also astronomy. For we see daily how markedly common calculation departs from the truth.

Rheticus refers here to Pico's philosophical refutation of astrology published posthumously in 1496, *Disputationes in astrologiam divinatricem* (*Disputations against Divinatory Astrology*), which depicted astrology as the source of all superstitions infecting arts and sciences—philosophy, medicine and religion included. Pico's main argument was that it is impossible to infer real effects from universal causes because individual effects are consequences of individual causes (e.g., the direct cause of the growth of the wheat in the fields is not the stars, but the farmer's planting seeds). In a vulgarization of Pico's treatise, *Trattato contro gli astrologhi* (*Treatise against Astrologers*), the Dominican preacher Girolamo Savonarola bolstered this criticism with theological arguments, considering astrological necessity to be irreconcilable with human

32 Rheticus, *The Narratio*, 122.

33 Ibid., 126–7. GA VIII/1, 13.

responsibility and divine freedom. Astrologers, according to him, were nothing more than false prophets.

In the *Narratio prima*, Rheticus focuses on books number eight and nine of Pico's *Disputationes*, those dealing with the reliability of mathematical astronomy and with the predictive capability of astrology. If the calculation of celestial positions is not extremely accurate, so Pico, astrological forecasting cannot be valid because even a small variation should determine very different effects. For the sake of prognostication, it is important to establish, first, the exact moment of the beginning of an event; second, the exact relative positions of celestial bodies; and third, the causal correspondence between celestial and terrestrial events. Pico argues that none of these three points could be ascertained or, at least, nobody had ever been able to do so.[34] Among the shortcomings of mathematical astronomy listed by Pico is the impossibility to count all visible stars and to establish whether there are other ones out of sight. He also mentions other controversial issues, including the number of celestial spheres, the reform of the calendar and the rate of the precession of the equinoxes.[35] He argues that it is impossible to cast any birth horoscopes due to the difficulty of determining the precise position of celestial bodies at any given moment and the errors of existing astronomical tables. Spherical astronomy and planetary theory, he argues, are too uncertain to offer a reliable basis for astrology.

Well, contrary to Pico, Rheticus claimed that prognostication had been restored thanks to Copernicus. He asserted that all theoretical problems had been solved. Thus, astrologers should employ Copernicus's theory and Copernican tables for their predictions.[36]

6 Giuntini's Post-Copernican Astrology

Among Renaissance astrologers using Copernican computations, the Italian theologian Francesco Giuntini, a religious exile in Lyon, occupies a prominent position. In 1573, he published a momentous work in two volumes entitled *Speculum astrologiae* (*Astrological Mirror*). It included several astronomical

34 Pico, *Disputationes*, II, 287.

35 Ibid., 229 and 245.

36 In *The Copernican Question*, Westman has overemphasized these statements. According to his narrative, Copernicus's hidden project was to strengthen astrology through an emendation of its astronomical-mathematical basis, beginning with planetary order. Yet Westman does not bring new evidence about Copernicus's interest in prognostication, apart from circumstantial observations on the scientific culture of his epoch.

and astrological writings, among them a commentary of Sacrobosco's *Sphaera*. This was itself an extensive treatise that had already been published separately.

This commentary on the *Sphaera* is a general introduction to astronomy. It is not particularly well structured, as various issues are discussed randomly and inserted in the body of Sacrobosco's text, such as digressions on trigonometry, the employment of astronomical instruments, biblical chronology, literature (including long quotations from Dante Alighieri), a defense of the priority of Vespucci's discovery of America over Columbus's, and much more. In the second book, Giuntini tackles the solar theory and makes reference to the "Copernican" doctrine of the Wheel of Fortune.[37] He also discusses portentous phenomena, such as the nova of 1572, and comets. Following Aristotle, he regards comets as meteorological phenomena and contrasts the "Pythagorean" opinion that they are like planets. Hence, he rules out their power to exert astrological influence or announce calamities.[38] As to the nova, Giuntini limits his remarks to the observation that it appeared above the Moon, an extraordinary fact in contrast with the Aristotelian principle that nothing can be generated above the lunar sphere.

The *Speculum astrologiae* included many writings dealing with the details of astrology. The first essay of the collection, *Defensio bonorum astrologorum de astrologia iudiciaria adversus calumniatores*, was a defense of "good" astrologers against "calumniators" like Augustine, Pico, Savonarola and Calvin. Giuntini repeated the commonplace that astrology is the science of Providence. Even though he supported this practice, he did not renounce human and divine freedom, as he claimed that stars influence human actions without compulsion, and that God can subvert the laws of nature if he wishes to do so.

In a long catalog (*Catalogus doctorum virorum, quorum, ad absolvendum astrologiae speculum, annotationes, lucubrationesque nos iuvarunt*), Giuntini listed all astronomers on whom he relied. The series begins with Hermes Trismegistus and includes Abu Ma'shar and other Arabs, Campanus, Sacrobosco, Regiomontanus, Werner, Stöffler, Peter Apian, Oronce Finé, Cardano, Leowitz, Stadius and Clavius. It is likely that the omission of Copernicus is due to the fact that he appreciated *De revolutionibus* only for its solution of special problems and heavenly parameters, while he disagreed with Copernicus's hypotheses and regarded his contribution to astrology as only indirectly relevant.

Yet, many references to Copernicus are spread throughout Giuntini's work. The second volume of the *Speculum* contains astronomical tables (*Tabulae resolutae astronomicae de supputandis siderum motibus*) that refer

37 Giuntini, *Commentaria*, vol. 2, 285–86.

38 Ibid., vol. 1, 55.

explicitly to Copernicus's observations and Reinhold's tables (*secundum observationes Nicolai Copernici, et Prutenicae Tabulae*).[39] In fact, Giuntini's tables are derived from the *Prutenicae tabulae*.[40] In the introduction, the author points to the superiority of the Copernican tables over the Ptolemaic, also referring to Frisius's *De radio*.[41] Here Giuntini's praise of Copernicus's achievement follows:[42]

> Since it has always been the custom of our ancestors to correct errors, and investigate, renew and illuminate the truth [...], nobody shall be surprised if the mathematicians abandoned Ptolemy's tables and constructed for themselves and their followers new ones closer to the truth (how much in fact those are distant from the truth is evident to everybody conversant enough in the discipline). Among them, King Alfonso and, in our times, Nicholas Copernicus (who deserves the first place in astronomy for his merit) dedicated to this task so much effort and care that the former [Alfonso] did not hesitate to put this unique pursuit before the royal power, and the latter [Copernicus], aiming solely at the truth, wished that all his efforts be focused on this [aim].

Giuntini's positive opinion of Copernicus does not concern planetary hypotheses, as he adheres to geocentrism. In addition, he maintains the Aristotelian separation between the sublunary sphere and the superlunary. He considers the heavens to be the noblest part of the universe. They are lucid, luminous, unalterable, composed by a quintessence and set in constant circular motion.[43] Giuntini brings forward many arguments against terrestrial motion, although he does not renounce a presentation of that "paradoxical" doctrine. He ascribes to the Pythagoreans the theory that the heavens are made of the same elements as the Earth, and that the Sun is a fiery body.[44] He ascribes the invention of heliocentrism to them, considering their assumption of a fire at the center of the world to be a reference to the Sun. In this manner, Giuntini reinforces the myth of the Pythagorean inspiration for Copernicus's views:[45]

39 Ibid., vol. 2, 371 ff.
40 See Proverbio, "Giuntini."
41 Giuntini, *Speculum*, vol. 2, 372b.
42 Ibid., vol. 2, 372a.
43 Cf. Giuntini, *Commentaria*, vol. 1, 99.
44 Ibid., vol. 1, 103.
45 Ibid., vol. 1, 212–13.

> Many among the philosophers who held that the world is limited said that the Earth is at its center, for example Anaximander, Anaxagoras, Democritus, Empedocles and Plato. But the Pythagoreans said that fire is situated in the center of the world, while the Earth moves, like a star, in a circle around the center of the world. They also claimed [the existence of] another Earth opposite to this Earth, which they deemed to move just as this one; they called it "Antichthona," because it is located opposite to this Earth. It is possible, as Saint Thomas says, that they asserted this without meaning it literally [*secundum apparentiam sermonum*]. Rather, they metaphorically meant that the fire is at the center, because the natural heat produced by the Sun and the stars penetrates [everything] down to the center of the world, warming up everything. Moreover, they called the Earth a star, because it is the cause of day and night through its relation to the Sun. They also called the Moon another Earth, only because it is not penetrable by the light of the Sun, as appears on occasion of the eclipses, just as the terrestrial element. Others said that the Earth is at the center of the world and rotates there in a circle around the world's axis. A third group [of philosophers] said that it is at the center of the world and rests there, but they argued in different ways for this immobility.

To summarize, Giuntini focused on the advantages of Copernicus's parameters for astronomical computation and astrological forecasting. He distinguished between the validity of the numerical values and the physical tenability of cosmology. He rejected the motion of the Earth and the immobility of the Sun, which he considered to be the tenets of the Pythagorean worldview rather than a new planetary theory. On his judgment, parameters could be considered to be the only original contribution to astronomy on the part of Copernicus. Yet, Giuntini was not indifferent to the cosmological issue and considered it to be worthy of attentive discussion. For this reason he accompanied his astrological writings and his astronomical tables with considerations on the world system, albeit in disagreement with Copernicus.

7 Magini: Copernican Ephemerides, Astrology and Planetary Hypotheses

The case of Giovanni Antonio Magini, professor of mathematics at Bologna, has many parallels with Giuntini's. Magini published the first Italian ephemerides relying upon Copernicus in 1582. In the frontispiece, he declared that his computations were "in accordance with Copernicus's hypotheses, Reinhold's tables and the Gregorian calendar." This reference to hypotheses suggests that Magini was not merely interested in the computational aspect, but also in the planetary foundations of *De revolutionibus*.

Magini's ephemerides were preceded by some introductory essays. The first was a note (*animadversio*) against Stadius, whom he accused of failing to follow Reinhold with due accuracy. Magini defined the *Prutenicae tabulae* as a kind of mathematical "miracle" and called them "divine." In addition, he praised Copernicus for his predictive superiority over Alfonso, for his observations and his "new hypotheses":[46]

> Wherefore the complete investigation of this science was miraculously reserved for our age, when, in recent times, it was enlightened by two supreme masters of the art, namely Nicholas Copernicus and Erasmus Reinhold, stirred up by a special grace of God [*illustrata*], and it [astronomy] was restored to its original integrity. In fact, Copernicus brought his own observations together with the most certain [observations] of the ancients, and theses of more recent [authors] and accomplished his work *On the Revolutions of the Heavenly Spheres*. He moreover shared it openly with posterity [*posteri*]. Out of that divine work, Reinhold put together the *Prutenic Tables*, not without immense work.

Magini ensured the reader that his ephemerides were rigorously based on the *Prutenicae tabulae*, in contrast to Stadius, who, after 1595, computed his ephemerides from Cyprianus Leowitz. Magini also complained about the imprecision of Giuntini's tables.

In Magini's ephemerides, astronomy and astrology are closely linked. His work included a *First Treatise on Natural Astrology* based on Ptolemy. In its first section "On the Name, Partition, and Subject Matter of Astrology" (*De nomine, divisione, et subiecto astrologiae*), Magini reassessed the classic partition of astronomy into the theoretical and the practical (or astrological), one treating heavenly motions mathematically, and the other concerned with predictions, judgments and divination.[47] In turn, the first principles of astrology (*principia iudiciorum*) are derived from Ptolemy's *Quadripartitum*. They concern nature, forces, qualities of celestial bodies, and the partitions of the heavens. According to Magini, the use of astrology is legitimate only in four fields: 1. "the state of the world" (*de universi mundi statu*), that is politics, war and peace, as well as plagues, earthquakes and deluges; 2. air mutations (*de mutationibus*

46 Magini, *Ephemerides* (1582), f. 1*v*.

47 Ibid., f. 33*v*. Cf. Westman, *Copernican Question*, chap. 1.

aeris), that is, a sort of meteorology; 3. private life (*de privata cuiusque hominis vita*), health and luck, habits as well as bodily and character predispositions depending on one's nativity; and 4. indications for navigation, agriculture and medicine (*De initiis operum, actionum, rerum, et aegritudini*). The employment of prognostication beyond these boundaries is mere superstition.

Magini later repeated these ideas about the limited legitimacy of astrology in an apology entitled *De astrologica ratione* (*On Astrology*, published in Venice in 1607 and in Frankfurt on Main in 1608), issued after the Roman prohibition of astrological practice in 1586. In this work, he offered indications for medical practice according to Hippocrates and Galen. The correct employment of astrology in medicine (in accordance with the mentioned classical sources) should not be confused with its abuse in ethics (which is said to be the error of the "Orientals," in particular of Abu Ma'shar). In *De legitimo astrologiae in medicina usu* (*On the Legitimate Employment of Astrology in Medicine*), a brief tract from this collection, Magini claims that the Catholic Church should banish astrology from ethics, in which only will and personal responsibility count, but not from medicine, where it is necessary.[48] *De astrologica ratione* is essentially a commentary on the third book of Galen's *De diebus decretoriis*. Legitimate astrology, so Magini, brings us closer to God by revealing his Providence. It is so important for medicine that Galen called those who treat diseases without sufficient astrological education "murderers" (*homicidas appellat medicos astronomiae ignaros*). Magini lists many illustrious physicians who used astrology for their therapies, including the aforementioned founders of the discipline, as well as Ibn Sina (*Avicenna*), several papal physicians, and doctors from Padua and Bologna. He also mentions Reiner Gemma Frisius's son Cornelius,[49] and, in an additional annotation on medical-astrological sources, Stadius's *Iatro-mathematica*.

Hence, Magini's ephemerides, which are "Copernican" in the limited sense that they rely on Reinhold, are embedded in the tradition of astrological prediction and medical practice. The Catholic suspicion of astrology forced him to defend the employment of ephemerides in astrology and the legitimacy of this practice so far as it is based on Ptolemy, Hippocrates and Galen, and not on Arab sources. He only disapproved of the application of astrology to ethics as a source of irresponsible behavior and fatalism or, in a certain sense, of a doctrine *de servo arbitrio*.

This perspective did not hinder him from writing on hypotheses as well. In the *Novae coelestium orbium theoricae congruentes cum observationibus*

48 Magini, *De astrologica ratione*, 64.

49 On Cornelius Gemma, see: Hirai, *Cornelius Gemma*.

N. Copernici (*New Theories of the Celestial Spheres in Accordance with the Observations of N*[*icholas*] *Copernicus*, 1589), Magini stated that Copernicus had convincingly demonstrated the heliocentric orbit of the inferior planets. He did not renounce terrestrial centrality, but put the circles of the Sun, Mercury and Venus on three concentric epicycles transported by the same deferent:[50]

> For this reason, the theories of these three planets correspond to those imagined by Copernicus except for the fact that I put also the Sun in motion on an epicycle like Venus and Mercury. Hence, [their] three epicycles are transported by the same eccentric circle. In other words, they are so disposed that one encircles the other, although they do not lie on the same plane and this accounts for their motions in latitude.

Magini declared that his arrangement made it possible to fully appreciate Copernicus's achievement: "Moreover, I hope that this interconnected theory of these three planets will shed much light on Copernicus's considerations on the heavenly bodies. In my opinion, it makes his observations and demonstrations more intelligible."[51] Magini aspired to satisfy the requirements of the philosophers (*philosophorum rationes*) without renouncing Copernicus's and Reinhold's works, upon which his own ephemerides relied. The Capellan model seemed to him to be an arrangement that satisfied both mathematical and natural requirements.[52]

8 A Dispute on the Reliability of Ephemerides in Turin

The enduring link between ephemerides and astrology can be stressed through consideration of a special dispute over the reliability of ephemerides that erupted in the northern Italian town of Turin between 1580 and 1581, pitting Benedetto Altavilla, an obscure man from Vicenza, against the court mathematician Benedetti. The controversy was sparked by the publication of some *Animadversiones in ephemeridas* (*Remarks against Ephemerides*, 1580) by Altavilla.[53] The author's aim was to denounce the inexactitude of all existing astronomical computations. For this purpose he compared predictions

50 Magini, *Novae coelestium orbium theoricae*, ff. b3*v*–b4*r*.

51 Ibid. f. b4*r*.

52 On Magini as a theoretical astronomer, cf. Voelkel-Gingerich, "Magini's 'Keplerian' Tables."

53 On astronomical-astrological quarrels in Renaissance Italy and Turin, see Omodeo, "Stravagantographia" and Tessicini, "Comet of 1577."

and horoscopes cast using different sets of tables and ephemerides. In particular, he pointed out that ephemerides diverged from each other even more than the astronomical tables, Alfonsine or Copernican, from which they were derived. In his opinion, this fact undermined the reputation of astronomy in general, regardless of whether its cause was the inaccuracy of the compilers (*calculatores*) or the inexactitude of the tables themselves: "We consider nothing to be more odious than an unreliable person who is regarded by many as trustworthy."[54] Altavilla declared himself unwilling to decide between Alfonsine or Copernican computations. However, he himself was probably interested in the cosmological issue, judging by the fact that the *Animadversiones* were introduced with a poem by Pandolfo Sfondrati in favor of a new world system with the Earth in motion.[55]

Altavilla had established through observations that both Alfonsine ephemerides and Stadius's Copernican computations were in disagreement with the heavens. Still, Stadius's computations proved to be in better agreement with the heavens. The reference to Stadius is not casual, since the Flemish astronomer had been a protégé of Duke Emanuele Filiberto of Savoy, as one can read in the *Ephemerides novae* of 1556, where the author titled himself "mathematician to the King [of Spain] and the Duke of Savoy" (*Regius et Ducis Sabaudiae mathematicus*). Altavilla listed predictive errors of Ptolemaic astronomers (Regiomontanus, Stöffler, Leowitz) as well as those of post-Copernican ephemerists (Stadius and Giuntini). This led him to skepticism toward predictions in general: "You see, dear reader, how reliable ephemerides are."[56] Altavilla invited scholars (*magistri*) to trust only their eyes and to correct astronomy through observational campaigns with no regard for any authority: "Posterity should learn how dangerous it is to blindly adhere to the opinions of the ancients without [perfecting the art through] daily observations of the heavens, and to prefer their opinions to truth."[57]

The *Animadversiones* were soon followed by a second publication in Italian: *Breve discorso intorno gli errori dei calculi astronomici* (*Brief Discourse on the Mistakes of Astronomical Calculations*, 1580). A poem by a certain Francesco Onto of Pinerolo, inserted as a preface to the *Breve discorso*, made its polemic target explicit: "Altavilla has unveiled the astrologers' fallacy, as they think to cast sure [astrological] judgments about our lives relying on wrong ephemerides."[58]

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54 Altavilla, *Animadversiones*, f. A2*r*.

55 See Omodeo, "Poesia copernicana," and idem, "Sfondrati." See chap. 8,17.

56 Altavilla, *Animadveriones, Conclusio*.

57 Ibid.

58 Idem, *Breve discorso*, 2.

Altavilla's criticism was directed mainly against astrology, whose validity he considered to be doubtful due to the inaccuracy of predictions. His argumentative strategy was no different than that of Pico's in books eight and nine of the *Disputationes*, that is, an attack on mathematical astronomy aimed to discredit astrological forecasting. Altavilla even claimed that astrologers and ephemerists should renounce their activity, as they were not capable of superseding the flaws of their discipline: "Since it is impossible for the scholars in those sciences (especially those who are not capable of using the tables) to renounce ephemerides, and they know that they will encounter irremediable errors, they should be forced to abandon their studies."[59]

In his second publication, the *Discorso*, Altavilla complained that many scholars (not named) pretended to ignore his criticism. He explained that the decision to write another booklet, this time in Italian instead of Latin, originated from the desire to reach readers outside academic and scholarly circles, probably the Savoy court: "In these few pages, I aimed at demonstrating not only to the learned man, but also to everybody else, that the errors [of the ephemerides] are worthy of consideration."[60] He first reassessed the inadequacy of Alfonsine tables and Alfonsine ephemerides (Peuerbach, Prugnerus, Bianchini, Regiomontanus, Stöffler, Schöner, Gaurico, Pitati, Simi, Carelli, Moletti, Leowitz and others). He moreover stressed the superiority of the Copernican tables, in order to show the inconsistency of some unnamed Turin ephemerists, who used Alfonsine ephemerides for their predictions although they declared to prefer Copernicus. To illustrate this inconsistency, he analyzed some astrological figures on the basis of Stadius's and Giuntini's tables. In the last section, Altavilla turned on Copernican ephemerists, denouncing the excessive difference between computations based on Stadius and Giuntini: "And the difference between one computation and the other is really great and monstrous."[61]

This attack on the reliability of astronomical computations and astrology provoked negative reactions at university and court. Altavilla thus felt compelled to challenge his critics to an academic debate on 14 and 15 August 1581, announcing it through a broadside which is still preserved in the libraries of Turin, along with copies of his *Animadversiones*.[62] The public dispute concerned the theory of Mars for which, as one reads, some scholars blamed him. He held, in fact, that Mars cannot stay in a zodiacal sign for more than two

59 Ibid., 4–5.

60 Ibid., 3.

61 Ibid., 6.

62 In Turin: Biblioteca Nazionale di Torino, coll. Q.V.191, and Biblioteca Reale di Torino, coll. G.25.12.

months, considering that its entire revolution lasts twenty-four months. He argued that ephemerides are wrong if they forecast that it would spend six or even seven months in the same zodiacal constellation. This incorrect opinion presented the court mathematician and philosopher Benedetti with an occasion to intervene and criticize Altavilla on this and other issues related to astronomical theory, computation and astrological prediction.

9 Benedetti's Defense of Post-Copernican Ephemerides and Astrology

Soon after Altavilla's public dispute, Benedetti published an epistle "on some recent remarks and emendations directed against ephemerists" (Torino, 1581). At the beginning, Benedetti indicated Altavilla's intentions: "I assume [...] that his [Altavilla's] intention, was only to demonstrate that [different] ephemerides assigned a different place to the planet in the same point of time [...] and that, as a consequence, they offer no certain ground on the basis of which the future can be judged or predicted."[63] In his account, Benedetti rejects Altavilla's complaint that Copernican and Alfonsine ephemerides diverge from each other more than the tables from which they are derived. He ensures that "the computers have been very accurate and trustworthy" (*i calcolatori sono stati diligentissimi e fedeli*) and they are exact in their computations, although some minor and accidental mistakes can occur.[64]

Moreover, he accuses Altavilla of misunderstanding Ptolemy's astrology, interpreting it in light of Abu Ma'shar and al-Qabisi (*Alcabitius*). In particular, Altavilla draws from these sources the rule of the "triplicity" of the conjunctions of Jupiter and Saturn, according to which these planets meet four times in the same three astrological signs, or trine, before they can meet in the next trine. Altavilla neglects the fact that, although the mean motions of two planets should meet in the triplicity sign, nonetheless their "real" motions (those observed and calculated by the ephemerides upon which astrological predictions rely) may meet elsewhere. This is an obvious consequence of planetary theory, which distinguishes—so Benedetti—between "mean" motions, which correspond to the revolutions of the deferents, and "real" motions, which correspond to observable phenomena and are the product of moving epicycles. Benedetti calculates the period of triplicity to be 794 years and 138 days,

63 Benedetti, *Lettera*, 5.

64 Ibid., 6.

whereas the Arabs on whom Altavilla relies overestimated it at 960 years.[65] He furthermore remarks that Altavilla neglected planetary theory by criticizing those who let Mars run too fast or too slowly along the signs of the zodiac. Simple observations would show the correctness of the theory according to which the planet can remain in the same sign for six or even seven months. Benedetti explains that the amplitude of Mars's epicycle accounts for its complex phenomenology, in particular the long period of retrograde motion. He even reports an observational campaign accomplished between 1565 and 1566 in order to check Stadius's ephemerides:[66]

> Yet, he [Altavilla] dared too much, seeking to reprimand so many talented ancient and modern men who, as is required by diligent observers of the heavens, controlled with their own eyes these appearances of Mars as well as of the other [planets]. From those [observations], they were forced to "imagine" such a large [Martian] epicycle. By contrast, he has never observed the motions of either this or any other planet, but rather limited himself to look at what is written in the ephemerides. In fact, if he had at least said that he observed Mars's journey for a certain period, and that he found that the others' opinion was false, he would have at least given some "color" to his opinion. In my assessment, however, if he had made the observation of the path of Mars, he would have not held the contrary. In fact, the truth is the following: in every revolution of its epicycle, Mars in the lower part of its epicycle always stays many months (six or seven, or more) in a twelfth [*duodecatemerio*] of the zodiac. I observed this many times, for instance, in the years 1565 and 1566, as follows. First, consulting Stadius's ephemerides, I found that Mars would finish its retrograde motion on about 12 January 1566, in 16° of Gemini, and that, equally, Mars would be in the same place on the last day of August 1565, before it began its retrograde motion. Second, I found that, after that retrograde motion, on 11 April 1566, Mars would be in 16° of Cancer, so that it would take [Mars] seven months and eleven days [to move] those thirty degrees, from 16° of Gemini to 16° of Cancer. After these computations, I took the instruments and got ready to make a test. And I found that the last night of August of the year 1565 Mars was in the aforesaid 16° of Gemini, as Stadius had noted. I then made observations every week, in order to see the retrograde motion, and I saw that, at about the end of October, the [planet] began its retrograde motion and that retrograde

65 Cf. Bonoli, *Pronostici*, 49–55.

66 Benedetti, *Lettera*, 17–19.

> motion lasted until January (or about January) 1566. I later observed the position of that planet on 11 April, and I found it in 16° of Cancer, that is, the place where Stadius had located it. Thus, my experience confirmed Stadius's computations and I found that he was not mistaken. In the same manner, everybody can ascertain the truth every two years, by carrying out observations.

Hence, Benedetti demonstrated not only the theoretical incompetence of his opponent, but also his lack of empirical verification. Altavilla's appeal to base astronomy on observation backfired. Benedetti challenged his opponent to observe Mars's backward motion in Cancer which, according to Stadius's tables, would begin on 20 November 1582 and last until the end of February 1583. He furthermore observed that everyone familiar with planetary theory would understand the reasons for the orbit of Mars and other planets. For the theory, he added, it did not matter whether one relied on Ptolemy's *Almagest* or on the "*Rivolutioni de gl'orbi celesti* dell'eccellentissimo Copernico."[67] They were equivalent only as far as the understanding of a system of deferents and epicycles was concerned, but not in their general hypotheses, since Benedetti was himself inclined toward heliocentrism, as he declared in other writings that will be considered in the next chapters.

As to the difference between Leowitz's and Stadius's computations, Benedetti traced this back to the contrast between the theories underlying the Alfonsine and the Copernican tables. Nonetheless, he ensured that ephemerides never diverged by more than three degrees. Thus, if Altavilla detected greater discrepancies, this was due only to wrong computations. Benedetti added that Stadius's superiority over Leowitz was a consequence of his employing better parameters. He advised Altavilla to always rely on the most recent observations and tables.[68] In fact, the progress of astronomy was such that more recent tables would inevitably be superseded by new ones, augmented and perfected through new observations, just as Copernicus had superseded Alfonso. Divergence between ephemerides was not a shortcoming, but a necessary and desirable sign of the advancement of knowledge and predictive accuracy.

As a court mathematician, Benedetti also defended the validity of some astrological figures that Altavilla criticized in his second published work, *Breve discorso*. These horoscopes had probably been cast by somebody that he knew

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67 Ibid., 20.

68 Ibid., 32–33.

well. In fact, Benedetti was also charged with casting horoscopes for the dukes.[69] Altavilla complained that some astrological figures had not been calculated on the basis of Copernican tables. Benedetti replied that it was not always necessary to use the best tables for predictions, especially if a generic horoscope was expected and if the astrologer had no Copernican tables to consult. He showed, moreover, that Altavilla himself was not able to employ Giuntini's tables properly and made mistakes of computation. He concluded: "And such monsters [those denounced by Altavilla] are not generated by different tables or ephemerides but, instead, they are the offspring of this author."[70] He added as a remark: "As to the difference of the Sun according to Copernicus and Alfonso, no learned man, [expert] in these sciences, ignores it, and, as a consequence [everybody knows] the different place [assigned to it] in the heavens during the annual revolutions."[71] In 1581, the general views of *De revolutionibus* were so well known in Benedetti's environment that he deemed it unnecessary to expand on them in the context of a polemic on the accuracy of heavenly computations. The cosmological problem of hypotheses was not addressed explicitly in this dispute. However, the defense of mathematical astronomy could not avoid a reference to Copernicus as a source for tables (Reinhold, Stadius, Giuntini) and theory. In this context, "Copernican" and "not Copernican" are expressions that merely mean "based on Copernican tables" or not. Altavilla's criticism would have been more effective if it had been directed against astrological beliefs as such, rather than attempting to show the inconsistency of the mathematical basis of astrology without sufficient preparation. On the other hand, Benedetti, in his *Lettera*, focused on the mathematical aspects and cautiously avoided expanding on ethical issues related to astrology.

Altavilla never responded to the court mathematician who had rebutted him so brilliantly. The epilogue of their quarrel was the inclusion of a Latin translation of the *Lettera*, as *Defensio ephemeridum* (*A Defense of Ephemerides*), in Benedetti's *Diversae speculationes mathematicae et physicae* (1585).[72] In this same volume, Benedetti, like Gemma Frisius and Stadius, did not limit himself to considering astronomy from a merely computational point of view, but also wrote on cosmological issues and in defense of Copernicus's system.[73] I will discuss this in the next chapters. By now it is sufficient to stress that Benedetti, too, was one of those who dealt with ephemerides and astronomical

69 Roero, "Benedetti." On the Turin environment, see Mamino, "Scienziati."

70 Benedetti, *Lettera*, 37.

71 Ibid., 37–38.

72 Benedetti, *Diversae speculationes*, 228–48, "Defensio ephemeridum."

73 See Di Bono, "Astronomia copernicana" and Omodeo, "Cosmologia."

predictions, also in connection with astrology, without renouncing speculations on cosmological hypotheses. The section of the *Diversae speculationes* that includes the Latin translation of the writing on ephemerides, *Epistles on Physics and Mathematics*, also contained pages about the Copernican system.

10 Origanus's Planetary System

I shall now consider another ephemerist, very famous in his time, and his contribution to the discussion on cosmological hypotheses, in particular the motion of the Earth. David Tost, latinized as "Origanus," was professor of Greek and mathematics at Frankfurt on Oder beginning in 1586. He was renowned for his *Ephemerides novae* (*New Ephemerides*, 1599), for the years up to 1630, and the *Ephemerides Brandenburgicae* (*Brandenburg Ephemerides*, 1609), for the years up to 1655. Both ephemerides were preceded by broad astronomical and astrological introductions, but only the *Ephemerides Brandenburgicae* are relevant for the history of the reception of Copernicus's hypotheses because, unlike the first ones, they supported terrestrial motion and brought forward a series of arguments in favor of its physical and theological tenability.[74]

While the introduction of *Ephemerides novae* adhered to the Ptolemaic system, by 1609 Origanus had revised his opinion concerning astronomical hypotheses and adopted a variant of the Tychonic system. The *Ephemerides Brandenburgicae* comprise three volumes, a broad theoretical introduction and two volumes of ephemerides. Volume one is an overview of astronomy and astrology and has three sections: the first, "On Time" (*de tempore*), deals with chronology and the calendar; the second, which is the most relevant for our discussion, is entitled "On Motions" (*de motibus*) and deals with planetary theory; the third part, "On the Effects of Celestial Bodies" (*de effectibus astrorum*), concerns astrology.

In the subsection I,2 chap. 1, "General Notions on Stars, Spheres, Circles and Aspects" (*De stellis, orbibus, circulis et aspectibus generalia quaedam*), Origanus presents the geoheliocentric model. A planetary diagram derived from Brahe's *De recentioribus phaenomenis* is also included.[75] The author starts by explaining that the heavens are fluid, an assumption that should account for the intersection of the solar orbit with Mars: "It is surely for optical reasons that no physical spheres [*orbes*] or real circles exist in the heavens but rather stars

74 Cf. Omodeo, "Origanus's Planetary System."

75 Origanus, *Ephemerides Brandenburgicae*, 122.

move in spheres and circles in the most pure air or aether thanks to an inner force provided by God."[76]

Origanus considered the geoheliocentric system to be a five-heavens model: 1. Moon, 2. Sun encircled by Mercury and Venus, 3. Mars, 4. Jupiter and 5. Saturn. He traced this scheme back to Apollonius of Perga, following Ursus's assertion in his quarrel with Brahe over the authorship of the geoheliocentric model. Origanus, however, mentioned both predecessors with due respect and did not enter into the dispute.[77] He preferred to talk about the system of "Apollonius of Perga [. . .] and his followers: the very noble Tycho and the very subtle Ursus."[78] Along with Brahe, Ursus claimed that such hypotheses could bring together the advantages of the Copernican system without incurring the error of an almost infinite enlargement of the universe.

The model proposed in the *Ephemerides Brandenburgicae* diverged from Brahe's in two significant aspects: the assumption that the stars are located at various distances from the Earth, as witnessed by their different sizes and brightnesses, possibly derived from Brahe's opponent Ursus,[79] and the axial rotation of the Earth. Thus, Origanus derived different elements from the two competing geoheliocentric systems.[80]

According to Origanus, the so-called first motion (*motus primus*) is a product of the axial rotation of the Earth. The reasons are not merely optical, but physical: "This motion cannot be really ascribed to the stars, instead it is due to the Earth as a physical necessity."[81] To illustrate the apparent fixity of the Earth, he resorts to the Copernican *topos* of the ship, paraphrasing a line by Virgil often mentioned by advocates of the terrestrial motion, beginning with Copernicus himself: "Forth from the harbor we sail, and the land and the cities slip backward" (*Provehimur portu terraeque urbesque recedunt*).[82]

> The first motion of the heaven is the most evident and the most rapid among all celestial motions and is perceived by everyone. It goes from east to west around the poles of the world in 24 hours. Hence, this motion

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76 Ibid., 121.

77 Cf. Jardine, *Birth*, and Jardine-Segonds, *Guerre des astronomes*. See also Rosen, *Three Imperial Mathematicians*, Schofield, *Tychonic and Semi-Tychonic World Systems* and Granada, *Debate cosmológico*.

78 Origanus, *Ephemerides Brandenburgicae*, 121.

79 Ursus, *Fundamentum*, 38, th. 18.

80 Origanus, *Ephemerides Brandenburgicae*, 132–33.

81 Ibid., 133.

82 Ibid. Cf. Copernicus, *De revolutionibus* (1543), I,8, f. 6*r*. Cf. GA II, 15. See chap. 5,2 and 5,5.

> is called "raptus" and νυχθημέρινος, that is, daily (because it takes a civil day), as well as "prior" and "common," because all stars share it. This motion belongs properly to the Earth, which occupies the same place in the middle of the world like a movable globule hanging from a wall by a nail or an axis and rotates once a day about its poles and the world's axis from west to east. All stars in the heavens accordingly seem to go the other way round, from east to west in the south and from west to east in the hidden part of the heavens in a civil day. Similarly the coast seems to move in the opposite direction to the sailors, whereas it is the ship and not the coast that moves. If this motion did not exist, the Sun would rise and set down only once a year; the Moon once a month; <Saturn> about every thirty years, and so on. I demonstrated the impossibility of ascribing this motion to the stars and the physical necessity of terrestrial motion in my cosmographic writings [*in Cosmographicis demonstravimus*]. The second motion in the heavens is that proper to [every] celestial body [...].[83]

The cosmological writing on cosmography mentioned in this passage is lost. Nonetheless, it is possible to derive plenty of physical as well as theological arguments in favor of terrestrial motion and reflections on natural philosophy in the *Ephemerides Brandenburgicae*.

11 Origanus's Arguments in Favor of Terrestrial Motion

The dedicatory letter to Johann Sigismund of Brandenburg that opens the ephemerides of 1609 is a remarkable introduction to the cosmological and natural issues underlying Origanus's conception of astronomy. The beginning of this letter follows in Copernicus's footsteps, in particular the dedication to *De revolutionibus* to Pope Paul III, where Copernicus rejected as inconsistent the scriptural objections of those who are ignorant about mathematics and adduced the case of Lactantius who considered the Earth to be flat. According to Origanus, the investigation of nature and the search for scientific truth implies that opinions held for indubitable in the past can be questioned or even dismissed.[84] Cosmological views, in particular the thesis of terrestrial motion, so Origanus, underwent many changes among philosophers. The list of classical supporters of terrestrial motion is an established Copernican commonplace: "Herakleides of Pontus, Ekphantus the Pythagorean along with Hiketas [*Nicetas*] of Syracuse

83 Ibid., 132–33.

84 Origanus, *Ephemerides Brandenburgicae*, ff. a3*r*–*v*.

and Aristarchus of Samos."[85] Origanus sides with Copernicus only on the issue of the axial rotation, which is the premise of his geokinetic but geocentric planetary system.[86]

Among the natural causes of axial rotation, the principal is magnetism.[87] Origanus refers to the "prince of magnetic philosophy," the English physician William Gilbert (*Guilhelmus Gilbertus, magneticae philosophiae princeps*) who, in *De magnete*, described the Earth as a huge lodestone kept in motion by an intrinsic magnetism. The same source exerted a great influence on Kepler who, in *Astronomia nova* (published in the same year as the *Ephemerides Brandenburgicae*), derived from Gilbert the idea of a magnetic motive force of planets.[88]

Origanus equates magnetism and gravity. Actually, he prefers to call gravity a "natural appetency that preserves unity and integrity" (*appetentia naturalis, qua conservatur unitas et integritas rei*). In fact, he agrees with Copernicus's statement in the first book of *De revolutionibus* that rectilinear downward motion is the natural motion of a part separated from its whole: "If some part of the Earth or [something] with a principally terrestrial nature is removed, pushed back or is somehow out of its natural place, which is in his whole, the Earth will attract it perpendicularly toward the center of its whole."[89] Additionally, gravity so conceived cannot be restricted to terrestrial elements but is a general law of nature also valid for other heavenly bodies.[90] This motion of the part to its whole for the sake of self-preservation always travels the shortest distance, that is, a rectilinear vertical motion, independent of the velocity of the axial rotation of the Earth.[91] Hence, magnetism is deemed to account for the vertical falling of bodies toward the gravitational center (*motus gravium ad centrum gravitatis*) in spite of terrestrial displacement.

Origanus embeds magnetism in a vitalistic philosophical framework. It is an expression of the life of the Earth, which is itself a huge ensouled animal. The spontaneous generation of animals also bears witness that the Earth is alive.[92] It/she is said to be the mother and nourisher of all creatures living on it/her

85 Ibid., f. a3*v*. For a discussion of issues related to the sources of Copernican astronomy, see among others: Gingerich, "Did Copernicus," Aujac, "Le géocentrisme," and Biliński, *Pitagorismo*. See also Grant McColley, "Theory of the Diurnal Rotation."

86 Origanus, *Ephemerides Brandenburgicae*, ff. a3*v*–a4*r*.

87 Ibid., f. a6*r*.

88 See Bennet, "Cosmology and the Magnetical Philosophy." Cf. chap. 6,9.

89 Ibid., f. a6*v*. Cf. Copernicus, *De revolutionibus* (1543) I,8, f. 6*v*.

90 Ibid.

91 Ibid.

92 Ibid., f. b2*v*.

(*omnium nascentium mater et nutrix*);[93] therefore, so Origanus, animals generally refresh by sleeping at night, when they are closer to their vital origin, rather than during the day, when the Sun shines and they consume their energies.[94]

These conceptions are traced back to the *prisca philosophia* of Hermes Trismegistus, Zoroaster, Orpheus, and "our Gilbert."[95] Remarkably, there is no reference to any Italian Renaissance sources that could support these views, not even to Bruno, who—in many writings, but above all in the Italian cosmological dialogues (1584) and in *De immenso et innumerabilibus* (1591)—argued that heavenly bodies are huge animals crossing cosmic space moved by their souls, that they provide their inhabitants with life, and that gravity is a conservative appetency of detached parts toward their whole. Origanus perhaps avoids mentioning Bruno because the latter was suspected of impiety and was furthermore a Copernican who did not write on astronomy in mathematical terms. Still, he agrees with Bruno's attribution of a soul to the Earth and other planets to account for their motions in finalistic terms: "This soul of the terrestrial globe (which has a close affinity to the souls of celestial globes, since they all carry their globes in circles), that is, the terrestrial soul [*anima Terrae*] [carries] the Earth in a circle about its center and its axis."[96] Furthermore, the animal tendency for self-preservation is the source of universal harmony.[97] This vitalistic approach leads Origanus to equate magnetism with a life principle or soul. Thus, he describes the Earth in a rather picturesque way, as a big animal whose body is crossed by metallic and magnetic veins:[98]

> In this [terrestrial globe] (to say at least something about the admirable wisdom of God the Creator), waters are transported through underground channels toward dry regions in order to moisten and nourish them. These [waters] are spread here and there exactly like the blood through the veins. Moreover, the metallic forces of the Earth's treasures (a kind of [earthly] blood from which men particularly benefit) are diffused like blood through vital arteries. Finally, that force acting upon the globe's poles is communicated through magnetic bodies which extend

93 Cf. Pliny, *Natural History*, 288.

94 Origanus, *Ephemerides Brandenburgicae*, f. b3*v*.

95 Ibid., f. b2*v*.

96 Ibid., f. b3*r*. See Bruno, *De immenso* IV,15, "De principio motus quo per aethera moventur astra et alia id genus animalia."

97 Ibid.

98 Ibid., f. b2*v*.

> from the depths of the Earth up to its surface like nerves, which are instruments of motion communicating the force of motion to all limbs.

In addition to this, Origanus shares with Copernicus the opinion that motion is more suited to the Earth as *locatus* (what is placed in space), than to the *locus* (the "place" itself), that is, the heaven of the fixed stars. Second, Origanus brings forward a common Copernican argument, later called the "Achilles argument" by Giovan Battista Riccioli in *Almagestum novum* (1651), according to which the excessive rapidity required by the sphere of the fixed stars to accomplish the daily rotation is untenable.[99] A vitalistic argument follows: if all animals move in space, why should their life-giving mother be deprived of this capability?[100] Another vitalistic and finalistic argument is derived from the necessity that the Earth exposes all its sides to the Sun to get warmth and vivify its surface, an argument which could be drawn from Bruno.[101] Origanus even resorts to the cosmo-anthropological analogy between the microcosm and the macrocosm to depict the Earth as the moving feet or the pulsating heart of the worldly machine.[102] He derives a further argument from the phenomenon of the tides, long before Galileo made it one of his principal (albeit incorrect) Copernican arguments in the *Dialogo* of 1632.[103] Origanus writes that tides are concomitantly produced by the westward rotation of the Earth and the attraction of the Moon. According to some reports on Atlantic explorations, it takes less time to sail from Portugal to America than to come back, and this should bear evidence to the fact that seas are influenced by the daily rotation of the Earth.[104]

Origanus also addresses Aristotelian and Ptolemaic arguments against terrestrial motion. Among others, he denies that the immobility of the Earth derives from its centrality. According to mathematical astronomy, the geometrical center of planetary orbits is only a point, and eccentric planetary circles are not perfectly centered on the Earth.[105] Moreover, contrary to what Ptolemy

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99 Ibid., f. b3*r–v*. Copernicus, *De revolutionibus* (1543) I,8, f. 7*r*. See also Lerner: "L'Achille des coperniciens," and Siebert, *Große kosmologische Kontroverse*, 89–104, chap. 3,1 "Das Achilles-Argument (Riccioli)."

100 Ibid., f. b3*v*.

101 Ibid., f. b4*r*. See Granada, "Héliocentrisme de Giordano Bruno."

102 Ibid., f. b5*v*.

103 Cf. Omodeo, "Riflessioni sul moto terrestre."

104 Origanus, *Ephemerides Brandenburgicae*, f. b5*v*.

105 Ibid., f. c1*r*.

argued in the first book of the *Almagestum*, axial rotation does not imply the dissolution of the Earth; it does not make buildings collapse and does not leave clouds and birds behind.[106] In fact, the daily rotation is deemed natural and the Earth partakes of it, including air and fluctuating bodies. For these reasons, Origanus rejects Aristotelian physics and invites scholars to draw a distinction between the rectilinear motion of the parts rejoining their whole and the circular motion of the whole itself.[107]

To sum up Origanus's cosmological considerations, they prove original in many respects and his reworking of Brahe's and Ursus's geoheliocentric system is quite ingenious. Furthermore, the assumption of the Earth's axial rotation and its magnetic-vitalistic foundation shows Origanus's free and eclectic reading of astronomical and natural sources, among which Gilbert is predominant. The wide dissemination of Origanus's ephemerides must have also spread his philosophical and cosmological assumptions. It should be noted that his system was embraced by Brahe's pupil Longomontanus, in his *Astronomia Danica* (1622): "We agree with D. Origanus and other illustrious men of this time that the Earth moves about its center in the middle [of the world] and accomplishes the daily rotation from west to east with great economy for nature."[108] Longomontanus added that only an excessive attachment to a literal interpretation of a few biblical passages could motivate an irrational rejection of Origanus's planetary model. In actual fact, he wrote this bitter remark six years after the Catholic censure of the Copernican system, including terrestrial motion. Origanus's defence of the latter thesis, although embedded in a geo-helicentric framework, must have also interested the followers of Copernicus. In particular, his considerations on the scriptural issue seem to be relevant for the reconciliation of a realist reading of Copernicus's hypotheses with the Bible, which was to become a heated issue of cultural debate soon after the publication of the *Ephemerides Brandenburgicae*, as Galileo's *affaire* and the censure by the Inquisition demonstrates. In this context, it is not surprising that Origanus's name appeared among those of the Germans who "Copernicanize" (*copernicoturire*)—along with Nicholas of Cusa, Copernicus, Rheticus and Mästlin—in Tobias Adami's preface to the first edition of Tommaso Campanella's *Apologia pro Galilaeo* (1622).[109]

106 Ibid., ff. c1*r*–*v*.

107 Ibid., f. c1*v*.

108 Longomontanus, *Astronomia Danica* (1640), vol. 2 [*pars altera*], I,1, 161.

109 Campanella, *Apologia* (1622), 4.

12 Conclusions

In this chapter, I considered several "Copernican" ephemerists and table makers: Stadius, Giuntini, Magini and Origanus. I called them "Copernicans" in the sense that they relied on Reinhold's tables. This practical rather than cosmological employment of the adjective "Copernican" is supported by its sixteenth-century use. For instance, Benedetti distinguished, in Italian, between "effemeridi copernice" and "effemeridi alfonsine." Furthermore, Magini did not hesitate to mention Copernicus in the title of his ephemerides, even though he did not adhere to the heliocentric system. In other words, to be a Copernican in the context of astronomical practice did not mean endorsing specific planetary hypotheses. Yet neither did it mean neglecting the study of hypotheses. As I have showed, all ephemerists considered here speculated on cosmology and often accompanied their computations with prefaces, introductions, even entire books, aimed at clarifying the physical foundations of astronomy. In this respect, Gemma Frisius's letter to Stadius, set as a preface to the *Ephemerides novae* of 1556, is an excellent example of such a convergence of computational and cosmological interest, in his case a defense of heliocentrism. Stadius himself was inclined to accept the Copernican system either in its entirety or in the Capellan variant, as most clearly emerges from the dedicatory epistle of his *Tabulae Bergenses* (1560). The other Copernican ephemerists considered here supported different systems. In his commentary to Sacrobosco and in the *Speculum astrologiae*, which includes a set of astronomical tables based on Reinhold, Giuntini expanded on the "Pythagorean cosmology" (meaning the Copernican system) but rejected it in favor of a traditional geocentric view. Furthermore, Magini, in the *Novae coelestium orbium theoricae* (1589), reworked the Capellan system. In his model, the Sun and the inferior planets moved on three concentric epicycles transported by the same deferent. Remarkably, he declared in the very title of this treatise that he was following in Copernicus's footsteps. He also claimed that his partially geocentric (almost geoheliocentric) model was inspired by Copernicus. Some years later, in the first volume of the *Ephemerides Brandenburgicae* (1609), Origanus defended a geoheliocentric model derived from Brahe and Ursus. He assumed that the Earth rotates about its axis, and collected natural and scriptural arguments in favor of terrestrial motions. These must have played an important role in the discussion on Copernicus, as evinced, among other things, by their mention in Campanella's *Apology for Galileo*.

Furthermore, the computation of ephemerides cannot be neatly separated from astrological and medical practice. Stadius attached to his ephemerides a treatise on Hermetic medicine; Giuntini published his tables as part of an extensive volume devoted primarily to astrology; Magini wrote extensively on the astrological and medical applications of astronomy, even apologizing for astrology; and Origanus regarded his ephemerides as a support for astrological prediction. Rheticus stressed this applicative aspect in the *Narratio prima*, in which he prompted astrologers to use *De revolutionibus* and to neglect Pico's criticism of astronomy based on skepticism about the reliability of astronomical computations. The entangled discussion of computational and astrological issues also emerges from the Turin dispute on the reliability of ephemerides and the validity of astrology, which involved Benedetti and an obscure polemist from Vicenza. This episode shows Benedetti's rather relativistic attitude, if not his indifference, to the use of Copernican rather than Alfonsine tables for astrological prediction. He was aware that the Copernican ephemerides were not in perfect agreement with heavenly phenomena, but claimed their relative superiority based on empirical tests. Benedetti, himself a supporter of the Copernican system, is an example of a Renaissance mathematician interested in computation (and astrology) who was also concerned with physical and cosmological matters.[110] Origanus also dealt with cosmological and natural issues, developing a vitalistic and magnetic philosophy. In conclusion, the image of Renaissance ephemerists that emerges from this chapter is very distant from that of computers with no interest in hypotheses and natural philosophy. Quite on the contrary, their activity was situated at the point where astrological practice, cosmological theory and natural philosophy intersect.

110 See chap. 4,7 and 5,7.

CHAPTER 4

A Finite and Infinite Sphere: Reinventing Cosmological Space

According to a renowned historical thesis by Alexandre Koyré, the infinity of space was an essential component of the "modern scientific" worldview. The first two chapters of his *From the Closed World to the Infinite Universe* (1957) were an outline of the development of the idea of an unbounded universe from Cusanus to Gilbert through Palingenius Stellatus, Copernicus, Digges and Bruno. More recently, Jean Seidengart, in *Dieu, l'univers et la sphère infinie* (2006), analyzed the variety of options concerning cosmological infinity, also taking into consideration other authors relevant to this history, like Patrizi, Benedetti and Ursus. This chapter will tackle the issue of the dimensions of the universe and cosmological infinity from the perspective of the reception of *De revolutionibus*. Copernican planetary theory did not support cosmological infinity directly and explicitly, but elicited a wide debate on the dimensions of the universe. It reawakened the interest in alternative cosmologies from antiquity. The annual rotation of the Earth around the Sun, in fact, forced Copernicus and his followers to raise their calculated distances to the fixed stars to account for the absence of any observable stellar parallax or, rather, for the fact that the horizon of any terrestrial observer always bisects the celestial sphere. Moreover, axial rotation made it possible to conceive of the universe as infinite instead of spherical, as Copernicus noted in *De revolutionibus* I,8: "The chief contention by which it is sought to prove that the world is finite is the motion [of the heavens]."[1] In the cosmological debate of the sixteenth century, classical authors whose models diverged from the geocentric and spherical became fashionable, no matter how fragmentary and obscure the available information about their views might have been. In the effort to rethink cosmological space, Renaissance scholars rediscovered and partly reinvented what they referred to as the "Pythagorean," the "Stoic," or the "atomist" worldviews. As Koyré and Seidengart, but also Blumenberg and others have stressed already, Cusanus played an essential role in the debate on infinity.[2] His name tended to appear in association with Copernicus but, as we shall see, not in

1 Copernicus, *Revolutions*, 16 (translation revised); GA II, 15.

2 Koyré, *From the Closed World*, Seidengart, *Dieu*, and Blumenberg, *Legitimität*, especially part 4, "Aspekte der Epochenschwelle: Cusaner und Nolaner."

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a unique manner. In the case of Cusanus, as in that of the ancient sources, ideas were often distorted, simplified or reinterpreted to fit into new theoretical and philosophical frameworks. This chapter is conceived as a further clarification of and a contribution to the understanding of the connection between Copernican astronomy and the debate on cosmological space.

1 The Finite Infinity of the World Revised

In a famous passage in the *Historia naturalis* (II,1), Pliny called the heavens "finite but resembling the infinite" (*finitus et infinito similis*) in consideration of their immeasurable extent.[3] As Ptolemy remarked, "the Earth has, to the senses, the ratio of a point to the distance of the sphere of the so-called fixed stars," because the naked eye cannot detect any discrepancies in celestial observations depending on the latitude of the observer.[4] Neither for Pliny nor for Ptolemy did the amazing extension of the world raise any doubts concerning its spherical form or terrestrial centrality. In *Almagest* I,5, "That the Earth Is in the Middle of the Heavens," Ptolemy demonstrated through geometrical-astronomical arguments that heavenly phenomena can be explained only if the Earth is situated at the intersection of the axis of the daily rotation and the ecliptic. Ptolemy's presupposition was that the dimensions of the heavens are such that appearances would be noticeably different if the Earth did not lie in the middle of the cosmos. In Pliny's case, the assessment of the "infinity" of the universe maintained an epistemological meaning, depending on the limits of human faculties. In Copernicus's day, the impossibility of ascertaining the dimensions of the heavens was almost a commonplace. It was reasserted, among others, by the astronomer Jacob Ziegler, a friend of Calcagnini, the geokinetist who appreciated Cusanus and perhaps knew the *Commentariolus*.[5] In Ziegler's commentary on the astronomical passages of the *Historia naturalis* (1531) one reads: "*And similar to infinity*: [Pliny] said so, not concerning the power of nature but rather considering human faculties. Although the world is finite in itself, we perceive it as infinite."[6]

In the light of the heliocentric theory, the dimensions of the universe had to be revised and Pliny's statement about the finite and infinite dimensions

3 Pliny, *Natural History*, II,170–71.

4 Ptolemy, *Almagest* (I,6), 43. Cf. Omodeo-Tupikova, "Cosmology."

5 A poem by Calcagnini was inserted at the beginning of Ziegler's commentary (*Commentarius*, ff. a2*r*–*v*). See chap. 1,2.

6 Ziegler, *Commentarius*, 45.

of the heavens took on new meaning. Copernicus stressed this consequence in *De revolutionibus* I,6 on "The Immensity of the Heavens Compared to the Size of the Earth." He used here the argument from "stellar parallax" to show the negligible dimensions of the terrestrial orb. Copernicus even turned the claim that the Earth is like a point compared to the heavens against Ptolemy, in a conclusive remark: "Indeed, a rotation in 24 hours of the enormously vast universe should astonish us even more than the rotation of its least part, which is the Earth."[7] He directly referred to Pliny in the manuscript version of *De revolutionibus*: "For what I have undertaken to do, those propositions of natural philosophy which seemed indispensable as principles and hypotheses, namely, that the universe is spherical, immense, and similar to the infinite, and that the sphere of the fixed stars as the container of everything is stationary, whereas all the other heavenly bodies have a circular motion, have been briefly reviewed."[8] Although Copernicus did not clearly question heavenly sphericity, he was forced to enormously enlarge the dimensions of the universe and to consider the possibility of an infinite space (*De revolutionibus* I,8). Additionally, his pupil Rheticus claimed that the heliocentric theory conferred a clearer sense to Pliny's assertion of the infinite-like dimension of the world: "It is quite clear that the sphere of the stars is, to the highest degree, similar to the infinite, since by comparison with it the great circle vanishes, and all the phenomena are observed exactly as if the Earth were at rest in the center of the universe."[9]

In *De revolutionibus* I,8, Copernicus mentions the Aristotelian idea that there is nothing *extra caelum*. If there is nothing, "no space, no body, no void," *beyond* the heavens (*dicunt quod extra caelum non esse corpus, non locum, non vacuum*), the heavens should be held together by nothing. By contrast, the assumption that the universe is unbounded would better account for the stability of the heavens. That thesis would explain better than Aristotle why the universe includes everything and why there is nothing in this world *except for* the heavens themselves (*extra caelum*). Copernicus surmises that the heavens could be finite only in their interior, occupied by the planetary system, but they could be infinite outside. Whether or not Copernicus regarded the stars as part of this system is not clear from his words. The expression "extra caelum" might be equivocated, allotting to it, apart from a spatial meaning (*beyond the heavens*), an ontological one as well (*except for the heavens*). Either meaning acquires a clearer sense by assuming that the universe is infinite. Copernicus

7 Copernicus, *Revolutions*, 13.

8 Ibid., 26. Cf. GA I, f. 13*r* and GA II, 490.

9 Rheticus, *The Narratio Prima*, 145. Cf. GA VIII/1, 23.

concludes that one of the principal reasons why the ancients thought that the universe is finite was that they ascribed the daily rotation to the stars and not to the Earth:[10]

> But *extra caelum* [beyond the heavens] there is said to be no body, no space, no void, absolutely nothing, so that there is nowhere the heavens can go. In that case it is really astonishing if something can be held in check by nothing. If the heavens are infinite, however, and finite at their inner concavity only, there will perhaps be more reason to believe that *extra caelum* [except for the heavens/outside the heavens] there is nothing. For, every single thing, no matter what size it attains, will be inside them, but the heavens will abide motionlessly. For the chief contention by which it is sought to prove that the universe is finite is its motion.

However, Copernicus avoids taking sides in a possible controversy over the dimensions of the universe. He prefers to leave this discussion to the *physiologi*, those dealing with natural questions: "Let us therefore leave the question as to whether the universe is finite or infinite to be discussed by the natural philosophers."[11]

2 Cusanus's Two Infinities

Nicholas of Cusa occupies a special place in the history of cosmological infinity. In *De immenso*, which is the Latin presentation of his own views on infinity, Bruno associated Cusanus with Copernicus, as if the astronomical theses of the latter could be a clarification of the speculations of the former: "It is incredible, oh Copernicus, that you could emerge from the great blindness of our age, when all light of philosophy lies down extinguished [...], so that you could assert more audaciously what Nicholas Cusanus had already affirmed with a lower voice in the book *On Learned Ignorance*."[12] After Bruno, the affinity between these two "modern" authors to which he owed much of his natural philosophy became a commonplace. Although much has already been written

10 Copernicus, *Revolutions*, 15–16. Cf. GA II, 15.

11 Ibid., 16.

12 BOL I,1, 382.

on Cusanus's cosmology, it is important to reconsider some of his views for their relevance in the post-Copernican debate.[13]

The second book of his treatise "on learned ignorance," *De docta ignorantia* (written in 1440) deals with "one infinite universe" (*unum infinitum universum*). Cusanus openly claims that his concept of "infinity" should not be confused with the views of the ancient atomists. As one reads in the first book of the *Docta ignorantia*, infinity properly belongs to God alone, since God includes everything in its maximum power. Infinity is not comparable with anything finite, therefore God is ineffable and incomprehensible, according to negative theology. In order to express this "negative infinity" (*negative infinitum*), Cusanus employs the metaphor of the infinite sphere, derived from medieval neo-Pythagoreanism. According to the second definition of God in the *Liber de XXIV philosophorum* (*The Book of the Twenty-Four Philosophers*), "God is the infinite sphere, whose center is everywhere and whose circumference is nowhere."[14] The universe, as a derivation from its principle or, rather, an unfolding (*explicatio*) of God, must display divine infinity without actually being infinite. Cusanus calls it *privative infinitum*.[15] Reversing Pliny's expression (*finitus et infinito similis*), he says that the world is "neither finite nor infinite" in comparison to God. The universe is *infinitum* in the sense that it is not terminated (*finitum*) by anything external, as it is itself the collection of all existing beings. On the other hand, it is not extensively (nor intensively) infinite, because of its intrinsic ontological limitation.[16] Therefore, Cusanus also calls it a "finite infinity" (*infinitas finita*).[17]

In order to grasp the paradoxical nature of Cusanus's infinite cosmology, it is important to recount that he never rejected the spherical form of the world. In *De ludo globi* (*The Bowling-Game*, 1463), he stated that a sphere has a natural tendency to move circularly, and this assumption explains the motion of the heavens: "If [a sphere] is moved on its own center, so that it is the center of its own motion, then it is moved perpetually. And this motion is a natural motion. By means of a natural motion the outermost sphere [of the heavens]

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13 For Cusanus's cosmology, see: Krafft, "Das kosmologische Weltbild," Hujer, "Nicholas of Cusa," and Omodeo, "Nikolaus von Kues als Kopernikaner." For Cusanus's contributions to the rise of modern natural conceptions and epistemologies: Reinhardt-Schwaetzer, *Nikolaus von Kues: Vordenker*.

14 Pseudo-Hermes, *Liber*, 208. See Baeumker, *Studien*.

15 Cusanus, *Docta ignorantia* II,1, 64.

16 Ibid., II,1, 65.

17 Ibid., II,2, 68. Cf. Mahnke, *Unendliche Sphäre*, 81–87.

is moved without constraint or fatigue."[18] In the first book of *De docta ignorantia*, he remarked that the circumference of the infinite sphere, that is, God, is a straight line. He developed this idea in the second book, by presenting the irreducibility of a curve to a straight line (that is, the difficulty of squaring the circle) as revealing the overwhelming distance between God and creation. This is the gulf which separates negative and privative infinity, the infinite sphere and the finite. Moreover, in a brief essay dealing with the squaring of the circle from a philosophical-theological viewpoint, *De theologicis complementis* (*Complementary Theological Considerations*, 1453), he pointed out that divine Trinity can be represented through the center, the radius and the circumference of a sphere. This geometrical figure is therefore the most suited for God's creation.

In the Middle Ages, the termini *sphaera* and *coelum* were very often used as synonyms. Cusanus did not intend to reject this universally accepted connection in order to introduce the idea of an extensively unlimited universe. Still, he challenged the traditional conception by introducing a paradox. He claimed that the sphere can express infinity without being itself infinite, and thus that the physical universe can be said to be infinite. In so doing, he maintained the distinction between God, the infinite sphere, and the world, while indicating an analogy between them. It should be remarked that, in the *Docta ignorantia*, Cusanus used the expression *sphaera infinita* exclusively for God, and referred to the world merely as *machina mundi*, or *machina mundana*. Moreover, in the *De theologicis complementis*, he explained that the circle is the figure in which finiteness and infinity coincide, as it is a polygon with infinitely many sides:[19]

> The universe is conceived to be brought forth from that one point as if from one point a line were brought forth, so that from the line there were made a trigon and a tetragon and finally the circle, the most simple and most perfect thing, the thing most like the Creator. [...] In a circle oneness and infinity coincide—a oneness of essence and an infinity of angles. Or better: [in a circle] infinity itself is oneness. For the circle is the whole angle. Thus, the circle is both one and infinite; and it is the actuality of all the angles that are formable from a line. From the foregoing considerations you may elicit how it is that the Creator of the one universe caused a single universe similar to Him to come forth from a single point.

18 Idem, *Treatises*, 1191; *De ludo globi*, 24–25.

19 Idem, *Treatises*, 761. Cf. id., *De theologicis complementis*, chap. 9, 44–45.

The circumference, “immeasurable measure,” is the image of the coincidence of the opposites, the basic principle of Cusanus’s epistemology and ontology. Like the universe, the circle is infinite and finite at the same time. It partakes of (infinite) plurality and unity. The sphere is the visual exemplification of the finite infinity treated in the *Docta ignorantia*.

Copernicus had something similar in mind when he wrote (*De revolutionibus* I,6) that the heaven of the fixed stars “infinitae magnitudinis speciem prae se ferre.”[20] In other words, the universe partakes of divine infinity. This does not explicitly mean that it is itself infinite, since it is only a derivation from God. In Cusanus’s case, pointing to infinity as a character of the universe does not imply abandoning the idea of the heavens as a sphere. Koyré correctly hinted at the relevance of *De docta ignorantia* for the history of cosmological infinity, but missed the sense of Cusanus’s words: the universe is physically finite, but also infinite in its essence because the spherical form partakes of infinity.[21]

3 Cusanus’s Role in the Copernican Debate

Among the readers of *De revolutionibus*, it became quite common to connect Copernicus’s and Cusanus’s views, especially from the end of the sixteenth century on. Bruno strongly contributed to this entangled reception.[22] Also, Kepler expressed his admiration for Cusanus in the *Mysterium cosmographicum*, whereas Adami mentioned him as one of the most distinguished German supporters of the Copernican system in his preface to Campanella’s *Apologia pro Galilaeo* (1622).[23] Later, René Descartes would refer to Cusanus in his considerations on cosmological infinity (or, to be more precise, “indefiniteness”), which he conceived as a consequence of God’s omnipotence. After Galileo was condemned by the Inquisition, Descartes decided to keep his own post-Copernican cosmology secret. He nonetheless continued regarding Cusanus as an ally in the cosmological-theological controversy on heliocentrism and the infinity of space.[24]

Cusanus openly and repeatedly declared his support for a Pythagorean mathematical approach to nature. This could explain the admiration for his

20 GA II, 12.

21 Koyré, *From the Closed World*, 13 (ed. 1958): “The exact meaning of the conception developed by Nicholas of Cusa is not quite clear.”

22 For the intertwined reception of Bruno and Cusanus, see Meier-Oeser, *Präsenz*.

23 Campanella, *Apologia* (1622), 4.

24 Descartes to Mersenne (Deventer, late November 1633), in *Œuvres*, vol. 1, 270–73.

work by several followers of Copernicus. In fact, a shared conviction was that the Pythagorean doctrine included terrestrial motion. Cusanus also believed in the numerical structure of reality and therefore endorsed a mathematical epistemology which he traced back to Pythagoras.[25] He thought that mathematical order underlies nature since numbers symbolize ideas in God's mind.[26] "The Platonists and also our leading [thinkers] followed him [Pythagoras] to such an extent that our Augustine, and after him Boethius, affirmed that, assuredly, in the mind of the Creator the number was the principal exemplar of the things to be created."[27] Universal harmony is a consequence of these premises: "The Milesian Thales, the first of the wise, says that God is very ancient because he is unbegotten and that the world is very beautiful because it was made by God. When I read these words in Laertius, they very greatly pleased me. I behold our very beautiful world, united in a wonderful order—an order in which the Supreme God's supreme goodness, wisdom, and beauty shine forth. I am moved to inquire about the Designer of this very admirable work."[28]

Still, Cusanus's mathematical epistemology should be distinguished from that of seventeenth-century scholars, among them his admirer Kepler. Cusanus owed to Plato and neo-Platonism the conviction that mathematical perfection cannot be fully realized but only approximated by nature. In *De docta ignorantia*, he asserted the basic rule (*regula nostra*) of inequality: "Precise equality befits only God" (*precisa aequalitas solum Deo convenire*). Accordingly, "there is no precision in nature" (*praecisio non est in natura*). The epistemological corollary of these theses is that "the measure and the measured thing are necessarily different" (*mensura a mensurato necessario differire*). This principle should also be applied to astronomy:[29]

> As already said, precise equality befits only God. Wherefore, it follows that, except for God, all possible things differ. Therefore, one motion cannot be equal to another; nor can one motion be the measure of another, since, necessarily, the measure and the measured thing differ. Although these points will be of use to you regarding an infinite number of things, nevertheless if you transfer them to astronomy, you will recognize that the art of calculating lacks precision, since it presupposes that the motion

25 Cusanus, *Docta ignorantia*, I,1, 6.

26 Cf. idem, *Idiota*, 133. For Cusanus's opinion on the status of mathematics, see Pukelsheim-Schwaetzer, *Mathematikverständnis*, as well as Müller, *Perspektivität*.

27 Cusanus, *Treatises*, 19; *Docta ignorantia*, 23.

28 Idem, *Treatises*, 1283; *De venatione sapientiae*, 8–9.

29 Idem, *Treatises*, 58; *Docta ignorantia*, 61.

> of all the other planets can be measured by reference to the motion of the Sun. Even the ordering of the heavens [...] is not precisely knowable. And since no two places agree precisely in time and setting, it is evident that judgments about the stars are, in their specificity, far from precise.

