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Boundaries, Extents and Circulations

Space and Spatiality in Early Modern Natural Philosophy

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Introduction: Early Modern Ideas of Space and Spatiality

> O God, I could be bounded in a nutshell and count myself
> a king of infinite space, were it not that I have bad dreams.
>
> —Hamlet

The subject of this book is concepts of space and spatiality in the European late Renaissance and early modern period, in particular in natural philosophy and related fields. We wish to show their richness, fluidity, and variety. These can be vast spaces of elemental circulation and cosmography, but also spaces of vision and microscopic interstices. Frequently, these spaces are mathematical; they may *be* mathematics itself. Sometimes, these spaces are powerful; they may even seem magical. Why is their history so fascinating? Space is a crucial concept for natural philosophy, but also the most mundane aspects of daily life are filled with references to space. We are constantly giving and taking directions by describing spaces: spaces around certain objects or locations, and spaces that determine certain objects or locations. Linguistically, this is the realm of prepositions: in, on, around, over, and through. Our local spaces can grow and grow to uncertain dimension. We all live *in* the universe, for whatever that means. To bring the scale down, we are all *on* the surface of the earth, the space of maps, and GPS. We are simultaneously operating with spaces that are different not only in scale but also quality. Yet most of the readers of this book will agree that space is a unity. Where a strict Aristotelian might have seen a nesting of diverse spaces, we effortlessly intuit and see a single space running through all objects, independent of those objects. This is an extraordinary feat of abstraction and, arguably, of sensory abnegation. And herein lies a major interest in the history of space. A homogenous "Euclidean" space partly filled with matter feels, to put it naively, like the mind's factory-setting experience of the world. Yet traditional histories of space, those of Jammer and Koyré, showed that it was not and is not.[1] What passes for Newtonian

[1]Two "traditional" accounts can be found in Jammer (1954) and Koyré (1957). For a sampling of classical texts, see, e.g., Capek (1976).

space is a construct. In the history of Western natural philosophy, it was a late arrival and after two centuries was replaced, at a fundamental level, by relativistic space-time. But it remains supremely useful for conceptualizing the mechanics of daily life—the low-velocity physics of home and office, as it were.

The late Renaissance and early modern period stand out because Newtonian space seems to be either the seed or flower of classic mechanics, either a necessary precondition or the most elegant conclusion. This necessity is, at least in part, a historiographical illusion. The traditional narrative of Jammer or Koyré stretches from Cusa to Copernicus, then onward to Newton, and then, in the most ambitious accounts, to Einstein. It keeps its disciplinary focus very tight: astronomy, natural philosophy, and a sort of purified metaphysics whose highest production was the Newton–Leibniz controversy. There were, however, many strange but important conceptualizations of space and place which stand in need of revaluation and study. The traditional story also smacks of teleology. In Koyré's account, the warring visions of Newton and Leibniz are the background and precondition for the ensuing most durable synthesis: the cosmos where absolute and absolutely mathematical space and time (Newton) are suffused with a perfection of law and self-perpetuity (Leibniz).[2] It is important, however, for a historian to look at early modern spaces without the Newtonian hindsight. On the one hand, the traditional narrative has proved its usefulness and resilience. It was picked up and much improved by later historians such as Edward Grant and Amos Funkenstein.[3] On the other hand, its continuing authority should provoke us to question its presuppositions and methodology.

In the current volume, to counterbalance familiarity, we will not shy away from the strangeness of early modern ideas of space and place. Instead of promoting a potted history, we prefer to explode boundaries and open up the historiography to a wider scope of disciplines. We are especially interested in the *uses* of spatial concepts, including those outside explicit theorizations of space. In bringing together the different studies of this volume, we show our preference for a variety of perspectives on early modern space, over and above any artificially created unity of storyline. At this moment, the historiography of spatial concepts will be better served by a disunity and variety in contributions than by a forced synthetic effort.

But how many spaces were there in the late Renaissance and early modern period? Let us first stress that this collective volume is a contribution in cultural and intellectual history: The authors will focus on actors' categories and on the explicit and implicit uses of concepts of spatiality; they will not analyze the actual

[2] See Koyré (1957, 273–276).

[3] Grant (1981) and Funkenstein (1986). Their work played down the discontinuity of the early modern period, even if in Grant's case he maintained that a rupture had occurred at the level of space. See Grant (1981, 264).

spaces in which the historical actors moved, debated, and conducted experiments.[4] Even then, if we looked at all the spaces our historical actors were interested in, we could expand the number of spaces indefinitely. We could discuss how early modern savants conceptualized political spaces, urban spaces, spaces of the *beaux arts*, memory spaces, spaces of commerce and pilgrimage, and agricultural and animal spaces.[5] The possibilities are limitless. We will allude to some of these spaces, but they will not be the focus of this book. Because we want to promote a critical discussion with the traditional historiography, we will remain relatively close to its field of interest. We will look at the conceptualization of geometrical, geographical, cosmographical, perceptual, and elemental spaces, from a different point of view or by focusing on uncharted authors.

A tacit conception of space is hard to do without, and it is present in disciplines that do not treat the issue head-on. An astrologer or chemist's conception of space probably does not fit into a purified Aristotelian, Cartesian, or Newtonian framework. A Leibniz puzzling over fossil formation might give us a new perspective on "Leibnizean" ideas of space and place. A Cartesian in the laboratory might work on making and breaking vacuums even if Descartes denied the existence of vacuums. Of course, we do not have to see the word *spatium* in order to detect a notion of space. The authors in this volume pay particular attention to actors' terminologies, but they cast their nets wider than a history of the words "space" or "*spatium*."[6] In doing so,

[4]For this kind of work, see the "spatial turn" in the history of science. Cf. Livingstone (1995, 2003). For a specific focus on urban spaces, see Van Damme (2005a), and Romano and Van Damme (2008). For a focus on Parisian spaces of science, see, e.g., Belhoste (2011) and Van Damme (2005b). Of course, the spaces a scientist moves in are not independent of the spaces that he or she thinks with and thinks about. As Henri Lefebvre put it, "*le mode de production organise – produit – en même temps que certains rapports sociaux – son espace et son temps. C'est ainsi qu'il s'accomplit*." Lefebvre (1974). Every society produces its own space, spatiality, and awareness of spatiality. If space is a social production, it is also an instrument of thought and action, including domination and power.

[5]To be clear: Our authors do not study actions in space; they do study space-related practices to a limited extent, but they focus especially on concepts and epistemologies of space. Of course, space-related epistemic practices, such as map making, also have a material aspect. See, e.g., Gordon and Klein (2010), which analyzes the material practice behind the concept of mapping, as well as the impact of cartography on the shaping of social and political identities in early modern Britain. In the present book, the focus will rather be on the conceptual aspects of space-related practices.

[6]Focusing on actor's categories has been a long accepted methodology in a historical study of concepts. As Quentin Skinner puts it: "the surest sign that a group or society has entered into the self-conscious possession of a new concept is that a corresponding vocabulary will be developed, a vocabulary which can then be used to pick out and discuss the concept with consistency." (Skinner 1980). According to Skinner, however, words do not track concepts perfectly. He gives the example of John Milton (1608–1674), who found it important to be original, even if the word 'originality' did not exist before the Romantic era. Skinner claims that Milton possessed the concept of originality, but not the word. We may argue against Skinner that Romantic "originality" was a quite different concept to the one supposedly endorsed by Milton, but this does not mean that there were no relevant similarities. A focus on the word "space" and "*spatium*" is thus legitimate, as is a broader approach that aims at detecting relevant spatial concepts and practices not necessarily expressed in terms of "space" and "*spatium*."

they welcome a larger corpus of texts and disciplines, a corpus encompassing both classical *novatores* and authors outside the historiographical mainstream.

This book is the result of cooperation within the framework of the project *PNEUMA. The Space of Spirit: Theories of Space, Pneumatology and Physico-Theology in the Newtonian Age*, directed by Laurent Jaffro and Philippe Hamou and financed by the French *Agence Nationale de la Recherche*. This partnership led to an international conference, *Spaces, Knots and Bonds: At the crossroads between early modern "magic" and "science,"* held on 21–23 June 2012 at the *Observatoire de Paris* and at the *Université Paris Diderot*, organized by Jonathan Regier and Koen Vermeir.[7] We would like to thank the participants of this conference, Roger Ariew, Delphine Bellis, Jean-Marc Besse, Michel Blay, Brian Copenhaver, Vincenzo de Risi, Ofer Gal, Philippe Hamou, Hiro Hirai, Laurent Jaffro, Michela Malpangotto, Thibaut Maus de Rolley, Luc Peterschmitt, Claire Schwartz, and Jean Seidengart for their rich contributions and stimulating discussions. Special recognition is due to the project PNEUMA for financing the conference, and to the Research Unit SPHERE (UMR 7219: CNRS/Université Paris Diderot) and the Research Unit SYRTE (UMR 8630: CNRS/Observatoire de Paris/Université Pierre & Marie Curie) for hosting the conference. We would also like to thank Nad Fachard and Virginie Maouchi for their help with logistics.

The idea of a volume on space going beyond the traditional authors and narratives grew out of the interdisciplinary discussions at this conference. Some of the conference participants have contributed to the present volume, but we also invited other scholars to write chapters based on their specific expertise. We are very grateful that they decided to join us in this exciting project. The preparation of this volume has led to a close collaboration between the two editors, working and commenting on the different chapters and writing the introduction together. We are much obliged to Volny Fages, Sebastian Grevsmuehl, and Isabelle Sourbès-Verger for giving us the opportunity to present a version of the introduction at the *Centre Alexandre Koyré*, Paris, in the seminar "Cosmos, histoires, représentations, politiques et techniques."

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[7]Many of the chapters have been prepared for the 2012 conference and have been revised in the light of comments by referees and editors. Because of the publication timeline, the authors have not been able to take into account scholarship that has been published in the last few months, such as Giovannozzi and Veneziani (2014) (proceedings of a 2013 conference) or De Risi (2015).

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Paris, France — Koen Vermeir, Jonathan Regier

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Chapter 1
Boundaries, Extents and Circulations: An Introduction to Spatiality and the Early Modern Concept of Space

Jonathan Regier and Koen Vermeir

Abstract This introductory chapter spells out our vision of a more inclusive history of space. We start with a close look at the meaning of the concept of space and its cognates, noting their practical as well as theoretical implications. In exploring earthly, imaginary and (un)godly places and spaces, we remain in continuous interaction with the classical historiography of space but also add unexpected perspectives. Suspicious of linear or teleological accounts, we stress the flourishing and mixing of many different ideas about space. This chapter is simultaneously a stand-alone introduction to the history of early modern space and an introduction to the contributions that follow, which we locate in a thematic network.

> If space is nothing, we ask in vain if space exists. If space does not exist, we likewise ask in vain if space is something else. It is a notion common to all people that space is and that it seems to be something, such that it was given the following or similar names: dimension, distance, interval, *diastasis* [interval], *diastema* [extension].[1]—Patrizi (1587).

[1]"Si spacium nihil est, frustra quaeratur, an spacium sit. Si verò spacium non sit, frustra itidem quaeretur, an spacium sit aliquid. Communis quaedam omnium hominum notio, spacium, et esse, et aliquid esse videtur voluisse, cum nomina haec, vel talia formaret, Dimensio, Distantia, Inveruallum, Intercapedo, Spacium, Diastasis, Diastema." Patrizi (1587, 2v).

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1.1 The Concepts of Space and Place

We might start with a few words on language. The English "space," French "*espace*," and Italian "*spazio*," descend from the Latin "*spatium*." "*Spatium*," in turn, is very closely drawn from the Doric "*σπάδιον*" (or "*στάδιον*" in Hellenistic Greek). "*Stádion*" connoted a specific unit of distance, the stade. It could likewise refer to a stadium or a racecourse, since the track at Olympia was exactly one stade long. "*Stádion*" was also, according to the LSJ, capable of signifying any area that might be distinguished, particularly an area for dancing. The LSJ also tells us that it could refer to a nice walk in the garden. The Latin "*spatium*" took a wider range of signification than its Greek progenitor, yet the central connotations were passed along: a spatial interval; a designated area or space; a movement in a designated space. To this, we might add another frequent sense of the Latin "*spatium*," that of a temporal interval.

What is striking for a historian of science is the prevalence of concrete meanings that originated in everyday contexts or related to bodily orientation, many of which continued into the vernacular (e.g. the now obsolete "to space" in English or the still common "spazieren" in German, meaning "to ramble"). We find that spaces and spatiality related to concrete embodied practices such as dancing in a dance hall or racing on a racecourse. Most often, "space" denoted sufficient room for a concrete action or purpose. This room could be a distance, an area or temporal interval. If we look at uses of the word "space" in the early modern period, the meaning of temporal interval would probably be the most prevalent. In a way, space and time were interchangeable, because distances were often measured in the time needed to traverse them. Bodies in movement often defined and delineated spaces. Early travel maps did not represent an abstract geographical space but reflected the concrete itinerary of a traveler from city to city (Fig. 1.1). In such maps, space is the fact of an interval to be traversed.

Not only movement, but also boundaries characterized and ordered space, as, perhaps most prominently, in architecture. The importance of architecture in the conceptualization of "space" can be seen in Isidore of Seville's sixth-century attempt at giving an etymology: "Intervals are spaces between the top of the walls, that is, the posts from which the walls are made; from this, we speak of other spaces, that is, from posts [*stipes*]."[2] Isidore's etymology insists on the architectural sense of "*spatium*." When we turn to Vitruvius, who would influence Renaissance writers of all shapes and sizes, we find that "*spatium*" indeed refers to the distance between two points, as between two columns.[3] Yet we also notice a surprising diversity of connotations. "Spatium" can refer to the overall space of a building. But it can also refer to vague enveloping spaces, as when Vitruvius writes about the danger of winds that are forced through the narrow streets of a

[2]Isidore (1911, XV.9.2): "Intervalla sunt spatia inter capita vallorum, id est stipitum quibus vallum fit; unde et cetera quoque spatia dicunt, ab stipitibus scilicet".

[3]Vitruvius (1912), III.3.11.

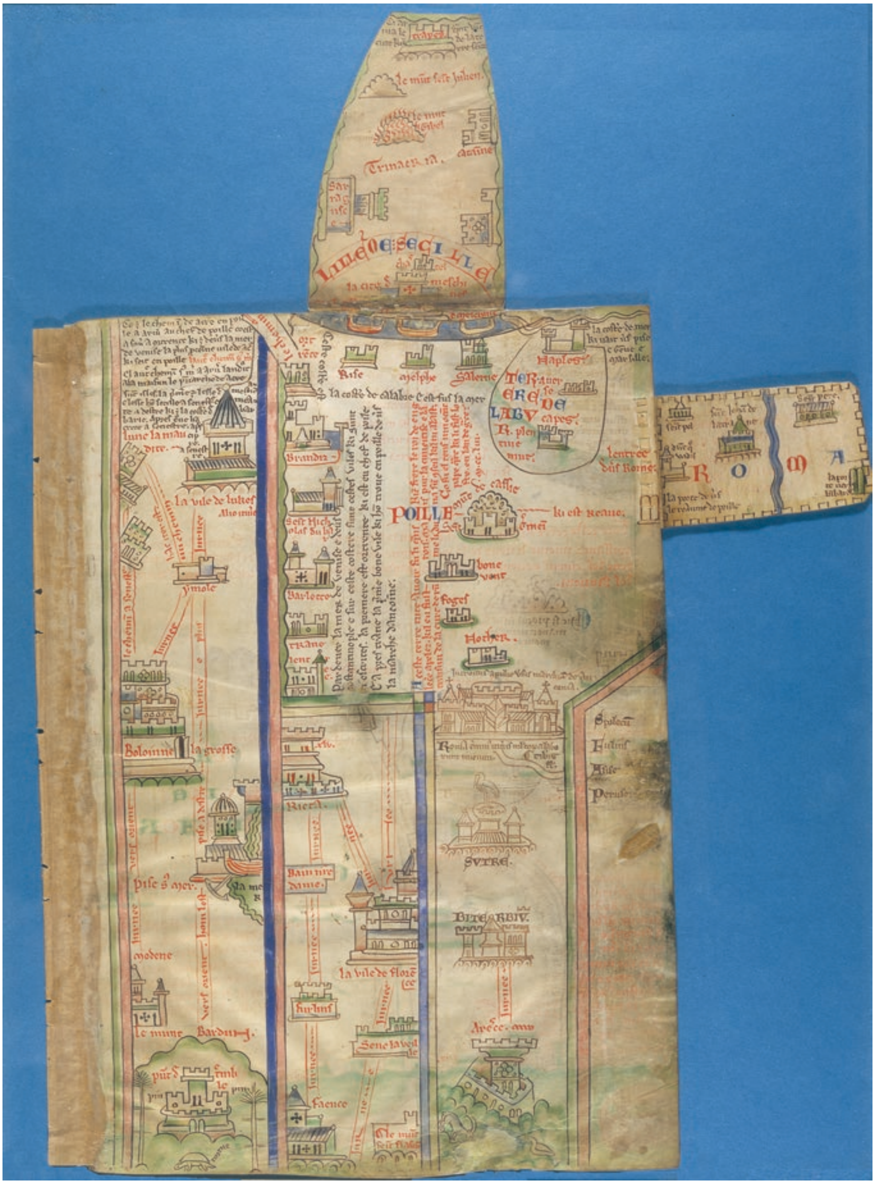

Fig. 1.1 Page from the itinerary from London to the Holy Land with images of towns, their names, and descriptions of places. From Matthew Paris, *Historia Anglorum, Chronica majora*, Part III, England (St Albans), 1250–1259, Royal 14 C. vii, f. 4r. Courtesy of the British Library

city, winds that had once flown freely through the open space of the sky (*ex aperto caeli spatio*).[4] There are only eight winds, Vitruvius continues, but the currents are multiplied as each wind is subject to the uneven surface of the earth's great space (*magno spatio*).[5]

"*Spatium*" does not only refer to biggish spaces for Vitruvius. It can also refer to the tiny pores in wood (*spatia foraminum*).[6] The possibility of great and small *spatia* should send us swerving into the pixilated landscape of Lucretius. In the *De rerum natura*, "*spatium*" can signal the universe's infinity as well as the tiny intervals of vacuum.[7] In Lucretius, body and space are contrasted: bodies move in space, which can be filled or emptied. Thus one can talk about empty space or full space.[8] "*Spatium*" is clearly the term favored by Lucretius when he talks about infinite space, yet at times he uses "*locus*" and "*spatium*" such that they seem interchangeable.[9] At other times, he distinguishes them, so that "*locus*" keeps its Aristotelian sense—a place determined by corporal borders—whereas "*spatium*" denotes the container space that, along with body, is an eternal principle of the universe: "Then further, if there were nothing void and empty, the universe would be solid; unless on the other hand there were definite bodies to fill up the places [*loca*] they held, then the existing universe would be vacant and empty space [*spatium*]."[10] In contrast to the concrete meanings of "*spatium*" we mentioned earlier, space here is a key philosophical concept. And as opposed to the common usages in classical and medieval Europe, Epicurean space comes across as an abstract entity, seemingly approaching early modern notions of absolute space.[11]

With all this talk of *space*, we cannot forget "*topos*" (*τόπος*), generally rendered into English as "place" or "position," but sometimes just as appropriately as "space" too.[12] The broad meaning of "*topos*" as place could take on any number of significations. Aristotle gave it its most notorious Greek definition: as the unmoving boundary containing an object. Elements had their natural places

[4]Ibid., I.6.8.

[5]Ibid., I.6.9.

[6]Ibid., II.9.14.

[7]For infinity: Lucretius (1910, I.984–986), for vacuum: Ibid., I.378–379.

[8]Ibid., I.426–427.

[9]Ibid., I.426–428, also 503–510.

[10]Ibid., I.520-523. Lucretius (1992, 45). Finally, Lucretius, as was common, uses "*spatium*" frequently to refer to intervals of time. These intervals might be short or as long as the innumerable ages that preceded us. On the space of ages past, see Ibid., I.234–236.

[11]The traditional narrative has ascribed the invention of absolute space to the Scientific Revolution, e.g. Jammer, who argued for a development of container space only after the Renaissance. Interestingly, Albert Einstein, in his introduction to Jammer's book, undermines one of its core conclusions, arguing that "the atomic theory of the ancients, with its atoms existing separately from each other, necessarily presupposed a space of [this] type" (Jammer 1954, xvi). The history of ideas has continued to revise and refine its views on this subject. Gassendi's reception of Epicurean thought, and especially of Epicurean space, deserves more study in this respect, as in Delphine Bellis' work in progress on Gassendi and space.

[12]There is no etymological relationship between "*topos*" and "place."

(*τόπος οἰκεῖος*) within the fundamental, large-scale spaces of the world: the earth at center, water around the earth, then air, then fire. With little elaboration, Aristotle ascribed to these places a kind of power (*δύναμις*) in relation to elements, even if it is not obvious what he meant by power here.[13] In any respect, the *telos* of an element was linked to its natural place: bits of earth seek out their natural place by falling; fire shoots upward to rejoin its heights. Arab and Latin commentators would later try to fill in the details, going far beyond Aristotle in explicitly charging the natural place as either a formal or efficient cause.[14]

As Roger Ariew shows in his contribution to this volume, powerful places persisted much longer in Western history than we might be inclined to think. In natural philosophical terms, specific places could possess virtues or powers: places had an effect on the elements found within them. Ariew considers what Leibniz's theory of fossils has to do with terrestrial place and the circulation of elements. Early on, a young Leibniz followed the theories of the Jesuit polymath Athanasius Kircher and the Lutheran chemist Joachim Becher on fossil formation, believing that fossils arose in certain places according to nature's formative force. Later, Leibniz came to reject almost all of his early ideas about fossils. Eventually, he saw them as the petrified imprints of animals whose flesh had been destroyed. Leibniz's renunciation of formative places brought up a host of new questions: for example, how to explain the location of certain shells and fossils improbably resting far from the sea or on mountaintops? To answer, Leibniz required a certain understanding of how the elements related, how fire and water shaped the earth across periods of time surpassing biblical record. Ariew shows how Leibniz's later theory was consistent with a natural philosophy of orderly transformation, where the earth is an ancient sun that has crusted over, where the disorder of fire and deluge give way to stability. Such a natural philosophy could not be consistent with Genesis, even if Leibniz quite strongly downplayed the contradictions.

The long survival of the idea that there exist special places with extraordinary powers should not surprise us, considering the importance of location in Christianity. As Alessandro Scafi points out in a later chapter, the incarnation of Christ and His sacrifice on Golgotha are thought by Christians to have sanctified earthly space and historical time conclusively. Indeed, the lives of Christ and the saints were mapped out across the earth. Places of worship and pilgrimage were unique and had miraculous powers. It was the drive to understand and localize these religious places that stimulated many of the early cartographic representations. To a modern eye, these maps seem to have a strange disregard for geography, or a curious preoccupation with reconciling heavenly and earthly topographies. Since Augustine's literal and typological reading of Genesis, paradise was supposed to be located on earth, somewhere "to the east," and Christian cartographers gave it a prominent place at the top of their maps.[15] Not

[13]On natural place, see Algra (1995, 195–221).

[14]Ibid., 197. Neoplatonists, in particular, contested Aristotle's denial of place's intrinsic causal power.

[15]Scafi (2006).

all holy places referred back to biblical times. The church had the power to consecrate places and commonly introduced gradations of sanctity between sacred, holy and religious places.[16] These practices and distinctions would come under attack during the Reformation, with Puritans arguing that such consecrated holy places were Catholic perversions of original Church practices.[17] Nevertheless, semi-magical places with inherent powers remained well into eighteenth-century natural philosophy. And they have remained prominent today in a great number of religious contexts, if not in most.[18]

During the period covered by our volume, many of the religious and magical ideas of "place" found their source in earlier (Jewish and pagan, cf. the *genius loci*) religious practices, but also looked for a theoretical legitimation in Greek Neoplatonic sources. Neoplatonic authors had staged a forceful challenge to Aristotle's original definition of place, the theory that would be dominant until the revival of Neoplatonic currents during the high Renaissance. One notable change the Neoplatonists had pushed through was the acceptance of many more kinds of "place," such as the "place" of the intellectual world or of the Platonic forms.[19] For Simplicius, extension was found only at lower levels in the hierarchy of being; higher order places corresponded to ideas or numbers. Hence one could speak of the "place" of an idea in a set of categories or conceptual system. Concomitantly, the Neoplatonists vastly expanded the powers of place, far beyond the Aristotelian idea of natural place. Indeed, place did not only encompass an object, it also sustained the object into its very being.[20] Place could also "strengthen" or elevate an object, or draw it together with other objects. In short, place itself became powerful, capable of affecting what it contained. And the less material a place was, the more powerful. This meant that incorporeal places were more powerful than the physical objects inside them. Objects therefore got their power to a great extent from the places they occupied in a hierarchized cosmos. In Sambursky's interpretation of Neoplatonic texts, the power of incorporeal place even generates extension: place does not depend on a pre-given cosmic extendedness, as posited by the Epicureans and Stoics, but is responsible for the extension of the objects that it serves to situate.[21]

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[16]Hayes (2004). She argues that there existed an ambiguity between sacred and profane spaces during the Middle Ages, and both were often mingled. During the early modern period, sacred and secular space became increasingly compartmentalized and differentiated.