Cusanus derives notable cosmological consequences from the rule of inequality, especially concerning the Earth. The assumption that absolute rest suits only God implies that the Earth "cannot be devoid of all motion."[30] Still, he conceives of this motion as close to immobility: "Indeed, it is even necessary that the Earth be moved in such a way that it could be moved infinitely [i.e. indefinitely] less [*per infinitum minus moveri*]."[31] The place of the Earth is not exactly at the center of the world, but it should be close to it: "although the Earth—as a star—is nearer to the central pole, nevertheless it is moved."[32] To explain why our senses do not detect its displacement, Cusanus resorts to the metaphor of the ship, which he could derive from fourteenth-century *impetus* dynamics.[33] A corollary of these ideas is cosmological homogeneity, in particular the conception of the Earth as a "star" (*Est igitur Terra stella nobilis*).[34] This leads to a doctrine of the plurality of worlds: all planets are inhabited and are composed of the same elements.[35]

Among the reasons for the early modern reading of Cusanus as a Copernican or as a proto-Copernican, one should not neglect his authority as a Catholic cardinal who was part of the Roman curia. This aspect became particularly relevant when the reconciliation of the Bible and the "Pythagorean system" of Copernicus became a heated issue, precisely between the end of the sixteenth century and the beginning of the seventeenth. Apart from this, the fact that Cusanus belonged to the Platonizing humanist culture made him appealing to those who shared this cultural background. The French humanist Léfèvre d'Étaples, editor of Cusanus's *Opera* (1514), praised in the preface the author's anti-Aristotelian philosophy (*philosophiae Aristotelicae acerrimus disputator fuit*), his Christian stylistic simplicity, the concordant spirit of his views on religion, and his Platonic approach to mathematics.[36]

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30 Ibid.

31 Ibid.

32 Idem, *Treatises*, 92; *Docta ignorantia*, 102.

33 Ibid., 93. See chap. 5,3.

34 Idem, *Docta ignorantia* II,12, 105.

35 Cf. Dick, *Plurality of Worlds*.

36 Léfèvre d'Étaples, "Dedicatory letter" in Cusanus, *Opera* (1514).

4 The Invention of Pythagorean Cosmology

Renaissance scholars rediscovered and reinvented the views of the Ancients, often relying on few extant sources. In this respect, the history of cosmology resembles that of many other scientific fields, for instance mathematics, mechanics, and cosmography.[37] In all these disciplines, classical works had to be restored not only formally but also in terms of their contents. Copernicus makes no exception to this trend and thus sought to strengthen his geokinetic and heliocentric theory by tracing it back to classical precedents. In the *Commentariolus*, he remarked on the Pythagorean origin of this key thesis: "In case anyone believes that we have asserted the movement of the Earth for no good reason along with the Pythagoreans, he will also receive considerable evidence [for this] in the explanation of the circles."[38]

The idea of reestablishing Pythagoreanism was part of the early modern reception of Copernicus throughout the sixteenth and seventeenth centuries. Digges entitled his English vulgarization of the cosmological part of *De revolutionibus*, book I, *A Perfit Description of the Caelestial Orbes according to the most aunciente doctrine of the Pythagoreans, latelye revived by Copernicus and by Geometricall Demonstrations approved* (1576). In a similar manner, Tolosani criticized Copernicus's alleged revival of the Pythagorean worldview, while Foscarini sought to reconcile it with the Bible in his famous theological defense of Copernicus's astronomy, published in Naples, in 1615: *Lettera sopra l'Opinione de' Pittagorici e del Copernico: Della mobilità della Terra, e stabilità del Sole, e del nuovo Pittagorico Sistema del Mondo*.[39] Kepler considered Copernicus's and Pythagoras's views to be one and the same. Galileo, too, presented the heliocentric theory, "the true and good philosophy, especially concerning the structure of the universe," as a renewal of Pythagoreanism.[40] At the end of the seventeenth century, Otto von Guericke was still convinced that Copernicus had restored the planetary system of the Pythagoreans (*Experimenta nova*, 1672, I,5, "De Systemate Mundi Pythagorico, secundum Copernicum, in quo Sol ponitur pro centro huius Mundi") and also pointed to Cusanus as a forerunner.[41] The common reference to Pythagoreanism does not mean that all these authors

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37 For mathematics, see Rose, *Italian Renaissance*. For geography, see Broc, *Géographie* and Vogel, "Cosmography." Concerning mechanics, see Renn-Damerow, "Transformation."

38 Copernicus, *Brief Description*, 439.

39 See chap. 7,4 and 7,11.

40 Galileo, *Istoria e dimostrazioni intorno alle macchie solari e loro accidenti*, in EN vol. 5, 99 and 102.

41 Guericke, *Experimenta*, 8–9.

were in agreement on even the most basic cosmological theses, such as the finiteness or infinity of the universe.

Most followers of Copernicus found (or meant to find) a confirmation that the Pythagorean cosmology included terrestrial motion, and the solar immobility and centrality posited in Aristotle's *De coelo* II,13:[42]

> It remains to speak of the Earth, where it is, whether it should be classed among things at rest or things in motion, and of its shape. Concerning its position there is some divergence of opinion. Most of those who hold that the whole Universe is finite say that it lies at its center, but this is contradicted by the thinkers of the Italian school called Pythagorean. These affirm that the center is occupied by fire, and that the Earth is one of the stars, and creates night and day as it travels in a circle about the center.

Ibn Rushd, in his commentary on *De coelo* (II,72, 17–26), observed that the Pythagoreans conceived of the Earth as a planet ("dicunt quod Terra est aliqua stellarum et quod movetur circa medium") but did not go so far as to identify the central fire (*ignis in medio totius*) with the Sun. Ibn Rushd restricted himself to acknowledging the uncertainty about the cosmological theories of the ancients.[43] By contrast, Copernicus's followers tended to interpret the mentioned passage as a reference to the heliocentric planetary model. Copernicus had already confronted the arguments against terrestrial motion brought forward by Aristotle in opposition to the Pythagoreans and *Timaeus*, as reported by Rheticus in his *Encomium Prussiae* (*In Praise of Prussia*).[44] In the introduction to his *Harmonice mundi* (*The Harmony of the World*, Linz, 1619), Kepler interpreted the controversial passage of *De coelo* as a reference to the system that he supported. The Pythagorean *Weltanschauung* included other important philosophical assumptions, besides: the quest for the numerical principles of nature as well as a harmonic conception of the cosmos; in particular, the idea that heavenly motions are musical.[45]

Another cosmological source for Pythagoreanism was Plato, who let the Pythagorean Timaeus present the doctrine of terrestrial rotation in the dialogue that bears his name. By describing how the divine demiurge arranged stars and planets, Timaeus states (40b–c):[46]

42 Aristotle, *Heavens*, 217. On this issue, cf. also Giuntini's position, as presented in chap. 3,6.

43 Averroes, *Commentum Magnum*, II,72, 32–34.

44 Rheticus, *The Narratio prima*, 194–95.

45 Cf. *De caelo*, II,9, 290b 12–291a 6.

46 Plato, *Dialogues*, vol. 2, 21.

> The Earth, which is our nurse, clinging around the pole which is extended through the universe, he [the demiurge] framed to be the guardian and artificer of night and day, first and eldest of gods that are in the interior of heaven.

This passage presents the Earth as the cause of day and night, because it spins around its own axis, which coincides with the axis of the whole universe. Aristotle asserted that Plato believed the Earth to rotate.[47] According to Plutarch, Plato learned Pythagorean cosmology from Philolaus.[48] In *De revolutionibus* I,5, Copernicus accepted this version: Plato went to Italy to learn astronomy from Philolaus the Pythagorean:[49]

> It will occasion no surprise if, in addition to the daily rotation, some other motion is assigned to the Earth. That the Earth rotates, that it also travels with several motions, and that it is one of the heavenly bodies, are said to have been the opinions of Philolaus the Pythagorean. He was no ordinary astronomer, inasmuch as Plato did not delay going to Italy for the sake of visiting him, as Plato's biographers report.

In the *Commentariolus*, as already remarked, Copernicus claimed the Pythagorean origin of his theory and dissociated himself from the natural philosophers: "I have […] asserted, with the Pythagoreans, the motion of the Earth […]. For the principal arguments by which the natural philosophers attempt to establish the immobility of the Earth rest for the most part on the appearances; it is particularly such arguments that collapse here, since I treat terrestrial immobility as due to an appearance."[50] In the dedicatory letter to *De revolutionibus*, he wrote to Pope Paul III that he had read "all philosophers" (*omnium philosophorum*), in search of confirmations of his worldview. From classical sources he drove the names of several "forerunners": Hiketas, whose name he altered as "Nicetus," Philolaus the Pythagorean, Herakleides of Pontus and Ekphantus the Pythagorean.[51] In the manuscript version of his main work he also mentioned Aristarchus of Samos as an ancient advocate of his planetary model.[52] "Therefore, having obtained the opportunity from these sources,

47 Aristotle, *De coelo* II,13, 293b.
48 Cf. De Pace, "Plutarco."
49 Copernicus, *Revolutions*, 12.
50 Rosen, *Three Copernican Treatises*, 59.
51 Cf. Aujac, "Géocentrisme," and Biliński, *Pitagorismo*. See also D'Alverny, "Survivances."
52 Gingerich, "Did Copernicus." See also Omodeo, "Archimede e Aristarco."

I too began to consider the mobility of the Earth. And even though the idea seemed absurd, nevertheless I knew that others before me had been granted the freedom to imagine any circles whatever for the purpose of explaining the heavenly phenomena."[53] All these authorities could come, by and large, under the compass of Pythagorean and Platonic philosophy. The sense of an ideal bond *cum Pythagoricis* is reinforced by an annotation in Copernicus's hand in a copy of Pliny's *Historia naturalis* (Venice, 1487):[54]

> See Cicero's *Academicae quaestiones*, book II: Hiketas [*Nicetus*] of Syracuse, according to Teophrastus, maintains that the heavens, the Sun, the Moon, the stars and everything superior is immobile, and that nothing in the world moves besides the Earth. If it rotates and twists about its axis with the greatest velocity, it produces the same effects as if the Earth is immobile and the heavens are moved. It is believed that also Plato holds the same in *Timaeus* although [he expresses this doctrine] a little more obscurely.

Copernicus did not clearly distinguish between Pythagoreanism and Platonism. There are plenty of passages in his and Rheticus's works bringing the two schools together. In the *Narratio prima*, Rheticus pointed out the Platonic-Pythagorean background of Copernicus's astronomy: "Following Plato and the Pythagoreans, the greatest mathematicians of that divine age, my teacher thought that in order to determine the causes of the phenomena circular motions should be ascribed to the spherical Earth."[55]

Concerning cosmological infinity, Copernicus was rather elusive. The attempt to connect or separate Pythagoreanism and infinitism was in fact undertaken by later followers of the heliocentric system. As the connection between Copernicanism and Pythagoreanism was generally taken for granted, the discussion on the dimension of the heliocentric system was seen as a way of illuminating the worldview of these ancient predecessors.

5 Pythagoreanism and Cosmological Infinity according to Digges

Thomas Digges is renowned for his early connection of Copernicanism with Pythagoreanism and infinitism. His *Perfit Description* was a paraphrase

53 Copernicus, *Revolutions*, 4.

54 Prowe, *Coppernicus*, 421.

55 Rosen, *Three Copernican Treatises*, 148–49.

in English of the cosmological parts of *De revolutionibus* I,9—"De ordine caelestium orbium"—as well as I,7 and I,8—the refutation of Aristotelian and Ptolemaic arguments against terrestrial motion. He did not consider Copernicus's hypotheses to be merely computational tools: "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."[56] Instead, the Copernican hypotheses lay the foundation of the true planetary system, which was allegedly known to the Pythagoreans.

The *Perfit Description* is not only a summary of Copernicus. It is rather a partial reworking in which the arguments in favor of the heliocentric model are reordered and partly expanded.[57] The most original aspect of this presentation concerns the dimensions of the universe. Digges remarks that, if one assumes the Pythagorean doctrine (that is, the Copernican), the terrestrial orb (*orbis magnus*) loses any detectable proportion (*proportion sensible*) to the sphere of the fixed stars: "This distance therefore of the inmoveable heaven is so excedinge great, that the whole *Orbis magnus* vanisheth awaye, yf it be conferred to that heaven."[58] Saturn's sphere is "next to the infinite Orbe immoveable garnished with lights innumerable."[59] Terrestrial corruptibility, "our Elementare corruptible worlde," is opposed to the fixity of the heavens, the "sphaericall altitude without ende." Digges's illustrative and rightly famous diagram of planetary orbs is different from that in *De revolutionibus* in the significant aspect that it represents the orb of the fixed stars as open. Stars are in fact scattered beyond the sphere of Saturn. This diagram exerted great influence in England, where the infinity of the universe became part of the Copernican theory. Gilbert, for one, adopted this image in *De mundo nostro sublunari philosophia nova* (*New Philosophy of Our Sublunary World*, 1651), adding the remark that stars appear to us to be at rest because they are beyond the action of the Sun, which extends only up to Saturn.[60]

Digges demonstrates the infinity of the sphere of the fixed stars on the basis of a kind of "principle of plenitude." It would be surprising (*straunge*) that something could hinder the possibility (*essence*) and the existence (*beinge*) of beings (*thinge*) beyond the heavens (*without the Heaven*):[61]

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56 Digges, *Perfit Description*, 100.

57 See Johnson-Larkey, "Digges," 98 on Digges's method of translation in which "the original is not slavishly followed word for word, but freely rendered."

58 Digges, *Perfit Description*, 88.

59 Ibid., 87.

60 Gilbert, *De mundo*, 202.

61 Digges, *Perfit Description*, 91.

> But say they without [beyond] the Heaven there is no body, no place, no emptynes, no not any thinge at all whether heaven should or could farther extende. But this surelye is verye straunge that nothing shoulde have sutche efficiente power to restrayne some thinge the same having a very essence and beinge.

Digges connects the infinity of the starry heaven with its immobility. Like Copernicus, he argues that the only reason why the ancients did not accept cosmological infinity was their false opinion about the daily motion of the stars:[62]

> For the cheefest reason that hath mooved some to thincke the Heaven limited was Motion, whiche they thoughte without controversie to bee in deede in it. But whether the worlde have his boundes or bee in deed infinite and without boundes, let us leave that to be discussed of Philosophers, sure we are yet the Earthe is not infinite but hath a circumference lymitted, seinge therefore all Philosophers consent that lymitted bodyes maye have Motion, and infinyte cannot have anye. Whye dooe we yet stagger to confesse motion in the Earth beinge most agreeable to hys forme and nature, whose boundes also and circumference wee knowe, rather then to imagyne that the whole world should sway and turne, whose ende we know not, ne possibly can of any mortall man be knowne.

The Earth, according to Copernicus and the Pythagoreans, is located between Venus and Mars. Its elementary sphere is encircled by the Moon:[63]

> Therefore neade we not to be ashamed to confess this whole globe of Elements enclosed with the Moones sphere together wyth the earth as the Centre of the same to be by this great Orbe together with the other Planets about the Sun tourned making by his revolution our yeare.

It should be remarked that the Earth appears to be the only place of elements and, as a consequence, the only realm where changes take place. Evidently, Digges does not assume cosmological homogeneity, unlike ancient atomists. In Digges's cosmology, the qualitative difference between the center and the (infinite) periphery has not vanished.[64]

62 Ibid., 91–92.

63 Ibid., 86.

64 Cf. Granada, *Digges, Bruno e il Copernicanesimo*, 134.

6 The Infinity of Space and Worldly Finiteness as a Restoration of the Stoic Outlook

Digges's apparently inconsistent combination of infinitism (albeit predicated only of the sphere of the fixed stars) and the Sun's centrality, a conception in which the infinity of space does not imply the abandonment of a cosmological center, is not unique in the Renaissance. This conception of an infinite with a center could be traced back to the cosmology of the Stoics. Bruno synthesized their perspective in few words in *De l'infinito*: "They say that the world is finite but the universe infinite."[65] This worldview was widely known thanks to works like Cicero's *De natura deorum*, Diogene Laertius's *Vitae* and Cleomedes's *De mundo*. Stoic cosmology was expounded in detail in Cleomedes's introduction to Stoic cosmology, an edition of which was printed in Basel in 1547 as *De mundo sive circularis inpectionis meteororum libri duo* by Heinrich Petri, together with Proclus's *De sphaera liber* and other astronomical and cosmographical texts.

According to Stoicism, the geocentric and finite cosmos originated from a differentiation of elements stemming from an all-pervading living and intelligent *pneuma* (a mixture of fire and air). An increasingly pure pneuma, they said, fills the space between our globe and the stars, beyond which there is only an infinite void. Contrary to Aristotle, the Stoics held that heavens are not constituted of an unalterable quintessence. Instead, they are fluid. Heavenly bodies are fires and move spontaneously because they are intelligent living beings like birds and fish. Moreover, the Stoics assumed that there is an exchange of matter between the Earth and the stars which lasts until the final consumption of the matter of the world and its collapse. After that a new cosmic cycle begins.[66]

The idea of worldly finiteness and spatial boundlessness was reassessed in the Renaissance by Palingenius Stellatus, author of the successful ethical-cosmological poem *Zodiacus Vitae*, published for the first time in Venice in 1534 and put on the index of prohibited books in 1558.[67] This work, dealing with the correspondence between the signs of the zodiac and virtues, played a significant role in the acceptance of actual infinity. Palingenius imagined a universe in which the geocentric planetary system is surrounded by unlimited

65 Bruno, *Dialoghi*, 347.

66 Cf. Barker, "Stoic contributions."

67 Dauphiné, *Palingenius*, and Baldini-Spruit, *Catholic Church*, vol. 1, 137.

space, brimful with divine light.[68] In his perspective, the infinity of space did not fit together with cosmological homogeneity. His main argument was based on consideration of a divine almighty: God's power would be limited if his creation were finite (XII,20–32).[69]

It should be noticed that the *Zodiacus vitae*, translated into English by Barnaby Googe between 1560 and 1565, strongly influenced Digges's *Perfit Description*. As the man of letters Gabriel Harvey witnessed, "M. Digges hath the whole Aquarius of Palingenius bie hart: and takes mutch delight to repeate it often."[70] Digges probably owed to the *Zodiacus* the conception of an infinite space as well as that of a qualitative difference between center and (infinite) periphery. Yet, contrary to Palingenius and the Stoics, he embraced the Copernican planetary model and conceived of space as populated by innumerable stars.

It seems that the French mathematician Pena, too, derived some of his views from Stoicism, in particular that of the fluidity of the heavens permeated by an airy and vital element. However, the most explicit and illustrious attempt to restore Stoic cosmology, in particular the doctrine of a finite world plunged in a boundless space, was that of the neo-Platonic philosopher Francesco Patrizi of Cherso. In *De rerum natura libri II priores. Alter de spacio physico, alter de spacio mathematico* (*First Two Books on Nature, One on Physical Space and One on Mathematical Space*, 1587), he proposed precisely this doctrine.[71] Additionally, in the *Nova de universis philosophia* (1591), he gave an accurate, though brief, account of this ancient worldview: "Diogenes distinguished world and universe. He thought that the latter is infinite and the former finite. The Stoics taught that the universe is infinite along with the void and that all which is not the void is the world, and this is finite. The reasons for their theses [dogmata] are unknown. In fact, their writings are lost."[72] In the cosmological section of the *Nova de universis philosophia* entitled *Pancosmia*, Patrizi defended the thesis of an infinite and luminous space beyond the fixed stars, liberated cosmic space from material spheres and conceived of planets as moved by an inner force.[73] He adduced three aprioristic reasons for cosmological infinity. The first

68 Palingenius also supported the eternity of time (*Zodiacus vitae* XI). Cfr. Chomarat, "La crèation," 85–97.

69 Palingenius, *Zodiake*, 228; cf. *Zodiaque*, 475.

70 Cf. Johnson-Larkey, "Digges," 103.

71 Patrizi, *De rerum natura*, f. 9v. See also ibid., I,6.

72 Idem, *Pancosmia*, in *Nova philosophia*, f. 82*v*.

73 Cf. Rossi, "Negazione," Rosen, "Patrizi," Vasoli, "Patrizi," and Garin, *Cultura filosofica*, 402–31, "Motivi della cultura filosofica ferrarese nel Rinascimento."

is a logical-ontological doctrine of the unity of contraries, according to which the existence of actual finiteness implies that of actual infinity. Second, he claimed that the infinite power of God must necessarily express itself through a boundless creation. In addition, the all-inclusiveness of the universe implies that it cannot be encapsulated in anything external to it, because by definition it already encompasses everything, corporeal and incorporeal.[74] Like the Stoics, Patrizi asserted that the world's finiteness and space's infinity coexist; therefore, space has a qualitative center, namely the Earth, "Terra haec, quae in medio infiniti mundi posita" (this Earth located in the middle of the infinite world).[75]

7 Benedetti's Approach to the Copernican System

In the late Renaissance other authors also sought to restore the conception of a finite world in an infinite space. I would like to consider in the following two mathematicians who developed their cosmologies independently: Benedetti in Turin, Italy, and Pegel in Rostock, Germany. The Stoic elements they shared reveal the wide diffusion of certain ideas. However, I shall also underline the differences, especially the fact that Benedetti was a supporter of the physical reality of the Copernican system while Pegel was not.

In Benedetti's major work *Diversarum speculationum mathematicarum et physicarum liber* (*Various Speculations on Mathematics and Physics*, 1585) cosmological remarks are scattered across different sections.[76] Although his main scientific interest concerned arithmetic, geometry and mechanics, he also tackled astronomical issues like the calendar reform and the nova of 1572, among others.[77] Brahe referred to this section with admiration in the *Progymnasmata*, and to Benedetti's observations of Venus in his correspondence with the Landgrave of Hesse-Kassel.[78]

In the epistle "On the Aim of Celestial Bodies, and Their Motions" (*De fine corporum coelestium, et eorum motu*) to the court historian Filiberto Pingone, Benedetti reveals his commitment to a realist interpretation of Copernicus's

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74 These arguments are reviewed briefly in Patrizi, *Nova philosophia*, f. 83*v*.

75 Ibid., f. 151*v*.

76 See Di Bono, "Astronomia copernicana" and Omodeo, "Cosmologia."

77 Benedetti, *Diversae speculationes*, 371–74, "De stella Cassiopeiae," and 205–10, "De temporum emendatione."

78 Brahe to Rothmann (21 February 1589), in idem, *Opera*, vol. 6, 172, where Brahe refers to Benedetti, *Diversae speculationes*, 257.

hypotheses. He remarks that it is not reasonable to believe that the heavens were created only to assist or govern terrestrial events, "since those [celestial] bodies are divine, uncountable, endowed with maximal dimensions and very fast motions."[79] This assertion is strengthened, so Benedetti, by the planetary doctrine of Aristarchus and Copernicus.[80] Moreover, the thesis that the Earth is just a planet supports the principle of homogeneity. The analogy between the Earth and the other planets leads Benedetti to assume that other planets are not immune to change, life, death, and corruption (*ab ortu, et interitu*), as supposed by Aristotle. The Peripatetic objection that no change in the heavens has ever been observed is not valid, because the distance does not permit to verify whether any life exists or alterations occur on other heavenly bodies.[81] Benedetti surmises that other planets are moons reflecting the solar light to dark earths, invisible to us, around which they turn.[82] He considers this arrangement to be the genuine Copernican theory. It is probably an attempt to account for the epicyclic motions of other planets through an analogy with the lunar epicycle around the Earth. Benedetti also rejects the Ptolemaic and Aristotelian arguments against the motion of the Earth. Like Copernicus in *De revolutionibus* I,8, he remarks that its axial rotation substitutes the exaggeratedly quick rotation of the fixed stars.[83] Moreover, the annual revolution respects the dignity of the "divine body of the Sun" (*divinum corpus solare*) that stands still at the center of the planetary circles.[84] In the final passage of his letter, Benedetti repeats Copernicus's argument that bodies suspended in the air partake of terrestrial motion:[85]

> Ptolemy's counterarguments against [terrestrial motion] have no cogency according to them [Aristarchus and Copernicus]. In fact, they say, all parts partake of the nature of the whole. Thus, the air and water around the earth clearly receive the same natural impetus of motion. This [motion] is slower, the more distant the air is from the Earth itself. According to such opinion, there is no necessity for the place of the fixed [stars] to be bounded by any surface, either convex or concave.

79 Benedetti, *Diversae speculationes*, 255–56.
80 Ibid.
81 Ibid.
82 The same thesis is presented ibid., 195–96.
83 Ibid., 255–56.
84 Ibid., 256.
85 Ibid.; cf. *De revolutionibus* I,7–8.

According to this passage, the air close to the Earth is transported by the motion of the planet and slows down the further away it is located from it. The fixed stars are placed in a motionless *aer* whose place (*locus*) has no boundaries, neither convex nor concave.

Benedetti discusses "the form of the world" in a letter to the courtier Giovanni Paolo Capra.[86] He refers to the heavens as a sphere encompassed by an infinite space. In fact, he distinguishes between *spacium* (space) and *coelum* (heavens), like the Stoics and Palingenius Stellatus. It is likely that, concerning this issue, he was influenced by his correspondent Patrizi or exerted some influence over him.[87]

Furthermore, Benedetti rejects the existence of material spheres deputed to transporting planets: "You should not remain with that common opinion concerning the distinction of celestial spheres. Rather, you should believe that the whole is a kind of continuum containing the bodies of the stars. This is no novelty since several philosophers of solid doctrine agreed with it."[88] Celestial bodies' motions are accompanied by that of certain vapors (*fumi*). This motion should be the actual cause of the sparkling of the most distant stars.[89] The unsteadiness of the light of the 1572 nova in Cassiopea is further evidence of its great distance above the Moon.[90]

The *Diversae speculationes* also include a discussion on and a refutation of Aristotelian physical and celestial theses *de motu*. Although this section has a rather neutral title, "Disputation on Certain Aristotelian Opinions" (*Disputationes de quibusdam placitis Arist*[*otelis*]), it is in fact an attempt to rethink basic concepts of natural philosophy such as *locus* (place) and *tempus* (time). I will consider these disputations in further detail in the next chapter. By now it shall be sufficient to point out that there Benedetti defends the theory of the infinity of space and explicitly directs it against Aristotle.[91] In this context he also reaffirms the atomist thesis of the existence of a physical void.

Moreover, in this anti-Aristotelian section, Benedetti endorses the Copernican hypotheses even more explicitly than in the aforementioned letter to Pingone, repeating the "Achilles argument" of the excessive speed of the daily motion if ascribed to planets and stars. Close to the equator, the

86 Ibid., 285–86, "De motu molae, et trochi, de ampullis, de claritate aeris, et Lunae noctu fulgentis, de aeternitate temporis, et infinito spacio extra Coelum, Coelique figura."

87 For Benedetti's correspondence with Patrizi, see Claretta, "Lettere tre."

88 Benedetti, *Diversae speculationes*, 411.

89 Ibid., in the section entitled "Disputationes de quibusdam placitis Arist[otelis]," 186.

90 Ibid., 371–74, "De stella Cassiopeiae." See Di Bono, "Astronomia copernicana."

91 Ibid., 181.

Sun should cover 1,000 Italian miles per minute and Saturn 260,000 miles per minute, not to mention the speed of the fixed stars. The assumption of this inconveniently rapid speed could, of course, be avoided if one assumed the "wonderful theory" (*pulcherrima opinio*) of Aristarchus, "divinely" restored by Nicholas Copernicus:[92]

> This [very rapid motion of the heavens] might seem very difficult; however, it would not occur according to the beautiful opinion of Aristarchus of Samos, divinely reworked by Nicholas Copernicus. It is clear that neither Aristotle's nor Ptolemy's arguments can validly object to it.

From a Copernican perspective, the Sun would cover "only" 48 miles per minute and Saturn 24, whereas the heavens would be stationary.

Benedetti supports the plurality of worlds, as well (*plures mundos existere*). "Mundus" means in this context a "planet" similar to our own globe. According to Benedetti, every planet should be regarded as another Earth with its elements and natural places.[93] He reasserts here his bizarre analogy between the Moon and the planets. Like our satellite, all these light-mirroring and wandering bodies are supposed to turn about dark earths which, in turn, spin about their axes:[94]

> If Aristarchus's system [*opinio*] is correct, it will be perfectly logical that the same things occurring to the Moon occur also to the other five planets. Thus, just as the Moon, thanks to its epicycles, revolves around the Earth, as on the circumference of a certain epicycle in which the Earth is like a natural center (i.e., it is in the middle) and is carried by the sphere of annual motion around the Sun; in the same way also Saturn, Jupiter, Mars, Venus, and Mercury might revolve about some [celestial] body located in the center of their major epicycle. And this body, also having some motion about its axis, might be opaque, possessing conditions like those of the Earth, while on that epicycle there might be things similar to those of the Moon.

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92 Ibid., 195.

93 Ibid.

94 Ibid., 195–96. Translation revised from Drake-Drabkin, *Mechanics in Sixteenth-Century Italy*, 222.

8 Stoicism in Germany: Pegel's Cosmology

If one considers Pegel's *Universi seu mundi diatyposis* (*The Order of the Universe or World*, 1586), one finds an eclectic collection of cosmological theses, which emerged from an environment very different from Benedetti's. Pegel is a rather obscure figure in the history of science. He came from Rostock, where he also completed his studies. From 1575 to 1581 he was professor of mathematics at the newly opened University of Helmstedt. He later taught in Rostock, from 1591 to 1605. Then he moved to Prague, where he presumably stayed at the court of Rudolph II until the emperor's death in 1612. As to his scientific connections, he met and befriended some of the most illustrious astronomers of the age. He declared himself proud of his acquaintance with the Landgrave Wilhelm IV of Hesse-Kassel and his son Moritz in *Thesaurus rerum selectarum* (*Treasure of Selected Issues*, 1604), a book of political, medical and mechanical "inventions." According to Pegel's report, Wilhelm discussed with him astronomical issues, showed him a celestial globe on which the positions of stars had been corrected, and shared with him observational data.[95] At the court of Kassel, Pegel also met the famous instrument builder Jost Bürgi, whom he called a friend.[96] Pegel also met Brahe, whose astronomical instruments and observations he very much admired.[97] In the *Thesaurus*, one reads about their mutual esteem and friendship, in spite of some disagreement on planetary theory.[98]

The *Diatyposis* is presented as "an anatomy of the macrocosm and the whole from inside as well as from outside."[99] Pegel's cosmological overview begins from the ethereal region in a section "On the Aethereal or Starry Region of the World." After that, he tackles "that part of the world below the stars and above the so-called elementary region." Pegel deals first with the universal "container" (*continens*), which he also calls "air" (*aer*) and then the contained things (*contenta*). The Earth—or earthly-and-watery globe—is called *continens integrus*. The author lists its parts (*partes terreni globi maiores*): geographical continents and seas, as well as the *partes minores* (smaller parts) "such as plants, metals, stones and fossils."[100] The final section deals with animals, or rather, the hierarchical chain of living beings culminating in man.

95 Pegel, *Thesaurus*, 73–74. Cf. Omodeo, "Disputazioni."
96 Ibid., 74.
97 Ibid., 75.
98 Ibid., 75–76.
99 Pegel, *Diatyposis*, f. A2*r*.
100 Ibid., f. B4*r*.

The first section of the *Diatyposis*, on the ethereal region, presents a series of anti-Aristotelian theses. Following the Stoics, Pegel distinguishes a finite heaven and an infinite universe:[101]

> First, we will posit and demonstrate that the [outermost] heaven [*caelum*] or world [*mundus*] is finite. Second, we will briefly discuss those things that are considered to be in the interminable universe outside the heaven. Finally, we will demonstrate that the extreme border of this heaven is round.

As to the "inner form" (*figura interior*) or "heavenly machine" (*machina coeli*), Pegel rejects the existence of material orbs. Instead, he considers its matter to be aerial and advocates the "unity and continuity" (*unitas seu continuitas*) of space.[102] He also underlines the similarity between the "natures" and "essences" of the heavens and the sublunary sphere. As a consequence of this equation, the heavens are "corruptible" and "fruitful." Hence, life is not restricted to the Earth.[103] Stars are innumerable but not infinite in number, and are not equidistant from us.

The main celestial motions are three: the first is said "motum coeli totius [...] ab ortu in occasum" (motion of the entire heavens from east to west), has a rate of 24 hours, and accounts for the daily rotation of the heavens around the poles. The second one concerns special displacements of the seven planets and the stars, which are supposed to vary their positions (*longitudinum et latitudinum mutationes*). The third one accounts for the millenarian phenomena, like the precession of the equinoxes. Air is the transmission medium of the first and the third motions downward. Pegel surmises that air is more rarefied at the center and gradually less so the further it gets from the Earth. This gradual rarefaction explains why heavenly motions only partially affect the air close to us.[104]

According to Pegel, the "place" of the Earth cannot be determined with precision. It is not at the center of any solid spheres—in fact, they do not exist—nor of the concave surface of the heavens—probably because it is not neatly separated from the inferior *aer*. Since the distances to the stars change, they cannot be taken as a reliable reference to establish the position of the

101 Ibid., f. A2*r*.
102 Pegel, *Diatyposis*, f. A2*r*.
103 Ibid., f. A2*v*.
104 Ibid., f. A4*v*.

Earth in the long term.[105] Still, Pegel holds that the Earth is located on the rotation axis of the daily motion, although not necessarily at its mean point.

In another work of his, entitled *Aphorismi thesium selectarum de corporibus mundi totius primariis* (*Aphorisms of Selected Theses on the Primary Bodies of the Entire World*, 1605), Pegel places the Earth at the point where the axis of the daily rotation intersects the ecliptic plane.[106] In this later work, he openly embraces the so-called Capellan system: "Venus and Mercury do not move in circles below the Sun, not above it, but around it."[107]

Pegel tackled the Copernican theory in the *Diatyposis*: "We will treat the question as whether the entire terrestrial globe moves or rests; whether this globe could have a daily or an annual motion, as somebody asserts not as a mere hypothesis but as something real. Hence very remarkable considerations will follow."[108] These *considerationes haud indignae*, here announced, are not reported in the text. As was usual with academic disputations, they were discussed only orally. We can assume that Pegel criticized terrestrial motion. In the later work *Aphorismi*, in fact, he expressly rejected the three motions that Copernicus attached to the Earth, because he considered them untenable from a physical point of view.[109]

The author is suspicious of hypotheses, which, he writes, are devised only for the computation of positions (*calculus logisticus*). In order to achieve accurate predictions, long and repeated observations of the heavens should be carried out. This would improve astronomical theory more rapidly and better than any speculations concerning planetary arrangements. Pegel also discusses whether real effects (*motus veri*) could be drawn from false presuppositions (*ex falsis*). Like de la Ramée, he claims that hypotheses are "labyrinths" that should be abandoned.[110] In the *Aphorismi* of 1605, he denounces the arbitrariness of all hypotheses (thesis 101), due to the irregularity of all celestial phenomena

105 Ibid., f. B2*r*.

106 Ibid., f. A3*v*.

107 Pegel, *Diatyposis*, f. A3*v*. For the medieval reception of Capella, see Eastwood, *Ordering*, chap. 4, "Martianus Capella's Synopsis of Astronomy in 'The Marriage of Philology and Mercury' and its Major Carolingian Commentaries." In the early modern cosmological debate, the Capellan system was widely spread in the Netherlands as well: cf. Vermij, *Calvinist Copernicans, passim*.

108 Pegel, *Diatyposis*, f. B2*v*.

109 Pegel, *Aphorismi*, f. A3*v*, theses 17 and 18.

110 Pegel, *Diatyposis*, f. A4*r*. Cf. Jardine-Segonds, "Challenge."

(thesis 114), and proposes substituting astronomical geometry for celestial "geography" (thesis 116).[111]

An original aspect of the *Diatyposis* is the treatment of the vacuum, with which Pegel deals in the section on the *aer*. The *aer*, he explains, should be conceived as a universal *continens*: "This aerial extension, already defined with certainty, admits nothing else than itself as having the nature of a container."[112] It entails *vacuum*: "And also the air contains inside its substance, much of that thing that is usually called "vacuum." And the vacuum, to which is usually refused existence, in reality is present inside all substances and things just like in the air."[113] The void permeates the *aer*, all substances and beings. It even has the character of a metaphysical and vitalistic principle underlying reality:[114]

> Furthermore, that so-called vacuum is itself the substance or even the essence of air and of the other things and provides [them with their substance or essence], it penetrates everything, conveys life and actions into everything and transforms itself into other things as well. What's more, without that vacuum or content [*contentum*], things would have no location [*domicilium*] or place [*continens*], and there would be no principles and elements nor accidents of any other kind.

This conception of void seems to owe much to the pneuma of the Stoics. This all-pervading and life-giving principle communicates motion to nature, it is "the substance of the substances" and "of the accidents," and the principle of principles. It should be therefore distinguished from metaphysical *nihil*. Pegel clearly explains it in the *Aphorismi* of 1605 (thesis 3), in which he also defines it as "locus sine corpore," a kind of absolute space.[115]

Philosophical vitalism and the idea of the becoming of all things are closely linked with this conception. All bodies have perceptions and are constantly in motion.[116] There is a universal *nexus* linking all living beings, a bond with the whole, the "corpus universum [...] unum et sympaticum" ("the universal body

111 Pegel, *Aphorismi*, ff. C3*r*–*v*.
112 Pegel, *Diatyposis*, f. A4*v*.
113 Ibid.
114 Ibid.
115 Pegel, *Aphorismi*, f. A2*v*.
116 Idem, *Diatyposis*, f. C1*r*.

which is one and sympathetic").[117] Also the Earth incessantly changes its face according to a *rerum vicissitudo* (vicissitude of things) that resembles, as we shall see, Bruno's idea of the *vicissitudine*.[118] Bruno was in northern Germany in those years and frequented Helmstedt shortly after Pegel left. I would not exclude the possibility that they influenced each other, since their views on nature have several points in common.

9 Bruno's Pythagorean Correction of Copernicus's Planetary Model

Like Copernicus and most of his contemporaries, Bruno traced his conception back to ancient doctrines. However, his sources of inspiration were quite varied. All they had in common was the potential to be directed against Aristotelianism. It has been observed, though, that Bruno developed his most innovative views as a response to Aristotelian philosophy, according to "a program of offensive reception and philosophical reinterpretation."[119] Accordingly, his anti-Aristotelian theses were a "masterwork of scholastic-antischolastic polemics."[120]

Whatever his Aristotelian legacy, Bruno presented his anti-Aristotelian physical theses in the *Camoeracensis Acrotismus* (1588), as a revival of the Pythagorean and Platonic views on nature.[121] Fundamental aspects of his doctrine were at odds with the Peripatetic conception, especially the immensity of the universe, the infinite number of worlds and cosmological homogeneity. In his rejection of Aristotelian views, especially in *De l'Infinito* (dialogues IV and V) and *De immenso* (books II and VII), Bruno regarded the atomists, the Pythagoreans and the philosophers of the *physis* as his forerunners: "Now, Heraclitus, Democritus, 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 that 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."[122] Still, the metaphysical foundation of the infinite universe

117 Ibid., f. C1*v*.

118 Ibid., ff. B3*r–v*.

119 Blum, *Bruno*, 77.

120 Ibid., 76.

121 Ibid., 80–81.

122 Idem, *Supper*, 206.

is a reworking of a more recent source, namely Cusanus's *Docta ignorantia*, on which Bruno based his rebuttal of the Scholastic distinction between God's *potentia absoluta* and *potentia ordinata* (absolute versus ordered powers).[123] This distinction accounted for the fact that the infinite power of God has a certain order and limitation in the created world.[124] By contrast, Bruno held that divine Almighty shall unfold in a boundless universe.

According to Bruno, heliocentrism is a genuinely Pythagorean doctrine. Aspiring to the restoration of ancient cosmological wisdom, he even departed from the letter of *De revolutionibus* in his treatment of planetary order. In his Latin writings *Articuli adversus peripateticos* (1586), *Acrotismus* (1588), *Articuli adversus mathematicos* (1588), and *De immenso* (1591), he outlined a planetary model in which the Earth and Mercury share the same concentric deferent, although they are set on diametrically opposite points of the same circle. The Moon and Venus are their respective satellites. The almost central Sun rotates on a small circle, which is supposed to account for the variation in its apparent size during the year. As to the superior planets, Bruno surmises in *De immenso* that they could have a disposition similar to that of the inferior ones.[125] This awkward arrangement can be seen as an attempt to reconsider the theory of *De revolutionibus* in the light of philosophical assumptions based on a presumed Pythagorean cosmology. To sum up, Bruno sought to correct Copernicus through what he considered to be the genuine Pythagorean model.

Bruno departed from Copernicus concerning the motions of the Earth as well. In the *Cena*, he ascribed four motions to it, even though their number is limited to three in *De revolutionibus*. In fact, he derived the principal heavenly phenomena from Peuerbach's *Theoricae novae planetarum*. Accordingly, he transferred four motions from the Sun (annual motion) and the fixed stars (three motions) to the Earth. Thus, Bruno's first and second motions of the Earth are daily rotation and annual revolution, like in Copernicus, whereas the third is the precession of the equinoxes and the fourth the trepidation. This can be shown by a textual comparison with Peuerbach:

123 Granada, "Rifiuto."

124 Granada, "Rifiuto."

125 For a detailed presentation of this model, see Granada, "Héliocentrisme." Cf. also Tessicini, *Dintorni*.

Bruno, ***La cena de le Ceneri***	**Peuerbach,** ***Theoricae novae planetarum***
The third motion derives from that which makes it seem that the eighth sphere moves over the poles of zodiac in the direction opposite to the diurnal motion, following the order of the [zodiacal] signs, but so slowly that in two hundred years it shifts no more than one degree and twenty-eight minutes.[126]	The second [motion comes] from the ninth sphere, which is called the second movable and which always moves uniformly on the poles of the zodiac following the order of the [zodiacal] signs, against the first motion, so that every two hundred years it advances nearly one degree and twenty-eight minutes.[128]
The fourth motion is derived from the trepidation, approach and recession [*accesso e recesso*], which the eighth sphere is said to perform over two equal circles imagined in the concavity of the ninth sphere, above the principles of Aries and Libra of its zodiac.[127]	The third motion [of the eighth sphere], which is called the motion of trepidation or approach and recession [*accessus et recessus*] of the eighth sphere, is special to this sphere and is made on two equal small circles in the concavity of the ninth sphere. These two circles are described over the principles of Aries and Libra of the same sphere, in such a way that two particular points of the eighth sphere, diametrically opposite, which are called the "heads" of Aries and Libra of the same sphere, uniformly describe the circumferences of those two circles of the ninth sphere.[129]

Bruno read Peuerbach through Copernicus or, the other way around, interpreted Copernicus through Peuerbach, with the result that he augmented the number of terrestrial motions to four.[130] As to the Copernican motion of declination, which was postulated mainly to explain the constant inclination

126 Bruno, *Supper*, 221. Cf. idem, *Cena*, 126.

127 Idem, *Supper*, 221. Translation slightly revised. Cf. idem, *Cena*, 126.

128 Aiton, "Peuerbach's *Theoricae*," 36–37. Cf. Peuerbach, *Theoricae novae*, f. g8*r*.

129 Aiton, "Peuerbach's *Theoricae*," 37. Translation partly revised. Cf. Peuerbach, *Theoricae novae*, f. g8*r*.

130 Omodeo, "Bruno and Copernicus" and Granada, "Héliocentrisme de Bruno."

of the terrestrial axis, Bruno considered it to be unnecessary, as one reads in *De immenso*.[131]

10 Bruno's Defense of Cosmological Infinity

Bruno connected heliocentrism and the infinity of space with the principle of universal homogeneity. "The Nolan [Bruno] [...] holds that the universe is infinite, whence it follows that no body can simply be in the middle of the universe or at its periphery or anywhere between these two limits except through certain relations to other nearby bodies and artificially imposed limits."[132] In this passage from the *Cena* (1584), he asserted cosmological infinity and what one can refer to as a "cosmocentric" principle: it is impossible to trace a center and a periphery in an infinite homogeneous space. Whereas Cusanus employed the paradox of the infinite sphere exclusively as it relates to God, Bruno extended it to the world.

The universe is, so to speak, the corporeal all; the bodies in it, for instance the Earth, the Moon and the Sun, are called *mondi*. This terminological choice is already at odds with Aristotle, according to whom world and universe are synonyms. Bruno explains that he assumes the vocabulary of the Epicureans:[133]

> The difference is well known except to the Peripatetic school. The Stoics distinguish between world and universe in that the world is all that which is filled and doth constitute a solid body; the universe is not merely the world but also the void, the empty space beyond the world; and therefore they call the world finite but the universe infinite. Epicurus similarly nameth the whole and the universe a mixture of bodies and of the void; and in this universe and in the capacity thereof to contain the void and the empty, and furthermore in the multitude of the bodies contained therein he maintaineth that the nature of the world, which is infinite, doth exist.

In the first dialogue of *De l'infinito*, one finds the arguments in favor of cosmological infinity. The first step in the argumentative line is the demonstration of its logical possibility. The next step is to stress its "metaphysical convenience." As to the methodology, Bruno remarks that rationality, not sensation,

131 BOL, I,1 393.
132 Bruno, *Supper*, 152.
133 Idem, *Infinite Universe*, 272–73.

is the human faculty able to decide about cosmological infinity.[134] In fact, the senses cannot establish the boundlessness of the universe for their intrinsic limits. Observation is incomplete and can elicit only rational investigation.[135] Finiteness and infinity are both possible from a logical point of view. "Elpino: How is it possible that the universe can be infinite? Filoteo: How is it possible that the universe can be finite?"[136] These are the first lines of *De l'infinito*. Bruno claims that a major difficulty in Aristotle's arguments in support of the worldly finiteness is entailed in the definition of "place" as the surface in which a body is included. According to Aristotle, the world should be "nowhere" since he assumes that there is "nothing" beyond it. Bruno also resumes Archyta's argument: if someone could stretch his arm beyond the last boundary of the world, the arm would be nowhere and its being would be annihilated. This difficulty could be overcome only by the assumption of an infinite space. The Aristotelians also said that the universe is in itself or in its parts. Bruno objects that, although the parts do have a place in the universe, it is not possible to hold the contrary, that the entire is entailed in its components. Even if the universe were spherical, it would necessarily be placed in a boundless space.

Once the infinity of space is accepted, the existence of a single world becomes unacceptable. Bruno writes: "I will expound so that, if thou wishest to make a frank confession, then will thou say that it can be, that it should be, that it is. For just as it would be ill were this our space not filled, that is, were our world not to exist, then, for the indifference (*per la indifferenza*), it would be no less ill if the whole of space were not filled. Thus we see that the universe is of infinite size and the worlds therein without number."[137] If space is fit to contain one world, there is no reason why it should not contain an infinite number of worlds. The Silesian follower of Bruno, Abraham von Franckenberg, would later synthesize this idea in a motto on an engraving at the beginning of his *Oculus sidereus* (1644), a fervent defense of the cosmology of *De immenso* tinged with heterodox theological elements: "One world is not enough in an immense aether" (*unus in immenso non sufficit aethere mundus*).[138]

In Bruno's reasoning, the demonstration of the logical possibility of infinity is followed by consideration of its convenience, and convenience leads to necessity since God cannot but choose the best.[139] He would not be almighty

134 Del Prete, *Bruno, l'infini*, 40; Omodeo, "Mondo (*mundus*)."
135 Bruno, *Infinite Universe*, 250–51.
136 Ibid., 250.
137 Ibid., 256 (translation slightly revised).
138 Franckenberg, *Oculus*, f. A1*r*.
139 Bruno, *Infinite Universe*, 260.

and good if he did not realize an infinite universe. Only a *tutto infinito* is fit to divine power. In this respect, Bruno distinguishes between the infinity of the universe, which is extensive and composed of finite parts, and that of the efficient, which is intensive, because God is everywhere and totally in every single point:[140]

> I say that the universe is entirely infinite [*tutto infinito*] because it hath neither edge, limit, nor surfaces. But I say that the universe is not totally infinite [*totalmente infinito*] because each of the parts thereof that we can examine is finite and each of the innumerable worlds contained therein is finite. I declare God to be entirely infinite [*tutto infinito*] because he can be associated with no boundary and his every attribute is one and infinite. And I say that God is totally infinite [*totalmente infinito*] because the whole of him pervadeth the whole world and every part thereof infinitely and totally. That is unlike the infinity of the universe, which is totally in the whole but not in those parts which we can distinguish within it [the universe] (if indeed we can use the name parts, since they appertain to an infinite whole).

Finally, Bruno argues, like Spinoza in the following century, that freedom, will and necessity coincide in God: "Wherefore we perceive the complete identity of liberty, free will and necessity and, moreover, we recognize that action and will, potentiality and being are but one."[141] God cannot choose whether to generate a finite or an infinite universe.

11 Homogeneity, Aether and Vicissitude according to Bruno

Bruno's cosmological principle of homogeneity unifies the terrestrial and the celestial realms. The heavens are not constituted of an incorruptible quintessence and elements have no natural place, contrary to Aristotle. In other words, Bruno rejects "quel bell'ordine e quella bella scala di natura," that nice order and that lovely scale of nature connected to cosmological hierarchization and the Peripatetic views on heavens, natural places, and elements. He substitutes the concentric heavens with an infinite space (or "aether") which has the natural attitude to contain infinite bodies.

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140 Ibid., 261–62. Translation substantially revised. For the original Italian text, see *De l'infinito*, 335.

141 Ibid., 263.

In the *Cena*, Bruno reports about a heated discussion with two Oxonian Aristotelians asking him "of what substance those bodies are made, which are believed to consist of quintessence, that is of an unalterable and incorruptible material, the most dense parts of which are the stars."[142] To this "he answered that the other globes, which are earths, are not at all different from this one in kind; but [differ] only in being bigger and smaller, [just] as inequality occurs in any other species of animals through individual differences."[143] The only qualitative difference is that the suns are warm and luminous, whereas planets are cold and dark and their luminosity reflects solar light. Moreover, heavenly spheres are mere phantasies because celestial bodies "are not embedded in a single cupola, a ridiculous notion which children might conceive, imagining perhaps that if they were not attached to the celestial tribune and surface by a good glue, or nailed with stoutest nails, they would fall on us like hail from the air immediately above us. But you consider that those innumerable other earths and vast bodies hold their positions and their proper distances in ethereal space just as doth our Earth, which by her own revolution giveth an impression that they are all chained together and are revolving around it."[144]

The analogy between the Sun and the stars and that between the Earth and other planets, visible or invisible for their distances, leads Bruno to imagine that the universe could be inhabited by a plurality of worlds or systems. "There are then innumerable suns; and an infinite number of earths revolve around those suns, just as the seven we can observe revolve around this Sun which is close to us."[145] Their number is infinite, exactly like the extension of space. This is not only "plausible" but also convenient—and necessary. Bruno's argumentative line is the same as that employed to demonstrate the infinity of the universe: "If God can, he will." We see the stars but not the planets due to the reduced dimensions of those earths, their distances from us and the fact that their light is only reflected.

As Bruno wrote in his comedy *Candelaio*, published in Paris in 1582, "Time takes away and offers everything; all things change and nothing is annihilated. There is only one being that cannot change, only one is eternal and can remain one forever, similar [to itself] and the same."[146] Cosmological homogeneity implies that everything in nature, not only terrestrial beings, is subject to becoming, contrary to Aristotle: "since annihilation is impossible to Nature

142 Bruno, *Supper*, 153.

143 Ibid., 154.

144 Idem, *Infinite Universe*, 299. Translation slightly revised.

145 Ibid., 304.

146 Idem, *Candelaio*, 7. See Granada, "Bruno y Manilio."

itself, therefore it renews itself with the passage of time in some order, altering, changing, and transforming all its parts."[147] In addition, "the matter and substance of things is incorruptible and every part of it must be the subject of every form, so that every part can become every thing (insofar as it is able), and be everything (if not at the same time and instant of eternity, at least at different times, at various instants of eternity, successively and alternately)."[148]

Bruno assumes that, although everything changes, nothing is annihilated in its atomic and metaphysical substance. According to *De triplici minimo* (1591), the atom, a terminus which is intechangeable with "monad" and "individuum," can be considered from different viewpoints, as a point, according to geometry, as a minimum body, according to physics, and, most prominently, as God, according to metaphysics. The ontological principle of reality is an all-encompassing and indivisible unity, in which minimum and maximum coincide. In a derivate manner, souls descending from and depending on God can also be said atoms (or monads). They are indivisible, thus immortal minima.[149] As to the distinction between atom as essential unity and atom as physical indivisible particle, it can be conveniently expressed as the distinction between *minimum participatum* (the essence which is participated) and *minimum participans* (the being that participates of that essence).[150] They also survive the death, that is, the dissolution, of the body they inhabit.

All changes in natural phenomena can be traced back to local motion: "Local motion has most properly been considered the source of all other mutations and forms, and without it there could be nothing else."[151] Universal becoming or *vicissitudine* and atomism are interrelated, as one reads in *De l'infinito*: "I declare on account of such vicissitudes, it is not inconvenient but on the contrary most reasonable to state that the parts and the atoms have an infinite course and infinite motion, owing to the infinite vicissitudes and transmutations both of form and of position."[152] The transformations which take place in nature therefore presuppose the existence of physical vacuum and of atoms. Democritus and Epicure are mentioned as those "who better understood and contemplated nature with open eyes."[153]

147 Idem, *Supper*, 213.

148 Ibid.

149 On Bruno's atomism: Omodeo, "Minimum und Atom," and Bönker-Vallon, "Mathematische Konzeption" and *Metaphysik und Mathematik*.

150 Cf. Dagron, "Philosophie en devenir."

151 Bruno, *Supper*, 214.

152 Idem, *Infinite Universe*, 285.

153 Ibid., 374. Translation emended.

Concerning the dissolubility of the worlds, they do not dissolve necessarily, as Bruno claims in accordance with the Platonic motto (*Timaeus*, 41a–b): "Voi siete dissolubili, ma non vi dissolverete,"[154] or "Vos quidem dissolubiles estis, nequaquam vero dissolvemini."[155] In *De immenso*, Bruno raises a doubt concerning this issue: "We do not know this with certainty although we know for sure that they are composite and, as a consequence, dissoluble."[156] As Granada has recently stressed, in *De immenso* Bruno abandons his previous conviction that the worlds can be indefinitely maintained in their being thanks to an intrinsic principle of self-preservation, because he acknowledges that their *potentia* is limited.[157] Nonetheless, he maintains that they can persist eternally for extrinsic and providential reasons. Since power and will coincide in God, their never-ending conservation is at least plausible, although one shall concede that "worlds could [but must not] dissolve, if their nature is dissoluble."[158]

12 Kepler's Anti-Brunian Pythagoreanism

Unlike Bruno, Kepler tried to keep heliocentrism and infinitism separated, and not to intermix Pythagoreanism and atomism.[159] Yet, he had to confront Bruno, whose infinitist philosophy was very popular in Prague. Heinrich Julius of Braunschweig, who was Bruno's patron during his stay in Helmstedt from January 1589 to April 1590 and to whom the Latin poems (*De triplici minimo et mensura*, *De monade* and *De immenso*) were dedicated, was a member of Rudolph II's court beginning in 1607. He died in Prague a year after the emperor, in 1613. Rudolph II also supported Bruno: in 1588, he rewarded the philosopher for the *Articuli adversus mathematicos* (*Articles against the Mathematicians*, 1588), which were dedicated to him. To the supporters of Bruno there, one ought to add the imperial counselor Wackher von Wackenfels, who was a benefactor of Kepler—as famously appears from the dedication of the latter's essay

154 Idem, *Cena*, 119; *Supper*, 213: "You are dissoluble, but you will not dissolve." Cf. Omodeo, "Mondo (*mundus*)."

155 BOL I,1 176 (*Camoeracensis Acrotismus*).

156 Bruno, *De immenso* II,5. See BOL I,I, 274.

157 Granada, "Voi siete dissolubili."

158 BOL I,I, 272.

159 It is worth mentioning that Kepler's acquaintance with Aristotle's *De coelo*, II,13–14 is documented by his translation of the text, in German, with additional commentaries: KGW, vol. 20/1, 161–67.

on snowflakes.[160] Wackenfels also supported the poet Havekenthal, known under the pseudonym Valens Acidalius, who had known Bruno in person and dedicated to him a celebratory poem included in his *Epigrammata* (1589).[161]

After the publication of Galileo's telescopic observations in 1610, it seemed that the novelties of *Sidereus nuncius* could offer empirical evidence for Bruno's conceptions: the number of stars was considerably augmented and the Moon appeared similar to the Earth, confirming the principle of cosmological homogeneity. Moreover, new "worlds" had been discovered around Jupiter, confirming the plurality of rotational centers. In his reply to Galileo, *Dissertatio cum Nuncio sidereo*, Kepler reported that he was informed of the novelties by his friend Wackenfels. The latter believed that the recently discovered Medicean celestial bodies confirmed the plurality of worlds in an infinite space. However, he was not well informed:[162]

> Wackher [...] maintained that these new planets undoubtedly circulate around some of the fixed stars (he had for a considerable time been making some such suggestion to me on the basis of the speculations of the Cardinal of Cusa and of Giordano Bruno). If four planets have hitherto been concealed up there, what stops us from believing that countless others will be hereafter discovered in the same region, now that this start has been made? Therefore, either this world is itself infinite, as Melissus thought, and also the Englishman William Gilbert, the founder of the science of magnetism; or, as Democritus and Leucippus taught, and among the moderns Bruno and Bruce, who is your friend, Galileo, as well as mine, there is an infinite number of other worlds (or earths, as Bruno puts it) similar to ours.

Edmund Bruce, mentioned here, was an English aristocrat about whom little is known besides that he was an expert in mathematics, the art of war and botany, as well as a disciple of Bruno. He was a mutual acquaintance of Kepler and Galileo.[163] Upon Wackenfels's announcement, Kepler saw his view of the cosmic harmony threatened. He wondered whether the discovery of new planets could be reconciled with his Pythagorean harmonic views concerning the cosmos. The conceptions of *Mysterium cosmographicum* were, in fact, based

160 KGW, vol. 4, 263.

161 Di Giammatteo, "*Valentini Acidali Epigrammata*."

162 The English translation is taken from Rosen's edition: Kepler, *Conversation*, 10. Cf. KGW, vol. 4, 289.

163 Cf. Bucciantini, *Galileo e Keplero*, 93–116.

on the finiteness of the universe and the proportion among its parts. Later, when Kepler was able to read the copy of the *Sidereus nuncius* belonging to the Tuscan ambassador in Prague, he was reassured that the new celestial bodies encircled not a star, but Jupiter. Whereas the discovery of other planetary systems would have undermined his cosmology, the Medicean satellites were reconcilable with his geometrical world system.[164]

The dissemination of Bruno's philosophy in Prague could account for a remarkable shift in Kepler's judgment on Cusanus and, in particular, in his interpretation of the latter's opinion of the infinity of space. In the *Mysterium cosmographicum*, Kepler referred to him as a source in favor of the spherical finiteness of the world. He praised the "divine Cusanus" (*divinus mihi Cusanus*) for his doctrine of learned ignorance and for the idea that the circle (and the globe) is an appropriated image of the Christian God. He accepted Cusanus's view (*Learned Ignorance*, II,3) that the center symbolizes the Father, the surface the Son and the radius the Holy Spirit. According to young Kepler, this was a theological legitimization for the spherical finiteness of the world, created in the likeness of the Trinity.[165]

Thus, in the *Mysterium*, Kepler did not regard cosmological infinity as a consequence of Cusanus's reflection on the *sphaera infinita*. This negligence could have been motivated by Cusanus's distinction between the infinite sphere, which is God, and the worldly machine, which only partakes of God's essence. It should be further remarked that the theological ideas underlying Kepler's treatment did not stem from the *Docta ignorantia*, but rather from *De theologicis complementis*.[166] This brief essay, treating the squaring of the circle from a philosophical-theological perspective, recovered the theses of the *Docta ignorantia* that the circle symbolizes the Divine Trinity, and that planetary revolutions were imprecise or, better to say, "almost circular" (*quasi circulares*), contrary to Aristotelian-Averroist cosmology.[167] Also, displacement of the moving Sun was deemed to be imprecise.[168] This essentially anti-heliocentric assertion did not prevent Kepler from considering Cusanus as a Copernican, since the Sun's rotation, interpreted as an axial rotation, was part of his reworking of the Copernican system (*Mysterium cosmographicum*, chap. 20). As Cusanus asserted the circular form of the universe in *De theologicis complementis*, it

164 Cf. Granada, "Kepler and Bruno."

165 For Kepler's theological approach to cosmology see: Martens, *Kepler's Philosophy*, Barker-Goldstein, "Theological Foundations," and Schwaetzer, "*Si nulla*."

166 For Kepler's Cusanian sources see: Bialas, "Zur Cusanus-Rezeption," 45–53.

167 Cusanus, *De theologicis complementis*, 29–33 and 37.

168 Ibid., 39.

is very likely that this treatise determined Kepler's early interpretation of its author as an advocate of a finite and spherical world, in contrast to the opinion of the most of his contemporaries.[169]

When Kepler wrote the *Mysterium*, he was not yet acquainted with Bruno's philosophy and cosmology. He must have heard of him for the first time when he moved to Prague, before the publication of *De stella nova* in 1606. In this book, in fact, he criticized Bruno's infinite cosmology, although he acknowledged that the Copernican thesis of the immobility of the stars could lead to speculations concerning the boundless dimensions of the universe: "That Aristotle demonstrated the finitude of the world from its motion while Copernicus admits that the sphere of the fixed stars is infinite, since it has no motion."[170] However, due to the lack of empirical evidence, he regarded such speculations as a "misuse of the authority of Copernicus as well as a corruption of astronomy in general, which proves [...] that the fixed stars are at an incredible altitude."[171] Kepler countered Bruno, remarking that stars are not equally distributed in the heavens. He addressed this issue again in the *Dissertatio cum Nuncio sidereo* (1610) and in the *Epitome astronomiae Copernicanae* (*Summary of Copernican Astronomy*, 1618–1622). In the former publication, he added that the heavens would be bright even at night if one accepted Bruno's thesis that the stars are similar to the Sun and infinite in number. The confrontation with Bruno and his followers in Prague must have influenced Kepler's understanding of Cusanus. In later works, in fact, he adopted the Brunian interpretation of Cusanus as an infinitist. As I have mentioned, the Cardinal appears in the *Dissertatio* along with post-Copernican infinite cosmologists like Bruno, Bruce and Gilbert.[172] In the *Narratio de observatis quatuor Iovis satellitibus* (*Account on the Observation of the Four Satellites of Jupiter*, 1611), too, he repeated this equation of Cusanus's and Bruno's cosmology: "If the author [Galileo] had lied about those new planets why, may I ask, did he not feign infinite many others around infinite many fixed stars, as Cardinal Cusanus, Bruno and other claim, and did he not declare them plausible, in accordance with their authority?"[173]

As far as Kepler's Pythagoreanism is concerned, it was the reverse of Bruno's. Whereas Kepler interpreted the Pythagorean cosmology in the light of the advancements of mathematical astronomy, the Italian philosopher corrected Copernicus's theory through a doctrine that he believed to be the

169 Omodeo, "Contingente geometria."
170 Kepler, *De stella nova*, in KGW, vol. 1, 253.
171 Ibid. (translated by Granada, "Kepler and Bruno," 479).
172 KGW, vol. 4, 289.
173 Ibid., 317.

true Pythagorean worldview.[174] Concerning the dimensions of the universe, it is clear that Bruno and Kepler relied on different metaphysical principles and natural philosophies, even though both claimed the Pythagorean origin of their views.

13 Conclusions: Eclectic Concepts of Cosmological Space in the Renaissance

The issue of cosmological space and the dimensions of the universe was a heated topic in the post-Copernican Renaissance debate. Recent "forerunners" like Cusanus and Palingenius were read attentively and quoted by convinced disciples of the heliocentric system, as witnessed by Digges's love for the *Zodiacus vitae* and Bruno's positive mentions of *Docta ignorantia* and his criticism of Palingenius in *De immenso*, VIII. Copernicus's readers reflected on the enlarged dimensions of the universe, in particular the augmented distance of the stars entailed by the heliocentric theory. They also considered the possibility of cosmological infinity opened up by the axial rotation of the Earth, since this thesis questioned one of the main astronomical arguments for the sphericity (and the finitude) of the heavens. In this context, various cosmologies of the past were rediscovered as valid alternatives to the Aristotelian. Among them, Pythagoreanism played an important symbolic role, since it was believed that this ancient philosophy, which emphasized the mathematical structure underlying nature, should also have supported a heliocentric system. As I have showed, due to the lack of precise information aside from a few fragments, Pythagoreanism was not much more than a label. Different followers of Copernicus made reference to this philosophy in order to rework the system presented in *De revolutionibus* in various ways, as the cases of Benedetti, Bruno and Kepler show. Stoicism and atomism also provided scholars with cosmological theses, among them that of infinite space. According to the Stoics, boundlessness did not mean renouncing a cosmological center, since one could suppose a qualitative difference between the realm below the celestial vault and the empty space above the fixed stars. Several Renaissance scholars adhered to this conception of a finite *coelum* surrounded by an infinite *spacium*, for instance Patrizi and Benedetti in Italy, and Pegel in Germany. Democritean atomism met with novel success as well, and the idea of a boundless but homogeneous space, deemed to be part of this ancient doctrine, played a crucial role in Bruno's reworking of Copernicus. His Pythagorean correction

174 See Granada, "Héliocentrisme," 35.

of the number and form of the terrestrial and planetary motions is, in a sense, the reverse of Kepler's attempt to restore a finite and harmonious heliocentric system. Not only were ancient conceptions freely transformed by Renaissance scholars, but this happened to relatively recent authors as well, most evidently to Cusanus, whose alleged Pythagoreanism was often connected to the Copernican system. Cosmological order (or disorder) and the extension of the universe and of space were discussed during the late Renaissance by relying on eclectic sources, read and corrected so as to better fit with the arguments and views different thinkers sought to advance. The closed world and the infinite universe, rather than termini of a linear progression from the former conception to the latter, seem to be the poles of a intense discussion in which different models of cosmological space were evaluated, proposed and defended, mixing different astronomical and natural elements. As we have seen, Copernicus's work was a point of reference for scholars interested in these issues; however, there was no standard Copernican view on the concept of space. For this reason, too, *De revolutionibus* could be twisted in different directions and be interpreted from an infinitist point of view or a finitist one, integrated with and enriched by Pythagorean, Cusanian, atomist or Stoic elements.

CHAPTER 5

A Ship-Like Earth: Reconceptualizing Motion

The physical problem of Copernican astronomy, that is, the question concerning the interrelation between mechanics and planetary theory, is an issue that has been debated at length in the history of science. Yet, it remains controversial. This chapter offers a reassessment, focusing on the Renaissance discussions before Galileo. This analysis seems particularly pertinent in consideration of the remarkable discordance between the two major narratives about the historical ties between astronomy and physics in early modernity.

In *Die Mechanik in ihrer Entwickelung: historisch-kritisch dargestellt* (*Science of Mechanics: A Critical and Historical Account of Its Development*, 1883), Ernst Mach presented the interconnection of mechanics and planetary theory as a late stage in the development of mathematical physics, namely the result of the efforts of Kepler and, more maturely, Newton. These scholars did, in fact, treat planetary motions as a physical issue, investigating the laws and the forces ruling the solar system as a whole.[1] According to Mach—who closely followed Lagrange's overview of the history of mechanics in *Méchanique analitique* (*Analytical Mechanics*, 1788) on this point[2]—mechanics originated independently of astronomy, namely from a tradition whose roots are not only theoretical but also technical, material and social. The development of statics from antiquity to the Renaissance, one reads, "illustrates in an excellent manner the process of the formation of science generally. [...] These beginnings point unmistakably to their origin in the experiences of the manual arts."[3] Concerning dynamics—on Mach's account, "entirely a modern science"[4]—celestial physics was an extension of "terrestrial" mechanics applied to astronomy.

Alexandre Koyré later offered a quite different, if not opposite, narrative of what he called the "Scientific Revolution," a development of ideas which presumably extended from Copernicus's astronomy up to Newton's synthesis of terrestrial and celestial physics via Bruno, Galileo and Descartes. He reduced this process to the emergence of a few ideas, in particular the principle of

1 Mach, *Science of Mechanics*, 231 ff.

2 Lagrange, *Méchanique*, I,1, "Sur les différens Principes de la Statique," 1–12 and II,1, "Sur les différens Principes de la Dynamique," 158–89.

3 Mach, *Science of Mechanics*, 89.

4 Ibid., 151. Cf. Lagrange, *Méchanique*, 158.

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inertia, which was vaguely conceived by Galileo and defined in a "clear and distinct" manner by Descartes. Koyré assumed that the scientific revolution had a prologue and an epilogue in the heavens, with Copernicus's system at its outset and Newton's unification of terrestrial and celestial physics its final result. His thesis was that the mathematical science of nature developed by Galileo, Descartes and Newton emerged as a direct consequence of the Copernican criticism of the Aristotelian worldview.[5] The Copernican assertion that the Earth becomes a celestial body would lead to post-Galilean physics, hinged on the concept of inertia.[6]

Both historical approaches show some disadvantages. A special difficulty in Mach's narrative lies in the fact that it does not take into account the "physical problem of Copernicanism," that is to say, the questions concerning dynamics that arise from terrestrial motion. Mach regarded as relevant only the mechanical treatment of the solar system as a whole. Koyré's narrative is incomplete in other respects. First, it is rather dubious that modern mechanics can be reduced to a small set of ideas turning about the principle of inertia. Older and recent research on practical mathematicians, "scientist-engineers" and "challenging objects" has confirmed Mach's claim that the modern development of physics was firmly rooted in a tradition of mechanics, including its technical and material aspects.[7] The question I will ask is therefore: if so-called "classical physics" cannot be regarded as dependent on post-Copernican astronomy, how should we regard it in its undeniable connection with astronomy and cosmology?

In the following, I will consider the two major narratives and integrate them in order to overcome their one-sidedness. My treatment will not be restricted to the question as to how the development of astronomy influenced physics. I will also discuss whether and how Copernicus's astronomy was modified by the emerging mathematical physics, that is, how its meaning was transformed and evaluated in light of the developing mechanics. Copernicus himself hinted at the physical problems with his cosmological doctrine in *De revolutionibus*, in some of the most famous chapters of the first book. I will thus begin from Copernicus himself and one of his contemporaries, Celio Calcagnini, who

5 Koyré, *Galileo Studies*, 131.

6 See also Westfall, *Construction*, 22.

7 See, among others, Renn-Damerow-Rieger, "Hunting the White Elephant," Bertoloni Meli, *Thinking with Objects*, Valleriani, *Galileo Engineer*, Renn, "Galileis Revolution," and Renn-Damerow, "Transformation."

envisaged some solutions to the physical difficulties entailed by terrestrial motion. I shall also recall the historical precedents, which, in one way or another, paved the way for later discussions on astronomy and motion in general. It should be remarked that the connection between cosmology and physics was treated differently by different readers of *De revolutionibus*. I will focus on Bruno, Benedetti and Brahe. The first conceived of heliocentrism as a crucial element of a philosophical and cultural renewal. Accordingly, his discussion of Copernicanism and physics, even as early as the *Cena*, is part of a general philosophical program. In Benedetti's case, planetary theory is not the focus of his investigation (I will consider the *Diversae speculationes* of 1585). Nonetheless, he presented heliocentrism as relevant for the foundations of physics. Third, although Brahe was in disagreement with Copernicus about terrestrial motion, he felt compelled by the ongoing discussions on terrestrial motion to examine all conceivable arguments for and against it. In his writings, which greatly influenced both supporters and opponents of Copernicus, one can find one of the most extensive sixteenth-century treatments of the physical consequences of Copernican theory.

1 The Connection between Cosmology and Physics in Aristotle and Ptolemy

The close connection between cosmological and physical arguments for geocentricism and against terrestrial motion had been established by Aristotle and reinforced by Ptolemy. Copernicus confronted and criticized these two classic pillars of the science of the heavens, in order to demonstrate the plausibility of the heliocentric option. Aristotle's advocacy of geocentricism, in *De caelo* II,13–14, essentially relied on his hylemorphic natural philosophy (his matter-form conception of natural beings), the doctrine of natural places and the theory of violent and natural motion. According to Aristotle, the elements are intrinsically heavy or light: earth and water have a natural tendency downward whereas air and fire have an analogous but reverse tendency upward. As for Ptolemy, in the first book of the *Almagest* he derived the centrality of the Earth from geometrical considerations based on the assumption that celestial appearances should be altered by a supposed displacement of the Earth from the cosmological center.[8] Along with their different premises, Aristotle

8 Omodeo-Tupikova, "Post-Copernican Reception."

and Ptolemy deemed different observational phenomena to be relevant in ascertaining the position of the Earth in the heavens: the behavior of bodies on Earth and astronomical observation, respectively.[9] It should be mentioned that arguments derived from both Aristotle and Ptolemy had been merged, albeit abridged and simplified, in Sacrobosco's medieval scholastic textbook *De sphaera* and its innumerable commentaries.

Chapters five to eight of *De revolutionibus*, introducing and defending the motion of the Earth, are essentially a response to *Almagest* I,5–8. Not only does Copernicus there reject Ptolemy's arguments, he also reworks them (or part of them) as premises leading to opposite conclusions concerning the position of the Earth and its motion.[10] In *Almagest* V,1, Ptolemy demonstrates that the Earth is situated at the intersection of the axis of the daily rotation and the ecliptic by speculating on the variations that the heavenly phenomena would show if the Earth were displaced from the center in different directions (north-south, east-west). Copernicus summarizes Ptolemy's viewpoint in *De revolutionibus* I,5:[11]

> Many [i.e. Ptolemy and his followers] have thought it possible to prove by geometrical reasoning that the Earth is in the middle of the universe; that being like a point in relation to the immense heavens, it serves as their center; and that it is motionless because, when the universe moves, the center remains unmoved, and things nearest to the center are carried most slowly.

A few lines before this passage, Copernicus already hints at the inconsistency of Ptolemy's geometrical demonstrations. He contends that the Earth's distance from the center does not affect the appearance of the stars or, conversely, that the stars are far enough from the Earth that its displacement remains unperceived. For this purpose, Copernicus repeats a Pythagorean argument, remarkably, one that he could derive from Aristotle's *De caelo* II,13:

9 Iidem, "Cosmology and Epistemology."
10 Cf. Kokowski, *Copernicus's Originality*, 80 ff.
11 Copernicus, *Revolutions*, 12; GA II,11. In references to the *Almagest*, I follow the numbering of the chapters in the 1515 Venice Latin edition, which is also preserved in Toomer's English edition.

Copernicus, *De revolutionibus* I,5	**Aristotle, *De caelo* II,13**
Anyone who denies that the Earth occupies the middle or center of the universe may nevertheless assert that its distance [therefrom] is insignificant in comparison with [the distance of] the sphere of the fixed stars, but perceptible and noteworthy in relation to the spheres of the Sun and the other planets.[12]	Since the Earth's surface is not in any case the center, they [the Pythagoreans] do not feel any difficulty in supposing that the phenomena are the same although we do not occupy the center as they would be if the Earth were in the middle. For even on the current view there is nothing to show that we are distant from the center by half the Earth's diameter.[13]

According to Aristotle's report, the Pythagoreans derived consequences from the absence of stellar parallax that suit the Copernican view: the lack of any perceptible variations in their angular distances evinces the insignificance not only of the terrestrial radius, as in the *Almagest* (and in *De coelo* II,13), but also the negligibility of the terrestrial annual revolution in comparison with the distance to the fixed stars. Copernicus adds that the displacement of the Earth from the center is insignificant in comparison to the dimensions of the heavens, but not as compared to those of other planetary orbs. It should be further noted that Aristotle, in another passage of *De caelo* (II,14), quite inconsistently resorted to the argument of stellar parallax to support geocentricism.[14]

Ptolemy faces the issue of (the absence of) stellar parallax in *Almagest* I,6 to demonstrate that the Earth is a mere point compared with the heavens. In other words, the terrestrial radius has no meaningful proportion to that of the celestial sphere. Copernicus dismisses this argument as irrelevant in *De revolutionibus* I,6, "The Immensity of the Heavens Compared to the Size of the Earth." There, he also assumes that the heavens are "immense" compared to the Earth and that this makes the axial rotation of the Earth plausible, since "a rotation in twenty-four hours of the enormously vast universe should astonish us even more than a rotation of its last part, which is the Earth."[15]

12 Ibid.

13 Aristotle, *De caelo*, II,13 293 b 25–30; *On the Heavens*, 221.

14 Ibid., II,14 297 a 2–8; *On the Heavens*, 247.

15 Copernicus, *Revolutions*, 13; GA II,12.

De revolutionibus I,7 deals with ancient arguments for geocentricism which are derived in part from *Almagest* I,7 and in part from Aristotle, especially from *De caelo* II,13–14. These arguments are mainly physical, that is, they concern the laws ruling the behavior of bodies on Earth. They can be grouped into three classes: first, gravity (and lightness); second, the simplicity of motion; and third, the behavior of bodies suspended in air.

Concerning the first point, Copernicus reports that geocentricism could be supported by reasons derived from heaviness and lightness. He writes: "the Earth being spherical, by their own nature heavy objects are carried to it from all directions at right angles to its surface." This remark can be found in *De caelo* II,14 (296 b 7 ff.), where it is said that an observer who notices that heavy bodies fall vertically to the ground at all latitudes (and already knows that the Earth is spherical) can easily conclude that heavy bodies fall in a straight line toward the center of the Earth. Ptolemy reports the same observation in *Almagest* I,7, not as a proof of geocentricism but as one of its consequences:[16]

> In absolutely all parts of the Earth, which, as we said, has been shown to be spherical and in the middle of the universe, the direction and path of the motion [...] of all bodies possessing weight is always and everywhere at right angles to the rigid plane drawn tangent to the point of impact.

As to the Earth, it should be at rest in the middle "thanks to its weight."[17] This is a rather Aristotelian assumption. Ptolemy writes: "If the Earth had a single motion in common with other heavy objects, it is obvious that it would be carried down faster than all of them because of its much greater size."[18] According to Aristotelian physics, in fact, a bigger heavy object falls more quickly than a smaller one made of the same material.[19]

Second, Copernicus recalls the Aristotelian thesis that a simple body (a natural element) has a simple motion. This implies that a body cannot move vertically and circularly at the same time. Since the four elements of the Aristotelian tradition move either upward or downward in a straight vertical line, it should be excluded that terrestrial motion can bring them into circular motion without violence. For this purpose, Copernicus recalls the thesis of *De caelo* II,14 that a simple body, as an element, can have only one motion and

16 Ptolemy, *Almagest*, 43.

17 Copernicus, *Revolutions*, I,7, 14.

18 Ptolemy, *Almagest*, 44.

19 Aristotle, *De caelo*, II,13 294 a 11 ff.

cannot simultaneously move toward the center (the Earth) and from the center (for instance, the Sun), as would be the case if the Earth moved.[20]

Third, Copernicus reports Ptolemy's remarks about the disruptive consequences of terrestrial motion and the effects of flying and thrown objects.[21]

> The revolving motion of the Earth must be the most violent of all motions associated with it, seeing that it makes one revolution in such a short time; the result would be that all objects not actually standing on the Earth would appear to have the same motion, opposite to that of the Earth: neither clouds nor other flying objects would ever be seen moving towards the East, since the eastward motion would always outrun and overtake them, so that all other objects would seem to move in the direction of the west and the rear.

2 Copernicus's Physical Considerations

De revolutionibus I,8 is one of the most famous and frequently commentated astronomical passages ever. It was paraphrased in English as early as the 1570s by Digges, in *A Perfit Description*. In chapter eight Copernicus tries to respond to the Ptolemaic and Aristotelian objections to terrestrial motion that he has just illustrated. Chapter nine then expounds the motions of the Earth in detail. One can say that, from the point of view of the book's structure, chapters seven and eight correspond to chapter seven of the *Almagest*, and chapter nine of the former to chapter eight of the latter. In *Almagest* I,8, Ptolemy presented the motions of the stars and of the other planets, which, according to Copernicus, should be explained by taking into account terrestrial motion. In fact, the motions of the heavens, or more precisely, of the fixed stars, pertain to the Earth, while the annual revolution around the Sun accounts for stations and retrograde planetary motions.

Copernicus first revises the theory of natural and violent motions. These concepts ought to be reconsidered from a heliocentric perspective: "If anyone believes that the Earth rotates, surely he will hold that its motion is natural, not violent."[22] Therefore, terrestrial motion cannot have disruptive consequences. Second, the rotation of the starry heavens is more absurd than that

20 Ibid. II,14, 296 b 25 ff.

21 Cf. Ptolemy, *Almagest*, 45. On the copy of *Almagest* used by Copernicus and his interpretation of it, see De Pace, *Copernico e la fondazione*, 121–39.

22 Copernicus, *Revolutions*, 15.

of the Earth, as already said before, because the speed of this rotation would immensely exceed that required for the relatively small Earth to accomplish it. Copernicus's third remark concerns space and infinity.[23] While the dimensions and the form of the universe are a controversial matter, so Copernicus, those of the Earth are well known. Since motion is natural for a sphere, one should not hesitate to attribute to the Earth motions which are more convenient for it, rather than to heavens, the boundaries of which we cannot establish with certainty. All celestial phenomena relative to the fixed stars would remain unchanged by the assumption of terrestrial motion, because this hypothesis is an optical equivalent. Renaissance readers of *De revolutionibus* found in these pages a quotation from Virgil's *Aeneid* (III, 72) which was to become a sort of Copernican motto: *Provehimur portu, terraeque urbesque recedunt*, that is, "Forth from the harbor we sail, and the land and the cities slip backward."[24]

Concerning flying and thrown objects, Copernicus assumes, first, that things in the air partake of terrestrial motion, either because they share the same "nature" of the Earth, or because the air close to the Earth is transported without resistance. He secondly assumes that the vertical motion of the elements (*cadentium vero et ascendentium*) is a composite motion (*duplicem*) relative to the whole (*mundi comparatione*), with a rectilinear and a circular component. This assertion contrasts with the Aristotelian principle that natural motion cannot be composed. According to Copernicus only circular motion is natural. It belongs not only to celestial bodies but also to the elements in their natural place. By contrast, rectilinear motion is that of bodies detached from their whole and impelled to rejoin their original state of union with it. However, this motion does not have a uniform speed, but is accelerated. On top of this, Aristotle was wrong to assume that a body is heavy or light in its own place, since it ceases to be heavy or light once it is in its proper place.

A further argument of metaphysical character is that "immobility is deemed nobler and more divine than change and instability, which are therefore better suited to the Earth than to the universe."[25] This passage shows a typical Aristotelian understanding of motion as not reduced to local displacement but including all forms of change. *Immobilitas* is opposed to *mutatio* and *instabilitas*. The Earth, as the realm of change, cannot be deprived of local motion. The heavens, being the realm of perfection, shall be stable and unchangeable. The reasoning may be Aristotelian, the conclusion is not.

23 See chap. 4,1.

24 GA II,15. Copernicus, *Revolutions*, 16.

25 Copernicus, *Revolutions*, 17.

3 Nominalist Sources on Terrestrial Motion

The sources of Copernicus's physics have been discussed at length by historians of science and philosophy. In particular, the relevance of nominalist sources for the development of a theory of motion which could be accorded to the heliocentric hypotheses was strongly supported by scholars of medieval science like Pierre Duhem, Anneliese Maier and Marshall Clagett.[26] The issue at stake for them was to show the origin of the idea of inertia from the medieval *impetus* dynamics. Koyré rejected this direct derivation, showing the intrinsic limits of the *impetus* theory as adopted by the young Galileo.[27] More recently, Fritz Krafft and Anna De Pace traced Copernicus's natural ideas back to other sources, in particular Plutarch. According to them, Copernicus's physics owes much more to Plutarch's *The Obsolescence of Oracles* and *Concerning the Face… of the Moon* than to Parisian nominalism. In fact, contrary to Aristotle and the Stoics, Plutarch stated that the Earth is not necessarily at the center, that gravity and lightness are relative and not absolute, that only gravity is a positive force, namely the tendency of the parts to reach their whole, and that the world has a plurality of centers.[28] All of these theses must have played a role in the reconstruction of a theory of motion in a geokinetic framework. On the other hand, in keeping with many biographers of Copernicus's early years, André Goddu reassessed the presence and dissemination in Cracow of ideas stemming from Parisian Aristotelianism.[29] Be that as it may, I will presently restrict myself to review those ideas stemming from Parisian nominalists which apparently influenced the reception of Copernicus regarding the physical problems that provided sixteenth-century scholars with theories, arguments or, at least, metaphors.

Clagett especially underlined the importance of two works: Buridan's *Quaestiones super libris quattuor de caelo et mundo* (*Questions on the Four Books on the Heavens and the World*) and Oresme's *Le livre du ciel et du monde* (*Book on the Heavens and the World*). Both tackled the motion of the Earth and argued its plausibility from a merely logical point of view. Moreover, they treated this issue on different levels (relative to optics, physics and scriptural exegesis). Buridan and Oresme believed the persistence of motion to depend

26 Duhem, *Études sur Léonard*, Clagett, *Science of Mechanics*, and Maier, *Zwei Grundprobleme*.

27 Koyré, *Galileo Studies*, *passim*.

28 Krafft, "Copernicus retroversus II," De Pace, "Plutarco" and *Copernico e la fondazione*, 149 ff. On Platonic theories of motion, see also Knox, "Ficino, Copernicus and Bruno," "Bruno's Doctrine," and "Copernicus's Doctrine."

29 For a recent account of Copernicus's student years, see Goddu, *Copernicus*.

on an inner tendency, called *impetus*, in agreement with more or less ancient predecessors beginning with Johannes Philoponus of late antiquity, who had provided Aristotelian natural philosophy with an alternative theory of motion.[30]

Buridan regarded *impetus* as a quantity that he roughly associated with the matter of the projectile and its speed. He explained its final arrest through the impediment presented by its weight and the resistance of air. Additionally, Buridan thought that *impetus* could account for the perpetual motion of celestial bodies as a *virtue* conferred to them by God in the act of Creation. The same force explained the acceleration of falling bodies: gravitation, in fact, gives a body a growing *impetus* the longer it falls. Oresme conceived of the imparted virtue in a slightly different manner. He considered it to be transient and was dubious whether it should be regarded as the cause of uniform motion or, rather, of acceleration.[31]

In book II, question 22 of his reflection on Aristotle's *De coelo*, among the questions Buridan posed was whether the Earth is the center of the world (*utrum Terra sit directe in medio mundi*) and "whether, in positing that the Earth is moved circularly around its own center and about its own poles, all the phenomena that are apparent to us can be saved" (*salvari omnia nobis apparentia*).[32] The solution to this *dubitatio* was that celestial appearances would be respected if one assumed the immobility of the starry sphere along with the axial rotation of the Earth. In order to persuade his reader, Buridan introduced the successful example of the ship:[33]

> If anyone is moved in a ship and he imagines that he is at rest, then, should he see another ship which is truly at rest, it will appear to him that the other ship is moved. This is so because his eye would be completely in the same relationship to the other ship regardless of whether his own ship is at rest and the other moved, or the contrary situation occurred. And so we also posit that the sphere of the Sun is everywhere at rest [relative to the daily motion], and that the Earth in carrying us would be rotated. Since, however, we imagine that we are at rest, just as the man located on the ship which is moving swiftly does not perceive his own motion nor

30 Sorabji, *Philoponus*. See also Lettinck, *Aristotle's Physics*, and Grant, "Aristotle, Philoponus."

31 According to Maier, *Zwei Grundprobleme*, 291, Buridan's and Oresme's approaches to the *impetus* theory diverged on precisely this point.

32 Buridanus, *Quaestiones*, 226–27. For the translation, see Clagett, *Science of Mechanics*, 594.

33 Clagett, *Science of Mechanics*, 594. Cf. Buridan, *Quaestiones*, 227.

> the motion of the ship, then it is certain that the Sun would appear to us to rise and then to set, just as it does when it is moved and we are at rest.

Heavenly phenomena would remain unchanged on the basis of the simple optical law of the relativity of the perception of motion.

In the *Quaestiones de caelo et mundo*, Buridan advanced some arguments that could make terrestrial motion "probable." The first, later reassessed by Copernicus, is that heavenly bodies—and above all the highest sphere—must have nobler conditions than the Earth. Since rest is the noblest state, it should be attributed to that which is most perfect in nature. Moreover, one could appeal to a principle of economy, which is also part of Copernicus's line of argumentation.[34] Moreover, Buridan remarked that Aristotle's authority could not be used against terrestrial motion, because astronomy is concerned only with how to account for phenomena (*quod sufficit astrologos ponere modum per quem salventur apparentia sit ita in re sive non*).[35]

In spite of this quasi-conventionalist assertion, Buridan did not neglect the physical problems of terrestrial rotation. He rejected the Ptolemaic idea that terrestrial motion would be detectable from the resistance of the air: "Earth, water and air in the inferior region are moved simultaneously by that daily motion, so that the air does not exert any resistance to us."[36] He moreover considered the trajectory of an arrow launched vertically in the air: if the Earth moves, does the arrow fall down back to the point from which it was shot, or not? Even though it could be argued that the air transports the arrow along with the Earth, Buridan did not accept this. In fact, he held that it is physically impossible that a body be subject to two *impetus* with different directions. This is why he considered the argument of the arrow as the strongest against terrestrial motion. As we shall see, Brahe would revive it literally in his physical arguments against the Copernican system.

Although his cosmology was geocentric, Buridan did not exclude the possibility of all terrestrial motion. In fact, he surmised that the gravitational center could vary periodically. The geometric center and the gravitational center are not one and the same because, according to him, the elements are not distributed equally on the Earth. The globe is thus subject to periodical adjustments. Geological phenomena like mountain erosion redistribute matter and produce constant changes relative to the gravitational center.[37]

34 Buridan, *Quaestiones*, 228–29.

35 Ibid., 229.

36 Ibid.

37 Cf. Duhem, *Études sur Léonard*, 332–36, and Omodeo, "Riflessioni sul moto."

In *Du ciel et du monde* (*On the Heavens and the World*), Oresme reassessed and perfected Buridan's hypothetical arguments in favor of terrestrial motion. Section II,25 is devoted to this issue. There, he declared his willingness to test the doctrine of Herakleides of Pontus, who asserted the immobility of the heavens and terrestrial rotation.

He began by recapitulating the principal arguments deriving from experience that were brought forward by the opponents of terrestrial motion: the motion of the stars, the fact that air and wind do not blow eastward, and the observation that a stone thrown upward vertically falls back exactly to the point of departure. Relative to the motion of the stars, Oresme objects that motion is relative. To illustrate this, he resorts, like Burdian, to the ship metaphor:[38]

> It is stated in book four of *The Perspective* by Witelo that we do not perceive motion unless we notice that one body is in the process of assuming a different position relative to another. I say, therefore, that, if the higher of the two parts of the world mentioned above were moved today in daily motion—as it is—and the lower part remained motionless, and if tomorrow the contrary were to happen so that the lower part moved in daily motion and the higher—that is, the heavens, etc.—remained at rest, we should not be able to sense or perceive this change, and everything would appear exactly the same both today and tomorrow with respect to this mutation.

Concerning the motion of the air, Oresme says that it shares that of the Earth. Contrary to his master's opinion about the cogency of the arrow argument (*experience* [...] *de la seëtte ou pierre gecte*[*e*] *en haut*), he believes that bodies suspended in the air can be expected to partake of its motion.[39] This can be illustrated through the example of a man moving his arm on a ship. He would think that he is accomplishing a vertical motion, whereas his arm is also carried horizontally by the vehicle. Motion, one reads, can thus be composed. In the case of an axial rotation of the Earth, all vertical motions must have a straight as well as a circular component. Oresme considers in particular the upward vertical motion of fire:[40]

> I maintain that, just as with the arrow above, the motion of *a* in this case also must be compounded of rectilinear and, in part, of circular motion,

38 Oresme, *Livre du ciel*, 523.

39 Ibid., 524.

40 Ibid., 525.

> because the region of the air and the sphere of fire through which *a* passes have, in Aristotle's opinion, circular motion.

Beyond the arguments from experience, another group relies on reason (*monstré par raison*). Against those who held that terrestrial motion would undermine astronomy, Oresme holds that it does not matter whether the observed thing or the observer moves.[41]

He further proposed some "likely" arguments in favor of terrestrial motion, especially the principles of economy and simplicity according to which "an action accomplished by several or by large-scale operations which can be accomplished by fewer or smaller operations is done for naught."[42] Terrestrial rotation has the advantage of avoiding the excessive speed attached to the eighth sphere. Moreover, it eliminates the celestial sphere deputed to the daily rotation (the eighth); therefore, the fixed stars move with only one motion in order to produce the precession (traditionally explained through a ninth sphere).

In spite of his detailed argumentation, in his conclusion Oresme reassesses the immobility of the Earth, adducing that the geostatic model is in better agreement with the letter of the Bible: "However, everyone maintains, and I think myself, that the heavens do move and not the Earth: "For God hath established the world which shall not be moved" [*Deus enim firmavit orbem Terrae, qui non commovebitur*]."[43] Nonetheless, Oresme's and his master Buridan's ideas and arguments concerning terrestrial motion provide us (and provided Renaissance thinkers) with a large collection of arguments and suggestions that reappeared in different forms in the sixteenth-century astronomical debate.

4 Calcagnini

Before dealing with Copernicus's successors, let us first consider the essay *Quod coelum stet, Terra autem moveatur* (*That the Heaven Stands Still whereas the Earth Moves*), which was composed by Copernicus's learned contemporary Celio Calcagnini of Ferrara. This short treatise, written about 1518–1519 but not printed until 1544, is a modest work considered from the point of view of mathematical astronomy, but contains significant natural and philosophical

41 Ibid., 530.
42 Ibid., 535.
43 Ibid., 536.

arguments in favor of terrestrial motion.[44] It includes a list of real or alleged authoritative sources of terrestrial motion, as well. Its cultural background can be traced back to Erasmian humanism, Renaissance Platonism and a fascination for Pythagoreanism and Oriental wisdom. In fact, Calcagnini's writing appeared for the first time in a heterogeneous collection, *Opera aliquot*, which was published by Froben in 1544, and contained many other essays by Calcagnini like "De rebus Aegyptiacis" ("On Egyptian Things") and "De re nautica" ("On Navigation"), commentaries and paraphrases of Cicero and Aristotle (for instance, considerations on *Meteorologica*), discussions on various philosophical issues (e.g. *De concordia, De calumnia, De salute ac recta valetudine*) and even a "Compendium magiae" (*Summary of Magic*).

The treatment of terrestrial motion is embedded in a general discourse on the fallibility and the illusions of our senses in accordance with the skepticism of the ancient Academy: "Did you not hear that, in the ancient Academy, the opinion was diffused, concerning things and the whole nature, that nothing can be grasped or understood with certainty about it[?] A discipline of this kind is either a mere form of ignorance, or something very close to ignorance."[45] Calcagnini's distrust concerning the reliability of sensation could be reformulated, in a less rhetorical and radical manner, by Copernicus's words at the beginning of the *Commentariolus*: "I treat terrestrial immobility as due to an appearance."[46] Calcagnini was doubtlessly familiar with the Platonic distinction between knowledge and opinion, ἐπιστήμη versus δόξα. He in fact advocated Platonic rationalism against Aristotelian sensualism and against Epicure, who, deceived by his trust in the senses, deemed the Sun to measure about two feet. He contrasted the reliability of reason and the illusions of the senses relative to terrestrial motion as well:[47]

> I imagine that someone could ask what the aim of my long speech is. It is to make clear to your mind that you should not trust your eyes and immediately accept as persuasive and ascertained what they show. I just told you that this heavenly sphere, that you deem to turn around with such incredible speed, this Sun and those stars, that you believe to be carried in the same circular motion, are at rest. They enjoy a perpetual rest attached to their spheres. By contrast, this Earth, which you think to be

44 De Ferrari, "Calcagnini," 496.

45 Calcagnini, "Quod caelum," 388.

46 Rosen, *Three Copernican Treatises*, 59.

47 Calcagnini, "Quod caelum," 388.

> immobile and fixed, does not stand still or rest for the dimensions of its elements, as most people believe—so far your sight deceives you.

The Earth is steadily in motion, as its restless rotation (*vertigo*) shows us constantly changing heavenly spectacles. Calcagnini compares the Earth to a ship, quoting the same passage from Virgil that also appeared in *De revolutionibus* and was to become a Copernican refrain:[48]

> I often warned you in vain to depart from your eyes at last, and to meditate on those verses of that [famous] poet: "Forth from the harbor we sail, and the land and the cities slip backward." In fact, if somebody sailing on a ship, although he knows, and perceives that he is carried by the ship, and although he is included in so narrow limits and his sight embraces the vehicle from every side, nonetheless, if he looks at the closest cliffs and woods near the shore without attention, does he not believe himself to be located in a resting place, and the banks and forest to pass by? Therefore, it has to be regarded as less astonishing that we, placed on such great mass [of the Earth], are taken away and moved as if we were ignorant about our human condition. Namely it depends on the size of our location that the impulse of that Earth is not perceived by the senses, since the great mass deceives the intellect and the swiftness confuses it.

Calcagnini repeats the metaphysical argument according to which rest pertains to the highest and noblest things; therefore, as the heavens are nobler than the Earth, they are motionless. Moreover, there are some natural reasons for terrestrial rotation: our globe is compelled to show all its sides to the solar light by the same natural force (*vis naturae*), or συμπαθεία, that turns flowers toward the Sun and explains the lodestone's attraction to iron. The Earth would be sterile if it were not continuously exposed to the Sun. It should be remarked that Copernicus, in the *Commentariolus*, also hinted at a possible magnetic source of the terrestrial motions of declination: "In more common matters, I know, of course, that an iron needle rubbed by a lodestone will always point toward the same region of the world. Still, it has seemed a preferable theory that [this motion] is brought about by some sphere, [and that] the poles themselves are moved in the direction of the motion of this sphere, which without doubt will necessarily be under the Moon."[49] Considerations on magnetism

48 Ibid., 389.

49 Copernicus, *Brief Description*, 445.

would then accompany the discussion of Copernican astronomy from Gasser to Gilbert and Kepler.

Calcagnini also outlines a principle of the conservation of a communicated motion: "In fact, once the Earth has received from nature that impulse [to motion], it cannot interrupt motion anymore without subverting and dissolving natural order [*rerum ratio*]."[50] The velocity of terrestrial motion, according to Calcagnini, is not exaggerated because the velocity needed by the stars to complete a whole circle within 24 hours would be much greater. As I have already remarked, this argument was to become one of the principal pro-Copernican arguments. It can be found not only in *De revolutionibus* itself but also in most (if not all) of the apologies for Copernicus's planetary theory.[51]

Calcagnini's view on terrestrial motion does not include the annual revolution around the Sun. Nevertheless, he ascribes to the Earth the cause of other celestial phenomena along with daily rotation. Its motion is seen as responsible for the variation of the height of the Sun during the year as a consequence of the oscillation of the terrestrial axis.[52]

> Solstices and equinoxes, the growing and shrinking of the Moon, and the variety of shadows clearly show that the Earth does not turn in a single and perpetual movement, but bends at times toward one direction and at times toward another one, for an arcane deliberation of nature, that nothing shall be certain and stable in those vicissitude of all mortal things, apart from the fact that nothing is certain and stable. Among all [nations], this is most clearly understood by those who inhabit the countries close to the pole, which the ancients once believed to be damned by darkness and cold. Actually, the fact that these have a six-month day and a six-month night does not depend on the Sun moving forth and back [*ultro citroque*] between Cancer and Capricorn, but rather on the Earth bending at times southwards and at times northwards.

The motion of the Earth, so Calcagnini, is the key to a great number of heavenly phenomena. It is supposed to be the cause of trepidation as well:[53]

> What shall I say about the trepidation of the eighth sphere, or the various movements of epicycles and deferents? Although Proclus said that

50 Calcagnini, "Quod caelum," 390.
51 Lerner, "Achille."
52 Calcagnini, "Quod caelum," 393.
53 Ibid.

> the recent authors invented all those things καθ'ὑπόθεσιν [as hypotheses], nonetheless they have been transmitted with the general approval of the mathematicians and have been approved by those who have found no other manner to account for [*demonstrarent*] those various heavenly appearances [*aspectus*], that which the Greeks called τὰ φαινόμενα.

As an erudite man, Calcagnini does not neglect to mention ancient sources that could underpin his idea: Archimedes, Hiketas, Plato and Cicero. It should be remarked that the name of Hiketas is here misspelled as "Nicetas" in the same manner as in *De revolutionibus*. This could be evidence, albeit weak, for Copernicus's acquaintance with Calcagnini's writing. They also shared the same Erasmian cultural background.[54]

As for the plausibility of a Copernicus-Calcagnini connection, the most convincing clues are biographical coincidences, above all Calcagnini's contacts with Poland and Eastern Europe. Moreover, it cannot be excluded that Copernicus remained in contact with Ferrara, where he had concluded his studies. Also, Calcagnini's contacts with Erasmus and the editors Froben and Petri in Basel should be taken into account since, as we have seen, this was an important center for the early reception of *De revolutionibus*.[55] The proximity of our two authors was noted even back in the seventeenth century, among others by Paulus Merula, professor of history in Leiden in his *Cosmographia generalis* (1605) and by the Oxford librarian Robert Burton in the *Anatomy of Melancholy* (1621).[56]

5 Renaissance Variations on the Ship Metaphor

As we have seen, the image of the Earth as a ship had already been employed by Parisian nominalists and was picked up by Calcagnini and Copernicus. It

54 See chap. 1,1 and 1,2.

55 Froben published Calcagnini's writing in support of Erasmus, *Libellus elegans de libero arbitrio ex philosophiae penetralibus* (Basel, 1525). According to Seidel Menchi, *Erasmo*, Calcagnini was a champion of Erasmus, whom he interpreted from a "Protestant viewpoint." He may have been responsible for the circulation of some of Luther's writings under the false name of Erasmus.

56 Vermij, *Calvinist Copernicans*, 31–32: Paullus Merula mentions Calcagnini along with Copernicus, Pontus de Thyard, Gemma Frisius and Johannes Stadius. In the chapter "Air Rectified. With a Digression of the Air" of Burton's *The Anatomy of Melancholy*, Calcagnini is listed among the "Copernicans," along with Telesio (sic.), Digges, Kepler, Rothmann, Gilbert, Galileo, Lansbergen and Origanus (Burton, *Anatomy* II, 58).

can be found in many other Renaissance authors before and after Copernicus.[57] Cusanus, for one, had recourse to it in the *Docta ignorantia*. He observed that the Earth moves although our senses do not detect it, and argued that its apparent immobility can be grasped through consideration of the perceptions of a ship's passenger: "If someone, sitting on a ship in the middle of the water, did not know that water is flowing and did not see the shore, how would he recognize that the ship was being moved? [...] It would always seem to each person (whether he were on the Earth, the Sun, or another star) that he was the center, so to speak, and that all other things were moved."[58] According to Cusanus, motion is relative to the observer and the ship metaphor serves to illustrate his thesis.

Explicit reference to *impetus* can be found in *De ludo globi* (*The Bowling-Game*, 1463), in a passage concerning the motion of a thrown bowling ball. The speed of this body decreases slightly in proportion to the diminution of the force communicated to the projectile by the thrower (*vis insita*). The ball stops when this force is consumed in full.[59] Cusanus affirms that a sphere has the natural tendency to move circularly: "A sphere that behaved always in the same way, on a flat and even surface, would always be moved, once it began to be moved. Therefore, the form of roundness is the form that is most suitable for the perpetuity of motion. If [a sphere] is moved on its own center, so that it is the center of its own motion, then it is moved perpetually. And this motion is a natural motion. By means of a natural motion the outermost sphere [of the heavens] is moved without constraint or fatigue."[60] It should be remarked that the natural tendency of spherical bodies to move circularly can be employed with equal success in a heliocentric or in a geocentric planetary framework: it can account either for the motions of the Earth and other planets, from a Copernican perspective, or for those of the outermost stars. Actually, in the aforementioned passage, Cusanus is referring to the sphere of the fixed stars.[61]

The ship metaphor can be found later in Digges's *Perfit Description*, together with Virgil's refrain "provehimur portu, terraeque urbesque recedunt." Digges uses it to demonstrate the optical equivalence between a model with the Earth in motion and the traditional one, as well as the composition of rectilinear and curved motion in the case of falling bodies. In the wake of the Parisian masters,

57 Cf. Mormino, "Immagine."

58 Cusanus, *Treatises*, 93 (translation revised); *Docta ignorantia*, 103.

59 Idem, *De ludo globi*, 26–27. Cf. idem, *Treatises*, 1179–274, 1192.

60 Ibid., 1191 (translation revised), idem, *De ludo globi*, 24–25. See also *ibid.*, 6–7 and idem, *Treatises*, 1183–84.

61 Cf. Maier, *Die Vorläufer*, 152, fn. 39.

Digges remarks that, if one dropped a plumb from the top of a mast to the bottom, its motion would appear rectilinear to a passenger although it is a mix of straight and circular motion:[62]

> No otherwise than if a shippe under sayle a man should softly let a plummet downe from the toppe alonge by the maste even to the decke: This plummet passing alwayes by the streight maste, seemeth also too fall in a right line, but beinge by discours of reason wayed his Motion is found mixt of right and circulare.

The reconciliation between terrestrial motion and the perpendicular fall of heavy bodies is also treated by Bruno through the metaphor of the ship and with a terminological choice that goes directly back to the idea of an *impetus* as the source of motion and its persistence. If a passenger on a moving ship lets a heavy object fall, Bruno writes, the trajectory of the body will also have a horizontal component. "This results—so the author at the end of the third dialogue of the *Cena*—from nothing other than the fact that the stone which falls from the hand of the person in the ship and which, as a result, shares its motion, has such an impressed force [*virtù impressa*] as is not possessed by the other, which proceeds from the hand of the person outside the ship, although the stones have the same weight, pass through the same air, and start (assuming it possible) from the same point and bear the same thrust."[63] In this way, the *impetus* and the metaphor of the ship are utilized once more to sustain terrestrial motion. Of course, the framework has changed from a geocentric to a heliocentric one.

The endurance of the ship metaphor among the readers of Copernicus is demonstrated by Galileo, who used this image to illustrate the behavior of bodies sharing terrestrial motion and the relativity of motion:[64]

> Motion is motion and operates as motion by how much relation it has to things which want motion; but in those things which all equally partake of it, it operates nothing and is as if it never were. Thus the merchandises with which a ship is laden move only as the ship leaves Venice and sails by Corfu, Crete, and Cyprus for Aleppo. Venice, Corfu and Crete stand

62 Digges, *Perfit Description*, 93.

63 Bruno, *Supper*, 164. Cf. idem, *Dialoghi*, 88–89.

64 Galileo, *Dialogue*, 128–29. Cf. EN, vol. 7, 141–42. For a comparison of Galileo's *Dialogue* and Bruno's *Cena*, see Aquilecchia, "*Massimi sistemi*" and Gatti, "Bruno's *Ash Wednesday Supper*."

> still, not moving with the ship. But the distance between Venice and Syria is as nothing to the chests, bales, and other parcels in respect to the ship itself, as nothing alters between them. But if a bale of the cargo were moved one inch from a chest, this alone would be a greater motion for that bale in respect to the chest, and to the ship, than the whole voyage of more than two thousand miles made by them together.

Like Copernicus and Bruno, Galileo concluded that every motion of the Earth should also be shared by its inhabitants, seen as passengers who can perceive motion only indirectly through the displacement of the heavens. The same line of reasoning concerns the motion of clouds and of the bodies suspended in the air: "the air itself through which they [the birds] fly [...] naturally, following the whirling of the Earth, like as it carries the clouds along with it, so it transports birds and everything else which is suspended in it. Therefore, as to the business of keeping place with the Earth, the birds need take no care but as far as that is concerned they might go to sleep."[65] Two centuries after Galileo, Pierre-Simon Laplace would make use of the same metaphor, the ship-Earth analogy, to present the "true" structure of the planetary system (*Des mouvemens reels des corps célestes*), and would quote Virgil's "Copernican motto" as an epigraph to the book two of his *Exposition du sytème du monde* (*Exposition of the World System*, 1796).[66]

6 Bruno's Vitalist Conception of Terrestrial Motion

Here a synthesis of Bruno's views on motion follows:[67]

> You must realize firstly, that since the universe is infinite and immobile, there is no need to seek the motive power thereof. Secondly, the worlds contained therein such as earths, fires and other species of body named stars are infinite in number, and all move by the internal principle which is their own soul, as we have shown elsewhere; wherefore it is vain to persist in seeking an extrinsic cause of their motion. Thirdly, these worlds move in the ethereal region and are not fixed or nailed down on to any body, any more than is our Earth, which is one of them.

65 Ibid., 196. Cf. EN, vol. 7, 209–10.

66 Laplace, *Exposition*, 102.

67 Bruno, *Infinite Universe*, 266; *Dialoghi*, 340.

This passage from *De l'infinito* entails the central theses of Bruno's celestial dynamics: there is no *primum mobile*, or first mobile, of the universe, deputed to communicate its motion to all heavenly bodies beginning with the outermost heaven. Bruno's principle of homogeneity and his conception of ether as a uniform and infinite space entails the rejection of the existence of any celestial spheres. According to him, planets move thanks to an inner vital principle. Bruno further rejected Aristotle's theory of natural places with its absolute spatial determinations as irreconcilable with the ideas of cosmological infinity and the infinite number of worlds. Against this background, motion results from an inner tendency, so this thesis has to explain planetary revolutions as well as gravitation in a universe that has lost its gravitational and cosmological center as well as heavenly spheres.

In the fourth dialogue of *De l'infinito* Bruno asserts that this inner principle is an *anima motrice*, that is, a moving soul: it is a natural impulse (*appulso naturale*) "to seek that position where it may best and most easily find means to maintain itself and to preserve his present state of being, since this, however ignoble, is the natural desire of all things."[68] The motive soul is thus ruled by a universal principle of conservation, since all beings aspire to their self-preservation.

The planets or "principal bodies" (*corpi principali*) display circular and not rectilinear motions because they are in themselves complete, and circular motion guarantees their self-preservation. On the other hand, straight motion is the tendency of the parts toward their whole, where they can rest. As to planetary circular motion, the Earth turns and spins in order to progressively expose its entire surface to the life-giving warmth and light descending from the Sun.[69] Like our Earth, all other planets existing in the universe turn around their suns to get warmth and perpetually renew and regenerate (*rinnovandosi* and *rinascendo*) themselves.[70] More generally, the watery earths (*terre-acqui*) and the fiery suns (*soli-fuochi*) live thanks to a reciprocal exchange of opposite virtues: the former cool down the central suns whereas the latter warm their planets.[71]

Bruno's natural philosophy is essentially vitalistic. Planetary motive souls are sensitive and intellective: "The Earth and the other stars move according to the peculiar and local differences of their intrinsic principle, which is their own soul […] [which is] not only sensitive […] but also intellective, and not

68 Ibid., 337–38; *Dialoghi*, 413.

69 Bruno, *Cena*, 119–20.

70 Ibid., 119. Cf. Omodeo, "Bruno and Copernicus."

71 Idem, *Infinito*, 399. Cf. Gatti, *Bruno and Renaissance Science*, 57–58 and 67–68.

only intellective as our souls, but perhaps even more so."[72] Accordingly, celestial and terrestrial motion can be explained in teleological terms. As we have seen, Bruno, like Copernicus, holds that gravity is the tendency of the parts to rejoin their whole and to avoid separation from it (*fuga dal contrario*).[73] Even the acceleration of falling bodies is expressed in vitalistic terms: "It is a certain and proved fact that particles of our Earth are accustomed to return from certain distant recesses to their own containing body, and that the nearer they approach it, the more they hasten."[74]

Gravity, according to Bruno, cannot pertain to an entire body situated in a place convenient to its nature (*intiero e naturalmente disposto e collocato*).[75] This means that celestial bodies—and the universe as a whole—have no weight because they have no tendency to rejoin anything else. Gravitation is therefore not a universal characteristic of matter. Moreover, heaviness and lightness are relative, because the same thing can be heavy or light depending on its center of reference or the medium (*mezzi*), in which it is located.[76]

Similar to weight, Bruno assumes that directions (up-down, right-left, center-periphery) and motion are also not absolute in an infinite universe.[77] Motion itself is relative to the observer. That which is immovable from a certain viewpoint can be in motion from another. "We cannot apprehend motion except by a certain comparison and relation with some fixed body. Wherefore if we suppose a person within a moving ship in the midst of waters, who knoweth not that the water is in motion, nor seeth the shores, he would be unaware of the motion of the ship."[78]

Bruno's dynamics contains many fruitful ideas derived from Copernican and infinitistic premises. The relativization of directions, motion and weight are important elements for a new physics departing from Aristotle. His speculations should be regarded as part of a broader debate on the physical consequences of *De revolutionibus*. In order to find a different treatment of motion, bringing into the discourse ideas derived from mathematics and the tradition of mechanics, one need not wait for Galileo, since Bruno's contemporary Benedetti undertook this task.

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72 Idem, *Supper*, 156; *Cena*, 81.

73 Idem, *Infinito*, 441–42.

74 Idem, *Infinite Universe*, 335; *Dialoghi*, 411.

75 Idem, *Infinito*, 355.

76 Ibid., 355–36.

77 Ibid.

78 Idem, *Infinite Universe*, 311; *Dialoghi*, 385.

7 Benedetti's Archimedean Dynamics

In the same years in which Bruno completed and published the *Cena* in London, Benedetti printed a treatise that sheds light on possible theoretical ties between dynamics and Copernican astronomy, "Disputationes de quibusdam placitis Aristotelis." This is the fourth book of the *Diversae speculationes.* It is a criticism of Aristotle's opinions on local motion and cosmology as presented primarily in *Physica* and *De caelo*. Benedetti further seeks to lay the foundations of a post-Aristotelian physics and cosmology, based on a mathematical philosophy of nature (*inconcussa mathematicae philosophiae basis*). The principal concepts for the treatment of motion are derived from Archimedes's *Floating Bodies* and Euclid's fifth book of the *Elements*, on proportions. It should be noted that the reader of the *Diversae speculationes* would find a section dedicated exclusively *Elements* V directly following the anti-Aristotelian "Disputationes."[79] In these disputations, Benedetti reworks the pillars of physics—among them, the concepts of place and time—and openly advocates anti-Aristotelian views like the infinity of space and physical existence of vacuum. His treatment culminates with cosmological reflections, including a defense of the system "of Aristarchus and Copernicus."

Benedetti begins with a criticism of *Physics* IV,8, where Aristotle rejects the existence of vacuum and the infinity of space while discussing motion through different media. Aristotle argues that vacuum and infinity would undermine any reasonable theory of natural motion, meaning his own theory of natural and violent motions. This objection is directed against "those" who regarded vacuum as the condition for motion—he probably has in mind Democritus and his followers. He complains that there would be no absolute directions in an infinite vacuum and that the possibility of upward or downward motions would be precluded. Aristotle relies on the observation that the elements have a natural upward or downward tendency (water and earth downward, air and fire upward) which, according to him, is sufficient to dispel the notion that space is an infinite vacuum.

Physics IV,8 thus provides Benedetti with a series of entangled issues which he undertakes to analyze: vacuum, infinity and motion. He begins with the last, namely motion. Concerning displacements through a medium, in chapter two of the "Disputationes" he lists some common assumptions that he subsequently corrects and rejects.[80] The relevant cases are two: one can either

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79 Benedetti, *Diversae speculationes*, 198 ff., "In quintum Euclidis librum." Cf. Giusti, *Euclides reformatus*.

80 Ibid., 169.

consider different bodies in the same medium, or treat equal bodies in different media. The decisive difference between two bodies is the *virtus*, a force that he calls at times *gravitas* (gravity) or *pondus* (weight) and at times *levitas* (lightness). If we use V as in *velocitas* for speed, P as in *pondus* for *virtus*, and R as in *resistentia* for resistance, we can summarize the Aristotelian assumptions in a more modern way: $V_1 : V_2 \sim P_1 : P_2$, if the resistance is the same, whereas, if the *virtus* of the two bodies is the same, $V_1 : V_2 \sim R_2 : R_1$. Benedetti regards this Aristotelian treatment as inadequate, preferring to rely on Archimedes for this issue. He conceives of motion by analogy with the behavior of bodies in water and, according to the *Floating Bodies*, he holds that weight and lightness are not absolute, but relative properties because they depend on the medium.[81] Thus, the direction of a vertical motion and the velocity depend on the matter of a body and the fluid (e.g. air and water) in which it is located. In fact, in the second *disputatio*, Benedetti claims that the *pondus* of a body varies depending on the *densitas* (density) of the medium, in accordance with Archimedes's treatment in the first book of the *Floating Bodies*. The actual *virtus* (either weight or lightness) of a body results by subtracting from the total virtue (*virtus totalis*) a quantity which Benedetti calls *resistentia extrinseca*.

In order to illuminate the relation between physics and post-Copernican cosmology it is not necessary to go into further detail regarding Benedetti's dynamics. Rather, it is important to consider the philosophical section of the "Disputationes" included in chapters 19 to 22, which is an attempt to revise basic concepts of physics from an anti-Aristotelian perspective.

8 Benedetti's Post-Aristotelian Physics and Post-Copernican Astronomy

Once Benedetti has corrected the theory of motion, he feels legitimated in revising Aristotle's assertion that vacuum is not acceptable in nature. Chapter nineteen, "Aristotle's Demonstration that Void Does Not Exist Is Idle," is a transition between the Archimedean treatment of motion through a medium (chapters 1–18) and the reconceptualization of natural philosophy in general. According to his Archimedean dynamics, motion through vacuum is not absurd; it is simply quicker than through any other medium, because no resistance has to be subtracted from the body's *virtus*.

In chapter 20, Benedetti defines place (*locus*), in opposition to Aristotle, as *intervallum corporeum*, an expression which could be roughly translated as an

81 Ibid., 170.

invariable space suited to contain material bodies. Chapter 21 is devoted to infinity: "Whether Aristotle Correctly Understood Infinity." The answer is negative. Aristotle rejected the possibility of an infinite universe, because there cannot be any place (*locus infinitus*) capable of holding an infinite body (*infinitum corpus*). Benedetti considers this argument to be idle, since it relies on a *petitio principi*. Aristotle's objection to infinity depends on a questionable definition of *locus*: "Aristotle wants to refute the [existence of the] infinite thanks to [the concept of] place. Thus, it is a perverted order to start with [the refutation] of the infinite."[82] Benedetti's preliminary definition of place as *intervallum* entails no conceptual hindrances to accepting the infinity of the universe. As one reads: "In this manner, there follows no inconvenience that an infinite body can exist beyond the heavens."[83]

In the *disputatio* 22 on time, Benedetti questions the Aristotelian definition: time is "the measure and the number of motion" (*motus mensura numerusque*). He argues that this is intrinsically wrong because the measure and the thing measured must be homogeneous, while time and motion are qualitatively different. Benedetti calls time the "place of motion" (*locus motus*). His point is that the relation between time and motion can be compared to that between place and body: "As a dense body occupies less extension of place [*intervallum loci*], similarly a quick motion [*motus velox*] occupies less space of time [*temporis spatium*]."[84]

After this revision of the physical concepts of vacuum, infinity, space and time, Benedetti moves on to discard the Aristotelian theory of natural and violent motions (chapters 23–26). Chapter 24 is notable since it is a refutation of a series of Aristotelian convictions, like the idea that a projectile is transported by air once separated from its thrower. According to Benedetti, it is rather the contrary: air is a hindrance to motion because it resists penetration. Chapter 25 denies that vertical motion could legitimately be called natural. In fact, only perpetual and circular motion are natural: thus an entire (i.e. spherical) body and its parts spontaneously move in a circle.

The cosmological dimension of Benedetti's anti-Aristotelian project is documented in the last part of the "Disputationes." In particular, chapter 35, "Rectilinear and Curved Motion Are Comparable," is crucial for our analysis. In this section, nearly at the end of the "Disputationes," Benedetti introduces the Copernican theory. His viewpoint is at odds with *Physics* VII,4, where Aristotle denies that a straight and a circular motion can be compared, hinting at the

82 Ibid., 181.

83 Ibid.

84 Ibid.

qualitative difference between celestial circular motions and the vertical tendency of the elements in the sublunary sphere. From a Copernican perspective, Aristotle's thesis is an implicit rejection of terrestrial motion. In fact, if the Earth rotates, one should assume that the trajectory of a falling body is rectilinear for an observer on the Earth but has a circular component as well, if considered in relation to terrestrial displacements in the planetary system. Benedetti appeals to Archimedes's *De quadratura circuli* (*On Squaring the Circle*) to argue that the circle and the straight line are comparable: "Thus, since such squaring is possible, it is also possible that a straight line equals the circumference of the same circle."[85] In this case, a geometrical problem acquires cosmological significance. According to Benedetti, celestial and elementary motions are of course different, but this difference does not lie in the circularity of the former and the straightness of the latter. Rather, the difference is that between the uniformity of speed as opposed to acceleration.

These considerations offer Benedetti the occasion to expand on the velocity of celestial motions and elaborate his apology for the Copernican system. According to popular opinion (*secundum opinionem communem*), the heavens should cover an immense distance over the 24 hours of their daily rotation. Certainly, Copernicus's theory permits this inconvenient implication to be eliminated. In chapter 36 Benedetti reworks the doctrine of the *doctissimus Aristarchus*. It is entitled "Aristotle Could Even Less Convincingly Rebut the Opinion of Those Who Believe that There Are Many Worlds." According to Aristotle, a universe populated by many (if not infinite) Earth-like planets would be unstable and collapse, because the earthly parts of all worlds would fall toward the cosmological center while the fiery parts would eventually join the circumference of our sublunary world. This Aristotelian objection is based on preliminary acceptance of his theory of the natural places. By contrast, Benedetti argues that all worlds (in the meaning of planets) would have their elements and their places:[86]

> If they could be spoken of as worlds, each of them would have its own center and its own cirumference, and the various earths and fires would have tendencies to the centers and circumferences of their own respective worlds.

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85 Ibid., 194.

86 Ibid. Translation from Drake-Drabkin, *Mechanics in Sixteenth-Century Italy*, 222.

9 A New Alliance between Mechanics and Astronomy

To summarize my previous discussion of Benedetti, the views that he presented in "Disputationes de quibusdam placitis Aristotelis" are as complex as they are significant for a better understanding of the historical interplay between Copernican astronomy and natural philosophy. It treats at least four main topics: motion, the foundations of physics, astronomy and cosmology. Many ideas in the "Disputationes" are close to those of *De revolutionibus*: the rejection of the theory of natural places and of violent and natural motions, the excessive speed of the rotation of the heavens, vacuum and infinity, the naturalness of circular motion as opposed to the unnaturalness of the vertical motion of parts separated from their whole, and the criticism of Aristotle's assertion about the weight of bodies in their natural place. It should, however, be remarked that Copernicus did not expand on most of these ideas and presented them cursorily merely for the sake of his apology for terrestrial motion. By contrast, Benedetti's treatment is far more accurate. Moreover, his motivations and presuppositions appear to be quite different. His Archimedean and Euclidean treatment of motion is the basis for his rejection of the distinction between natural and violent motions. No consideration of this kind is found in Copernicus's work. Moreover, the reference to space infinity in *De revolutionibus* is limited to a single remark. Actual infinity receives a different treatment in Benedetti, since it is closely related to his attempt to redefine space as *intervallum corporeum*. It is precisely this natural and broad philosophical dimension that is absent in Copernicus's work, and which Benedetti did not derive directly from reading *De revolutionibus* or from astronomical concerns. It seems, by contrast, that he was interested primarily in the physical issue of a mathematical treatment of motion, and that his criticism of Aristotelian philosophy led him, quite naturally, to confront cosmology as well. Nor could issues like vacuum and atomism be reasonably derived from Copernicus. Even the planetary theory of Benedetti departs from *De revolutionibus*, as it includes theses like the plurality of worlds and the corruptibility of the heavens. However, it is clear that Benedetti's worldview is a conception into which the heliocentric and geokinetic theory fits perfectly. In light of his general theory, as he writes, Aristotelian and Ptolemaic arguments against Copernicus's theory appear extremely weak: "Against that [doctrine] the counterarguments proposed by Aristotle and Ptolemy are utterly powerless."[87] If one tries, in conclusion, to define the relation between mechanics and astronomy in Benedetti's "Disputationes," it now seems that Koyré's thesis of a (historical, theoretical

87 Ibid., 195.

and epistemological) dependency of the former discipline on the latter would miss the mark. In this significant case, it is preferable to speak of an alliance between a mathematized physics and post-Copernican cosmology, in which both mechanics and astronomy have the same dignity and are regarded as complementary.

Given the philosophical relevance of Bruno's work, it might also be useful to stress the common aspects and the differences between him and Benedetti. Both supported the Copernican planetary system, although neither accepted it literally and both introduced some modifications. Both were concerned about the physical problems of the new astronomy; however, Bruno considered the astronomical-cosmological issue to be primary, while Benedetti dealt primarily with the problems of motions stemming from mechanics and Archimedean hydrostatics. As we have seen in this and the previous chapter, both supported the infinity of space, the thesis of the plurality of worlds, the relativity of point of view, of spatial directions and of heavy and light. Both supported the existence of a physical vacuum and the non-existence of celestial spheres. The main difference between their views lies in the mathematical approach, which is fundamental for Benedetti, whereas Bruno criticized even Copernicus for limiting himself to a "more mathematical than natural science" (*più matematico che natural discorso*).[88] Moreover, Benedetti affirms the plurality of worlds but not their infinite number, and does not support the principle of universal homogeneity. On the other hand, he and Bruno share an aversion to Aristotelian natural philosophy and contributed to its demolition beginning with the reconceptualization of the basic concepts of *physica*. Anneliese Maier stressed their common recourse to impetus dynamics as well, tracing in the anti-Aristotelian employment of the *vis motrix* an ideal line connecting Bruno, Benedetti and Galileo.[89]

Concerning Benedetti's ties with Galileo, the form and the extent of his influence over the latter are a controversial issue in the intellectual biography of the famous scientist. The affinity between Galileo's early speculations and several theses of the *Diversae speculationes* is evident, beginning with the hydrostatic analogy to explain the motion through a medium, the relativity of heavy and light, and the subtraction of resistance from weight, which allows

88 Bruno, *Cena*, in idem, *Dialoghi filosofici*, 25. For Bruno's metaphysical and epistemological reasons, see Omodeo, "Perfection of the World" and Bönker-Vallon, *Metaphysik and Mathematik*.

89 Maier, *Zwei Grundprobleme*, 304–05.

motion through vacuum to be accepted and makes it physically plausible.[90] For instance, several chapters of Galileo's first manuscript among those gathered by Favaro under the title of *De motu* are very close to Benedetti's treatment; above all chapter eight, "in which it is shown that different bodies moving in the same medium maintain a ratio [of their speeds] different from that attributed to them by Aristotle;" chapter ten, "in which, in opposite to Aristotle, it is proved that, if there were a void, motion in it would not take place instantaneously, but in time;" twelve, "in which, in opposition to Aristotle, it is concluded that the absolutely light and the absolutely heavy should not be posited; and that even if they existed, they would not be earth and fire, as he believed;" and fifteen, "in which, in opposition to Aristotle, the conclusion is reached that rectilinear and circular motions have a ratio to each other."[91] It should be remarked that the Copernican element is absent from Galileo's early manuscript *De motu*, although this would become a crucial aspect of his later investigations. Also, the alliance of mechanics and Copernican astronomy, which emerged only later, bears witness to Benedetti's influence on his work.[92]

10 Brahe's Physical Considerations

If Bruno and Benedetti can be regarded as committed to a realist acceptance of the heliocentric system and as determined to develop a corresponding *physica*, Tycho Brahe influenced the discussion of the physical problem of geokinetic theory in a different way, precisely through his famous arguments against terrestrial motion. In his correspondence (*Epistolarum astronomicarum libri*, 1596), he thoroughly discussed *pro* and *contra* the Copernican system with Christoph Rothmann.[93] In consideration of the amplitude and influence of these arguments in the Renaissance debate on the tenability of the heliocentric system, it is convenient to review his long list of anti-Copernican arguments, especially those summarized in a conclusive note attached to his correspondence with Rothmann.[94] As I will discuss, it included mathematical, physical

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90 Apart from Koyré, *Galileo Studies*, cf. also Drabkin, "Introduction" to Galileo, *On Motion*, 9–10. Galluzzi, *Tra Atomi*, stresses the interconnections without subordinating Galileo's investigation of motion, cosmology and matter.

91 Galileo, *On Motion*.

92 Drabkin, "Benedetti and Galileo's *De motu*," Drake, "Further reappraisal," Renn-Damerow, *Equilibrium Controversy*, 142–55, and Renn-Omodeo, "Del Monte's Controversy."

93 Mosley, *Bearing the Heavens*, especially chap. 2,II.

94 Brahe, *Opera*, vol. 6, 218–23. Cf. Blair, "Brahe's Critique" and Granada, *Debate cosmológico*.

and theological arguments, often inseparably interwoven. Brahe organized his arguments into two groups: those against the axial rotation of the Earth, and those contrary to its annual revolution. However, he did not maintain this division strictly, since some arguments presented in the first part could also suit the second, and *vice versa*.

Arguments against the Axial Rotation of the Earth (*but Also Its Motion in General*)

1. The tower argument of falling bodies:[95] This argument is based on the assumption that a terrestrial displacement would affect the trajectory of heavy bodies falling downward. In an earlier letter to Rothman (Uraniborg, 24 November 1589), Brahe had already challenged his Copernican correspondent to propose a convincing reason why a plumb falling from a very high tower should cover a perfectly perpendicular path and reach the ground at the foot of the building.[96]

2. Argument of the simplicity of motion:[97] This is the Aristotelian argument that a simple body can have only a simple motion. In other words, circular and rectilinear motion must hinder each other. Brahe is far from accepting that a motion can have different components, circular and rectilinear, or that the trajectory can depend on the reference system, as was the case for Copernicus and the supporters of the physical reality of his system.

3. Argument against air transportation:[98] Brahe rejects the idea that suspended and flying bodies are able to participate in terrestrial motion because they are transported by air.

4. Argument against the holistic explanation of gravity:[99] As we have seen, a recurrent physical argumentation in favor of heliocentrism was that bodies fall vertically in order to rejoin their whole. This is why parts of the Earth that have been (violently) separated from it should be inclined to reach it in a straight line, which is the fastest way to return to their whole. Still, Brahe contends that there is no evidence in favor of this thesis. He notes, in fact, that a part of a stone separated from a boulder does not display any tendency to rejoin it again.

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95 Ibid., 218.
96 Ibid., 197.
97 Ibid., 218.
98 Ibid., 218–19.
99 Ibid., 219.

5. Cannonball argument: The trajectory of a cannonball is not affected by terrestrial rotation as one would expect assuming Copernicus's hypotheses. In a Copernican framework, a cannonball should partake of three motions, whereas only the violent one, caused by the explosion, and gravitation, should be taken into account. Brahe's explanation is that a cannonball would reach the ground vertically, following its nature, if it were not hindered by the violent motion caused by the explosion. The Copernican system and the dynamics derived from it are at odds with the distinctions between natural and violent motions. Hence, they make it impossible to account for motion in general, and ballistics in particular.[100] A further remark is based on the observation that, if the Earth turned about its axis, one cannonball shot eastward and one westward should cover different distances, since the first would go in the direction of the terrestrial motion, thus covering a shorter distance, and the other would cover a longer distance.[101] Since a cannonball shot westward does not go further than one shot eastward, no terrestrial motion is admissible.

6. Shotgun argument of different velocities at the poles and at the equator:[102] To the previous argument Brahe adds a sort of experience. Given the different speeds of terrestrial motion at different latitudes, two bullets, one shot at the poles and one at the equator, should behave differently. At the poles, which are at rest, the bullet should cover the same distance in all directions. Things should be different at the equator but this is not the case.[103]

7. Argument of the ship and the arrow:[104] Brahe resorts to the Parisian nominalist argument of the arrow shot vertically from a moving ship, employing it as a refutation of terrestrial motion. The faster the motion of the ship, so Brahe, the further from it the arrow will fall. The same should be observable on Earth, given that it moves with different speeds at different latitudes.

8. Argument of the ocean:[105] A remarkable argument concerns the effects of terrestrial motion on the waters of the ocean. The natural circular flow of its waters, so Brahe, as well as its various motions, are not affected by the alleged circular displacement (*circumferentia*) of the terraqueous globe (*communis Globus*). The reports of navigators could therefore document the falsity of the Copernican hypothesis.

100 Ibid.

101 Ibid.

102 Ibid., 220.

103 Ibid.

104 Ibid.

105 Ibid.

Arguments against the Annual Revolution of the Earth

After discussing (and rejecting) the first Copernican motion, Brahe tackles the second one, the annual revolution. This separation of arguments concerning the daily motion from those concerning the annual revolution is not rigorous. In fact, he begins his section against the revolution around the Sun with a theological remark which refers to the rotation around the axis and not around the Sun.

9. Argument of divine omnipotence:[106] Relative to the velocity of the daily motion of the stars, Brahe notes that this is evidence of the mysterious wisdom and power of God, who decided to create huge heavenly bodies and endow them with an amazingly rapid but uniform motion, divided into two components in accordance with the twofold motion of the heavens of the fixed stars (daily rotation and precession of the equinoxes). The argument of Divine omnipotence for celestial motions is an answer to the so-called Achilles argument of the followers of Copernicus, who held terrestrial motion to be more reasonable than that of the fixed stars, due to the relatively reduced dimensions and speed of the Earth.

10. Argument of the nobility of motion:[107] This argument (which could also be applied to axial rotation) reverses the Copernican assumption that rest is more noble than motion. Quite on the contrary, so Brahe, motion is noble, therefore it is appropriate for ethereal bodies and not for the Earth. From this argument and the previous one it is clear that metaphysical, axiological or aesthetic arguments often miss the mark since they can be used to support diametrically opposite opinions.

11. Biblical argument from *Genesis*:[108] The biblicalpassage revealing that God "created the Heavens and the Earth" proves, according to Brahe, that the Earth is at the center and the heavens at the periphery of Creation. Hence, the heliocentric model infringes on the scriptural distinction between a terrestrial and a celestial realm by denying the centrality of the Earth.

12. Argument of the impossibility of vacuum:[109] This argument is based on a reflection about the "excessive" distance of the sphere of the fixed stars from the center of the world. If the Copernican thesis is accepted, the implication is that the distance from the Sun to Saturn is much smaller than that from Saturn to the fixed stars. As a consequence, one must allow for a wide void bereft of

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106 Ibid., 220–21.

107 Ibid., 221.

108 Ibid.

109 Ibid., 222.

any stars or celestial bodies. This would mean that Creation includes something useless, namely a vacuum.

13. Argument of the excessive dimensions of the fixed stars:[110] Given the great distance of the fixed stars, one would be forced to admit that the stars of the third magnitude are as big as the whole orb whose radius is the mean distance between the Earth and the Sun. But this cannot be admitted.

14. Argument of the cosmological preeminence of the Sun:[111] The Sun must be the largest celestial body, according to its dignity. This remark is directed toward refuting another Copernican assumption, that of the centrality of the Sun due to its physical and metaphysical preeminence.

As a conclusion to his reasoning, Brahe added that the heliocentric system lacks any harmony, in spite of the opposite conviction of Copernicus, Rheticus and most of their followers. According to him, the disproportion between the solar system and the universe in its entirety is too striking.[112]

To sum up, Brahe's refutation of terrestrial motion was based on astronomical, physical, as well as metaphysical and theological considerations. It was a nearly unique collection of anti-Copernican arguments, the most extensive until Giovanni Battista Riccioli's *Almagestum novum* (1651). Thus, Brahe's work could not be neglected by those who undertook a defense of the geokinetic model. Galileo was well acquainted with his writings, as *De mundi aetherei recentioribus phaenomenis* as well as the aforementioned *Epistles* were certainly discussed in the Pinelli circle of Padua.[113] In a sense, Galileo's program of a defense of the physical as well as the scriptural acceptability, if not necessity, of the Copernican system is a response to Brahe. Thus, the anti-Copernican writings of the latter cannot be separated from the work of the realist upholders of heliocentrism of that time. They are an essential contribution to the Renaissance debate on the planetary system. The richness and depth of Brahe's treatment is in itself the best testament to the relevance of his opinions.