[17]Neal (1732, 201). He rejected that consecration of churches and holy places was part of the original church, asserting that these practices "were not known in the Christian Church till the very darkest Times of Popery". The consecration of a place was often compared with the baptism of a person.

[18]Since the consecration of the bread and wine used in the Eucharist and the consecration of a place were similar ritual processes, it is interesting to note here Leibniz' attitude towards sacraments such as the Eucharist. See Fouke (1992), Backus (2011).

[19]See Sorabji (1988, 206). Regarding the general discussion in the above paragraph, see Casey (2013, 90).

[20]See Sambursky (1982, 43).

[21]Ibid., 45.

Philoponus takes this reasoning a few steps further when he reduces *topos* to *diastasis* (διάστασις) or especially *diastêma* (διάστημα), empty dimensionality or interval or extension.[22] Hence, the place of a body is the empty extension that its volume occupies. Place becomes space. Philoponus was not alone here. His otherwise antagonist Simplicius had a similar position.[23] They associated space with some intellectual activity, that of measuring, orienting, unfolding. Such a vision of place continued through Arabic philosophy, as in Ibn al-Haytham's *Fī al-makān* (*On Place*). Ibn al-Haytham, known in the Latin West as Alhazen, compromised between Neoplatonists and Aristotle. He circumvented the metaphysical and physical complexities of empty space by postulating a universal, abstracted extension. The place of a given body was its abstracted, immobile extension superimposed on this imagined void-space.[24] We see here a convergence—or even a deliberate confusion—of space and place, a tendency that would continue throughout Western intellectual history. The histories of space and place are inextricably intertwined.[25]

1.2 Mathematical Extents

Aristotelian physics at some level embraces geometrical places: *topos* is the inner limit of a containing body. As such, Aristotelian *topoi* have long been interpreted as surfaces.[26] *Topos* had a relatively precise meaning in ancient Greek mathematics, and one that Aristotle would have known. This sense of *topos* is still translated as "locus," denoting a geometrical entity—line, surface or volume—furnishing all the points corresponding to certain constraints.[27] Greek geometry is probably best described as a place-centered geometry, which is why the term "Euclidean space" must be used with caution. Euclid never in the *Elements* offers a boundless three-dimensional space. We can agree that it is flat, such that parallel lines never cross.

[22]For an excellent example of *topos* as *diastasis* and *diastêma*, see Philoponus (1888, 587), ln 22–30. Translation in Philoponus (2012, 74). In general, on Philoponus's conception of space, see Sedley (1987). For Philoponus in the context of Neoplatonic philosophies of place, see Sambursky (1977).

[23]Note, however, that in contrast to Philoponus' idea that place is empty spatial extension, Simplicius' notion of place implies that it only becomes extended with bodies and is not extended on its own, independently of bodies. Simplicius (1992, 67). "Place is extended through its participation in the object in place, just as the object in place is measured and located by means of place." Centuries earlier, Sextus Empiricus had ascribed the idea to Dogmatic philosophers, as Grant notes. Grant (1981, 276, n. 67).

[24]See Rashed (2002, 655–685).

[25]This becomes very clear, for instance in Casey, who purports to give a *longue durée* intellectual history of "place" but ends up writing more about space than place, in an otherwise wonderful book (Casey 2013).

[26]For more on Aristotelian *topos*, especially *topos* as *not* a surface, see Lang (1998, 66–121).

[27]For instance, the circumference of a circle is the *topos* of all the points equidistant to a given point. For Greek locus theorem, see Thomas (1951, 490–501).

But geometrical objects do not exist within, or arise from, some all-encompassing structure. Instead, the Euclidean object has priority and determines its own interior or neighboring places. In the early Greek context, the best chance to find something akin to boundless, geometrical space is perhaps in optics. Euclid's visual rays behave as ideal geometrical objects, linear without fail, going on and on with no set boundary and doing things like reflecting at the same angle as their incidence. Because the ray was conceived or demonstrated to travel through a flat plane, some continuum had to be assumed, if only as an abstraction.

Even if places were measurable, they were not necessarily mathematical. Places were often thought of as a kind of mold in which the object fit. This holds for Aristotle's definition of a place as an immobile bordering area, as well as for Neoplatonic definitions, which often explicitly referred to the idea of a mold.[28] Molds were crucial to pre-modern practices of measuring, which remained prevalent well into the nineteenth century. In order to measure the volume of a pile of grain or other material, it had to be placed and "molded" into the measuring vessel. To measure is to fit an object (in)to its measure. In early modern Europe, standards of measurement were kept in guild halls or bricked up in the wall of the city hall (so the units of fraudulent merchants could be checked). Even if these units of measure could be counted, they did not allow for measuring smaller parts. Nor did they add up or compare easily as in a metric system. Measurement was inseparable from local practices as well as from the object being measured. Every town had its own measures, relating in different ways to other units. Most measures were anthropocentric and qualitative, referring to the labor a person could do at a certain location in a given period of time and expressing tangible worth and equity. What is more, such units of measure were unstable, subject to negotiation and evolving.[29]

The association of place and measure made place more amenable to mathematical treatment, something that comes to the fore especially in Neoplatonic theorizing. Contrary to Aristotelians, Neoplatonists believed that mathematics was engrafted in the cosmos. For them, places were intrinsically like molds, as "measures of things in that place." Yet only for the lower hierarchies of being did they consider space as extended. Hence, they also accepted intelligible, conceptual places, which gave order to the world of numbers and ideas. This metaphysical superstructure allowed unextended intelligible numbers to measure everything, implying a certain universalism of mathematized measurement. As Simplicius puts it, "The well-ordered condition, as being a participation by the measured in the measurer and being coordinated with the measured object, is extended with and stretched out beside it, just as our cubit is an extended measure deriving from the

[28]"Place is as it were a sort of outline *(proupographe)* of the whole position *(thesis)* and of its parts, and so to say a mold *(tupos)* into which the thing must fit, if it is to lie properly and not be diffused, or in an unnatural state." Damascius, cited by Simplicius, *In Aristotelis physicorum libros quattuor priores commentaria* and translated by Sorabji (1988, 206). Also see Casey (2013, 91).

[29]See e.g. Alder (2002, Chap. 5).

unextended measurer, that is, the cubit in the soul."[30] The measured object participates in the measurer, that is, in the numbers of our intellect.

Neoplatonic metaphysics naturally connected number to extension. The quantification of place or space reached its apex in late antiquity probably in the work of Philoponus. In his *Commentaries on Aristotle's Physics*, this Christian Neoplatonist commented in detail on Aristotle's definition of the essence of place and discussed concepts that modern readers are apt to identify with "space." Philoponus defined place as quantified immaterial and three-dimensional extension (διάστημα). Extension provides room (χώρα) for body. It is pure dimensionality, which need not in principle be filled with body or matter (even if it will always be so, in fact). If we compare the Greek text of Philoponus with the Latin translation published during the Renaissance, we find that when Philoponus interprets place (τόπος) as extension (διάστημα), the translator renders "place" as "*spacium*."[31]

These Hellenistic mathematized places were taken up and further developed by Arabic philosophers and came to resemble even more what we today would call mathematized "space." We can now appreciate why a scholar such as Ibn al-Haytham posited "place" as a universal, abstracted and "imagined" void, i.e. as a series of distances conceived as running through the world. Indeed, he had a very good mathematical reason to do so, as Roshdi Rashed has argued: "this conception allowed Ibn al-Haytham to do what was prohibited his predecessors: to be able to compare the different geometrical solids and various figures that occupy the same place, as well as the places that they occupy. From here on, Ibn al-Haytham is allowed to consider their relations of location, their positions, forms and sizes, just as he envisioned in *On Knowable Entities*."[32] The existence of this 'imagined void' was secured in the imagination, like other geometrical entities, and it consisted of imagined immaterial distances set between the opposite points of the surfaces surrounding it.[33]

The geometrization of space would be taken up and further elaborated in the Renaissance. What is more, it would also lead to a "spatialization" of geometry. Vincenzo de Risi studies a high point in this development, not so much in practical geometry as in its epistemology. In 1586, Francesco Patrizi claimed that he had revolutionized geometry, transforming it into a science of space. According to de Risi, this is the first moment when geometry could be something other than a science of magnitude. Patrizi established a new—spatial—ontology of geometrical entities. Space, in turn, became more than continuous quantity. It was "the source and origin" of quantity and the ontological bedrock for both geometry and natural

[30]Sorabji (2004, 242).

[31]See Vincenzo de Risi's chapter in this volume, as well as Jean Seidengart's.

[32]"Or cette conception permet à Ibn al-Haytham ce qui était interdit à ses prédécesseurs: de pouvoir comparer les différents solides géométriques, ainsi que les diverses figures, qui occupent un même lieu, aussi bien que les lieux qu'ils occupent. Il lui est désormais permis de penser leurs relations de repérage, positions, formes et grandeurs, comme il le projetait dans *Les Connus*." Rashed (2002, 662).

[33]Also see El-Bizri (2007), Rashed (2005).

philosophy.[34] What is more, empty space was not an imaginary construct for Patrizi, but a real thing: an incorporeal, immaterial extension, three-dimensional and infinite, which received within itself and preceded all created beings. For Patrizi, space even preceded the world and enjoyed ontological primacy over nature and mathematics. The question that Patrizi found difficult to answer was how God related to space. If their association was too close, his program of quantifying space risked making God quantifiable, dimensional and maybe even divisible, an obviously heretical position. Patrizi thus sought refuge in negative theology, dodging the issue that had troubled centuries of natural philosophical and theological speculation.

1.3 The Divine Void

In 1277, the then Bishop of Paris Etienne Tempier issued a famous series of condemnations of doctrines that limited the power of God. One of the condemnations forbade the doctrine that God could not move the cosmos to a different place. He could indeed move the world. In other words, such movement had to make logical and physical sense, which suggested a possibly infinite space. The condemnations of 1277 heralded an era of creative speculation about space, and especially about the extra cosmic void. The question of extra cosmic space had long been a conundrum. The Pythagorean Archytas, a good friend of Plato, is said to have proposed a thought experiment: if someone at the very end of the sphere of the fixed stars stretches out his hand beyond it, where will his hand be? Since the argument is recursive, to say that the hand will be somewhere implies an infinite space. The Aristotelians vigorously denied the possibility that someone could stretch his hand out beyond the cosmos, and they denied the existence of extra-cosmic void. From 1277 onwards, theological sanction dictated that an omnipotent God could expand the universe beyond its borders, could move it, and could even create multiple worlds, which seemed to need a potential location somewhere in a potentially infinite space.[35]

Medieval thinkers had explored this notion of infinite space and had also tried to make it consistent with Aristotelian physics. In a common fourteenth-century thought experiment, God would annihilate the whole cosmos, thereby leaving a great void. Even if such an event could not arise from (Aristotelean) natural causes, it can surely be *imagined*, and God could make it happen. Such thought experiments were one of the reasons why medieval authors invoked "*spatium imaginarium*" or "*vacuum imaginarium*" to describe the space extending beyond the boundaries of the cosmos. In the thirteenth century, theologians such as Thomas Aquinas and Pseudo-Siger would hold that these spaces were imaginary,

[34] "Non est quantitas. Et si quantitas est, non est illa categoriarum, sed ante eam, eiusque fons et origo." Patrizi (1587, 15v).

[35] See especially Grant (1979).

not real. If we talk about extra cosmic void, they reasoned, or if we do thought experiments, we need to imagine this space, but it does not necessarily exist. Likewise, God *could* create infinite extramundane space, as the 1277 condemnations required, but it did not follow that He had actually done so.

The ontological status of imaginary space is often ambiguous, but it seems clear that philosophers such as Nicole Oresme and Thomas Bradwardine attributed to it a certain reality and existence. Oresme writes that there exists some space beyond the heavens, whatever it may be. He would try to pin down this "whatever it may be," granting his imaginary space a special ontological status. In a way, space is nothing, almost a fiction, because it is neither substance nor accident, Oresme argues, but unlike an illusion, space is not absolutely non-existent either. Imaginary space is the infinity that God could turn into places by creating bodies.[36] Thus the "spatium imaginarium" solved problems related to God's power and presence. As Thomas Bradwardine writes, "There [in imaginary space] He can be said to be omnipresent and omnipotent. He can be said by the same reasoning to be in some way infinite, infinitely great, or of an infinite grandeur, and even in a sense, albeit metaphysically and inappropriately, extended."[37] Every created being must be placed in a continuum, of which God's presence must be attached to every point. For more or less these reasons, Oresme maintained an infinite, non-dimensional, extra-cosmic space, and he went even further than Bradwardine in identifying it with the immensity of God and with the place of the world.[38]

In his chapter, Jean Seidengart examines later developments in the ontology of space, starting from Nicolaus Copernicus, but focusing especially on the work of Giordano Bruno (1548–1600), showing how Bruno was indebted to Greek sources on the question of space and also the nature of Bruno's originality. He explains that for Bruno, space could neither be a substance nor an accident, neither form nor matter, but something that was not directly ontologically definable. In contrast to Oresme, who concluded that space had a relatively low ontological status (lower than an accident), Bruno attributed a high ontological status and a strong physical reality to space. He is today still mainly known for his defense of a real infinite space, which was filled to the brim with a material ether. Most striking is that some interpretations of Bruno read space as coeternal with God but independent of Him:[39] God locating Himself and his Creation in an autonomous infinite space.[40]

[36]If He was capable of creating a body in extra-cosmic space, it followed that He was present there. Because He was immutable, He had always occupied this space.

[37]"[…] unde & veraciter omnipraesens sicut & omnipotents dici potest. Potest quoque simili ratione dici quodammodo infinitus, infinitè magnus, seu magnitudinis infinitae, etiam quodammodo licet Metaphysicè & impropriè extensiue […]" Bradwardine (1618, 179).

[38]Kirschner (2000, 167–170).

[39]See especially Bruno's *De immenso*. See Grant (1981, 191).

[40]The contrast and similarity with Bruno's contemporary, the mystic and theologian Valentin Weigel (1533–1588), studied by Alessandro Scafi, is striking. Weigel argues that the world hangs against an infinite abyss of God, which is not conceptualized as a Brunean infinite space, but as a spiritual nothingness.

The traditional narrative presents the development of absolute infinite space as a great revolution. Nevertheless, we should note that infinite space was a minority position in the sixteenth century, and even among its few proponents it was not a clear cut thing. It could be empty or a plenum. It could be resolutely mathematical, as it was for Patrizi, or its purely-mathematical implications could be quite unimportant, as they were for Bruno. A homogenous, mathematical space need not be infinite or unbounded either. Almost always, space was itself bodily, and it only carried reference by way of the bodies that composed it and circulated in it. Despite the eventual success of Newtonian space, it was exceedingly rare to find a non-material space serving as some underlying reference for the bodies within. However strong the similarities with Newton's *sensorium dei*, medieval and Renaissance writers almost never equated God's immensity with dimensionality.[41] To have done so would have been to make God into something extensive. Even Oresme, one of the most original thinkers of the middle ages, and one of the most daring exponents of infinite space, held that infinite space was dimensionless, exactly because he identified this space with God's immensity. God Himself was nondimensional, unextended and indivisible. His immensity was not spread out, even if He was present everywhere in the universe, in each of its parts and beyond, infinitely and totally. Because God was present everywhere, "*spatium imaginarium*" was not only extramundane void, it was also the void that might exist within our world. For Oresme, if God annihilated everything between two bodies, a distance—that is, imaginary space—would remain between them. Such arguments led Oresme to formally reject the Aristotelian doctrine of place and demonstrate that the place of a body was the imaginary space filled by it.

The imaginary spaces developed in the thirteenth and fourteenth centuries would have a long and varied afterlife. Thomas Hobbes famously claimed that by the word "space," he always meant imaginary space. Hobbes was inspired by medieval and Renaissance uses of imaginary space[42] and developed his ideas explicitly in reaction to a contemporary treatise, the *De mundo dialogi* (1642) by the English Roman Catholic priest Thomas White. Against White's notion of imaginary space, which followed Scholastic discussions on extra cosmic void, Hobbes based his definition of imaginary space on a materialist theory of imagination and perception. In Hobbes's causal theory of perception, the reality of a perceptual image is reduced to the combined effect of pressure on the body from the outside and, in reaction, movements inside the body. What we see appears to be outside us but is in reality in our imagination. Space is likewise a part of that image of things held in our imagination. These imaginary spaces can be added up and extended in all directions by the imagination, resulting in an infinite imaginary space internal to the mind. This imaginary space will form the basis of Hobbes' natural philosophy.[43]

[41] Cf. Grant (1981).

[42] Cees Leijenhorst (1996).

[43] Martine Pécharman (2014). We would like to thank Martine Pécharman for making her text available to us before publication.

Ranging from scholastic discussions on the imaginary void, to geometrical constructs and theories of perception and imagination, imaginary spaces had accrued different meanings and varied philosophical potential. Hobbes's philosophy makes clear that space is also, and maybe preeminently, something that exists in the mind. Hobbes was not the only early modern to explore the mental construction or reconstruction of space. The new optics offered by Johannes Kepler and René Descartes had to account for the experience of space in the mind. Kepler's optics almost completely transformed vision into a physical phenomenon.[44] Vision and its vagaries could be understood by knowing the paths of light as it passed through a special optical instrument, the eye, which was a sort of *camera obscura* whose back wall was the retina. The question thus becomes: how can a picture of space emerge in the mind from the effects of geometrically determined rays? Delphine Bellis, in her contribution, takes up this question on several fronts. Beginning with Kepler, she shows how he explained images formed by reflection and refraction as optical illusions. These images arise, for Kepler, from psychological factors, especially the way imagination projects abstracted rays into space. Kepler's greatest acolyte, René Descartes, took up this process in order to explain the mental triangulation that yields accurate depth perception. In other words, Descartes adopted recent methods of surveying and theories of illusion and made them into a theory explaining the mind's reconstruction of space from mechanical, sensory information.

It is well known that for Descartes, space was nothing more than matter: the void did not exist. At this point, it must be clear to what extent the plenum was a dominant position among late Renaissance and early modern authors. But to put it rather inelegantly, there were many more varieties of "plenism" to choose from than varieties of "vacumism." We should not think of plenism as monolithic. If we look in detail at Descartes' followers, Mihnea Dobre argues in his chapter, we can find that they struck an interesting relationship with the void, in order to communicate and exchange with their non-Cartesian colleagues. The Cartesians, with their hard distinction between body and mind, and with their refusal of absolute space, were perhaps at an acute disadvantage in explaining one of the great consequences of mechanical philosophy: the laboratory-produced vacuum. Dobre shows how these Cartesian experimentalists were, in fact, not constrained by their metaphysical principles and even adopted a loose, practical use of the vacuum. Dobre points out the importance of studying the common language of experimentalists, which was largely devoid of deep philosophical speculation. In a sense, the Cartesians had adopted Boyle's program for avoiding points of irreconcilable contention. Dobre likewise points out that vacuumists, faced with an empty chamber, had essentially to grapple with the same problem as Cartesians: determining the nature of the invisible. After all, truly empty space is as hard to "see" as the refined aether that supposedly fills it. The practical demands of experimentation were in this instance relatively independent from theoretical constructs and deserve to be studied on their own terms.

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[44] Simon (2003).

1.4 Earthly and Celestial Spaces

In the previous section, we have seen that cosmic spaces, microscopic interstices, mathematical spaces and mental spaces were related in various ways, in theory and in practice. In this section, we will consider how these spaces were also connected to practical and theoretical spaces in geography, astronomy, optics and art, and also to the concrete spatiality of surveying and chemistry. As a point of introduction, let us look at how one exemplary figure, Reinier Gemma Frisius (1508–1555), combined all these different spaces in his work. Professor of medicine at Leuven University, Gemma Frisius was not only a physician but also an important mathematician, astronomer, cartographer, philosopher, and instrument maker, and he helped make Leuven into one of the important centers of mathematical learning of the time. Summing up his fields of interest and his accomplishments already makes clear the syncretism between so many intellectual practices that we today hardly consider together. One way they were brought together in the sixteenth century was under the relatively novel label of cosmography. What interests us here in the first place is the ways Gemma Frisius' cosmographical work connected geographical and cosmological spaces through new practical techniques of measurement.[45]

The *Cosmographicus liber*, an early book on cosmography, was published by Peter Apian in 1524, but it was only in improved and expanded later editions by Gemma Frisius that it became the central text of the discipline. The book, called the *Cosmographia* in later editions, consists of two parts: firstly, an exposition of the foundations and beginnings of cosmography and geography, and of the instruments that belong to these disciplines; secondly, a general and particular description of the different continents. Written for a broader audience of intellectuals and interested laypeople, it explains how to find latitude, longitude and time with mathematical instruments. It also teaches the mathematics needed for reading coordinates and converting them into distances or for constructing a cosmographical map. As Steven Vanden Broecke explains, understanding a map or a globe was still a challenge in the sixteenth century and held a considerable sense of fascination for the intellectual and social elite.[46] Besides this important textbook, Gemma Frisius' workshop also sold the mathematical instruments, globes and maps described in the book.[47] The success and extensive circulation of his work and that of his students, including Gerard Mercator, contributed significantly to creating a new sense of place and space in the early modern period.

Their work fits into a longer evolution within practical mathematics, engineering, astronomy and geography: constructing gridded spaces for celestial and geographical expanses. Older thirteenth- to sixteenth-century so-called "Portolan charts" represented compass directions and observed distances, but they were restricted to

[45]Vanden Broecke (2000). Also see Hallyn (2008).

[46]Vanden Broecke (2000, 133).

[47]Gemma Frisius' nephews, Walter and Jeremias Arsenius, were instrument makers. The signatures on the instruments often referred to Gemma Frisius, e.g.: 'Gualterus Arsenius nepos Gemmae Frisii'. These instruments were very popular and used by John Dee, Tycho Brahe and others.

coastlines, did not involve cartographic projection, and were thus not coordinated on a universal grid. This changed with the reception of Ptolemy's *Geography* in the fifteenth and sixteenth centuries, when spatiality became mathematized and standardized.[48] Olaus Magnus' beautiful *Carta marina* (1539), for instance, focuses on the northern seas but also represents the mysterious northern countries for the first time (Fig. 1.2). His map combines concrete places and lived spaces with a mathematical grid. It shows spaces inhabited by northern people and wondrous creatures together with historical events with exact representations of distances and water currents.[49] In the border of the map, a grid with latitudes and longitudes is indicated together with older divisions of the earth, similar to the Ptolemy editions of the fifteenth and early sixteenth centuries (the map border probably was not used for the initial drawing and was added after completion). Gemma Frisius used a new projection for his extremely popular (but now lost) 1540 *Mappa mundi* that, 55 years later, Mercator's son would still esteem the best method (better than the "Mercator projection").[50] Apian's and Gemma Frisius' *Cosmography* not only projected a grid on geographical and cosmological spaces, the second part of the book also classified more or less familiar places in tables, ordering 1417 places with their coordinates, subsuming them under a unified, mathematized and global space.

The contribution of Renaissance perspective and art on the mathematization of space remains contested among historians,[51] but its influence on the new cosmography is significant.[52] Echoing Ptolemy, Apian and Frisius compared geography with a painting "of the most important and renowned parts of the earth itself, in as far as the entire and noted earth consists of them," because it "commits the order and location of places most easily to our memory. And so the perfection and end of Geography consists in the consideration of the whole earth."[53] A famous image (Fig. 1.3) symbolizes the perspective underlying cosmography. Lines emanating or converging in the eye, as in a perspective drawing (even if this eye can only be the *mind's* eye of the cosmographer), connect the earth's surface with the celestial sphere. This procedure resulted in the construction of a gridded terrestrial globe. As Vanden Broecke puts it: "cosmographical maps and globes achieved *imitatio*, the perfect illusion of visible nature, by applying techniques similar to those of linear perspective painting."[54] Renaissance art and cosmography often shared the same practitioners, patrons and techniques, and their projective techniques had shared

[48]On early modern cartography and cosmology, see e.g. Besse (2003), (esp. 111–149 for Ptolemy's reception and the grid). Also see Short (2004), Smith (2008).

[49]On the exactness of the water currents, Rossby and Miller (2003).

[50]Hallyn (2008, 52).