The arguments proposed by Brahe vary widely in strength and originality. Some are merely a repetition of Aristotle and Ptolemy or a reassessment of well-known biblicalobjections. Some others stem from Parisian nominalism, for instance, argument number seven of the ship and the arrow. Arguments twelve and thirteen, on vacuum and the excessive dimensions of the universe,

110 Ibid.

111 Ibid.

112 Ibid.

113 Bucciantini, *Galileo e Keplero*, 23–48, chap. 2, "Padova: Pinelli, Tycho, Galileo." On the Pinelli circle, see also Ordine, *Soglia*, app. II, 242–53.

respectively, confront a central philosophical problem of the Copernican system, which was treated by Bruno, Benedetti and many others.[114] It is important to underscore that all of these authors, as well as their successors beginning with Kepler and Galileo, addressed the natural problem of vacuum and of the dimensions of the heavens, although they offered different philosophical solutions.

Additionally, Brahe brought forward new arguments that would be widely discussed after him. This is the case for his ballistic considerations (arguments five and six), which Galileo dealt with extensively in the *Dialogo*. Another remarkable argument, albeit a very short one, is number eight, about the presumed effects of terrestrial motion on the oceans. It is well known that Galileo regarded the phenomenon of the tides as evidence of the motion of the Earth and treated this issue in detail in the fourth day of the *Dialogo*.[115] It is less known that similar considerations were advanced by other supporters of terrestrial motion. I would like to mention two. The English Epicurean atomist and Copernican Nicholas Hill advanced the hypothesis that the motions of terrestrial waters depend on the displacements of our planet. One of the main reasons for supporting terrestrial motion in his *Philosophia Epicurea, Democritana, Theophrastica* (1601) is derived from "the evident motion of the unbalanced waters of the Earth."[116] A later reappraisal of the idea that the motion of the waters on Earth, as we have already seen, is caused by terrestrial motion, or more precisely, the axial rotation, can be found in the *Ephemerides Brandenburgicae* (1609) by David Origanus.[117] As one reads in the dedicatory epistle to this work, tides are the effect of the concomitant action of terrestrial westward rotation and lunar attraction. Origanus derives further evidence from some reports by Atlantic sailors, according to whom the journey from America takes longer than that from Portugal to the New World.

11 Concluding Remarks

As a conclusion to this chapter, I would like to mention an English Copernican whose treatment of the physical problem of terrestrial motion documents the European scale of this debate. Like Benedetti with his dynamics, William

114 Chap. 4.

115 Clutton-Brock and Topper, "Plausibility." A similar argument was also used by Sarpi: Heilbron, *Galileo*, 116.

116 Hill, *Philosophia Epicurea*, 34 and 155. See chap. 8,16.

117 See chap. 3,11.

Gilbert, in his influential treatise on magnetism *De magnete* (1600), decided not to limit his work to describing and explaining a particular physical phenomenon (in this case magnetism), but to embed it in a cosmological framework.[118] In fact, the sixth and last book of *De magnete* dealt with the Earth as a huge lodestone and accounted for its motion through magnetic causes. In chapter VI,5, "Arguments of Those Denying Terrestrial Motion, and Their Confutation" (*Terrae motum negantium rationes, et earum confutatio*) one finds a review of the physical arguments, also taking into account Brahe's examples. It seems to be a variation of the lines of argumentation already displayed by other followers of Copernicus considered in this chapter:[119]

> Some raise a doubt how it can be that, if the Earth move round its own axis, a globe of iron or of lead dropped from the highest point of a tower falls exactly perpendicularly to a spot of the Earth below itself. Also how it is that cannon balls from a large culverin, fired with the same quantity and strength of powder, in the same direction and at a like elevation through the same air, would be cast at a like distance from a given spot both eastward and westward, supposing the Earth to move eastward. But those who bring forward this kind of argument are being misled: not attending to the nature of primary globes, and the combination of parts with their globes, even though they be not adjoined by solid parts. Whereas the motion of the Earth in the diurnal revolution does not involve the separation of her more solid circumference from the surrounding bodies; but all her effluvia surround her, and in them heavy bodies projected in any way by force, move on uniformly along with the Earth in general coherence. And this also takes place in all primary bodies, the Sun, the Moon, the Earth, the parts betaking themselves to their first origins and sources, with which they connect themselves with the same appetence as terrene things, which we call heavy, with the Earth. So lunar things tend to the Moon, solar things to the Sun, within the orbes of their own effluvia. The emanations hold together by continuity of substance, and heavy bodies are also united with the Earth by their own gravity, and move on together in the general motion: especially when there is no renitency of bodies in the way. And for this cause, on account of the diurnal revolution of the Earth, bodies are neither set in motion, nor retarded; they do not overtake it, nor do they fall short behind it when violently projected

118 On the physical and cosmological meaning of Gilbert's *De magnete*, cf. Freudenthal, "Theory of Matter."

119 Gilbert, *On the Magnet*, 228–30. Cf. idem, *De magnete*, 228–29.

> toward East or West. [...] So the diurnal motion of the Earth is by no means refuted by the illustrious Tycho Brahe, through arguments such as these.

Gilbert was a reader not only of Brahe, but also of Benedetti and Bruno.[120] He also composed a cosmological work, *De mundo*, which was published posthumously, many years after his death (1651). Among many other amazing contents, it also included observational records concerning the tides (II,11 "Observationes ad aestum maris pertinentes"), probably intended as a method for detecting terrestrial motion, since he believed tides to be the simultaneous effect of terrestrial motion and the action of the Moon.[121]

To sum up the results of this chapter, Copernicus and his contemporary Calcagnini were well aware of the intrinsic physical problem entailed in the theory of terrestrial motion, namely the dissolution of the Aristotelian theory of natural and violent motions. A special difficulty resided in the fact that Aristotle's dynamics was based on principles that agreed with common sense, for instance the claims that heavy bodies fall down in a straight line because they have a natural downward tendency, and that the center of the Earth coincides with the center of the world. Copernicus and Calcagnini, as well as later supporters of geokinetic theory, were forced to question the reliability of common sense as well as received physical theories, and to point out the epistemological gap between appearance and reality. This precisely is the main goal of Calcagnini's "Quod coelum stet." In the first book of *De revolutionibus* Copernicus also confronted Aristotle's and Ptolemy's arguments against terrestrial motion. Besides the problem of stellar parallax, which is particularly relevant for Ptolemy, the most challenging arguments were physical. They rested on considerations about the alleged consequences of terrestrial motion on bodies falling or rising in a straight line and moving through the air. From Plutarch Copernicus was able to derive a theory that accounted for the fall of heavy bodies on a moving planet based on the fact that the parts have a natural tendency to join their whole. More arguments in favor of terrestrial motion were provided by medieval nominalist sources, such as Oresme and Buridan. Although it is controversial how much they influenced Copernicus himself, they provided a set of arguments and metaphors that met with great success among those who discussed the physical problems with the Copernican

120 For a reference to Benedetti on the reflection of light on the lunar surface, see Gilbert, *De mundo*, 173. For references to Bruno's speculations on the solar system, see ibid., II,22, 196 ff.

121 Ibid., 306, II,16.

system in the sixteenth century. In particular, the metaphor of the Earth as a moving ship became a kind of Copernican *topos* repeated by every supporter of geokinetic theory: we cannot perceive terrestrial motion in the same way that the passengers of a ship cannot detect whether they are at rest or not. Falling or flying bodies also share the motion of the ship. The same medieval sources asserted that terrestrial motion would not affect the fall of heavy bodies, as the motion of a ship does not hinder the vertical fall of heavy bodies on board. The idea of *impetus* as an inner cause of motion was well known to those who tried to defend the physical tenability of the Copernican doctrine, like Bruno, Benedetti and, later, Galileo.

As I have already remarked, late sixteenth-century scholars did not adhere to Copernicus's dynamics literally, nor did they simply try to revive any ancient or medieval theory that could have preceded the considerations of the first book of *De revolutionibus*. Bruno envisaged in particular a new physics based on vitalistic principles. According to him, Copernican theory needed to be embedded in a general view of nature that could account for the animal-like motions of the planets as well as for the tendencies displayed by moving bodies. Benedetti's mechanical considerations are particularly interesting, since they seem to originate from physical-mathematical concerns, in particular the program of an anti-Aristotelian Euclidean and Archimedean theory of motion. His research seems to match Mach's narrative of a mathematical physics stemming from mechanical research that developed independently of astronomy. Nevertheless, Benedetti insisted that his theory could be connected to the Copernican theory and made this attempt in the *Diversae speculationes*, which were to exert a marked influence on Galileo. *Pace* Koyré, it is not possible to consider this conception as dependent on astronomy. In his case, it is more accurate to speak of an alliance of mechanics and Copernican cosmology.

Brahe also participated in the physical debate on Copernicanism. His chief contribution was to create a synthesis of existing arguments and to add new ones that his opponents were forced to address. Moreover, he forged powerful images and connections (among them, the cannonball argument and the link between tides and terrestrial motion), which were to be thoroughly discussed, refuted and developed by Galileo in the *Dialogo*.

CHAPTER 6

A priori and *a posteriori*: Two Approaches to Heliocentrism

One could consider the earliest reception of *De revolutionibus* to be concluded with the publication of *Mysterium cosmographicum*, an ambitious attempt to reaffirm the reality of heliocentrism which signaled its author, the young Kepler, as one of the most promising and original mathematical and philosophical minds of his time. He did not embrace the geo-heliocentric "third way" of Ursus and Brahe, and would later reject the infinitist viewpoint of Bruno and his followers. Rather, he reassessed the Copernican system from a completely new perspective. After a period of intense astronomical observations (the approach supported by Landgrave Wilhelm IV and Brahe as well as by Mästlin and Magini), Kepler claimed that it was possible to grasp the design of the heavens from an *a priori* perspective. His intention was, in fact, to unveil the archetypal reasons for the planetary order rooted in Divine Providence. He called this hidden astronomical truth, in Latin, the *mysterium cosmographicum*, i.e. the cosmic secret. An important aspect of his speculations was the project of unifying mathematical and physical astronomy, which he would especially develop in *Astronomia nova* (1609) and in *Harmonice mundi* (1619). On the other hand, Galileo's telescopic discoveries, first communicated in *Sidereus nuncius* (1610), strengthened the heliocentric cause by bringing new data that were not reconcilable with either Ptolemaic geocentrism or with the Aristotelian principle that the heavens are unalterable.

The Copernican alliance between Kepler and Galileo was in many respects a historical contingency, since they came to support the heliocentric system for different reasons and starting from very different conceptions of science. Among other historians, Ludovico Geymonat, in his *Galileo Galilei* (1957), distinguished the "engineering" and experimental use of mathematics by Galileo from the "numerologies" of Kepler. From a different perspective, the art historian Erwin Panofsky, in *Galileo as a Critic of the Arts* (1954), contrasted the "progressive empiricism" of the former and the "idealistic conservatism" of the latter. Koyré, who was significantly influenced by Panofsky, considered Kepler's concept of harmony pre-modern, since it was intimately linked to the idea of an ordered and finite cosmos, which was to be overthrown, according to his narrative, by the "modern scientific outlook." More recently, Massimo Bucciantini, in *Galileo e Keplero*, traced the parallel developments of the works

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by these two authors and argued for their complementarities, emphasizing the mutual esteem of the authors. Yet, Bucciantini also stressed their different philosophical approaches: "The Galilean project to found a Copernican science of motion was, from the beginning, in opposition and concurrence to Kepler's new celestial dynamics. [...] Hence derive two different manners to be modern, that is to say, to be philosophers and scientists who supported Copernicus's views [...]."[1]

In the following I will highlight the epistemological premises of these two approaches, mainly focusing on *Mysterium* and *Sidereus nuncius*. This treatment, especially if compared with chapter two, will make clear the different philosophical framework that emerged in the late sixteenth and early seventeenth centuries and paved the way for the natural investigations and visionary worldviews of the Baroque. As Robert Westman pointed out in *The Copernican Question*, the passage from Kepler's and Galileo's generation to that of Descartes and his successors was marked by a shift from a discussion on planetary models and their physical justification to natural philosophy, that is, philosophical attempts at embedding astronomical issues in mechanical conceptions of nature and at deriving planetary models from the most general principles of nature.[2]

1 Mästlin's *a posteriori* Astronomy

I would start from the University of Tübingen, around which, for a long time in the late sixteenth century, the work of two convinced champions of Copernicus's heliocentrism gravitated: Michael Mästlin and his pupil Kepler. It has already been remarked in studies on Renaissance astronomy that Mästlin's publications show a sharp divergence between his research and his teaching activities with regard to the acceptance of the heliocentric cosmology. In the works directed to a learned readership of specialists, he praised the hypotheses of Copernicus, while in his books destined for teaching he maintained a strictly Ptolemaic approach. Considering, for instance, the *Epitome astronomiae* (*Summary of Astronomy*), first published in 1582 (but with many reprints and several new editions), one is struck by the elementary nature of the exposition.[3] However, this was a text with a pedagogical intent, based on the model of Sacrobosco. The Earth was presented as the center of the world

1 Bucciantini, *Galileo e Keplero*, 336. Cf. Field, "Cosmology."
2 See also, as a standard reference, Dijksterhuis, *Mechanization*.
3 See Methuen, "Maestlin's Teaching."

and the cosmos was depicted according to the traditional scheme.[4] And not only that: he proposed all the Aristotelian-Ptolemaic arguments in support of the centrality of the Earth.[5] Likewise, a *disputatio* of 1582 entitled *De astronomiae hypothesibus sive de circulis sphaericis et orbibus theoricis* (*Astronomical Hypotheses, or Theories of Spherical Circles and Orbs*), also shows a traditional approach to the first and second mobiles (fixed stars and planetary orbits). The only aspect of interest in this text was the discussion of the epistemological question of "whether those circles and spheres really exist in the heavens, or rather, they are only mathematical fictions."[6] Addressing the doubt about the true existence of the circles and the orbs described by astronomers, Mästlin proposed a solution halfway between the conventionalism of hypotheses and physical realism. On the one hand, he accepted that the celestial bodies should be investigated *a posteriori*, i.e. *ab apparentiis* (from the appearances), and not *a priori*, since nobody has privileged access to the ethereal region. On the other hand, he contended that the names we attribute to the parts of the heavens, although conventional, correspond to something real: for instance, we call "east" the zone where the Sun rises or "ecliptic" its path (*qua perpetuo incedit*) with an objective reference.

Mästlin's works directed to scholars had a different tenor. I would like to mention the *Ephemerides* of 1580 as an example. They are a computational work that Mästlin conceived as a continuation of Stadius's work. The dedication includes an examination of the state of astronomy, a judgment on the work of Copernicus, and a presentation of the author's scientific projects. The dedication opens with a celebration of the sixteenth century, seen as *praestantius* (more outstanding) with respect to the past ages since it produced new discoveries, and all the "arts," especially philosophy, were brought to a peak. Only astronomy, Mästlin lamented, remained incomplete. Although its theoretical part could not be improved, having already reached its perfection, he believed that the practical part of the discipline was still lacking. It should be noted that Mästlin's practical astronomy did not mean astrology, as was the custom, but simply the computational part of astronomy, that part concerning the parameters of the celestial motions and the compilation of tables.[7]

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4 Mästlin, *Epitome astronomiae*, 21–22 and 34.

5 Ibid., 71–73.

6 Mästlin, *De astronomiae hypothesibus*, f. A2*r*.

7 Mästlin, *Ephemerides novae*, ff. X3*v*–X4*r*. Mästlin's distrust of astrology is well known and is extensively discussed in Westman, *Copernican Question*, 262–64.

> To be sure, one notices that, among the philosophical sciences, only the second part [*species*] of astronomy significantly lacks perfection. Actually, the first part, called theoretical astronomy, does not need any improvement, since the practitioners [*artifices*] ascertained, through superhuman diligence and admirable skill, the immense magnitude of the entire worldly machine, the very ordered distribution of the spheres [*orbes*] and the innumerable vicissitudes of the heavenly revolutions [*conversiones*]. They moreover demonstrated [these points] with so much certainty that no new investigation of the rules [*rationes*] of [heavenly] motions has been left for posterity. By contrast, in the other part of astronomy—that expressing the motions of the spheres with numbers—the computation of motion contained in the tables so far existing does not accord the [calculated] positions of the stars to the [observable] heavens with the same certainty.

Speaking "of the most orderly distribution" of the *machina mundi* and affirming the perfection of the *theoricae planetarum*, Mästlin made veiled reference to the work of Copernicus. Indeed, later one finds an appreciation of the Copernican hypotheses: "[God's goodness] glorified Copernicus as a new Ptolemy for the discovery [*prolatione*] of hypotheses mostly congruent with observation."[8] By saying that this part of astronomy did not need improvement, Mästlin was suggesting that Copernicus's work was insuperable in this regard.

There was still much to be accomplished in Mästlin's time concerning the computation of parameters and the calculation of the positions of the stars. The author cautioned not to seek solutions "in the intellect," but instead "in the stars," i.e. to improve theory on the basis of systematic observations. Taking up a topic that we already encountered in Rheticus's *Narratio prima*, Mästlin observed that Ptolemy, the "prince of the astronomers" (*astronomorum princeps*), had not had the wealth of data of the moderns at his disposition. This explained his inaccuracy, which emerged in the long term. Alfonso, instead, restored the tables of celestial motions, but committed many mistakes, which, as Mästlin assured, were now universally known. According to him, Copernicus had corrected the parameters of his predecessors in a still inadequate manner.[9] It was Reinhold who deserved credit for having compiled the best astronomical tables. However, they were not without errors, as shown by the calculations of the motions of Mars and the Moon. Mästlin added that the catalogue of the fixed stars also needed to be corrected through new observations. In those

8 Ibid., ff. X4*v*–XX1*r*.

9 Ibid.

years, this emendation in particular was attracting the attention and efforts of Brahe, of the Landgrave of Kassel, and of Magini.

Based on the limits seen in practical astronomy, Mästlin conceived a plan to reform the parameters of the discipline. In *Ephemerides*, he promised to follow the example of Ptolemy and Copernicus: to conduct new observations and bring them together with those of his ancient and modern predecessors in order to precisely establish the celestial parameters:[10]

> Therefore, I decided to undertake this task [*operam sumere*], to follow the example of Ptolemy and Copernicus by recording the heavenly positions and motions of fixed stars and planets. I decided moreover to bring my observations together with those of the last thousand years observed and transmitted to us through the writings of the Babylonians, Timocharis, Hipparchus, Ptolemy, al-Battani, al-Zarqali, Copernicus and others. This would enable me to revise, with the aid of God, the computation of motions and to renew the entire astronomy, as much as possible, from its roots.

Mästlin's observational diligence aroused the admiration of his contemporaries, as shown by Brahe's declarations in his works on the comets and by a letter from the Strasbourg astrologer Helisäus Röslin (included by Mästlin in *Ephemerides*), in which he praised the extreme precision of the observations of the comet of 1577–1578. Mästlin considered his reform of astronomy to be only at the beginning. To this end, he wanted to construct two large observing instruments in the conviction that, even though there were innumerable astronomical instruments, two would be sufficient to establish the positions of the stars: a *quadrans magnus* and a *radius*. In fact, they would be sufficient for the two main purposes of the observation: to measure the heights of the Sun and of the stars, and the distances among celestial bodies.

2 The Young Kepler and the Secret Order of the Cosmos

Kepler, who was to become Mästlin's brightest student, enrolled at the University of Tübingen in 1589.[11] He arrived in Tübingen with the intention of becoming a theologian, but his exceptional gifts as a mathematician would

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10 Ibid., f. X4*v*.

11 Methuen, *Kepler's Tübingen*. Information on the life and work of Kepler in: Caspar, *Kepler*, Martens, *Kepler's Philosophy*; Segonds, "Introduction" to Kepler, *Secret*. Also see Gerlach, *Kepler*, 73–96.

lead him to follow another path. However, theological and metaphysical concerns accompanied him throughout his life.

In the preface to *Mysterium cosmographicum*, Kepler told the reader how he was introduced to the doctrine of Copernicus—and relieved of "common opinions" (*usitatae de mundo opiniones*)—by Mästlin who often and gladly mentioned *De revolutionibus* in his lectures.[12] The young disciple was so fascinated by the heliocentric hypotheses that he even undertook to defend Copernicus, in 1593, in a public *disputatio* on physics that has been preserved only in part.[13] In fact, while still a student, he had composed a "precise dissertation" *de motu primo* in which he advocated the theory of terrestrial motion and indicated its origin in the action of the Sun's motive force (*vis motrix*).[14] In this attempt, he would later boast, he had not followed the mathematical approach of Copernicus to the new hypotheses, but had instead sought the physical and metaphysical reasons for planetary order: "I had then reached the point of ascribing to this same Earth the motion of the Sun, but where Copernicus did so through mathematical arguments, mine were physical, or rather metaphysical."[15]

In 1594, Kepler obtained a post as mathematician in the *Stiftschule* of Graz. Thus, he interrupted his theological studies and moved to the Austrian region of Styria, where he began the less than exhilarating teaching of mathematics to sons of the local aristocracy. As one reads in *Mysterium cosmographicum*, one question particularly bothered him in that period, namely the hidden reason for the order and the number of the planetary orbits. He was a fervent supporter of the Copernican system, but he also wished to satisfy, beyond the correctness of calculation, another type of need, one I would call "metaphysical":[16]

> There were three things in particular about which I persistently sought the reasons why they were such and not otherwise: the number, the size, and the motion of the circles. That I dared so much was due to the splendid harmony of those things which are at rest, the Sun, the fixed stars and the intermediate space, with God the Father, and the Son, and the Holy Spirit. […] Accordingly, since this was the case with those things which

12 Cf. Kepler, *Mysterium*, in KGW, vol. 1, *Praefatio ad Lectorem*, 9–14.

13 Cf. KGW, vol. 20/1, *Fragmentum orationis de motu terrae*, 147–49. See also Voelkel, *Composition*, 26–32.

14 Granada, "A quo moventur."

15 Kepler, *Secret*, 63. Cf. KGW, vol. 1, 9. On Kepler's physical turn, see Stephenson, *Kepler's Physical Astronomy*.

16 Ibid. Cf. KGW, vol. 1, 9–10.

> are at rest, I had no doubt that for things which move, similar resemblances would reveal themselves.

Moved by theological concerns, Kepler concentrated on the "number, quantity and motion" of the spheres. His approach was not empirical, but rather speculative, based on the presupposition that the order of the world is in some way an unfolding of the divine mysteries.

The search for some order or proportion in the world system as a whole occupied his thoughts for a long time. He finally arrived at the long-sought solution when he related the five regular solids to the number of the planets—six in all, according to Copernicus. He thought that he had succeeded in discovering the harmony chosen by God at the moment of creation. His enthusiasm was based on having managed to successfully inscribe–and circumscribe–the spheres of the planets, in relation to their respective distances, within the regular solids, the so-called Platonic ones:[17]

> As an aid to memory I give you the proposition, conceived in words just as it came to me and at that very moment: "The Earth is the circle which is the measure of all. Construct a dodecahedron round it. The circle surrounding that will be Mars. Round Mars construct a tetrahedron. The circle surrounding that will be Jupiter. Round Jupiter construct a cube. The circle surrounding that will be Saturn. Now construct an icosahedron inside the Earth. The circle inscribed within that will be Venus. Inside Venus inscribe an octahedron. The circle inscribed within that will be Mercury." There you have the explanation of the number of the planets.

Kepler provided a first accurate description of the *ratio a priori* concerning the number of planetary spheres in a letter to Mästlin on 3 October 1595. Mästlin appreciated this vision and assumed the burden of its publication in Tübingen, attaching to the text on the "cosmic secret" a new edition of Rheticus's *Narratio prima* and an essay on the distances of the planets from the center of the world. In this form, *Mysterium cosmographicum* appeared in Tübingen in 1596.

Apart from two free-standing chapters (I and XXIII), Kepler's work can be divided into three main blocks: chapters II–XII dealt with the nature, number and classification of regular polyhedra; chapters XIII–XIX compared the geometric hypotheses of the order of the planets with the Copernican data, with which it must agree; chapters XX–XXII sought a law and a physical explanation

17 Ibid., 69. Cf. KGW, vol. 1, 13. On Kepler's "radical Platonism," see Field, *Kepler's Geometrical Cosmology*.

to express and explain the relationships among the periods of the different planets. The somewhat separate chapters were the first and XXIII, in which Kepler discussed the reasons in favor of the Copernican system and the world's Great Year of Platonic tradition, respectively. Apart from these two sections, all the other chapters dealt with the proportions of the planetary orbits or "second mobiles":[18]

> It is my intention, reader, to show in this little book that the most great and good Creator, in the creation of this moving universe, and the arrangement of the heavens, looked to those five regular solids, which have been so celebrated from the time of Pythagoras and Plato down to our own, and that he fitted to the nature of those solids, the number of the heavens, their proportions, and the law of their motions.

The *Mysterium* was dedicated to Friedrich Freiherr von Herberstein, governor of Styria. Addressing him, Kepler assured that his ideas were the same as those of Pythagoras, but that he was the first to disseminate them: "A work [...] of tiny bulk, of modest effort, of contents in every way remarkable. For if we look to ancient times, it had been attempted two thousand years before by Pythagoras."[19] Kepler promised to reveal the secrets of the book of nature, that divine book in which one can admire the very image of God, as in a mirror: "Here we are concerned with the book of nature, so greatly celebrated in Sacred Writings. It is in this that Paul proposes to the Gentiles that they should contemplate God, like the Sun in water or in a mirror."[20] The author warned, therefore, that the matter of *Mysterium* was not addressed to everyone. The greatest glory of an astronomer, he declared, was to write for philosophers and kings: "For astronomers let it be glory enough that they write for philosophers, not for pettifoggers, for kings, not shepherds."[21] This declaration imitates the Copernican motto "mathemata mathematicis scribuntur" but, at the same time, it enlarges the potential public from mathematicians to philosophers and wealthy patrons.

18 Ibid. Cf. KGW, vol. 1, 9.
19 Ibid., 53. Cf. KGW, vol. 1, 5.
20 Ibid. Cf. KGW, vol. 1, 5.
21 Ibid., 74. Cf. KGW, vol. 1, 7.

3 Kepler Defends and Expounds the Hypotheses of Copernicus

In the first chapter of the *Mysterium cosmographicum*, Kepler explained why he believed that scholars should accept the Copernican hypotheses. According to his original plan for the work, an apologia for the agreement of the doctrine of terrestrial motion with the Bible should also be included, but theologians had discouraged him from this undertaking.[22] Due to this opposition, Kepler postponed the discussion about the accordance between Copernicus and the Scriptures to another work. Eventually, this scriptural defense of Copernicus's system would appear as a preface of his *Astronomia nova* in 1609. In the *Mysterium* he limited himself to an allusion to that defense in the first chapter: "Although it is proper to consider right from the start of this dissertation on nature whether anything contrary to Holy Scripture is being said, nevertheless I judge that it is premature to enter into dispute on that point now, before I am criticized. I promise generally that I shall say nothing which would be an affront to Holy Scripture, and that if Copernicus is convicted of anything along with me, I shall dismiss the accusation as worthless."[23]

Kepler claimed that the superior explanatory capability of Copernicus's hypotheses and the agreement of the Copernican tables with the phenomena were convincing reasons to accept his system. Particularly important was Kepler's absolute rejection of conventionalist interpretations of astronomical hypotheses: how could one deny the hypotheses and accept the consequences deriving from them? Deny the Copernican explanation of the celestial motions, but accept his numerical tables? Some, as Kepler argued, thought that false premises could generate true conclusions. By contrast, he rejected as hypocritical the attitude underlying these affirmations. In his opinion, one ought to accept the doctrine of *De revolutionibus* in its entirety:[24]

> On this point I have never been able to agree with those who rely on the model of accidental proof, which infers a true conclusion from false premises by the logic of the syllogism. Relying, as I say, on this model they argued that it was possible for the hypotheses of Copernicus to be false and yet for the true phenomena to follow from them as if from authentic postulates.

22 Cf. in particular the letter from the Tübingen theologian Hafenreffer to Kepler of 12 April 1598 (in KGW, vol. 13, 203); also see Rosen, "Kepler and the Lutheran Attitude," and Voelkel, *Composition*, 60–66.

23 Kepler, *Secret*, 75 (transl. slightly modified). Cf. KGW, vol. 1, 14.

24 Ibid. Cf. KGW, vol. 1, 15.

Brahe, too, that "astronomer greater than any celebration" (*astronomus omni celebratione maior*), although not in agreement with Copernicus on the place of the Earth, had placed the Sun at the center of the five planets, in the manner of *De revolutionibus*. Copernicus had in fact provided the simplest explanation, and nature "loves simplicity." Mästlin was also mentioned as an authority in the first chapter of *Mysterium*: his observations in 1577 had demonstrated that the comet that appeared in that year revolved around the Sun together with Venus, providing further proof of the true trajectories of the celestial bodies. Moreover, Kepler believed that the heliocentric system was demonstrable *a priori*, and this would be his greatest contribution: "Nor do I hesitate to affirm that everything which Copernicus inferred *a posteriori* and derived from observations, on the basis of geometrical axioms, could be derived to the satisfaction of Aristotle, if he were alive [...], *a priori* without any evasions."[25] In particular, Kepler was convinced that *a priori* reasons could be grasped solely on the basis of geometrical considerations about the proportions between figures and between their internal elements.[26]

4 The Distances of the Planets: Mästlin's Contribution

Although the nature of Kepler's approach was *a priori*, or metaphysical, nonetheless, the archetypal geometric model he attributed to the Creator of the world had to agree with the empirical data, or else the basic idea of *Mysterium* would have been refuted.[27] Hence, the accurate calculation of the distances of the planets *a posteriori* was of fundamental importance to test the polyhedral hypothesis. This was the reason for an intense exchange between Kepler and his teacher in Tübingen in the years immediately preceding the publication of *Mysterium*.[28] Mästlin, who had carefully studied the details of *De revolutionibus* and was expert in astronomical calculations (indeed, he had taken care of the new edition of Reinhold's *Prutenicae tabulae*, compiled ephemerides and conducted celestial observations), determined for Kepler the values needed to test the validity of his theory. Mästlin sent these data to Kepler, as an appendix to a letter dated 27 February 1596. His calculations responded to his pupil's

25 Ibid., 77–79. Cf. KGW, vol. 1, 16.

26 For considerations on Kepler's epistemology see Omodeo, "Perfection of the World," 96–99 and Regier, "Method and *a priori*," 156.

27 Cf. Field, "Kepler's Cosmological Theories."

28 An account of this dense correspondence can be found in Caspar, "Nachbericht," 418–22. On Mästlin's involvement with the *Mysterium*, see Voelkel, *Composition*, 41–45.

requirements: that the distances of the planets be computed in relation to the Sun and not to the center of the *orbis magnus*, the annual orbit of the Earth, as Copernicus had done. In fact, Kepler was convinced that all planetary theory must be consistently based on the centrality of the Sun, ignoring the eccentricity of the orbit of our planet hypothesized in *De revolutionibus*.[29] Galileo would appreciate this, and pick up the values of planetary distances and periods from the *Mysterium* for his cosmogonic mental experiments about the height from which planets "fell down" at the moment of the creation of the planetary system in order to acquire their velocities.[30]

In a series of letters written in April 1596, Mästlin and Kepler addressed the issue of Mercury's orbit. Thus, among Kepler's numerous mentions of his teacher in *Mysterium*, there is a very long passage in chapter XIX on the problem of Mercury's orbit and the eccentricity of the Earth. The opinions of the teacher, expressed in a letter, are quoted verbatim.[31] Regarding instead the calculation of the various planetary distances, Mästlin included an appendix providing all the data on the topic. This appendix was entitled "On the Dimensions of the Heavenly Orbs and Spheres According to the Prutenic Tables, Descending from Nicholas Copernicus's Theory [*ex sententia Nicolai Copernici*]." It is Mästlin's most conspicuous contribution to his pupil's work. In it, he did not hesitate to praise Kepler for demonstrating *a priori* what his predecessors, including Copernicus, had sought *a posteriori* and with great effort. If we remember what he had written years earlier on the need for *a posteriori* investigation of the laws of the universe, we cannot help but be struck by the enthusiasm with which he greeted Kepler's work. In the appendix, the pupil was now called, with an abundance of superlatives, "eruditissimus," "ingeniosissimus" and "doctissimus." In introducing the appendix, Mästlin explained that his computation, together with Rheticus's *Narratio prima*, was the only element that was missing to make *Mysterium* perfectly intelligible.[32]

Mästlin explained that his calculations, conducted according to the Copernican hypotheses, had been taken from Reinhold's *Prutenicae tabulae*, whose author he greatly admired. Indeed, he lamented the grave loss to astronomy brought by Reinhold's untimely death, which robbed him of the time to bring to fruition a *Commentarium in Copernici libros* (*Commentary of Copernicus's Books*). If Reinhold had published such work, he would have made known the mathematical models which he had employed to compile the

29 Segonds, "Introduction," XV.

30 Büttner, "Galileo's Cosmogony."

31 KGW, vol. 1, 67–68.

32 Mästlin, *De dimensionibus*, in KGW, vol. 1, 132.

renowned astronomical tables, and which Mästlin had been forced to laboriously reconstruct.[33]

Mästlin began with the solar orbit, or better, in a Copernican perspective, with the terrestrial one (*Theoria Solis, seu potius Orbis Magni Telluris, eiusque dimensio*). This was followed by the lunar theory, and then Mästlin calculated the dimensions of the lunar and terrestrial spheres in order to determine the Earth-Sun and Earth-Moon distances. There followed in good order the theories of Saturn, Jupiter and Mars, with the calculation of the dimensions of the respective spheres, and the theories of Mercury and Venus, with the dimensions of their circles. These numbers were to have revealed the splendor of Kepler's precise work and, according to the theological convictions of both authors, the wisdom of God in the creation of the world. This is why the appendix closed with quotations from Isaiah 40:26, "Lift up your eyes on high and see who has created these stars" (*Levate in excelsum oculos vestros, et videte quis creaverit ista*), and from Psalm 148:1, "Praise the Lord. Praise the Lord from the heavens, praise him in the heights above" (*Laudate Dominum de coelis; laudate eum excelsis*).

5 Mästlin: Finally We Have an *a priori* Astronomy

Mästlin's admiration for Kepler's achievement clearly emerges from his preface to the "candid reader" of the *Narratio prima*, included as an integral part of *Mysterium*. As I have mentioned, until Kepler's discovery of the correspondence between the distances of the planets and the five regular solids, Mästlin had excluded that astronomy could proceed *a priori*. Hence, as one reads, even greater was his admiration for the person who had been able to accomplish the impossible, something that had never entered the mind of so many recent astronomers, not even in the long sleepless nights they had been forced to endure in order to observe the stars. While all of his predecessors had tackled astronomy "from behind" (*a terga*), searching for heavenly regularities on the basis "of effects," Kepler had opened a path leading to the same conclusions as Copernicus, but proceeding "from the front" (*a fronte*):[34]

> Even though these [mathematics] are admirably difficult [*admiranda et ardua*], nonetheless our illustrious mathematician, Master Johannes Kepler teaches us how to fly much higher thanks to their [mathematical]

33 Ibid.

34 Mästlin, *Candido Lectori*, in KGW, vol. 1, 82–85, 82.

> wings. Certainly, practitioner-astronomers have so far discovered great things. Yet, all of them have so far dealt with astronomy from behind. They investigated motions, as well as dimensions and distances by the sole means of observations. No one, not even the most capable practitioner [*artifex*], has so far considered, not even in dreams, whether there is an *a priori* access (that is, from the front) into these measurements, as if there were no other geometrical rule to examine the ascertained numbers of [heavenly] motions and quantities except for observations.

Mästlin stated, in the first lines of the letter to the reader, that Plato's doctrine was right to assume that arithmetic and geometry are the "wings" of astronomy proceeding from the phenomena to the causes. However, Kepler added a new perspective to this science, since he had revealed to all the secret of God's creation, founded in geometric archetypes. As a consequence, everyone should accept Copernicus's hypotheses: this was the conclusion drawn by Mästlin. Note the different tone now adopted by the teacher, who until then had hinted at his predilection for heliocentrism, without, however, proclaiming it too loudly. As we have seen, he had even concealed it in his teaching textbooks. It was with a completely different tenor that he now fiercely defended the planetary theory of *De revolutionibus*, strengthened by the reasons advanced in the *Mysterium*.[35] Mästlin even launched into a reproach to Copernicus's detractors, blinded by prejudices, which they now had to reconsider in the light of the new *a priori* demonstration:[36]

> There might be someone who, like many so far, is offended by the strangeness [*absurditas*] of Copernicus's hypotheses, which many unduly and unreasonably condemned and slandered. [He might] moreover [dislike the fact] that Kepler, in his discovery [*inventum*], maintains, along with Copernicus, that the fixed stars, at the extremity of the world, and the Sun, at its center, are immobile whereas the Earth moves in circle at some distance from the center. This person should first consider and examine the issue, rather than judging by rash prejudice.

Concerning the physical arguments on gravity and levity, Mästlin believed that Copernicus had sufficiently answered objections. And, with a touch of irony, he added that he did not understand why all creation should have been designed around an insignificant little point like the Earth on which we live.

35 Segonds, "Introduction," XXVI.

36 Mästlin, *Candido Lectori*, in KGW, vol. 1, 83.

Another argument in favor of Copernicus was undoubtedly that of the symmetry and order of his system, characteristics that had impressed Rheticus and found fulfillment in Kepler's metaphysical hypotheses:[37]

> Copernicus's hypotheses enumerate, dispose, connect and measure the order and dimensions [*magnitudo*] of all orbs and spheres in such a way that nobody can change or transpose anything in them without producing universal disruption; in fact, they eliminate all doubts concerning the location and the series [of the celestial bodies].

For Mästlin, the entire construction of the world was so consistent and well structured that nothing could be altered or moved without causing its ruin. His polemic dart was aimed at Brahe, and together with him all those (e.g. Ursus, Röslin, and Magini) who were busying themselves with "mixed models" of the world,[38] advancing physical objections against Copernicus which Mästlin and Kepler considered laughable. To them, Copernicus's world system seemed as orderly as that of his detractors seemed uncertain, inconclusive even on the number of the celestial spheres. And that was without addressing the usual question of the very fast motion of the eighth sphere assumed by Ptolemy and his followers: "What shall I say on this very rapid and inestimable velocity of this so great body of the world, if it turns daily?"[39] Mästlin thus attacked the *recentiores*, the supporters of geo-heliocentric systems presented as "some very excellent mathematicians [who] try to prepare some cure for those illnesses."[40] What keeps the Earth still and leaves the other planets to revolve around the Sun? The promoters of such hypotheses, wishing to avoid difficulties that they deem to be intrinsic to heliocentrism, jump headfirst into much graver absurdities.[41] Brahe, who is implicitly mentioned here, must be superseded by *Kepler noster*, following the motto "Plato is my friend, Socrates is my friend, but truth is a better friend."[42] The mixed hypotheses, as Mästlin added, are not so very original, but rather old clothes worn anew: "To tell the truth, through that emendation of hypotheses they do not do anything but repair an old and worn toga with some new piece of clothing, so that the next tearing will be

37 Ibid.

38 See chap. 1,10 and 2,16.

39 KGW, vol. 1, 84.

40 Ibid.

41 Ibid., 84–85.

42 Ibid., 85.

even worse."[43] Remember Rothmann's objection to Brahe as to his hypotheses, which he regarded as an inconvenient alteration of the Copernican.[44]

6 The Sun as the Universal Motive Force

The geometric hypotheses of the *Mysterium* were put to a harsh test by Brahe's careful observations, which Kepler inherited at his death. Thus, the search for the harmony hidden in nature and in the heavens would cost Kepler further years of investigations and renewed attempts, leading to later famous publications. Nonetheless, although Kepler's metaphysical hypotheses were destined to fail, his work of 1596 brought an indubitable contribution to the knowledge of the heavens with regard to at least one aspect: the necessity of relating the motions of the planets to the true position of the Sun. This found justification, in Kepler, in the conviction that the diurnal star was not only the geometrical center of the cosmos, but that it also exerted a force on the planets that maintained them in motion in their orbits. In this regard, his biographer Max Caspar observed that Kepler expediently "corrected" Copernicus,[45] and Gingerich pointed to the fact that "Copernicus gave the world a revolutionary helio*stati*c system, but Kepler made it into a helio*centric* system."[46]

The problem hinged on the relationship of the speeds of the planets to their distances from the Sun, an issue dealt with by Kepler in chapter twenty of the *Mysterium* after he had established, in the earlier sections, the relation between the distances of the planets and the geometric solids. These presuppositions were derived from Platonism: archetypal numerical ideas must be seen as the basis of creation. On this point, Kepler mentioned the "divine" Nicholas of Cusa as his forerunner.[47] In fact, he praised him for having compared God to the spherical surface of the heavens. On Kepler's account, it was necessary to believe that the world in its entirety was "constituted" by curved lines, which set limits, rather than by straight lines, which have neither end nor order: "The idea of the universe is perfect. Nevertheless, let us reject straight lines and surfaces, as they are infinite, and consequently scarcely admit of order, from this complete, thoroughly ordered, and most splendid universe."[48] From Cusanus,

43 Ibid., 84.

44 See chap. 2,16.

45 Caspar, "Nachbericht," 406.

46 Gingerich, "Kepler's Place," 263. Cf. Rybka, "Kepler and Copernicus," 214 and 216.

47 Omodeo, "Nikolaus von Kues." See chap. 4,12.

48 Kepler, *Secret*, 95–97. Cf. KGW, vol. 1, 25.

Kepler maintained the idea of the correspondence (theological coincidence) of the center and the periphery of the universe, understood as images of two persons of the Trinity, while leaving aside any infinitist speculation. In Kepler's world, the Sun, at the center of the divine epiphany, acquired a very strong symbolic position. This was undoubtedly one of the central elements in his acceptance of Copernicus's hypotheses.[49]

The Sun also played an important role in the search for the law of the motion of the planets. In chapter twenty of the *Mysterium*, the author sought a rule for the planetary motions that demonstrated the relation between their distance from the center and their periods. For him, Aristotle's precept that "the movements of each planet are proportional to their distance" should be maintained, albeit in a completely different conceptual and cosmological framework.[50] In fact, Kepler observed that this precept was extremely problematic for those who stick to geocentrism. If the planetary motions were conceived as centered on the Earth, then Mercury, Venus and the Sun should have the same period of revolution, lasting one year. That would determine a situation by which the Sun, being more distant from the center than the other two bodies and having to cover a greater distance in an identical period of time, would move more quickly than the inferior planets. But this would mean breaking the aforesaid Aristotelian rule, which instead was respected by Copernicus.

For Kepler, there were not as many motive forces as there were planets, but only one motor, precisely the Sun. Its central body, a luminous image of the first person of the Divine Trinity, was the universal cause of motion. Therefore, the more remote planets, less affected by its power, moved more slowly.[51]

> But if, nevertheless, we wish to make an even more exact approach to the truth and to hope for any regularity in the ratios, one of the two conclusions must be reached: either the moving souls are weaker the further they are from the Sun, or there is a single moving soul in the center of all the spheres, that is, in the Sun, and it impels each body more strongly in proportion to how near it is. In the more distant ones on account of their remoteness and the weakening of its power, it becomes faint, so to speak. Thus, just as the source of light is in the Sun, and the origin of the circle is the position of the Sun, which is at the center, so in this case the life,

49 Cf. Martens, *Kepler's Philosophy*.

50 Granada, "A quo moventur," 118.

51 Kepler, *Secret*, 199–201. Cf. KGW, vol. 1, 70. For a reconstruction of Kepler's criticism of the plurality of internal intelligences accounting for planetary motions, see Granada, "A quo moventur."

> the motion and the soul of the universe are assigned to that same Sun; so that to the fixed stars belongs rest, to the planets the secondary impulses of motions, but to the Sun the primary impulse. In the same way the Sun far excels all others in the beauty of his appearance, and the effectiveness of his power, and the brilliance of his light. Consequently the Sun has a far better claim to such noble epithets as heart of the universe, king, emperor of the stars, visible God, and so on.

7 The New Astronomy

Kepler's detailed examination of the physical dimension of planetary astronomy culminated in the publication of *Astronomia nova* in 1609. The full title of the work indicates the "novelty" of which Kepler was proud: *Astronomia nova αἰτιολογιτός seu physica coelestis de motibus stellae Martis* (*New Astronomy Investigating the Causes, or Celestial Physics Concerning the Motions of Mars*). It was the promise of a "celestial physics," that is, an astronomy intertwining mathematics and physics, rigorous demonstrations and material causes.[52] Concerning the division between the two approaches to astronomy, that of the natural philosophers versus that of the mathematicians (that of Aristotle versus that of Ptolemy and Copernicus), Kepler's pretension to reconcile the two aspects of the study of the heavens was of no little account. Historians of science have often dealt with this aspect. Edward Rosen, for one, wrote: "This was a new astronomy, and […] what was new about it was his introduction of physical causes into the subject so that astronomy had now become celestial physics."[53] That need to unify physical and mathematical explanations had already been appreciated by the preceding generation of thinkers and scientists: we need only think of the work of Brahe, and of Bruno, as well as the broad discussion of the geo-heliocentric and Capellan models. In the *Mysterium*, Kepler proposed an explanation of the motion of the planets based on some motive force of the Sun, a crucial aspect at which he had already hinted in his Tübingen dissertation *de motu terrae*.[54] This subject was now expanded and deepened in *Astronomia nova*.

Kepler opened the book with a quotation from de la Ramée's *Scholae mathematicae*, a passage in which the latter condemned astronomical hypotheses as absurd. De la Ramée had criticized mathematical astronomers, and

52 Cf. Gingerich, "Kepler's Place," 261–78.

53 Rosen, "Kepler's Place," 280.

54 Voelkel, *Composition*, 26–32.

particularly Copernicus, for using "mathematical expedients" aimed at "saving the phenomena" without taking care for the physical correctness of their explanations.[55] He was unwilling to accept the opportunistic justifications that true consequences could be derived from false causes.[56] Having rejected the use of false hypotheses to obtain knowledge of nature as it really is, he had staked a claim on discussions regarding the role of geometric models in astronomy. Kepler even quoted the famous passage by de la Ramée attacking Copernicus's hypotheses.[57]

De la Ramée had promised to cede his chair of *lecteur royal* in Paris to whomever succeeded in liberating astronomy from hypotheses. In the *Astronomia nova*, Kepler responded to this challenge (long after the death of the philosopher) to claim the prize promised in exchange for an astronomy "without hypotheses." Kepler accepted the thesis that one could not deduce real effects from false hypotheses. Yet, he added that a similar error could be imputed to Copernicus only by a misunderstanding. Copernicus did not "postulate" the motion of the Earth; he "demonstrated" it:[58]

> It is a most absurd business, I admit, to demonstrate natural phenomena through false causes, but this is not what is happening in Copernicus. For he, too, considered his hypotheses true, no less than those whom you mention considered their old ones true, but demonstrates it; as evidence of which I offer this work.

Indeed, according to Kepler, Copernicus should have been considered as a philosopher. In *Astronomia nova*, he additionally revealed the identity of the author of the preface to *De revolutionibus* on the conventionality of the hypotheses, Andreas Osiander, arguing that Copernicus must have been unaware of the interpolation.

8 Natural Arguments in Astronomy

The focus of *Astronomia nova* was natural causes: "I discuss natural causes" (*disputo de causis naturalis*).[59] As can be read in the *Introductio*, since ignorance

55 See chap. 1,6.
56 Kepler, *Astronomia nova*, in KGW, vol. 3, 6.
57 Idem, *New Astronomy*, 28; cf. KGW, vol. 3, 6.
58 Ibid.; cf. KGW, vol. 3, 6.
59 KGW, vol. 3, 18.

of causes compels one to a thousand conjectures aimed at understanding phenomena, celestial physics and astronomy should be dealt with together: "in this work, I mixed celestial physics with astronomy."[60] To the reader, who may have been surprised by this novelty, Kepler noted that it was convenient to merge the two discourses in a mixed science (*scientia mixta*), that is, a science that takes its data from the senses and its demonstrations from mathematics.

The conflict between the plane of hypotheses and that of causes, one reads in the introduction, had led to two different schools (*astronomorum sectae*). "Coryphaeus" of the first one was Ptolemy, while the second combined those who treated the planetary theory as a unified system. The latter school was divided into the followers of Copernicus and those of Brahe. Kepler observed that those various hypotheses (i.e., geocentric, heliocentric and geo-heliocentric ones) were equivalent from a merely geometric point of view. Via slight mathematical transpositions, it would have been possible to translate the models into each other. All three approaches were virtually equivalent also from the perspective of their predictive capacities. Thus, in order to "save the phenomena," Ptolemy, Copernicus and Brahe were interchangeable. The discussions of the hypotheses could be truly idle, as de la Ramée had written, if one limited them to geometry and optics. The ultimate decision about the correct model would, therefore, depend on the real causes, or the physical explanation of the phenomena. Kepler assured his readers that he had succeeded in amending all three models by inaugurating a "new" astronomy, the *physica coelestis* announced in the title of the 1609 work:[61]

> For each of these three opinions concerning the world there are several other peculiarities which themselves also serve to distinguish these schools, but these peculiarities can each be easily altered and amended in such a way that, so far as astronomy, or the celestial appearances, are concerned, the three opinions are for practical purposes equivalent to a hair's breadth, and produce the same results. My aim in the present work is chiefly to reform astronomical theory (especially of the motion of Mars) in all three forms of hypotheses.

Kepler assured that only the Copernican system was salvageable, "pauculis mutatis," among the three competing ones.[62]

60 Ibid., 19.

61 Idem, *New Astronomy*, 28; cf. KGW, vol. 3, 19–20.

62 KGW, vol. 3, 20.

These “little modifications” were momentous indeed, and they are still remembered today, with his name, as the first two laws of planetary motion. Kepler established the relationship between the distance and the speed of a planet with respect to the center of an eccentric trajectory in the third part of *Astronomia nova*. According to the modern formulation, the line connecting the center of the Sun and the center of a planet sweeps out equal areas during equal time intervals. Therefore, Kepler reintroduced the inequality of planetary motions, opposed by Copernicus, which the ancients had explained by means of equants. “For whether it is the Earth or the Sun that is moved, it has certainly been demonstrated that the body that is moved is moved in a non-uniform manner, that is, slowly when it is farther from the body at rest, and more swiftly when it has approached this body.”[63] Another variation from Copernicus was the elliptical orbit that Kepler assigned to Mars in the fourth part of *Astronomia nova*. According to the generalization of this elliptical motion to all the planets, their orbits are elliptical with the Sun at one of the foci. Kepler’s physical turn is conveniently synthesized by his terminological and conceptual shift from an explanation of planetary motions through “orbes” (orbs, or spherical shells) to one based on “orbitae.” Instead of the nested circles used by earlier astronomers, he introduced the concept of orbit, “that is, the path together with its physical causes—expressed as physical laws.”[64] According to Kepler, the shape and the velocities of planetary orbits depend on the strength of the solar *vis*, that is, on physical reasons.[65]

Kepler observed that neither Copernicus nor Brahe had ever actually placed the Sun at the center of the planetary orbits in their planetary theories. In a manner inconsistent with the respective assumptions, both astronomers had limited themselves to transposing the Ptolemaic system. Ptolemy’s terrestrial eccentricity was thus transformed in both cases into a system in which the orbits of the planets were centered on an empty point in space, at a distance from the Sun equal to the eccentricity taken from the *Almagest*. The plea to put the Sun at the true physical, and thus also mathematical, center of the planetary motions led to the aforementioned change from the helio*static* model of Copernicus to an accomplished helio*centric* one:[66]

63 Idem, *New Astronomy*, 51; cf. KGW, vol. 3, 22.

64 Goldstein-Hon, “Kepler’s Move,” 76.

65 Establishing the shape of planetary orbits was no easy task for Kepler: cf. Donahue, “Kepler’s Fabricated Figures,” and “Kepler’s First Thoughts.” See also Wilson, “Derivation.”

66 Ibid., 48; cf. KGW, vol. 3, 20. See Caspar, “Nachbericht,” 406; Gingerich, “Kepler’s Place,” 263; Rybka, “Kepler and Copernicus,” 214.

> Now my first step in investigating the physical causes of the motions was to demonstrate that [the planes of] all the eccentrics intersect in no other place than the very center of the solar body (not some nearby point), contrary to what Copernicus and Brahe thought.

Of the three models, Kepler believed that Ptolemy's should be rejected first, since it lacked the systematic consistency common to Copernicus and Brahe. Between two explanations, as Kepler contended, the simpler one always suits nature (*axioma quippe in physica receptissimum est, naturam paucissimis uti quam possibile est*); hence, geocentrism should without doubt be abandoned. The choice between Copernicus and Brahe was more complicated.

Kepler observed that, after the moment when the crystalline spheres were abandoned, the cause of the planetary motions should be sought in the Sun. Hence, from the physical point of view, the decision between the geocentric and geo-heliocentric models depended on establishing whether the Earth moves the Sun or *vice versa*. It seemed improbable to him that our very small planet should escape from the force that the Sun exerts on the other planets (also according to Brahe) while the Sun must be pushed (according to Brahe) together with its court of planets by some force issued from the Earth. Therefore, the Copernican model was more likely from a natural perspective.

Furthermore, Kepler proposed the metaphysical argument that the centrality of the Sun could be deduced from its dignity and brightness. For further information, he referred the reader to the *Mysterium* or to the exposition of the doctrine of the Pythagoreans in the second book of Aristotle's *De caelo*. He assumed, in fact, that the Aristotelian passage about the "central fire" (*ignis*) of the Pythagoreans should be viewed as a reference to the Sun.[67]

9 *Gravitas* and *vis animalis*

Further analysis of the Copernican theory in *Astronomia nova* concerned the discussion of gravity and levity. Kepler began by rejecting one of the central assumptions of Aristotelian physics, which had also been asserted by Brahe: the geometrical center of the world must coincide with that of gravity. Kepler replied that a mathematical point has no attractive property. Indeed, a natural body cannot be attracted by virtue of any type of force or *sympathia* by a mathematical point, a geometric center which is a *nihil* from a natural viewpoint.

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67 See chap. 4,4.

The author wished to abandon the *doctrina vulgaris de gravitate*, the popular theory of gravitation, in the name of a new one, and he outlined its principles. As a reader of Gilbert's *De magnete*, he considered gravity a magnetic force that was attractive and reciprocal between two similar bodies. Hence, not only does the Earth attract the stone toward itself, Kepler stated, but also the stone attracts the Earth toward itself, even though with much lesser force, since the force of attraction is proportional to the sizes: "Gravity is a mutual corporeal disposition among kindred bodies to unite or join together; thus, the Earth attracts a stone much more than the stone seeks the Earth (the magnetic faculty is another example of this sort)."[68] This was the definition of the force of gravity as *vis cognati corporis*. In Kepler's physics, it was accompanied by another complementary force, the *vis animalis*, or "animal force." While the force of gravity attracts only the similar to the similar (hence, it is not a universal force of attraction between all bodies, inasmuch as they are bodies), the animal force moves the planets and maintains them in their trajectories. One meets a similar *vis animalis* in Bruno and in other authors, for instance Origanus, who considered it a kind of motive force of those large animals, the planets.[69]

Kepler underlined that gravity attracts bodies to the center of the Earth not because the center is the center of the world, but because it is the center of a body (the Earth) consistent in itself (*rotundus*) and similar to the bodies striving toward its center. Kepler thus rejected the opinions of those who considered terrestrial motion at odds with the perpendicular fall of bodies. By contrast, he held that the bodies will behave in the same manner wherever they are located on the Earth, or wherever the planet is transported by virtue of its animal force.[70]

Bodies tend to remain in a state of rest: "Every corporeal substance, to the extent that it is corporeal, has been so made as to be suited to rest in every place which it is put by itself, outside the sphere of influence of a kindred body."[71] Therefore, each motion requires an explanation: gravity or *vis cognati corporis* provides a reason for the fall of bodies toward the center of our planet. If it were not for the *vis animalis* that maintains the planets in their trajectories, the Earth and the Moon would unite, moving toward each other, with each covering a distance inversely proportional to their sizes. Moreover, if the

68 Kepler, *New Astronomy*, 55; cf. KGW, vol. 3, 25.

69 See chap. 3,11 and 5,5. Cf. Boner, "Kepler's Vitalistic Views."

70 Kepler, *New Astronomy*, 55.

71 Ibid.

Earth did not attract all its parts to itself, its waters would be drawn upward as far as the Moon.

On the basis of these principles, Kepler replied to two physical arguments by the opponents of terrestrial motion. Against the argument of the cannon-ball, proposed by Brahe in his correspondence with Rothmann, he replied that no violent force, not even that by which a projectile is launched, can exempt terrestrial bodies from the dual action of gravity and the traction of the local motion of the planet. Against the argument of the perpendicular fall of bodies (recall the matter of the arrow proposed, among others, by Brahe), Kepler observed that the magnetic force of gravity is such that neither the motion of the Earth nor any air movement can abduct an object projected aloft and prevent it from falling back to the Earth in a vertical line:[72] "Consequently, anything shot vertically upwards falls back to its place, the motion of the Earth notwithstanding. For the Earth cannot be pulled out from under it, since the Earth carries with it anything sailing through the air, linked to it by the magnetic force no less firmly than if those bodies were actually in contact with it.[73]

According to the program he had established to identify the real causes of celestial motions,[74] Kepler also tried to indicate the source of the motion of the single planets, and he identified it, as previously in *Mysterium*, in a force emanating from the Sun in its whirling axial rotation:[75]

> Moreover, I have specified the manner [in which this occurs] as follows: that the Sun, although it stays in one place, rotates as if on a lathe, and out of itself sends into the space of the world an immaterial form [*species*] of its body, analogous to the immaterial form [*species*] of its light. This form [*species*] itself, as a consequence of the rotation of the solar body, also rotates like a very rapid whirlpool throughout the whole breadth of the world, and carries the bodies of the planets around with itself, its grasp stronger or weaker according to the greater density or rarity it acquires through the law governing its diffusion.

The trajectories of the planets, Kepler revealed, are not circular, but rather elliptical: "the course of a planet in the heavens is not a circle, but an oval path, perfectly elliptical."[76] Finally, Kepler advanced the hypothesis that all

72 See chap. 5,10.

73 Kepler, *New Astronomy*, 58; cf. KGW, vol. 3, 28.

74 KGW, vol. 3, 34.

75 Kepler, *New Astronomy*, 67; cf. KGW, vol. 3, 34.

76 Ibid., 68; cf. KGW, vol. 3, 35.

the planetary motions could be referred to mere “facultates corporeae, hoc est magneticae” (corporeal faculties, that is, magnetic) and that only the spinning of the Sun must be ascribed to a living force (*vitali facultate*).[77]

10 Celestial Messages

In the years during which Kepler wrote and published *Astronomia nova*, he had known for some time that he could count on an Italian ally in the “Copernican cause.” In August 1597, Galileo, then professor of mathematics at Padua, had taken up paper and pen to praise *Mysterium cosmographicum*, of which he had received a copy: “[…] and I promise that I will read your book with a favorable disposition, because I am sure that I will find wonderful things in it. I make this with even more pleasure since I embraced Copernicus’s theory many years ago, and from his perspective I could find the causes of many natural effects that would have been inexplicable for the common hypothesis.”[78] In 1597, therefore, Galileo not only declared that he had been convinced of the correctness of Copernicus’s cosmological hypotheses, but he also assured that he had put together a series of arguments aimed at strengthening them. He added that he had written them down, but had not yet dared to publish them, held back by the awareness of the aversion to the doctrines of *De revolutionibus* by countless opponents (*apud infinitos*).[79]

Galileo had been dealing for some years with problems of physics that could be inserted into a Copernican cosmological framework. In his lectures he followed the Aristotelian-Ptolemaic doctrines, as demonstrated by *Trattato della sfera ovvero cosmografia* (*Treatise on the Sphere or Cosmography*, published for the first time in 1656).[80] Yet his juvenile reflections *de motu*, stimulated in part by the reading of Benedetti, attest to a departure from Aristotelian physics,

77 Ibid.

78 Galileo to Kepler (4 August 1597), in EN, vol. 10, 67–68. On the first contacts between Kepler and Galileo: Biancarelli Martinelli, “Paul Homberger,” and Rosen, “Galileo and Kepler.”

79 For a detailed study of this letter and the relationship between Galileo and Kepler in general: Bucciantini, *Galileo e Keplero*. Regarding Galileo’s attention to *Mysterium*, also see: Drake, “Galileo’s Platonic Cosmogony.”

80 In depicting the Venetian cultural environment that Galileo joined, Gaetano Cozzi also briefly covered Galileo’s program of lectures in the Padua period: *Sphaera* and Euclid (1593), the fifth book of Euclid’s *Elementa* and *Theoricae planetarum* (1594), *Almagest* (1597), again *Elementa*, together with pseudo-Aristotelian mechanics (1598), *Sphaera* and Euclid (1599), idem (1603), *Theoricae planetarum* (1604). See Cozzi, “Galilei, Sarpi,” 152.

especially regarding the conception of the fall of bodies, with the formulation of a concept of *levitas* understood as "greater or lesser gravity."[81] In *Le mecaniche* (*The Mechanics*), written starting from 1593, which had a wide manuscript circulation (many years later published in French by Mersenne in 1634), Galileo developed a concept of gravity that fit well within a Copernican cosmological discourse, defining gravity as a downward tendency and not toward the *centrum mundi* as per Aristotelian tradition.

But well before Galileo's studies of dynamics reached maturity and obtained a wide dissemination, the Tuscan scientist acquired universal fame by means of the amazing celestial observations carried out with a telescope. In 1609, perfecting a similar instrument invented in the Netherlands, Galileo built a "perspicillum" and aimed it toward the stars.[82] His observations were published in *Sidereus nuncius*, hastily printed in Venice in 1610, to communicate the great novelties as quickly as possible: "the great and marvelous sights that Galileo Galilei [...] observed with the aid of a spyglass, recently discovered by him, on the face of the Moon, in innumerable fixed stars, in the Milky Way, and in nebulous stars, but above all in four planets that revolve around the star Jupiter with amazing speed at different distances and in different periodic times, unknown to anyone up to this day."[83] The recipient of the work was the Grand Duke of Tuscany Cosimo II de' Medici, after whom four satellites of Jupiter, observed for the first time, were named.[84]

The first marvel dealt with by Galileo was the face of the Moon, which appeared to him for the first time in the telescope with all its ruggedness and craters in beautiful view: "The observational evidence is so compelling that anyone can grasp for himself that the Moon's surface is not smooth and

81 Cf. Camerota, *Galilei*, vol. 1, 63–64. On the studies on motion in the Pisa period, cf. Festa, *Galileo*, 17–21 and Camerota-Helbing, "Galileo and Pisan Aristotelianism." Festa deals with the writings on mechanics of the Padua period at pp. 41–43. In the writings *de motu*, there is also a reference to Copernicus' so-called "mechanism of reciprocation," the composition of two circular motions to produce a rectilinear one. The same mechanism had already been adopted, with reference to *De revolutionibus*, by the Paduan professor of mathematics Moletti, to whose chair Galileo succeeded. Cf. Moletti, *Dialogo intorno alla meccanica* (Milano, Biblioteca Ambrosiana, Ms S100 sup.), ed. by Laird, *Unfinished Mechanics*, 102–06.

82 Galileo, *Sidereal Message*, 56. Cf. Ronchi, *Galileo e il suo cannocchiale*; Bucciantini-Camerota-Giudice, *Telescopio*, chap. 1, in particular map 1.

83 Ibid., 49.

84 For a rapid panorama of Galileo's celestial observations, see: Shea, "Revelations." For the importance of the telescopic observations for modern empirical science, see Baldo Ceolin, "Galileo e la scienza sperimentale."

polished but rough and uneven. Like the face of the Earth, it is covered all over with huge bumps, deep holes, and chasms."[85] Therefore, not only had the telescope removed any doubt about the mountainous nature of the lunar patches, it had also allowed the establishment of a parallel between the Earth and its satellite, striking a fatal blow to the Aristotelian doctrine of the incorruptibility and perfection of the heavens. Hence, Galileo's observations assumed natural-philosophical and cosmological importance, demonstrating (or making very likely) the homogeneity of the universe, explicitly reviving the Pythagorean doctrines and indirectly the specters of atomism and Brunian philosophy.[86] "So if someone wanted to revive the ancient Pythagorean theory, namely that the Moon is like another Earth, its land surface would be more fittingly represented by the brighter region, and the expanse of water by the darker one. I have never doubted that if the terrestrial globe were observed from afar, bathed in sunlight, the land surface would appear brighter and the expanse of water darker."[87] Just as the lunar disc presents patches, then—Galileo maintained—the Earth must appear exactly the same if observed from the Moon. Moreover, for Galileo the faint light we see in the dark part of the lunar disc was to be attributed to the reflection of sunlight by our planet: "Indeed, the Earth gives back to the Moon an illumination like the one that it receives from her during nearly the whole time in the deepest gloom of the night."[88]

After Galileo had described all the phenomena he had observed on the face of the Moon, he continued his account of the celestial novelties, moving on to the fixed stars. When observed through the telescope and before they were magnified, they lost the radiant outline usually observed and, therefore, appeared less increased in size than the Moon and the other planets. A very surprising observation was the multiplication of the stars and the appearance of myriads of small points of light invisible to the naked eye. The telescope had also allowed Galileo to establish the nature of the brightness of the Milky Way: "the Galaxy is nothing else but a collection of innumerable stars heaped together."[89] In a similar manner, nebulae also turned out to be "groups of small stars herded together in a wonderful way."[90] Still more notable for Galileo was the discovery of four satellites revolving around Jupiter. Indeed, to his eyes, the

85 Galileo, *Sidereal Message*, 55.

86 How the doctrines of *Sidereus nuncius* were directly linked to those of Bruno by some contemporaries, particularly by Kepler, was discussed by Garin, "Galileo e gli scandali."

87 Galileo, *Sidereal Message*, 60.

88 Ibid., 69.

89 Ibid., 73.

90 Ibid.

existence of these small planets assumed cosmological importance, somehow supporting the Copernican hypothesis.

The explicit, albeit discreet, declarations of acceptance of the Copernican planetary doctrine contained in *Sidereus nuncius* are significant. In the dedication to Cosimo, Galileo argued that the satellites' motions around Jupiter should be included in a heliocentric system:[91]

> Behold, therefore, four stars reserved for your famous name. They do not belong to the common and less distinguished multitude of fixed stars but to the illustrious rank of the planets. Moving at different rates around Jupiter, the noblest of the planets, as if they were his own children, they trace out their orbits with marvelous speed while, at the same time, with one harmonious accord, they go round the center of the world, namely the Sun itself, and complete their great revolutions in twelve years.

Galileo returned to the Copernican hypothesis at the end of the treatise, where he announced a future cosmological essay, *De systemate mundi* (*The System of the World*), an intention that would lead many years later to his *Dialogo* on the Copernican and the Ptolemaic systems. In addition to reaffirming the revolution of the planets (together with their satellites) around the Sun, Galileo saw in the discovery of the Medicean stars the possibility of removing some reservations raised about the Copernican system concerning the apparent exceptionality of the Moon, until then believed to be the only planetary satellite:[92]

> Furthermore, we have a particularly strong argument to remove the scruples of those who are willing to examine dispassionately the revolution of the planets about the Sun in the Copernican system, yet are so troubled by the fact that our one and only Moon should go around the Earth while at the same time both carry out an annual revolution around the Sun, that they consider that this theory about the constitution of the universe should be rejected as impossible. But now we have not only one planet revolving about another one, while both trace out an annual circle around the Sun, but our own eyes show us four stars travelling around Jupiter as the Moon travels around the Earth while, at the same time, they make a grand revolution around the Sun.

91 Ibid., 52.

92 Ibid., 92.

Galileo's astronomical observations did not stop at the discoveries of *Sidereus nuncius*. In the years immediately following its publication, he pointed his telescope at the other planets and the Sun, encountering a series of other phenomena worthy of note. On 30 July 1610, he wrote to Belisario Vinta, chief counselor to the Grand Duke of Tuscany and Secretary of State, to announce the discovery that Saturn was "three-bodied."[93]

Galileo, who in the meantime had been named by Cosimo II "Principal Mathematician" of the University of Pisa as well as "Principal Mathematician and Philosopher" of the court, soon discovered that Venus also exhibited notable features when viewed through the telescope.[94] He announced the novelty to Giuliano de' Medici, the Florentine legate in Prague, by means of an anagram to be deciphered. The letter enthusiastically announced that this discovery would allow the choice between the competing world systems:[95]

> I am looking forward to receiving your answer to two letters of mine recently written to His Very Illustrious and Reverend Signoria to hear the opinion of Mister Kepler on Saturn's extravagance. For the time being, I send you the ciphered sentence about another special phenomenon, that I have recently observed, which can solve great astronomical controversies, in particular it embeds a strong argument in favor of the Pythagorean and Copernican model [*costituzione*]. At an appropriate moment I will publish its deciphering and other details.

It is evident from this passage that Galileo sought confirmation of the Copernican image of the cosmos through his celestial observations. In reality, their result was the vision of a universe that was not only heliocentric, but also characterized by other aspects extraneous to *De revolutionibus*, which Galileo attributed to the "Pythagorean school." In this regard, it is possible to speak of a "philosophical integration" of Copernicus, in a manner similar to what Bruno had speculatively attempted.[96]

93 Galileo to Belisario Vinta (Padua, 30 July 1610), in EN, vol. 10, 409–10. The definitive explanation that Saturn is surrounded by a ring came, after many scholars had dealt with the question (Scheiner, Riccioli, de Divinis, Fontana, Gassendi, Helvelius), in Huygens's work *De systema saturnio* of 1659, containing remarks on the phases of the planet and on the appearance it assumes when seen from an Earth in motion. See Radelet-de Grave, "L'univers selon Huygens."

94 On the social implications of these titles, cf. Biagioli, *Galileo, Courtier*.

95 Galileo to Giuliano de' Medici in Prague (Florence, 11 December 1610), in EN, vol. 10, 483.

96 See chap. 4,9.

The discovery announced to Giuliano de' Medici and Kepler in Prague was revealed by Galileo in the following January: it was the observation of the phases of Venus (and of Mercury), just like those of the Moon. In fact, Galileo's cryptogram said: "Cynthiae figuras aemulatur mater amorum", that is "Venus imitates the figures of the Moon."[97] Such empirical proof demolished Ptolemy's geocentric image, as it made tangible the fact that the inferior planets revolve around the Sun. His great joy at this discovery pushed Galileo to a sarcastic reproach to the Peripatetic philosophers, who preferred to cling to their books and ignore what their eyes could have shown them:[98]

> From this admirable observation [*esperienza*] [of the phases of Venus] we have a sensible and certain demonstration concerning two great theses [*questioni*] that have niamered so far undecided for the most talented men of the world. The first one is that all planets are tenebrous (since the same happens to Mercury as to Venus). The other one is that Venus necessarily rotates around the Sun, like Mercury and all other planets, as the Pythagoreans, Copernicus, Kepler and me firmly believed, although this had not been proved through observation, yet—as is presently the case with Venus and Mercury. Therefore, it is the glory of Mr. Kepler and the other Copernicans that they correctly believed and philosophized in spite of the fact that all bookish [*in libris*] philosophers considered us as less intelligent and almost foolish.

Another celestial novelty was the close-up observation of the spots on the bright disc of the Sun, whose rotation "from west to east" which "by the obliquity of the horizon seem to us to decline from south into north" might confirm Kepler's hypothesis of the *Mysterium* and *Astronomia nova*, according to which the planetary motions could be ascribed to the *vis* of a Sun rotating on itself.[99] Galileo, between 1612 and 1613, interpreted the sunspots as phenomena of combustion on the body of the Sun, an opinion that put him at odds with the Ingolstadt Jesuit Christopher Scheiner.

Under the pseudonym of Apelles, in 1612 Scheiner had published in Augsburg an essay in which he presented sunspots as his own discovery, interpreting them as hordes of small planets. Galileo entrusted the confutation of that hypothesis to three letters addressed to the counselor of the Holy Roman

97 Galileo to Giuliano de' Medici in Prague (Florence, 1 January 1611), in EN, vol. 10, 11–12.

98 Ibid.

99 Galileo, *Istoria e dimostrazioni intorno alle macchie solari*, in EN, vol. 5, 96. Cf. Van Helden, *On Sunspots*.

Empire and duumvir of Augsburg Marcus Welser, patron and protector of Scheiner. They were published in Rome in 1613 under the title *Istoria e dimostrazioni intorno alle macchie solari e loro accidenti* (*History and Demonstrations Concerning Sunspots*). In this report on sunspots, Galileo returned to his celestial observations. He reviewed all of them, from the Moon to the Medicean moons, from the stars to the planets. Moreover, he reaffirmed the cosmological importance of his empirical work. In those pages, he again took the side of the school of Pythagoras and of Copernicus and reiterated his acceptance of the image of a Sun "around which, as the center of their revolutions, turn all the other planets."[100]

11 First Reactions to the Celestial Novelties

The illustrations of the Moon in Galileo's treatise had an extraordinary impact on the imagery of the time, even appearing in the figurative arts: Ludovico Cigoli, a friend of his, painted the Moon with the features revealed by the telescope in the Church Santa Maria Maggiore, in Rome.[101] Galileo personally undertook the dissemination of his discoveries. On 24 and 36 April 1610, he was in Bologna visiting Magini to convince him of the reliability of his observations and, above all, of the telescope. In May of the same year, he gave three lectures in Padua in the presence of the whole university. In the meantime, the Medici of Florence undertook to confirm the veracity of Galileo's discoveries, especially of the four Jovian satellites named after their family. The Tuscan courtiers, particularly the Counsellor to the Grand Duke Belisario Vinta, asked Kepler, through the ambassador to Prague Giuliano de' Medici, to pronounce on the novelties. On that occasion, the imperial astronomer gave Galileo the best service possible: he quickly wrote a *Dissertatio cum Nuncio sidereo* in which he confirmed all the discoveries, albeit reserving the right to personally conduct an examination of the heavens with the telescope as soon as possible.

That there was a certain discontent and suspicion toward Galileo is shown by the qualms of Neapolitan astrologers, whose discipline was thrown into crisis by the multiplication of the stars and the marked expansion of the sidereal spaces.[102] Moreover, Magini's wariness, notwithstanding the homage by Galileo who had paid him a visit in Bologna, emerges from Magini's

100 Ibid., 99. Cf. Camerota, *Galilei*, 258.

101 Cf. Panofsky, *Galileo as a Critic*, *passim*. Bucciantini-Camerota-Giudice, *Telescopio*, 240–45. Ibid., chap. 4 provides a detailed account of the first circulation of *Sidereus nuncius*.

102 Ibid., 81. Cf. Lomonaco, *Galileo e Napoli.*

correspondence with Kepler, who had sent him a copy of *Dissertatio cum Nuncio sidereo* accompanied by the comment: "You ask my opinion about Galileo's *Nuncius*. Here you are: the similar rejoices of the similar. Yet [*tamen*], I believe (if you read attentively) that I was precautious enough and, where I could, I induced him to reflect on his principles."[103] Kepler's reserve, that "tamen" (yet), was misinterpreted by Magini, who, in a letter of 26 May 1610, gave voice to his scepticism about the existence of the Medicean planets: "It remains to eliminate and drive away those four new servants of Jupiter. This will soon be done: between the 24 and the 25 April, he spent the night in my home with his telescope, in order to show me those [satellites] encircling Jupiter; but he was not able to do so."[104] However, after his secretary, the Bohemian Martin Horky, printed a furious polemic pamphlet against the reliability of the telescopic discoveries, *Brevissima peregrinatio contra Nuncium Sidereum*, Magini immediately distanced himself from him.

In March 1611, Galileo, then mathematician and philosopher to the Grand Duke of Tuscany, visited Rome. In this period, buoyed by success, he also hoped for approval of his observations by the Jesuits.[105] As Gaetano Cozzi explained, "what really counted was the Company of Jesus: nor had Galileo become aware of that only recently. It counted because of its religious, cultural and political prestige, because of its influence not only on the curia but on the main courts of Europe, on the emperor, on the kings of France, Spain and Poland, on the Italian princes, because of its confessors who controlled the consciences of most of the Catholic governing class, because of the schools in which the scions of this society were educated."[106]

On 19 April 1611, Cardinal Bellarmino requested the opinion of the mathematicians of the College of Jesuits on the following matters:[107]

> First, whether they approve the multitude of the fixed stars invisible to the naked eye, in particular in the Milky Way and in the nebulas, deemed to be heaps of very small stars.
>
> Second, that Saturn is not a simple star but three conjunct stars;
>
> Third, that the star Venus changes its aspect, and grows and decreases like the Moon;
>
> Fourth, that the Moon has a rugged and irregular surface;

103 Kepler to Magini (Prague, 10 May 1610), in EN, vol. 10, 353.

104 Magini to Kepler (Bologna, 26 May 1610), in EN, vol. 10, 359.

105 Cf. Baldini, *Nova*, 64 and Van Helden, "Telescopes and Authority."

106 Cozzi, *Galilei, Sarpi*, 190.

107 Camerota, *Galilei*, 207.

> Fifth, that four wandering stars turn around Jupiter and their motions are different among them and very quick.

Note that all the points subjected to examination by Bellarmino were extremely pernicious for Peripatetic natural philosophy, since they opened the door to considerations on the immense vastness of the universe and on its homogeneity, and they undermined Ptolemaic geocentrism. Moreover, these were philosophical theses that Bellarmino knew well, having heard them supported years earlier by Bruno during his heresy trial.[108] Despite that precedent, the Jesuit mathematicians gave a favorable opinion on Galileo. Yet they did not pronounce on the consequences implicit in the telescopic observations. The elderly Clavius, together with Christoph Grienberger, Odo van Maelcote and Paolo Lembo, accredited the novelties concerning Saturn, Venus and the Medicean planets. They raised some doubts concerning the Milky Way, while they registered a true divergence of opinions regarding the Moon: while some believed that its surface was truly irregular, Clavius preferred not to shift from the Aristotelian teaching on the incorruptibility of the heavens, maintaining that the apparent ruggedness should be attributed to different densities of the parts of the satellite.[109]

Galileo's Roman visit also led to his membership, on 25 April 1611, in the academy founded by the influential prince Federico Cesi, the Lyncean Academy, which had been joined immediately before him by the Neapolitan scholar Giambattista Della Porta. The destiny of Galileo, who from then on would always sign his name as "Linceo," would come to be closely linked to the fate of this academy. The members helped him publish the letters on sunspots and later his *Saggiatore* (*Essayer*, 1623).[110] Together they conducted a diplomatic and cultural battle in Rome for the success of a program including opposition to Aristotelian natural philosophy, a mathematical-natural study aimed at usefulness, and openness to the Copernican system.[111] On the last controversial point, Lino Conti observed: "For the Lynceans, in fact, non-hostility to Copernicanism had ended up assuming the role of a necessary condition for the admission of new members to the Academy."[112]

In 1612, another upholder of the heliocentric system was admitted to the Lincei: the Neapolitan mathematician, architect, physician and natural

108 See chap. 7,9.
109 Ibid., 207–08.
110 See Redondi, "Fede lincea."
111 Conti, "Francesco Stelluti," 141.
112 Ibid., 144.

philosopher Nicola Antonio Stigliola, whose infinite cosmology and atomism have often been mentioned in connection with Bruno's views. At that time, Stigliola had in mind a broad philosophical project, entitled *Encyclopedia Pythagorea* (*Pythagorean Encyclopedia*). This should provide a philosophical foundation for all natural knowledge, also for astronomical novelties. Regrettably, only its index was published, in 1616. Religious reasons probably hindered the printing of other parts of the work. Besides, Stigliola also composed a treatise on the telescope, printed posthumously as *Il telescopio over ispecillo celeste* (Naples, 1627).

Galileo's discoveries had a great impact outside the Italian peninsula as well. From France, King Henry IV asked him to identify a new bright star to be assigned the name "Arrigo" in his honour. The Jesuits of the College of La Flèche solemnly celebrated the Medicean planets in June 1611. The diffusion of *Sidereus nuncius* may have been the basis of a renewed interest in Copernicus in the Parisian cultural environment, as well. It was probably the *lecteur royal* David Sainclair (who had given a series of lectures *in Sphaeram Copernici* between 1607 and 1608) who ordered from the publisher Jean Libert an anthology of extracts of cosmological importance from *De revolutionibus* (I,1–11. II,1–2 e 13, III,1–4), printed in Paris in 1612.[113]

Regarding the Jesuits' initial positive reactions to the celestial novelties, the validity of Galileo's observations were underlined once again in the Roman assembly of May 1611, promoted by Cesi. The Belgian Jesuit van Maelcote even read a celebratory oration known as *Nuncius sidereus Collegi Romani*.[114] Faced with the evident collapse of the Ptolemaic system in light of the new observational data, Clavius, in the last edition of his famous commentary on Sacrobosco (1611), invited astronomers to find a new disposition of the celestial bodies able to account for the new phenomena.[115]

12 Kepler's Discourses with Galileo

What distinguished Kepler's work from that of his Italian colleague was the persistence of the "Pythagorean" concern about the mathematical harmony of the cosmos, which also emerged from Kepler's initial reaction to *Sidereus*

113 See chap. 1,6. Cf. Lerner, "Copernicus in Paris." In a reconstruction of the Parisian book stocks in the sixteenth century, Doucet noted the complete absence of any trace of *De revolutionibus* (Cf. Doucet, *Les bibliothèques*).

114 Cf. Camerota, *Galilei*, 209–10.

115 Cf. Lerner, "Entrée de Tycho."

nuncius. In contrast, as Panofsky observed, "Galileo himself—perfectly free from any belief in numerology, Biblical or Pythagorean, and thoroughly immune to animism—would have accepted any number without question because he held that we must not ask nature to accommodate herself to what we may think the best arrangement and disposition, but must adapt our intellect to what she has produced."[116] Instead, the observation of new planets aroused in Kepler the immediate concern that the discovery could overturn the cosmic order illustrated in the *Mysterium* and corroborate Bruno's infinitism.[117]

In the letter to Galileo *Disseratio cum Nuncio sidereo*, Kepler carefully analyzed all the important points in Galileo's book. On the Moon's patches, he pointed his correspondent toward the reading of Plutarch and Mästlin, and his own studies on optics (*Astronomiae pars optica*, 1604).[118] Regarding the telescope, he underlined that it was an instrument already known, theorized by Giambattista Della Porta in his *Magia naturale* (*Natural Magic*, 1558 and 1589), as well as by himself in his studies on optics. He staked his claim to the clarification of the laws and properties of lenses. "I do not advance these suggestions for the purpose of diminishing the glory of the technical inventor, whoever he was. I am aware how great a difference there is between theoretical speculation and visual experience; between Ptolemy's discussion of the antipodes and Columbus's discovery of the New World, and likewise between the widely distributed tubes with two lenses and the apparatus with which you, Galileo, have pierced the heavens. But here I am trying to induce the skeptical to have faith in your instrument."[119] Kepler ascribes to Galileo an achievement, in astronomy, similar to that of Columbus, whose voyage has been regarded "as the first great experiment in the history of early modern science."[120] As a matter of fact, the European encounter with the antipodes was a premise of Copernicus's geokinetic theory, since it led to the conception that the terrestrial and watery globe were a unity, thus casting into doubt the established Aristotelian conception of the elements as concentric (or almost-concentric) spheres.[121] In a similar manner, Galileo's observation provided evidence against traditional views concerning the superlunary world.

In late August or early September of 1610, Kepler received a telescope on loan from Ernest of Bavaria passing through Prague, a telescope that the duke

116 Panofsky, *Galileo as a Critic*, 12.

117 See chap. 4,12.

118 On Kepler's use of sources, cf. Grafton, "Kepler as a Reader."

119 Kepler, *Conversation*, 17.

120 Vogel, "Cosmography," 478.

121 Idem, "Problem der relativen Lage."

had been given by Galileo. Kepler then invited some friends to conduct a series of verifications, which demonstrated the veracity of Galileo's observations. Kepler hurried to publish a brief account confirming the celestial novelties announced to the world by Galileo. With this *Narration About Four Observed Satellites of Jupiter, Which the Florentine Mathematician Galileo Galilei, as Their Discoverer, Called Medicean*, Kepler reinforced his tie of solidarity with the Italian scientist.

If we return to the pages of *Dissertatio cum Nuncio sidereo*, Kepler's reflection on the existence of vacuum is also interesting. He would have liked to have had Galileo pronounce on such a delicate thesis, directly referable to the Democritean philosophy of matter. Kepler believed that if such distant planets and stars were clearly visible through the telescope, it was necessary to deduce that the medium, the space in between, provided no impediment to their vision because it was without matter:[122]

> Under your guidance I recognize that the celestial substance is incredibly tenuous. [...] A single fragment of the lens interposes much more matter (or opacity) between the eye and the object viewed than does the entire vast region of the ether. For a slight indistinctness arises from the lens, but from the ether none at all. Hence we must virtually concede, it seems, that that whole immense space is vacuum.

Kepler's remarks on the Moon were aimed at reinforcing Galileo's predecessors, above all Plutarch who had considered the "ancient" patches (those more extensive and visible to the naked eye) to be lakes or seas. Kepler was also interested in a reflection on the nature of the lunar mountains and wondered why all the chains had a circular form and no valley presenting a sinuous appearance like those on the Earth carved by rivers. He surmised that our satellite is perhaps a piece of pumice stone. Nor did he avoid the question of whether there might be life on the other planets, to the point of raising the possibility that the lunar craters were artificial. With regard to the faint light on the shadowed parts of the Moon, he pointed out that the idea had already been defended by Mästlin, who maintained that it was sunlight reflected from the Earth.

In the discussion on the fixed stars and their vast multiplication when seen through the telescope, Kepler took into consideration Bruno's cosmology, which was apparently confirmed by the sidereal novelties of Galileo.[123]

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122 Kepler, *Conversation*, 19.

123 Ibid., 34.

> Your [...] highly welcome observation concerns the sparkling appearance of the fixed stars, in contrast with the circular appearance of the planets. What other conclusion shall we draw from this difference, Galileo, than that the fixed stars generate their light from within, whereas the planets, being opaque, are illuminated from without; that is, to use Bruno's terms, the former are suns, the latter, moons or earths?

Despite this attention, Kepler soon refuted Bruno's radical views concerning space infinity. In fact, he observed, if the stars are so many suns and the geometric sum of their surfaces equals or even surpasses that of the Sun, why is the night not illuminated like the day? "Why do they [the stars] all together transmit so dim a light to the most accessible places?"[124] The distance did not seem to Kepler a satisfactory explanation, considering that the ether is in no way "opaque" and thus does not act as a filter to the light. Contrary to Bruno, he concluded that "the body of our Sun is brighter beyond measure than all the fixed stars together, and therefore this world of ours does not belong to an undifferentiated swarm of countless others. I shall have more to say about this subject later on."[125]

In fact, the discussion of Bruno did not end there, since, despite his errors, Kepler considered him a precursor of Galileo. From the text, it seems almost that he wanted to force Galileo to pronounce on this matter. Kepler noted that the telescopic observations had not completely vindicated Bruno, since the new planets had been observed to revolve around Jupiter and not around a fixed star: "If you had discovered any planets revolving around one of the fixed stars, there would now be waiting for me chains and prison amid Bruno's innumerabilities, I should say, exile to his infinite space."[126]

In his *Dissertatio*, Kepler also gave a kind of epistemological lecture which might even have been offensive to his interlocutor. Indeed, by maintaining the superiority of an *a priori* approach to nature, Kepler claimed in a not very veiled manner the superiority of his own work, but also that of the natural philosopher Bruno over that of Galileo. The discourse starts with an exaltation of the ancients, of Pythagoras, Plato and Euclid, who, guided only by the light of reason, believed that the universe could not have been arranged by God if not on the basis of a harmony observable in the relationships of the regular solids (this was the hypothesis of *Mysterium cosmographicum*).[127] By revealing the motions of the planets and the centrality of the Sun, Copernicus was limited to

124 Ibid., 35.

125 Ibid., 35–36.

126 Ibid., 36–37.

127 Fabbri, *Cosmologia e armonia*, 49.

establishing the mere facts, or τὸ ὅτι. Kepler, fortified by his writings on the cosmic secret, ascribed to himself the merit of having gone from τὸ ὅτι to the διότι, from the regularities of the stars to the archetypal plan in the divine mind. Nevertheless, Plato proclaimed the same doctrines many centuries before in a completely *a priori*, rational and, thus in Kepler's judgment, superior manner:[128]

> Surely those thinkers who intellectually grasp the causes of the phenomena, before these are revealed to the senses, resemble the Creator more closely than the others, who speculate about the causes after the phenomena have been seen. Therefore, Galileo, you will not envy our predecessors their due praise. What you report as having been quite recently observed by your own eyes, they predicted, long before you, as necessarily so. Nevertheless, you will have your own fame. Copernicus and I, following him, pointed out to the ancients the mistaken way in which they considered the five solids to be expressed in the world, and we substituted the authentic and true way. Similarly, you correct and, in part, unsettle Bruce's doctrine, borrowed from Bruno.

The Jovian satellites inspired in the ardent supporter of Bruno's views, Wackher the conclusion that Jupiter also must rotate like the Earth so as to produce the motion of its companions, just as our planet was believed to be responsible for the revolution of the Moon, and the Sun for that of the other bodies of its system, according to the hypothesis exposited by Kepler both in *Mysterium* and in *Astronomia nova*. Resuming the Copernican argument of *Sidereus nuncius*, Kepler underlined the possible agreement with Copernicus of the motion of the Medicean stars around Jupiter, whose observation had refuted the idea that the only satellite in our planetary system is the Moon.[129]

All in all, the emphasis of Kepler's *Dissertatio cum Nuncio Sydereo* was on the aspects that Galileo had omitted, the cosmological premises merely touched on in *Sidereus nuncius*, which the German scientist wished to fully and explicitly analyze: the defense of the heliocentric system, Giordano Bruno's philosophy of nature, the dimensions of the universe, the existence of the void, and similar topics with a strong anti-Aristotelian impact. Kepler also wished to supplement Galileo's text by indicating the hidden sources: in addition to Copernicus and Bruno, also Cusanus, Della Porta, Brahe, Mästlin and himself. Moreover, Kepler did not hesitate to impart to Galileo a lesson in epistemology, which, in his eyes, can be summarized in the implied precept of the *Mysterium cosmographicum* according to which "good science is done *a priori*."

128 Kepler, *Conversation*, 38 (translation slightly revised).

129 See chap. 4,12.

CHAPTER 7

The Bible versus Pythagoras: The End of an Epoch

1 Condemnation

Scriptural and theological concerns, attempts at censorship, apologies and forms of self-censorship accompanied Copernicus's ideas from the beginning. His condemnation by the Catholic Church in 1616 was the culmination and epilogue to the sixteenth-century debate, foreshadowing the extraordinary persecution of Galileo. In the session of the Roman Holy Office on 24 February 1616, three Father Theologians condemned the hypothesis of the immobility and centrality of the Sun, calling it "foolish and absurd in philosophy, and formally heretical," and they banned the idea that the Earth moves, calling it false and "at least erroneous in faith."[1] On 5 March, the Sacred Congregation of the Index decreed that the theory of terrestrial motion and immobility of the Sun was contrary to the faith and thus all books teaching the dangerous "Pythagorean doctrine" should be censored and banned.[2]

In the history of the reception of Copernicus, the 1616 sentence marked a clear break between a period in which his ideas were discussed in a basically free manner and an epoch of censorship that conferred a confessional dimension on astronomical thinking. The 5 March decree did not expressly declare that Copernican teaching was "heretical" (a label attributed instead to the immobility of the Sun by the theological councillors on 24 February). Nonetheless, as Michele Camerota explained, "on the basis of [this] censorship [...] the Copernican conception came to constitute an opinion no longer sustainable by all believers intent upon remaining in the womb of holy mother Church."[3] Moreover, even though Galileo tried to mitigate the reactions to the decree, it was clear to all that he was the person struck most.[4]

Interrogated by the Venetian Senate on the appropriateness of publishing the papal censorship decree in the Most Serene Republic, Paolo Sarpi, who favored the Copernican system, declared himself astonished by the Roman

1 Galileo, *Documenti*, 99–100.

2 Ibid., 102–03.

3 Camerota, *Galilei*, 310.

4 Cf. Bucciantini, "Reazioni alla condanna."

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decision.[5] Yet, after assessing that publication of the censorship decree would not bring any political disadvantage to Venice, Sarpi declared that the Roman request could be granted.[6]

Those most directly affected by the censorship were the members of Federico Cesi's Lyncean Academy, an institution of which Galileo was a very prominent exponent.[7] The positions of the Lynceans on the doctrine of motion of the Earth and fixity of the Sun were not clear: the only thing that can be stated for sure is that none of them opposed it. In his *Lettera sopra l'opinione de' Pitagorici, e del Copernico* (1616), Foscarini even maintained that "all" Lynceans held "the Pythagorean opinion" of *De revolutionibus*. As a matter of fact, following the Inquisition's decree, Luca Valerio, a member of the Academy, was expelled, probably for having taken an anti-Copernican (and anti-Galilean) stand in 1616.[8]

In 1620, corrections to *De revolutionibus* were made by Cardinal Caetani and, after his death, by the consultant to the Congregation of the Index Francesco Ingoli. Although opposed to heliocentrism, Ingoli faced the impossibility of eliminating or correcting every one of Copernicus's statements about the motion of the Earth without suppressing the entire work. Therefore, he censored or altered only the passages that dealt with it in an affirmative (*assertive*) and not hypothetical (*hypothetice*) manner.[9]

2 First Scriptural Reservations in the Protestant World

The first theological reservations about the new cosmology came from the ranks of the Reformation. The Wittenberg reaction to Copernicus was ambiguous. It is reported that Luther, in one of his table talks, the *Tischrede* of 4 June 1539, criticized the paradoxical planetary theory of terrestrial motion:[10]

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5 Sarpi's acceptance emerges from *Pensieri*, written between 1578 and 1597 (Sarpi, *Pensieri*, n. 568). Cf. Festa, *L'erreur* and idem, *Galileo*, 163–65 and 200, and Lerner, "Copernic suspendu," 45.

6 Cozzi, *Sarpi*, 119 ff.

7 On the origins of the Accademia dei Lincei, cf. Baldriga, *Occhio*.

8 Cf. Conti, "Stelluti."

9 Cf. Lerner, "Copernic suspendu." For a thorough study of the person and role of Ingoli in this matter and especially for the Galileo-Ingoli-Kepler dispute in relation to Copernicanism, see Bucciantini, *Contro Galileo*. See also Finocchiaro, "Biblical Argument," 632–36.

10 Luther, *Tischreden*, vol. 1, 419.

> He mentioned a certain new astrologer who tried to demonstrate that the Earth is moved instead of the heavens, the Sun and the Moon, in the same manner as someone, transported on the board of a ship, might think that he is not moving but rather the land and the trees are moved. The explanation is the following: Who wants to appear smart, he has to do something original, like he does in his attempt to invert the entire astronomy. But I believe that those ideas are refuted by the Sacred Scriptures since Joshua ordered the Sun to stop and not the Earth.

This original position ("die ursprüngliche Nachschrift," according to the Reformation historian Heinrich Bornkamm) was revised by Luther's pupil Aurifaber who, in the 1566 edition of the *Tischreden*, made the condemnation more explicit: "That foolish man wants to turn the whole discipline of astronomy on its head."[11]

Copernicus had heard of the zeal of some theologians and sought the protection of the pope, to whom he wrote: "Perhaps there will be babblers [ματαιόλογοι] who claim to be judges of astronomy although completely ignorant of the subject and, badly distorting some passages of the Scripture to their purpose, will dare to find fault with my undertaking and censure it; I disregard them even to the extent of despising their criticism as reckless [*tamquam temerarium*]."[12] The author showed great confidence and ridiculed the petulant theologians with the example of Lactantius, the Father of the Church who maintained that the Earth was flat due to his ignorance of astronomy.

With greater prudence, the theologian Osiander added the anonymous introductory note to the first edition of *De revolutionibus*, aimed at accrediting a computational approach to mathematical astronomy.[13] He had already given the reasons for this decision in letters to Copernicus and Rheticus on 20 April 1541, in reply to a lost letter by Copernicus (of 1 July 1540) in which the latter must have expressed some fear about the criticisms of theologians.[14] Osiander, who had received a copy of *Narratio prima* from Rheticus in 1540, invited Copernicus to cautiously avoid all controversy.[15]

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11 See chap. 1,4. See Bornkamm, "Kopernikus," 177–78.

12 Copernicus, *Revolutions*, 5. Cf. GA II,6.

13 See chap. 2,7.

14 Osiander to Rheticus (Nuremberg, 1540), in idem, *Gesamtausgabe*, vol. 7, 281. This is a fragment, which we know thanks to Kepler's transcription in *Apologia Tychonis contra Ursum*.

15 Idem to Copernicus (Nuremberg, 20 April 1541), in *Gesamtausgabe*, vol. 7, 333–36. Cf. Lerner-Segonds, "Sur un 'avertissement' célèbre."

> I have always maintained that hypotheses are no articles of faith. Rather, they are the basis for computation. Thus, even if they are false, there is no inconvenience, provided that they accurately exhibit the apparent motions. If we accept Ptolemy's hypotheses, who could tell us whether the unequal motion of the Sun should be called epicycle or eccentric? In fact, both options are possible alike. Hence, it would be expedient for you to hint at this issue in the preface [of *De revolutionibus*]. In this manner you might calm down those Peripatetics and theologians whom you fear to contradict.

Osiander gave the epicyclic and eccentric models as examples of useful devices for mathematical astronomy, albeit without any correspondence to physical reality. The content of the letter he sent to Rheticus on the same occasion (Nuremberg, 20 April 1541) was similar. Osiander advised the young mathematician to follow the Peripatetics and theologians and to assume a conventionalist position on hypotheses: "Peripatetics and theologians will easily calm down, if you tell them that various hypotheses could account for the same apparent motion and that you do not affirm the reality of them [your hypotheses], but only that they are the most convenient for the computation of apparent and compounded motions."[16]

3 Rheticus and the Scriptures

Rheticus's attitude to the agreement between Copernican astronomy and the Bible was very different from the prudence counseled by Osiander. In a letter to Rheticus on 26 July 1543, Giese, the Bishop of Chełmno, expresses his joy upon the publication of *De revolutionibus*, his mourning for the passing of Copernicus and his anger at Osiander's anonymous letter. He wishes for a new edition of the Copernican work accompanied by some of Rheticus's writings: a *praefatiuncula* aimed at re-establishing the (non-hypothetical) sense of the new astronomy, the biography of Copernicus written by Rheticus (now lost) and a *Booklet, in Which It Is Argued Against the Irreconcilability of Sacred Scriptures and Terrestrial Motion* (*opusculum tuum, quo a Sacrarum Scripturarum dissidentia aptissime vindicasti Telluris motum*).[17] Supposedly, Rheticus's opusculum was the companion to a similar one by Giese, only the title of which is

16 Idem to Rheticus (Nuremberg, 20 April 1541), in *Gesamtausgabe*, vol. 7, 337–38.

17 In Burmeister, *Rhetikus*, vol. 3, *Briefwechsel*, 54–59.

known: *Hyperaspisticon*.[18] It is likely that Rheticus wrote his opusculum during his stay in Frombork, sometime before 1541. Reijer Hooykaas, the historian who rediscovered it, inferred the date of the work from the fact that Giese had read it and that the writing was characterized by an Erasmian tone and by a self-styled Catholic religiousness, which were typical of Copernicus's milieu.[19] As for the title, the 1651 edition bore a simple *Epistola cuiusdam anonymi de Terrae motu* on the frontispiece and the indication *Dissertatio de hypoth*[*esibus*] *astron*[*omiae*] *Copernicanae* (*Dissertation on the Hypotheses of Copernican Astronomy*) as the internal heading, while Giese alluded to an *Opusculum quo a Sacrarum Scripturarum dissidentia Telluris motus vindicatur*.

The booklet, which I will call *De Terrae motu et Scriptura Sacra* (*Terrestrial Motion and Sacred Scriptures*) following Hooykaas, opened with references to Augustine and "Catholicism," which marked the horizon and limits encompassing Rheticus's discourse. As Augustine had written in his unfinished *De Genesi ad litteram* (*On the Literal Interpretation of Genesis*), we should treat natural things that are obscure to us not by affirmation, but by searching for truth: "The obscurities of nature, which we sense as the work of God, the almighty Architect, should be dealt with, not by making assertions, but by research."[20] And this searching, Rheticus was quick to add, must not stray from the "universal faith" (*Catholicae fidei*). It was an attempt to remain above the fray, with Erasmian conciliatory and universalistic attitudes. Hooykaas considered Rheticus's reference to Catholicism vague and non-compromising, although it was consistent. Yet, the urgency to respect the bounds of Catholicism must have pleased the adversaries of the Reformation more than its supporters. Moreover, both his friend the Bishop of Chełmno and his beloved astronomy teacher, a Frombork canon, were faithful to the authority of Rome. Rheticus himself visited different confessional environments: from a Catholic family, he frequented the reformed Zurich and the Lutheran Wittenberg, was part of the college of theologians of the Protestant University of Leipzig, and then returned to the Catholic (but not too Catholic) Cracow.

18 Title inferred from J. Broscius, *Epistulae ad naturam ordinatarum figurarum plenius intelligendarum pertinentes* (Cracow, 1615).

19 Cf. Hooykaas, *Rheticus' Treatise*. The opusculum on the possible agreement of the Scriptures and Copernicanism mentioned by Giese was long considered lost. However, it was found not many years ago when Hooykaas identified it in an anonymous publication from 1651. This publication contained two essays, different from each other but sharing their intrinsically anti-Aristotelian nature: *Idea Physicae* by the atomist David van Goorle (*Gorlaeus*, 1591–1612), and the writing by Rheticus.

20 Rheticus, *Terrae motus*, 65; cf. ibid., 43.

Relying on the authority of Augustine, Rheticus stated that, when the Bible deals with questions of nature, it does so not in the manner of philosophers, but according to different aims: "When there is mention in the Sacred Writings of the things of nature, it is clear that the Holy Spirit does not want to speak of them in the manner of philosophers."[21] The aims of the Scriptures are manifold, explained Rheticus, but they converge on the goal of salvation. As for the *Genesis*, he mainly wished to affirm three truths, all of which are theological: that God created all of nature from nothing (*totam hanc naturam a Deo ex nihilo conditam esse*), that He is made manifest to all nations through nature (*Deus per naturam inter gentes voluerit innotescere*) and that He is almighty.[22]

Against the Peripatetic conception, particularly against the eternity of the universe, he recalled that Plato also believed that the world had been created. He also added that Plato introduced Oriental doctrines similar to those of Moses to his Academy. Against the Peripatetic philosophers, moreover, Rheticus wrote: "There will not be lacking those who will bellow that it is monstrous to attribute movements to the Earth, and who will take occasion to draw on and display their wisdom taken from the philosophers of nature. They are ridiculous, as if God's power could be measured by our force or our intellect."[23] The recourse to God's omnipotence allowed the author to deplore the Aristotelians' pretension to limit the Creation through fallacious arguments.

If the aim of the Bible is salvation and its manner of expression is suitable to simple people's capacity for understanding, Rheticus observed, basing his argument on Augustine, it will be necessary to allow non-literal interpretations of biblical passages concerning natural questions.[24] This theory of accommodation was proposed by all realist supporters of Copernicus in the face of scriptural difficulties. Rheticus underlined that drawing natural teachings from the Bible is dangerous because it drives away from the faith of the erudite and wise men of our age (*eruditi et sapientes huius saeculi*).[25]

> Scripture should be received in the way in which the Holy Spirit wished it to be understood, so we do not study the passages about nature as if Scripture were a philosophical textbook, but rather as books in which the Holy Spirit desired to teach us something necessary for our salvation.

21 Ibid., 67.

22 Ibid., 44–45.

23 Ibid., 91.

24 Ibid., 45–46.

25 Ibid., 70–71.

Instead, God has left the investigation of nature to the man, through reason and the senses:[26]

> But as it is clearer than the day that God has left a good deal to our own efforts so as to stimulate the arts and sciences necessary for life, and the things that pertain to education and the honest use of our mind, we should really follow in these things the thread of nature, by which first principles, reason and daily experience lead us.

Moreover, God loves men of science and guides them:[27]

> And, since God desires to be glorified in nature, there is no doubt that our study will be pleasing to Him. Therefore he prompts the minds of great men to inquire into nature which he created, and he furthers and conducts their studies.

The science of nature is not within the purview of either theologians or Bible exegetes, whose purpose is not to teach the *physica* but rather to give order to human life (*vitae regulam conscribere*). Biblical exegesis must deal with the fact that Copernicus's hypotheses on the motion of the Earth are indisputably true because they are demonstrated through mathematics (*mathematice compertae*). Confirming what he had written in *Narratio prima*, Rheticus reaffirmed the objectivity of the Copernican hypotheses, which show a concordance with the phenomena similar to that of a good definition able to be converted into what it defines. Although the Scriptures cannot contrast with natural truth, wrong interpretations of them certainly can.

After a quick review of the terrestrial motions and some supporting reasons, topics already dealt with exhaustively in his *Narratio*, Rheticus went on to consider some biblical points that could support Copernicus, such as the term "firmament" in reference to the starry sphere, which was firm and immobile according to the new astronomical hypotheses. To Rheticus it seemed that the correctness of the Copernican system was assured not only by mathematics but also by some duly interpreted biblical passages.[28] But what could be said about affirmations that seem to oppose the geokinetic and heliocentric views? According to him, they should be interpreted in an adequate and non-literal manner. The biblical references to the stability of the Earth should be

26 Ibid., 71.

27 Ibid.

28 Ibid., 59.

understood in terms of the integrity of the Earth and not of its immobility.[29] There is also the passage in Joshua, on his miracle of stopping the Sun (*Joshua* 10:12–14), and those of *2 Kings* and *Isaiah*, on the backward motion of the shadow on the Ahaz sundial (*2 Kings* 20:8–11). According to Rheticus, such passages do not pose any interpretative difficulty, as long as one considers the difference between appearance and reality. In other words, the biblical passages describe the appearance of celestial events, not what they were according to their causes. The truthfulness of the passages notwithstanding, the astronomer could provide a heliocentric explanation for them. Drawing on some arguments from the late medieval Parisian disputes,[30] Rheticus provided a heliocentric explanation of the account of Joshua commanding the Sun to stand still: “The Earth ceased from its daily motion. To those to whom the Sun was above the horizon, the day continued until God allowed it to return to its natural course.”[31]

The opusculum ended with an appeal and a warning. The appeal was made to the *Ecclesia Catholica Christi* to accept the rigorous mathematical work with which Copernicus honored the republic of letters (*respublica literarum*). The warning, clearly directed at theologians embracing the letter of the Bible too closely, was not to forget the human ignorance of natural things. Rheticus argued for maximal liberty in debating hypotheses.

4 Spina and Tolosani

If the positions expressed by Osiander and Rheticus were indicative of the qualms the Copernican doctrine provoked in Protestant circles, the worries of theologians in Rome were also quick to surface. Despite the open-mindedness of Clement VII and his entourage in the 1530s and the support of eminent men like Cardinal Schönberg, the publication of *De revolutionibus* also met with negative reactions. Shortly after the institution of the Inquisition by Paul III and in times of aggravation of the doctrinal confrontations with Protestants, the Dominican Bartolomeo Spina, Master of the Sacred Palace, expressed a harsh judgement about Copernicus’s *De revolutionibus*.[32] In his *Treatise on the Preeminence of the Sacred Theology* (*Tractatus de preeminentia*

29 Ibid., 59–60.

30 Cf. Oresme, *Livre du ciel*, 530. See chap. 5,3.

31 Ibid., 99–100.

32 Lerner, “Aux origines.” Paul III established the Inquisition with the bull *Licet ab initio* on 21 July 1542. Not even a year later (12 June 1543), an edict was published which severely

Sacrae Theologiae, which had several editions: Rome, 1576, Cologne, 1581, and Venice, 1584), Spina had already affirmed the superiority of theology over any other science. He was also known for his polemics over the doctrine of the immortality of the soul, opposing not only Pietro Pomponazzi but also the moderate Cardinal Cajetan. He had shown great intransigence toward the Reformation, as well. In this context of doctrinal rigor, Spina even became suspicious of unconventional views on nature. He intended to write a confutation of Copernicus's planetary theory but was prevented from doing so by illness and then death, in April 1547.

After him, the task of disproving Copernicus fell to his Dominican brother Giovanni Maria Tolosani. He decided to add several "theological-scientific" essays to his book on *The Purest Truth of the Divine Scriptures Against Human Errors* (*De purissima veritate Divinae Scripturae adversus errores humanos*), previously approved by Spina on 6 August 1546; these included an opusculum *On the Immobility of the Outermost Heaven, the Stability of the Earth, Lowest in Position, and the Mobility of the Other Intermediate Heavens and Elements* (*De coelo supremo immobili et Terra infima stabili, ceterisque coelis et elementis intermediis mobilibus*), a confutation of the Copernican hypotheses. Yet Tolosani was also unsuccessful in censoring Copernicus, since he died at the beginning of 1549 while sorting his documents, destined to languish on the shelves of San Marco and of the Biblioteca Nazionale in Florence until their rediscovery in the 1970s.[33]

Tolosani's anti-Copernican writing was divided into four chapters: in the first, he described the structure of the cosmos according to the Scriptures and, secondarily, according to Aristotle; in the second, he censured Copernicus's presumption to revive the Pythagorean doctrine of terrestrial mobility; in the third, he summarized the "physical" reasons to reject this doctrine and in the fourth the "astronomical" reasons. Tolosani sought to demonstrate how the Aristotelian-Ptolemaic geocentric model was implicit in various scriptural passages. Hence, the opusculum began with a quotation from *Genesis* 1:1: "In the beginning God created Heaven, and Earth" (*In principio creavit Deus coelum et Terram*). This passage should indicate that God occupied the highest place of the universe, the Earth the lowest. The geocentric cosmos was contained in the bright and immovable heaven of the Empyrean: "The uppermost heaven is deemed to be the place of God and his holy angels, as well as the souls of the blessed, and, after the last judgment, it is prepared to [receive] their immortal

prohibited the printing, selling and reading of works by heretics (or suspected heretics). Cf. Prosperi, *Tribunali* and idem, *Inquisizione Romana*.

33 Garin, "A proposito."

bodies."[34] The Earth instead was the lowest place of the life of mortals, at the center of the universe.

Tolosani also tried to benefit from the passage in which Paul calls the highest heaven the "third heaven" (Paul, *2 Cor.* 12:2). The "three heavens of theologians" to which Paul alludes were to be identified as follows: the first is that of the planets and stars (eight celestial spheres), the second corresponds to the *primum mobile* (a material heaven responsible for the diurnal rotation of all celestial bodies) and the third corresponds to the Empyrean.[35] To the question of whether Aristotle recognized the existence of this heaven of the angels and the blessed, the Aristotelian Tolosani replied that, although the *magister philosophiae*, being pagan, did not have the fortune of learning of its existence from the Scriptures, he nevertheless came to recognize it for natural reasons. In fact, the motion of the heavens, including the *primum mobile*, necessarily occurs in an immobile place, namely the Empyrean.[36]

The author observed that the motion of the Sun is unequivocally affirmed in *Ecclesiastes*, 1:4–5. In this regard, Tolosani observed in passing that the Sun is the universal source of light, even of that of the stars.[37] He observed that, although some ancient philosophers, "who are called Pythagoreans, in Italy," placed "fire" at the center of the universe and the Earth in motion around it, Aristotle in *De coelo* and Thomas in his commentary had collected arguments sufficient to refute them.[38]

In the second chapter, Tolosani undertook his criticism of Copernicus, a man whom he judged more interested in showing off his intelligence than in the truth: "In our assessment, this Copernicus [...] does not believe that opinion to be true. Rather, in his book, he wanted to show to others the sharpness of his wit instead of teaching the truth."[39] Tolosani acknowledged that Copernicus had some virtues (in addition to his great intelligence): the mastery of Latin and Greek, an eloquence marred only by some linguistic eccentricities, and skill in the mathematical and astronomical sciences. Yet, Copernicus appeared to be ignorant of physics and logic, and had not carefully studied the Scriptures, running the serious risk of sullying himself with impiety.

According to Tolosani, an astronomer ignorant of natural philosophy, like Copernicus, lacks the fundamentals of his science, for which he may be

34 Tolosani, *Opusculum quartum* (ed. Lerner), 693.
35 Ibid., 695–96.
36 Ibid., 696.
37 Ibid., 699.
38 Ibid., 699–700.
39 Ibid., 701.

inclined to draw absurd conclusions. An approach to astronomy renouncing Aristotle, or even contrary to him, was unthinkable: "One ought not to discuss with somebody who denies even the first principles of the sciences, because conclusions are rationally derived from the first principles."[40] Therefore, Copernicus, unaware of the Aristotelian refutation of terrestrial motion, had fallen into the Pythagorean error of believing in terrestrial motion and solar centrality. Tolosani believed it unnecessary to waste too many words against him; it was sufficient to recall what had already been written by Aristotle and by Thomas against the Pythagoreans, who did violence to sensation, preferring their imagination and forcing phenomena in order to adapt them to certain "unacceptable resons and opinions that they came up with."

Tolosani realized that the introductory letter in *De revolutionibus*, which was actually included by Osiander, was spurious. He criticized "that anonymous author" (*authorem illum, cuius nomen ibi non annotatur*): conventionalist reservations would not strengthen the mathematical theories of Copernicus; on the contrary, they would underline their foolishness.[41] To present the planetary theory of *De revolutionibus* as merely hypothetical would be a subterfuge to revive a false, unreasonable and impious doctrine.[42]

5 Rothmann's Opinion on the Scriptural Issue

In Protestant circles, Copernicus's ideas were initially able to spread only by the avoidance of any discussion of their theological implications. This came about by means of the dubitative approach inaugurated by Osiander or through the attempts to translate Copernicus's geometrical models into a geocentric framework: an eminently "mathematical" interpretation of *De revolutionibus*, which allowed the safeguarding of geocentrism from the physical point of view and the avoidance of conflicts with the Bible. It was probably the growing interest in the physical-cosmological aspects of the new astronomy around the 1580s and the 1590s that brought about a reversal of Copernican acceptance. Ethical and religious concerns were again included in mathematical discussions. An example is the case of the court astronomer of the Landgrave of Hesse-Kassel Christoph Rothmann, who, in accepting the Copernican cosmology as a physical reality, also had to deal with the scriptural question.

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40 Ibid., 703.

41 Ibid., 709.

42 Ibid.

In spite of Luther's and Melanchthon's reservations concerning the possibility of terrestrial motion, one cannot speak of true censorship at Wittenberg. In fact, as I discussed earlier, once the theological difficulties had been avoided by means of a selective reading of *De revolutionibus* or geocentric translations of Copernicus's models, an environment extremely receptive to Copernicus's work was established.[43] Some of his first admirers, including theologians, taught at the local university. Not only Peucer but also Caspar Cruciger, Luther's friend and collaborator, appreciated *De revolutionibus*, as shown by the funeral oration written by Melanchthon and pronounced by Reinhold on the occasion of Cruciger's death.[44]

Accepting the physical reality of heliocentrism, Rothmann had to face the scriptural question that his Wittenberg predecessors had carefully managed to avoid. His ideas were made known in 1596 when Brahe published their correspondence.[45] In a letter of 21 February 1589, Brahe tried to persuade Rothmann of the validity of the geoheliocentric model, outlining a series of physical, but also scriptural, arguments against Copernicus. As far as the exegetical problem was concerned, Brahe was harsh:[46]

> Even less worthy are those arguments that you bring forward in favor of those [Copernican] hypotheses, against which the Sacred Scriptures assert the contrary. In fact, the reverence toward the authority of the Divine Scriptures is and must be greater than the present hypocritical manner [*modo cothurni*].

In which biblical passages, asked Brahe, could Rothmann find support for the motion of the Earth? Rothmann's reply in August 1589 was extremely terse: "You raise objections toward me that cannot derive from my letter, nor have they ever come to my mind."[47] Rothmann was upset about Brahe's aggressive tone and, above all, about the veiled accusations of impiety. He was convinced of the theological admissibility of Copernicus: "Where have I downplayed the

43 See chap. 1,4 and 2.

44 See Wohlwill, "Melanchthon und Copernicus," 183.

45 The problem of the fluidity of the heavens was also tackled by Rothmann in *Descriptio accurata cometae anni 1585*, published posthumously by W. Snel (as an appendix to his *Descriptio cometae qui anno 1618 mense Novembri primum effulsit*, Leiden, 1619), but already known by Brahe who received a copy. Cf. Granada, "Problema astronomico-cosmologico" and idem, "Eliminazione delle sfere."

46 Brahe to Rothmann (Uraniborg, 21 February 1589), in idem, *Opera*, vol. 6, 166–81, 177.

47 Rothmann to Brahe (Kassel, 22 August 1589), in Brahe, *Opera*, vol. 6, 181–84, 181.

authority of the Holy Script in any way?"[48] Rothmann invited Brahe to read Augustine, who "spoke much more freely about the Sacred Scriptures" (*multo liberius de Sacris Literis loquit*). He also informed him that he had shown the letter with the accusations of impiety to the Landgrave and the court theologians so that, as he explained, the matter would not seem a personal question between him and his correspondent. Rothmann proudly reported that neither the Landgrave nor the theologians had any objection about the scriptural acceptability of his cosmological conceptions, particularly the one concerning the liquidity of the heavens. Thus, he shifted the discussion to the subject of the matter of the heavens.[49] In this regard, the Bible can accommodate different approaches: be it an "elementary" conception of the heavens, supported by Rothmann, or an Aristotelian ethereal conception, which he erroneously attributed to Brahe. In conclusion, Rothmann was anxious to separate the cosmological discussion from the scriptural one, since he believed that the Sacred Scriptures can accommodate different philosophical positions on nature and the heavens.

In his reply of 24 November 1589, Brahe feigned surprise and wondered what was behind Rothmann's animosity to his previous letter. He assured him that he had never accused him of impiety.[50] He withdrew from further polemics, denying that he was able to decide what is pious and what is not. Nevertheless, he challenged Rothmann to produce any biblical passages that could support Copernicus's triple motion of the Earth. He would even have been satisfied with the authority of any Father of the Church. Rothmann had mentioned Augustine. Brahe did not understand that Augustine had been used as an example of an authoritative non-literal interpreter of the Scriptures. He believed instead that Rothmann thought that Augustine could in some way directly support Copernicus's cosmological theses, therefore he emphasized that this ancient theologian had been so ignorant of mathematics that he even denied the existence of the antipodes. He would never have been able to accept the triple motion of the Earth:[51]

> The question was whether the mobility of the terrestrial globe, namely the threefold one asserted by Copernicus, is possible in reality, whether it should be preferred to my discovery [*inventioni nostrae*], and whether the Sacred Scriptures are contrary to that imagination or not. Thus, if

48 Ibid.

49 Cf. Granada, "Astronomy and Cosmology" and "Brahe, Peucer, and Rothmann."

50 Brahe to Rothmann (Uraniborg, 24 November 1589), in idem, *Opera*, vol. 6, 185–200, 185.

51 Ibid., 186.

> you found something favorable to the theory of Copernicus [*Copernicea assertio*] and yours in the holy prophecies, or in their interpretations, for instance by Augustine or other Fathers, please, quote from their writings. I will not contradict solid reasons. Yet, I sufficiently know that Augustine, the only one whom you mention, never conceded the motion of the Earth, neither annual nor diurnal, since he, being no mathematician, denied the antipodes and so destroyed its rotundity [although he admitted it].

Rothmann also wrote a chapter of an ultimately unpublished treatise on the theological admissibility of the fluidity of the heavens.[52] In chapter 23, he proposed that the Scriptures should be adapted to acquired natural truths, taking a position similar to that of Rheticus.[53] Yet, after visiting Brahe in 1590, he became seriously ill and never returned to Kassel, nor did he ever publish his manuscripts. Brahe, in the volume of his epistles, claimed to have convinced Rothmann of his geoheliocentric system.

6 Censorship in Tübingen

Despite the lack of publication of Rothmann's work and the ethical-religious scruples raised by his acceptance of Copernicus, one cannot truly speak of any form of censorship in his case. A few years later, however, Kepler suffered interference by Protestant theologians of the University of Tübingen when he published his *Mysterium cosmographicum* (1596). In composing this work, Kepler was animated by a fervent desire to understand the divine plan underlying the creation of the world. The approach was speculative, permeated by theological influences. Kepler had concentrated on the "number, quantity and motion" of the spheres with an approach that was non-empirical but founded on the presupposition that the divine mysteries appear in the order of the world. Father, Son and Holy Ghost would be mirrored in the stillness of the Sun, of the fixed stars and in the intermediate space.[54]

At the time of the *Mysterium cosmographicum*, he wrote to Mästlin that he was relieved that the work had been published and, in particular, that "the defenders of the Holy Scripture had not raised objections to [...] [his] book, as

52 Rothmann, *Handbuch*.

53 Cf. Granada, "Problema astronomico-cosmologico."

54 Kepler, *Mysterium*, KGW vol. 1, 23. See chap. 4,12.

instead he feared."[55] Indeed, the university authorities could have prevented it from being printed, since the publisher Gruppenbach had made them responsible for assessing its legitimacy. In a letter of 30 October 1597, Mästlin warned Kepler that, in effect, there had been a certain resistance by the theologians to the public defense of Copernicus's ideas. In particular, he mentioned Hafenreffer, a convinced believer in the contrast between the heliocentric cosmology and the Sacred Scriptures, but also tolerant toward those who limited themselves to mathematics and computation, that is, a conventional use of hypotheses.

Kepler exchanged some letters with Hafenreffer, who was always cordial to him but admonished him not to enter into theological and scriptural discussions about the acceptability of Copernicus. From their correspondence, one can see that a form of censorship was practiced: Kepler had to eliminate a whole section in which he attempted a reconciliation between Copernicus and the Bible.[56]

Nevertheless, Kepler returned to a scriptural defense of Copernicus some years later in the introduction to *Astronomia nova* (1609). Later this text would be included in the Latin edition of Galileo's *Dialogo* (1635), conveying the sense of an agreement between the two authors on the Scriptural issue.[57] Kepler basically observed that the Scriptures were written for the common people and that they did not deal with natural philosophy:[58]

> Now the Holy Scriptures, too, when treating common things (concerning which it is not their purpose to instruct humanity), speak with humans in the human manner, in order to be understood by them. They make use of what is generally acknowledged, in order to weave in other things more lofty and divine.

As for the scriptural passage of Joshua who caused the Sun to stand still in the sky, it could very well have been interpreted as a momentary stopping of our planet, without any threat to the biblical truth about the miraculous event. *Genesis* also received an allegorical interpretation: the passage about God's creation of the Heaven and the Earth could be understood as a reference to the totality of creation, in that Heaven and Earth are its two parts most perceivable by the senses. In *Ecclesiastes*, where one reads that the Earth *in aeternum stat*,

55 Letter of 9 April 1597. Cited by Rosen, "Kepler and the Lutheran Attitude," 326.

56 Ibid. Also see: Segonds, "Introduction" to Kepler, *Secret*.

57 Galileo, *Systema*, 459–64. Voelkel, *Composition*, 76.

58 Kepler, *New Astronomy*, 60. Cf. KGW, vol. 3, 29.

there would be merely an admonishment on the frailty of human life, certainly not a lesson in astronomy.

If the Bible invites us to admire the divine work in the heavens, exclaimed Kepler, what work would be more pious than his new astronomy? Indeed, it would have revealed the most hidden and admirable aspects of creation, such as the motion of the Earth. The common man is able to contemplate the heavens only with his senses, the astronomer instead with the eye of the mind, so that both, according to their respective abilities, will celebrate divine wisdom.

While the principle of authority rules in theology, it is necessary to exercise reason in philosophy. Holy are the Fathers of the Church and its Doctors, concluded Kepler, but very much holier is the truth:[59]

> So much for the authority of the Holy Scripture. As for the opinions of the pious on these matters of nature, I have just one thing to say: while in theology it is authority that carries the most weight, in philosophy it is reason. Therefore, Lactantius is pious, who denied that the Earth is round, Augustine is pious, who, though admitting the roundness, denied the antipodes, and the Inquisition nowadays is pious, which, though allowing the smallness of the Earth, denies its motion. To me, however, the truth is more pious still, and (with all due respect for the Doctors of the Church) I prove philosophically not only that the Earth is round, not only that it is inhabited all the way around at the antipodes, not only that it is contemptibly small, but also that it carries along among the stars.

7 Scriptural Defense of Terrestrial Motion by Origanus

Another defense against scriptural attacks on the motion of the Earth in Lutheran circles can be found in David Origanus's *Ephemerides Brandenburgicae* (1609). Although he only supported axial rotation, he sought to reject anti-Copernican criticism (*contra Copernici mentem*) based on the biblical passages that we have already discussed: the miracle of Joshua, who stopped the Sun to prolong the day and give the Israelites more time to defeat their enemies, and Isaiah's miracle of the backward motion of the shadow on the sundial of Ahaz. Origanus, too, claimed that these passages should not be taken literally. Instead, they should be interpreted according to a principle of accommodation, as they were written to be understood by common people and they do not concern natural questions: "[Scriptural passages] are mostly accommodated to

59 Cf. ibid., 66. Cf. KGW, vol. 3, 33–34.

our senses and understanding when they concern not our salvation but rather worldly matters, especially natural and physical questions, and they do not reveal to us any secret of nature."[60] As a consequence, the principle of accommodation should guide the interpretation of all biblical passages concerning the fixity of the Earth or the motion of the Sun:[61]

> It should be noticed that Joshua referred *in primis* to the Earth in [the passage on] the standstill of the Sun and the Moon. When he commanded the Sun to stop at Gibeon and the Moon in the valley of Aijalon he evidently referred to the [merely] apparent standstill of the luminaries and the real [standstill] of the Earth. Similarly the Holy Bible, [in the passages] on the retreat [of the sundial] in Hezekiah's time, refer *in primis* to the shadow of terrestrial bodies. The observed retreat of the shadow was a consequence of the backward motion of the Earth from east to west although it seemed that the Sun moved back.

The reasons therefore are aesthetic-metaphysical and theological. For his system, Origanus adduced that it was the most harmonious and the best description of Divine Providence. According to his hypotheses, all celestial bodies have no more than a single motion from west to east: the planets about the Sun, the Moon and the Sun about the Earth, the so-called millenary precession of the fixed stars about the poles of the zodiac, and the Earth about its own axis.[62]

8 In Iob Commentaria

A notable exception to the general scepticism about terrestrial motion in the Catholic reception of Copernicus was the theological defense of the Copernican system by the Spanish Augustinian monk Diego de Zuñiga (known as "*Didacus a Stunica*" in Latin) in the pages of a commentary *In Iob*, which first appeared in Toledo in 1584 with a dedication to the King of Spain.[63] This publication, which the author later recanted, merely reproposed the theory of accommodation. Zuñiga, as one can read in the *Prolegomena* of his commentaries, wished to draw from the story of Job a biblical model of patience and virtue, as well as

60 Origanus, *Ephemerides Brandenburgicae*, f. a4*r*.

61 Ibid., f. a5*r*.

62 Ibid., f. a5*r*.

63 Cf. Arámburu Cendoya, "Zúñiga," and Kelter, "Refusal," 38–42.

a reflection on the mysterious operation of Divine Providence, a "very obscure" theme "of God's benevolence toward pious men which is hidden and occult while they live.[64] Therefore, the main purpose of the commentary was very distant from cosmological and astronomical questions, even if the study of nature was a form of piety for its author.[65]

In chapter IX, Zuñiga dealt with the list of works of divine power and wisdom in which Job states that God is He who "shakes the Earth from its place and makes its pillars tremble."[66] Zuñiga drew on this verse to support the Copernican system. This scriptural passage, he explained, is difficult to understand unless reference is made to the Pythagorean doctrine, which, through the motion of the Earth, is able to explain the apparent irregularity of the motions of the stars.[67] He even called the motion of the Earth natural. Such statement, in direct contrast to Aristotle, was directly related to the physical and cosmological debate raging at the end of the sixteenth century.

Without excessive originality, Zuñiga listed those in antiquity who had accepted the doctrine of terrestrial motion: Philolaus, Herakleides of Pontus, "most astonishingly, the elder divine Plato," and, finally, Copernicus:[68]

> In our times, Copernicus explains the planets' motions together with that thesis [*sententia*] [of terrestrial motion]. Without doubt, the planets' places can be derived from his theory [*doctrina*] much better and with more certainty than from Ptolemy's *Almagest* or others' opinions [*placita*].

After mentioning the limits of Ptolemy's astronomical work, Zuñiga attempted to demonstrate the agreement of the Scriptures with Copernicus.[69] He clarified that, in the passage of *Ecclesiastes* "The Earth *stays* eternally" (*Terra autem in aeternum stat*), the stability of the Earth mentioned by Solomon does not regard the local motion, but rather serves to contrast the decline of the races of

64 Cited by Zuñiga, *In Iob*, 4.

65 Ibid., 523.

66 Ibid., 137.

67 Ibid., 140.

68 Ibid.

69 Drawing on Copernicus and Rheticus, Zuñiga observed that Ptolemy had not been able to give a certain rule of the motion of the equinoxes. Only his Arabic and Latin successors, having more data, had elaborated a complete theory (ibid.). Both Alfonso and Thabit ibn Qurra dealt with the correction of Ptolemy, but only Copernicus solved the problem, carefully defining the course of the Sun and explaining it through terrestrial motion. Cf. ibid., 141.

men with the Earth, which always remains the same (*et eodem modo se habet*). Whoever interprets the passage differently ignores its relationship with the context. "Terrestrial motion—Zuñiga noted in the margin—is not contrary to the Scriptures" (*Motus Terrae non est contra Scripturam*). Moreover, although many scriptural passages refer to the "motion of the Sun," such references are not related to the natural truth but to the common manner of expression, that used even by Copernicus and his followers in everyday speaking.[70]

> The fact that, in that passage of the *Ecclesiastes* and many others, the Holy Bible mentions the motion of the Sun, which Copernicus considers to be immobile at the center of the universe, does not contrast with his opinion at all. In fact, terrestrial motions are often ascribed to the Sun in conversations even by Copernicus himself and those who follow him. Hence, they often call the motion [*cursus*] of the Earth Sun's motion.

The passage continued as follows:[71]

> Furthermore, no place in the Sacrosanct Scriptures says so explicitly that the Earth does not move, or that it moves. According to that thesis [*sententia*], it is easy to explain that aforementioned place: it shows the admirable power and wisdom of God who moves the entire Earth, even though it has a very heavy nature. It says: "[He shakes the Earth from its place] and makes its pillars tremble," which means that it is moved from its fundaments in accordance with that doctrine.

The trembling of the terrestrial pillars, of which Job spoke, could support the Pythagorean-Copernican cause. Zuñiga returned to the topic of the foundations of our planet in chapter 38, where he commented on the biblical passage in which God shows Job his ignorance of divine things, also mentioning the creation of the world: "Where were you when I laid the foundation of the Earth? (*Ubi eris quando ponebam fundamenta Terrae?*)" Who laid the foundations of the world? The problem of where the Earth is supported is not resolved here in the manner of Aristotle, who taught that its globe does not move because its weight maintains it at the center of the cosmos. Zuñiga proposed a "Copernican" solution instead: the Earth is held together thanks to a force infused by God on all its parts.

70 Ibid.
71 Ibid.

In chapter 37, commenting on the *Genesis* passage on the separation of the waters above from the waters below, Zuñiga introduced an argument which, as I shall discuss in the following, was proposed in those years by Bruno and also presented by Campanella in the part of his *Theologia* dedicated to cosmology: according to them, the reference in *Genesis* to the "waters above" alluded to a cosmic principle of homogeneity by which the same natural elements present on the Earth would also exist on the other planets. However, Zuñiga interpreted the passage more traditionally as an allusion to clouds. The "firmament" that divides the waters above from those below would in this case be interpreted as *media aeris regio* (middle region of the air).[72]

It should be noted that Zuñiga's commentary was republished in Rome in 1591, from which I would infer that there were opinions favorable to the new astronomy within the Church. Indeed, Zuñiga had influential contacts in the Curia. Moreover, the typographer who printed the second edition of the commentary, the Venetian Francesco Zanetti, belonged to a family of publishers who worked in close contact with religious institutions and orders. For example, he published Clavius's *Gnomonices*, while his son Luigi printed a series of writings by the same Jesuit mathematician. Luigi even had his workshop in the Roman College and managed the typography of the Congregation of the Oratory.

Francesco Zanetti dedicated the new edition of Zuñiga's commentaries to Gregory XIV, boasting of having been much appreciated by his predecessors and above all by Gregory XIII. It should also be noted that Gregory XIV, of Cremona's Sfondrati family, was a relative of Pandolfo Sfondrati, an atomist and probably a Copernican, who was active in Turin and in 1591 dedicated a work on the tides, *Causa aestus maris* (*The Cause of Tides*, 1590), to the pope. Gregory XIV was also the dedicatee of Patrizi's *Nova de universis philosophia* (*New Philosophy of the Universe*, 1591). All this suggests that there were openings to Copernicus's astronomy and new natural views in Spanish and Roman Catholic circles in the 1580s and 1590s. Moreover, as in the case of Zuñiga, there was hope for the theological acceptance of new philosophical-cosmological doctrines.

9 Bruno, Copernicus and the Bible

The year 1600 began under the inauspicious sign of the burning at the stake of Giordano Bruno as a heretic in the Campo dei Fiori Square in Rome. The

72 Ibid., 529.

Copernican philosopher dealt explicitly with the scriptural question of heliocentric cosmology in the fourth dialogue of the *Cena*. His defense strategy was based on two assumptions that we have already encountered by other authors: that the Scriptures should not be used to draw philosophical-natural teachings, but only moral ones, and that they are adapted to the way of knowing of common people. "Those divine books which serve our intellect do not deal with demonstrations and speculations about natural matters, as if with philosophy"—Bruno warned before adding—"[The Divine Legislator] speaks to the common people according to their way of understanding and speaking, so that they can understand what is most important."[73] However, he did not support the idea of a double truth, a division of science and faith, but rather a civil vision of religion, according to which theology is subordinated to natural truth.

In Bruno's view, what "is principal" in the Scriptures is the "law." Indeed, the purpose of religion is cohabitation and social order, and thus it cannot enter into conflict with philosophical and natural studies. "For this reason al-Ghazali [*Alchazele*], a philosopher, high priest, and Mohammedan theologian, said that the purpose of the laws is not so much to seek the truth of things and speculations as to achieve benign usage, the advantage of civilization, the concord of peoples and practice of convenience of human intercourse, the maintenance of peace, and the growth of commonwealths."[74]

Still, to satisfy the "more impatient and rigorous" men of religion, Bruno gave proof of how the Bible could very well support the Copernican cosmological theories or, better to say, of how his approach to nature even "supports religion better than all other kinds of philosophies."[75] Like Zuñiga, Bruno showed that the book of Job, "full of good theology, naturality and morality," could be interpreted so as to support Copernicus. The term "firmament," conveying an idea of stability, confirmed the immobility of the heavens. Moreover, Bruno interpreted the biblical reference to the division of the "waters above" from those "below" as a call to his own principle of homogeneity, according to which the elements existing on our planet could be found everywhere in the infinite universe:

> Moses also follows this doctrine; he uses the word firmament for the air in which all these bodies exist and are situated, and by whose extent the inferior waters, that is, those on our globe, are divided and distinguished

73 Bruno, *Supper*, 177.

74 Ibid., 178.

75 Ibid., 178 and 182.

> from the superior waters of the other globes; that is why it is said that waters are divided by waters.[76]

For Bruno, one should not dwell on the literal meaning of the Scriptures but avoid "taking as a metaphor what has not been said metaphorically or, on the contrary, taking to be true what has been said as a simile."[77] For instance, it is not possible to accept *ad litteram* the passage by Moses on the two great lights of the Moon and the Sun (*Genesis*, 1:16–18), which are certainly not the two largest bodies in the universe.

Documents concerning the Inquisition trial against Bruno show that he began his self-defense by presenting his post-Copernican cosmology. The Jesuit Cardinal Roberto Bellarmino was the one among Bruno's persecutors with whom the prisoner argued most on theological and philosophical issues. In the last phases of the Roman trial, Bellarmino asked him to recant eight heretical propositions contained in his books: the Roman Inquisition's decree of 14 January 1599 reports that "eight heretical propositions were read which taken from his [Bruno's] books and trial by the venerable fathers the Commissar and Bellarmino."[78] From the summary of the trial compiled in early March 1598, it is possible to establish with certainty that cosmological errors figured among the charges against Bruno, namely the plurality of worlds (*plures esse mundos*) and the eternity of the universe (*circa aeternitatem mundi*).[79] In addition, Bruno's *responsiones* to the censorship of his books indicate that they included the theory of terrestrial motion (*circa motum Terrae*). Therefore, Bruno's trial marked the first signs of the concerns that would end in the theory's explicit condemnation in 1616.