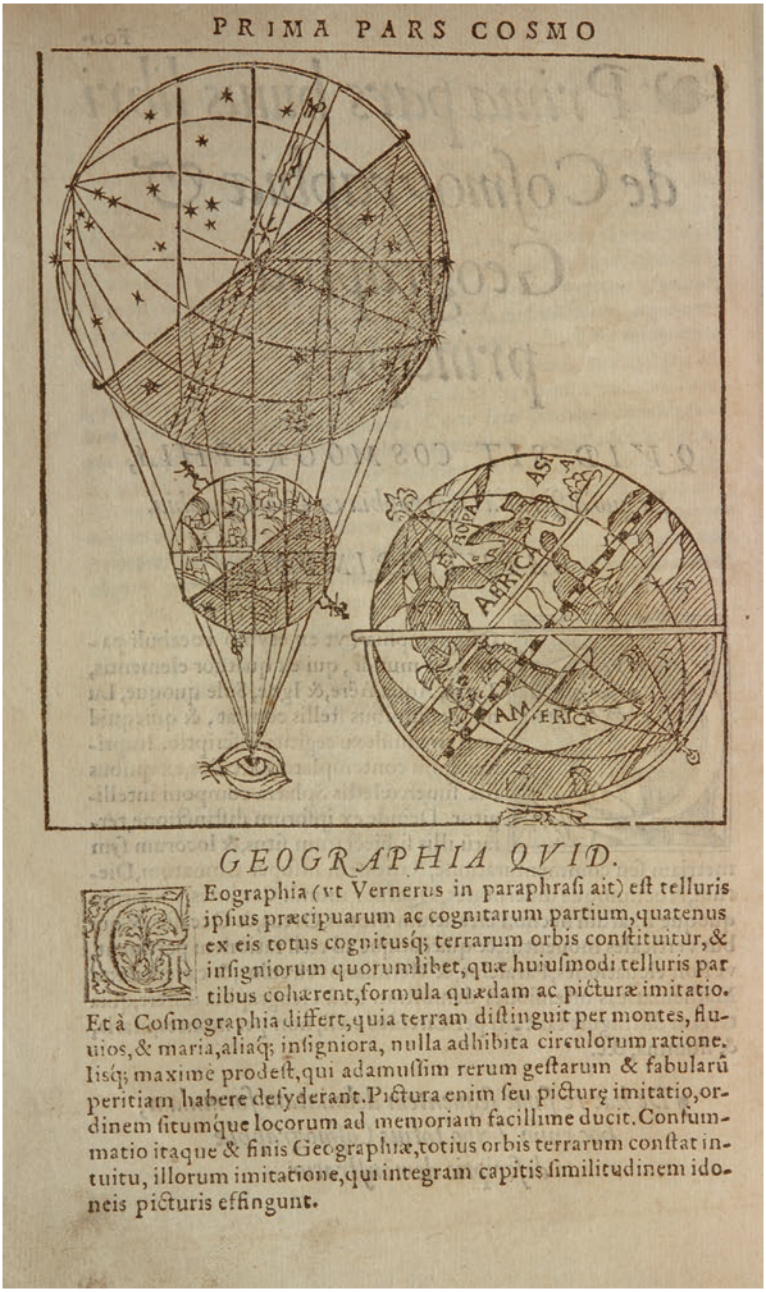
[51]There is a wide range of works on perspective spaces in art and architecture, and their rapport with natural philosophy, beginning with Panofsky's classic study: Panofsky (1927). Also see Kubovy (1988); Damisch (1987). For more recent volumes, see Cojannot-Le Blanc et al. (2006), Carpo and Lemerie (2008); Massey (2007).

[52]See Vanden Broecke (2000), Hallyn (2008, Chaps. 4 and 5).

[53]Apianus and Frisius (1564, ff.3r).

[54]Vanden Broecke (2000, 137). Also see Besse (2003, 123–129).

Fig. 1.2 Olaus Magnus, *Carta marina et Descriptio septemtrionalium terrarum ac mirabilium rerum in eis contentarum, diligentissime elaborata Annon Domini 1539 Veneciis liberalitate Reverendissimi Domini Ieronimi Quirini*, Venice, 1539. Courtesy of the James Ford Bell Library, University of Minnesota


PRIMA PARS COSMO

GEOGRAPHIA QVID.

Geographia (vt Vernerus in paraphraſi ait) eſt telluris ipſius præcipuarum ac cognitarum partium, quatenus ex eis totus cognitusq; terrarum orbis conſtituitur, & inſigniorum quorumlibet, quæ huiuſmodi telluris partibus cohærent, formula quædam ac picturæ imitatio. Et à Coſmographia differt, quia terram diſtinguit per montes, fluuios, & maria, aliaq; inſigniora, nulla adhibita circulorum ratione. Iisq; maxime prodeſt, qui adamuſſim rerum geſtarum & fabularũ peritiam habere deſyderant. Pictura enim ſeu picturę imitatio, ordinem ſitumque locorum ad memoriam facillime ducit. Conſummatio itaque & finis Geographiæ, totius orbis terrarum conſtat intuitu, illorum imitatione, qui integram capitis ſimilitudinem idoneis picturis effingunt.

Fig. 1.3 Peter Apian and Gemma Frisius, *Cosmographia*, Antwerp: Gregorius Bontius, 1550, f. 1v. Courtesy of the Max Planck Institute for the History of Science roots in Ptolemy's *Geography*, the Latin translation of which was published in 1475.[55] Their techniques helped to see the space of the world as a unified whole.

Gemma Frisius assured extensive circulation for his writings by appending some of them to the widely popular *Cosmography*. His *Libellus de locorum describendorum ratione* or "Booklet concerning a way of describing places" was published as an annex to the 1533 edition and explained a new method for "describing" places: that is, for measuring them, calculating their distances and, eventually, locating them in a gridded space. This novel method of triangulation would drastically change how earthly space was measured. Until the launching of satellites and GPS localization, it was the only tool capable of producing accurate maps (with their incredible economic, political, military and scientific significance), and it would be at the heart of the standardized metric system.[56] In his 1530 *De usu globi* ("*On the use of the Globe*"), Frisius described a new method for finding longitude by means of transporting clocks.[57] This method was independent from unreliable or insufficient data about the moon (e.g. eclipses), and is claimed to mark the beginning of modern navigation.[58]

In 1545, Frisius published a work called *De radio astronomico et geometrico liber*, a handbook on a new form of cross-staff of his own invention, an instrument for measuring the distance or angle between two objects. This book also contains the earliest printed, largely positive, discussion of Copernicus' *De revolutionibus*. More significant, perhaps, is Frisius' use of his new T-shaped instrument which had an adjustable crossbeam. With this instrument, he measured the distance between stars as they changed latitude. Lo and behold, as he writes in his book, he recorded no change in distance.[59] This was a quite radical result. Atmospheric refraction, long an accepted part of astronomy, *ought* to change the perceived interstellar distances (and, in fact, Frisius's observations must have been erroneous). Yet the confidence Gemma Frisius had in his instrument was infectious.

Jean Péna, in the introduction to his 1557 translation of Euclid's *Optics*, accepted Frisius's results. Based on the supposed absence of atmospheric refraction, he drew inspiration from Stoic philosophy and concluded that there were no celestial spheres and that the universe was filled with a life-giving air indistinguishable from what we breathe. Péna's argument is generally noted to be the first empirical argument against solid spheres.[60] Indeed, he recognized the possibility of solving what we would call "cosmological" problems through a study of light's behavior. In turn, he set optics at the core of his Pythagorean natural philosophy. Optics had a special capacity for unveiling errors of perception: "What art shows the reasons for so many

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[55] Ptolemy's *Geography* was rendered into Latin by Jacopo d'Angelo, who gave the book the title *Cosmographia* because Ptolemy's method connected the earth with the heavens. The translation circulated in manuscript form from 1406 onwards.

[56] Cf. Alder (2002).

[57] See esp. Chap. 18 of Frisius (1530).

[58] Pogo (1935).

[59] Goldstein (1987), especially 173.

[60] See Barker (1985). Also see, Barker (2008).

illusions, so many deceptions, in which the human mind is necessarily born? What science reveals the causes of so many miracles? A small quantity appears frequently to be enormous; a curved line can be seen as straight, a straight line curved […] Is the human intellect to be mocked by the nature of these illusions or will it for once and all turn to an investigation of the causes?" Péna responds to his series of rhetorical questions: "Only by optics can man reveal these deceptions of nature."[61]

A different kind of optical argument would eventually be marshaled against solid spheres to great effect, with Tycho Brahe demonstrating that cometary parallaxes place comets well outside the lunar orb. Brahe himself opts for a super-thin aether almost equal to empty space. "In effect," he writes, "although the sky is something very thin and is amenable all over to the movement of the stars and presents no obstacle, however there exists by no means at all anything incorporeal (otherwise it would be infinite and non-localized in space)."[62] With the telescopic observations of Galileo and the resulting mathematical and philosophical discussions, optical instruments and arguments would provide an even stronger challenge to the old cosmology.[63] The telescope also heralded new perceptions and theories of macroscopic and cosmic space. It brought distances close by and made the moon a world like the earth. The microscope would do something similar for microscopic space.[64]

In his work, Gemma Frisius connected concrete places, specific distances and lived spaces with mathematized grids, geographical spaces and cosmic structures through new practical and instrumental techniques of measurement, observation, calculation and representation. In order better to understand how this diversity of practices and disciplines interconnected, we need a more "connected history," a fuller perspective on early modern spaces and their changing conceptualizations.[65] Even if we look only at one discipline, cosmography, multiple approaches and perspectives are necessary. Cosmography was in many ways a hybrid of celestial and earthly sciences, and of academic and artisanal practices. In that sense, cosmography can be singled out as the sixteenth-century discipline devoted to spatiality and boundaries of space. There was not yet a consensus about the definition of this young discipline,

[61]"Quae enim ars tot praestigiarum, tot fallaciarum, in quibus humana mens per se caecutire nata est, rationes monstrat? Quae scientia tot miraculorum causas aperit? Parua moles ingentis magnitudinis saepè apparet: curua rectis, recta curuis […] quibus natura ingenium hominis vel ludificari, vel certè ad causarum inquisitionem mouere voluit? […] sola Optice has naturae fallacias retegat […]" Péna (1557), aa.iir-aa.iiv of *praefatio*.

[62]"Etsi enim totum Caelum tenuissimum quid, & ubiq motui Siderum absq, nullo obstaculo pervium sit: prorsus tamen incorporeum (alias etiam infinitum & illocale esset) nequaquam existit." Brahe (1610) [1602], liber primus, 794.

[63]For Galileos conservative position in the case of cometary parralax, see e.g. Gal and Chen-Morris (2013, Chap. 3).

[64]Here we are on familiar terrain, researched in detail and described *in extenso* in history of science textbooks.

[65]Of course, we are not referring here to a "connected history" that connects different places and studies circulations of knowledge, but rather to a historiography that connects different practices in order to better understand interconnections between various conceptualizations of different spaces.

but spaces, boundaries and distances were central. John Dee wrote that cosmography "matcheth Heaven and the Earth in one frame," and its practice required astronomy, geography, hydrography and music.[66] For Peter Apian and Gemma Frisius, it was essentially a "mathematical" discipline, because its central goal was to map the circles that the celestial motions projected on the earth.[67] They left to geography the description of mountains, seas and rivers. For Kepler and Galileo, cosmography meant the search for the hidden mathematical structures of the universe. Other authors had a more inclusive definition of cosmography. For Sebastian Münster, it was an encyclopedic enterprise, less involved with mathematics, focusing on the description of place. Münster's enormous *Cosmographia universalis* organizes, recombines, and recounts knowledge on "peoples and nations of the whole world, their studies, sects, customs, habits, laws, creation of lands, animals, mountains rivers, seas, swamps, lakes and other things of the sort which are celebrated by historians and cosmographers."[68] The last two hundred or so pages of the French translation concern the recently discovered lands, beginning with a chapter entitled, "The lands discovered in our time, to which we have given the name of the New World, the Occidental Indies, or America. And firstly on why they have been called the Indies and if the name is truly appropriate."[69] Improved techniques of practical mathematics, astronomy and navigation had led to unprecedented travel and discoveries of new geographical spaces, presenting a new unification of the world, which in turn led to new conceptualizations of space in cartography and cosmography.

We see the overlap of these spaces in Thibaut Maus de Rolley's contribution, which studies the exchange between travel accounts, cosmography, natural philosophy and demonology. It turns out that the cosmographical revolution changed the way that demonologists thought about the devil, his powers and his spatial presence. Demons of the late Renaissance, Maus de Rolley explains, were natural-philosophical experts, ruling over the elements and traversing elemental boundaries, flitting in the air and producing devious tricks of weather. The all-seeing eye of the devil was equivalent to the eye of the cosmographer, perceiving the totality of the earth all at once (see again Fig. 1.3). While the demonic empire was always considered to be "on the move," as Maus de Rolley shows, demonic hoards were thought to have their favorite places. Like the monsters in Oleus Magnus' map, they preferred the margins, which meant, at the time, northern Europe and the New World. With the new sea voyages, explorations and exchanges, however, these margins were disturbed and the demons began crossing the seas and returning to the civilized world. The best way to counter them was to study them, to study the places they inhabited and the people whom they led astray. The demonologist had become a practical cosmographer.

[66] Euclid (1570, page 24 of Dee's unnumbered preface).

[67] Apian and Frisius Apianus (1564) [1533]. See the definition of cosmography under *caput primum*, 1r.

[68] Sebastian Münster, *Cosmographia universalis* (Basel: Heinrich Petri 1550, 1162), in McLean (2007, 151).

[69] This is from the table of contents of François de Belleforest's 1575 French translation, *La cosmographie universelle de tout le monde*. For a list of the translations and editions, see McLean (2007, 346).

From this vision of impious cosmographies we turn to the pious, with Alessandro Scafi's study of Valentin Weigel. Weigel, a radical Lutheran pastor in Saxony, adept of Paracelsus, was also informed in the latest developments of cosmography. He adopted contemporary geographical knowledge to argue a remarkable religious vision. Locations, places and bodies were internal to the earthly world, which floated incommensurably against a background of infinite nothingness. This nothingness Weigel associated with the spiritual world, the inner world of spirit that was not bound to place and that occupied no space. His work offered a mystic's sensitivity to the opposite poles of matter and spirit, body and soul, earth and heaven. The visible world was the result of the Fall, an "excrement" that would dissolve with the inception of the Kingdom of God. Yet God was not absent in this material world, made nonetheless in His image. The spiritual realm of the angels was invisibly present, constituting the world's divine dimension.

Spiritual and earthly spaces have been married in different ways. In Fig. 1.1, Matthew Paris' multi-page visualisation of the itinerary from London to the Holy Land was as much an exact earthly itinerary as an imaginary and spiritual one.[70] In the early modern period, the breakdown of boundaries between earthly and heavenly realms was remedied in different ways. Even as boundaries were modified by voyage and discovery, even as mapping became rigorous, the religious and cosmographical remained closely tied.[71] Some, like Weigel, reasserted a spiritual distinction between earth and heavens. Others, in continuity with the medieval scheme, still placed the heavens as outside the natural world. Looking at Apian and Frisius's cosmographic map (Fig. 1.4), we see that it includes the *caelum empireum* outside of the natural world, like its medieval predecessors. Texts about the nature of the Empyrean persisted well into the seventeenth century, inquiring into Paradise's dimensions, air, cities and population.[72]

1.5 Boundaries and Circulations

Sebastian Münster's *Cosmographia* (1544) opens on a point of circulation and boundary: the relationship between elements. He explains how "the earth at the beginning of its creation was wholly covered and enclosed by water."[73] The waters were drawn away from a portion of the earth, leaving a place for plants, animals, and men to live. "The sea," he writes, "has even to this day never had its natural position, and thus having been pulled to the opposite side of this terrestrial mass

[70]See Connolly (1999, 2009).

[71]For the early modern development of mapping and the great difference between the sixteenth-century vision of the world and what had come before, see Smith (2008).

[72]See Randles (1999, 133–150). Note, however, that discussions of the Empyrean do not contradict absolute space, as e.g. in Henry More. See e.g. Vermeir (2012).

[73]We cite the 1575 French translation. Münster (1575, 5).

Fig. 1.4 Peter Apian and Gemma Frisius, *Cosmographia*, Antwerp: Gregorius Bontius, 1550, f. 3r. Courtesy of the Max Planck Institute for the History of Science

has doubled its depth."[74] In fact, Münster's account of earth and ocean was already centuries old, dating at least to Jean Buridan.[75] It represented a very neat synthesis of Aristotle and Genesis. In the moments after Creation, the elements formed concentric spheres, exactly as they did in most astronomical and cosmographical illustrations—as, for example, in the medieval Psautier of Robert de Lisle (Fig. 1.5).[76] Thus, before creating life in this elemental scheme, God had to offset the watery and earthy spheres, separating them enough that the northern hemisphere could stick out like a nub from the vast expanse of ocean that submerged the southern hemisphere. There is a remarkable woodcut in the Latin translation of Münster's cosmography (Fig. 1.6).[77] To the modern reader, the composition looks like it was done through a fish-eye lens. The visual effect puts the earth and water into contrast. The earth stands like an island in the sea. The reader can almost sense the tension of God separating the elements into a livable globe.

Yet such a vision of the earth-water relationship was already being undercut by recent voyages and discoveries. In fact, the scheme described by Münster had almost upended Columbus's plans when counselors for the throne of Spain initially denied him financing, concerned that the ocean crossing would be disastrously long and perilous to sail.[78] Yet in the decades following his voyage, and with the well-publicized 1501 voyage of Amerigo Vespucci, a new sense not only of cartographic but also natural philosophical boundaries was emerging, especially outside the universities. Columbus, for example, had been favorable to Ptolemy's account rather than to the medieval one, where the oceans sat in depressions on the earth, giving the earth and water the same surface.[79] Consider Fig. 1.4 again, from Peter Apian and Gemma Frisius's *Cosmographia*, which bears comparing with the medieval predecessor we have just seen.[80] In many ways, the two are identical. A major difference, if not *the* major difference, is the representation of the earth.[81] In the sixteenth-century chart, the earth and water clearly share the same surface. Even more, they are rendered as a landscape. Copernicus likewise took the position that water sits atop depressions on the surface of the earth, whose volume dwarfs the overall volume of water.[82] At the same time, he applies this argument in a quixotic way. He explains the earth's movement by its geometrical form: its ideal sphericity—the shared surface of earth and water—opens up the possibility of

[74]"La mer donc des ce jour n'eut point sa situation naturelle, ains estant retiree en la partie opposite de cette masse terrestre, a autant redoublé sa profondeur, comme elle a descouvert de la terre." Ibid., 6.

[75]Other Renaissance savants of considerable repute, among them Gregor Reisch (1467–1525), also carried Buridan's idea well into the sixteenth century. See Besse (2003, 91–96).

[76]The image illustrates a passage from Jean Peckham's *Tractatus de sphera*.

[77]Münster (1550, 1).

[78]Vogel (2006, 477–478).

[79]Ibid.

[80]Apian and Frisius (1964, 3r).

[81]See Besse (2003, 16).

[82]Ptolemy (2000, 60).

Fig. 1.5 A table of spheres, based on the introduction to John of Peckham's *Tractatus de sphera*. From the *De Lisle Psalter*, England, c. 1310, Arundel MS 83, 123v. Courtesy of the British Library


1

COSMOGRAPHIAE uniuersalis ex probatis quibusque au thoribus tam historicis quàm cho rographis per Sebastianum Munste rum in unum collectæ, Liber primus.

De primordiali terræ & maris creatione & dispositione, Cap. I.

HABENT sacræ literæ, terram ab initio suæ formationis undi que obductã & inclusam fuisse aquis maris, donec iussu crea toris aqua ab aliqua parte superficiei terræ subducta, siccũ & cõmodum mansionis locum hominibus atq; animalibus ter restribus reliquit, plantis quoq; unde omnia uiuentia uictita rent, firmum in ipsa arida adaptaretur fundamentum. Mare ergo ab illa die non obtinet naturalem suum situm, sed quan tum terra est discooperta, tantum illud in oppositam terrenę molis partem semotum, profunditatem illam cõduplicauit, quam Oceanũ uocãt, sacræ autẽ literę appellant תְּהוֹם רַבָּה id est, abyssum magnã, ubi scilicet immẽsa est collectio aqua rũ atq; profunditas imperscrutabilis, qualis passim ultra Hi spaniã, Iberniam, Scotiã, extremitatẽ Africę & in India inuenitur, ubi profunditas maris nulla industria humana indagari potest. Si enim iuxta philosophorũ traditionem, elemen

Oceanus abyssus magna.

a tum

Fig. 1.6 Sebastian Münster, *Cosmographiae uniuersalis Libri VI*, Basel: Heinrich Petri, 1552, 1. Courtesy of the Bavarian State Library movement.[83] Revolution, he writes, is the movement natural to a sphere: hence, the earth as a perfect sphere can also revolve. The configuration of terrestrial elements links to the reshuffling of celestial bodies.

New boundaries and circulations in the sixteenth and seventeenth centuries were to a great degree caused by a revival of Neoplatonic, Stoic and Epicurean ideas, by the quick spread of Paracelsian philosophy, and by a reenergized Galen. Authors proposed different causal schemes to explain forces that seemed to act at a distance. Again, spaces were defined by the bodies that moved through them or by the powers they sustained. Authors who accepted forces at a distance had to reckon with different orbs of virtue, virtues with limited powers or new boundaries of efficacious action. Others who did not accept action at a distance filled spaces with subtle matter, the circulation and interaction of which also created distinct kinds of spatiality. Magnetism and light were distance forces *par excellence*. Sometimes they were understood as quasi-living forces or as bodily spirits. These fine pneumatic winds that also passed through the nerves and corridors of the brain were often compared with light, as the French physician André Du Laurens did when he wrote that "[…] the nerves, for the continuity that they have with their principal, as rays with the Sun, carry from the brain the true power in a highly subtle body, that is, the animal spirit."[84] *Spiritus* was one of the late-Renaissance's great causal entities. At times, it was related to "spiritual beings" such as demons and angels. At other times, it was more or less equivalent with the Stoic *pneuma*. Because it was thought to cause intellectual activity by moving through the brain, it was closely related to higher functions, particularly imagination. *Spiritus* or its vital heat, in some cases, came to be identified with the soul itself, as in Cardano and Telesio. In short, the spaces and bodies of the sixteenth and seventeenth century were saturated with such spiritual substances, whether material or not. They were able to connect body and mind, mind and the material environment as well as the world and the heavens.[85]

At the turn of the seventeenth century, William Gilbert, Johannes Kepler and Francis Bacon developed natural philosophies largely based on orbs of virtue, power, force or spirit. Dana Jalobeanu, in her article, considers how interconnected spatial concepts play a constitutive role in their philosophies. She points out the insurmountable problems that arose when Gilbert and Kepler tried to simplify the number of virtues active in the world. Unlike Gilbert and Kepler, Jalobeanu argues, Bacon did not try to reduce the number of spherical emanations that could play upon bodies. Bacon's interest, Jalobeanu explains, was instead in mapping and measuring the "limits" and "borders" of these orbs through laboratory procedures.

[83] He makes a point of telling his readers that mountains and valleys, although impressive from up-close, hardly modify the "perfect rotundity" or "perfect sphericity" of the earth.

[84] "[…] les nerfs pour la continuation qu'ils ont avec leur principe, comme ont les rayons avec le Soleil, apportent du cerveau le pouvoir reelle en un corps bien subtil, qui est l'esprit animal […]" du Laurens (1615, 7r).

[85] On this interconnectedness of mind, body and environment through spirits and imagination, see e.g. Vermeir (2004). The idea that the imagination was so powerful that it could extend its action outside the body was often debated in medieval discussions of action at a distance.

The circulation of entities through different spaces occupied a central place in medicine and alchemy. Jean Fernal and Girolamo Fracastoro established new theories of contagious disease, of agents spreading out in space. This is the so-called "ontological" view of disease as a full-fledged entity capable of transmission, rather than a mere corruption of air and water.[86] The circulation of formal seeds, or *rationes seminales*, had entered into Christian natural philosophy long before, particularly through Saint Augustine, who adopted the idea from the Stoic *logoi spermatikoi*. The concept, present in some medieval writers, enjoyed a great resurgence in Ficino and slightly later in Paracelsus. A major use of these formal seeds was to explain spontaneous generation. However, their formative force was explicitly related to the power of celestial bodies. As such, formal seeds defied any easy cosmological categorization and were well-suited to new, non-Aristotelian boundaries of space. They were a typical instance of circulation between celestial and earthly realms. Luc Peterschmitt, in his chapter, discusses the spatiality and circulation of spiritual entities and seeds in the chemical-cosmological theories of Joseph Duchesne and Pierre-Jean Fabre, both Paracelsians, and Herman Boerhaave, the celebrated eighteenth-century chemist. Peterschmitt shows how these theories of circulation relate closely to the cosmic or spatial structure promoted by each author. He also identifies a hardening of the materialist stance, from Duchesne to Boerhaave, although he still detects remnants of circulating spiritual entities in Boerhaave's work. Peterschmitt ends by considering how, in comparing the three authors, we move from organized or hierarchical spaces in Duchesne and Fabre to a homogenous, fire-infused space in Boerhaave, providing another new perspective of the general transformation from multifarious places and hierarchized spaces to a universalized ubiquitous space.

1.6 Conclusion

Early modern spatial practices and concepts are part of a long history. The word "space," as we have seen, has Greek and Latin roots, and the early modern meaning of space followed in many ways connotations long carried by the Latin term "*spatium*." Space and *spatium* could mean concrete intervals, distances, areas or time. Some meanings were lost on the way. In antiquity, "*spatium*" could denote the paths of the celestial bodies, but early modern authors such as Regiomontanus, Peurbach, Copernicus, Brahe and Kepler, used terms like "*cursus*," "*sphaera*," and "*orbis*" instead.[87] In turn, some of the early modern uses of "space" have now

[86]See Nutton (1983), Nutton (1990). Also see Forrester and Henry (2005, 22–28).