It is likely that Bruno's stance weighed heavily on the astronomical-theological debate. Indeed, his position on the relationship between natural knowledge and faith was marked by the radical negation of any compatibility between them.[80] For him, faith was synonymous with "asininity" and "ignorance," the opposite of knowledge and science. In the *Cabala del cavallo pegaseo* (*Cabala of Pegasus*), he described the pious as "asses of wicked disposition." In fact, as one reads, "the less they know while imbibing false information, the more they think they know."[81] This type of ignorant person included both sceptics (who

76 Ibid., 180.
77 Ibid.
78 See the documents collected by Firpo in *Processo*, 311–13.
79 Ibid., 247 f., 267 and 270.
80 See chap. 8,2.
81 Bruno, *Cabala of Pegasus*, 46. Idem, *Cabala*, 708.

"deny, with the light of sense and reason, any light of reason and sense") and Christians, who are blindly guided by the "lantern of faith."[82]

Therefore, Bruno contrasted knowledge, considered the peak of desirable things, and faith. In the table of values he sketched in the *Spaccio*, the personification of knowledge, *Sofia*, occupied one of the highest steps, near the summit constituted by the *Verità* (truth). He linked the cosmological discourse, and thus also the teaching of Copernicus, to a fierce anti-Christian polemic in *Cabala* and especially in *Spaccio*, where he derided all the dogmas and beliefs of the Christian religion. For this reason, the association of his name with that of Copernicus must have influenced the inquisitors' negative judgment about the new astronomy.

10 The Galileo Affair

The clouds of ecclesiastical censorship became increasingly dark over the Copernican cause shortly after the publication of the *Sidereus nuncius* and Galileo's arrival in Florence, because his observations raised new questions about the nature of the heavens and the admissibility of Copernicus's theories. An "anti-Galilean party" formed in Florence, centered around the figures of Giovanni de' Medici, who was a natural son of Cosimo I, and the Archbishop of Florence Alessandro Marzi de' Medici. The group was comprised of philosophers, theologians and preachers who were concerned about the primacy of faith and Aristotelian philosophy over the mathematical theories of Copernicus and Galileo.[83] In 1612, the Florentine Dominican friar Niccolò Lorini overtly took a position against "the opinion of Copernicus," as contrary to the Scriptures, in a public conversation with several noblemen. This episode worried Galileo who, with his recent publications, had taken a position in defense of Copernican astronomy and in strong antithesis to Peripatetic philosophy.[84]

He asked Cardinal Carlo Conti for an opinion on the scriptural problem of Copernicus and received a conciliatory reply, which also mentioned Zuñiga's commentary on Job.[85] Not content with this information, Galileo addressed the matter personally in a letter of 21 December 1613 to Father Benedetto Castelli, a Benedictine friar with whom Galileo had a close relationship of friendship and

82 Ibid., 47.

83 Guerrini, *Galileo e la polemica*, 22–35.

84 Bucciantini, *Contro Galileo*, 20 and Guerrini, *Galileo e la polemica*, 32–34.

85 Camerota, *Galilei*, 261–62.

scientific collaboration.[86] Castelli had just informed his friend of a debate in which he had defended Copernicus in the presence of the "Serene Highnesses" the Grand Duke of Tuscany Cosimo II, his consort and his mother Grand Duchess Christina of Lorraine (letter of 14 December 1613). Galileo wrote to congratulate him and took the occasion to emphasize that the Scriptures be kept at the periphery of natural disputes.

In his letter to Castelli, Galileo supported the usual theory of accommodation: although the Bible cannot contradict natural truths, it is nevertheless written so as to be comprehensible to the common people, that is to say, to those whom he defined with a certain aristocratism as "rough and undisciplined peoples." One should not expect precise explanations of celestial phenomena from the Bible, but rather propositions which "in the naked sense of the words have an appearance different from the truth" since they are addressed to the *vulgo* (common people) and its way of understanding.[87] Hence, Galileo's invitation not to dwell on the literal sense of the Scriptures, but to read them on different levels.

Galileo distinguished two approaches for two different *dettature* (dictations) of the Divine Word, that is, nature and Holy Scripture: he contrasted the interpretative necessity of the former with the interpretative freedom of the latter.[88] The interpretation of nature, based on experience and demonstration, has a specific character of necessity. Therefore, Galileo admonished theologians to deal with their own field of expertise, the "articles concerning the health and establishment of the faith," without adding to them physical opinions at the suggestion of ignorant people able neither to judge nor even to comprehend natural questions:[89]

> Because of this, it would be most advisable not to add anything beyond necessity to the articles concerning salvation and the definition of the faith, which are firm enough that there is no danger of any valid and effective doctrine ever rising against them. If this is so, what greater disorder would result from adding them upon request by persons of whom we do not know whether they speak with celestial inspiration, and of whom also we see clearly that they are completely lacking in the intelligence needed to understand, let alone to criticize, the demonstrations

86 Cf. Festa, *Galileo*, 137 f.

87 Galileo to Benedetto Castelli (21 December 1613), in EN, vol. 5, 277–88, 282.

88 Ibid., 283.

89 Ibid., 284. English translation from Galileo, *Essential*, 105–06.

> by means of which the most exact sciences proceed in the confirmation of some of their conclusions?

Moreover, why would God instruct us on natural questions other than by means of the senses and the reasoning with which he endowed us?

Further on in his incisive letter to Castelli, Galileo demonstrated the agreement with Copernicus of the Old Testament passage in which Joshua stopped the Sun and prolonged the day. Contrary to what would appear at first sight, this miracle would also have disproved geocentrism. With irony and logical rigor, Galileo interpreted to his own advantage one of the biblical passages on which opponents of Copernicus had relied to disprove him. Galileo's reasoning proceeded as follows. Firstly, he conceded to the adversaries that one must make a literal interpretation of the scriptural passage in question. He then went on to a clarification: the Sun has two (apparent) motions, the diurnal one and the annual one. Therefore, it is necessary to establish to which of the two the biblical passage refers. Since the Sun's diurnal motion is not its own but, according to the traditional astronomy, an effect of the *primum mobile*, i.e. the motion of the most external heaven which drags the fixed stars, the planets, the Moon and the Sun by its motion, this is certainly not what Joshua refers to. Otherwise he would have ordered: "Stop *primum mobile*!" The Sun's actual motion is the annual one along the ecliptic, on which depend the seasons and not day and night. However, since this annual motion proceeds in a direction opposite to the diurnal one, had the Sun stopped it would have caused the acceleration of its diurnal motion and not prolongation of the day, as one can read in the Bible.[90] Consequently the Aristotelian-Ptolemaic astronomy cannot agree with the Sacred Scriptures unless one assumes a non-literal interpretation of the passage.[91]

By contrast, Copernicus agreed much better with the letter of the Bible, especially in the light of Galileo's new observations on sunspots, which proved the axial rotation of the Sun. In his letter to Castelli, Galileo even proposed a Keplerian cosmological hypothesis: the Sun itself is the efficient cause of the motion of the planets through the action of its light and heat, which animate the universe. This hypothesis, which would allow an easy interpretation of the passage of Joshua, cannot be directly ascribed to Copernicus but is

90 See Galileo, *Lettera a Cristina di Lorena*, EN, vol. 5, 307–48, 343–44.

91 See Festa, *Galileo*, 147–48. Cf. Stabile, "Linguaggio."

found in the doctrines proposed by Kepler since the publication of *Mysterium cosmographicum*.[92]

> For I have discovered and conclusively demonstrated that the solar globe turns on itself, completing an entire rotation in about one lunar month, in exactly the same direction as all the other heavenly revolutions; moreover, it is very probable and reasonable that, as the chief instrument and minister of nature and almost the heart of the world, the Sun gives not only light (as it obviously does) but also motion to all the planets that revolve around it; hence, if in conformity with Copernicus's position the diurnal motion is attributed to the Earth, anyone can see that it suffices stopping the Sun to stop the whole system, and thus to lengthen the period of diurnal illumination without altering in any way the rest of the mutual relationships of the planets; and this is exactly how the words of the Sacred Scriptures sound. Here then is the manner in which by stopping the Sun one can lengthen the day on Earth, without introducing any confusion among the parts of the world and without altering the words of Scripture.

On 21 December 1614, another Dominican, Tommaso Caccini, made new accusations against Copernicus, Galileo and the mathematicians in the prestigious Basilica of Santa Maria Novella in Florence. The Dominican opponents in Florence continued the theological and cosmological line of Tolosani, from which derived inspiration and arguments. Caccini can be regarded as the "last representative of that tradition of thought."[93] Meanwhile, the letter to Castelli circulated from hand to hand, finally arriving in the wrong ones of the aforesaid Dominican Niccolò Lorini. On 7 February 1615, he presented to Cardinal Paolo Camillo Sfrondati, Prefect of the Congregation of the Index, a copy of Galileo's letter altered, it seems, in some important points to appear more compromising than it would have been *per se*.[94] As Camerota observed, "Lorini's action should not be considered an individual and isolated gesture, carried out by a single, perfidious and irreducible Galilean antagonist. It is likely, instead,

92 Galileo to Benedetto Castelli (21 December 1613), in idem, *Essential*, 109. Cf. EN, vol. 5, 287–88.

93 Guerrini, *Cosmologie*, 16.

94 See Selvaggi, "Responsabilità," especially 240–41. Cf. also Camerota, *Galilei*, 275–79. For the letter, see: Galileo, *Documenti*, 69–71.

that the Florentine friar orchestrated his initiative with other opponents of Galileo."[95]

Galileo, perhaps warned of the suspicious climate, revised the controversial text, rewriting and expanding it. He addressed the new letter to his old protectress, the Grand Duchess of Tuscany, Christina of Lorraine, the mother of Cosimo II. Its purpose was to definitively clarify Galileo's position on the relation between faith and science and to defend it against possible ecclesiastical censorship.

In the meantime, an expert appointed by the Holy Office decided that Galileo's letter (which was deemed heretical by Lorini) was inappropriate in some passages but irreproachable from the doctrinal point of view. Moreover, a handwritten letter was not within the purview of the Congregation of the Index, responsible only for the examination and eventual censorship and prohibition of printed texts. Nevertheless, the situation did not abate, since on 20 March Caccini returned with a formal accusation of heresy against Galileo. Presenting himself at the Holy Office to testify *pro exoneratione conscientiae*, Caccini accused his adversary of supporting doctrines contrary to the Scriptures and to the teaching of the Fathers that "the entire Earth moves, also of the daily rotation; [and that] the Sun is immobile."[96] Thus began the trial of heliocentrism by the congregation charged with the doctrine of the faith, which would have so many consequences for the development of science in the Catholic world.[97] Indeed, the historical consequences went far beyond the merely personal events, since they profoundly affected the development of scientific thinking in Italy and Europe, transforming astronomical questions into questions of faith and conscience.

11 Foscarini *pro Copernico*

Before looking at further developments of the Galilean affair and examining the letter to Christina of Lorraine, it is necessary to mention another voice in the debate: that of Paolo Antonio Foscarini of Montalto, a Carmelite friar and provincial superior of Calabria. He was the author of a defense of Copernicus

95 Camerota, *Galilei*, 276. For the anti-Galilean party in Florence, see Guerrini, *Galileo e la polemica*.

96 Ibid., 293. Cf. Galileo, *Documenti*, "Deposizione di Tommaso Caccini del 20 marzo 1615," 80–85.

97 Bucciantini, in his study of the *affaire* (Bucciantini, *Contro Galileo*), maintains that Galileo was the main target of the 1616 trial.

conducted mainly on theological grounds, which appeared at the exact peak of the debate. In 1615, while en route to Rome, where he was to participate in the Lenten preaching (from 5 March to 11 April) in the church of Santa Maria in Traspontina, he stopped in Naples where he had two works printed by the typographer Lorenzo Scoriggio. The first was a certain *Trattato della divinatione naturale cosmologica* (*Treatise on the Natural Cosmological Divination*), in which he dealt with the problem of natural divination in relation to weather forecasts. It was inspired by the natural philosophy of Bernardino Telesio based on the interaction, in nature, of the opposite principles of solar heat and terrestrial coldness. The second publication was the famous *Letter Concerning the Opinion of the Pythagoreans and Copernicus.* In it, Foscarini announced the publication of other works of his: a treatise on cosmography (*Della cosmografia*) and an epitome of the Liberal Arts (*Compendio dell'arti liberali*).[98] They were to constitute the first and second volumes of an encyclopaedic project entitled *Instituzioni di tutte le dottrine*. They were to be followed by another five volumes on philosophy and theology.[99] In addition to this ambitious project, Foscarini announced the book *De oraculis* and the treatise *De divinatione artificiosa*.[100] Unfortunately, none of these works was ever published and the manuscripts, long conserved in the library of the convent of Montalto Uffugo, were lost some time after 1700.[101]

Foscarini's apology for Copernicus appeared immediately before Galileo's letter to Christina of Lorraine. His aim, as the author stated at the beginning, was to demonstrate that the opinion "of the mobility of the Earth, and stability of the Sun, held in ancient times by Pythagoras, and then put into practice by Copernicus," did not contrast with the principles of physics or with the authority of the Holy Scriptures.[102] Demonstrating the theological acceptability of the new-old astronomy was an urgent matter for the reverend father, a student of natural subjects and an admirer of the work of Galileo, with whom he corresponded.[103]

Foscarini exalted the moderns, who had been given the privilege of advancing both the liberal arts and mechanics. The discovery of America had made it

98 See Foscarini, *Opinion of the Pythagoreans*, 218.

99 Ibid., 250–51.

100 Ibid. See also see Caroti, "Sostenitore napoletano."

101 Cf. Boaga, "Annotazioni." On Foscarini, see also Ponzio, *Copernicanesimo e Teologia*.

102 Cf. Foscarini, *Opinion of the Pythagoreans*, 217–18.

103 Of the correspondence between Galileo and Foscarini, there remains only a letter reported by Berti in *Antecedenti*. In this regard, see Boaga, "Annotazioni" and also Caroti, "Sostenitore napoletano."

possible to confirm that the antipodes existed and were inhabited, questions that the ancients had long discussed without ever arriving at a solution and often making errors. For instance, Augustine and other Fathers of the Church had expressly denied the existence of the antipodes but, as Foscarini wrote, "if they could have seen and observed what the moderns have seen and observed, and if they would have understood their arguments, then without doubt they would have changed their minds and would have believed these most evident truths."[104]

Continuing, Foscarini proposed a parallel between Columbus and Galileo, the discoverers of new worlds. The new observations by Galileo, made with his telescope (*occhiale di prospettiva*), allowed one to infer the solidity of Copernicus's doctrine (and that of the Pythagoreans) against Ptolemy.[105] The theory of the latter was so uncertain as to be considered by the very astronomers who had used it nothing more than a verisimilar theory, useful for prediction, but wrought with a thousand insoluble difficulties. These derive from the broad use of imaginary geometrical entities, like epicycles, equants and deferents. Foscarini mentioned the past authors most critical of mathematical astronomy, who claimed that it was useful only for calculation and unsustainable according to the principles of physics. They were Plato, Callippus, Eudoxus of Cnidus, Ibn Rushd, Cardano and Fracastoro, i.e. supporters of the homocentrism of planetary orbits.[106]

Foscarini assumed a clear position on the relation between nature and Scripture, in line with Galileo: "That opinion would not be opposed to Sacred Scripture, because one truth is not contrary to another. Hence, if the Pythagorean opinion is true, then without doubt God has dictated the words of Sacred Scripture in such a way that they can be given a meaning which agrees with, and is reconciled with, that opinion."[107] Nevertheless, his position diverged from that of Galileo on one important point. Foscarini did not support a real independence of the study of nature from questions of faith, as might appear from the passage taken in isolation. Instead, he maintained, as appears from his general discourse, that the contents (also cosmological) of the Scriptures reveal themselves progressively, thanks to the progress of humanity. In fact, at the beginning of the work, he affirmed the prominence of

104 Foscarini, *Opinion of the Pythagoreans*, 219.

105 Idem, S*opra l'opinione de' Pitagorici*, 205.

106 Idem, *Opinion of the Pythagoreans*, 221.

107 Ibid., 223.

faith over reason and over sense, establishing a triple plan of human access to the truth: revealed, rational and sensory.[108]

In defense of heliocentrism, Foscarini listed six classes of biblical passages problematic for his cause:[109] (1) those affirming that the Earth is stable, (2) that the Sun moves, (3) that the heaven is above and the Earth below, (4) that hell is at the center of the world, (5) those opposing the Earth to the heavens, as center and circumference, and (6) those saying that the Sun will stop in the east after the Last Judgement. Foscarini countered these classes of problematic passages with six *foundations* reasoned so as to provide indications both for an interpretation of the Scriptures compatible with Copernicus, and for its natural philosophical justification. According to the author's intentions, they would mark the way for the resolution of the aforesaid difficulties:

1. "When Sacred Scripture attributes something to God or to any other creature which would otherwise be improper and incommensurate, then it should be interpreted and explained in one or more of the following ways [...] metaphorically [...] *secundum nostrum modum cognoscendi* [according to our understanding] [...] *secundum opinionem vulgi* [according to the vulgar] [...] *respectu nostri* [*secundum apparentiam*] [according to us, or to appearance]."[110] This is an invitation to a non-literal interpretation of biblical passages that seem to contradict a physical truth: the so-called doctrine of accommodation.

2. "All things, be they spiritual or corporeal, perpetual or corruptible, unchangeable or changeable, have been given by God a perpetual, immutable, and inviolable law of their being and nature."[111] This reference to the stability of nature and thus to the rigor required of natural explanations did not correspond to any exegetical freedom. It rather showed the need to interpret the Bible in a well determined manner: whenever it speaks of the stability of the Earth, it is referring to the constancy of the law governing its motion. In the same way, one commonly says that fortune "is constant, and inviolable in its continuous inconstancy."

3. "If a thing moves in one of its parts but not as a whole, it cannot be said to be moved 'simply and absolutely but only accidentally, for 'simply' refers rather to its stability."[112] Hence, with respect to the whole, the Earth is not alterable, but stable; with respect to its parts, it is subject to change. This is how the

108 Cf. ibid., 220.
109 Ibid., 223–26.
110 Ibid., 226.
111 Ibid., 237.
112 Ibid., 238.

following passage in *Ecclesiastes* 1:4 should be interpreted: "A generation goes, a generation comes, yet the Earth stands firm forever" (*generatio praeterit, et generatio advenit, Terra autem in aeternum stat*). The verb "stat" does not refer to the immobility of the Earth, as the absence of local motion, but rather to its persistence as a whole. Just like Theseus's ship remains the same although single planks have changed.

4. "Every material thing, whether it be mobile or immobile, from the beginning of Creation has its own proper, natural and proportional place."[113] This principle closely follows what Copernicus stated in the seventh chapter of the first book of *De revolutionibus*, where he established that rectilinear motion is that of the parts to their whole and not, as Aristotle had maintained, that of the simple elements toward their natural place, identified in terms of absolute high and low. In saying that the motion of the part to their whole is natural, Foscarini certainly committed a *lapsus*: educated in Aristotelian physics, he learned that the rectilinear motion of an element to its proper place is defined as "natural and not violent;" but, in a Copernican perspective, the motion of the part to its whole is not itself natural, even though it leads to restoration of a natural state. In fact, a few lines later Foscarini states that the only natural motion is the circular one.

5. "Some things were created by God such that their parts are separable from each other and from the whole, while other things do not have such parts, at least when considered collectively. The first are contingent, the second are perpetual."[114] This principle almost repeats what was stated by the preceding one, but "this principle differs from the preceding one only insofar as that one considers the parts in relation to place, while this one considers the parts in relation to the whole."[115]

6. "A thing is said to be something simply when it is related to, and compared with, a whole class, or at least to many things and to a large part of the class."[116] This principle serves to affirm the relativity of high and low or big and small. In this way, it would be possible to state that the Earth is really "below" if considered in relation to the fixed stars, to Mars, Jupiter, Saturn and also the Moon. Hence, in relation to the immensity of the Empyrean, which according to Foscarini should be outside the eighth sphere, it can be stated that the Earth is (almost) at the center of the world. This allows one to say that Christ really "descends" from the heaven to become incarnate and then "ascends"

113 Ibid.
114 Ibid., 239.
115 Ibid., 240.
116 Ibid., 243.

there. Likewise other similar difficulties can be resolved in order to reconcile heliocentric hypotheses and religious orthodoxy. As for the Sun, Mercury and Venus, they could be said to be "above" the Earth *respectu nostri et secundum apparentiam*, that is to say, relative to terrestrial observers.

Regarding the question of the site of punishment of damned souls, it should not be feared that, "if the Earth actually were to revolve around the Sun, it would necessarily follow that hell together with Earth would be in the heavens, and that hell also revolves with the Earth around the Sun in the third heaven. But there is nothing more monstrous or extravagant than that."[117] To this fear, which could have been raised by theologians averse to the heliocentric cosmology (fourth class of objections), Foscarini replied that when Copernicus spoke about the heaven he did not mean paradise; likewise the center of the world is not hell (*infernus*), as could be argued on the basis of a wrong literal interpretation of words (*una sorta di gelosia del cattivo suono de' vocaboli*).[118] For the Carmelite, the problem was easily solved: "In both the common opinion and the Copernican opinion, hell is the scum of elements, and it is located in the center of the Earth to imprison and punish the damned."[119]

In presenting the physical arguments in favor of Copernicus, Foscarini proved to be well versed in the natural philosophical difficulties threatening the Copernican theory. His discussion shows that he had good knowledge of the first book of *De revolutionibus*, which presented a criticism of Aristotle's physics. He was also aware that, according to Copernicus's physical considerations, it made sense to speak about gravity and natural motion, since no absolute high and low and no distinction between terrestrial and celestial physics was maintained.

The purpose of Foscarini's work remained that of rendering the cosmological novelties acceptable to Christianity. Hence, his apology moved essentially on the theological and exegetical planes. He summarizes his intentions in the conclusion:[120]

> From these principles and their delineation it is very clear that the opinion of Pythagoras and Copernicus is so probable that it is perhaps more likely than the common opinion of Ptolemy. For from it one can derive the most precise system, and the hidden constitution of the world in a

117 Ibid., 225.

118 Foscarini, *Sopra l'opinione de' Pitagorici*, 227.

119 Idem, *Opinion of the Pythagoreans*, 246.

120 Ibid., 247.

> way which is much more solidly based on reason and experience than is the common opinion. It is also quite clear that the new opinion can be explained in such a way that there is no longer any need to be concerned whether it is contrary to passages of Sacred Scripture or to the justification of theological propositions. On the contrary, it not only saves the phenomena and appearances of the celestial bodies with ease, but it also reveals many natural reasons which otherwise would be difficult to find. In effect it simplifies both astronomy and philosophy.

12 Galileo to Christina of Lorraine

Both Foscarini's letter and the one written by Galileo to Castelli in the defense of Copernicus were placed under examination by the Inquisition. Galileo's letter to Christina of Lorraine essentially repeated the previous one, albeit in a more extensive manner. Unlike the first version, this one contained many references to Augustine and the Fathers of the Church. Theologians who supported the non-literal interpretation of biblical passages concerning physical questions were used as models. In reference to the controversial pages of Joshua, Galileo mentioned Dionysius the Areopagite, Augustine and the Spanish theologian Alonso Tostado Abulensis, who had maintained that the miracle of stopping the Sun in the sky should be attributed to the *primum mobile* of the Aristotelian-Ptolemaic cosmology, thus offering a non-literal interpretation of the passage.[121] With a hint of irony, Galileo also mentioned a puzzling opinion of the Bishop of Burgos Paul de Santa Maria: the miracle of the retrograde motion of the Sun witnessed by Hezekiah did not occur in the Sun, but rather in the sundial.[122]

In the letter to Christina of Lorraine, Galileo invited theologians to use caution on natural questions because they require sensory experiences and necessary demonstrations. Galileo constantly referred to the Fathers who warned not to link faith to philosophical doctrines, which could prove false, because this risked jeopardizing the preaching of the Gospel. Among others, the Jesuit theologian Benito Pereyra, author of *Commentarii et disputationes in Genesim* (*Commentaries and Disputations on Genesis*, Rome, 1591–1599), had warned not to forget that the Sacred Scriptures could not be contrary to the true reasons (*verae rationes*) or experiences (*experimenta*) of the sciences.[123] Augustine

121 Galileo, *Lettera a Cristina di Lorena*, EN, vol. 5, 337–38.

122 Ibid.

123 Ibid., 320.

had warned not to be opposed to *sapientes huius mundi* (the wise men of this world) and to free the doctrines of faith from philosophical disputes, so as not to risk falling along with them:[124]

> In obscure subjects very far removed from our eyes, it may happen that even in the Divine Writings we read things that can be interpreted in different ways by different people, all consistent with the faith we have; in such case, let us not rush into any one of these interpretations with such precipitous commitment that we are ruined if it is rightly undermined by a more diligent and truthful investigation.

Shielding himself behind the authority of the Fathers, Galileo intended to strengthen the freedom of natural research and *a fortiori* of the Copernican doctrine. Nevertheless, he was invading the territory of theologians, who were little inclined to accept intrusions: the formal accusation of heresy by Tommaso Caccini and the subsequent events clearly showed this. Among his innumerable invitations to caution, Galileo also vehemently advised the theologians of the Church not to abuse their power:[125]

> For in regard to these and other similar propositions [by Copernicus] which do not directly involve the faith, no one can doubt that the Supreme Pontiff always has the absolute power of permitting or condemning them; however, no creature has the power of making them be true or false, contrary to what they happen to be by nature and *de facto*.

13 Foscarini to Bellarmino

In March 1616, the censor charged with inspecting Foscarini's *Lettera sopra l'opinione de' Pitagorici e del Copernico* observed that it contradicted the common opinion of the Fathers and of theologians concerning the immobility of the Earth and that their teachings had not been given due consideration.[126] The Carmelite heard of the accusations and, alarmed, decided to write Bellarmino a letter, now conserved in the General Archive of the Carmelites in Rome. The

124 Ibid., 339 (from Augustine, *De Genesi ad litteram*, I,17–18). English translation from Galileo, *Essential*, 136.

125 Ibid., 343. Cf. Galileo, *Essential*, 140.

126 Cf. Boaga, "Annotazioni," 188. The text of the censor's decision was published by Berti in *Antecedenti*, 72–73. See also Fantoli, *Galileo*, chap. 3,3, 138–45.

letter opened with a drastic affirmation of Foscarini's positions, which can be summarized by the motto: "The thesis of terrestrial motion does not cause any problem to faith, but rather to theology."[127] Foscarini then immediately emphasized that Copernicus raised more concern for (Aristotelian) theology than for (Catholic) faith. His position gives the impression that he was trying to assure a theological reflection free of the yoke of Scholastic philosophy and in agreement with a post-Copernican natural philosophy, in view of the encyclopaedia which he planned to write. In fact, the distinction between faith and theology would have favored the development of a science and a natural philosophy independent of Aristotelian physics but compatible with Christianity.

In the letter to Bellarmino, Foscarini showed that he was aware of the accusations made against his work on the Pythagorean-Copernican doctrine. He was accused of having favored an imprudent opinion and of having explained the Scriptures differently from the Holy Fathers. The accusation of "temeritas" seems to have worried Foscarini who, after considering the definition of that concept given by the Spanish Dominican theologian Melchior Cano in *De locis theologicis* (*Theological Places*), tried to exonerate Copernicus and himself from such accusations. For Cano, there were three kinds of temerity: inconsiderate behavior; audacious declarations in which one breaks from the faith and from the universal law of the Scriptures "sine adaequato testimonio aut probabili ratione" (without sufficient evidence or likely reason); and propositions that contradict the decrees and definitions of the Councils (if this is what is meant by the expression "celebres Universitates communes"). Copernicus was not guilty of any of these forms of rashness: he had not spoken *inconsulte et fortuito*, but on the basis of physical and mathematical principles (*ex principiis petitis ex doctrinarum naturalium et mathematicarum*); nor had he broken from the faith or from the law, since the Bible was compatible with his doctrine; nor had he contravened any decree of the *Universitas communis*.[128]

> The thesis [*propositio*] of terrestrial motion is not reckless [*temeraria*] at all. That terrestrial mobility or immobility has nothing to do with faith is clear also from the fact that its truth or falsity can be ascertained through human senses and observation. By contrast, that which is believed through faith is always true and irrefutable. But the posited [*posita*] or demonstrated [*sublata*] assertion of the mobility or immobility of the Earth is not of this kind, neither relative to faith in those things that have to be believed, nor relative to the customs or Catholic religion and

127 Foscarini to Bellarmino (1615), 205.

128 Ibid., 206.

> dogmata. Therefore, [the decision between] terrestrial mobility or immobility is not up to faith.

Foscarini continued by taking into serious consideration the Fathers of the Church and their authority. In this way, he wished to preclude the accusation that he had neglected them; however, he also specified that, although it was not permissible to contradict their teaching in terms of *fides* (faith) and *mores* (customs), even saints could be mistaken with regard to *res philosophicae intelligentiae* (issues pertaining to philosophy).

It should not be forgotten, added Foscarini, that the words of the Scriptures are addressed to the common people and are linked to the opinions of the time in which the narrated events took place, as taught by St. Jerome: "Many things in the Scriptures are said according to the opinion of that time to which the facts refer, and not according to the true disposition of things."[129] It should be noted that several quotations of the Fathers in Foscarini's letter are the same as those reported by Galileo in his *Lettera a Cristina di Lorena*. In all probability, the two men, put in contact with each other by common acquaintances such as Dini and Cesi, worked together, exchanging suggestions and information.[130]

Foscarini justified the accommodation of the Bible by noting that the Fathers and the Doctors of the Church did not hesitate to use similar interpretative approaches when faced with the difficulty of reconciling Bible and nature. For instance, Thomas Aquinas, unlike Augustine, interpreted the Genesis passage in which the Sun and Moon are called *duo luminaria magna* as a reference to the manner in which they appear to us: the Moon seems to us to be the largest celestial body after the Sun, even though it is not. There follows a list of errors on natural questions committed by the Fathers: Justin Martyr believed that the Earth was founded above the waters, deceived by the sound of the words of the Bible; Basil of Caesarea and Augustine believed that the Moon was the second largest body in the heavens; Justin Martyr, Basil, Ambrose, John Chrysostom, Theophylact of Ohrid, Theodoret of Cyrus, Lactantius and Procopius of Gaza held that the sky was vault-shaped rather than spherical … "Quidem similiter sunt alia permulta."[131]

In light of all this, Foscarini repeated the idea that the anti-Copernican qualms were not based on the problem of reconciling Pythagorean cosmology with the Bible but rather with Aristotle. Foscarini wrote to Bellarmino that basing the authority of the Scriptures on this philosophy or on the astronomy

129 Ibid., 210.

130 On this aspect, see Damanti, *Libertas*, IX,3.

131 Foscarini to Bellarmino (1615), 210–12.

of Ptolemy could turn out to be extremely harmful to the Catholic faith. If such doctrines were disproved, as, according to Foscarini, was inevitable, then the authority of the Church would risk being ruined along with them.[132]

> Thus, so far as the worldly order is concerned, we shall not adhere so stubbornly to Aristotle's philosophy or Ptolemy's system that it seems that we are fighting for our altars and hearths. Moreover, we shall not make our interpretation of the authority of the Sacred Scriptures so closely dependent on the opinions of Aristotle and Ptolemy that, if some new argument [*ratio*] or observation, experience or demonstration, make the dogmata of those philosophers false (as mostly happens) or at least very unlikely, our faith in the Scriptures themselves is shaken and threatened, because we base our understanding of the Scriptures on their doctrines [*sententiae*].

14 Bellarminian Zeal

On 12 April 1615, Cardinal Bellarmino dictated a laconic letter in reply to Foscarini. Although Foscarini had written a broad discussion, documenting his ideas with numerous quotations and references and inviting the inquisitor's opinion on his *Lettera sopra l'opinione de' Pitagorici*, the reply was unexpectedly terse and peremptory. Indeed, the eminent cardinal responded with arrogance to the worried Calabrian in search of reassurances: "You ask for my opinion, and so I shall give it to you, but very briefly, since now you have little time for reading and I for writing."[133] Bellarmino rebuked the friar and also Galileo, with whom he associated him: "Gentlemen, proceed with caution." Invitations to prudence by an inquisitor of the Holy Office were not friendly advice. Galileo and Foscarini should be content, we read, to talk about the astronomy of Copernicus *ex suppositione* and not *absolute*. It was more than a reference to the age-old question raised by Osiander in the introduction to *De revolutionibus*.[134]

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132 Ibid., 212.

133 Bellarmino to Foscarini (12 April 1615), in Boaga, "Annotazioni," app. 3. English translation by Finocchiaro, in Galileo, *Essential*, 146. On Bellarmino's personality: De Santillana, *Crime*, 74–109.

134 Galileo, *Essential*, 146. Cf. Boaga, "Annotazioni," 215.

> However, it is different to want to affirm that in reality the Sun is at the center of the world and only turns on itself without moving from east to west, and the Earth is in the third heaven and revolves with great speed around the Sun; this is a very dangerous thing, likely not only to irritate all Scholastic philosophers and theologians, but also to harm the Holy Faith by rendering Holy Scripture false.

The cardinal, aware of his power, did not waste time with discussions. His reply seemed to purposely ignore all that Foscarini had written and sent to him. Accusing him of having generally spoken well of how the Scriptures were to be interpreted but never having applied his principles, Bellarmino showed his interlocutor that he had given no consideration to the pages of the *Lettera sopra l'opinione de' Pitagorici e del Copernico*. Bellarmino reminded Foscarini that the Council of Trent had prohibited any interpretation of the Scriptures that contrasted with the consensus of the Holy Fathers. Since the letter he had received from Foscarini was studded with references to the Fathers, the inquisitor added with a certain satisfaction: "If the Holy Friar will wish to read not only the Holy Fathers, but also modern commentaries on *Genesis*, on the *Psalms*, on *Ecclesiastes*, on *Joshua*, he will find that all agree in interpreting *ad litteram* that the Sun is in the heavens and it circles [...]." Foscarini's fault was to have neglected not only the Fathers but also the interpretation of modern theologians:[135]

> Consider now, with your sense of prudence, whether the Church can tolerate giving Scripture a meaning contrary to the Holy Fathers and to all the Greek and Latin commentators. Nor can one answer that this is not a matter of faith, since if it is not a matter of faith "as regard the topic," it is a matter of faith "as regards the speaker;" and so it would be heretical to say that Abraham did not have two children and Jacob twelve, as well as to say that Christ was not born of a virgin, because both are said by the Holy Spirit through the mouth of the prophets and the apostles.

This is a second, more sinister, invitation to prudence: in theology, prudence is one of the four cardinal virtues, which guides the intellect by showing it what is correct and leads man to salvation. Bellarmino raised the accusation of heresy: the motion of the Earth is contrary to the faith. In a letter to Galileo written in January 1615, Cesi reports that, "relative to Copernicus's opinion, Bellarmino himself, who is among the chiefs in the congregations deciding about such

135 Ibid, 147. Cf. Boaga, "Annotazioni," 215–16.

matters, told me that he regards it as heretical and that, without any doubt, terrestrial motion is contrary to the Bible."[136] Indeed, he was an authority on facts of orthodoxy, having written on the subject one of the most widely circulated works of those times, *De controversiis Christianae fidei, adversus huius temporis haereticos* (*Controversies on Christian Faith against the Heretics of These Times*), whose printings continued at a frenetic pace.

In the rest of his letter, Bellarmino took care to demonstrate how it is possible always to be right. Based on the principle that the Bible cannot be mistaken, he assured that if the world system described by Copernicus were to be demonstrated "then it is necessary to proceed with much consideration in explaining the Scriptures." But since the occurrence of such a thing is inadmissible, then it is unnecessary to give any new interpretation to the Holy Texts. On the other hand, if Solomon, who received from God the highest knowledge of the Creation, said that the Sun circles and the Earth rests, it is necessarily so. Bellarmino did not brook any discussion: "And that is all for now. With which I greet the Holy Friar and I beg God give him every contentment." It seems clear from the letter that the intransigent cardinal had now decided on the correct role for himself and for the Church in the dispute over Copernicus's system. After all, we have seen the role that he played in the conviction of Bruno.

15 Campanellan *Libertas*

A generous attempt to mend the fracture between science and faith was made by the Calabrian Dominican friar Tommaso Campanella, today remembered as one of the greatest philosophers of his time but then an almost forgotten prisoner in Neapolitan and Roman jails, incarcerated for lèse majesté and heresy. In 1622, one of his tracts appeared in Frankfurt, in which he sought an answer to the question: "Is the philosophy which Galileo has made famous and important in harmony with or opposed to the Holy Scriptures?"[137] It was an apology in favor of Galileo, written in March 1616 but published some years later in Germany thanks to his Lutheran friend Adami.[138] In the *Apologia pro Galilaeo*, Campanella fought openly for the right to freely conduct scientific

136 Cf. Cesi to Galileo (Acquasparta, 12 January 1615), in EN, vol. 12, 128–31, 129.

137 Campanella, *Defense*, [6].

138 Lerner, "Introduzione" to Campanella, *Apologia*, in particular XXVIII–XXIX. Lerner discusses in detail both the problem of dating and that of the diffusion and publication of Campanella's manuscript. Concerning Campanella's works published in Germany by Adami, also see Firpo, "Adami."

investigations and to support the Copernican theory. In addition to the scriptural question, Campanella also discussed the more general problem of the relationship between theology and cosmology or, from the ontological perspective, between God and the world. The *Apologia*, which has been seen as a manifesto of the struggle for the *libertas philosophandi* or even for the *libertas theologizandi*,[139] is perhaps the culmination and philosophical synthesis of the passions, hopes and tragic disappointments that accompanied discussions of the legitimacy of Copernicus's teaching between 1615 and 1616.

For Luigi Firpo, there was no reason to doubt that Campanella knew and held discussions with Bruno in 1594, when both were detained in the Roman prisons of the Inquisition together with many other illustrious thinkers such as the Florentine heretic Francesco Pucci and the Neapolitan supporter of Copernicus, Nicola Antonio Stigliola.[140] It is not possible to say whether the positions which Campanella assumed on the relation between religion and science were a response to Bruno, to whom he was opposed in many ways. In fact, Campanella took an antithetical position on the incompatibility of science and faith and on the appropriateness of abandoning the Christian conception of the relation between God and the world. On one point, however, the two agreed: on the need to go beyond Aristotelian and Thomistic theology.

For Campanella, the Christian religion had nothing of the dark image outlined by Bruno who, following Machiavelli, regarded it as a political instrument for the control of the masses kept in ignorance. In the complete adherence to Christianity professed in *Atheismus triumphatus* (*Triumph Over Atheism*, ca. 1605), Campanella railed against Machiavelli and Machiavellism. The friar's polemical targets were "politicians" who believed that each religion had a terrestrial origin, denying God and Providence. To them he opposed the "philosophers," experts in the only true, certain and natural law, common to all peoples. In particular, the universal and natural reason *par excellence* was Christianity, as Campanella affirmed in the *Città del Sole* (*The City of the Sun*), written in the early years of his imprisonment after his arrest in 1599. According to him, there must be no contradiction between reason and Catholic faith.

For him, glorification of the Christian faith and anti-Machiavellian ethical and political positions were combined with a strong natural philosophical interest. As he maintained in *De gentilismo non retinendo* (*That Paganism Shall Not Be Kept*), whose topics anticipated those of *Apologia pro Galilaeo*, religion

139 Cf. Firpo "Campanella e Galileo," and Corsano, "Campanella e Copernico."

140 Firpo, "Introduzione" to *Scritti scelti*, 9. Germana Ernst is more prudent concerning a possible meeting of the two philosophers: Ernst, *Campanella*. See also Lerner, "Campanella lecteur," Gatto, *La meccanica*, and Ricci, "Stigliola. Enciclopedista."

and science are complementary. Indeed, "the grace of God perfects nature;" therefore, Christians, illuminated by such grace, are much more accustomed to investigation of the truth in all fields than heathens: in theology, in natural philosophy and in ethics. Therefore, heresy is not the investigation of new truths, but rather the absolutization of the thinking of a single philosopher.

On the question of the relationship between God and the world, Campanella took a very different route than Bruno. He aimed at a harmonization of Telesio's natural philosophy with the Holy Scriptures and the dogmas of Catholicism. Between faith and science there must be the most perfect agreement. Therefore, in his *Theologia*, an encyclopaedic work in thirty volumes aimed at demonstrating the comprehensiveness of the Bible with respect to all the sciences, Campanella took on the task of detaching theology from Aristotelian philosophy, incompatible with the developments of natural knowledge. Exemplary of the path he had taken to reconcile nature and the Bible was the third book of *Theologia*, specifically the section dedicated to *Cosmologia*, which, according to a letter written to Galileo in March 1614, must have been completed by that time.[141]

16 Campanella's *Cosmologia*

Campanella's *Cosmologia* began with a discussion of the relationship between God and the world: "That God is the efficient cause of the things, matter and space" (*Deum esse causam efficientem rerum et materiae et spatii*). The author dealt with the concept of Creation, a kind of divine emanation of which space, matter and multiplicity are the descending degrees. The philosopher maintained that the Creation occurred *ex nihilo* and that it regarded more the simple being than the compound (*magis simplicem quam compositum*). Specifying that divine Creation was not carried out by any one of the three divine persons but by the whole Ttrinity, the author underlined the theological framework of his discussion.

In the second chapter, Campanella attacked Aristotle on a matter that was also one of the fundamental principles of Bruno's cosmology: the eternity of the world, incompatible with creationism. The proofs of the eternity of the world were opposed by "physical" proofs demonstrating that the universe undergoes a historical transformation. Reality is subject to change and the appearance of novelty (*rationes vero probantes novitatem esse physicas magis*). To argue against the eternity of the world, Campanella used arguments inferred from

141 Campanella to Galileo (8 March 1614). Cf. EN, vol. 12, n. 982, 31–33.

empirical science. He referred to the comets and new stars, to the diminution of the eccentricity of the Sun and to the precession of the equinoxes.[142]

> Who could deny that the world as a whole is temporal? In fact, the heavens are moved, there are alterations in the celestial bodies [*in sideribus*] such as comets and new stars [*stellae novae*] which are produced in all spheres, even in the starry one, as witnessed by Tycho and Galileo and shown through parallax arguments. Similarly, the diminution of the eccentricity of the Sun of about 110,000 miles from Christ to us, the restriction of the obliquity of 24', the anticipation of the solstices, the variation of the location of the celestial signs of 28°—and all of them irregularly—indicate the mutation of the entire heavens and the destruction of the world by fire, as we have shown in the *Metaphysics*. Hence, the arguments by Aristotle rebound against him, since he, as somebody lacking astronomical observations, foolishly utters many things with ignorance.

The only certainty we have about the world's past, Campanella concluded, is what Moses revealed.

The third chapter dealt with questions of theodicy announced in the preceding chapter (*malum nullum est in mundo substantialiter, sed solum respective*).[143] The first article in the third chapter recited: "The visible world is good as a whole" (*totum mundum visibilem esse bonum*).[144] The next article (III, 2) was of most interest for the debate on heliocentrism. It was conciliatory toward the doctrine of a Copernicus interpreted through the eyes of Bruno. To the question of whether space and bodies are infinite, Campanella replied that he did not dare say so. He observed that the infinity of the universe could not be disproved by the motion of the stars, since it could be that the starry heaven is immobile, "as Copernicus demonstrates" (*ut Copernicus probat*), or that it ends with other bodies that do not move with it and that these other bodies end with others *ad infinitum*. Campanella seemed to vacillate on the solution of the problem of the infinity of space. At first, he wrote that we cannot assume that it is infinite. Here he rejected the idea of the infinity of space (*non audemus spatium dicere infinitum*), since it would seem to be linked to an idea of its eternity in contrast to the history of divine Creation. Immediately afterward, however, with an unexpected change of direction, Campanella added: "yet, I consider space to be very similar to infinity" (*puto tamen spatium persimile esse*

142 Campanella, *Cosmologia*, 44.
143 Ibid., 60.
144 Ibid., 78.

infinito).[145] In the same article, he established the principle, confirmed in the rest of the work, that the universe is homogeneous in all its parts, since the physical matter of the heavens, of the Earth and of all bodies is identical.

Chapters IV–X of *Cosmologia* undertook the same exegetic task that Bruno attempted in the pages of the *Cena*: to interpret *Genesis* in the light of an anti-Aristotelian cosmology. However, Campanella's treatment was by far more elaborate. Each of the final seven chapters dealt with an interpretation of every single day of Creation based on the natural doctrines, reporting natural processes to the interaction of those opposite principles Campanella had developed following Telesio's *Natura iuxta propria principia* (*Nature According to It Own Principles*).[146] In chapter V, Campanella maintained (like Rheticus, Zuñiga and Bruno before him) that the creation of the "firmament" and the separation of the waters above from those below (as recounted by Moses) confirmed the cosmological doctrines of the Pythagoreans rather than those of Aristotle. Campanella's argument proceeded along the same lines as that of Bruno. Firstly, he introduced the Pythagorean doctrine in which each star is a world, heavenly bodies contain water, earth and atmosphere as in our system, while fire is in the interior of each celestial body, as shown by the volcanoes of our planet. He recalled that the Pythagoreans believed that our Earth was a planet like the others and that it revolved around the Sun, while the fixed stars were immobile, as the word "firmament" suggests. The Earth rotates about itself in twenty-four hours and has the Moon as its satellite. It should be noted that Campanella was describing the main features of Bruno's cosmology, clearly identifiable from the doctrine of the plurality of star systems. What is surprising is the affirmation that immediately follows: "Copernicus supports this constitution of the world" (*huic mundi constructioni subscribit Copernicus*)[147] In other words, Campanella attributed to Copernicus doctrines that were not his, but Bruno's. Now, it cannot be established whether he had been able to discuss them with Bruno in person, but it is certain that he knew Copernicus's *De revolutionibus* through the mediation of Bruno's cosmology.

In addition to Copernicus, Campanella attributed the Pythagorean doctrine to *multi astronomi recentiores* (many recent astronomers), who believed that only the fixed stars were stable. It cannot be said for sure whether he was covertly referring to Bruno or to Galileo. The Pisan scientist was mentioned

145 Ibid.

146 For an assessment of Telesio's place in the astronomical debates of his age, cf. Granada's introduction to *Telesio: Sobre los cometas.* See also Mulsow, *Frühneuzeitliche Selbsterhaltung*.

147 Campanella, *Cosmologia*, 122–24.

on account of his telescopic observations, which revealed that six planets revolved around our Sun and other planets around those planets, as shown by the Medicean satellites of Jupiter.[148]

Campanella concluded in the same terms as Bruno: if the Pythagorean system of the world were true, then it is clear that the waters above the sky mentioned in *Genesis* are those existing in the planets, which act to moderate the heat of the suns around which they circle and from which they draw heat. Bruno had also supported the same Telesian principle in the *Cena*: the relation between worlds and suns serves to exchange heat between cold and hot bodies.[149]

Finally, I would like to mention *Cosmologia* VII,2, which is an article dealing with "the plurality of heavens, and the place of the Sun according to the Scriptures," in which Campanella affirmed the neutrality of the Bible in the dispute between Copernican and Ptolemaic astronomers. The affirmation that the Scriptures did not fear that the one or the other cosmological and astronomical thesis should prevail assured that Copernicus had the right of citizenship in the Christian world and avoided linking the fate of the religion to that of a philosophical school.

Therefore, all the arguments for the defense of Galileo's scientific freedom were already present in the *Cosmologia* and it was only circumstances that prompted Campanella to put them all together, in a different manner, in the *Apologia*.

17 *Apologia pro Galilaeo*

Sensing the anti-Copernican conspiracy, Galileo traveled to Rome toward the end of 1615. On 8 January 1616, he sent his *Discorso del flusso e reflusso del mare* to Cardinal Orsini. In this work, he proposed his well-known interpretation of tidal events as an effect of the dual terrestrial motion, according to the assumption, which he would explain some years later in a letter to Cesi, that "if the Earth is immobile, high and low tides are impossible; by contrast, if it moves of the aforementioned motions, these [tides] are necessary, along with all other observed accidental consequences."[150] This hypothesis would reappear in the fourth day of his *Dialogo sopra i due massimi sistemi del mondo*.

148 On Campanella, Galileo and Copernicus: Lerner, "Livre vivant."

149 Campanella, *Cosmologia*, 124.

150 Galileo to Cesi (Bellosguardo, 23 September 1624), in EN, vol. 13, 208–09.

But it was too late: the theologians' censorship arrived on 24 February 1616 and the ban decree on the following 5 March. The recommendations of the theological experts were read in the weekly meeting of the Inquisition cardinals. Bellarmino later summoned Galileo to his own residence, to which he was conducted by two armed gendarmes, and communicated the verdict to him, imposing on him the *monitum* (warning) or *praeceptum* (advice) to abandon the Copernican doctrine. The fact was then reported by the cardinal to the Sacred Congregation. The decree of censorship of books that defended Copernicus was presented on the same occasion.[151] *De revolutionibus* and Zuñiga's *In Iob commentaria* were suspended *donec corrigantur*. Other possible Copernican books were generically prohibited, while Foscarini's *Lettera sopra l'opinione de' Pitagorici, e del Copernico* was condemned as "a book to be completely prohibited and condemned (*librum omnino prohibendum atque damnandum*). The Carmelite died shortly thereafter, while Galileo took the defeat without being directly affected, since none of his works had been prohibited or censored. Yet, Bellarmino's admonition would weigh heavily on Galileo's trial following the publication of the *Dialogo* (1632).

Campanella's *Apologia pro Galilaeo* arrived somewhat later than these events and Galileo could not have read it before autumn 1616, as shown by the letter of Federico Cesi on 8 October of that year: "I had the manuscript [by Campanella] that you mentioned, and I sent it to be copied so that I can send it to you, as I will do as soon as I receive it: meanwhile I do not know what to say, not having had time to read it."[152] In this defense, the central question as to "whether Galileo's way of conducting philosophy concords or not with the Scriptures" was changed into that of the theological and exegetical acceptability of the Copernican doctrine. Campanella's work was divided into five sections. The first and second discussed the arguments for and against Galileo (*scilicet* Copernicus). The central part of the apology established some general principles for the resolution of the dispute. The fourth section included a response to the arguments against Galileo on the basis of such principles, and in the conclusion, Campanella protected himself against possible retaliation by the authorities, claiming not to know whose side to take between those who supported the Copernican system and those who opposed it, and thus preferring to suspend judgement.

The recapitulation of the arguments against Galileo did not present any novelty. Campanella referred to the question of whether introducing doctrines

151 Cf. Galileo, *Documenti*, "Decreto della S. Congregazione dell'Indice sui libri proibiti" (5 March 1616), 102–03. On this topic, also see Mayer, "Roman Inquisition's Precept."

152 Cesi to Galileo (8 October 1616), in EN, vol. 12, 285–86.

contrary to Aristotle could subvert theology. He also recalled the difficulty in reconciling Copernicus with the Scriptures, with the interpretations of the Fathers and with the biblical passages concerning Joshua's miracle and that of the sundial of Ahaz. The arguments in favor of Galileo were also more or less the same as those of Foscarini and Galileo himself. There was again the mention of the fact that the biblical term "firmament" represented an advantage for Copernicus's cause. Campanella appealed to St. Ambrose and to Pico to support the Jewish origin of Pythagoras, whose cosmology would thus have derived from the same wisdom as that of Moses.

The core of the apology, however, was the third section and it is this I shall look at most carefully. Campanella proposed three assumptions that were to be *probatissima fundamenta sive hypotheses* (unquestionably proved fundaments, or hypotheses) conforming to the doctrine of the saints, to the decrees of nature and to the consensus of nations. The first of those hypotheses established that, to deal with a religious question that also involved natural knowledge, the theologian must have both the "zeal of God" and science, otherwise he cannot act as judge. The second consisted of a series of warnings, that I will soon consider, while the third affirmed that the Bible, as a book of God, cannot contradict the other divine book which is nature.

A first warning by the Calabrian friar in the *secunda hypothesis* was that both astronomy and physics are necessary to the theologian who wishes to argue against the followers of controversial philosophical theories. He also recalled that astronomy had still not reached its highest degree of perfection, as shown by its continuous progress and new discoveries, as for instance new stars, comets and sunspots. Thus, it was not possible to absolutize Aristotle's natural philosophy, which had been disproved by observations made with very refined instruments like the telescope. To this he added the further observation that neither Moses nor Jesus had taught natural philosophy or astronomy but rather how to live well.

Campanella then went on to deal with a very delicate point, which was one of the most incisive and original in his apology. According to him, prohibiting Christians from studying philosophy and the sciences is the same as forbidding them from being Christians. Theology cannot ban the sciences, since they are its servants. Only a sectarian religion is afraid of being contradicted by the truth, whereas a universal religion, aware that natural truths cannot contrast with those revealed by the same God that created the world, does not fear disproof. Campanella went on: "Christians are those who are wise and rational." In fact, Christians adore the "Divine Word" in Christ, which is nothing less than the "highest rationality, from which we are said *rational* for participation."[153]

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153 Campanella, *Apologia* (2006), 78.

Hence, Campanella was a supporter of a rational, and as such, universal religion, to be shared by all people and open to all the sciences. In his eyes, the greatest heresy was sectarianism, manifested in the jealousy of a school, as well as in the grounding of theology in Aristotle. For Campanella, it was necessary to defend at all costs the philosophical freedom (*libertas philosophandi*), which would be a credit to Christianity. This was his true defensive strategy regarding Galileo, more than quibbling about single biblical passages and philosophical-scientific arguments: the affirmation of a right to free rational searching for the truth in all its aspects, beginning with the study of nature. What instead was harmful was to deny truths acquired through experience and reason:[154]

> Those who use the doctrine of Christian faith to attack philosophers demonstrating their theses through reason and experience (if these opinions do not explicitly contrast the [passages of the] Sacred Scriptures that cannot be interpreted in different manners) [these critics] behave perniciously against themselves, impiously against the faith, and with mockery against others. Even worse is the behavior of the one who adapts the sense of the Scripture to [the doctrines of] a single philosopher as to contrast those of others.

In short, factiousness was bad for a religion that wished to be universal. Thus, the central point of Campanella's defense of Galileo against the opposing arguments was the attempt to separate theology from Aristotelianism, like Foscarini. "We now say briefly it is heresy to maintain that theology is founded upon Aristotle."[155] Whoever wished to condemn Galileo because he opposed Aristotle should first condemn Augustine, Ambrose, Basil, Eusebius, Origen, John Chrysostom, Justin Martyr and other holy doctors who preferred Plato and the Stoics. Hence, from the depths of his prison, the Christian Campanella made a courageous, paradoxical appeal to the powerful inquisitor Cardinal Bellarmino not to condemn science and risk making the Roman Church look ridiculous:[156]

> I believe therefore that his [Galileo's] manner of philosophizing should not be forbidden. We are aware how vigorously the Ultramontanes complained because of the decrees of the Council of Trent. The new philosophy will be embraced eagerly by heretics and we shall be ridiculed. What

154 Ibid., 68–70 (translation revised from Campanella, *Defense*, 16–17).

155 Ibid., 44.

156 Ibid., 98 (translation revised from Campanella, *Defense*, 37). For a confrontation between Campanella and Bellarmino, see also Moiso, "Libertà."

> shall they think when they hear we have rebelled against physicists and astronomers? Will they not immediately cry out that we block the way, not only of nature, but of Scripture? This Cardinal Bellarmino knows.

18 Conclusions: Accommodation and Convention

The Roman ecclesiastical condemnation in 1616 was not a bolt from the blue. It was preceded by a long and vexed cultural debate, which began even before the publication of *De revolutionibus*, a debate leading to a dispute between mathematicians and theologians and involving both Catholics and Protestants. The Roman censorship took the form of a prohibition to hold the hypotheses of Copernicus as a reality, except for the mere purpose of astronomical calculation, as well as the prohibition of advancing a biblical interpretation in accordance with the Copernican system.

A realist acceptance of the Copernican system was a position irreconcilable with the literal interpretation of the biblical passages mentioning the motion of the Sun and the fixity of the Earth (particularly the miracle of Joshua and that of the sundial of Ahaz). Therefore, the condemnation of 1539 attributed to Luther is not surprising, nor is the critical position taken by Melanchthon. The condemnation by Spina and by Tolosani is set under the same sign: the dilemma between a realist interpretation of Copernicus and a literal one of the Scriptures was resolved in favor of the latter.[157] The only sixteenth-century author who, to a certain degree, opted for the opposite solution was Bruno, who rejected "Christian asininity" in favor of a cosmological conception strongly based on Copernicus. As we have seen, Bruno's position oscillated; indeed, in the *Cena* he even claimed better agreement of *Genesis* with Copernicus than with Aristotle and Ptolemy. Similar attempts were made by Galileo, Foscarini and Campanella, who recorded possible agreements between the Bible and the cosmology of the Pythagoreans. Moreover, Zuñiga made a striking attempt to find biblical confirmation for terrestrial motion, which, not surprisingly, was subjected to censorship by the Inquisition in 1616.

157 By contrast, it has been noted that, although Calvin did not accept Copernicus's heliocentric cosmology, by proposing a biblical exegesis based on the principle that the Scriptures are adapted to the way of understanding of men, he unintentionally opened the doors to the reconciliation of Copernicus and the Bible. Cf. Granada, "Problema astronomico-cosmologico," 799. See also Hooykaas, *Rheticus' Treatise* and Rosen, "Calvin's Attitude."

Theologians were generally bound to a literal reading of the Scriptures as regarded the problem of terrestrial motion and solar immobility (the position of Bellarmino is exemplary). On the opposite side, that of astronomers who accepted Copernicus's doctrine as true, an interpretation of the problematic biblical passages *respectu nostri et secundum apparentiam* began to prevail. Their interpretation often referred to the authority of Augustine. The theory of accommodation of the Bible to the manner of understanding of the common people and, *vice versa*, the adaptation of exegesis to the advance of natural knowledge, was favored by the principal supporters of heliocentrism as true *systema mundi*, namely Rheticus, Rothmann, Bruno, Kepler, Foscarini, Galileo and Campanella. In truth, the positions of these authors often oscillated between the desire to keep the discussion on salvation separate from that on nature and the temptation to support Copernicus by means of the Sacred Scriptures. Moreover, in Campanella and Galileo, the appeal for natural (and, in the case of the former, also theological) research free from the rigid schemes of Aristotelianism and of Scholastic theology was particularly heartfelt.

Can one speak of some form of censorship before 1616? The case of the Tübingen theologians provides an affirmative reply. Yet this was limited censorship, to counter Kepler's incursion into the field of biblical interpretation in the light of Copernicus, and it remained very circumscribed. It is difficult to say whether the non-realistic reading of *De revolutionibus* by Osiander or the geocentric revision of Copernican geometries by the Wittenberg school was a form of self-censorship. The theological ban must have weighed heavily, but there were also other cultural factors, mainly depending on physical and natural concerns.

In Catholic circles, the censorship of 1616 marked the beginning of a new season, in which the cause of Copernicus and of science had to assume a religious and confessional meaning. The confessionalization of the astronomical debate appears most vividly from the tremendous efforts by the Jesuits in the seventeenth century to contrast heliocentrism and to support geo-heliocentric planetary models similar to that of Brahe. In particular, the *Almagestum novum* (*New Almagest*, 1651) by the Jesuit astronomer Giovanni Battista Riccioli is the most remarkable attempt after Copernicus, Galileo and Kepler at affirming a geocentric cosmology. It is a huge folio edition in two volumes, conceived as a *summa* of all astronomical knowledge. The fourth section of the second volume, entitled "De systemate Terrae motae" (On the System with the Earth in Motion), is a lengthy discussion (more than 200 pages!) and rejection of geokinetic planetary models. There, Riccioli reviews all arguments he could gather and conceive against Copernicanism. This incredibly long refutation ended up with an abstract of the Inquisition decree of the 5 March 1616 and a short list of the most reprehensible passages of *De revolutionibus* to be censured (*Locorum, quae in Copernici libri visa sunt correctione digna, emendatio*). After that, Riccioli added the condemnation of Galileo and his abjuration (*Sententia in Galilaeum and abiuratio eiusdem*) as a conclusion to the planetary debate.[158] It is, however, clear that this censorial addition is not the conclusion but rather the premise of Riccioli's reasoning.

About twenty years after the publication of Riccioli's *magnus opus*, Otto von Guericke had his *Experimenta nova* printed in Amsterdam (1672), a book which is duly famous for the reports about private and public experiments on void, but was basically conceived as a cosmological treatise, in which the cause of the heliocentric theory was vindicated. Book VI,16, a chapter entitled "On the True System of the World" (*De vero systemate mundi*), tackled the Scriptural issue and pointed out the confessional turn of the Copernican debate after 1616. Guericke questioned in particular that, after the Inquisition decree, Catholics were able to practice science, that is to say, a free investigation of nature and an explanation based on reason instead of faith. He remarked that every astronomer, Riccioli included, recognized the untenability of Ptolemy's system, therefore Peripatetics and Catholics were forced to embrace Brahe's model or a variant of it. Given their dogmatic adherence to a certain cosmological view, Guericke, as a Protestant, doubted the validity of their natural investigation: "Those who follow either the Peripatetic school or the papal decree of 1616, which was carried out by the Congregation of the Cardinals [...], are forced to accept no other system but that [revolving] around the immobile Earth. Yet, they could devise nothing else but the Tychonic [...]. They have to embrace and advocate it, no matter whether it is true or false. A question [hence] arises: in this manner, is a true astronomy (or a correct and just coordination and disposition of worldly bodies) possible?"[159] Moreover, Guericke summarized the Galilean distinction between the discourse on salvation and that on nature. There is a profound difference, he wrote, between faith and knowledge. The former is not required where man can reach the truth with his own faculties, and should be kept out of the natural discourse. Convinced as he was that Copernicus's planetary model could be supported by more reasons than any other world system, he concluded:[160]

> *There is a difference between believing and knowing*: Since there is a difference between believing and knowing (believing means in fact to give

158 Riccioli, *Almagestum novum*, 496–500.

159 Guericke, *Experimenta*, 217–18.

160 Ibid., 218.

an assent for something on the basis of somebody's authority, whereas knowing [*scire*] means to understand [*cognoscere*] something through its cause). Hence, it is easy to conclude that an [astronomical] system known through its cause is true and ought to be preferred to another supported by authority. As Augustine says: "Why do you order me to believe if I can know?" You can know the Copernican system through causes but not the Tychonic [. . .]. Therefore, the Copernican system is true and should be preferred to others.

CHAPTER 8

Laughing at Phaeton's Fall: A New Man

Thomas Kuhn, in *The Copernican Revolution* (1957), claimed—but did not demonstrate—that the average sixteenth-century man must have felt uncomfortable with the idea of a universe in which the Earth loses centrality. According to him, people might have considered their values and religion to be under threat. Basic Christian beliefs, such as the Fall and Salvation of man, lost credibility in the face of the idea that the Earth was merely a planet among others, immersed in an immense universe perhaps inhabited by other rational beings. "These questions have answers. But the answers were not easily achieved; they were not inconsequential; and they helped to alter the religious experience of the common man. Heliocentrism required a transformation in man's view of his relation to God and of the bases of his morality."[1]

Arthur Lovejoy, in his classic on the history of ideas *The Great Chain of Being* (1936), gave a different assessment of the ethical consequences of Copernican cosmology. He contended that the motion of the Earth exalted the human condition without necessarily arousing fears of novelties. Rather, the new astronomical perspective freed man from a "diabolocentric" worldview. In fact, in a heliocentric system, man ceased to be segregated in the lowest place of the Creation, far from the empyrean seat of the Divinity.[2] Some years earlier, Ernst Cassirer, in *Individuum und Kosmos in der Philosophie der Renaissance* (*The Individual and the Cosmos in Renaissance Philosophy*, 1927), showed that modern cosmologies propagated a rather optimistic view of man. He observed that the natural novelties of the Renaissance, in particular the loss of cosmological centrality and the idea of an infinite space, prompted a reassessment of the relation between ethics and science due to the transformation of the relation between man and nature. Cassirer, a keen reader of Nicholas of Cusa, stressed the centrality acquired by every single being from the angle of an infinite sphere without center and periphery, that is, the individual acquired the dignity of an infinite center of infinite relations. Agnes Heller was even more radical in her monograph on the *Renaissance Man* (*A reneszánsz ember*, 1967): referring to Gilbert and Bruno, she remarked that "to be for or against Copernicus, then, was to be pro or contra on the question of human freedom,

1 Kuhn, *Copernican Revolution*, 193.

2 Lovejoy, *Great Chain*, 102.

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greatness, and dignity."[3] These scholars' accounts suggest that the reception of Copernicus's planetary theories and the development of post-Copernican cosmologies produced ambivalent reactions from the point of view of values and the dignity of man: it probably was a mixture of exaltation and fear. All of the aforementioned historians agreed that the key to the connection between science and ethics was anthropology, the change in the idea of man depending on new views about the heavens and Earth.[4]

As some scholars showed—among them, magisterially, Fernand Hallyn—transformations of poetic imagery during the Renaissance, in particular of metaphors derived from classical literature, could also be considered testimony to this post-Copernican shift concerning the symbolic meaning of space and the place of man in the world. Solar motion, according to Greek mythology, was Apollo's journey on his chariot. A well known myth told of the god's son Phaeton trying to drive the solar chariot without success, in particular the version of Ovid's *Metamorphoses*, book II. As the story goes, due to his inability to control the horses and maintain the Sun in its regular path, Phaeton caused the Earth and the heavens to burn. Eventually, in order to stop his disastrous path, Jupiter struck him with a thunderbolt and the young man crashed into the waters of the river Eridanus. Now: what became of this myth in the light of Copernicus's theory of the solar immobility? The Epicurean and perhaps Copernican poet Pandolfo Sfondrati answered in verse in 1580 in Turin: "Now Apollo could laugh at Phaeton's case/since man seems to occupy a place higher than the demigods" (*Tum demum risit casum Phaetontis Apollo/Cum mage semideis sidere visus homo est*).[5] This is not only a change in the poetic imagery, but also the sign that a new conception of the human being and his relation to nature was emerging.

1 Holistic Views in the Astronomical-Astrological Culture of the Renaissance

The interconnection of astronomy and ethics is ancient. The endurance of an ethical conception of astronomy is documented through the centuries by very famous literary works, such as Dante's *Divina Commedia*, presenting human destiny as part of a cosmic design, and, during the Renaissance, Palingenius's

3 Heller, *Renaissance Man*, 375.
4 Cf. Danielson, "Great Copernican Cliché."
5 Sfondrati's poem is at the beginning of Altavilla, *Animadversiones*.

Zodiacus vitae, where the zodiacal signs indicate vices and virtues.[6] During the Renaissance, a unitary and organic conception of the world and of nature prevailed. It was based on the idea that every single part of the living whole was in communication with all others and reflected this universal connection. Conversely, the whole was deemed to be present in every single part. The images of the microcosm and the macrocosm were a synthesis of these views. Copernicus resorted to it when he contrasted, in the dedicatory letter of *De revolutionibus* to Pope Paul III, the harmonic unity of his own planetary theory to the asymmetry of his predecessors' arrangements: "Yet, they could not find out the most important thing, that is, the form of the world and the precise symmetry of its parts. On the contrary, their experience was just like someone taking from various places hands, feet, a head and other pieces, very well depicted, it may be, but not for the representation of a single person; since these fragments would not belong to one another at all, a monster rather than a man would be put together from them."[7]

In the *Narratio prima*, Rheticus, presenting the heliocentric system, compared the Sun, the Emperor of the world, to the heart in a living body: "My teacher is convinced [...] that the heart does not move to the head or feet or other parts of the body to sustain a living creature, but fulfills its function through other organs designed by God for that purpose."[8] As Galen had taught in *De usu partium* (*On the Parts' Functions*), the components of a living whole are interconnected in a harmonic way by an inner finalism, in the same way as the organs of an animal are coordinated by the soul for the common purpose of life.