[87]For example, Cicero (1917) II.49. Early modern writers did not ignore "*spatium*" or its frequent variant "*spacium*." However, they stuck to the other connotations. Consider how Rheticus, explaining the Copernican order, fans out a series of terms each referring to a different kind of space: "[…] between the concave surface of Mars's orb [*orbis*], and the convex orb of Venus, the space [*spacium*] must be large enough to surround the globe [*globum*] of the earth, along with the adjacent elements and the Lunar orb." "…sed intra concauam superficiem orbis Martis, et conuexam Veneris, cum satis amplum relictum sit spacium, globum telluris cum adiacentibus elementis, orbe Lunari circundatum…" We have used the edition of the *Narratio prima* (1540) published in 1596 and reprinted in Kepler (1937).

become obsolete. Paying close attention to sources, the early modern period is special not because the Newtonian idea of absolute space was developed then, but rather because of the flourishing and mixing of many different concepts of space. Many older meanings were still present, and newer meanings began to manifest, attesting to an expansive interest in spaces and spatiality. Some of this richness is captured in the present volume.

Fig. 1.7 Opicinus de Canistris, *Mappe*, 1296, Vaticanus latinus 6435, f. 84v. Courtesy of the Vatican Apostolic Library

In this introduction, we have tried to frame the contributions in a bigger picture, relating them to the tradition and historiography of spatial concepts and theories. In this sense, our introduction is neither a general overview of concepts of space, nor a genealogy of spatial theories. Some aspects of early modern space could not be presented at all. Moreover, there are fascinating treatments or representations of space that would have merited discussion—whether in our brief introduction or in one of the chapters—were it not that they transgress the temporal or historiographical limits that we set ourselves in this book. (One example that we cannot resist to mention is the anthropo-mystical maps of Europe drawn by Opicinus de Canistris in the fourteenth century; see Fig. 1.7). We leave it to future researchers to open up the discussion even further by extending the cultural, social, educational and even spatial historiographies of space.

As we have suggested, the contributions in this book do not follow the traditional focus on absolute space and its forerunners; nor do they reject this traditional narrative out of hand. As with our introduction, they remain in continuous interaction with this tradition, adding sometimes unexpected perspectives or giving twists and turns to the received views. For example, our authors do write about the ontological status of infinite space and its mathematical properties, but they are also interested in concrete measurements and experimental practices. Imagined spaces, spatial perception, metaphorical and conceptual spaces are at least as important as "real" spaces, whatever the latter may mean. In reading the different chapters, we become more aware of the powers of place and body—places and bodies often constitute, determine and structure space. Early modern spaces cannot be studied *in abstracto* or *in absoluto*: one should pay close attention to the particular boundaries and interactions between them. This is certainly the case for the connection between earthly, cosmic and heavenly spaces, subject to great attention and contestation in the early modern period. In order to understand spaces, we argue, we must study what moves in them and how. We must study their boundaries, circulations, and powers.

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Chapter 2
Leibniz and the Petrifying Virtue of the Place

Roger Ariew

Abstract The medieval account of fossils is that animals are sometimes changed into stones because of the petrifying virtue of certain places. This doctrine continues well into the second half of the seventeenth century. The standard account, then, is that fossils are the remains of animals; it inherits the difficulty of explaining how the remains are petrified, or are constituted by some matter different from that of the original animals. It is easy to see how this doctrine could evolve to become the view of Athanasius Kircher and others that fossils are the creation of the power of the place mimicking animals, without there being any actual remains of animals. Kircher and the others provide a ready answer for the obvious differences between fossils and living creatures, including the problem of the stony matter of the fossils, but they achieve this status at the cost of severing links between creatures and fossils. This is the background for Leibniz's writings on fossils. I trace Leibniz's development from a follower of Kircher to one of his critics (having been influenced by Nicolaus Steno among others). I also show the resilience of the original doctrine; ultimately Leibniz's rejection is only partial.

In his "Eloge de Monsieur Leibnitz," Fontenelle complained that Leibniz's interests were very wide-ranging, so broad, in fact, that he could not write about Leibniz's works chronologically because "Leibniz wrote about different matters in the same years, and this almost perpetual jumble, which did not produce any confusion in his ideas, these abrupt and frequent transitions from one subject to another completely different subject, which did not trouble him, would trouble and confuse this history." Clearly, Leibniz's interests were broad even by eighteenth century standards. Fontenelle continued: "In the same way that the ancients could

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manage simultaneously up to eight harnessed horses, Leibniz could manage simultaneously all the sciences"—and by all "the sciences" Fontenelle meant all the traditional sciences of mathematics, metaphysics, natural philosophy, and theology."[1] Leibniz's interests even encompassed the relatively newer sciences of geology, mineralogy, and paleontology. The collection of Leibniz's writings published in the eighteenth century by Dutens, from the most readily available sources, gives three items dealing with fossils: a letter on fossils, a report to the Académie des Sciences de Paris about fossils[2] (both items having been published by Leibniz during his lifetime), and the unpublished book-length manuscript called the *Protogaea*,[3] which is Leibniz's single volume preface to his proposed three-volume history of the House of Hanover.[4] Some sections from the *Protogaea* even made their way into the *Theodicy,* his major published philosophical treatise. But, as with much of what he theorized about, Leibniz completely changed his mind about the elements of geology, mineralogy, etc., and even about the origin and constitution of fossils. An early, unedited manuscript in his hand has him denying that fossils are the remains of animals:

> I find it difficult to believe that the bones one sometimes finds in the fields, or that one discovers by digging in the earth, are the remains of real giants; similarly, that the Maltese stones commonly called serpent teeth are parts of fish, and that shells often found rather far from the sea are the certain marks of the sea having covered these places and, upon withdrawing, having left behind these shells, which then became petrified.
>
> If that were true, perhaps the earth would have to be much older than is reported by the Holy Scriptures. But I don't want to stop at this, and we need to give natural reasons here. Thus, I believe that these shapes of bones of animals and shells are often only games of nature, which have been formed apart without having come from animals. For it is invariable that stones grow and take on a thousand strange shapes, as testify the stones that the Reverend Father Kircher has amassed in his *Subterraneous World*.[5]

Clearly Leibniz was driven to his conclusions because of the creationist account in Genesis. He could not believe that fossilized bones of animals were the remains of extinct species and thought that the process of petrification that might produce fossilized shells would take much longer than the amount of time allegedly elapsed since the creation of the earth.

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[1]Bernard de Fontenelle, "Eloge," in Leibniz (1768, I, xx).

[2]*Epistola ad authorem dissertationes de figurus animalium quae in lapidlibus observantur & lithozoorum nomine venire possunt* and *Memoire sur les pierres qui renferment des plantes & des poissons desseches,* in Leibniz (1768, II.2, 176–77 and 178–80). "*Epistola*…" was published in *Miscellanea Berolinensia* … 170, and "*Memoire*…" was published in *Histoire de l'Académie Royale des Sciences de Paris*, 1706. There is also a 2 pp. tract called *Protogaea autore GGL* in *Acta Eruditorum,* January 1693, not in Dutens.

[3]Though this may not have been Leibniz's title. See Garber (2011, 65–66), Smith (2011, 219).

[4]Leibniz intended to preface his history of Hanover with a dissertation on the state of Germany as it was prior to all histories. As he says at the beginning of the book, "Even a slight notion of great things is of value. Therefore, those who would trace our region back to its beginnings must also say something about the original appearance of the earth, and about the nature of the soil and what it contains," Leibniz (2008, 3).

[5]Cohen (1994, 79 and 1998, 140–141). See also (Garber 2011, 170–71).

Later on in his manuscript, Leibniz discusses the question of the petrified shells one finds on the tops of mountains. He expresses doubts that there could be enough water to have covered these mountains for a sufficient amount of time and wonders where the great quantity of water could have gone. He asserts that it is rather unlikely that a large part of the sea and of the earth had been compressed, then eventually dispersed, and these small shells could have escaped such a great upheaval. He adds, "one finds stony shells of several unknown species that one would seek in the sea in vain," and concludes that these shells provide "an indication that they are games of nature, unless one maintains that they are lost species, which is not likely." He also comments that "the more one finds such a great quantity of shells, bones, and fish piled on top of one another, the more reason one has to believe that the earth in which they lie has a particular force for producing them in such quantity than to imagine that the sea has brought them all to that specific place." Leibniz then argues against the likelihood that bones are the remains of terrestrial giants, in the fashion of Kircher, but referring also to Galileo's reasoning about the limits of terrestrial animals and the greater size of aquatic animals, which are better supported by water than by air. But he concludes that "even if we agree that there have been giant behemoths," it should nevertheless be maintained that "often the alleged bones of terrestrial animals or fish we believe had been petrified some thousands of years ago are just real stones, formed perhaps not long ago by the plastic virtue of the earth."[6] Leibniz thus accepts the view that some fossils, having the shape of stony bones and shells, are the product of the earth, games of nature (*lusus naturae*), that have been formed and grown apart by some plastic virtue of the earth (*vis lapidifica*), without having to derive from animals.

In fact, Leibniz will ultimately deny just about every sentence of his early manuscript. With respect to the beginning paragraphs of his manuscript, he will assert that the bones one discovers by digging in the earth are the remains of real giants; that Maltese stones are parts of fish; that shells found far from the sea are the marks of the sea having covered these places and, after the sea withdrew, the shells became petrified. He will imply that the earth is much older than is reported by Genesis. He will deny that the shapes of bones of animals and shells are often only games of nature and reject Athanasius Kircher's thesis that stones grow and take on a thousand strange shapes.

To make sense of Leibniz's transformation, we should set the context for his early views, namely, the scholastic account of fossils, leading to Kircher's theory; we need to provide enough intellectual counter-balance to these accounts to overcome the resistance imposed upon him by the story in Genesis. Now, the standard scholastic doctrine, as represented by the tradition of commentaries on Aristotle's *Meteorology* or such scholastic treatises as the *De mineralibus*, was that fossils are, in fact, the remains of animals.[7] The scholastic tradition then had the difficulty of explaining how these remains are petrified, or are constituted by some matter

[6] Cohen (1998, 140–141).

[7] See, for example. Avicenna (1927, 46–47); Albertus Magnus (1559, I, i, Chap. 2 and ii, Chap. 9).

different from that of the original animals. The responses to such questions were seldom satisfactory: it is not obvious how the original animals could have left their form but not their matter or could have transferred their form from one matter to another. The view that had great currency was that the remains of the animals were turned into stone by the place itself and its petrifying power (the *vis lapidifactiva* or *virtute quadam minerali lapidifactiva*). Here is a typical expression of it from Albertus Magnus, using Avicenna as an authority:

> It seems wonderful to everyone that sometimes stones are found that have figures of animals inside and outside…. And Avicenna says that the cause of this is that animals, just as they are, are sometimes changed into stones, and especially salty stones. For he says that just as Earth and Water are material for stones, so animals, too, are material for stones. And in places where a petrifying force is exhaling, they change into their elements and are attacked by the properties or the qualities which are present in those places, and the elements in the bodies of such animals are changed into the dominant element, namely Earth mixed with Water; and then the mineralizing power converts the mixture into stone, and the parts of the body retain their shape, inside and outside, just as they were before.[8]

The theory has its roots in Plato and Aristotle. One can detect many of its elements in the popular account of the formation of stones by Theophrastus, from his *History of Stones.* Theophrastus describes the origins of things formed in the earth as being from earth and water, and the mechanism of formation involving exhalations ("afflux" or "percolation"). He adds that stones have many properties or qualities, including the power of petrifying or converting other things wholly to stone.[9] Theophrastus' explanation, as far as it goes, is about inorganic bodies. According to him, stones originate from earth and they, not places, have the power of turning other things to stone. Albertus Magnus' account that animals are sometime changed into stone in places where a petrifying force is exhaling, seems to be something supplementary, something overlaid upon the account of Theophrastus, that earth and water are material for stones.

We can also see the Medieval explanation, with a few other twists, reflected in a seventeenth century context, for example, in the multi-volume textbook of the Dominican Antoine Goudin, *Philosophy, Following the Principles of Saint*

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[8]Magnus (1967, 52).

[9]Of Things formed in the Earth, some have their Origin from Water, others from Earth. Water is the Basis of Metals, as Silver, Gold, and the rest; Earth of Stones, as well the more precious, as the common. … All these we are (plainly speaking) to judge formed by the Concretion of Matter pure and equal in its constituent Parts, which has been brought together in that State by mere *Afflux*, or by means of some *Percolation*. … There are in *Stones* of different Kinds many peculiar Qualities. … These Qualities *Stones* have, therefore, from the common Differences of the Matter and Manner of the Affluxes of their constituent Parts: But besides these, they have others which arise from the more peculiar Powers of their concreted Masses; such are their acting upon other bodies, or being subject, or not subject to be acted upon them. Thus some are fusible, others will never liquefy in the Fire; some may be calcinated, others are incombustible. … Some are said to have a Power of making Water become of their Colour, as the *Emerald*. Others of petrifying, or converting wholly into Stone, whatever is put into Vessels made of them" (Theophrastus 1746, 3–15).

Thomas. According to Goudin, fossils are mixed inanimate bodies formed in the bowels of the earth; they can be reduced to three classes: stones, metals, and fossils, commonly speaking, or minerals:

> Their common matter comes from earth and water; but these elements are first purified and reduced into variously tempered exhalations, then distilled and combined among themselves, and finally concretized into these bodies. Their efficient cause is, on the one hand, the heat that produces certain exhalations from within the depths of the earth, and on the other, from the action which the sun and stars from above exercise on terrestrial products by modifying them secretly; finally it is also a certain force earth itself possesses variously, following the different places in which the mixed body is formed. This force, similar to the maternal bosom from which animals arise, assuredly plays a great role in the formation of these bodies; this is why, according to Aristotle and Saint Thomas, earth and water furnish to everything arising from the bowels of the earth their matter and bosom, as would a mother, while heaven and the stars fulfill the office of the father, who imparts the form.[10]

The elements used by Albertus Magnus are still in play (though they are now attributed to Aristotle and Thomas Aquinas). We are dealing with earth and water as material causes and still referring to the petrifying power of the place and to various exhalations. But an occult element is introduced, the action of the sun and stars on earthly places. This element plays the role of formal cause to the material cause of earth and water. Earthly places produce fossils, but they need the influence of the sun and the stars. We can also note the loosening of the link to animals, which are not mentioned, though, of course, Goudin's account is brief and general, covering the traditional rudiments about stones, metals, and minerals.

It is easy to see how this generic view could evolve to become the views of Kircher and Joachim Becher that fossils are the creation of the power of the place mimicking animals, without there being any actual remains of animals. The doctrines of Kircher and Becher, therefore, should be understood as continuous with the standard scholastic doctrines, as attempts to improve upon them. They provide a ready answer for the obvious differences between fossils and living creatures, including the problem of the stony matter of the fossils. These views achieve this status at the cost of severing the links between creatures and fossils and rejecting any historical account for the genesis of fossils.[11]

The sequence of views from Avicenna and Albertus Magnus through the seventeenth century to those of Kircher and Becher, as a continuous series, diverges somewhat from the usual accounts in the history of paleontology, where the organic origins of fossils is often described as a triumph of modern mechanism over medieval mysticism. Here is one such analysis, from among many:

> The Middle Ages retained the ideas of Aristotle, and almost unanimously adopted the theories of the spontaneous generation of fossils or petrifactions under various formulas, such as plastic force, petrifying force, action of the stars, freaks of nature, mineral concretions, carved stones, seminal vapors, and many other analogous theories. These ideas continued to reign almost without opposition till the end of the sixteenth century. … The

[10]Goudin (1859 [1668] III, 292: *De mixtis inanimatis; seu de fossilibus*).

[11]Rudwick (1985, Chaps. I and 2, esp. 60–68).

> seventeenth century saw little by little the antiquated theories of plastic force and of carved stones disappear, and the animal or vegetable origins of fossil remains was definitely established.[12]

This Whiggish history contains some true elements, of course, but it does not do justice to the history of paleontology. As we have indicated, influential medieval theories, such as those of Avicenna and Albertus Magnus, accepted the organic origins of fossils, even though they attributed their transformation to a petrifying force. Stephen J. Gould who quotes this passage and numerous other similar inaccurate historical accounts, rejects the claims that paleontologists before the scientific revolution "could not even conceptualize fossils as organic remains," and "attributed the petrified likenesses of plants and animals to occult forces of the mineral world." Gould makes the important point that both the inorganic and organic theory of the origins of fossils "were simultaneously and prominently 'in play' starting with the first printed paleontological texts," from the opening decades of the sixteenth century, and that "no consensus ever existed for interpreting fossils as inorganic sports of nature."[13]

Gould also disputes the representation of Kircher as "the last 'pre-modernist' holdout against the consequences (for the earth's age and for historicity in general) of an organic origin for the petrified remains in the geological record."[14] He correctly points out that Kircher's *Subterranean World*, Book VIII, "On the Stony Substances of the Earth; on Bones, Horns, Fossils, and on Subterranean Animals, Humans, and Demons," is divided into four Sections, of which the First is "On Stones in Common," and the Second "On the Transformation of Liquids, Salts, Herbs, Plants, Trees, Animals, and Humans into Rock, or on the Petrifying Force."[15] Because of the materials in his Sect. 1, it is clear that Kircher thinks of some fossils, perhaps even most fossils, as Gould would have it, as being of organic origin. In his Sect. 2, about the *transformation* of various things into rock, Kircher even asserts that he "will not speak here of the innumerable oysters, clams, snails, fungi, algae and other denizens of the sea that have been converted to stone, because these are obviously found everywhere in such a state, and hardly merit any mention."[16] But it is Kircher's Sect. 1 that most captures the imagination. Chapters 8 and 9 of Sect. 1 are about the various shapes, forms, and images Nature constructed on rocks and gems, with Chap. 9 specifying that its subject-matter concerns "the remarkable natural pictures of works, forms, shapes, and images, which are drawn on rocks and gems and about their origins and causes."[17] The two chapters are accompanied with a multitude of figures, including representations of the

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[12] Depéret (1909, 4–5).

[13] Gould (2004, 199 and 203). Gould cites the Depéret passage on 199 and provides numerous such quotations on 199–203.

[14] Gould (2004, 202).

[15] Gould (2004, 210–211). Kircher (1678, II, *Index Argumentorum*, 3 and 48).

[16] Gould (2004, 211). Kircher (1678, 50).

[17] Kircher (1678, 29 and 30–48).

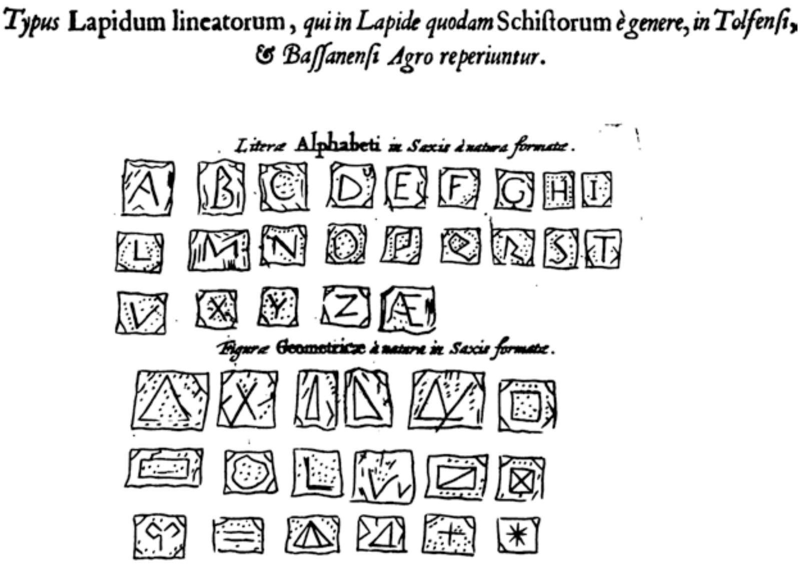

Fig. 2.1 The alphabet and geometrical shapes inscribed on the surfaces of stones (Kircher 1678, 23)

alphabet inscribed on the surfaces of stones, drawings of minerals, such as topaz and beryllium, imprints of ferns or leaves, human and animal shapes (containing the forms of monks and saints), the images of demons and devils, and fossilized fish. (See Figs. 2.1, 2.2, 2.3 and 2.4). It is clear as well that Kircher considers these works of the imagination. He asserts: “Consider how the human imagination leads us to see such a variety of things in heavenly clouds—now flying dragons; then ships, mountains, cities, and castles; then crosses, human figures, and similar fantasies composed of clouds and represented in our imaginations.”[18]

Gould blames the caricature of Kircher on late eighteenth to early twentieth century historians of paleontology.[19] However, as we have already indicated, Kircher’s seventeenth century contemporaries, both friends and foes, with Leibniz taking both sides, also emphasized Kircher’s games of nature and the petrifying

[18]Kircher (1678, 40), trans. Gould (2004, 217).

[19]Gould has a couple of arguments about the structure of the *Mundus Subterraneous*, that it contains a classification of fossils as inorganic or organic. According to Gould, Book 8 Sect. 1 is about shapes on the surface of rocks (i.e., two dimensional shapes) and Sect. 2 about three dimensional shapes. Thus Sect. 1 is about fossils that are of inorganic origin and Sect. 2 about those of organic origins. Gould gives as evidence an earlier sketch (*Prodromus*) of the *Mundus Subterraneous* in Kircher’s (1657), in which Book V, *Metalloscopus* enumerates chapters without regard to their organic/inorganic origins. But I am not convinced of Gould’s account, given Kircher’s representations of trees, leaves, and fish in Sect. 1 and the argument that the fossilized bones of Sect. 2 are not the remains of giants. Even if Gould is right, what I find important is that Kircher’s contemporaries understood him to argue that many fossils are games of nature produced by the petrifying force of the place.

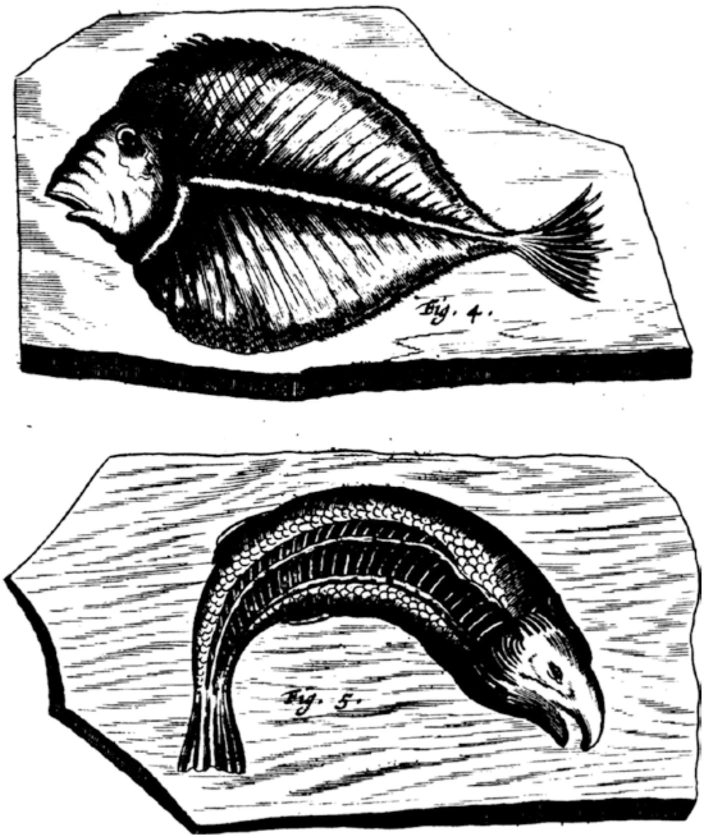

Fig. 2.2 Fossilized fish (Kircher 1678, 36)

force of the place. Seventeenth century theorists understood that Kircher and others who accepted games of nature and the petrifying force also thought that some fossils could be of organic origin. Even Leibniz in his initial manuscript, which specifically names Kircher and his *Subterraneous World,* ends by asserting the same: "Nevertheless, to show that I am fair-minded, I admit that one should say these stones were once parts of animals in the case where too perfect a resemblance would be found that could not be the effect of chance."[20]

In fact, the general attack on the views of Kircher in the seventeenth century took the form of a broad argument that went from a subsidiary claim establishing a class of stones as of organic origin to applying the result for all similar stones. The

[20]Cohen (1998, 140–141). Another version of the manuscript bears the following marginal note "I always except the case when the conformity between the part of the animal and what one has found is too great, even in its least parts, to be able to be attributed to a game of nature." See Garber (2011, 171).

Fig. 2.3 Human shapes in stone (for example, John the Baptist, St. Jerome, and Christ on the cross) (Kircher 1678, 39)

class of stones that were argued to be of organic origins was glossopetrae, or tongue stones. Agostino Scilla and Nicholas Steno both published widely read treatises arguing that glossopetrae are fossilized shark's teeth. Scilla, an Italian painter, wrote an informal work[21] in 1670 proposing that the shells, or stones in the likeness of shells found in hills and quarries, once enclosed fish that became fossilized inside those shells: the shells acted like molds for the liquid matter that got in after the fish was consumed. Scilla's overall argument was by analogy to a

[21]Scilla (1670, 74–75) and elsewhere.

Fig. 2.4 Giants, the smallest being common man, then Goliath, etc. Kircher (1678, 59)

process by which shark teeth become glossopetrae. He compared glossopetrae with the teeth in the jawbones of sharks and found them to be not just similar to, but the same as, the shark teeth. For Scilla, the great variety and disorderliness of the glossopetrae at a particular place entailed that they were not originally grown there or generated and created by a fixed seminal principle. And if there were such a seminal principle, it is not likely that it should be common to fish, shells, and glossopetrae. The argument, of course, was directed against those who asserted that the shells were originally formed by a plastic power of the earth. Scilla maintained that the shells were once real and scattered by a flood, not formed by a vegetative virtue in the particular soil in which they lay that determined them to their peculiar shape.[22]

Steno studied medicine in his native Denmark. His skills in dissection were legendary. In the 1660s, he investigated the musculature of the heart and brain anatomy, both inquiries yielding conclusions at odds with those proposed by Descartes, who was a powerful influence on him from the beginning.[23] The dissection of the head of a great shark led him to examine its teeth and to hypothesize that glossopetrae, usually treated as magical objects, were not-so-magical fossilized shark teeth.[24] This also brought him to consider the problem of solids within solids—that is, fossils—which resulted in the publication of his greatest work, the *Prodromus,* in 1669. Steno was trying to prove that fossils did not grow in situ by giving an account of their formation as the mechanical layering of sand and the action of water over a long time. In the *Prodromus*, he attacked the thesis that fossils are produced by some kind of petrifying force that place possesses. He first examined the thesis that glossopetrae are produced by the earth and argued that "if we grant the earth the power of producing these bodies, we cannot deny to it the possibility of bringing forth the rest." Similarly, with other bodies dug up from the earth, "if one should say that these bodies were produced by the force of the place, one must confess that all the rest were produced by the same force." And if that is so, we should be able to ascertain "whether a fossil was produced in the same place in which it is found; that is, one must investigate not only the character of the place where it is found, but also the character of the place where it was produced."[25] Ultimately, Steno held that "he who attributes the production of anything to the earth names the place indeed, but since the earth affords place, at least in part, to all the things of earth, place alone does not account for the production of the body."[26]

In their broader context, the seventeenth-century doctrines of Steno and Scilla should be considered in part as a return toward the older theories of Avicenna and Albertus Magnus, that fossils are the remains of animals, but with a different, mechanistic or Cartesian account, as opposed to an account based upon some kind of virtue or power, for the process of petrification. The evidence for Steno and Scilla being indebted to Cartesianism or being counted as Cartesians is strong.[27] In the *Prodromus* Steno adopts the outlines of the corpuscular theory of matter: a body is an aggregate of particles; a fluid differs from a solid in having its particles

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[22]Scilla (1698, 181–187).

[23]Steno (1669a). He particularly criticizes Descartes' description of the pineal gland and Descartes' alleged function for it.

[24]Steno (1667). The first part of the book is a treatise written *in more geometrico* about muscle action, in mechanistic terms.

[25]Steno (1669b, 8–9).

[26]Steno (1669b, 15).

[27]Roger (1973, 23–48).

in constant motion.[28] Steno even cites Descartes as an authority: "And Descartes also accounts for the origin of the earth's strata in this way."[29]

So the question is, when did Leibniz first read Scilla or Steno? And when did he write the early manuscript in which he holds views rejected by Scilla and Steno? The issue is complicated by the fact that the early manuscript is undated. Still, we can set some upper and lower limits for the answer. Leibniz wrote his manuscript after Kircher's *Subterraneous World* was published in 1665, and could not have been acquainted with Steno's views before 1667 or Scilla's before 1670. Since the manuscript in Leibniz's hand was written in French, one can infer that Leibniz wrote it after going to Paris in 1672. Leibniz's early letters and works are written in Latin. In the early 1670s, one can find some letters written to him in French (by Carcavy, for example), with Leibniz replying in Latin. Leibniz wrote a long letter in French (to Mariotte) in 1673. Similarly, Leibniz's early philosophical treatises are written in Latin. There are some notes about optics written in French in 1672, but even so, French Leibnizian manuscripts are more common from 1675 on, with some articles in French published in the *Journal des savans*. One can readily conclude with his biographers that "when Leibniz arrived in Paris his mastery of the French language needed improvement."[30] So the early manuscript was most likely written after 1672, but before 1678. Leibniz met Steno at the court of Hanover in 1677 and purchased a copy of the *Prodromus* in 1679. By 1678, he had already become convinced that the shell and bones found in the ground are often the remains of animals that were once alive, thus rejecting his own earlier views.[31]

In the *Protogaea* Leibniz follows the path constructed by Scilla and Steno. One can see this clearly in Chaps. 31–32, "Glossopetrae are shark teeth," and "The Use of Glossopetrae in Medicine is well-known." Leibniz sometimes gets the credit in the secondary literature for demystifying glossopetrae, but, as he himself indicates, he was simply repeating the views of previous Italian naturalists,[32] and among them, Scilla, to whom he refers: "One hardly doubts any more that [glossopetrae] are teeth from some kind of whale fish or from sea dogs. … And just as these animals have mostly curved teeth that are turned toward the inside of their mouth, so it is with glossopetrae, that is with fossil teeth. It is therefore possible, as the painter Scilla noted, to recognize whether they sat on the right or on the left."[33] Leibniz even reproduced Steno's drawing of glossopetrae and a monstrous shark from his treatise on the dissected shark head: "I would like to append images

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[28]Steno (1669b, 10–11).

[29]Steno (1669b, 28).

[30]Antognazza (2009, 140).

[31]Garber (2011, 172) and Roger (1968, 137).

[32]Cf. Accordi (1977, 33), who credits Fabio Colonna as the first to recognize glossopetrae as shark's teeth.

[33]Leibniz (2008, Chap. 30, 79). Cf. also Chap. 29, 75: "to these I oppose a learned painter, who declared in a recently published book that, though he had been shown many such things, the more carefully one observed them, the more tenuous the similarity."

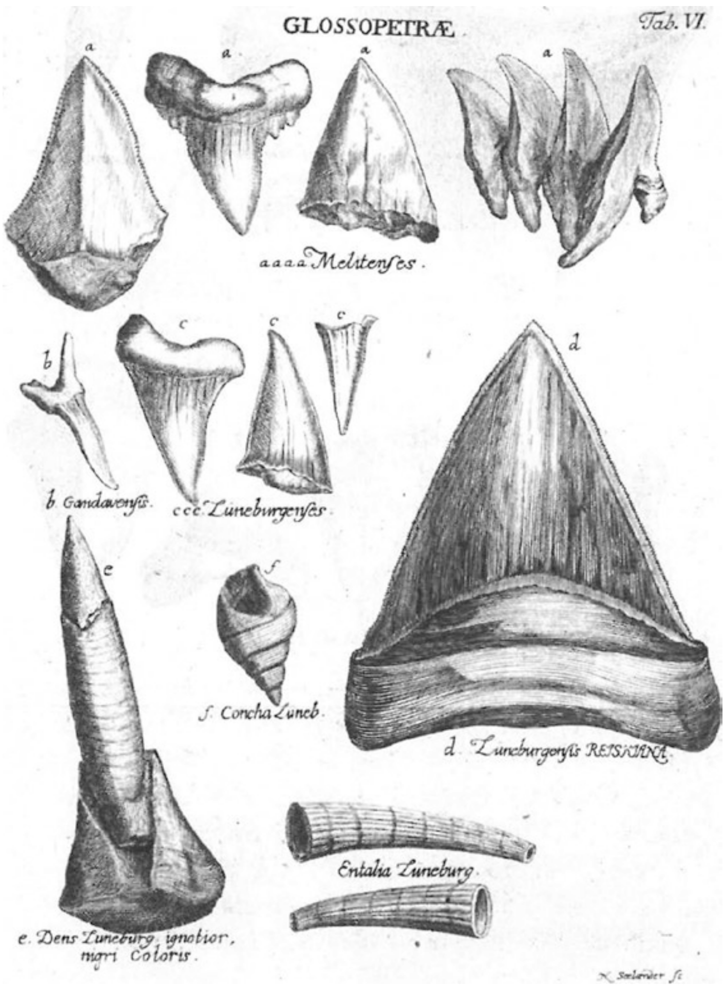

Fig. 2.5 Fossilized shark teeth (Glossopetrae) (Leibniz 1768, Tab. VI)

of our glossopetrae and of the Maltese, so that whoever has seen shark teeth can testify as an eyewitness that there is no difference. I would also like to append, by way of comparison, the head of a great shark with its teeth, from a drawing by Steno."[34] (See Figs. 2.5 and 2.6). Thus Leibniz compares glossopetrae with shark teeth and reaffirms the conclusions of Scylla and Steno. And he continues the removal of glossopetrae from the realm of magic. He relates the various claims made for their curative properties: an antidote against poisons, a medicine for

[34]Leibniz (2008, Chap. 30, 79). The drawing is from *Canis Carchariæ dissectum caput, et dissectus piscis ex Canum genere*.

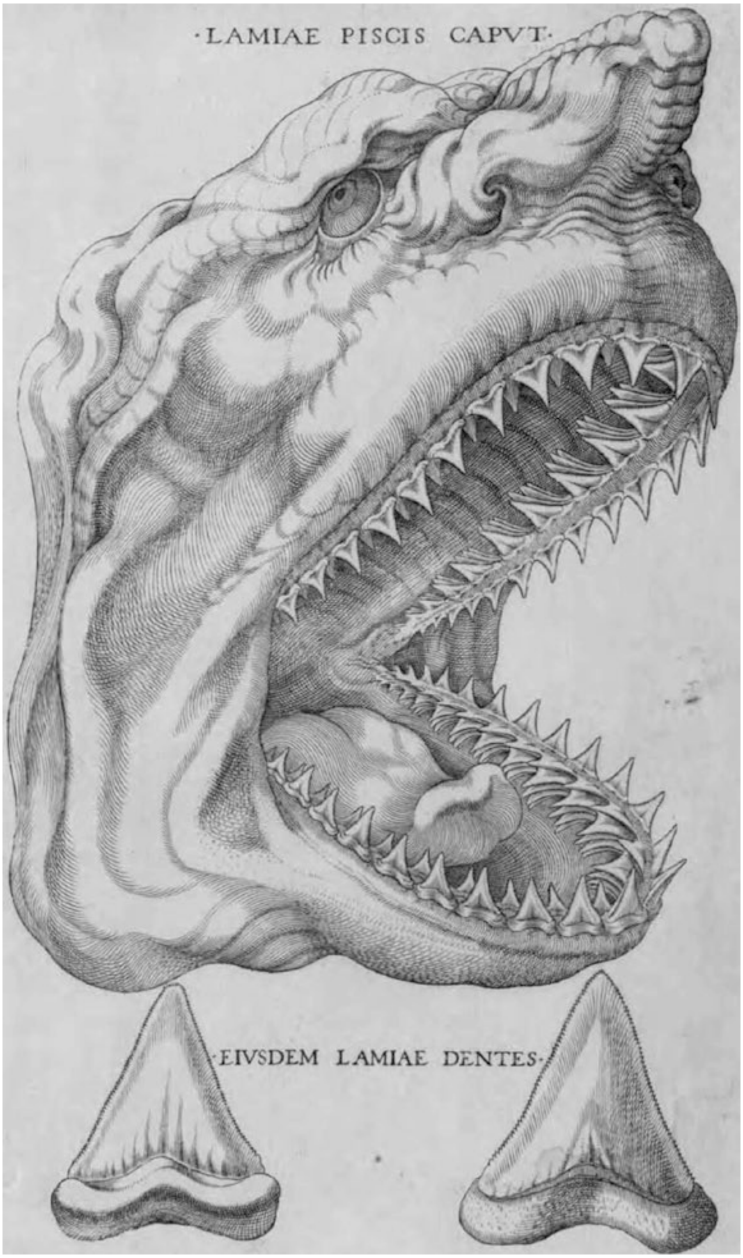

Fig. 2.6 The head of a shark (Leibniz 1768, Tab. VII)

stomach aches, sore throats, blisters that arise from sour humors, and internal acids. He claims that they have "a certain healing power, which has been exaggerated by the credulous. … But of all the uses of glossopetrae, I believe that none is more reliable than for cleaning teeth; the powder from crushed teeth is recommended because of a certain hardness and roughness, and because tooth against tooth seems to be the least harmful."[35]

By now, for Leibniz, fossils are the remains of animals. They are the real products of a natural furnace, the earth, created on analogy with goldsmiths who produce a golden insect by pouring gold into a mold made by covering an insect with some suitable metal and driving away its ashes.[36] He understands his thesis as a direct attempt to oppose the views of Kircher. As he says, "whoever believes the contrary is seduced by the fairy tales of Kircher and Becher, and of other credulous or vain writers of this sort, who describe the wonderful games of nature and its formative power, all embellished with a great display of words."[37]

Leibniz summarizes his thoughts on fossils in his *Mémoire* to the Académie des Sciences on *Stones Containing Dried Plants and Fish*. There he argues that some kind of earth has covered up various lakes and buried plants and fish. That earth then hardened into clay, and time, or some other cause, then destroyed the delicate matter of the plants or fish, in the same way flies and ants wither away in amber. The matter of the plants or fish, having been consumed, left behind in the clay an imprint that was then filled by some other matter and baked by the subterranean fire. Having given his naturalistic account of fossils as the petrification of the remains of animals, Leibniz then takes on his opponents:

> Several authors have called these kinds of representations of fish or of plants in stones, *Games of Nature;* but that is a purely poetic idea…. If nature played, it would play with greater liberty; it would not subject itself to express so exactly the smallest traits of the original, and, what is still more remarkable, to conserve their dimensions so strictly. When this exactness is not found, the things can be games, that is, arrangements that are in some sense fortuitous.[38]

There is a similar story in the *Protogaea*; Chaps. 36–37 of the work depict some local German caves and the bones found in them: "the earth is black and filled … with many animal bones. These are indeed broken and scattered about, but you can still easily distinguish the body parts. There are many kinds of teeth of various colors; they are often shiny and, not infrequently, are still inserted into pieces of jawbones. Some are so large that they cannot be ascribed to any animal

[35] Leibniz (2008, Chap. 31, 85–87).

[36] Leibniz (2008, Chap. 18, 31): "We find something similar in the art of the goldsmith, for I gladly compare the secrets of nature with the visible works of men. They cover a spider or some other animal with suitable material, though leaving a small opening, and bake this material to stone in the fire. Then by pouring in some mercury, they drive away the animal's ashes through the hole, and finally, they pour in silver in the same way. When the shell is removed, they uncover a silver animal with its entire complement of feet, hairs, and fibers, which are wonderfully imitated."

[37] Leibniz (2008, Chap. 29, 73).

[38] Leibniz (1768, II.2, 179).

known to us."[39] Leibniz continues with his description of the contents of the caves: "In one column, they think they see a monk; in another, Moses with two horns." But he concludes "the games of nature presented in those caves demand the support of the imagination."[40] Having definitively argued for the organic origins of fossils, he can describe the games of nature found in his caves and underscore that they require help from the imagination to be seen as the head of Moses, etc., what is not the case for fossils and other remains. Basically, Leibniz wishes to divide the world between fossils and games of the imagination, with neither of these two categories being games of nature.[41] It is clear, however, that he is not dogmatic about the nature of the process resulting in petrification. Although he denies the accounts of contemporaries, such as Kircher and Becher, he specifically allows the account of older scholastics, suggesting that he could accept fossils as remains of creatures *transformed* by some petrifying force:

> If however, someone does not want to accept that nature burns rocks, and prefers to think that the mud enveloping the fish turned to stone, either through time alone and according to the nature of the material, or through some petrifying spirit, or through some other cause, … then I do not oppose it, though I find it hard to understand. I do not dare to assert anything with certainty, except one thing, which suffices for us here: namely, that the coppery fish are the imprints of real ones.[42]

We have seen Leibniz reject the hypotheses of his early manuscript: "that the Maltese stones commonly called serpent teeth are parts of fish … that these shapes of bones of animals and shells are often only games of nature, which have been formed apart without having come from animals … that stones grow and take on a thousand strange shapes, as testify the stones that the Reverend Father Kircher has amassed in his *Subterraneous World*." We have also seen him suggest that he would accept the thesis "that the bones one sometimes finds in the fields, or that one discovers by digging in the earth, are the remains of real giants."[43] Leibniz, in

[39]Leibniz (2008, Chap. 36, 108–09).

[40]Leibniz (2008, Chap. 37, 113). See also Chap. 29: "ludicra imaginationis"; "fictas pleraque aut semivisa … imaginatio in rerum signaturis ludit"; "sed haec imaginationis judicia sunt, non occulorum.".

[41]Leibniz (2008, Chap. 20, 53): "As to the supposed appearance of the Pope's tiara, of Luther, and all sorts of other shapes etched in the stone of Eisleben, I consider these to be, not games of nature, but of the human imagination, which sees battles in the clouds and hears its favorite melodies in the sounds of bells or the beating of drums."

[42]Leibniz (2008, Chap. 20).

[43]Here the giants are terrestrial or aquatic animals. Human giants would offer their own special difficulties. If they were generated spontaneously at a particular place, they would then belong to the "class of creatures that 'are similar to people in all respect except in having a soul,'" and not to genuine humans; (Gliozzi 1977, 310–311). These are very complex issues that are extremely well covered in great detail by Gliozzi (1977).

fact, embraces the possibility of terrestrial giants and extinct species.[44] In *Protogaea*, Chap. 35, entitled "The unicorn's horn, and an enormous animal unearthed in Quedlinburg," he even admits some remains as originating from unicorns, considered initially as an aquatic animal, that is, as fossilized narwhal teeth.[45] However, Leibniz does not think that all the remains of unicorns can be accounted for in the same way: "Nevertheless, we should not disguise the fact that a four-footed unicorn of the size of a horse has been found in Abyssinia …. The skeleton that was found in 1663 near Quedlinburg on the Zeunikenberg in the rock, while lime was being excavated, also looked more like a land animal." So Leibniz concludes that the skeleton, whose picture he reproduces (see Fig. 2.7), discovered by Otto von Guericke, was indeed the remains of an extinct terrestrial species, a unicorn: "In the book about the vacuum, Guericke, mentions in passing that the skeleton of a unicorn was found with the rear part of its body bent back, as is common with animals, but with a raised head and carrying on its forehead an extended horn about five yards long; the horn was the width of a human leg and tapered gradually."[46]

As for the other hypotheses that once troubled Leibniz: shells found far from the sea being "the certain marks of the sea having covered these places and, upon withdrawing, having left behind these shells, which then became petrified" and the earth needing "to be much older than is reported by the Holy Scriptures," Leibniz also made accommodations for both possibilities: "As in the beginning, before the light had separated itself from darkness, fire seized everything, just so does one reckon that later, after the fire had been extinguished, everything was plunged under water. These things have been passed on through our sacred histories, which agree with the old stories of other people, but the inland vestiges of the sea offer

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[44]In fact, Leibniz even considers the possibility of changes in animals resulting or having resulted in new species; in the *New Essays* he suggests that "Perhaps at some time or some place of the universe there are or were or will be species of animals more subject to change than those at present, and several cat-like animals, such as the lion, tiger, and lynx, could have been of the same race and may now be like new subdivisions of the ancient species of cat," Leibniz (1890, V, 296). Similarly, in a 1696 letter to Thomas Burnett of Kemney, Leibniz indicates that "species can be radically changed by the duration of time as well as by the interval between places, as is testified by the differences between the animals of America and ours," Leibniz (1993, 201–202). A similar claim is made in a letter to 1696 Bussingius, (Leibniz 1718, 30–31). See Smith (2011, 255–258).

[45]Leibniz (2008, Chap. 35, 101): "Bartholinius has demonstrated that the horns of unicorns, which were in the past the most celebrated ornaments in the displays of cabinets of curiosities, and which today still amaze the eye of the crowd, come from fish of the Polar Sea. It is still right to believe that fossil unicorn, which also appears in our region, was of the same origin."

[46]Leibniz (2008, Chap. 35, 101). Leibniz's figure was originally printed in 1704 by Michael Bernhard [Valentini], who drew it from notes and sketches by von Guericke and descriptions of it by Johann Mayer (Accordi 1977, 42). Accompanying the unicorn is another figure, which, it is alleged, is sufficiently natural that contemporary geologists can identify it as a fossil elephant molar. The inference is then drawn that Leibniz's unicorn was an imaginative reconstruction of the bones of an elephant with only one tusk: "C'est de reste à la suite de la découverte par Otto von Guericke à Quedlemburg, dans le Harz, en 1663, des fragments d'un squelette (les ossements d'un éléphant, mais avec une seule défense), que Leibniz fut convaincu de la réalité des licornes," Schnapper (1988, I, 94).

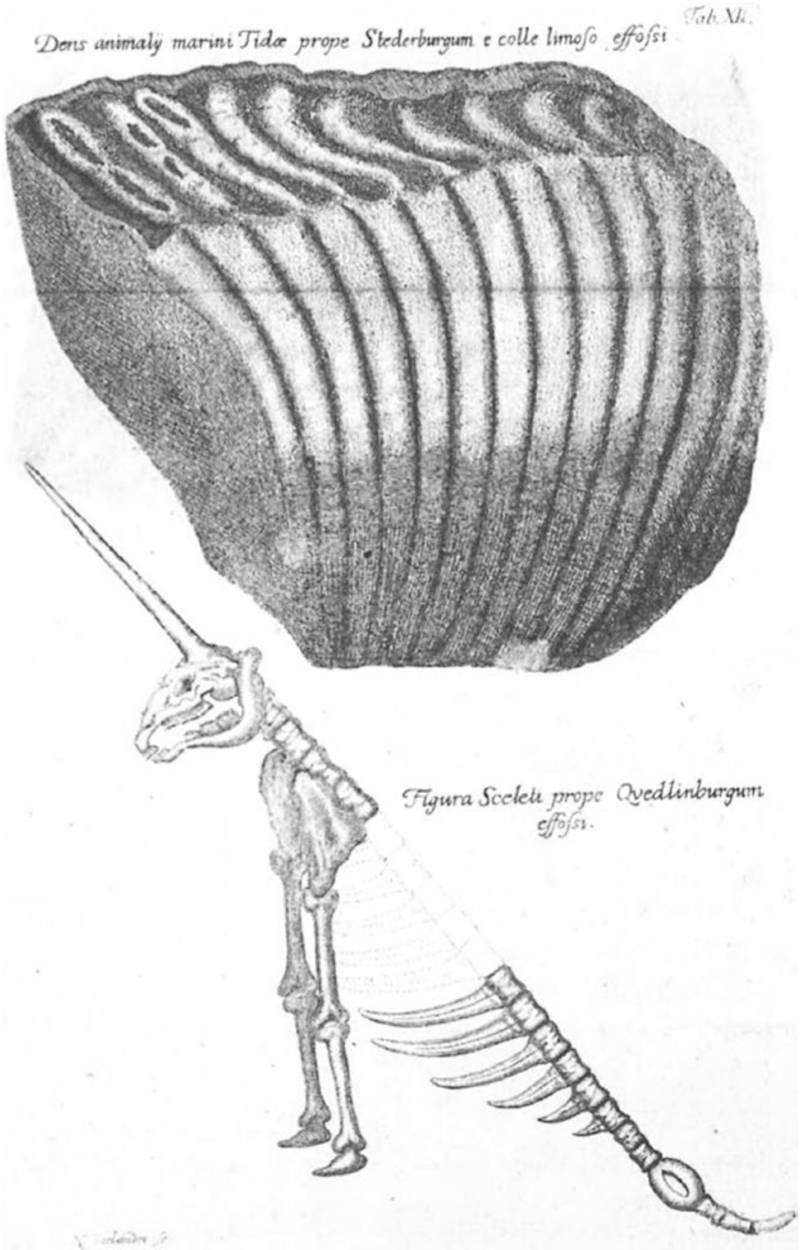

Fig. 2.7 A fossilized tooth (said to be from a marine animal) and a reconstructed skeleton found at Quedlinburg (alleged to be the remains of a unicorn) (Leibniz 1768, Tab. XII)

the best support. For seashells have been transported onto the mountains."[47] Leibniz therefore investigates "the source of so much water which rose above the mountains, and where it eventually flowed when they became dry again." He gives a number of tentative answers: "Some, by means of a scheme more clever than it is clear, explain the matter purely through a shift of the earth's center; according to this theory, the [inclination] of heavy things changed direction and, though the surface was preserved, yet the height and depth of places changed completely; they cannot therefore be measured for themselves, but according to their distance from the center."[48] But Leibniz rejects this and similar hypotheses as insufficiently plausible: "I do not dare to adduce external causes, such as the near passage of a comet, or the moon that was closer than today, whose attraction could have caused the waters to gush forth. Nor do I trust a change in the direction or the center of heaviness." He thinks more plausible that

> the water could have penetrated the inner depths of the globe through hidden passages that were just ripped open for the first time, before being swallowed up by vast caverns; … nothing appears more sure than our belief that the vault of the earth collapsed at the point where it was buttressed by weaker supports, that a huge mass then crashed into the sea which lay under it and had previously been enclosed, and that the mountain peaks were thereby exposed. Having thus been forced up out of the caverns, the waters flooded the highest mountains.[49]

And the waters receded because the masses that were thrown into the depths broke through caverns filled with air.