Astronomers, physicians and philosophers shared the conception of the world as a large animal. Campanella, in *Il senso delle cose e la magia* (*The Sense of Things and Magic*, written about 1604 as an Italian remake of a Latin work composed in the 1590s), offered a clear synthesis of holism and vitalism (I,9): "We ought to affirm that the world is an animal, endowed with sensibility everywhere, and that all its parts benefit from common life; just as in our bodies the arm does not want to be separated from the humerus, nor the humerus from the shoulder blade, nor the head from the neck, nor the legs from the thighs, but all resist division and dislike it, likewise the whole world abhors being divided [...]."[9] In the same book, in section I,13 "That the World is a Mortal Animal, and on What Can Be beyond It" (*Il mondo essere animale mortale,*

6 Cf. Palingenius, *Le zodiaque* and Chomarat, "Création."

7 Copernicus, *Revolutions*, 4 (translation revised); cf. GA II,4.

8 Rheticus, *The Narratio Prima*, 139.

9 Campanella, *Senso delle cose*, 26.

e quel che può essere fuor di lui), Campanella argued for the motion of the world, precisely the rotation of the spheres of the fixed stars, due to the animal nature of the whole, capable of moving as all living creatures within it. He nonetheless acknowledged that the motion of the Earth asserted by Copernicus could account for the heavenly appearances, but only from an optical point of view.[10]

Cosmography and medicine were permeated by the idea that the whole (both the microcosm/animal and the macrocosm/world) was the functional and living unity of the parts. This is one of the most influential philosophical assumptions of the science of that age. A clear example of these tendencies is given by *De naturae divinis characterismis* (*On the Divine Characterizations of Nature*, 1575) by the royal physician Cornelius Gemma, son of the mathematician Reiner and himself an advocate of the physical reality of the Copernican system like his father, as I will discuss later.[11] Cornelius Gemma attempted to develop an all-inclusive science which he called "ars cosmocritica." This art was to bring together astronomy/astrology and medicine following the teachings of Galen and of Hippocrates, especially. In fact, as Hippocrates taught, "medicine and divination are closely related, also seeing that the unique father of both is Apollo, an ancestor of ours capable of detecting present and future illnesses, and of healing those who were ill or were to become ill."[12] Medicine and astrology deal with symptoms to be interpreted, which might concern the human body, society or the large worldly animal. In a similar way, Peucer, professor at Wittenberg, assumed these cosmic and disciplinary correlations in *De praecipuis divinationum generibus* (*On the Main Genres of Divinations*), and included medical semiotics, that is, "that part of medicine dealing with signs," among other kinds of prognostication such as magic, *ars de incantationibus*, meteorology, *physiognomonia* and astrology.[13]

One section of Peucer's book dealt with *teratoscopia*, defined as "interpretation of wonders, marvels and monsters."[14] Cornelius Gemma was interested in *monstrua* and *prodigia* as well, for instance the nova of 1572. He considered this kind of amazing phenomenon to be revelatory of the *divinum*, the unitary principle of all things and, as he wrote, the source of all opposites that are the basis of nature. According to him, one could grasp that concealed truth only by going through all the steps of the *scala rerum*—that chain of beings that goes from matter to spirit, from the *anima* to the archetypal mind and, finally, to

10 Ibid., 33.

11 See chap. 8,17.

12 C. Gemma, *De naturae divinis characterismis*, 26.

13 Peucer, *De divinationum generibus*, 466.

14 Ibid., 720.

God. Following Ficino and Cardano, and drawing on Fracastoro's *De sympathia et antipathia rerum* (*On the Sympathy and the Antipathy of Things*), Peucer's *De divinationibus* and other sources, Cornelius Gemma believed that an investigation "directed to the form of an inner invisible nature, namely the divinity,"[15] should reveal the interconnection of all things with each other, "the nexus of divine things, and mutual dependency through the single parts in the universe, as the foundation of any demonstration."[16] In this perspective, the principles of medicine became universal rules for the care of the body and the soul as well as public and private affairs. The *ars cosmocritica* would detect and prognosticate changes and *crises* at a human level or at a cosmic one, and indicate the way to act in different situations. Thus, there was a structural analogy between microcosm and macrocosm, society and nature, the precepts of medicine and those of astrology and politics:[17]

> Once, the followers of Plato and, before them, Hippocrates taught with truth that the whole [*totum*] (called "world" or "universe") is one animal; its unique mind, or unique soul [*animus*], is endowed with one spirit and is disseminated with great homogeneity across the unique body [of the universe]. This is witnessed not by human reason as much as by the ordered beauty of the whole, the conspiracy of the single parts and their actions, [resulting] from the force and power of the intellect. Thus, we believe that this world is one and manifold and is distributed in a plurality of worlds which are like the joints and limbs of nature—either similar or dissimilar to each other. They are brought together from quarrel to friendship, and brought back from infinite plurality to one single form.

During the Renaissance, astrology was indissolubly embedded in the conception of nature based on the idea of a harmonious design of nature. The Aristotelian Pietro Pomponazzi, a thinker who wrote extensively on fate, providence and free will also in relation to astrology, regarded the stars' influences as the means of God's intervention in the inferior world and human will. In *De naturae effectuum causis sive de incantationibus* (*On the Causes of Natural Effects, That Is, on Spells*, posthumously published by Heinrich Petri in Basel in 1556), he explained that this influence shall not exempt man from moral responsibility. In fact, heavenly causality acts *in universale*, inclining human

15 C. Gemma, *De naturae divinis characterismis*, 24.

16 Ibid.; precisely, it is the subject of chapter I,2 as indicated in the table of contents of the *liber primus*.

17 Ibid., 34.

will to a certain direction, but does not force by necessity *in particulare*.[18] In his monumental *Speculum astrologiae* (*Astrological Mirror*, 1573), Francesco Giuntini revived these commonplaces, underscoring the divine origin of astrological influence.[19]

As a curious example of the alliance between geocentric astronomy and morals, I would like to mention a late sixteenth-century collection of engravings by Laurens van Haecht Goidtsenhoven, entitled *Μικρόκοσμος parvus mundus* (*Microcosm, Little World*, 1579). This book aimed at moral Christian education. It rested on the idea of a correspondence between the macrocosm and the microcosm, according to which man is firmly located at the center of creation. The *imagines*, that is, the figures in the book, reflect motifs from the Bible, classical mythology and history. Each one is surmounted by a title and a motto and is followed by a scriptural passage commenting on it. Each engraving is accompanied, on the opposite page, by a Latin poem.[20] In the frontispiece of the work, one sees the image of Adam, circumscribed by the celestial sphere (see figure 5). On the top of the *sphaera mundi*, a cross indicates the pious inspiration of the author. The "Explanation of the title" (*Expositio tituli*) clarifies the cosmological-anthropological meaning of the work:[21]

> Man is rightly called microcosm, that is to say, small world, due to his similarity to the world. As the world is round, has two luminaries, stars, warmth and coldness, and is ruled by four elements, in the same way also the human head is round, has two eyes, shining hair. And all other things that can be attributed to the world, can be truly attributed to man as well.

In the ornamental framework of the frontispiece, moreover, one can see the four animals representing the Empedoclean (and Aristotelian) elements: the chameleon for *aer*, the sturgeon for water, the phoenix for fire and the mole for earth. In the "Explanation of the title," the author stresses the medical correspondence between natural elements and human characters or humors: choleric nature (fire), bloody (air), phlegmatic (water) and melancholic (earth). Man is a synthesis of all beings and shares something with all of them: the inanimate and the living creatures, angelic beings, with whom he shares the

18 Pomponazzi, *De incantationibus*, 77–78.

19 Giuntini, *Speculum*, vol. I,5. Cf. Omodeo, "Fato."

20 According to its form, this is a book of emblems. Praz, in his *Studi sul concettismo*, stressed the employment of images, in this kind of book, for pedagogic as well as propagandistic purposes. As to the genre of the *imprese*, see Doglio, "Introduzione" to Tesauro, *Idea*.

21 Van Haecht, *Μικρόκοσμος*, "Expositio tituli huius libelli, f. I*v*.

FIGURE 5 *A representation of man as microcosm by Laurens van Haecht Goidtsenhoven,* Μικρόκοσμος parvus mundus (*Antwerp, 1579*)
COURTESY OF THE NIEDERSÄCHSISCHE STAATS- UND UNIVERSITÄTSBIBLIOTHEK GÖTTINGEN (GERMANY).

knowledge of God by means of faith, and God himself, with whom he shares the invisibility and immortality of the soul. "As all creatures are in the world, man is every creature, and "the world has an invisible and immortal Governor; also man has an invisible and immortal soul, endowed with three powers, that is, will, memory and intellect, by which reason is dominated."[22]

Van Haecht assumed that ethics was dependent on natural philosophy. Human activity was embedded in a providential design. In the dedicatory letter to Duke Matthias of Austria, Governor of the Netherlands (from 1577 to 1581) and later successor to Emperor Rudolph II, he claimed that natural philosophy and ethics were the two main fields of philosophy.[23]

The first engraving of the series is a variation of the cosmic Adam on the frontispiece. It is entitled *Μικρόκοσμος*, like the book, and is a representation of man encompassed by the worldly macrocosm. The world, depicted as a sphere, is characterized by the presence of the two main luminaries, the Sun and Moon. Here, too, the cross on the sphere reveals the pious meaning of the image. A biblical quotation (*Job* 14:1) conveys a quite hopeless view of man: "Man, who is born of woman, is short-lived and full of turmoil" (*Homo natus de muliere brevi vivens tempore repletur multis miseriis*).

Another usual representation of the idea of humankind as universal nexus (*copula mundi*), or as the universal link among all beings, was the "zodiacal man" in medical books showing the correspondences between the parts of the body and the zodiacal signs (see figure 6).[24] The sundial (or gnomon) also served as a symbol of universal correspondence since it captures the motion of the Sun and reveals the circularity of time (see figure 7). Man, at the center of the creation like a sundial, could be taken as a universal center of connections. The brevity of human life and time passing were also the basis of Van Haecht's cosmic Adam. The same metaphor occurs at the beginning of Bruno's first philosophically engaged work, *De umbris idearum* (*On the Shadows of the Ideas*, 1582). Bruno stressed the ethical and symbolic meaning of the reciprocal relations between the Sun and the Earth through the sundial metaphor. He compared knowledge to the Sun's light and its limits to shadows. Eternal ideas enlighten different men in different ways, under different conditions and in different places just as the light of the Sun casts different shadows at different locations or its light is differently by the Moon mirrored at different moments. Yet, the Sun is always one and the same, like truth, which appears differently to different people but cannot be affected in itself by the observers' perspectives.

22 Ibid.

23 Ibid., f. II*v*.

24 Cf. Azzolini, *Duke*, 12–15.

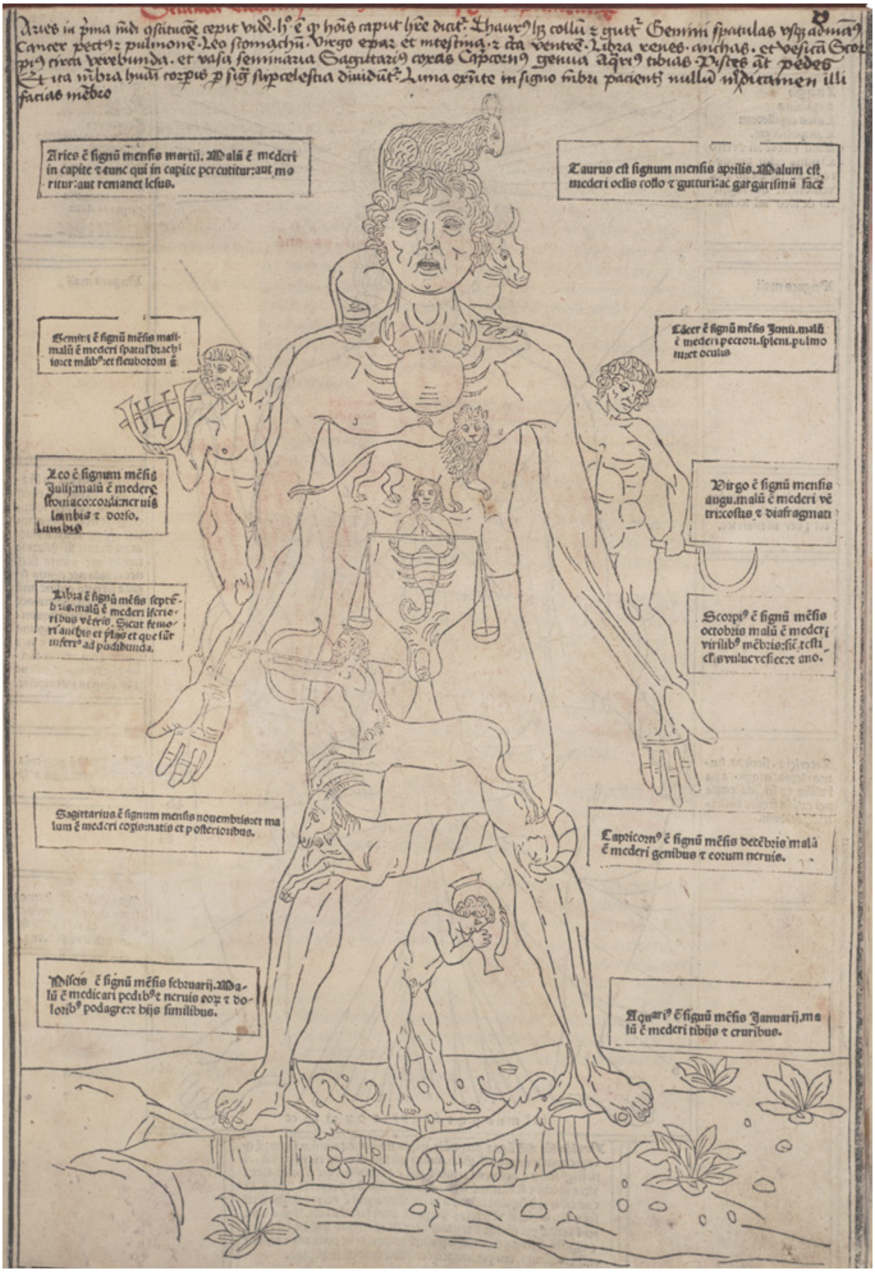

FIGURE 6 *The astrological man of medieval medicine from a 15th-century university textbook, Ketham,* Fasciculus medicinae *(1495)*

COURTESY OF THE DIBNER LIBRARY OF THE HISTORY OF SCIENCE AND TECHNOLOGY AT THE SMITHSONIAN INSTITUTION LIBRARIES (WASHINGTON, DC, USA).

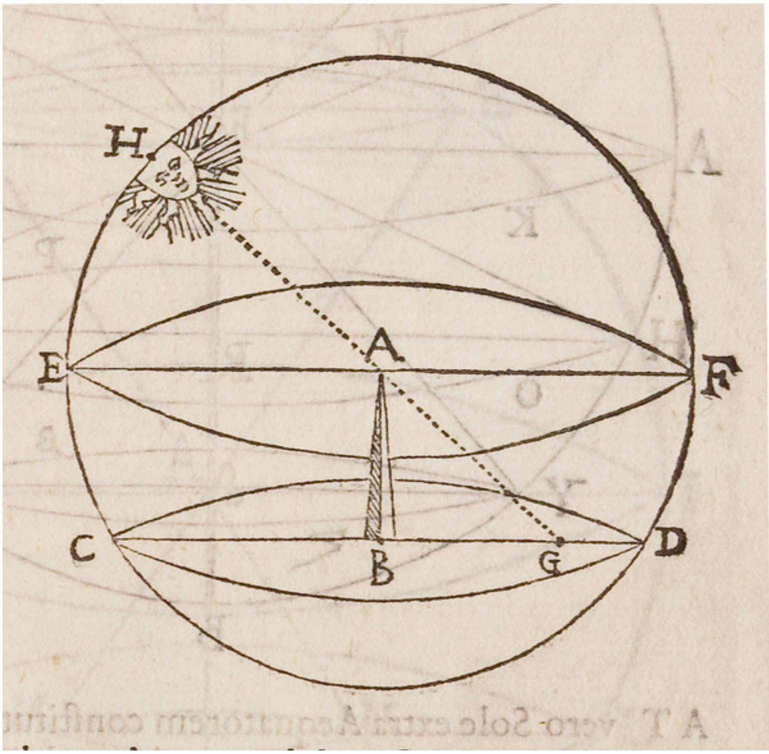

FIGURE 7 *Gnomon. From Clavius*, Gnomonices (*Rome, 1581*)
COURTESY OF THE MAX PLANCK INSTITUTE FOR THE HISTORY OF SCIENCE (BERLIN, GERMANY).

The passage presenting these ideas was also Bruno's first printed declaration of adherence to the Copernican system:[25]

> You certainly know that it is the same Sun and the same art. The same Sun [...] offers a perpetual light to some and a vicissitudinal one to others. While the stable intellect teaches that it does not move, the deceitful senses would rather persuade us that it is moved. Here, it rises to the revolving part of the Earth exposed to it; at the same time, it sets to that part differently disposed. [...] Thus, the same Sun, although it remains always the same, appears always differently to the ones and the others located in one way or another.

25 Bruno, *Opera*, vol. 2,1, 7–9. Cf. Granada, "Sole," and idem, "Terra."

2 The Ethical Question in Bruno: Philosophical Freedom and the Criticism of Religion

The multiplicity of themes in Bruno's philosophical reflections bears witness to the difficulties and enthusiasms accompanying the cultural reception of Copernicus's work and its philosophical-ethical reworking. Since Bruno regarded cosmological infinity as part of a post-Copernican worldview and this was inevitably at odds with the idea of a harmonic proportion between man and cosmos, he was led to reassess the relation between man and world. In his eyes, this relation should assume the features that were ascribed in the past to the relationship between man and God, namely between finiteness and infinity. The ethical counterpart of this cosmological abolition of measure and proportion was an accentuation of human freedom. Thus, Bruno took on the philosophical task of going beyond the limits set by the classical moral of measure. As Ernst Cassirer remarked, this meant an exaltation of the individual, no longer included in a hierarchical nature, but rather in a homogeneous and boundless whole where all beings are ontologically equal.[26]

The writings of Bruno that should be considered in order to stress the ethical implications of post-Copernican astronomy are the six Italian dialogues published in London in 1584–1585. The first three dialogues present Bruno's post-Copernican cosmology and natural philosophy: first, a defense of Copernicus's planetary system, used against Aristotelian natural philosophy (*Cena*); second, a work on the ontology supporting his view of the universe (*Causa*); third, an outline of his infinite cosmology. The next three dialogues expand on the anthropological, ethical and theological consequences of the cosmological and natural theses of the first trilogy. Thus, even though at first glance they appear heterogeneous in their themes and sources, they unfold a unitary philosophical project.[27] For the present discussion on the ethical dimension of Copernicus in his century, it is helpful to analyze the ethical theories developed by Bruno in his last three Italian dialogues.

For Bruno, freedom begins with a substitution of religion and revelation by an intellectual ethics permeated by Platonic elements.[28] His criticism of theological dogmas rests on the objection that all positive religions illegitimately

26 Cf. Müller, *Programm*, 244.

27 See in particular Granada, "Introduction" to Bruno, *Fureurs*, XVIII and Ordine, *Soglia*. The classical introduction is Gentile, *Bruno*.

28 See Secchi, "Teologia" and Ingegno, *Sommersa nave*. Granada ("Introduction" to Bruno, *Fureurs*, LXXX) has convincingly presented this perspective as a fusion of Platonic love and Averroist intellectual access to truth.

claim exclusive possession of an absolute truth. By contrast, he asserts that truth is given to the individual consciousness through contemplation of infinite nature. Since truth does not entail any mystery, its access does not require faith, but rather knowledge.[29] Action should be guided by the "fiery light of the intellect, through a kind of intuition of ideal good, albeit limited due to the intrinsic limits of the human faculties.[30]

In accordance with these premises, Bruno rejects revealed religions and their vindication of an exclusive possession of truth,[31] denounces their intolerance and regards them, without exception, as sects competing for a monopoly on truth and salvation. He especially accuses Christianity of disregarding civil values while extolling miracles *una tantum* and asceticism, which downplay humanity in favor of the supernatural. By contrast, he praises heroism, civil engagement and natural knowledge.[32] His anti-Christian polemic is particularly vehement in *Spaccio de la bestia trionfante* (*The Expulsion of the Triumphant Beast*, 1584). Contrary to the transcendent values of faith, Bruno gives credit only to civil values. Following an Averroist and Machiavellian line of thought, he dislikes religions that do not promote and guarantee pacific cohabitation among people.[33] Instead of establishing ethics, religion itself needs to be legitimized by philosophical or at least pragmatic considerations, for example, the sake of government and maintenance of peace.

In his polemics, Bruno does not spare Protestants, in particular the Calvinists, called "pedant grammarians" (*grammatici pedanti*) who pretend to reform the "deformed laws and religions" (*difformate leggi e religioni*), but in fact corrupt the very few things that are good in Christianity. They pretend to promote freedom, while producing "schism" between nations and between brothers. They follow someone who healed infirm people and resuscitated the dead, but bring illness and death through endless confessional conflicts. Moreover, they preach freedom and harmony but endorse a new form of "malicious and very presumptuous ignorance."[34]

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29 Cf. Grunewald, *Religionsphilosophie*, 200–01. See also Firpo, "Introduzione" to *Scritti scelti*, 12–13.

30 Ciliberto, *Giordano Bruno*, 15.

31 Canone, "La fine di tutte le cose," 54.

32 Bruno, *Spaccio*, 651.

33 Cf. idem, *Cena*, 92.

34 Ibid., 544–45. For an enlightening interpretation of Bruno's anti-Christian but especially anti-Calvinist polemics in the light of the tensions between politics and religion in Elizabethan England, see Sacerdoti, *Sacrificio*.

Bruno's criticism is clearly illustrated by the theme of asininity, the central theme of *La cabala del cavallo pegaseo* (*The Cabala of Pegasus*), where he ironically pits wisdom and reason against the attitude of the "right man, holy man, man of God" (*uomo giusto, l'uomo santo, l'uomo de Dio*),[35] who is a donkey that does not know the truth but has long ears to obey orders:[36]

> What is the point, oh curious ones, to study,/ To wish to know what nature does,/ If the stars are but earth, fire and sea?/ Holy asininity does not care for that,/ But wants to remain, hands joined, and on bended knees,/ Waiting for its reward [*ventura*] from God.

The Brunian symbol of the ass and the theme of asininity derive from a long tradition, which was well established in Renaissance literature and philosophy.[37] The ass is the protagonist of the *Cabala*, where the horse Pegasus (*cavallo pegaseo*) mentioned in the title is nothing other than the ass.

Bruno lists different kinds of asininity.[38] The first is that of the *Cabalisti*, "mystical theologians" who deny the validity of all natural knowledge while assuming that they can achieve wisdom and truth by means of a "negative ignorance," which consists in always denying and never affirming anything. Another kind of ass is represented by those "di prava disposizione," i.e. "of wicked disposition (and so the less they know while imbibing false information, the more they think they know)."[39] Asses and ignorant people are both the skeptics, who "deny, with their light of sense and reason, every light of sense and reason," and the Christians, who are guided by the "lantern of faith, win the intellect of Him who rises above them and purposefully rectifies and guides them."[40],This is the reversal of a metaphor, also used in Luther's *De servo arbitrio* (*On the Bondage of the Will*), where the will of the faithful Christian is likened to a beast of burden forced to follow the directions of its driver, either God or Satan.

Bruno underscores the affinity of skeptics and Christians: the former cast everything into doubt and thus deny the validity of natural knowledge, while the latter consider all their principles to be "recognized, approved, and with

35 Bruno, *Cabala*, 687.
36 Idem, *Cabala of Pegasus*, 14; cf. *Cabala*, 683.
37 Ordine, *Cabala.* See also Hufnagel, *Stück*.
38 Bruno, *Cabala*, 708–14.
39 Idem, *Cabala of Pegasus*, 46; *Cabala*, 708.
40 Ibid., 47.

certain argument manifested without proof and likelihood."[41] Also, in the latter case, knowledge is downplayed in favor of obedience. A skeptical attitude toward natural knowledge strengthens the faith in dogmas (neither demonstrated nor demonstrable) at the expense of reason. Finally, Bruno denounces with irony the obstinate ignorance of those following Paul's stance: "Have you never ever heard that the insanity, ignorance, and asininity of this world are wisdom, doctrine, and divinity in the other?"[42]

3 The Reformation of the Stars: A Metaphor for the Correction of Vices

In the *Spaccio*, Bruno castigated vices and false values, adopting the narrative model (employed by Lucian, Alberti and Erasmus) consisting in the presentation of moral reformation as a decision of the Olympic gods. In *Encomium moriae* (*The Praise of Folly*), Erasmus mocked the dissoluteness of the pagan gods, "corrupt corrupters" incapable of correcting their vices, especially after the banishment of Momus who, according to mythology, was their censor or a kind of moral consciousness.[43] Bruno adopts this theme but substitutes Erasmus's moderate attitude for a fierce attack on Christianity, deemed to be the core of all decadence. He imagines the ancient gods complaining that nobody respects them anymore. In reaction, they decide to amend the mistakes of the past and organize a reformatory council on the anniversary of the Gigantomachy. The celebration of the victory over the Titans is represented as the perpetual war of the soul against vices and passions, or *disordinati affetti*.[44] The gods even readmit Momus to Olympus and agree to follow his instructions. A moral reformation should result from this Olympic gathering as momentous as the Council of Trent. It will be the substitution of immoral constellations, linked to immoral myths, with new images of virtues and values.

In *Spaccio*, therefore, an overview of all virtues and vices is organized as a reform of the constellations. Palingenius Stellatus had also employed a celestial schema in his *Zodiacus vitae*, dividing his moral reflections into twelve sections corresponding to the twelve zodiacal signs.[45] Bruno's treatment is

41 Ibid., 48.

42 Ibid., 34; *Cabala*, 701.

43 Erasmus, *In Praise of Folly*, 22.

44 Bruno, *Spaccio*, 469.

45 Cf. Chomarat, "Présentation" in Palingène, *Zodiaque*, 7–15. The subtitle of *Zodiacus vitae* was *De hominis vita, studio, ac moribus optime instituendis*.

organized in accordance with the rules of the art of memory, about which he wrote several works such as *De umbris idearum* (1582).[46] A basic rule of that art was to conceive an imaginary place occupied by several ordered and differentiated "substrates" to which one could attach the notions one wished to remember. In a later moment, one's imagination could go through the "spaces" of the "fantastic place" and recall to memory different notions linked with certain substrates. In the case of *Spaccio*, the starry heaven is the fantastic place, whereas the constellations function as memory substrates. Assigning to each of them, by analogy or contrast, a value or a virtue (the contrast occurs when a constellation recalls a vice), Bruno gives a fantastic and mnemonic order to his ethical reflections. The Olympic gods themselves are metaphors of the different faculties of the mind: Jupiter represents will (*elezione*), Momus moral consciousness (*sinderesi*), Athena intellect, Mars irascible attitude (*irascibile*), and Venus desire (*concupiscibile*).[47]

As already remarked, Bruno attaches special relevance to civil values, virtues and institutions, for instance law, the application of justice, respect for the State and rebellion against tyranny. The art of war, patriotism (*zelo di patria*) and tyrannicide are accorded a place alongside more traditional virtues like courage, magnanimity and measure. Bruno also appreciates glory and honor deriving from public merits and philanthropy. Additionally, he reassesses some vices, regarding them as virtues depending on the situation. For instance, malice can help, under certain circumstances, to reveal impostures and false beliefs.

Bruno places *Verità*, Truth, at the top of the values hierarchy: "Truth alone, with absolute Virtue, is immutable and immortal: and if she sometimes droops and hides her head, yet no sooner does her handmaid *Sofia* reach forth her hand to lift her up, but she undoubtedly rises again."[48] In fact, Truth is the ontological and epistemological foundation of all values and moral habits.[49] It is the "sure Guide to those that wander thro' this Sea of Errors and Mistakes."[50] Providence (*Provvidenza*), or Prudence (*Prudenza*), occupies a place close to truth. Providence is the expression of a kind of metaphysical optimism. It

46 For a detailed treatment of Bruno's *logica fantastica*, see Rossi, *Clavis universalis*.

47 Ibid., 470.

48 Bruno, *Expulsion*, 22; idem, *Spaccio*, 495.

49 On the shadowy character of human knowledge according to Bruno, see Ciliberto, *Giordano Bruno*, where the *De umbris idearum* is deemed to be the heart of Bruno's philosophy, "il cuore della filosofia nolana" (ibid., 15). On the ontological meaning of truth by Bruno, cf. Nowicki, *Centralne kategorie*, 205.

50 Bruno, *Expulsion*, 52. Cf. *Spaccio*, 514.

concerns the perfection resulting from the realization of all possibilities in the infinite universe. It also refers to ontological necessity, that is, the dependency of all finite beings on a unique principle.[51] This metaphysics does not exclude individual freedom. In fact, ontological necessity and free will are located on two different levels, that of existence, on the one hand, and that of causes and human praxis, on the other. Accordingly, the freedom of finite beings to pursue their individual aims (with prudence) is accompanied by the necessity of their existence (as providence). Prudence, Bruno notes, is the shield with which mortals can face all difficulties. Thanks to this virtue, the wise person is never unprepared and receives all sorts of fortune with the same trust. The wise person has no uncertainties (*nulla dubita*) and "is prepared for everything" (*tutto si aspetta*); he benefits from past experience, disciplines the present and is prepared for any future eventuality.[52]

The third place in Bruno's scale of values is occupied by knowledge, which he designates in Italian as *Sapere* or *Sofia*. *Sofia* has two sides: it can be heavenly and superior or worldly and inferior. In the first case, it is identical with Truth, since there is no distance between the subject and the object of knowledge: "it is both Light and Eye; Eye that is Light itself, and Light that is Eye itself" (*occhio che è la luce istessa, luce che è l'occhio istesso*),[53] that is to say, an immediate intuition of Truth. In the second case, it is a human faculty that can only approximate Truth from outside, that is, seeing it in a shadowy manner.[54]

The fourth place is occupied by the Law (*Legge*), "daughter of the heavenly and divine Sofia."[55] *Sofia* unfolds its action through the law, which is the means for the realization of the requirements of wisdom.[56] Thanks to the law, "Princes reign, and Kingdoms and Commonwealths are maintain'd."[57] Since it also hinders abuses, it guarantees that "the Powerful may be supported by the Impotent, that the Weak be not oppress'd by the Stronger, that Tyrants be depos'd, and just Governours and Kings be establish'd and firmly settled."[58] In the heaven of values, the Law is followed by its ancillae, the Crown and the Sword (*Corona e Spada*), which ensure that justice is respected by means of balanced judgments and rewards or punishments. They should "warm them

51 Cf. Beierwaltes, "Einleitung," and Blum, *Bruno*.
52 Bruno, *Spaccio*, 534–36.
53 Idem, *Expulsion*, 83. Cf. *Spaccio*, 536.
54 Idem, *Spaccio*, 537.
55 Ibid., 516.
56 Ibid., 538.
57 Ibid.; *Expulsion*, 86.
58 Ibid., 539; *Expulsion*, 87.

[men] to those Deeds which inlarge, maintain and fortify Commonwealths."[59] While the "false religion" holds worldly glory in contempt as vain and considers faith to be more important than deeds, the ancient religions of Egypt, Greece and Rome had a positive civil function. Following Epicure, Bruno observes that nothing can threaten the perfection and beatitude of the gods. Hence, the only thing that matters is whether religion fosters or hinders people's happiness and prosperity. Bruno claims that the purpose of divine laws is man and not the glory of the gods.[60] Accordingly, the only sin conceivable is to act badly against other human beings, and the worst injustice is to threaten commonwealth (*pregiudicio della republica*).[61]

The sixth virtue is Force (*Fortezza*) represented by Heracles. A strong will, Bruno writes, is inspired by justice and its action is prudent and guided by reason.[62] It should avoid the excesses: temerity, audacity, presumptuousness, insolence, fury and boldness. The seventh place is occupied by the arts, by Mnemosyne with her daughters the Muses, corresponding to the arts: Arithmetic, Geometry, Music, Logic, Poetry, Astronomy, Physics, Metaphysics and Ethics.[63] All knowledge is covered by the nine arts, which depend on memory (*Mnemosine*), their mother. A correct use of memory is indispensable to order knowledge and recount notions.

All constellations are assigned some value and virtue, apart from the Great Bear and Eridanus, which are vacant. Bruno does not attach to them any value or virtue for the time being. He fills these gaps in the *Cabala*, where, being ironical about Christian religion, he assigns to these constellations Abstract Asininity (*Asinità in astratto*) and Concrete Asininity (*Asinità in concreto*): "In the seat immediately adjoining the site where Ursa Minor was, and in which you know the Truth has been exalted; Ursa Major having been removed from it (in the form that you have understood it) and by providence of the aforementioned counsel, Asininity has succeeded it there in the abstract; and there where you still see the river Eridanus in fantasy, it pleases them that you find Asininity in concrete."[64] One reads that it is no sacrilege to place the symbol of ignorance close to Truth, which has the highest dignity among values, since the "first and principal theologians" asserted that folly, ignorance and asininity

59 Ibid., 541; *Expulsion*, 90.
60 Ibid., 541–42.
61 Ibid., 542.
62 Ibid., 574.
63 Ibid., 577.
64 Idem, *Cabala of Pegasus*, 32; cf. *Cabala*, 700.

in this world are wisdom in the other.[65] It could be remarked that it is against the background of asininity that virtue and wisdom can emerge as a contrast.[66] However, Bruno's decision to place Christianity in the firmament, in the form of asininity, has deeper political-theological reasons, as Gilberto Sacerdoti demonstrated in his study on Elizabethan England.[67] In fact, given the necessity to govern ignorant masses, in the last part of *Spaccio*, Bruno expressed the conviction that Christian religion can be maintained only if it is subjugated by an enlightened political power able to distinguish between philosophical truth for the few and religious tales for the vulgar.[68] Bruno's program was clearly aimed at supporting Elizabeth's struggle to establish the supremacy of the Crown over the Church against Catholicism, on the one hand, and Calvinism, on the other.

4 A Copernican Sunrise

Bruno regarded a cultural and philosophical renewal not only as desirable but also as an impelling historical necessity:[69]

> At about noon, or exactly at that point (that is, when the enemy Error less offends and the friend Truth is fostered) [...], the triumphant beast is expelled, that is, the vices that predominate and are used to oppressing the divine part [of the soul]. Thus, the soul [*animo*] is purified from errors and it becomes adorned of virtues, due to the love of the beauty mirrored in natural goodness and justice, the desire for the pleasure deriving from its fruits, and the hate and fear of the contrary deformity and pain.

Protestants could identify the beast of the *Spaccio* with the Roman pontiff, although Bruno's polemic, as already remarked, was much broader and regarded Christianity as a whole.[70] Eschatological fears were widespread and

65 Ibid., 701.

66 Ordine, *Cabala*, chap. 3, "L'asino e Mercurio: una cifra per la 'coincidentia oppositorum.' "

67 Sacerdoti, *Sacrificio*.

68 See also Granada, "Introduction" to *Fureurs*. See also Ciliberto, "Fra filosofia e teologia."

69 Own translation from Bruno, *Spaccio*, 470.

70 This is the interpretation by Kaspar Schoppe in the letter of 17 February 1600 addressed to Konrad Rittershausen. See Firpo, *Processo*, 350, document 71. Canone remarks that Bruno does not limit himself to a reference to the pope, but "la Bestia trionfante è la personificazione di innumerevoli bestie e vizi" (Canone, *Magia dei contrari*, 65).

concerned the expectation of an imminent return of Christ who would drive out the anti-Christ, that is, the Pope, regarded by many Protestants as no less an enemy of the faith than were the Turks. For instance, among the polemic writings against the introduction of the Gregorian calendar, one can find a pamphlet by the *Würtenbergischer Hoffprediger* Lucas Osiander entitled *Ob der newe Bäpstische Kalender ein Notturfft bey der Christenheit seye* (*Whether the New Papal Calendar is Necessary for Christianity*, 1583), in which the introduction of the new calendar was accused of being a trap of the anti-Christ aimed at distracting Christians from the imminent end of the world.[71] In the polemic *Spaccio*, Bruno argued that all present miseries derive from neglect of civil values and ignorance due to Christianity. His condemnation, therefore, was directed against the papists as well as the reformers, in particular the Calvinists. In his assessment, the civil values of the pagans and the wisdom of the ancients had been obscured by Paul's asinine religion, a form of obscurantism that Lutheran literalism, or rather "pedantry," reinforced. Still, he believed that this condition of decadence was approaching its end. All religions, in fact, are subject to the laws of universal becoming, like all natural and cultural phenomena: "Thus the eternal Deities (without any Inconvenience or Injury done to the Truth of the Divine Substance) have different Names, in different Times, and different Nations."[72] Christianity was no exception. It was also destined to decline and give way to an enlightened age.[73] According to the inexorable law of vicissitude, everything flows and changes in the "wheel of time" (*ruota del tempo*); enlightened and obscure ages alternate:[74]

> And although by their means the Dignity of Mankind is so polluted and desil'd, that in place of Science, they have imbib'd Ignorance that is more than brutal; from whence they come to be govern'd without civil Justice and Law: yet this has not happen'd by their Prudence and good Management, but because Fate gives Time and Vicissitude to Darkness.

Bruno shared the expectation of an epochal renewal although, unlike his contemporaries, his perspective was essentially irreligious and his conception

71 Osiander, *Der newe Bäpstlichen Kalender*.

72 Bruno, *Expulsion*, 227; *Spaccio*, 634.

73 Historians of Bruno's philosophy have traced these opinions back to a historical-philosophical reflection hinged on the concept of *vicissitudine*. Cf. Ciliberto, *Ruota* and Blum, "Geschichtsphilosophie."

74 Bruno, *Expulsion*, 243; *Spaccio*, 644–45.

anti-eschatological, since his idea of history was cyclic.[75] Within such a conception of history, Copernicus's achievement occupied a special place. Bruno regarded him as the messenger announcing a historical turning point after which light would triumph over darkness. In the *Cena*, one reads that Copernicus was "ordained by the gods to be the dawn which must precede the rising of the sun of the ancient and true philosophy, for so many centuries entombed in the dark caverns of blind, spiteful, arrogant, and envious ignorance."[76] Accordingly, the new astronomy was part of a universal renewal, which included the science of the heavens, natural philosophy and ethics.

In the *Spaccio*, Bruno's reform begins with the rejection of false views of the world. Jupiter announces a reformation of constellations:[77]

> The principle and subject of our work is the world according to the imaginary form assigned to it by foolish mathematicians and accepted by no wiser physicians, among whom the peripateticians are the most idle [...]: first, it is divided into several spheres, and then it is divided into forty-eight images (by which they primarily mean the eight starry heavens, called by the vulgar the "firmament").

Bruno parallels Copernicus's celestial reform with the moral one of the *Spaccio*. According to him, the renewal of astronomy and natural philosophy anticipated the overthrow of old religious beliefs in favor of a philosophy of civil responsibility. The radicalization of the humanist theme of folly led not only to satire but also to radical criticism of the present, along with the expectation of a civil rebirth inspired by pagan cults. In the dialogue, the highest god of the pagans Jupiter bitterly complains that a "half man," the Christ, has occupied his place. Jupiter also suffered from the kicks of Christian asses, the "semi-beasts" or "worse-than-beasts" who rule the world, overthrowing civil order and prompting laziness.[78] According to Bruno, only polytheist religions really fostered human cohabitation and wisdom.[79]

75 Cf. Ciliberto, *Ruota*; Granada, "Introduction," to Bruno, *Fureurs*, LXVII.
76 Bruno, *Supper*, 87; *La cena*, 25.
77 Idem, *Spaccio*, 469.
78 Ibid., 492–93.
79 Cf. Secchi, "Teologia."

5 Beyond the Ethics of Balance

To better understand Bruno's ethics, one should consider his *Eroici furori* (1585). In this dialogue, which is at the same time a collection of poems and a commentary upon them, Bruno questioned the classical ethics of *mediocritas*, of moderateness and avoidance of extremes. The idea of *mediocritas* had been particularly important for the humanist *élites* of the fifteenth century, who regarded virtue as a form of balance mirroring individual dignity and civil engagement. The ethics of the "medietà non mediocre" (non-mediocre averageness) was, according to Eugenio Garin, "an ideal of worldly life, balanced and serene, human in taking delight at that what fortune brings, as well as in suffering pain with sincerity, acknowledging our limits, and profiting by what it can give us."[80] In his rejection of moral balance, Bruno's ethics was a refusal of all imposed rules and precepts, opportunity and measure. He conceived it as a form of enthusiasm that he called "eroico furore," or heroic frenzy. Inasmuch as heroic, this ethic was not for the vulgar, but only for the philosophical elite.

Bruno pitted the heroic frenzy against the Aristotelian ethics of measure. At the beginning of the second dialogue of *Eroici furori*, he noted that nobody in this world is satisfied with his state, "except for some senseless or foolish person." Happiness and satisfaction are foolish, but the philosophers' frenzy, i.e. striving toward truth, is foolish as well. Quoting King Solomon, Bruno remarked that the philosophical drive increases one's wisdom but, at the same time, one's suffering because it enhances the desire for something that cannot be reached, namely ineffable truth and beauty. "If he who is content is mad, and he who is sad is mad, then who has wisdom?" (*Chi dumque sarà savio?*)—a person of the dialogue asks. The answer is: "He who is neither content nor sad." (*Chi non è contento né triste*).[81] In other words, wisdom is defined, as with Aristotle, in negative terms: it is a minimum of happiness and a minimum of sadness. Virtue is indeed a form of renunciation. Bruno formally accepts this definition without really supporting the resulting ethics. Rather, he is inclined to go beyond a morality conceived as *mediocritas* and to substitute this idea of balanced virtue in favor of vicious frenzy:[82]

> This is the reason why, to come to our point, the heroic frenzy, which our present discourse somewhat clarifies, differs from other more ignoble

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80 Garin, "La fortuna dell'etica aristotelica nel Quattrocento," in *Cultura filosofica*, 60–71, 66 and 71.

81 Bruno, *Heroic Frenzies*, 99; cf. *Eroici furori*, 797.

82 Ibid., 100, *Eroici furori*, 798.

> frenzies not as virtue differs from vice, but as vice practiced in a divine way by a more divine subject differs from vice practiced in a bestial way by a more bestial subject. Therefore, the difference does not depend on the form of vice itself but on the subjects who practice it in different ways.

Bruno contrasted this heroic passion to instinct—"vizio ferino" (bestial vice) or "più basso furore" (lower vice)—and considered it to be the painful privilege of divine subjects. He formally supported the classical view of correct behavior by identifying wisdom and balance, but eventually articulated a defense of that sublime vice which he called *eroico furore*.[83]

The theme of *furore* famously derives from Platonism. Among others, Marsilio Ficino, the famous author of the *Theologia Platonica*, dealt extensively with this issue in his Italian commentary on Plato's *Symposium* entitled *Sopra lo Amore* (*On Love*).[84] The Florentine neo-Platonist's treatment of furor relied on Plato's distinction, in *Phaedrus*, between bestial and divine raptures. In chapter three of the seventh and last oration of his commentary, Ficino dealt with "Love, and How It is a Genre of Folly" (*de lo amore, e come è spezie di pazzia*): "In *Phaedrus*, our Plato defines furor as an alienation of mind and considers two kinds of alienation. One of them derives from human infirmity, while the other derives from divine inspiration. He calls the former foolishness and the other divine furor."[85]

Ficino treats frenzy as a form of dispossession from oneself, a "mind alienation" (*alienazione di mente*), which can lift one's soul up to God. This divine folly has several offspring. Accordingly, he distinguishes four kinds of divine frenzies: poetic, centered in the mysteries or sacerdotal, divinatory and loving. The last one is the most important, since others depend on it.[86] True love is a divine frenzy, a rapture toward God. It is the main reason for moral improvement and the process of knowledge. God's love is the reason for the creation and the conservation of the world. On the other hand, love is man's ladder to the sublime, that is to say, toward perfect beauty and goodness:[87]

> Eventually, when the soul is made one (that one, I mean, that is in the very nature and essence of the soul), immediately it is reduced to that

83 Ciliberto regards the "furioso" and the "sapiente" (wise) as the central figures of the *Eroici furori*. See the "Introduzione" to Bruno, *Eroici furori*, XX.

84 This legacy has been stressed by Granada in his "Introduction" to Bruno, *Fureurs Héroiques.*

85 Ficino, *Sopra lo Amore*, 140–41.

86 Ibid., 156.

87 Ibid.

> one that is located over its essence, that is, God. This is the gift brought to us by that celestial Venus through love, that is, the divine beauty, and the ardor of goodness.

It should be remarked that Ficino, like Bruno later, deems *furore* to derive from the love of infinity. He already dismisses the ethics of measure but, unlike Bruno, for theological reasons. According to Ficino, infinity, as the absence of any limitations, is suitable to describe God's light and beauty: divine infinity, which deserves an unrestrained love, namely infinite love. Ficino derives a twofold ethics from these premises: on the one hand, measure is the main virtue for dealing with the finite things of this world, on the other, an ethics of excess, "senza modo né misura," offers the only possible access to transcendence. In *Sopra lo Amore*, Ficino lets Diotima (the priestess who initiated Socrates in the secrets of love) explain this twofold conception of ethics: "I pray you, o Socrates, that you love the creatures with certain measure and limit, but love the Creator with infinite love. Avoid as much as you can loving God with any measure and limit."[88]

6 Heroic Frenzy

Bruno's heroic frenzy owes much to Ficino's divine frenzy. Yet, the terminological difference marks a philosophical turn. While Ficino regards the desire for divine beauty and goodness as a form of ascesis—a mystical drive to experience and annihilate oneself in God's infinity—Bruno extols the "divine subject's" heroism and his realization of great worldly achievements, in accordance with the civil values of the *Spaccio*. The cosmological dimension of Bruno's discourse, in the Italian dialogues, permits to conceive of this desire for infinity as immanent within nature. It seems therefore that Bruno can dismiss Ficino's Platonic distinction of a twofold ethics, divided into a worldly realm of application and a theological one, since he deems infinity to be a characteristic of nature itself, and not exclusive to God.

However, Platonic elements are also present in *Eroici furori*, for instance the omnipresence of the theme of the love of beauty and goodness—a desire that torments but at the same time motivates the frenzied person's action and search—and the conception of heroic frenzy as an infinite drive. The theme of love allows Bruno to present frenzy as an infinite search (*studio infinito*) for perfect beauty and goodness. Thus, the goals of knowledge, ethics and

88 Ibid., 131–32.

esthetics coincide. The objects of that love, namely the *eroico furore*, are those "two most beautiful stars in the world" (*due più vaghe al mondo stelle*),[89] those "two intelligible species of the divine beauty and goodness of the infinite splendor, which influence the intellectual and rational desire and cause it to aspire infinitely."[90] Beauty and goodness are a twofold ideal to be approximated *ad infinitum*: Bruno explains that the intellect can never be satisfied with a particular truth, once reached, and that, in the same way, the will is moved by an inextinguishable thirst that can never be satisfied with finite things which are not truth itself, or infinity.

To know the truth means to become one with it. Love is deemed to be the only suitable approach to knowledge, since it leads the subject to become one with his object. Comprehension of truth means, in fact, to grasp truth (*cum-prehensio*) and to be assimilated by it (*cum-prehensum*).[91] In line with Platonism, Bruno underscores that the cognitive experience and the frenzy leading to it are not irrational, since the *furore* is "a rational force following the intellectual perception of the good and the beautiful comprehensible to man, to whom they give pleasure when he conforms to them, so that he is enkindled by their dignity and light."[92]

Even though Bruno agrees with Ficino in conceiving of the *furore* as a rational (or hyper-rational) aspiration toward infinity, he diverges as to the conclusions. Ficino had focused on the joyful realization of a love whose fulfillment is neither impossible nor hindered. By contrast, Bruno concentrates on how difficul it is to reach the ideal. The way toward the object of love seems an infinite task, disproportionate relative to human forces:[93]

> The intellectual faculty is never in repose, is never pleased by any truth it attains, but proceeds onward toward an incomprehensible truth. Similarly we see that the will, which follows the cognition, is never satisfied with anything finite.

The *eroico furore*, according to him, appears only in exceptional people. "Because they are naturally endowed with a lucid and intellectual spirit, when under the impact of an internal stimulus and spontaneous fervor spurred on

89 Bruno, *Heroic Frenzies*, 261; *Eroici furori*, 954.

90 Ibid., 170. Cf. *Eroici furori*, 866.

91 Michel, "Introduction" to Bruno, *Fureurs héroïques*, 21. Cf. Farinelli, *Furioso nel labirinto*, 172–73.

92 Bruno, *Eroici furori*, 806.

93 Idem, *Heroic Frenzies*, 202; *Eroici furori*, 897.

by the love of divinity, justice, truth and glory, [...] they make keen their senses and in the sulphurous cognitive faculty enkindle a rational flame which raises their vision beyond the ordinary."[94] The *furioso* depicted by Bruno is a restless person, whose spirit is split into two tendencies: on the one hand, he is aware that balance and serenity are rooted in a sort of indifference, in accordance with the ethics of the *aurea mediocritas*; on the other hand, passion brings him far from emotional balance. The *furioso* is divided between rational aspirations and bodily ones, between the ideal and immediate passions. He has an extremely acute sensibility, which brings him from one excess to its opposite: from joy to anguish, and from exaltation to desperation. As one reads, "he is not dead, because he lives in the object, he is not alive, because he is dead to himself."[95] And elsewhere: "he is most base when he considers the loftiness of the intelligible object and realizes the weakness of his power. He is most lofty through the aspiration of the heroic desire that carries him far above the limit of his own nature, most lofty through the intellectual appetite [...] and he is most base because of the violence brought upon him by the contrary sensuality weighing [him] down toward the inferno."[96] It is a "dismembering" (*disquarto*) that separates and opposes the different faculties of the soul, opposing the desire for infinity and the finitude of the human being.

In this inner conflict, all harmony is broken. The accordance and unity among sensibility, corporeity, spirit and reason is lost since all faculties of the furious person are dominated by the love of intelligible beauty. Due to this passionate striving toward infinity, the human spirits neglect their normal functions, especially those devoted to the preservation of life.[97] It seems that the inner tension can be solved only through death (dissolution of the *macchina*, the "machine" where "through the spirit, the soul is connected to the body")[98] or faced with a superior humanity made out of "heroes" who can solve that inner conflict, or almost do so. In the scale of "intelligent beings" (*intelligenze*), heroes occupy a privileged place above common people.[99]

At the end of his infinite search, the *furioso* hopes to meet the whole, the universe and the absolute being. Truth is almost always beyond anything reached. Man is therefore similar to an infatuated blind person striving for a beauty he cannot see. In the fourth dialogue of the second part of *Eroici furori*, Bruno

94 Ibid., 108; *Eroici furori*, 805.
95 Ibid., 102; *Eroici furori*, 800.
96 Ibid., 102–03; *Eroici furori*, 800.
97 Idem, *Eroici furori*, 831.
98 Ibid.
99 Bruno, *Heroic Frenzies*, 137–38, *Eroici furori*, 834.

introduces nine blind men who symbolize humankind, incapable of seeing beauty and truth.[100] In fact, "[...] the divine light is in this life more an object of laborious emptiness than of tranquil fruition, since our minds move toward that light like birds of the night toward the Sun."[101] Our human intelligence is similar to the Moon on whose disk light and darkness alternate.

Bruno does not completely exclude the fruition of intellectual light, but he considers it to be extremely rare. If it comes, it happens all of a sudden. Although a long time must pass before a window is opened, the light enters the dark room instantaneously. The same happens with the apprehension of truth.[102] Bruno asserts that the human intellect is finitely infinite while the object to which it strives is infinitely infinite.[103] The finite being can come closer to the essence of reality only step by step, but the vision comes only as a surprising event, all of a sudden and unexpectedly.

The conclusion of *Eroici furori* has a positive accent: the nine blind men reacquire their sight and are illuminated by two goddesses representing beauty and truth: "[they] opened their eyes and saw the twin suns and were overwhelmed by a twofold felicity, that of having recovered the light formerly lost and that of having newly discovered the other light which alone could show them the image of the supreme good on Earth."[104] Blindness and darkness are not irreversible "for fate does not wish that good follow good,/ or pain be the presage of pain;/ but making the wheel turn,/ it raises, then it hurls down, as in mutability,/ the day gives itself to night."[105] This is the universal law of vicissitude upon which Bruno's conception of nature and history rests: just as light and obscurity alternate on Earth, likewise also the *furioso* can hope to eventually see the light and be rewarded for his troubles and sufferings.

7 Actaeon: The Unity of Man and Nature

According to Bruno's symbols, the furious hero can be represented as Actaeon. In Greek mythology, this man surprised Diana (Artemis) bathing naked, while he was hunting with his hounds. In rage, the goddess transformed him into a wild beast, condemning him to be torn to pieces by his own mastiffs (*mastini*)

100 Ibid., 933–50. See Canone, *Magia dei contrari*, 67–91.
101 Idem, *Heroic Frenzies*, 158; *Eroici furori*, 855.
102 Ibid., 945.
103 Ibid., 867.
104 Bruno, *Heroic Frenzies*, 263; *Eroici furori*, 956.
105 Ibid., 264, *Eroici furori*, 957.

and greyhounds (*veltri*).[106] Bruno presents his reworking of that myth in a famous sonnet:[107]

> The youthful Actaeon unleashes the mastiffs and the greyhounds to the forests, when destiny directs him to the dubious and perilous path, near the traces of the wild beasts.
>
> Here among the waters he sees the most beautiful countenance and breast, that ever one mortal or divine may see, clothed in purple and alabaster and fine gold; and the great hunter becomes the prey that is hunted.
>
> The stag which to the densest places is wont to direct his lighter steps, is swiftly devoured by his great and numerous dogs.
>
> I stretch my thoughts to the sublime prey, and these springing back upon me, bring me death by their hard and cruel gnawing.

As the author explains, Actaeon represents the intellect seeking divine wisdom, while the greyhounds are the "operation of the intellect" (*l'operazion dell'intelletto*), which is quicker than that of the mastiffs, representing the will, which is stronger and more effective than the intellect. The wood is the symbol of the lonely places that only a few people dare traverse; the wild beasts of the forest (*boscarecce fiere*) are "the intelligible species of ideal concepts" (*specie intelligibili dei concetti ideali*) which only a few can grasp. The water is the mirror of natural things reflecting ideal beauty. In it, the furious man can contemplate Diana, that is, the universe in its entirety and unity.[108] In the moment in which it grasps the fundamental unity of reality, one reads, the intellect is "converted" into its object, "for love converts and transforms into the thing loved" (*perché lo amore transforma e converte nella cosa amata*).[109] Actaeon, who looked for goodness outside, is transformed into the object of his own desire—he was it already without knowing it—and from hunter he becomes prey: "he perceived that he himself had become the coveted prey of his own

106 According to Beierwaltes, "Actaeon," Bruno's *Atteone* is the furioso searching for the ideal. In his version of this myth, beauty is treated from the point of view of the ascent to conquer it, which is the central theme of the *Eroici furori*. For the neo-Platonic roots of this reasoning, see idem, *Denken des Einen*.

107 Bruno, *Heroic Frenzies*, 123; *Eroici furori*, 819.

108 Ibid., 820–21.

109 Bruno, *Heroic Frenzies*, 125; *Eroici furori*, 821.

dogs, his thoughts, because having already tracked down the divinity within himself it was no longer necessary to hunt for it elsewhere."[110]

Bruno also describes the manner in which Actaeon, finally free from his limitations and participating in the comprehension of truth, "sees everything as one, no longer through distinctions and numbers [...]. He sees the Amphitrite, the source of all numbers, of all species, the monad, the true essence of the being of all things; and if he does not see it in its own essence and absolute light, he sees it in its germination which is similar to it and is its image: for from the monad, the divinity, proceeds this monad, nature, the universe, the world; where it is contemplated and gazed upon as the Sun is through the Moon."[111]

Bruno builds here a bridge between ethics, cosmology and ontology.[112] Ethics and nature share the theme of infinity, which man grasps through his engagement in the world and the contemplation of the infinite universe. Nature witnesses the majesty of its origin, as one reads in the *Cena*:[113]

> This philosophy [not only] contains the truth, but also [...] it supports religion better than all other kinds of philosophies, such as those which suppose the world to be finite [...]. These philosophies not only blind the light of the intellect through being false but, being also impious and lazy, they quench the fervor of good actions.

Astronomy does not lose its traditional function as a premise for ethics. Yet, the transformed vision of the universe transforms the idea of correct behavior and values. The ethics of finitude gives way to an ethics of excess, or furious heroism. The aspiration to infinity *senza modo né misura alcuna*, without measure, is transferred from theology to the world.

The horizon of the Brunian *furore* lies in the immanent dimension of civilization and science, and proves anything but "useless" (*inutile*) or "fruitless" (*infruttuoso*) for human cohabitation.[114] Hence, in the *Eroici furori* he reinterprets the theme of epochal renewal, transferring it from the historical-philosophical dimension illustrated in *Spaccio* to individual consciousness. The furious hero is the individual fighting for a reform of mankind and the establishment of that new age announced by Copernicus and his cosmology.

110 Ibid.
111 Ibid., 226, *Eroici furori*, 921.
112 Müller, *Programm*, 213.
113 Bruno, *Supper*, 182; cf. *Cena*, 95–96.
114 Cf. Canone, *Dorso*, 109.

8 Bruno's Polemics, Banishments and Excommunications

Given his radical heterodoxy, if not impiety, it is not surprising that Bruno raised polemics almost everywhere he resided and taught: Geneva, Oxford, Paris, Wittenberg, Venice and, as I will discuss in more detail, Lutheran Germany. In 1579, he was excommunicated and imprisoned in Calvinist Geneva for the publication of a pamphlet directed against a local professor whom he had accused of twenty mistakes in his classes.[115] A similar episode occurred a year earlier in Turin, where a "foreigner," maybe Bruno himself, published a twenty-point pamphlet criticizing the local physician Giovan Francesco Arma for his opinions on the comet of 1577–1578.[116] Bruno's quarrel with the Puritans in 1583 and the suspicious reactions to his natural philosophy and Copernican ideas at Oxford University are well-known episodes in his biography.[117] Later, in Paris, he entered into a harsh polemic with a practitioner, Mordente, against whom he wrote an insulting booklet, *Idiota triumphans* (*Triumphant Idiot*), a mixture of irony, satire and sarcasm.[118] In 1586, he left Paris for the German provinces, after a disputation of his anti-Aristotelian *Articuli* met with the opposition of exponents of the party of the *politiques* whose support he desired. At Wittenberg, after giving classes on Aristotle's *Organon* for two years, he had to quit in 1588 due to the unstable political and religious situation at that university. There, he issued a reworked version of his anti-Aristotelian theses, but not without controversy since they supported "dangerous" ideas such as the atomic structure of matter and the eternity of nature.[119] He sought refuge at Helmstedt, but was eventually excommunicated there by the Lutheran superintendent, in spite of the fact that Duke Heinrich Julius (patron of the local university) received him with favor. The imprisonment by the Inquisition in Venice and the subsequent trial for heresy, his transfer to Rome and execution on 17 February 1600 are too famous to be recounted here.[120] Let us now focus on the Helmstedt environment, since Bruno's activity there and his excommunication might be revealing of the conflicts among Copernican realism, new natural philosophies and ethics in that Lutheran-Melanchthonian philosophical and theological culture which played a fundamental role in the dissemination of Copernicus's work.

115 Spampanato, *Vita*, "Documenti ginevrini," 132.
116 Omodeo, "*Stravagantographia*."
117 See Ciliberto-Mann, *Bruno: English Experience*.
118 Aquilecchia, "Introductory note" to Bruno, *Due dialoghi sconosciuti*.
119 See Canone, "*Hic ergo*."
120 The standard reference is Firpo, *Processo*.

There is not much historical information about Bruno's excommunication in Helmstedt. The case is summarized in a short letter dated 6 October 1589 that Bruno addressed to the prorector of the University, the theologian Daniel Hofmann. He complained about the public excommunication by the primary pastor and superintendent of Helmstedt and protested that the reasons were private.[121] Hence he requested that the Academic Senate and the Consistory examine his case. As ascertained through recent archival research, Bruno's excommunicator was Johannes Mebesius, a *magister artium* from Marburg who had been a court preacher to Landgrave Philip of Hesse-Rheinfels.[122] In 1589, Mebesius had become general superintendent of Helmstedt and professor of Hebrew at the university.

A funeral sermon, delivered in 1591, is the only extant printed writing of his. Although it is an occasional speech, neither theoretical nor academic, it reveals the centrality, for Mebesius, of faith at the expense of knowledge acquired by natural or rational means. This concept is seen in phrases such as: "If you know the Christ, you know enough, even though you ignore the rest./ If you do not know the Christ, to know other things is nothing" (*Si Christum discis, satis est, si caetera nescis./ Si Christum nescis, nihil est, si caetera discis*), and "he who is proficient in the arts but not in morality lacks more than he owns" (*Quid enim proficit in artibus, et deficit in moribus, plus deficit, quam proficit*).[123] These statements are sufficient to indicate the irreconcilability between his opinions and those of the foreign philosopher who wrote so extensively against "Pauline asininity."[124]

As for the excommunication, it is unlikely that it was formally correct. According to the *Kirchenordnung* (Church orders) ratified by Duke Julius in 1569, excommunication was a complex procedure that could be undertaken only against a sinner belonging to the local (Lutheran) Christian community. First, the pastor of the suspected person had the duty to inform him about his religious mistakes. Second, the general superintendent was supposed to talk to him in the presence of the pastor and another two clergymen. The third step in the process of excommunication should be the intervention of the highest

121 The document is preserved in the Herzog August Library in Wolfenbüttel (Cod. Guelf. 360 Nov., f. 43). A reproduction of this letter can be found in Canone, *Bruno: Gli anni napoletani*, 133. Cf. Spampanato, *Vita*, "Documenti tedeschi," VI, 665.

122 Omodeo, "Helmstedt 1589."

123 Mebesius, *Concio funebris*, f. A3*v*.

124 See Ordine, *Cabala*. Cf. Ciliberto, "Fra filosofia e teologia," for a reconstruction of Bruno's position in England in the context of the religious, theological and political tensions of the 1580s, since the English controversies show similarities to the Helmsted conflicts.

religious authorities, who had the prerogative of the final condemnation. The pastor would then inform the sinner about his excommunication in the Church, after his Sunday sermon. Afer that, the sinner was banished from the Church and the community of believers. The punishment basically consisted in exclusion from the Eucharist. After this procedure, the excommunicated was forced to sit on a special pew in the church every Sunday to listen to the sermons, reflect on his sins and, eventually, repent.[125] It is unlikely that Bruno was subjected to such discipline. At least, it has not been possible thus far to find consistorial documents relative to a formal excommunication. In the absence of more information, it is expedient to suppose that Mebesius's action was personal, as Bruno himself contended in his letter to Hofmann, and that neither the Consistory nor the Academic Senate were directly involved in the decision. In any case, the conflict between Mebesius and Bruno is an indication of the theoretical, philosophical and scientific tensions of that age. I shall therefore consider the Helmstedt environment in more detail, in particular the scientific culture of the university and some disputes about cosmological and astronomical issues that took place there, immediately before Bruno's arrival.

9 Cosmological and Anti-Epicurean Disputations at Helmstedt

Some anti-Pythagorean and anti-atomist disputations held at the University of Helmstedt bear witness to hostility toward Epicureanism, atomism and cosmological novelties in the years when Bruno was in Germany. The *Academia Julia Helmstadiensis* was then a young but renowned Melanchthonian university, founded by an imperial concession of 1575 following the model of Wittenberg. Its rapid development made it the third German university, after Wittenberg and Leipzig, in terms of number of matriculations.[126]

Around 1586, the Scottish scholar John Johnston of Aberdeen held two astronomical disputations there, *Hypolepses de coelo* and *De loco, inani et tempore*, showing a marked interest in the cosmological issue.[127] The author registered as *magister* on 10 August 1585 and obtained a degree in medicine in 1589. *Hypolepses* (from Greek ὑπόληψις: "conceptions" or "surmises"), was defended by a student in 1586. The approach was rigorously Aristotelian and rested on the hierarchical distinction between the sublunary and the supralunary realms

125 Koldewey, "Giordano Bruno," III/7, 49.

126 Volkmann, *Academia Julia*; Bruning and Gleixner, *Athen der Welfen*; Omodeo, "Sixteenth Century Professors" and idem "German and European Network."

127 Anderson, *Records of the Marischal College*, vol. 1, 113, fn.

of nature. The heavens were divided into an aethereal part and an empyrean one, which is the place of the angels and God. Johnston claimed for the superiority of the physical approach over the mathematical, arguing for the conventional character of the geometrical constructions employed by astronomers: "Their [mathematical] description [of the heavens] was cleverly invented and retained in astronomy due to its utility and agreeableness."[128] A *corollarium*, following the *theses*, was directed against the Pythagorean doctrine of celestial harmony: "We assert that the motion of the heavens is carried out without any noise or harmony of sounds, contrary to the opinion of the Pythagoreans and others."[129] The second disputation by Johnston, *De loco, inani et tempore* (*On Place, Void and Time*), completed this cosmological controversy, reasserting the natural premises of the Aristotelian doctrine of the heavens, precisely the basic concepts of Christianized Peripatetic physics concerning place, void and time. On the one hand, it contained a vehement criticism of atomist ideas such as the existence of empty space; on the other hand, it rebutted the eternity of time and the world, views that Aristotle embraced but were at odds with Christian theology. Johnston also revived the old anti-Epicurean objection that the doctrine of void and atoms impiously questions natural harmony: [130]

> As their assertions directly concern nature and attempt to undermine its constancy and order, we shall fight against arguments stemming from that conception of nature.

Johnston's polemic was continued by the Grammar professor, Simon Mencius, who defended a series of anti-Epicurean arguments in a disputation, *Argumenta aliquot*, containing, as stated in the title, *Some Arguments against the Erroneous and False Theses Concerning the Stars Held by the More Recent Epicureans; along with More True Opinions Thereabout and Some More Issues Pertaining to Astrology* (1587). Mencius was a respected professor in the Philosophy Faculty who also taught mathematics and astronomy, beginning in 1593. His disputation against the *Epicurei posteriores* begins with a long list of their "sins":[131]

> It is reported that the late Epicureans [...] taught and disseminated among many other dangerous and absurd doctrines—such as the atomic

128 Johnston, *Hypolepses*, th. 23.
129 Ibid., "Corollarium."
130 Johnston, *De loco*, th. 11. Cf. ibid., th. 10.
131 Mencius, *Argumenta aliquot*, f. A1*r*.

> composition of the world, the identification of the highest happiness with pleasure (which should be, for man, without limits), the alternate birth and destruction of worlds, the indifference of God relative to the government of human things, the explicit negation of divine providence, the chance occurrence of good and bad events, the contempt of pain regarded as mere opinion, the corruptibility and death of human souls, their dissolution together with the bodies, the end of life like sheep and its dissolution like smoke, etc.—also the paradox that the visible stars in the heavens are breaths and vapors, which are daily nourished by the exhalations from the earth and the sea. The old ones explode and are extinguished while new ones are formed and are enlightened, like lamps, and perpetuate the species of the Sun, the Moon and the other stars.

Before rejecting the Epicurean cosmology in detail—basically the atomic structure of natural bodies, the negation of a providential design, the birth and the death of planets and the elementary nature of the stars—Mencius mentioned the most illustrious authors who opposed Epicureanism, among them some moderns belonging to the Lutheran reformers: Melanchthon, Camerarius and Peucer.[132] As to the treatment the Epicureans deserved, according to Mencius, their cosmological ideas should be dispersed as obnoxious vapors and, "si minus agendum sit" (at least), such philosophers should be banished.[133]

10 Mencius against Epicurean Cosmology

In his *Argumenta aliquot*, Mencius expanded on the cosmological views of the atomists that he considered to be untenable. Among other things, he rejected the elemental composition of the celestial bodies. His criticism was based on the assumption that the thesis of the elemental nature of the stars meant that their matter should come from Earth. He thus attached a Stoic doctrine to the Epicureans, such that his objection did not really touch atomism.