Leibniz's explanations constitute an attempt to give an account of fossils and the Flood as physical phenomena subject to the laws of nature, occurring in a historical timeframe that stretches well beyond the account of Genesis. But Leibniz is cautious with such materials. When he discusses the supposition that "when the ocean covered everything, animals that now live on land were aquatic" and when the waters departed, "these animals became amphibians, until their descendants eventually left that original home," he rejects it because he says that it "conflicts with the sacred writers, with whom it is impious to disagree."[50]

As we have asserted, Cartesianism seems to be a driving force behind much of seventeenth-century geology. It is easy to see the appeal of the main Cartesian doctrine: the universe, except for the special creation of man, can be explained from an initial chaos, using only the laws of motion; geology becomes a historical science. Leibniz does deviate from this doctrine in some ways, but still, it is a major theme with him, as it is with Scilla and Steno. Where Leibniz and Steno part

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[47] Leibniz (2008, Chap. 6, 15).

[48] Leibniz (2008, Chap. 6, 15). The translation has "descent" where I have "inclination." The hypothesis probably depends on some dubious earth-centered physics. But Leibniz rejects it for different reasons; he says: "This hypothesis could hold if the seas and mountains occupied separate regions of the globe and were not intermixed on the same hemisphere." (Leibniz 2008, Chap. 6, from MS B, 14 fn. 20).

[49] Leibniz (2008, Chap. 6, 15–17).

[50] Leibniz (2008, Chap. 6, 15).

company concerns secondary forces, the action of fire, for example. Steno attempts to explain geological phenomena primarily using the action of water, while Leibniz stresses that he needs the effects of both water and fire. That is what he explains:

> Insofar as it is possible for human knowledge to reach back, whether through reasoning or through the tradition of the scriptures, the first step in the formation of things is the separation of light from darkness, that is, of the active from the passive. The second step involves the differentiation of passive things from one another, that is of the wet from the dry. Wet and dry things, in turn, are separated from one another by their power of resistance and degrees of firmness. Bodies are therefore transformed by fires and waters in different ways. In all likelihood, those that now seem opaque and dry were initially ablaze; then they were swallowed by the waters; and after the separation of elements, they assumed their present appearance.[51]

Leibniz considers this doctrine significant enough to repeat it in the *Theodicy*.[52] In addition, he can place his geological theory into the framework of his theology; instead of being mere disorder, geological phenomena provide Leibniz with the image of order arising from disorder:

> the upheavals ceased finally, and the globe assumed the shape we see. Moses hints at these changes in a few words: the separation of light from darkness indicates the melting caused by the fire; and the separation of the moist from the dry marks the effects of inundations. But who does not see that these disorders served to bring things to the point where they are now, that we owe to them our riches and our comforts, and that through their agency this globe became fit for cultivation by us. These disorders passed into order. The disorders, real or apparent, that we see from afar are sunspots and comets; but we do not know what uses they supply, nor the rules that prevail in them. There was a time when the planets were held to be wandering stars; now their motion is found to be regular. Perhaps it is the same with the comets: posterity will know.[53]

The *Protogaea* suggests that some regular forms arise through the separation of light and darkness. The original fire engenders natural rocks, which can be detected by means of their crystal structures.[54] The doctrine of an original fire also fits well with Leibnizian cosmology. As Leibniz tells us:

> This conforms with what certain priests of wisdom have constructed, in the form of hypotheses, to explain more distinctly how such a separation of elements might have occurred. Indeed, they suggest that there were once huge globes, like the fixed stars or our sun, that either produced light or were jettisoned by a sun. Then their matter boiled and foamed until they were covered by the slags extruded during fusion. Similarly, as the ancients supposed, the sun would be veiled by increasing numbers of spots that would

[51] Leibniz (2008, Chap. 3, 5).

[52] Leibniz (1890, VI, 262).

[53] Leibniz (1890, VI, 263). He repeats his theological thesis a few years later, when in a letter to Bourguet, he defends himself against the claim that he alleges there is no chaos. According to Leibniz, there are disorders, but they are only apparent, something like what is caused by perspective: "Thus the apparent chaos is only a kind of distancing, as in a reservoir full of fish or, rather, as in an army seen from afar in which one cannot distinguish the order it deploys." To Bourguet, (Leibniz 1890, III, 565).

[54] Leibniz (2008, Chap. 19, 49). Roger (1973, 139).

> darken and eventually obscure it, something actually observed in our time, after the invention of the [telescope]. Still, the accretion of accumulated material extinguished the internal heat, with a cooled crust hardening all around. Thus was born an opaque star that would reflect external rays, just like the planets. They either suppose or imagine that we inhabit a volcano fashioned, as Moses wrote, through the division of light from darkness.[55]

Although Leibniz attributes these hypotheses to "certain priests of wisdom (*quidam sapitentiae mystae*)," it is clear that they are consistent with the other doctrines of the *Protogaea*, and that Leibniz is adopting them as his own. We live on a sun whose sunspots have hardened into a crust. There is a general homogeneity among all bodies, in this post-Scholastic cosmology; this is in direct opposition to the usual heterogeneity among sublunar and supralunar bodies. Leibniz is, of course, indebted to Descartes for the doctrine; it is simply lifted from the *Principles of Philosophy*.[56] Leibniz specifically attributes the view to Descartes in the letter to Bourguet, though he distinguishes between his hypothesis and Descartes': "I therefore lean toward Descartes' opinion, that our earth was once a fixed star or toward mine, that it could once have been part of a fixed star."[57]

However, the heterodoxy of such explanations is apparent. Even Descartes understood that he could not contradict the account of Genesis. When he discusses the relation between his views and Genesis, Descartes says that the simple and intelligible principles he assumes—all the bodies in the universe are composed of the same matter, a matter divisible into parts that are variously moved in circular motions, that there is always an equal quantity of motion in the world, and that God at first divided the matter into equal parts, etc.—these principles are false, because they are contrary to the account of creation from Genesis, which he takes to be true.[58] As Descartes notoriously states:

> There is no doubt that the world was created right from the start with all the perfection it now has. The sun and earth and moon and stars thus existed in the beginning … and Adam and Eve were not born as babies but were created as fully-grown people. This is the doctrine of the Christian faith, and our natural reason convinces us that it was so. For if we consider the infinite power of God, we cannot think that he ever created anything that was not wholly perfect of its kind.[59]

So Descartes calls his own explanations false and Leibniz is driven to ignore the vast amount of time required for the processes he sets out, pretending that the accounts he carefully lays out are generally consistent with the story of Genesis, when he understands they are not.[60]

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[55]Leibniz (2008, Chaps. 3, 5). The translation has "armed eye" for *oculi armatura*—clearly the telescope.

[56]Descartes, *Principles of Philosophy* III, art. 94-96.

[57]Leibniz, To Bourguet (1890, III, 566).

[58]Descartes, *Principles of Philosophy* III, art. 45.

[59]Descartes, *Principles of Philosophy* III, art. 44.

[60]See Roger (1973, 141–44). See also Smith (2011, 219–222).

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Chapter 3
Francesco Patrizi and the New Geometry of Space

Vincenzo De Risi

Abstract This chapter deals with the philosophy of space and the theory of geometry developed by the Renaissance philosopher Francesco Patrizi da Cherso. Patrizi's metaphysics of space shares several common features with other similar constructions (by Bruno, Campanella, and others) aimed at radically rethinking the notions of space and place present in Aristotelian traditions. The uniqueness of Patrizi's proposal, however, is to be found in his attempt to ground geometry in this new conception of space, thus claiming for the first time in history that geometry is the science of space rather than the "science of continuous magnitudes" as it had been conceived from Antiquity to his day and age.

3.1 Introduction

In December 1586, the philosopher Francesco Patrizi da Cherso (1529–1597) published, in Ferrara, a singular treatise *Della nuova geometria* (*On a New Geometry*), in which he claimed to have finally found that via *regia* to the discipline here in question which had escaped Euclid and all the mathematicians before him.

It was, of course, a very imperfect work, in which Patrizi's mathematical incompetence quickly comes to the fore; nor does it contain a single relevant geometrical result. The material it deals with—at great length over 15 books, 238

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theorems and more than 200 pages—does not in fact extend beyond the simplest results of Euclid's *Elements*. In fact, it scarcely covers the first half of Book One of this work. It also contains quite a few mistakes.

This unfortunate book, nonetheless, remains one of the most significant and important documents for the history of mathematical *epistemology* in the Renaissance, and might indeed almost be considered the turning point and dividing line between ancient and modern geometry. Its contents, very innovative for its age, consist in an almost uninterrupted chain of logical arguments *in forma* which proceed from simple definitions and aim (mostly by simple *modus tollens*) to prove the principal theorems of elementary geometry. There are no postulates nor any other geometric principles, so that in the end all results are supposed to be reduced to the definitions alone, which do not differ significantly from those of Euclid. And even if some figure or diagram can be found here or there, none of these is ever used in the course of a demonstration. It is, in short, an attempt (perhaps the very first attempt) at a completely formal, indeed even at a (so to speak) "logicist" demonstration (since Patrizi even wants to do without the axioms) of the elements of geometry. Given the enormousness of the goal set, therefore, it is no surprise that the execution was necessarily a quite faulty one, and that Patrizi became, perforce, entangled in fallacies and inconsistencies in the hope of producing some positive result—since, otherwise, there would have been little chance of extracting even one single theorem from those definitions.

At any rate, its purely logical approach to geometry is not the sole novelty of Patrizi's book (although it is the most evident). In fact, if we ask what sort of daemon had led him to undertake a project which was as innovative as it was doomed to failure, but at the same time so pregnant with future consequences, we immediately find that the (supposedly) demonstrative method of the *Nuova geometria* rests upon a vast and complex mathematical epistemology, and the latter in turn upon a new ontology of geometrical entities. Patrizi himself surely believed the novelty of his construction to rest entirely upon his revolutionary ideas regarding just what the *object* of the science he was discussing consisted in. Patrizi, that is to say, argues that all of mathematics (pure and applied) finds its proper object not by grounding it upon some abstraction made from the sensible magnitudes of bodies (as had been proposed by Aristotle); nor does mathematics find its proper object and foundation by turning to the ideal objects of διάνοια (as had been proposed by Plato and the orthodox Platonists of the Renaissance); nor is mathematics essentially concerned with the products of the imagination or φαντασία guided by the intellect (as had been suggested by Proclus and by the whole Neoplatonic tradition); rather, mathematics is a science concerned with space itself.[1]

[1]This declaration was originally formulated in the following terms: "Le Matematiche tutte, e principali, e subalterne, ne si astraggono dalle cose naturali, ne sono nella fantasia, ne nella dianea, ma lo spazio è generale lor subietto" (*Nuova geometria*, p. 2). Patrizi states the novelty of his project in the preface to the work, stressing that he has discovered a "royal road" to geometry which "è del tutto nuova, e da niuno antico ne moderno, che si sappia, non tentata".

This definition of geometry as the *science of space* may seem obvious today, but in the sixteenth century it was not. Patrizi was perhaps *the very first* to formulate it. It was a definition which gained broader acceptance in the course of the following century, although it met with some resistance too, and was at times defended precisely in Patrizi's name. It then finally won the approval not only of philosophers, but also of geometers, who were able to substantiate with proofs and theorems the new geometry which Patrizi had left, in the moment of its birth, largely undefended. Finally, it succeeded in imposing itself as the commonly-accepted definition of the discipline, to such a point that it is nowadays difficult to imagine that geometry could be (and could have been for centuries) anything else than the science of space. In this sense, Patrizi actually gave birth to a *new geometry*, or rather laid the first epistemological and ontological foundations for such a geometry to be, first, fully theorized and then, eventually, actually implemented.

In order to try to fully appreciate the extent of Patrizi's epistemological revolution in geometry, it will be appropriate to recall (very briefly) at what a great distance both the Classical and the Renaissance philosophies of mathematics remained from any such idea of space.

In fact, if one inquires into the question of just what the object of the geometry of antiquity was, one immediately finds that this geometry was concerned with straight lines and circles, triangles and parallelograms, ellipses and spheres, but never with space or with place. The word τόπος (almost) never appears in the thirteen books of Euclid's *Elements*, and very seldom in the whole corpus of ancient geometry—never, at any rate, with the implication that geometry should study space or its properties. Aristotle's philosophy of mathematics, which was the widest and most elaborate to be developed in the Classical Age and, what is more, the most influential for the following centuries, held the proper object of geometry to consist in *magnitude* (μέγεθος), that is, in continuous quantity; in other words, it considered all the shapes and figures which elementary geometry studies (triangles, circles, and spheres) as exemplifications and instances of the common genus 'magnitude'. Euclid's *Elements* themselves, which offered a general theory of μεγέθη (in Book Five), appeared to straightforwardly endorse the notion that it was just these magnitudes that formed the proper object, and the matter of the inquiry, of the science of geometry. The concept of (continuous) quantity, however, did not seem to have any connection with that of space (nor with that of position), and it was thus inconceivable that geometry would have to deal with such a concept. Magnitudes were always regarded as the magnitudes of particular objects (a triangular surface, a spherical body), that is, as properties of certain determinate substances, which are evidently independent of their spatial position. It is easy to see, in short, that this view regarding the proper object of geometry harmonizes with the general substantialistic assumption of the main Greek philosophical schools, which also regarded the world as an aggregate of discrete (either ideal or corporeal) unities which cannot be dissolved into mere relational elements within a broader system: i.e. the ontology of "substance" as opposed to that of "function" or structure. Mathematical practice is, in this regard, everywhere solidary and consistent with the metaphysical theories, and restricts itself to the consideration of individual figures, or configurations of individual figures, without ever focusing on the notion of an ambient space in which the figures would have to be located.

This theoretical framework, which certainly concords very well with the original Platonic philosophy and better still with Aristotelianism, begins to come apart already with the emergence of early Neoplatonism. The fundamental development (as regards the problem we are addressing here) probably consisted in the important metaphysical thesis that quantitative form inheres directly in prime matter, without the mediation of any substantial form. In other words: magnitude is not a property of substance, but of matter itself. This thesis liberated, in principle at least, the consideration of magnitudes from that of individual, determinate bodies. Thus, it carried mathematics beyond the status of a theory of individual shapes or figures. This marked the birth of the idea of a quantified *environment*, in which the determinate figures and magnitudes which geometry examines are located. This quantified prime matter, which is not yet a substance and therefore does not enjoy an existence independent of that of the bodies it constitutes, is certainly not a *space* in the proper sense, inasmuch as it lacks in itself all local or positional properties. It is, however, an abstract and indeterminate *extension* which is a condition of possibility of geometrical and quantitative objects.

The metaphysical variations upon this concept of extension in late antiquity and the Middle Ages were countless, and significantly different from one another. We cannot examine them here. It is worth remarking, however, that the concept of a prime matter quantified independently of any substantial form probably made its first appearance, and received a full-blown metaphysical justification, in Plotinus's *Enneads*, under the name of ὄγκος, that is, abstract material "mass".[2] Later, this concept came to play a central role in Proclus's epistemology of mathematics, who discussed an "imaginative matter" (ὕλη φανταστική) into which the geometer projects the mathematical ideas so as to be able to represent them in sensible form and thereby carry out his proofs. Thus, once again, this theory posited an ideal extension whose metaphysical constitution was that of a prime matter in which there inhered the form of quantity alone. Later still, the theory of quantified matter was developed by the late Aristotelian commentators, mainly by Philoponus and Simplicius, who provided an extensive metaphysical treatment of this theme (no longer immediately connected with geometrical epistemology). Finally, through these later Neoplatonic sources, the notion reached the Arabic-speaking world and acquired an important role in Ibn Rushd's metaphysics, and thus consequently in that of Latin Averroism.[3] In short, then, almost all the Renaissance theorists of geometry (be they philosophers or mathematicians) still held the proper object of geometry to be continuous quantities (with Aristotle and Euclid), and thought,

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[2]Plotinus discusses the notion of ὄγκος principally in *Enn*. II 4 [12], 11. I refer to Plotinus rather than to other Middle- or Neo-Platonic authors because, first and foremost, it seems to me that his strong anti-Aristotelianism, and his stature as an original thinker, contributed to the genuine establishment of this concept of quantified matter. Another reason is that (as we will shortly see) his personal views exerted a direct influence on the formation of the theories of mathematical space developed in the Renaissance. On Plotinian ὄγκος see Brisson (2000); for a more extensive treatment of the role of this concept in modern theories of space, see De Risi (2012b).

[3]On Philoponus's concept of quantified matter, see de Haas (1997). An excellent presentation of some medieval elaborations on the quantification of prime matter is to be found in Donati (2007).

moreover, that they were realized in an indeterminate extension, the exact metaphysical status of which could vary from author to author, but which everyone decidedly characterized as quantified matter. The fundamental metaphysical transition which we want to examine, therefore, is the transformation of this quantified material extension into space.

It should also be noted that the very notion of space underwent, in the course of the passing centuries, a transformation which seems to develop along the same lines. The major Greek doctrines on spatiality were, in fact, rather theories of *place* (τόπος), and this concept bore, for the most part, a merely "ecological" meaning, i.e. that of an orientation toward and within the surrounding environment, without being the object of a measurement and without reference to quantity. To be in a place meant to be in the Lyceum, in the Agora, on the river, on a boat, in a vessel. The main proponent of such a theory of place was doubtless once again Aristotle. But it would be naive to hope to find in the rival metaphysics of Plato or of the Atomists the traces of any notion of an abstract space which could find application in geometrical inquiry. It was, once again, Late Neoplatonism (especially Philoponus) that elaborated the first theories of place as a quantified immaterial (three-dimensional) extension or, in short, of space proper, with a metaphysical development which certainly mirrored the analogous theories of prime matter. These spatial developments, however, were much more timid and less revolutionary than those taking place regarding the concept of matter, and enjoyed very little success in the Middle Ages, to the point of being almost completely forgotten. During those centuries, to be sure, other conceptions of space were developed, which also went significantly beyond the ancient and Aristotelian theories (this was true, for example, of the vast Scholastic theorizations of imaginary spaces). But, in most cases, these discussions of space remained primarily theological in nature, and did not really address the concept of a quantitative extension. Nor did they ever try to establish a connection with mathematical epistemology. Moreover, no one (before Patrizi) would have held that magnitudes (the universal object of geometry) could be spatial, rather than material, objects.[4]

However, it cannot be denied that already at the end of the Middle Ages the doctrines being taught regarding space and spatiality were characterized by a growing intolerance of the general framework of Aristotelianism in its various forms, and exerted, in sum, an important stimulus for the reform, indeed for the revolutionizing, of the metaphysical system as a whole. Thus it happened that the philosophy of space started to acquire a growing importance in the sixteenth century and acted as the principal catalyst for the explosion of the new philosophies of the modern age. The main Classical and medieval doctrines about place—along with their corollaries regarding the causal efficacies of natural places, the theory of motion, action at a distance, and the existence (or nonexistence) of a void—were often subjected to an abundance of criticisms and rebuttals which betrayed a critical intention much more far-reaching than the academic discussion of one or the other Aristotelian or Scholastic doctrine.

[4]The most extensive survey of spatial theories in the Middle Ages is still Grant (1981).

The history of this battle against the conceptions of place prevalent in antiquity—a battle which eventually led to the birth of the modern notion of space—is very complex, far from linear, and rich in reconsiderations and hesitations. Among those joining in this battle were metaphysicians who hoped to overturn Aristotelianism (or perhaps to restore it), philologists and humanists who discovered ancient spatial doctrines radically different from the current ones, scientists working on the edification of a new mathematized natural philosophy, but also geographers, astronomers, theorists of optics and perspective, artists whose works offered examples in practice of these new concepts, and many other protagonists of sixteenth-century cultural life. All of them, at any rate, were sensible to the need for a transformation of the old theories, and regarded their new conceptions of space as the most appropriate crowbar for undermining the old order, and at the same time the principal result of the ongoing revolution.

It is very well known, on the other hand, that Patrizi's philosophical and metaphysical research concentrated most of all precisely on space; and historians of philosophy nowadays study his thought mostly because it is believed that he was among the first to succeed in formulating that new concept of space as a three-dimensional extension independent of the bodies occupying it which was to become the core of much metaphysics (and of much science) once the modern age had reached its maturity. He certainly shared this honor with many other figures of his age, from Telesio through to Bruno along with a few particularly innovative Scholastic thinkers—not to mention the scientists. In fact, there is a recurring historiographical question (though one, indeed, which tends to be posed the wrong way), as to whether it is legitimate to ascribe late-Renaissance metaphysical speculations on space to the history of science proper. It is certainly the case that, in the first place, Bruno's or Patrizi's theories on space do not refrain from resorting to the most incredible metaphysical constructions drawn from Neoplatonism and to vast theological speculations. They even boast magical or Kabbalistic references, and proudly lay claim to theoretical lineages running back to Hermes Trismegistus or to the Orphic hymns. Exact scientific references, on the other hand, are very scarce.[5]

It is usual to note at least the importance of these works for the history of cosmology, because of the infinitization of cosmic space, the abandonment of celestial spheres and (at least in Bruno's case) the rejection of geocentrism. But what, to my mind, makes the figure of Patrizi very peculiar and important among metaphysicians contemporary with him is the fact that none of these latter ever considered the possibility of erecting a geometry upon these new spatial doctrines and everyone chose to keep instead to the usual Scholastic or Platonizing mathematical epistemologies. Thus, I would like to take a rather different approach to inquiring into the relations between science and philosophy and to consider the matter from a quite particular standpoint: namely, that of the history of mathematical epistemology. We will need to investigate how these new theories of space were able to penetrate the geometrical discussion, contribute in a decisive measure to altering its object, and finally lead to the development of important and original results in

[5]On Patrizi and the Hermetic tradition, see at least Leijenhorst (1997).

mathematics. In other words, we want to better understand the implications of Patrizi's statement that the *new geometry*,—that is to say, the geometry of the modern age—is primarily the *science of space*.[6]

3.2 The Development of Patrizi's Philosophy of Space

Patrizi began to address the topic of the metaphysics of space, even if only as a way of criticizing Aristotelianism, in the four volumes of his 1581 *Discussiones peripateticae*, where he devotes great effort to showing how the classical theory of place is completely aporetic, without for his part proposing any sufficiently elaborate alternative.[7] The year 1586 saw the publication of the aforementioned *Della nuova geometria*, which certainly took as its foundation the new spatial metaphysics which Patrizi must have developed in the years immediately following the *Discussiones* but had not yet publicly presented.[8] These philosophical doctrines on space appeared later in the two booklets *De spacio physico & mathematico*, which represented the beginning of Patrizi's projected work *De rerum natura* and were published in Ferrara in 1587. In fact, they provide the foundations for the successive

[6]Henry (1979), Grant (1981), and Edelheit (2009) provide general treatments of Patrizi's theory of space. Vedrine (1996) is a French translation of *De spacio physico & mathematico*, with an introduction and annotations, and Brickman (1943) is a (partial) English translation with a short presentation. Cassirer's discussion of Patrizi in the first volume of *Das Erkenntnisproblem* is still very useful. There exist almost no studies on Patrizi's mathematics: besides the above-mentioned essays by Vedrine and Edelheit, and a short (but excellent) treatment in Cassirer, the reader might also usefully consult Muccillo (1993b).

[7]The first volume of the *Discussiones* was published in 1571. However, from a philosophical standpoint, it is the remaining three volumes, especially the fourth, that are particularly relevant; these latter were all published in 1581. On the genesis of the first edition of the work see Artese (1986); on the contents of the first volume, see Antonaci (1984). This was not Patrizi's first philosophical work. In his youth, he had published several booklets in Italian propounding Platonic and Ficinian philosophical views (especially on love). At any rate, the *Discussiones* remain Patrizi's first important and authentically original work.

[8]The frontispiece bears the date of 1587, but we know from Patrizi's correspondence with the mathematician Giambattista Benedetti that, as early as July 1586, he was in a position to send him the first printed pages, and that the whole book had appeared by early December of that year (Patrizi, *Lettere*, pp. 42–44; the December letter had already been edited, though erroneously dated, in Claretta 1862). It is remarkable, however, that Patrizi affirms in the treatise on geometry that he presupposes therein some principles which he has, so he claims, already proven in his two books on space, since the latter had probably not yet appeared in print by the end of 1586. We may assume, therefore, that he had already written his metaphysical essays by the time of the composition of the *Nuova geometria*. Conversely, in the final sentence of the two booklets *De spacio physico & mathematico*, Patrizi noted that the Italian treatise *Della nuova geometria* was intended as the *continuation* of the essays on space. This corresponds to the arrangement of the material in the synthesis of the *Nova philosophia*. We can also note that on p. 210 of the *Nuova geometria*, where he introduces the concluding book on the geometry of triangles, Patrizi states that he intends afterward to deal with the geometry of curves: he must, therefore, have conceived of a sequel for his geometrical work—which, however, never appeared.

elaboration of the whole philosophical system and show clearly how Patrizi's hopes for a radical reformation of Scholastic metaphysics rested chiefly upon that very concept of space. Patrizi's chief metaphysical work, the *Nova de universis philosophia* which took the place of the projected treatise on Nature, was published four years later. It included, in one of its sections, the older books on space, reprinted with a few alterations and some additions, as well as a greatly abbreviated Latin translation of the main results of the *Nuova geometria*.[9] In any case, it is not hard to realize that the huge and cumbersome mass of the 1591 work, which for the most part develops a strange and complicated Neoplatonizing metaphysics of light (which was also criticized by ecclesiastical authorities and caused Patrizi serious difficulties),[10] must have developed out of the older theory of space, which represents in many respects its most novel part and the one most rich in consequences.

[9]We know for certain that Patrizi had originally conceived of his books "*de spacio*" as the beginning of a larger work, since he explicitly states this in his letter to Tebalducci of 29 June 1587 (*Lettere*, p. 57), and repeats it in the incipit of *De spacio physico* (p. 2r). The alterations to the two treatises on space for their inclusion in the *Nova philosophia* amount to some marginal corrections and to a certain radicalization of the anti-Aristotelian positions. For instance, in Chap. 5 of *De spacio physico*, Patrizi criticizes certain ancient philosophers, not mentioned by name, whereas in the corresponding locus of the 1591 work their place is taken by "Aristotle". The only relevant addition is a philosophical introduction (*Nova philosophia*, pp. 61r–61v) which serves the function of welding these two books more tightly together in the context of the new work. The 227 pages of *Nuova geometria*, on the other hand, are so reduced in the Latin version that they only make up 5 sheets of the *Nova philosophia*. Their subject, in fact, largely exceeded that of a treatise on the metaphysics of light. Although the three works, on space and on geometry, had been conceived as a single unitary work (cf. the previous footnote), we possess a letter by Patrizi from 1590 which implies that, a mere few months before the appearance of the *Nova philosophia*, the work's outline was much different from the published version, and included only one generic book *De spacio* and probably nothing on mathematics; see Purnell (1978). Yet other arrangements of the book's matter are given as an appendix to Patrizi's *Lettere* (pp. 550–552). The work in its final form is divided into four sections titled *Panaugia*, *Panarchia*, *Panpsychia*, and *Pancosmia*, the latter of which includes the works on space and geometry as its Books 1–3.

[10]Patrizi dedicated one section of the *Pancosmia* to Cardinal Ippolito Aldobrandini. Just a few months later, Aldobrandini was elected Pope, taking the name of Clement VIII, and summoned Patrizi to Rome, where a new Chair in Platonic Philosophy was instituted at the Sapienza with the aim of fighting the dangerous heresies of radical Aristotelianism. Patrizi's lectures in Rome enjoyed a broad resonance and success and were attended by many prominent personalities (among whom was Torquato Tasso, whom Patrizi found at the time "smagrito e smagato e incanutito", *Lettere*, p. 88). However, precisely the novelty of his thought and his fervent anti-Aristotelianism caused suspicions to arise against him, so that by the end of 1592 his major work was under examination by the Holy Office, which found in it many theses worthy of censoring. Patrizi's defense consisted of an *Apologia* and certain *Declarationes* (now in Gregory 1955), and he also partially retracted his theses in an *Emendatio in libros suos novae philosophiae* (now in Kristeller 1970), but this did not prevent his book from being eventually, in 1596, added to the Index, after Toletus had also approved of this in 1594. On the condemnation, see also Firpo (1950) and Rotondo (1982). After news of the condemnation became public, the publisher, Meietti republished in 1594 in Venice some copies of the work bearing a fake frontispiece dated 1593 (that is, before the negative judgment passed by the Church), which are sometimes erroneously indicated as stemming from the work's second edition (whereas, in fact, no such edition appeared). Patrizi died a few months after the definitive condemnation in 1596, and in 1597 Roberto Bellarmino proposed the abolition of the Roman chair in Platonic Philosophy, judging

Finally, we know that, in the last years of his life, Patrizi was attending to a revision, perhaps a thorough one, of this his principal work. However, it does not seem that by his death in 1597 he had succeeded in reworking the books devoted to space.[11]

In the *Discussiones peripateticae* of 1581, we find, for the most part, the extensive *pars destruens* of Patrizi's metaphysics, which in many cases still lacks original solutions and rather insists on certain (modern, indeed, but in fact already common) views characteristic of the most advanced trends sixteenth-century metaphysics. The general strategy is to show that most of the Aristotelian (or Scholastic) doctrines on the fundamental topics of philosophy are wrong, and that all that which might be salvaged from them consists, in any case, in notions that Aristotle had copied from Plato or from philosophers of still earlier epochs.[12] The

Footnote 10 (continued)

the latter doctrine (at least in the reading of it propagated by Patrizi) to be even more dangerous than radical Aristotelianism. Clement refused to abolish the chair, but assigned it to the semi-concordist Jacopo Mazzoni, who professed Platonic views leaning towards Aristotelianism and would publish in the same year a study on the agreement of ideas between the two great Greek philosophers (*In universam Platonis et Aristotelis philosophiam praeludia*). Mazzoni, as is well known, had been Galileo's philosophy teacher and was still in contact with him (cf. Footnote 56 below). He had fought several intellectual disputes with Patrizi, especially of a literary character, as is attested by some booklets and by Patrizi's correspondence (see *Lettere*, pp. 54–56).

[11]This revision was certainly due to the inclusion of the work in the Index of prohibited books, from which Patrizi hoped thereby to rescue it. Already Garin (1953) published the first part of a reworking of the *Panarchia* (the second section of the *Nova philosophia*), and Gregory (1955) mentioned the existence of a manuscript with a revision of the *Panaugia* (the first section). More recently, Puliafito (1993) published all the extant materials of Patrizi's rewriting of the *Nova philosophia*. Nothing was found concerning the books on space and geometry. On the other hand, according to the ecclesiastical materials about the work's condemnation which have survived (which are, however, very incomplete), it does not seem that the Inquisition had ever objected to Patrizi's theses on space. Therefore, he would have most probably kept the contents of *De spacio physico & mathematico* as they were. Finally, there is a Patrizian manuscript from 1594 containing a treatise in Pythagorean numerology, *De numerorum mysteriis*, which is still unpublished to this day (see Muccillo 1993b).

[12]This attitude is in fact usually to be noted in Patrizi's other works as well, as he always boasted that his views were certainly *new* (as is indicated by such titles as the *Nova philosophia* or the *Nuova geometria*), but at the same time age-old and already propounded by the ancient Pythagoreans. For instance, when arguing in *De spacio physico*, p. 9v (=*Nova philosophia*, p. 63v) for the existence of extramundane space, Patrizi rejects the principle of authority, but also thinks he can oppose *an older authority* to that of Aristotle, who had denied such space. On other occasions as well he engages in a competition with his opponents (whoever they may be) to find the most ancient source and thus, as it seems, the one closest to the spring of wisdom. Patrizi's attitude was certainly also due to prudence, and most of the defenses he mounted against the Church's charges of heresy for his *Nova philosophia* consisted in arguing that it was at the same time a *perennis philosophia*, so that a great many of his positions could find support in the authority of the Church Fathers, or in that of ancient philosophers in general. Thus, in his *declarationes* to the Holy Office, he claims that his philosophy is genuinely new only insofar as it is *a whole*, that is, insofar as he had intended to reunite into a coherent system the fragments of Trismegistus, Ocellus, Archytas, and Timaeus which the corrosion of time had made barely comprehensible in their own right. It is quite remarkable, however, that Patrizi excluded from this

Aristotelian notion of τόπος too meets the usual fate, and Patrizi mounts a huge number of arguments (almost all of them, in fact, already traditional) against the famed theory of place in Book Four of the *Physics*, which he deems to be partly wrong and partly plagiarized.[13] No reference is made here, however, to any alternative theory of space.[14]

Patrizi's views on mathematics can, likewise, only with difficulty be extrapolated from the *Discussiones*, as he is here mainly concerned with demolishing the anti-Platonic theses of Aristotelian philosophy of mathematics. First and foremost, he attacks the idea that there can be a science of accidents, and thus that mathematics could simply be the study of the quantitative properties of corporeal substances. Nonetheless, he does not seem to espouse openly the Platonic (and, more recently, Ficinian) alternative of mathematics as a science of Ideas, and rather inclines towards some form of Pythagoreanism, which nonetheless remains rather indeterminate. Such doctrines, in fact, lead him, in a quite natural way, back to a view of mathematics as the study of the quantity of mundane beings (though quantity is now understood as their foundation rather than their accident), so that at times he seems to return to the conception highly typical of Aristotelianism—or rather, typical of Neoplatonism and of the Renaissance in general—of quantity as inhering in matter.[15] Patrizi appears decidedly to reject the abstractionist theory, but does not propose any alternative to it, and leaves the question as to the relationship between mathematical beings and the intellect unsettled. However, he discusses at some length the use of imagination in mathematics, which he connects with procedures

Footnote 12 (continued)

strategy precisely the foundations of his doctrine of space, especially the position that it holds within itself every being (as we will shortly see), which latter theses, he claims, "*propria nostra sunt*". He thus possessed the awareness and the pride of having at least offered a new theory of space. On the *declarationes* against the censors, see Gregory (1955, pp. 422–423). On the concept of *perennis philosophia* see (among others) Schmitt (1966) and Muccillo (1988). An extensive and elaborate examination of Patrizi's judgments on Aristotle and pre-Socratic philosophy in the *Discussiones* is provided by Muccillo (1975, 1981).

[13]The discussion of the Aristotelian theory of place is contained chiefly in *Discussiones* II, VI (pp. 246–248). It must be noted that the Platonic theory of place, which Patrizi here and there opposes to the the Aristotelian one of *Phys*. 1–5, only amounts to some few mentions of place from the *Parmenides*, since Patrizi, like the whole tradition of ancient and Renaissance Platonism, construed Plato's χώρα as prime matter rather than space.

[14]The discussions conducted in this work seem to suggest that Patrizi subscribed to a theory of place as the three-dimensional extension of the universe, which he probably shared with Philoponus. In the letter to Tarquinia Molza of 13 November 1577 (thus a few years before the *Discussiones*) he presented in fact a metaphysics of extended but finite space, which seems perfectly to accord with Philoponus's views; cf. *Lettere*, p. 15.

[15]*Discussiones* II, IV, pp. 221–224. On this locus see especially Muccillo (1993b).

of abstraction[16]; and he adds a discussion on the use of motion in geometry, which he deems very reasonable, since imagination cannot, in his view, abstract from motion. For this reason, he considers Aristotle to be wrong in holding that imaginary geometric objects are immovable.[17] Finally, he believes it necessary to criticize Aristotle's theory of science as well and seizes the opportunity to tackle the vast *quaestio de certitudine mathematicarum*, if only to argue that the inadequacy of Peripatetic logic and epistemology is also, and chiefly, evident from the fact that they cannot account for even the most common mathematical lines of argument. None of these theories was really new, and all could be found, in substance, in the writings of Alessandro Piccolomini and other contemporary authors.[18]

As regards the more general metaphysical aspect of the text, there should at least be mentioned the fierce criticism leveled by Patrizi against the notion of prime matter, understood as devoid of any determination. The question is of some interest for us because Patrizi goes so far as to claim that Aristotle probably never claimed the existence of a perfectly indeterminate matter and that this thesis was

[16]See esp. *Discussiones* II, IV, pp. 224–225. Mathematical abstractionism is, of course, of unequivocally Aristotelian origin (although Aristotle certainly provided a much more complex version of it than is to be found in Patrizi's *Discussiones*). The reference to imagination, however, is, properly speaking, only Neoplatonic, not genuinely Aristotelian. The tradition linking the object of geometry to φαντασία takes its starting point, as a whole, from Proclus's commentary on Euclid's *Elements*, but the Renaissance had received it through other sources as well (although Proclus's work had been published in Greek in 1533, together with the *editio princeps* of Euclid, and translated into Latin by Francesco Barozzi in 1560). Proclus, of course, was by no means an abstractionist, and in fact fiercely opposed Aristotle on this point. On Aristotelian-Neoplatonic eclecticism, and its characterization of mathematical imagination as an abstractive act, see Footnote 57 below, as well as Vasoli (1989) that comments on this passage of the *Discussiones*. It should also be noted that a form of geometrical abstractionism (without reference to imagination) is also presented in Patrizi's essay *De' corpi*, which probably dates from 1577 to 1578 (in *Lettere*, p. 171).

[17]It is perhaps worth recalling that the dispute on the legitimacy of employing motion in geometry was quite lively in the second half of the Sixteenth Century, at least since Jacques Peletier had fiercely criticized such use in his *Demonstrationum in Euclidis elementa geometrica libri sex* of 1557, and various mathematicians (including Clavius) had felt compelled to respond to him. At any rate, everyone in that era was convinced that Euclid and the other ancient mathematicians had admitted, rightly or wrongly, the use of motion in geometry (something which we, today, may have reason to doubt). It is certainly possible that Patrizi was aware of this discussion, and that he intended to take part in it in some way. At any rate, here he argues for the movability of the objects of geometry not for foundational reasons in this science, but rather simply in order to criticize the Aristotelian definition of mathematics as the science of non-separable and immovable objects (given in *Metaph.* E 1; but the immovability of μαθηματικά is restated in many other loci). See Footnote 60 below.

[18]Patrizi's treatment of the status of sciences takes up the whole Book Four of *Discussiones* III; the part mostly concerned with mathematics is on p. 318, where Patrizi denies that the Aristotelian definition of science can be applied to the demonstrative method of mathematics. These are opinions which were widely diffused in the Sixteenth Century, which had actually had their origin in Late Antiquity, had developed during the Scholastic Middle Ages, and had been revived by Alessandro Piccolomini's aggressive discussion in his *De certitudine mathematicarum* of 1547. On Patrizi's relationship with Aristotelian logic, see Deitz (2007).

only put in his mouth by certain later *denudatores* of prime matter. He seems to believe, anyway, that Aristotle admitted a concept of prime matter as a *non-sensible body*, that is to say, (on his interpretation) *non-qualified*.[19] In this manner Patrizi reverts to a reading of prime matter similar to that of many Scholastic thinkers, as pure quantitative extension, that is to say (as he himself remarks), as a mathematical body. Patrizi, however, strongly denies that there can be such a thing as non-qualified matter and criticizes (his own) Aristotle on this point, along with all modern philosophers who had embraced this idea of prime matter (quantified or not), for instance Telesio.[20] The passage in question is significant because it shows very clearly how Patrizi was already preparing to attack the idea (so widespread in the Renaissance) that the first substrate of quantity (and the object of geometry) had necessarily to be matter.

But the theoretical framework of the *Discussiones* changes quite radically with the publication of the first really constructive work of Patrizi's metaphysics, that is, of the two books *De spacio physico & mathematico*. In the 1587 *De spacio physico* we find the conception of space for which Patrizi is still famous right down to our own day and which was to gain currency in the following centuries: namely, (to put it briefly), that of an incorporeal, immaterial extension, three-dimensional and infinite, which receives within itself and precedes all created beings.

The most novel and relevant character of Patrizi's theory of space certainly consists in the latter's ontological primacy over the bodies which occupy it. Patrizi emphatically claims that space, as three-dimensional extension, is a condition of all the bodies located in it, that it is the first principle of nature, and that just as the world precedes the single bodies, so space precedes the world, which in fact could

[19]On prime matter, see *Discussiones* II, VI (pp. 236–238), then chiefly *Discussiones* IV, III. The distinction between Aristotle's genuine position and that of the "*Senatus Populusque Peripateticus*" about the quantification of prime matter can be found on pp. 392–94. Patrizi bases his belief that Aristotle construed prime matter as a non-sensible body (σῶμα οὐκ αἰσθητόν) on an incorrect reading of a passage in *De gen. et corr.* A 5, $320^{b}1$–2, which calls (dialectically, moreover) the void, and not prime matter, "non-sensible body"; based on this, Patrizi interprets "non-sensible" as "non-qualified", according to a conception of qualities which is much more Neoplatonic (Plotinian) than Aristotelian, thus ascribing to Aristotle the idea of a quantified prime matter—which is, in fact, a much later theoretical construction. On the concept of prime matter in the *Discussiones*, see Deitz (1997).

[20]Patrizi had cordial relations with, and certainly admiration for, Telesio. In 1572 Patrizi sent to the philosopher a thorough critical analysis of the first book of his *De rerum natura*, where he principally criticized him for allowing the existence of prime matter: as it is not perceptible to the senses it should, in fact, he argued, be rejected as a Scholastic chimera according to Telesio's own sensualistic and naturalistic standards (at least as Patrizi interpreted them). Patrizi's objections to Telesio and Telesio's reply can be read in Fiorentino (1872–1874, vol. 2, pp. 375–398; the criticism of prime matter is to be found on p. 382); on this subject, see also Garin (1949) and Aquilecchia (1993).

not exist if space were not there to receive it.[21] In this way, space becomes a sort of super-substance which is a substrate and condition for other substances[22]; general ontology here undergoes such a strong twist that it risks breaking apart, and certainly requires a complete reformation. But let us, for the present, confine ourselves to the discussion of the properly physical and cosmological consequences which are the principal object of *De spacio physico*. The first consequence of the altered metaphysical perspective is that Patrizi certainly admits the existence of empty space, and in fact argues at length that reason and experience agree in showing that it exists both in the world and outside it.[23]

The second important consequence, which is discussed at length in the booklet, is that cosmic space is certainly infinite and unbounded. Patrizi thus exhumes the vast arsenal of ancient arguments (from Archytas onwards) that had been employed to show the absurdity of a finite cosmos.[24] He can count, however, on

[21]On the primacy of space in Patrizi see the short introduction to *De spacio physico* (p. 2r) or the different introduction to the corresponding book of the *Nova philosophia* (for instance: "Id (*scil.* spacium) enim ante alia omnia necesse est esse, quo posito, alia poni possunt omnia; quo ablato, alia omnia tollantur", p. 61r). And see especially Chap. 8 of the same book, which is entirely devoted to this subject, and ends with these words: "Est ergo spacium sui natura mundo prius, primumque rerum omnium mundanarum; ante quod nihil fuit, & post quod omnia fuere" (*De spacio physico*, p. 14v; *Nova philosophia*, p. 65r).

[22]On the supersubstantiality of Patrizian space see for instance this passage: "Si substantia est, quae aliis substat, spacium maxime omnium substantia est; omnibus enim substat aliis naturae rebus. … Hisce ergo rationibus omnibus patuit clarissime, spacium maxime omnium substantiam esse, sed non est categoriae substantia illa. Sed alia quaedam extra categoriam substantia est" (*De spacio physico*, p. 15v; *Nova philosophia*, p. 65r). We ought to remember that Aristotle himself had remarked that such a conception of space as the foundation of all bodies (which he attributed to Hesiod's χάος) was actually incompatible with his metaphysics, and that he had, therefore, rejected it; cf. *Phys*. 1, 208^b34–209^a3: "If such a thing is true, then the power of place will be a remarkable one, and prior to all things, since that, without which no other thing is, but which itself is without the others, must be first. For place does not perish when the things in it cease to be" (trans. Hussey). Patrizi quotes this passage from the *Physics* approvingly (in *De spacio physico*, p.14r; *Nova philosophia*, p. 64v), and one could even suppose that Aristotle himself had provided him with the suggestion of how to overthrow Aristotelian philosophy. It can also be noted that the same train of thought had been expressed in the pseudo-Aristotelian work *De Melisso, Xenophane, Gorgia* (976^b17–18), which, somewhat ironically, Patrizi had claimed to be perhaps the only genuinely Aristotelian work among those transmitted under his name (*Discussiones peripateticae*, I, III; p. 26).

[23]The subject is discussed at length in Chaps. 4 and 5 of *De spacio physico* (=*Nova philosophia*, pp. 63r–64r), which admit all three sorts of void. These are, firstly, the disseminated void, i.e. the microscopic void which separates the particles from one another and originates the phenomena of rarefaction and condensation (Patrizi thinks that bodies are, in themselves, completely impenetrable and inelastic, and could not be compressed in the absence of a void); secondly, the coacervated void, that of perceptible size (here Patrizi presents the reader with some experiments with clepsydrae); and thirdly, the extracosmic void, beyond the stars. The clepsydra experiment, a rather classical one, is probably taken from Philoponus, *In phys.* 569. On the metaphysical rather than experimental character of Patrizi's theories on the void, see Schmitt (1967).

[24]Patrizi's arguments for the infinity of space are found mainly in Chap. 6 of *De spacio physico* (pp. 11r–12v = *Nova philosophia*, p. 64r). In Book Eight of the *Pancosmia*, Patrizi was to try to conclude that the world itself is infinite, but his discussion does not actually concern the infinity of corporeal matter; rather, it concerns, once again, only the infinity of space and of light (*Nova philosophia*, pp. 82v–83v).

many more reasons to support his claim of the unboundedness of space than his predecessors could rely on to support their claim of the unboundedness of place. Because if we understand place as dependent on corporeal matter (and as an accident of this latter), then the infinity of place can only follow from the (actual) infinity of matter itself. But the notion of the infinity of the material world was embraced by virtually no one, so that the idea of an infinite extra-cosmic space could, at best, be treated as a construction of the imagination or as a mere "negative being" (as indeed happened in the Medieval doctrines of a *spatium imaginarium*, but also well on into the Renaissance and the Modern Age). On the other hand, if space is altogether independent of the existence of bodies, nothing is capable of limiting it; and the classical arguments stating that only a space could limit another space recover all their force. Patrizi's space, of course, which does not depend either on mundane matter or on the consideration of the intellect, but is an autonomous ontological principle, is *actually* infinite, rather than being a mere indefinite or potentially infinite extension.[25]

In *De spacio mathematico* (also from 1587), on the other hand, Patrizi argues at length in favor of the existence of spatial *minima*, that is, of indivisible points and lines. He deems it necessary to respond to the mass of arguments which the (Aristotelian, but more generally mathematical) tradition had presented for the infinite divisibility of the continuum, and eventually concludes that such infinite divisibility leads to more grievous aporia than does the admission of an indivisible extension. Patrizi does not believe, therefore, that the continuum is constituted by unextended points (this seems absurd to him, as it did to many of his contemporaries), but claims that it is nevertheless composed of extended minima, namely, of indivisible lines.[26] Through this theory he certainly intended to restore the lost Platonic doctrines on this subject, which are attested to (albeit very indirectly) in

[25]Here is one of Patrizi's most explicit passages: "Cum ergo, nec corporis terminis, nec spacii alterius, nec suis, nec incorporeis finiatur, necessario concluditur, spacium illum a mundo recedens, in infinitum recedere, & infinitum esse … Nos spacium illud, actu infinitum esse concludemus" (*De spacio physico*, pp. 12r–12v; *Nova philosophia*, p. 64r).

[26]Patrizi devotes to his theory of minima the whole second chapter of *De spacio physico*, which by itself makes up the largest part of the work. Here he discusses first of all the classical Aristotelian arguments in *Phys*. Z on the continuum, opposing to them equally classical rejoinders (such as that if two lines of different lengths were both infinitely divisible, there would be greater and lesser infinites, which is absurd). It is evident, at any rate, that the theoretical principle of the dispute is precisely that space is divided *in actu*, since it is in no case (as, by contrast, had been true of matter) divided *in potentia*: hence Patrizi cannot accept the Aristotelian theory of the (material) continuum, which rests entirely upon the distinction between potential and actual parts. On the other hand, if the spatial continuum must be composed out of actual parts, these cannot be unextended. Patrizi believes he can prove geometrically that many unextended items (the points) cannot possibly compose something extended. The proof is given in the *Nuova geometria*, Book II, Prop. 2 (pp. 19–20), which, to be sure, proves nothing more than that *two* unextended points, taken together, do not occupy an extended space; to which a "Corellario" adds, without offering the least argument to this effect, that if this holds for two points, then it must hold for an infinity of points—which unfortunately is precisely what needed to be proven in the first place. Patrizi concludes from this that there must be minimum parts of extension, that is, indivisible lines (*De spacio mathematico*, pp. 20r–24r; *Nova philosophia*, pp. 66v–68r).

Aristotle, and at the same time to attempt to establish a different foundation for his new geometry.[27] On the other hand, it is also true that Patrizi considered the doctrines on minima to possess a *merely* foundational (better: metaphysical) interest, and that Euclidean geometry, in its most characteristic results, was not called into question by them; to this extent he did not deem it necessary to embark on the edification of a *new geometry of minima*—something which was, however, to be attempted by later metaphysicians sharing his views on the composition of the continuum (such as Bruno, or the later empiricist proponents of sensible minima)—and, instead, wisely confined himself (with better mathematical insight than the others) to the undertaking of a refounding of geometry in a spatial, but not simultaneously finitistic (discrete) direction.[28] From a metaphysical point of view, it is important for us to note here that Patrizi's spatial indivisibles are also *actually* given in the continuum, rather than representing a merely subjective limit of its division. This was to have the remarkable consequence for geometry that it was thenceforth possible to affirm the existence in space of all the figures present in it, which are composed precisely of such actual minima.