Mencius objected that the stars cannot be likened to *vapores*, that is, they cannot be composed of matter from the sublunary sphere. This was actually a Stoic doctrine, on which several classical sources reported (among them, Aristotle, Cicero, Diogenes Laertius and Seneca).[134] If the stars had a corruptible

132 See Dillenberger, *Protestant Thought*, 40 and Moran, "Universe," 10–13.

133 Ibid., th. 2, ff. A2*r*–*v*. On the theological inacceptability of atomism, see Redondi, *Galileo: Heretic*.

134 Granada, "Bruno et le banquet de Zeus."

nature, they could not show regular motions (*tanta motus certitudo tamquam constantes leges*). Mencius stressed the huge distance of the celestial bodies from Earth, which made it unlikely that they could be fed by terrestrial matter. In his argument, he derived their distances from Ptolemy, Regiomontanus and even Copernicus. Mencius deemed thus that it was possible to keep separate Copernican numbers and hypotheses, which he rejected. Following Aristotle, Mencius embraced the distinction between Earth and heavens against cosmological homogeneity, that is, between terrestrial corruptibility and celestial inalterability.[135]

The amazing velocity required for the fixed stars to accomplish their daily rotation—which appeared to Copernicus and most Copernicans as a compelling argument in favor of the axial rotation of the Earth—seemed to Mencius an argument in favor of celestial perfection. He extolled the stars' quickness: "The velocity of that motion, which Cicero and we regard as wonderful, can be easily grasped through consideration of the wide celestial spaces."[136] Additionally, some theses (precisely, 26 and 27) were directed against the "Pythagorean" idea of universal life both on and of the celestial bodies. In northern Germany, this idea was actually endorsed in those years by Pegel and Bruno for different reasons and was supported more generally by vitalist Renaissance philosophers:[137]

> But we leave assert and defend that doctrine—that the stars have life in the same manner as animals or they are endowed with a divine mind—to those who are delighted by such idle arguments and ridiculous reasons. Since there is no experience on Earth or any biblical passage in support of that opinion, we judge that it is right to reject it.

After this rebuttal of the Epicurean *delirationes*, Mencius expands on the order of those "very light and perfectly spherical celestial bodies" (*ea corpora coeli lucidissima, orbicularia et spherica*) considered to be "divine witnesses" (*divina testimonia*) of God's Providence. Their motions are the measure of the days and the years and enlighten the elemental realm. Thus, as thesis 30 states, the effects of the stars on the Earth are unquestionable. The influences of the closer planets are stronger than those of more distant bodies. In his eyes, astrology is the science of divine Providence, even though Luther did not accept it. This error committed by "the holy German prophet" (*sanctus Germanorum*

135 Mencius, *Argumenta aliquot*, f. A3*v*.

136 Ibid., f. B1*v*.

137 Ibid., f. B2*v*.

propheta) should be excused since astrology was corrupted by many superstitions that undermined its credibility.

11 Bruno's Support of Atomistic Views

Even though no direct relationship between the Helmstedt scholars Johnston and Mencius, on one hand, and Bruno, on the other, can be traced in 1586 and 1587, Bruno must have met Mencius in Helmstedt when he matriculated there. The contrast between their natural and cosmological views could not be stronger. In fact, in those years, Bruno was one of the most prominent supporters of Epicurean cosmological theses, which he disseminated in Germany. In particular, he was trying to unify the astronomical theory of terrestrial motion with natural theses on void and the atomic structure of matter. As I have already stressed, in the Italian dialogues issued in London in the years 1584–1585, he had already criticized the Aristotelian philosophy and expanded on the ethical consequences of his new worldview. Contrary to the Aristotelian principles reasserted by Johnston, in particular he revised the concepts of place and the possibility of infinity already elaborated in *De l'infinito*. In an infinite universe there was no possibility for absolute directions, as was the case in Peripatetic philosophy.

Even back in his Italian dialogues, Bruno celebrated Democritus and Epicure as those "who contemplated nature with open eyes" (*con occhi più aperti han contemplata la natura*) and he proved to be an attentive reader of Lucretius.[138] Thus, in *De l'infinito*, he exalted Epicure's doctrine, summarizing it as follows: "Epicure similarly nameth the whole and the universe a mixture of bodies and of the void; and in this universe and in the capacity thereof to contain the void and the empty, and furthermore in the multitude of the bodies contained therein he maintaineth that the nature of the world, which is infinite, doth exist."[139]

On this basis, Bruno questioned the theory of natural places. After his arrival in Germany, at Wittenberg, in 1586 (he matriculated on 20 August), he might have further disseminated his views to his students. In the *Oratio valedictoria*, delivered when he left the University of Wittenberg in 1588, he exalted

138 Bruno, *Infinite Universe*, 374; *De l'infinito*, 450. Cf. Granada, "Epicuro y Giordano Bruno."

139 Idem, *Infinite Universe*, 272–73; *De l'infinito*, 347.

Copernicus, whom he compared to Cusanus as one of the great German modern thinkers:[140]

> Who do you think Copernicus was, only a mathematician or rather (which is rather surprising) a physicist too? It seems that he grasped more in two chapters than Aristotle and all Peripateticians in their famous universal contemplation of nature.

It should be remarked that, in this passage, Bruno presented Copernicus not as a mathematician but as a natural philosopher and, what's more, as a radical opponent of Aristotle.

In his Wittenberg oration, Bruno praised Landgrave Wilhelm IV as one of the German restorers of astronomical wisdom, the roots of which could be traced back to the Babylonians and the Pythagoreans. Furthermore, Bruno summarized his natural ideas concerning the principle of universal homogeneity, the rejection of material heavenly spheres, the plurality of heliocentric systems in the universe, his vitalist planetary dynamics and the celestial nature of the Earth. This *Oratio valedictoria* is evidence that Bruno did not refrain from teaching his cosmological and natural ideas while residing in Wittenberg. Indeed, he tried to disseminate his ideas by all means, even on public occasions.

In the same year, 1588, Bruno issued a revised and augmented version of the Parisian theses against Aristotle. This work appeared in Wittenberg, as *Camoeracensis* or *Cambrai Acrotismus*, presenting *Arguments in Support of the Physical Articles Against Peripatetics*.[141] It was a polemical text repeating the aforementioned objections to Aristotelian natural philosophy while offering alternative views on the same topics. The *Acrotismus* also included a materialistic definition of nature (*Naturae nomine dignior est materia*) and an atomistic conception of matter (*Continuum ex indivisibilibus componitur*). Additionally, Bruno presented his Pythagorean-Platonic conceptions in opposition to those of the Aristotelians in a section unmistakenly entitled "Pythagorean and Platonic Assertions that We Support Contrary to the Peripatetics" (*Pythagoricae, et Platonicae peripateticis imperviae assertiones, quas probamus et defendimus*). He reassessed the doctrine of nature as a living artist (*ars vivens*) who forges things from within, "materiam perpetuo figurans" (perpetually forging matter).

140 Bruno, *Oratio valedictoria* (Wittenberg, 8 March 1588), in BOL, I,1, 17. Bruno's familiarity with the Wittenberg professors is demonstrated by the dedicatory letter of his *De lampade combinatoria lulliana* of 1587, which is directed to the chancellor and the Academic Senate.

141 Bruno, *Camoeracensis acrotismus* (Wittenberg, 1588), in BOL, I,1.

Bruno's Wittenberg publications, along with Johnston's and Mencius's Helmstedt disputations, reveal the ongoing natural debates and philosophical tensions at northern European Reformed universities. In those years, Pegel, who had been professor at Helmstedt from 1575 to 1581, published his Stoic theses on astronomy and void in Rostock.[142] The Helmstedt disputations seem to be an attempt to defend the Peripatetic views that Pegel questioned and Bruno would soon disseminate in Helmstedt as well.

12 "New Astronomy" at Helmstedt

In spite of these anti-Epicurean polemics, Bruno was initially well received in Helmstedt in 1589. On 1 July, he delivered an *Oratio consolatoria* in commemoration of Duke Julius, who had expired on 3 May of the same year. Thanks to this speech Bruno entered the graces of his successor, Duke Heinrich Julius.

Heinrich Julius was a cultivated man, with a lively interest in the arts, literature and science. His father Julius had founded the Lutheran University of Helmstedt, called *Academia Iulia* after him. Bruno matriculated there on 13 January 1589 as "Jordanus Brunus, Nolanus Italus."[143] The new duke's inclination toward the so-called "Philippism" (that is, a tolerant religiosity, open to humanist culture and inspired by Melanchthon) led to an open policy, very indulgent concerning the religious beliefs of the new professors appointed to the university. Attracted by this cultural atmosphere, several foreigners (or men of foreign origins) belonging to the so-called German Late Humanism (or *deutscher Späthumanismus*) moved there from Rostock, despite their possibly Calvinist background. At the beginning of 1590, Heinrich Julius attracted first Johannes Caselius, of Dutch origins. This scholar was a specialist in Greek literature, who wrote and taught on Aristotle's *Rhetoric*, *Ethics* and *Politics*. He was exempted from the usual duty to swear a Lutheran oath to the *Kirchenordnung* and was endowed a stipend much higher than any of his colleagues in the Theology Faculty. Furthermore, in 1591, the Scotsman Duncan Liddel, an acquaintance of Tycho Brahe and Paul Wittich, was welcomed as a professor of mathematics.[144] In July 1591 Cornelius Martini of Antwerp matriculated at Helmstedt and became a professor of philosophy, in particular logic, beginning in 1592.[145] As already remarked, Heinrich Julius protected Bruno as

142 See chap. 4,8.
143 Zimmerman, *Album*, vol. 1, 73, n. 31.
144 Ibid., 412–13.
145 Ibid., 432–33. See Pozzo, *Adversus Ramistas*, 20–22.

well. He endowed him with an award for the funeral oration delivered on the occasion of his father's death.[146]

The local Lutheran Church and the University of Helmstedt were subordinated to the political authorities, although they benefited from a certain autonomy. Bruno was supported at court but opposed from the pulpit. It is very likely that the animosity toward him originated in the university. Even though he did not occupy a chair, he was able to teach in private and gathered around himself a group of students. Among them, Hieronymus Besler had followed him from Wittenberg and would follow him to Italy.[147] Bruno's teaching met with success, as emerges from the printing of a poem, *Ad Iordanum Brunun Nolanum Italum* by Valens Havekenthal, known under the Latin pseudonym of Acidalius. This poem included a composition praising Bruno in his collection of epigrams (*Epigrammata*, 1589).[148] Acidalius was a humanist, philologist and physician who received his education at Rostock and Helmstedt under Caselius and later published in Bologna and Padua when Bruno was in Italy (actually during his Venetian stay and imprisonment).[149]

Concerning theological oppositions to Bruno, there is a relevant disputation of 1590 entitled *Oration on the Horrible and Unusual Earthquake That Has Recently Shaken Austria with Force … along with a Useful Explanation of the Causes of the Earth's Motion Both Physical and Theological*. The "terrae motus" in the title evidently refers to an earthquake, but some pages are dedicated to the Copernican *terrae motus* as well and offer a clue to the opinions of the Helmstedt theologians, or at least of *one* of them, concerning the heliocentric system. Heidenreich's judgment is negative for theological and natural reasons:[150]

> Certainly, the Earth has been founded by the highest Creator of all things, which is God, so that it is firmly established in a regular and ordinary manner, and it does not move. Rather, it benefits of eternal immobility for its stability. This is confirmed by the Sacred Scripture in several passages saying that the Earth does not move, but stands still, and this perpetually. […] And we shall use wit to contradict this statement, as several philosophers did in the past, in particular the Pythagoreans (according to

146 Bruno, *Documents I*, *Le procès*, 53, n. 11.

147 Besler matriculated at Helmstedt on 19 November 1589. Cf. Zimmerman, *Album*, vol. 1, 79.

148 Acidalius, *Epigrammata*, 11–12.

149 Canone, *"Hic ergo,"* 121, "Acidalius, Valens," NDB 1 (1953), 34, and Di Giammatteo, "*Valentini Acidali Epigrammata*."

150 Heidenreich, *Oratio*, ff. D1*v*–D2*r*.

> Aristotle), who taught that the Earth rotates about the center of the world. [...] Such opinions can be found also in Plutarch's *De placitis philosophorum* and have been revived by Nicholas Copernicus, in our times.
>
> We rightly reject those [theses] thanks to the clear witnesses from the Sacred Scripture and nature itself, actually experience. Those opinions are so distant from that [experience] that they are as certain and true as that assertion by the physicist Anaxagoras—the worst of all those ambitious philosophers—who seriously asserted that the snow is black and minimally white.

Bruno knew Heidenreich. This emerges from a letter by his pupil Besler, who reported that Bruno, after receiving an award of 50 florins from Heinrich Julius in Wolfenbüttel, participated in one of the theologian's disputations on 13 April 1590.[151] The Herzog August Library preserves two 1590 publications by Heidenreich, both theological. One contains two orations: *Orationes Duae, prior de vera viventis Dei cognitione, ... Posterior de duplici, sacra oracula tractandi ratione* (*Two Orations: One on the True Knowledge of the Living God ... the Other on the Two Ways of Treating Holy Oracles*). The second text is a theological disputation on the rule and foundation of faith (*Disputatio de norma et fundamento fidei, et religionis Christianae*). According to a handwritten annotation on the frontispiece, it was disputed on 10 April 1590.[152] There is no trace of the 13 April disputation which Bruno presumably attended, unless it is to be identified as this theological disputation (and one assumes that there is an error of date in the handwritten annotation). Thesis 21 of that disputation is directed against the Epicureans and affirms that the point of departure of theology is not philosophical or rational, but rather the inner certainty of faith.[153] Heidenreich's views, in particular fideism, anti-Epicureanism, and his rebuttal of the Copernican system are rather opposite to Bruno's convictions. They show the incompatibility between Bruno and several professors, among them Heidenreich and, of course, his excommunicator Mebesius.

13 Liddel's Teaching of Astronomy and Copernican Hypotheses

In the same year 1591, in which Bruno dedicated his Frankfurt poems to Heinrich Julius and the theologian Heidenreich criticized Copernicus in

151 Spampanato, *Vita*, "Documenti tedeschi," 666–67, n. 7 and n. 8.
152 Herzog August Bibliothek, coll. A: 202.14 Theol. (4).
153 Heidenreich, *Disputatio*, ff. B1*r*–*v*.

a dispute, Duncan Liddel was appointed as a professor of mathematics at Helmstedt. One of his credentials was thorough knowledge of Copernicus's astronomy and his acquaintance with Brahe, as shown by the documents relating to his appointment. In a recommendation letter for Liddel, Caselius informed the Academic Senate of the skills of the young Scottish mathematician. He mentioned Liddel's expertise concerning Copernicus's theories and underscored that the young mathematician had discussed them at length with the Rostock professor Heinrich Brucaeus.[154]

> I assure you that Duncan is a honest and humble man, with an acute intelligence and considered judgment. From childhood, he dedicated himself to all good arts with great diligence. He is outstanding in logic and physics. He especially excels in mathematics, so that the able mathematician and illustrious man Mr. Henricus Brucaeus likens him to the most skilful experts and openly declares that even he has benefited from his frequentation. In fact, I remember that they discussed Copernicus's hypotheses for many months. Moreover, Duncan discussed very subtle mathematical issues with the prince of the mathematicians of our age, namely Tycho Brahe.

For his appointment, Liddel sustained a disputation entailing *Astronomical Propositions on the Differences and Causes of Days and Years* (*Propositiones astronomicae de dierum et annorum differentijs et caussis*, 1591), which is also preserved among the university documents, *Acta M. Duncani Liddelii*, in the *Niedersächsisches Staatsarchiv* of Wolfenbüttel.[155] The topic is strictly astronomical. Copernicus is mentioned twice, not for his hypotheses but rather as a supporter of the motion of the Sun's apsides (th. 10) and as an emendator of Ptolemy's theory of the equinoxes (th. 19). It should be remarked that the aim of the disputation was not to raise controversial issues, but rather to ensure the success of Liddel's candidacy. Hence, he showed his familiarity with Copernicus's astronomy without tackling delicate cosmological problems. Another disputation, on *Philosophy and Its Instruments* (*De philosophia eiusque instrumentis*), of January 1592, reveals the author's philosophical background. Following Aristotle, he attaches to mathematics the dignity of a philo-

154 Caselius to the Academic Senate of the Academia Julia (1591).

155 Liddel, *Propositiones astronomicae*, in the aforementioned *Acta M. Duncani Liddelii*, ff. 50–52.

sophical and contemplative discipline along with the first philosophy (*prima philosophia*), or metaphysics, and natural philosophy (*physica*).[156]

> Alongside physics and metaphysics, mathematics is the third part of theoretical philosophy, occupying an intermediate place. It is a distinct contemplation of species, abstracted from natural substance, which, however, cannot subsist without that substance.

Liddel's conception relied on shared assumptions concerning disciplinary order and subdivisions: the objects of mathematics are abstract entities, which do not subsist *per se*, that is, quantities and the "species" and "affections" of quantity. Arithmetic, one reads, deals with discrete quantities, whereas geometry deals with continuous quantities. Astronomy is one of the mixed disciplines (*disciplinae mixtae*) based on both mathematics and physics. In this respect, astronomy is similar to music (*ratio sonorum*), *logistica* (or *algebra*, dealing with the "roots of cubes" and similar issues), optics (*de oculorum radijs, umbris*), *mechanica* (*de operibus et structuris*) and geodesy (*de dimensionibus rerum sensibilium*). Liddel's public disputation does not contain surprising theses, but an element of originality is shown by the *coronides*, the corollaries, directed against Pierre de la Ramée's epistemology. The fourth corollary, in particular, states the impossibility of an astronomy without hypotheses: "If one eliminates hypotheses, which save and explain celestial motions, it is impossible to make astronomy, *pace* Pierre de la Ramée."

Liddel did not openly declare his adherence to a particular planetary system in either the aforementioned disputations or in other extant writings. However, he was the first to officially introduce the teaching of Copernicus's hypotheses at Helmstedt, as documented for instance by the *Ordo Studiorum* of 1594/1595 (one of the few extant syllabi from the end of the sixteenth century): "Duncan Liddel will explain, with God's inspiration, the fundaments of geometry, all figures and geodesy, together with the doctrine of the triangles. After that, he will introduce the theory of celestial motions according to three hypotheses, and will moreover explain the tables, Alfonsine as well as Prutenic."[157] The three competing hypotheses mentioned are those of Ptolemy, Copernicus and Brahe.

When Brahe was informed of Liddel's classes, he was enraged and accused him of plagiarism, as emerges from his letters.[158] Yet other scholars appreciated the fact that Liddel dealt so extensively with hypotheses in his classes.

156 Idem, *De philosophia*, f. A2*v*.

157 *Ordo Studiorum et lectionum, in Academia Iulia… anno 1594*. Cf. http://diglib.hab.de/periodica/yq-2-4f-helmst-ws1594-1595/start.htm (15 May 2010).

158 Omodeo, "*Iter* europeo," 34–43.

Caselius, for one, wrote to the Scottish physician Craig, on 1 May 1607, that Liddel should be extolled as the first to introduce the teaching of the three major planetary models in German universities, first at Rostock and later at Helmstedt:[159]

> At Rostock our [Liddel] introduced almost the entire discipline [astronomy] more than once. To my knowledge, he was the first who, in Germany, taught the theory of heavenly motions at the same time according to the hypotheses of Ptolemy and Copernicus. Furthermore, he added the single planetary theories also according to the third hypothesis, whose outline [διατύπωσις] was proposed by Tycho in his book on the ethereal phenomena [*de aethereis phaenomenis*].

14 Hofmann's Quarrel over Faith and Natural Knowledge

A few years later, at the time Bruno was imprisoned and executed in Italy, Liddel was involved in a heated quarrel concerning the relationship between faith and natural science. Daniel Hofmann, who had probably orchestrated Bruno's excommunication in 1589, provoked the polemic. In 1598, the theologian harshly attacked philosophy and rational thought in the introduction of a disputation, *De Deo et Christi tum persona tum officio* (*On God, and the Person and Office of the Christ*) by Kaspar Pfaffrad, professor-to-be of the Theology Faculty. In particular, he accused philosophers of being the "patriarchs of all heretics" (*philosophos esse haereticorum patriarchas*), along with Tertullian (*De praescriptione haereticorum*, VII).[160]

Four professors of the Philosophy Faculty promptly reacted to the provocation. A polemic arose which is remembered as *Hofmannstreit* (the Hofmann controversy). Hofmann's opponents were Owen Günther, who occupied the chair of Aristotelian philosophy, the humanist Caselius, the professor of logic Martini, and Liddel. The closeness, or at least the ideal proximity, between Bruno and this group is indicated by the aforementioned *Epigrammata* of Acidalius (1589) in which the poem in honor of Bruno (one of the first of the collection) precedes verses *ad Cornelium Martinum* (p. 45, pp. 52–54 and p. 60) and follows poems dedicated to Caselius (three poems *ad Ioannem Caselium*: pp. 6–7, p. 7 and p. 8), Brucaeus (*ad Henricum Brucaeum*, pp. 8–9) and the Melanchthonian humanist Nathan Chyträus of Rostock (pp. 9–10). The polemic that erupted in

159 Caselius, "Epistola" to Craig (Helmstedt, 1 May 1607), f. †4*r*. This letter was later published as an introduction to Liddel's medical textbook *Ars medica* (*Medical Art*, Hamburg, 1608).

160 Hofmann-Pfafradius, *Propositiones de Deo*, ff. A2*r*–*v*.

1598 produced many writings, pamphlets and letters, most of which are preserved in the Herzog August Library of Wolfenbüttel. Among them: Günther's *Theologiae et philosophiae mutua concordia* (*The Mutual Harmony of Theology and Philosophy*), Caselius's *Epistolae ad D. Danielem Hofmannum scriptae item accusatio Facultatis Philosophicae* (*Letters to Dr. Daniel Hofmann Written in Response to His Accusation of the Philosophy Faculty*) and Martini's *Status litis Hoffmannianae* (*State of the Art of the Hofman Controversy*). Hofmann's colleagues in the Theology Faculty also failed to support him. Laurentius Scheurl, Mebesius's successor as general superintendent of Helmstedt, sided with the philosophers, while Heidenreich avoided entering the polemic.[161]

Apart from the relationship between philosophy and faith, another implicit point that divided Hofmann and his opponents might have come from the fact that Helmstedt Ramists shared the theologian's aversion to Aristotelian logics and metaphysics. In spite of the fact that the teaching of Ramism had been forbidden in Helmstedt since 1592, traces of that philosophy were present; otherwise it is difficult to understand the verve of several anti-Ramist publications by Martini (and anti-Ramist remarks in Liddel's writings). A supporter of Ramism was Kaspar Pfaffrad, who taught Ramist logic between 1588 and 1592.[162] This context of Ramist-Aristotelian polemics helps us understand a remarkable accusation of Martini written by Hofmann and addressed to the duke in September 1598. In that letter, Hofmann denounced Martini for the private teaching of Aristotle's metaphysics in spite of Luther's and Melanchthon's opposition to the doctrine.

To settle the controversy, Heinrich Julius instituted a board of inquiry composed of professors from the faculties of jurisprudence and medicine who were not directly involved in the matter. They accepted the arguments of the philosophers. At the same time, the duke prohibited any further polemical publications but, in the face of Hofmann's persistence, he ordered his house arrest, first at Helmstedt and then at Wolfenbüttel, with the interdiction to meet anyone. This severe decision weakened the theologian's obstinacy. At the same time Heinrich Julius requested an expert opinion from the University of Rostock in order to quickly dispel the controversy. The verdict from Rostock was favorable to the philosophers. Thus, by an act of supremacy over the Church and the University, Heinrich Julius disposed that all the litigants should sign an act of pacification. They declared their firm intention to cease the polemic and to strictly keep to the limits of their disciplines. In this way, a marked separa-

161 The most accurate account of this episode is Friedrich, *Grenzen*. See also Mager, "Lutherische Theologie."

162 Pozzo, "Ramus' Metaphysics," and idem, *Adversus Ramistas*.

tion of the competences of the philosophers and the theologians was affirmed. This also meant Hofmann's capitulation. He had to abjure his theses against philosophers on 19 March 1601 and, directly thereafter, went into exile for three years.[163]

15 Franckenberg and the Spiritualist Reception of Bruno and Copernicus

The reception of Bruno's work and the dissemination of his ideas in the seventeenth century strengthened the philosophical and ethical interpretation of Copernicus's achievement. Science historians know of the presence of several of Bruno's followers in Prague. The imperial functionary Wackher von Wackenfels, a follower of Bruno, gathered together several estimators of his philosophy, including Kepler's and Galilei's friend Bruce and the poet Acidalius. Furthermore, Heinrich Julius remained in Prague from 1607 until his death in 1613, in a period when the Rostock mathematician and physician Pegel also sojourned there. Emperor Rudolph II himself supported Bruno, awarding him three hundred talers in 1588 for the dedication of the *Articuli adversus mathematicos*. Apart from patronage and networks, two very different texts offer a clue about the seventeenth-century Brunian reception of Copernicus: *Oculus sidereus* by the German spiritualist Abraham von Franckenberg, and *Philosophia Epicurea, Democritana, Theofrastica* by the English philosopher Nicholas Hill. These two sources can be used to trace respectively a spiritualist, theological and heterodox line of reception and an Epicurean, atomistic and natural philosophical one. Since in both works Copernicus's system and Bruno's philosophy are interconnected and receive a clear ethical connotation, it is expedient to consider them in this discussion. I will begin with the spiritualist line of reception and then consider the Epicurean one.

The Silesian aristocrat Abraham von Franckenberg of Ludwigsdorf (known in Polish as "Ludwikowice Kłodzkie") is remembered in history mainly as a follower, a biographer and an editor of the mystic Jacob Böhme.[164] He is also known for his lively interest in natural philosophy, as well as in Paracelsian medicine, alchemy, cabala and speculative *mathesis*. The local religious authorities attacked him for his inclination towards an intimate and radical Christianity (including a refusal to take confession and the Eucharist, and an

163 A copy of the decree, in German and Latin, and of the *declarationes* by the opponents is preserved in the Herzog August Bibliothek in the miscellanea coll. H: 19 Helmst. Dr.

164 Gilly, "Zur Geschichte."

objection to every kind of war).[165] In order to avoid religious conflicts and the invasion by the Swedish army during the Thirty Years' War, he abandoned his native region. In 1642, he headed for Gdańsk, where, according to biographies, he was welcomed and supported by the astronomer Johannes Hevelius from 1641 to 1649.[166] Franckenberg became well acquainted with Hevelius, and their closeness is shown by the fact that they carried out astronomical observations together. In 1644, Franckenberg published *Oculus sidereus*, which is regarded as an important testament to the circulation of Bruno's work within the northern European "esoteric, pansophical and theosophical culture."[167] As one reads in that book, Hevelius not only carried out some telescopic observations of Venus and the Sun with him, he also showed Franckenberg a large number of drawings (probably the engravings that were to be published in *Selenographia*).[168] Apart from this, Franckenberg wrote to his correspondent in London Samuel Hartlib that Hevelius was one of those who, along with Johannes Amos Comenius, approved his *Oculus sidereus*.[169] A laudatory poem by Franckenberg was then included in Hevelius's famous work on the Moon, *Selenographia* (1647).[170] This short composition in verse is based on the play on words between the name "Hevelius" and the expression "ev-helius" (good Sun). In accordance with the assonance, Franckenberg likened Hevelius, for his achievement, to an enlightening benefactor of astronomy.[171]

As shown by a letter to the Jesuit Athanasius Kircher (27 February 1649), Franckenberg considered his philosophical work to be an introduction, or rather an announcement, of the natural truths that Hevelius had indisputably demonstrated in *Selenographia*.[172] In other words, he claimed the compatibility, even the complementarity, between *Oculus sidereus* and Hevelius's work.

Oculus deals with Copernican astronomy, telescopic discoveries (or alleged discoveries), Bruno's infinite cosmology and theological matters relative to the reconcilability of science and Scripture. It is composed of three parts. The first deals with terrestrial motion (*von Bewegung der Erdkugel*) and

165 Cf. Brecht, "Schlesischen Spiritualisten." On Franckenberg see also Czerniakowska: "Franckenberg," Bruckner, *Abraham von Franckenberg* and Stockum, *Zwischen Böhme und Scheffler*.

166 Cf. Zedler 9 (1735), *s.v.* and NDB 5 (1971), *s.v.*

167 Ricci, *Fortuna*, 137–38.

168 Franckenberg, *Oculus*, f. C3*v* and D1*v*.

169 Franckenberg to Samuel Hartlib (Gdańsk, 25 August 1646), in *Briefwechsel*, 197.

170 Hevelius, *Selenographia*, f. ****2*r*.

171 Franckenberg often employed this kind of pseudo-etymology in his writings. See Szulakowska, *Sacrificial Body*, chap. 7, 141 ff.

172 Franckenberg to Kircher (Gdańsk, 27 February 1649), in *Briefwechsel*, 224.

telescopic discoveries, the second with the form of the world as a whole ([*von*] *der eigentlichen Gestaldt, dieser sichtbaren Weldt*), while the third part aims to unveil the divine providence underlying nature (*zu höherem Erkandnüß Gottes, und seiner Wunder*). The first of these three sections is an exposition and a natural reworking of the Copernican doctrine of terrestrial motion along with a discussion of recent telescopic observations. The second part is a defense of infinite space and universal homogeneity, as well as the plurality of worlds. It is based entirely on Bruno. In fact, it is essentially a review of the *De immenso*. Franckenberg described this philosophical poem as "eight books presenting profound and exhaustively thorough investigation into obscure and revealed nature."[173] The third part of *Oculus* is a theological apology for a post-Copernican and Brunian cosmology. Here, Franckenberg claimed the fundamental accordance between nature and Scripture, "as two faithful, cherubic witnesses of the New and Old Testaments."[174] His main argument was that they are two forms of God's revelation.[175]

Franckenberg added some appendices as a conclusion. The first, *Appendix A*, contained a catalogue of all publications by Bruno that he could consult or hear of, followed by several quotations from these sources. The Brunian intention of Franckenberg's book is emphasized by the mottos in the frontispiece. They encircle a cosmological image, which includes a symbolic representation of astronomy at its center and pictures of the six planets (including the Earth), plus the Moon and the Sun, according to the features inferred through the telescope. The mottos hint at Brunian cosmological ideas: plurality of worlds (*non sufficit unus*), boundless space (*plus ultra plus ultra*), the so-called principle of plenitude (*unus in immenso non sufficit aethere mundus*), the intellectual deduction of infinity and pluralism (*plus ultra nitidos mens videt alia polos!*) and the omnipresence of the unitarian metaphysical principle of reality across the universe (*plus ultra, sine fine, per omnia, ubique*) (see figure 8).

Franckenberg declared his spiritual commitment in the preface: "Encouragement to the observers of the wonders of the Almighty: eternal wisdom delights the hearts of its children with the radiant light that emanates from it."[176] According to him, human beings are spectators of God's unfolding through nature. Divine revelation is not complete, however, because it is still

173 Idem, *Oculus*, f. E1*v*.

174 Ibid., f. 2*v*.

175 Summarized in section LVII, ibid., f. G3*v*.

176 Ibid., f. A2*r*.

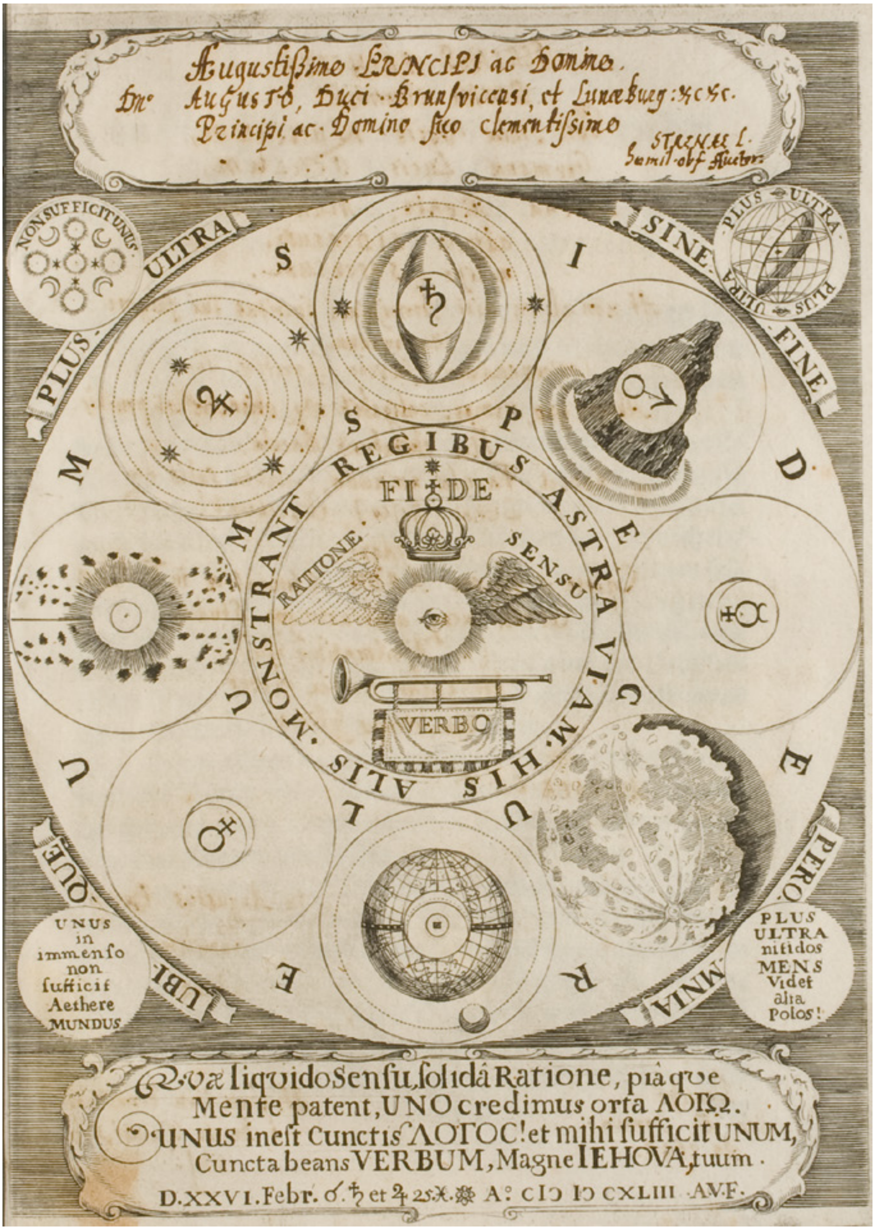

FIGURE 8 *Frontispiece of the Copernican and Brunian work by Abraham von Franckenberg,* Oculus Sidereus *(Gdańsk, 1644)*
COURTESY OF THE HERZOG AUGUST LIBRARY (WOLFENBÜTTEL, GERMANY).

an unfinished process. The advance of natural knowledge is itself a sign of the unveiling of the divinity through the ages.[177]

Franckenberg mainly owes his conception of the progressive revelation of God through science and nature to Campanella. He often refers to the *Apologia pro Galilaeo* (1622), which he quotes also in order to point out the gulf dividing the knowledge of the Ancients from that of the Moderns:[178] "The moderns can see things the ancients did not see" (*Quod non viderunt Veteres, videre possunt Moderni*). More generally, Franckenberg relies on a wide range of Renaissance authors (such as Patrizi, Scaliger, Postel, Agrippa, Kepler, and Galilei) whom he quotes extensively, demonstrating a thorough acquaintance with the scientific and philosophical literature of his time. Sporadic references to Descartes can be found as well.

As far as the defense of the Copernican system and terrestrial motion are concerned, these theses are included in an infinitist framework, which is derived from Bruno but also refers to Cusanus, whom Franckenberg mentions in relation to infinity of space and terrestrial motion.[179]

According to him, there are five motions of the Earth.[180] The first three are the three main terrestrial motions illustrated in Copernicus's *De revolutionibus* and Rheticus's *Narratio prima*: axial rotation, annual revolution and *motus declinationis* (the "motion of declination" which accounts for the constant tilt of the Earth's axis during the year and the precession of the equinoxes). Apart from these, Franckenberg adds "*das Erdbeben*,"[181] the earthquake, and "*das wachsende oder gebärende Leben*,"[182] which can be translated as the "growing and birthing life" of the Earth, which Franckenberg often calls *Terra Mater*. Man is a microcosm or, better, a "micro-Earth." Section XIX, on Adam, states that man "himself is a movable and moving Earth."[183]

To designate nature, Franckenberg uses expressions similar to those attributed to the Earth: "Natura Omni-varia Omnium mater [est]."[184] Nature, this powerful source of life, progressively and freely realizes a divine project.[185] Not only does human knowledge advance in time, but nature itself gradually realizes perfection.

177 Ibid., f. B1*r*.
178 Ibid., f. B1*v*.
179 Ibid., f. B4*r*.
180 Ibid., f. B4*v*. ff., section XIV.
181 Ibid., f. C1*r*, section XV.
182 Ibid., f. C1*v*, section XVI.
183 Ibid., f. C2*r*.
184 Ibid.
185 Ibid., f. C2*v*.

As a testament to natural and epistemic progress, Franckenberg reported the most admirable discoveries of his age. Most, but not all, of them were the results of post-Galilean telescopic observations: sunspots,[186] four satellites about Jupiter and two about Saturn,[187] and the phases of Venus and other planets.[188] As an additional discovery, he referred to the establishment of the Earth as a planet and a lodestone, according to several authors including Gilbert.[189] He then referred to the changing shape of Saturn, one and three-fold, and to the surprising observation of a great black mountain at the center of Mars, a mistake derived from some reports by the Neapolitan lens-maker Francesco Fontana.[190] The next major astronomical discovery, as one reads in *Oculus sidereus*, was the absence of material spheres to transport planets. Franckenberg rebutted this scholastic assumption and claimed that the heavens are exclusively filled with air (*aura*). He conceived of this element as a kind of Stoic life-giving pneuma:[191] "Lufft, Athem, Geist und Leben." These views are connected with infinity of space, an idea shared by Patrizi, Cusanus and Bruno, but also, among the ancients, by Pliny (*Naturalis historia*, II). Another "discovery" is the plurality of Earth-like inhabited worlds. Franckenberg supported that conception using an argument of plenitude, according to which nothing can be vain and void in the universe due to divine benevolence.[192] He even described the wonderful things to be expected on other planets.[193] In particular, he presented the Moon as follows:[194]

> One can expect to see, especially on the Moon, earth and water, stripes and lines, mountains and valleys, rivers and reefs, rain and dew, fields and forests, grasses and trees, and every kind of creature [...] cities and palaces, friends and enemies [...] an abundance of such animals, fauna, and people far greater, more beautiful and more immutable than ours [...] and thus not a discernible trace of vacuum or desert or barren emptiness.

The idea of life on other planets, in particular on the Moon, also emerges from many passages by Hevelius. Franckenberg's fantastic description of the life,

186 Ibid., f. C3*r*, section XXV.
187 Ibid., f. D1*r*, section XXVI.
188 Ibid., f. D1*v*, section XXVII.
189 Ibid., f. D2*r*, section XXVIII.
190 Ibid., f. D2*r*, section XXVIII.
191 Ibid., f. D2*v*.
192 Cf. Lovejoy, *Great,* and Granada, "*Rifiuto della distinzione*."
193 Franckenberg, *Oculus,* f. D3*v*. ff., section XXXI.
194 Ibid., f. D4*r*, section XXXII.

FIGURE 9 *A representation of the Moon by Hevelius in the* Selenographia *(Gdańsk, 1647)*
COURTESY OF THE HERZOG AUGUST LIBRARY (WOLFENBÜTTEL, GERMANY).

realms and cities of the Moon could be suited to describe Hevelius's famous geographical map *Tabula selenographica Fig. Q*, in *Selenographia*, which was an attempt to reconstruct the lunar continents and regions in analogy with the Earth (see figure 9).

16 Hill and the Epicurean Reception of Bruno and Copernicus

While Franckenberg is representative of a central European line of reception of Copernicus and Bruno marked by spiritual concerns, another line, characterized by a strong but eclectic Epicurean commitment, can be traced in the work of the English philosopher Nicholas Hill. This author's only printed book, *Philosophia Epicurea, Democritana, Theophrastica proposita simpliciter, non edocta* (*Epicurean, Democritean,* [*and*] *Theophrastic Philosophy Exposited in a Simple and Not Learned Manner*), appeared in Paris in 1601 and was reissued in Geneva in 1619. It was a collection of 509 theses aimed at a reassessment and dissemination of the Epicurean philosophy. In that work, among many other things, the author defended terrestrial motion, relying on Copernicus, Bruno and Gilbert.

Hill probably belonged to the inelletctual circle of Earl Percy of Northumberland, along with brilliant scholars such as Thomas Harriot, Francis Bacon and Walter Warner.[195] Yet the connection between the Copernican hypotheses and atomism in his booklet is significant not only for revealing certain features of an English cultural environment.[196] It also allows us to understand wider European intellectual developments, since it was first published in Paris, precisely where Pierre Gassendi would later propose a reappraisal of atomistic views and link it with the heliocentric system.

Perhaps Hill's Epicurean and non-ambitious spirit is marked by the fact that he dedicated his booklet to his child Laurentius Hill rather than to some patron, as usual in those times, preferring the joys of family and friendship over convention.[197] The tract was a mixture of natural views and moral precepts, even religious ones. As to the eclectic inspiration, the author acknowledged the absence of an ordered deductive method in his book and the dependency of his ideas on those of other thinkers.[198] As an excuse, he adduced that the disorderly form of his presentation depended on an anti-hierarchical conception

195 Cf. chap. 1,8.

196 Clucas, "Infinite Variety," 266–68. For English atomism: Kargon, *Atomism in England*.

197 Hill, *Philosophia Epicurea* (here and hereafter, I will refer to the 2007 edition), 79.

198 Ibid., 77. On Hill's eclecticism, see Plastina, "Philosophia lucis."

of nature and science, contrary to Aristotle. According to him, things are coordinated rather than subordinated, and science should mirror this equalitarian order of nature (*ut in natura, sic in scientia esse coordinata, non subordinata*). He chose an unsystematic style as well. Concerning the possible lack of originality, he asserted that his conception was new only in part and called it "neither new nor old philosophy" (*philosophia nec nova nec vetus*).[199] As one reads, he resorted to neologisms only if the novelty of the matter required him to do so.[200] Moreover, he argued that the contrast of his theses with widespread Aristotelian doctrines depended on his free philosophical attitude. Aristotle would have agreed with him on this, since he himself had famously disagreed on many aspects with his master Plato.[201] Hill also proudly asserted the anti-dogmatism of his own philosophical attitude: "I do not propose anything as a dogma [*dogmatice*], but I let anyone have his own opinion [*arbitrium*]."[202]

His old-new philosophy coincided with Brunian atomism. In fact, his conception of matter, which he deemed to be made out of indivisible *semina*, did not simply rest on the Democritean, Epicurean or Lucretian views. He added new elements to classic atomism. For instance, he regarded the soul as a special indivisible minimal entity or atom, in accordance with Bruno: "Birth is an expansion of the center, life is the conservation of the sphere, and death a contraction to the center."[203] Hill also dealt with the metaphysical ground of reality as a whole, asserting the closeness of nature and divinity. He regarded nature as "God's only-begotten daughter" (*Deus genuit naturam ... primogenitam et unigenitam, i*[*d est*] *unigenitam filiam*).[204] Certainly, this substitution of the figure of Christ, the "only-begotten son," by nature, or at least the identification of nature with Christ, might sound impious. Hill explicitly asked his readers not to judge too severely his conviction of "God's immersion in matter, since he intended to remain with the distinction between the natural and metaphysical levels of reality (or hypostases)."[205] He also asserted his will not to transgress the limits of Catholic faith. Still, this declaration sounds rather insincere since it appears to disagree with too many aspects of his Brunian philosophy.[206] Hill sustained theses that were at odds with basic Christian dogmas, for instance

199 Ibid., 80.
200 Ibid., 78, th. 7.
201 Ibid., 78, th. 3.
202 Ibid., 79.
203 Ibid., 95, th. 76.
204 Ibid., 109, th. 162.
205 Ibid., 79, th. 11.
206 Ibid., 80, th. 15.

the coeternity of God and world, and the infinite duration of the world (*duratio mundi infinita*, th. 55) and time (th. 394). According to Hill, space (*spatium*) is a continuum (*quantum continuum*) that cannot be divided *ad infinitum* (theses 359 and 397). The universe is itself an infinite sphere (th. 52) populated by a plurality of Earth-like worlds (th. 138). He ascribed the thesis of the world's infinity to the followers of Epicure and Democritus (*Epicurei et Democritani*) and based it on a sort of principle of plenitude, according to which God's infinity must unfold in an infinite reality: "Those who suppose the infinite God and the existence of finite worlds argue in an improper manner."[207] In an infinite universe, time could not depend on the regular motions of the sphere of the fixed stars. Thus, Hill asserted the independence of time from cosmology in his thesis 394: "Contrary to Aristotle, the activity of time [...] is independent of the sphere."[208]

Hill's approach was basically natural-philosophical. He regarded mathematics with suspicion.[209] Like Bruno, he considered mathematical hypotheses to be arbitrary in contrast to physical explanations, which were necessary:[210]

> [Thesis] 226. The same occurs in mathematical theses and hypotheses, where things are structures of the human mind [*ingenium*]; it is very different in physics where things depend on natural necessity, not on our power [*arbitrium*].

In his booklet, he introduced the motion of the Earth shortly after asserting that magnetism is an inner tendency of a body to move, and it cannot be reduced to attraction (th. 16). As one reads, terrestrial motion respects a principle of economy; in order to account for many celestial phenomena, it is "easier" (*facilius*) to introduce some terrestrial displacements:[211]

> [Thesis] 20. All celestial phenomena (daily, monthly, annual, secular and periodic) can be saved and explained through the supposition of terrestrial motion in a more convenient, easy and apt manner than through [the motion of] the Sun [and the heaven of the fixed stars].

207 Ibid. 103.
208 Ibid., 157.
209 Cf. ibid., 139, th. 311.
210 Ibid., 120.
211 Ibid., 84.

Hill reasserted this principle of economy in the second presentation of terrestrial motion, where he argued, from a theological perspective, that God does nothing in vain:[212]

> [Thesis] 49. God, nature and the wise man do nothing in vain. In vain means to produce with more means the same effect that can be produced with less, through motion that which can be produced through rest, through a fast motion that which can be produced by a slow one [...]. Thus, since the supposed motion of the Earth has the same ratio to the solar as 1 to 45,316, hence it follows that the Earth is moved rather than the Sun.

Hill derived terrestrial motion from different premises. Thesis 131 asserts that tides can depend on the concomitant influences of the Moon, the Sun and other (probably astral) factors, but perhaps also from the motions of the Earth.[213] The thesis immediately thereafter (th. 132) states that the Earth is more apt to move than the Sun because it is a solid and compact body, whereas the Sun is made out of a fluid igneous substance that would be dispersed by motion.[214] Additionally, thesis 384 asserts that the Earth is a large animal and, therefore, it can move.[215] Hill was convinced that the *mundi*, or celestial bodies, are endowed with life, sensibility and intelligence in a higher degree than human beings (th. 384). This is a Brunian thesis as well.

In a section (th. 434*bis*) entitled "[The following points] prove terrestrial motion sufficiently" (*Terrae motum sufficienter probant*), Hill listed nineteen arguments, or rather hints and considerations, in support of terrestrial motion, shortly after discussing motion in general. According to him, all Aristotelian categories of motion can be reduced to atomic fluxes (th. 432*bis*) and motion can be regarded as an effect of inner magnetic tendencies in the bodies. As a consequence, the first argument is the magnetic nature of the Earth as a lodestone. Hill's nineteen points are as follows:[216]

> [The following points] sufficiently demonstrate the motion of the Earth:/ [...] 1. The magnetic confluence of the heaviest bodies;/ 2. The constancy of the magnetic poles and of the axes; / 3. The likelihood of the planetary

212 Ibid., 89.

213 Ibid., 102, th. 131.

214 Ibid., th. 132.

215 Ibid., 104, th. 139.

216 Ibid., 166–67.

> [*astrea*] nature of the Earth; / 4. Empirical evidence [Φαινόμενον], that is, the best [*optata*] explanations of the appearances; / 5. The elimination of the absurdity of thousands of eccentricities; / 6. The fact that sleepy immobility [*torporifera quies*] is at odds with continuous generation; / 7. The manifest motion of the rather unbalanced waters of the Earth; / 8. That the Earth is suspended in the loose and free aether without a basis (that would be necessary for its immobility); / 9. That the animal and primordial nature of the Earth cannot be understood without local motion, which is the universal life of things; / 10. The acknowledged and demonstrated figure of the Earth; / 11. Terrestrial coherency and firmness; / 12. The absence of gravity, especially of those things that are in their natural places [*in propriis locis*]; / 13. Improbability of the infinity of a center, or a medium point; / 14. The absence of a medium point in an infinite world; / 15. The incapability of such a small Earth of constantly transporting the Sun; / 16. The indissolubility of the matter [*dissipabilis substantia*] of the fiery Sun; / 17. The economy of natural action; / 18. The necessary homogeneity of the main and most notable parts of the world; / 19. The rotation of separated parts.

These points are rather heterogeneous and sometimes confused, since Hill mixed up arguments, considerations and statements in a manner that is not immediately clear. The first two points hint at Gilbert's magnetic explanation of the terrestrial motion. Point three rests on the analogy (the likelihood) of the planetary nature of the Earth. The fourth one asserts that the Copernican hypotheses can best account for heavenly appearances. The fifth point, the elimination of eccentricities, could be interpreted as a reference to Copernicus's respect of the *axioma astronomicum*. Sixth, the life-giving motion of the Earth cannot be reconciled with its immobility. Seventh, the tides. Eighth, the suspension of the Earth in space and, as point ten stresses, the assumption that its spherical form must produce motion. Point nine refers to the *animalitas* of the Earth as a planet. Point eleven resorts to the argument of its solidity in opposition to the igneous fluidity of the Sun. Point twelve, on gravity, seems to be an assertion that terrestrial motion can be accorded with the fall of bodies and the preservation of the planet, against the Ptolemaic objection about the disruptive consequences of terrestrial motion. Point nineteen also seems to refer to the theory of the elements and their natural tendency, as separate parts, to rotate (presumably together with the Earth). Hence, points twelve and nineteen are related to the physical arguments of *De revolutionibus*, book one, and the post-Copernican debate on the physical difficulties entailed in the theory of terrestrial motion. Points thirteen and fourteenth refer to the absence of a cosmological center, from a Brunian perspective. Infinity makes it impossible to assert the centrality of the Earth. Moreover, once the assumption of the necessity of terrestrial centrality is eliminated, one can more easily accept its spatial displacement. Point fifteen argues for the absurdity that a relatively small Earth could impart any motion to the much larger body of the Sun. Point sixteen, on the solidity of the Earth and the fluidity of the Sun follows. Point seventeen, on *compendiositas*, is the principle of economy, according to which terrestrial motion is preferable to solar motion, and the Copernican system to the Ptolemaic.

Hill's theses are not particularly original, especially those on terrestrial motion and cosmology. Indeed, they seem to confusedly revive the ideas of the philosopher Bruno one year after his execution in Rome. Certainly more original is the context of Hill's reappraisal of heliocentric astronomy, atomism and Brunian philosophy. I would like to particularly stress the entanglement of natural and ethical elements. The booklet deals at length with ethical and religious concerns, such as human passions, virtue and faith. Divine Providence, free will, and the relation between religion and politics are dealt with as well. In general terms, Hill was a supporter of a tolerant attitude and rejected biblical literalism in favor of philosophical freedom. His approach to religion can be depicted as rational, since he refused to separate faith and reason: "All faith presupposes the intellect" (*Omnis fides praesupponit intellectum*).[217] Accordingly, nature and divinity should not be separated. Terrestrial motion, and motion in general, are discussed along with virtue, while passions and will are forms of motion. Atomism, infinitism and Copernican hypotheses do not belittle humankind. Hill does not renounce the idea of a correspondence between the microcosm and the infinite universe. It only needs to be embedded in a new worldview:[218]

> [Thesis] 63. Man is a microcosm, [and] the prince of all natural things; there is no virtue in the world, no generation, no substance to which something in man has not some correspondence: something derived from the heavens, something from the elements, something from the singular parts of nature, and inserted in his body [*fabrica*]. Looking at its exterior and interior aspects one detects the geometry of all figures and of the universal nature.

217 Ibid., 177, th. 463.
218 Ibid., 92, th. 63.

17 A New Imagery: Phaeton's Fall

The connection between new astronomy and atomism leads us back to the poet whom I mentioned at the beginning of this chapter, Pandolfo Sfondrati. Making his life as a courtier in Turin, this poet was interested in both astronomical novelties and the revival of Epicurean natural philosophy. His commitment to atomism is documented above all by his writing on the tides, *Causa aestus maris* (*The Cause of the Tides*, 1590) where he offered a mechanical, atomistic account of the motions of the waters on Earth.[219] In this context, he also declared his adherence to both the Platonic school (the *Academia*) and the Epicurean.[220] He also composed a Lucretian poem, *Democriti prohibent nosci corpuscula formas* (*Democritus's corpuscles prevent us from the knowledge of forms*), published in the opening of *Epistolarum Medicinalium libri XII* (*Twelve Books of Medical Epistles*, 1579) by the physician and philosopher Orazio Augenio. In that poem, Sfondrati presented the revival of atomism as the solution to the defects of *physica*—that is, Aristotelian natural philosophy and medicine—a discipline that he represented as a ship traversing dangerous waters and risking being sunk.[221] His ethical-cosmological poem *Inferiora regi dum sideris omnia motu* was issued in Turin in 1580 at the beginning of Altavilla's *Animadversiones* against ephemerides and astrology.[222] A translation of the poem here follows:

> Since we deem all things subjected to the celestial king to be in motion,
> We tried to know their motions [*vias*] through our art,
> And to account for their irregular habits through firm rules,
> In order to predict their positions.
> Apollo laughed at Phaeton's fall,
> From the moment when men seemed to occupy a position higher than the demigods.
> [Apollo] hit with the lightening of his rays his brothers,
> Receiving back not lesser hits.
> They exercise together their weapons to prove their forces.
> They move back and forth, stay, or flee.
> Even bigger is the tumult of the low plebs.

219 For a discussion of mechanical explanations of the tides in early modern science, see Clutton-Brock and Topper, "Plausibility."

220 Sfondrati, *Causa*, f. 31*v*.

221 See Omodeo, "Sfondrati."

222 See chap. 8,9.

Undisciplined crowds refuse to remain in a determined place.
From below they smash the heavens with the *testudo*,
And the inferiors make a bold war against the superiors;
They dig their heels in the ground and
Unite all of their forces to reach their goals:
The Earth, set in motion by the impetus of the feet, now bends [*vergit*] toward the north [*ad arctos*],
And then to the opposite, being moved closer to the Crux.
Now it goes westward, moved in a way that is almost imperceptible to the senses,
And offers its side to Taurus in a manner that is the reverse of [the usual].
And gradually it learns to immerse its sight [*lumina*] into the East [*ponto*],
A very astonishing issue.
Furthermore, the little man who believes
That the celestial bodies have always moved across the spaces with constancy is mistaken.
All of them have irregular motions [*instabilis locus*].
Thus it is impossible to observe the celestial bodies
Twice in the same place, according to some rule.
This complex issue [*studium*] is entailed in the *Alta Villa* [Altavilla and high villa]
Who warns us to abandon the old and mendacious dogma,
And easily ploughs the soil.
Hence, conduct the strong oxen under the curved yokes.

The poem written for Altavilla is more evocative than rigorous from the point of view of astronomy. Nonetheless, it entails references to the heliocentric cosmos and poetically reworks its consequences.[223] From the very beginning, the poem hints at the cosmological problem: "We now believe that all things subjected to the ruling star are in motion." All heavenly bodies ruled by the Sun, the celestial King according to an affirmed image of Renaissance neo-Platonism, are constantly moved: the Earth makes no exception. The planets indicated as brothers of the Sun (*Solis fratres*) exchange with it light beams (*fulgor radiis*) and influences (*ictus*). The Sun is even supposed to conduct them through the action of its rays (*Diversosque egit radiorum fulgure fratres*). The Earth becomes the celestial place of man freed from the low place traditionally accorded him. By contrast, mankind is elevated to the heights of the demigods (*Cum mage semideis sidere visus homo est*). The crystalline spheres,

223 For an analysis of this poem, see Omodeo, "Poesia copernicana."

the planet-transporting *orbes* of scholastic philosophy, give way to a fluid space where the Earth can freely travel. "Summum imo [plebes] quassant acta testudine coelum": the inhabitants of the Earth, now set in motion, break through (*quassant*) the heavenly walls like soldiers using siege engines (such as the *testudo*, here mentioned). As a consequence, Phaeton's myth is deprived of any sense, even metaphorical.

The image of the "low plebs" breaking the celestial vault refers to the annual motion of the Earth. The other heavenly revolutions are also transposed into a Copernican perspective. Sfondrati refers to the *trepidatio* as the oscillatory motion of the Earth between the North, indicated by the constellations of the Bears (*ad Arctos*), and the constellation of the Crux (*proprior Cruci*). This is also caused, according to his poetic representation, by the aforementioned low people (*ima gens*) stamping the ground with their feet. Moreover, the precession of the equinoxes, traditionally seen as a shift of the zodiacal constellations toward East, is now described as follows: "Nunc it [Tellus] in occasum minimo discrimine sensim/ Concita, datque Thoro, sed resupina, latus" (Now it goes westward, moved in a way that is almost imperceptible to the senses, / and offers its side to Taurus in a manner that is the reverse of [the usual]). Following Copernicus, Sfondrati regards the precession as a slow delay of the eastward rotation of the terrestrial axis, a delay which he describes as a "minimally perceptible" motion toward west. Through this, the Earth makes the constellations (Taurus is the *pars pro toto*) move in the opposite direction (*resupina*) to what they had assumed in the past. Eventually, the daily spinning is the solution to the conclusive conundrum: "Paulatimque eadem dediscit mergere Ponto" (gradually it learns to immerse its sight into the East). In fact, the Earth does not wait for the Sun to rise in the east. Rather, it moves toward that section: terrestrial motion takes over the functions of the *primum mobile*.[224]

It should be remarked that, according to Sfondrati, the physical dimension of the Copernican hypotheses produces a subversion of the hierarchical conception of the beings entailed in the geocentric schema. Similar considerations are suggested by other cosmological compositions in verse. In particular, I would like to mention the variations of Phaeton's myth, whose transformation, as a matter of fact, become part of post-Copernican imagery.[225] For instance,

224 On the difficulty of transposing motions traditionally ascribed to the sphere of the fixed stars to an heliocentric model, see also Omodeo, "Bruno and Copernicus."

225 Idem, "Renaissance Science and Literature."

a poem written by Brahe in honor of Copernicus in 1584 begins with the Earth taking over the chariot of the Sun:[226]

> The Earth traverses the aether accompanied by the Moon [*Diana*]
> So that Apollo [*Phoebus*] no longer has to impel his horses;
> By contrast, resting at the center of the world on his throne,
> He orders how the heavens [*Olympus*] shall be moved.

As one reads in the *Astronomical Letters* (*Epistolarum astronomicarum liber*, 1596), Brahe attached these verses to Copernicus's self-portrait (*In D. Nicolai Copernici Toronensis effigiem, quam ipsemet sua manu e speculo depinxisse*) which hung, together with those of Hipparchus, Ptolemy, al-Battani and Wilhelm IV of Hesse-Kassel, in his *Musaeum* at Uraniborg Castle. This was the place where Brahe studied, made his computations and kept his library.[227] More significantly, the Flemish astronomer, astrologer and physician Cornelius Gemma, himself a "realist Copernican," used Phaeton's myth to poetically represent the hubris of the moving Earth assuming Apollo's office. In the poem *Alma Dei, mundo cum mens infusa caleret*, which was first published in his *Ephemerides* of 1563 and then in *De arte cyclognomica* (1569), Cornelius Gemma treated the epistemic shift as an ontological change. According to Fernand Hallyn, in Gemma's verses "the world […] does not appear as the object of a new representation, but as its cause."[228] Great disgrace should be expected after the Phaetontic reversal of the ancient Earth-Sun relationship provoked by the publication of Copernicus's *De revolutionibus* (1543). Thus, heliocentrism was associated with an inversion of moral order in human society. Cornelius's verses were disseminated widely, and they were quoted by Adrianus van Roomen in *Ouranographia sive caeli descriptio* (*Uranography, That Is, Description of the Heavens*, 1591)[229] and translated into French by Guy Le Fèvre de la Boderie in *Diverses meslanges poétiques* (1582). Here are some lines from Cornelius's text, accompanied by the corresponding (rather free) French translation by Le Fèvre de la Boderie:[230]

226 Brahe, *Epistolarum astronomicarum liber primus*, in *Opera*, vol. 6, 270.

227 Ibid., 268–69.

228 Hallyn, "A Poem on the Copernican System," 27.

229 Van Roomen, *Ouranographia*, 20.

230 Hallyn, "A Poem on the Copernican System," 22–23. For the entire poem, see C. Gemma, *De arte*, 122–23.

Now, oh Apollo, the Earth dares to believe that your heaven belongs to her / and to take over your path and your horses. / It [the Earth] dares to take Phaeton's reins / that she once feared. / Thus, she will soon receive the same punishment [as Phaeton].

Nunc Tellus o Phoebe tuo se credere caelo Et cursus et equos ausa subire tuos. Audet, quas verita est quondam, Phaetontis habenas Supplicium casu mox luitura pari.

Or la Terre, ô Phebus, s'ose en ton Ciel guinder,
Et monter en ton char, et tes Chevaux guider,
Elle ose manier et le frein et la bride
Dont jadis Phaeton se monstra mauvais guide.
Afin de remporter pour sa temerité
Le supplice pareil, come elle a merité.

The poems by Sfondrati, Brahe and Cornelius Gemma show that Phaeton's myth was galvanized by Copernicus's heliocentric hypothesis, which assumed that the Sun/Apollo is immobile at the center of the world and its motion, deemed to be merely apparent, is overtaken by a running Phaeton-like Earth. Even a King, James VI of Scotland and I of England, employed a cosmological variation of Phaeton's myth in a poem, which he composed in honor of Brahe, extolling him as the scholar who developed the most viable alternative to the Copernican system. For this achievement, James regarded him as the dethroner of the Sun to whom Apollo should pass the reins of his chariot. It is another Renaissance variation of Phaeton's myth:[231]

More daringly than Phaeton and more excellently than Apollo,
Who governs with great effort the fire-belching horses,
You, Tycho, rule all stars together. Apollo gives up to you
The chariot and you are the guest, the pupil and the love of Urania.

Composed by King James and written by his own hand.

18 Conclusions: The New Humanity

In this chapter, I have dealt with the ethical implications and consequences of Copernicus's work by considering various sources and episodes, such

231 Brahe, *Opera*, vol. 2, 12.

as Sfondrati's poems and the transformation of poetic imagery in a post-Copernican context, classical and Renaissance sources on the microcosm and macrocosm, and, above all, the philosophy of Bruno, certain episodes of his life, and his legacy. All of these examples and episodes, in spite of their apparent heterogeneity, bear witness to the ethical expectations aroused by a new positioning of humankind in the world or, in many cases, in an infinite universe. As I have argued, the ties between astronomy and ethics could be traced back to ancient and medieval sources. The planetary novelties of Copernicus's age forced scholars from different disciplinary fields (astronomers, philosophers, poets and others) to reassess this question.

Bruno is the most evident Renaissance case of a reworking of Copernicus along with philosophical issues like the meaning of human existence, history and values. This entanglement is clear from the organization of the Italian dialogues. The so-called cosmological trilogy of *Cena, De la causa* and *De l'infinito* was completed by the ethical trilogy, consisting of *Spaccio, Cabala*, and *Eroici furori*. While the earlier works, as we have seen in previous chapters, were dedicated to the physical defense of terrestrial motion as well as the discussion of an infinite ontology and cosmology, the last three Italian dialogues expanded on the anthropological, political and theological consequences of the alleged restoration of the "ancient and true philosophy." The *Eroici furori*, a sort of *canzoniere* endowed with philosophical commentary, is the coronation of the six dialogues. It deals with the philosophical hero's infinite pursuit of Truth-Beauty-Goodness, a striving toward intellectual union with the divinity through the contemplation of boundless nature. No less important, *Spaccio* deals with values and civilization. It is a dialogue on broad ethical-political and cultural reforms connected with the cosmology announced by Copernicus as an "aurora."[232]

An ideal line connects the Copernican mise-en-scène of *Cena* and the ethical reform sketched in *Spaccio*. This is marked by a profound aversion to Christian asceticism and skepticism, or *asininità*, as Bruno called it in *Cabala*. He proposed either to return to a natural religion or to follow a rather Machiavellian (and Averroist) *Realpolitik* using religion as an *instrumentum regni* for the sake of commonwealth. If, on the one hand, religious superstition might be useful for government, on the other, the rulers and philosophers should not believe in its tales, but rather be aware that truth is attained by natural and philosophical means.

Hence, Bruno connected Copernicus's planetary astronomy with natural religion and Averroist and Machiavellian political pragmatism, a neo-Platonic

232 Bruno, *Supper*, 87.

exaltation of *furore* (which owed much to Ficino), cosmological infinity and atomism of Epicurean and Cusanian derivation.

This bizarre mixture significantly influenced the reception of Copernicus and the evaluation of his work by later authors. I have indicated two different lines of reception. First, the central European spiritualist Franckenberg embraced mystic Christianity *à la* Böhme. Second, I considered the English Epicurean Nicholas Hill. While the German spritualist stressed the pantheistic element of Bruno's reading of Copernicus, the English free-thinker reasserted atomism and Epicurean ethics. The profound divergences and different intentions of these two followers of Bruno document the rich potentialities of Bruno's reflection. As to the reworking of Copernicus on an ethical, anthropological, even religious level, both Franckenberg and Hill learned from Bruno to regard Copernicus's planetary theory as part of a natural philosophy able to free human beings from superstition and bring them closer to divinity.

I have treated Bruno's Helmstedt excommunication in more detail because it offers a clue to the tensions within the German Lutheran environment that played such a fundamental role in the early dissemination of Copernicus. Bruno confronted the opposition of the Helmstedt superintendent Mebesius for reasons that might have depended on his natural and ethical opinions. As I have illustrated, unorthodox natural opinions were fiercely opposed by several professors, who especially disdained Epicureanism, atomism and infinitism, but also Copernicus's planetary theory. In spite of the opposition of those scholars, certain philosophical freedom was granted to the new university by Duke Heinrich Julius. The teaching of the heliocentric hypotheses could enter the university curricula shortly after Bruno's departure. In fact, the Scottish mathematician Duncan Liddel taught the heliocentric hypotheses beginning in the 1590s, along with the Ptolemaic and Tychonic models. Liddel was also one of the protagonists of a furious controversy between the "philosophers," that is, some humanists of the Arts Faculty, and the theologian Daniel Hofmann, over the legitimacy of a rational investigation of nature, in particular its reconcilability with the Sacred Scriptures. This controversy can be considered characteristic of sixteenth-century tensions between theology and natural science in Protestant countries as well. In Helmstedt, it notably ended with the victory of the philosophical party.

Adherence to the Copernican system, natural philosophy and anthropology are also the themes of several poems considered here. The myth of Phaeton and Apollo served Sfondrati and many others to represent the new condition of man in a transformed world, where cosmological hierarchies are cast into doubt and the Earth is set in motion. The same myth, differently varied, accompanied poems on Copernicus by several authors, among them Cornelius

Gemma and Tycho Brahe. They all pointed to the upheavals provoked on a human, cosmic and historical level, by the substitution of solar motion by terrestrial motion and the conquest of a heavenly location by humankind.

As we have seen, the followers of Copernicus's planetary system were inclined to exalt the new condition of humanity, its freedom and its divine, celestial place. In other words, they assumed that a modification of the world-view would necessarily affect the idea and ideal of humankind, due to the fact that the post-Copernican condition is celestial and the inhabitants of a potentially infinite universe are "infinite centers." Phaeton's fall lost any possible meaning, since the Earth took over the role of the heavenly vessel once represented by the chariot of Apollo.

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