The complete system of Patrizi's natural philosophy is finally presented in the *Nova philosophia* from 1591, which expands on and completes many of the views outlined in *De spacio physico*. This work describes a cosmology with Stoic characteristics, in which a finite material cosmos is located within infinite space; there are no celestial spheres, and the planets and other celestial bodies wander through

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[27]The idea of extended minima was quite widespread in Renaissance philosophy, and was professed by a great many authors; it certainly had medieval origins (see Grellard and Robert 2009), but its proponents could support it with (alleged) classical theories. Bruno, an important representative of this current, was perhaps inspired by some remarks to this effect which are to be found in Cusanus (see, among others, Bönker-Vallon 1995, Seidengart 2000, De Bernart 2002 and Omodeo 2013; Vedrine 1976 also discusses Patrizi to some extent), but Patrizi's theory of indivisible lines does not appear to share the same sources (Patrizi mentions Cusanus in the Preface to the *Nuova geometria*, but does not seem to build on his work), and appears rather to be based almost uniquely on the pseudo-Aristotelian treatise *De lineis insecabilibus*, which presents (and refutes) a view on the indivisibility of minimal lines attributed to Plato and Xenocrates (but cf. also *Metaph* A 9, 992^{a}19–24; *De gen. et corr.* A 8, 325^{b}24–29). The view that Plato had postulated indivisible lines, or at least indivisible surfaces, had been espoused by Philoponus as well (see *In gen. et corr.* 27), although with arguments very different from Patrizi's; it is thus unlikely, but not impossible, that Patrizi also had in mind a revision of Philoponus's metaphysics in this field. He believed himself, at any rate, to be rendering a good service to Platonism (and to Pythagoreanism as well) by fending off Aristotle's attacks on that theory.

[28]To this extent, the fundamental step in Patrizi is the one stating that although the height of a minimal equilateral triangle (i.e., with sides of minimal size) cannot bisect the base, this fact does not bring the whole of geometry to ruin. It will, he argues, suffice to consider a bigger triangle, and there the theorem will be found to be valid. Here is the text: "Quòd si in minimo isopleuro, non possit minima cathetus basin secare, non ideo pernicies inde Geometriae creatur universae. Quin etiam ex pluribus minimis simul iunctis, maiorem lineam fieri, nihil vetat" (*De spacio mathematico*, p. 23r; *Nova philosophia*, p. 67v). This theory is important because it was to be shared by the proponents of sensible minima in the Eighteenth Century, and Berkeley was to offer a similar argument about the possibility of carrying out geometrical demonstrations on larger figures.

this space, each guided by its own daemon; the Earth itself, at the center of a finite material cosmos, rotates upon itself; only sidereal light, it seems, penetrates the distant recesses of extracosmic space—without, however, filling it.[29] The entire corporeal universe, then, would potentially be able to move within this absolute space, its size could grow or diminish within it, and it could finally even be annihilated and leave that space empty again, just as it had perhaps been before the universe's creation.[30]

The *Nova philosophia*, however, not only provides important details on the use of Patrizi's concept of space in natural philosophy, but also accomplishes a further, and fundamental, radicalization of the theses of *De spacio physico* in the form of the statement that all beings, not only bodies, are located in space and thus possess spatial attributes. The soul must in some sense be said to be in space, although Patrizi certainly does not consider it either to be corporeal or to be the simple Form of the body. Moreover: God himself must be considered as being in space according to the various, and contradictory, determinations in terms of which our reason represents him; he is *ubique*, *alicubi* and *nullibi* at the same time, but is certainly in relationship with space and cannot be conceived without it.[31] This shows very clearly

[29]Regarding Patrizi's astronomical and cosmological hypotheses, the most extensive discussion remains that included in Rossi (1977). The fundamental element in these hypotheses (besides the affirmation of the Earth's rotation) was the denial of celestial spheres and the decided affirmation of a fluid universe, which is certainly connected with Patrizi's spatial theories, although it is not their product. This cosmological view, indeed, was already present in Patrizi's aforementioned criticisms of Telesio from 1572, and thus predates by far the elaboration of a full-blown metaphysics of space of Neoplatonic spirit. Patrizi's anti-Aristotelian polemic had led him to deny celestial spheres before Brahe (though on the basis of metaphysical, rather than empirical, considerations), and he even failed to notice that the great Danish astronomer had arrived (and with stronger reasons) at the same opinion as him; thus, he criticized the latter for admitting the spheres, to Brahe's great resentment. The echo of this controversy (Patrizi apologized in vain for his misunderstanding) reached even Kepler, many years after Patrizi's death; although Kepler shared with the Italian philosopher a common Neoplatonic metaphysical framework, it seems that he did not esteem him very highly: the *Astronomia nova* voiced the harsh opinion that Patrizi had become "lucidly insane" (*cum ratione insanire*; cf. KGW III, p. 62).

[30]On the motion, augmentation or contraction of the universe, see *De spacio physico*, p. 11r; *Nova philosophia*, pp. 63v–64r. On annihilation, see *De spacio physico*, p. 14v; *Nova philosophia*, p. 65r. The hypothesis (certainly regarded as counterfactual) of a finite cosmos moving through infinite empty space precedes, of course, Patrizi's speculations, as does that of a universe changing its size. These doctrines, however, show in the clearest of ways the dependence of Newton's spatial philosophy (or of that of the tradition which inspired Newton) on Patrizi's work; these are precisely the theses which Leibniz, more than a century later, was to fiercely attack (against Clarke) to defend his own spatial theory, which was struggling to take the place of the one whose birth we are currently examining.

[31]In the *Discussiones* IV, IX (p. 463), Patrizi had claimed that God is not in space (see Vasoli 2006). In *De spacio physico & mathematico* we only find very few brief references to God. On the other hand, in the *Panarchia* section of *Nova philosophia*, so rich in theological determinations, we can even find a book (number Twenty) completely devoted to the relations between God and space, where Patrizi argues (mainly by negative theology) that God is not, properly speaking, in any place (since he is immaterial); however, he is everywhere, at least by his power (and indeed "*omnia ex Deo, ut ex loco; omnia in Deo, ut in loco*"); whereas it could not be said that he is

how the local doctrine of *De spacio physico* ends up informing and influencing Patrizi's whole mature ontology, which ultimately depends entirely upon it.[32]

Patrizi is indeed not unequivocal as to the ontological status of space with regard to the deity. Certainly space is not an aspect or attribute of God (as in certain medieval views), nor does it exist independently of him as an autonomous metaphysical principle (as in some other Scholastic and Renaissance theories). But the general context of Patrizi's philosophy fits more easily with Neoplatonic emanationism than with creationism, and whereas the material world seems to be the object of the creative will, Patrizi's space seems rather to be a necessary consequence of the first hypostasis.[33] At some point Patrizi even ventures the idea that

Footnote 31 (continued)

only somewhere, i.e., in the heavens, which is the position of the much-hated Aristotle (the whole discussion is on pp. 43r–44v). Finally, in the *Pancosmia* version of *De spacio physico*, Patrizi seems (at least dialectically) to concede the possibility of the opinion on God's celestial localization as well, and writes "Si divinitas universa indivisibilis sit, ut est, in spacio erit indivisibili, & a divisibili spacio circumque erit obvoluta. Si nullibi item sit, sine spacio non cogitatur, si sit alicubi, vel in coeli culmine, vel supra coelum, in spacio certe erit. Si vero sit ubique, in spacio non esse nequit" (*Nova philosophia*, pp. 61r–61v). In the same paragraph, Patrizi also argues for the soul's localization on the basis of the various ontological hypotheses regarding this latter ("Sin vero ratio, & mens animae corpus informet … Sin vero anima sit in corpore, non ut forma sed ut formatrix … Sin vero corpus sit in anima … ipsa quoque erit in spacio"), and thus concludes that "sunt ergo entia cuncta, & ea quae supra entia sunt, in spacio" (*Nova philosophia*, p. 61r).

[32]Patrizi ascribes to Plato the idea that all beings as such are located in place, on the basis of one *Timaeus* passage (52B) where the ancient philosopher does present this opinion, but in fact only to refute it (since the Ideas, for Plato, are in no place). The thesis which Plato intended to criticize, and which Patrizi embraces, should probably be attributed to Zeno and is ascribed to him in a passage of the pseudo-Aristotelian *De Melisso, Xenophane, Gorgia* (979^{b}25–26), a work which Patrizi, as we have seen, considered authentic. The thesis of the transcendentality of space, however, was held in Patrizi's age by other philosophers as well, and even by a Scholastic thinker like Fonseca, who advances it rather cautiously (*In metaphysicam* V, XV, q. 9, s. 3; vol. 2, pp. 768–769). Since that theory is not present in Patrizi's work from 1587 but rather first appears in 1591, it could in fact even be conjectured that it had come to Patrizi through Fonseca, whose positions had been published in 1589. Although it does not seem impossible that Patrizi had read Fonseca (in the *Discussiones peripateticae*, he had commented on Aristotle and was probably interested in every new exegetical effort in this field), the hypothesis is not strictly necessary, given the importance which space possessed in Patrizi's ontology already in earlier years. We can note here that Bruno, by contrast, considered space to be the place of bodies alone (*De immenso* I, VIII; *Opera*, I 1, p. 231).

[33]At times, Patrizi appears to liken space to the other corporeal elements (see Footnote 52 below), and in this sense it seems that the former would have to be created, just like the latter. Patrizi says in the introduction added to the discussion of space in the *Nova philosophia* (missing in the original *De spacio physico*) that space is the first thing God produced *extra se*; this could also suggest a creative act in the proper sense. However, in other places he apparently claims that God created both cosmic matter and light in space, which is the condition for their creation and appears itself to be uncreated. See for instance this passage: "At si iterum, coelos novos, terramque novam, Deus reficiat, … spacium praeexistit, quod novos capere possit coelos, terramque novam" (*De spacio physico*, p. 14v; *Nova philosophia*, p. 65r). We should bear in mind that since the Middle Ages the creation of an infinite being was generally held to be impossible (even for God); this was one of the reasons why space was more easily construed as a divine attribute than as one of his creations. On Patrizi's emanationism in the *Panarchia*, see Puliafito (1988) and Muccillo (2003).

God himself is *locus* (i.e. place, not space), which is in fact a rather classical claim, which is already to be found in the Church Fathers and several medieval theologians.[34] In this case as in the others, however, we need to understand the import of the claim within the framework of Patrizi's general revision of spatial doctrines. The various Scholastic assertions on God's local nature, or on his cosmic immensity, referred in any case to (classical and Aristotelian) non-quantified concepts of place; this made it possible to assert that God was unextended and nevertheless immense (locally present to all created beings). However, if place has now become space and extension, God's immensity immediately entails his quantification (and maybe even his divisibility into parts). Hence it is clear why Patrizi showed some hesitation in attributing spatial predicates to God, and sought refuge in the negative theology of *ubique alicubi et nullibi*. But little more was needed for interpreters and continuators of Patrizi's spatial conceptions to more casually associate the traditional Christian thesis of God's immensity with the new concept of space, and thereby risk heresy. These were, indeed, to be the Seventeenth-Century problems faced by More, Newton, Clarke—and, in a different direction, even by Spinoza.

3.3 Sources and Innovations of Patrizi's Metaphysics of Space

The development of Patrizi's spatial theories, as we have seen, unfolds entirely in a single, intense and crucial decade (the 1580s and the early 1590s), during which other authors (especially the Italian "naturalists") were also devising and publishing their revolutionary theories of space, which were all designed to entirely reform classical metaphysics. What is more, one gets a strong impression that this unanimous intellectual ferment was caused by the analogous inspiration of autonomous minds, who were for the most part unaware of each other; so that Patrizi could not support his metaphysical constructions with Bruno's philosophy of space,[35] nor

[34]The statement that God is place is from the *Panarchia*: "At ipse (*scil*. Deus) locus est, in ipso enim omnia sunt" (*Nova philosophia*, p. 42r). That God is the place of creatures is actually a quite common statement in the Middle Ages (in Eckhart, for example, or then in Weigel), or in the tradition (stretching into the seventeenth century up to More, Cudworth, and Newton himself) which saw in "*makom*", the Hebrew word for "place", the least inappropriate among divine names.

[35]Bruno's writings dealing more consistently with the formulation of a new theory of space are *De l'infinito, universo e mondi* from 1584, which thus predates by a few years Patrizi's works on space, and *De immenso et innumerabilibus*, whose composition probably began just after said Italian dialogue but which was completed and published in 1591, after Patrizi's *De spacio physico & mathematico* and simultaneously with his *Nova philosophia*. It seems that Patrizi never mentioned Bruno's works, and we do not know whether he knew them and what he thought of them. Bruno, for his part, in the 1584 *De la causa, principio e uno* passes a famous and tremendously negative judgment on Patrizi ("*sterco di pedanti*"), whose *Discussiones peripateticae* were at this time the only work known to Bruno; he believes that Patrizi had understood Aristotle

could the latter count on the former, nor either of them on Telesio.[36] It is therefore certainly important to investigate the common causes which could have given rise to the appearance of a pre-established harmony, that is, the main ingredients of the intellectual solution that was suddenly to precipitate into a new theory. It will be appropriate to examine more closely Patrizi's peculiar spatial metaphysics, to acknowledge its principal elements of novelty and to understand how, given those common causes, his philosophy alone among all the related philosophies could disclose the possibility of a new mathematical ontology and of an unprecedented epistemology of geometry as the science of space.

It is undeniable that many ancient and modern sources can be found for Patrizi's metaphysical theories, since he was certainly very well read and since he had the intellectual permeability to welcome into his system the most diverse suggestions: suggestions drawn from pre-Socratic philosophy, from mystery cults, from Plato, Aristotle and the Neoplatonists, from Stoic cosmology and Epicurean atomism, from the Church Fathers' theological metaphysics as well as the ample constructions of Scholastic thought in its Medieval and later Jesuit variants, from the naturalism of certain Italian philosophies of the early Sixteenth Century, and from many other sources besides. However, if what we are looking to identify is not the continuity of Patrizi's thought with the tradition but rather the origin of its novel elements and the points where it departs from this tradition—the watershed, so to speak, where the interaction with the sources turns into a new and original metaphysics—then I believe this watershed is certainly to be found in certain Neoplatonic constructs. There is no denying that Patrizi was first and

Footnote 35 (continued)

"né bene né male: ma che l'abbia letto e riletto, cucito scucito, e conferito con mill'altri greci autori amici e nemici di quello; et al. fine fatta una grandissima fatica, non solo senza profitto alcuno, ma etiam con un grandissimo sprofitto: di sorte che chi vuol vedere in quanta pazzia e presuntuosa vanità può precipitar e profondare un abito pedantesco, veda quel sol libro, prima che se ne perda la somenza" (*Oeuvres*, III, pp. 165–167). Bruno may perhaps have moderated his opinion of Patrizi after reading his *Nova philosophia*, and when he knew that Patrizi had been appointed by the Pope to the Roman chair precisely because of that work, Bruno thought that perhaps he himself could venture to return to Italy, since his views must have seemed to him not so dissimilar to those of Patrizi (whom he even believed to be an atheist, see Mercati 1942 and Yates 1964, p. 345). As we know, Clement VIII's liberality soon dissolved; the Roman fortune of the *Nova philosophia* lasted only a short time, and Bruno's an even shorter.

[36] Patrizi's aforementioned criticisms of Telesio were leveled against the second edition (1570) of *De rerum natura*, which does not contain extensive treatments of space. A discussion on the subject appears in the third edition from 1586, which thus precedes the publication of *De spacio physico & mathematico* by a mere few months (and follows that of Bruno's *De l'infinito*); thus, it is by no means apparent that Patrizi and Bruno could have been influenced by the book. Telesio's spatial theory, moreover, was rather similar to Philoponus's, so that the very same ideas were already in circulation independently of his work. On Telesio's theory of place, see first of all Chaps. 25–28 of Book One of the 1586 *De rerum natura* (pp. 36–42); on his theory of geometry, the objects of which are the magnitudes and shapes of bodies (and which has no relation to space), see Chap. 4 of Book Eight (pp. 316–318).

foremost a Neoplatonist (i.e. a proponent of one of the Renaissance variations on Neoplatonism), and only secondarily an eclectic thinker who was open to all these other influences; and while it is certainly true that there were other authors of his age who mixed together still more vigorously than did Patrizi their Neoplatonism with other doctrines, there is nonetheless to be recognized in this latter a special radicalism in his edification of an ample Neoplatonic metaphysics, which he develops with a singular rigor, and which probably allowed him to attain more consistent and original results than most of his contemporaries.

In particular, I think that Patrizi's concept of space, both as regards its incredible metaphysical properties and as regards its mathematizability, rests almost entirely upon a radical reinterpretation of the Neoplatonic concept of quantified matter (which was regarded, as we have remarked, as the foundation of geometric ontology) together with spatial doctrines of similarly Neoplatonic descent. It seems to me, in short, that Patrizi's conceptual model of space arose from the fusion—perhaps astute, perhaps incautious, but certainly novel—of those two ancient notions. The Enneadic metaphor of matter as an unchangeable, incorruptible, unalterable mirror in which the images of the Ideas appear and move must have provided a powerful inspiration towards the reinterpretation of this very matter as pure space. The fundamental advance of Patrizi's metaphysics, hence, consists in the first place in the revival and radicalization of this Neoplatonic concept of an unalterable extended substrate (which had been considerably watered down by later Aristotelianism of the Neoplatonic and concordist types); and in the second place, in the crucial transformation of this concept from the notion of a material substrate of bodies into a *spatial* extension which holds and localizes these latter. Thus arose a completely new concept which, immediately after its birth, promised the demolition of most of the ancient tradition and at the same time the elaboration of unprecedented new constructions.

The reference to this Neoplatonic notion of a substrate, however, which had arisen (in Plotinus) precisely in opposition to Aristotelian metaphysics, enables Patrizi to show the inadequacy of Aristotelianism in accounting for such an exceptional object: namely, space. Space as Patrizi conceives of it is neither a substance in itself; nor is it an accident of bodies; nor can it be said to be either matter or form or a compound of matter and form; nor can it be classified as a genus, or as a species either; in short, it does not fall under any Aristotelian predicament or predicable.[37] It is no surprise, therefore, that Patrizi adopts from the very start the tone

[37]On substance and accident, and the categories in general, see for instance this passage: "Sed sunto categoriae in mundanis bene positae, spacium de mundanis non est; aliud quàm mundus est, Nulli mundanae rei accidit, sive ea corpus est, sive non corpus, sive substantia, sive accidens, omnia haec antecedit; omnia illi uti accedunt, sic etiam accidunt; ita ut non solum quae in categoriis numerantur accidentia, verum etiam quae ibi est substantia, illi sunt accidentia. Itaque aliter de eo philosophandum, quam ex categoriis" (*De spacio physico*, p. 15v; *Nova philosophia*, p. 65r). A few lines further on, Patrizi asserts that space is neither form nor matter, and that it is not a genus because it is not predicated of either the species or the individual. Very similar arguments can be read in Bruno, especially in *De immenso*, I, VIII, where he claims that space is neither matter

of Plotinus's metaphysics of the genera of being, which, while making some concessions to the Aristotelian categorial apparatus as regards the explanation of the world, holds that such a system of concepts is completely inadequate for the comprehension and discussion of the true principles and foundations of that world, which are certainly supersensible and of which space is the most appropriate example.[38] Space, therefore, does not fall under any category, and in particular is not a substance, but rather a hypostasis in the Neoplatonic sense, or, more precisely, in Patrizi's words, an *extensio hypostatica*.[39]

The characterization of this extension as space rather than matter, moreover, naturally imposes a radical revision of the classical theories of place and

Footnote 37 (continued)

nor form (*Opera*, I 1, p. 232), neither substance nor accident (pp. 232–233), and neither genus nor species (p. 233); see also the *Articuli adversus peripateticos* (nn. 28–30) and the *Acrotismus Camoeracensis* (*Opera*, I 1, pp. 123–228), where Bruno states, *inter alia*, that place is a fifth kind of cause. On Bruno's spatial metaphysics see the article by Seidengart in this volume. It should be noted, however, that such a frontal assault on the Aristotelian ontology was not a prerogative of the Italian *novatores*, because already the Medieval notion of imaginary space, which in the Renaissance was commonly employed in the School, seemed by far to exceed the Peripatetic categories. Thus, we find that Fonseca himself, in the treatment of this concept of space (which he certainly accepts and employs), is obliged to conclude that it is neither substance nor accident, neither matter nor form, etc. (*In metaphysicam*, V, XIII, q. 7, s. 1; vol. 2, p. 604). Toletus, by contrast (who, as we have seen, played a role in Patrizi's condemnation) discusses at length the alternatives to Aristotle's conception of space, and seems to incline towards a notion of place as three-dimensional extension (less radical, of course, than Patrizi's own, and simply of Philoponian or Avicennian descent); but at the end of his extensive discussion, so rich in objections to Aristotle, he nevertheless concludes that such extension would be neither substance nor accident; this prompts him to reject this concept and to choose to keep rather to the Aristotelian definition, in spite of all its difficulties (see the *Commentaria in libros de physica auscultatione*, p. 116r).

[38]I think that the whole *De spacio physico* is rich in echoes of Plotinian thoughts about the genera of being, taken in the first place from *Enn.* VI 1–3 [42–44]; these intend to show the inadequacy of Aristotle's category theory for treating extramundane beings, and therefore employ the Aristotelian categories in a negative or especially emphatic form when predicating them of such beings. To be sure, neither Plotinus nor Patrizi really wish to accept Aristotle's natural philosophy as a correct description of the sensible world, and if Plotinus proposes his original system of sensible genera, Patrizi in the *Nova philosophia* also resorts to his non-Aristotelian elements (*lux, calor, fluor*) and to a cosmology completely different from the Peripatetic one; in any case, both philosophers insist on the insufficiency of the Aristotelian ontology for the proper description and discussion of the supersensible world. On the ancient sources of Patrizi's anti-Aristotelian polemic, see Leinkauf (1990); Plotinus's influence on the spatial doctrines had already been stressed by Kristeller (1964).

[39]The definition of space as hypostatic extension occurs in *De spacio physico*, p. 15v; *Nova philosophia*, p. 65r.

localization.[40] The immediate target of the new spatial theories is certainly the Aristotelian doctrine of place, since this theory excluded the possibility that place might consist in a three-dimensional extension, and rather proposed a thoroughly ecological and non-quantitative conception of place, or at most (in the case of Aristotle's account of "proper place") a definition of it as a two-dimensional surface. It must be noted, however, that, in the course of the centuries, many accounts of place as three-dimensional extension had developed, some of which had waged war on Aristotelianism, whereas others had even succeeded in reconciling with it.[41]

This was not, therefore, any groundbreaking novelty. The truly remarkable point was rather the ontological autonomy of space from body. On Aristotle's view of place, the latter is but an accident of the substance, and thus a property which depends ontologically on the located body. The anti-Aristotelian spatial doctrines which had proposed the notion of a three-dimensional and quantified place, and had in fact construed it as the spatial extension occupied by the body, had nevertheless not yet freed themselves from the ancient Aristotelian (and generally

[40]In the classical terminology, place (τόπος, *locus*) always designates a place occupied by some body and is, as such, opposed to the void; thus, by definition, there are no empty places (which of course is part and parcel of the consideration of place as an accident of a corporeal substance). Classical Antiquity also tried to articulate a concept of spatiality capable of being indifferent to plenitude and the void, and of representing the common genus of both notions: but this concept, merely sketched by some philosophers, remained so vague that it was not even given a name (see Sext. Emp. *Adv. Phys.* B 2). The Latin *spatium*, on the other hand, usually translates the Greek διάστημα (interval) which directly designates an extension (spatial or temporal), but lacks, in itself, any local character, and is more closely connected to the category of quantity than to place (though in *Phys*. 2, 209^{b}6–13, Aristotle somehow accommodates διάστημα in the broader discussion on the essence of τόπος, arguing at length precisely that it is completely *inadequate* to represent a principle of localization). Patrizi initially defines space as (hypostatic) extension, rather than as place (*De spacio physico*, p. 2v; *Nova philosophia*, p. 61v), and then intends to *prove* that the place of a body, to whose essence all Classical theories ascribe certain attributes (such as immovability and separability; Patrizi certainly has in mind the famous Aristotelian passage in *Phys*. Γ 4, 210^{b}34–211^{a}6), must also be extension, and thus space according to his definition (*De spacio physico*, pp. 6r–6v: *Nova philosophia*, p. 62v). In fact, he concludes the treatise (*De spacio physico*, p. 17v; *Nova philosophia*, p. 65v) precisely with a discussion of the various *powers* of space, the most important of which are that of conferring location on the bodies and of being an environment for them (*vis locandi et ambiendi*).

[41]It must be borne in mind that Aristotle himself seems at times to construe place as the tridimensional extension of the located body, considered separately from it. Some interpreters had believed themselves to recognize this theory in a rather obscure passage of *Cat*. 6, 5^{a}8–14, which seems to run counter Aristotle's explicit doctrines in the *Physics*. It is very doubtful, however, that in this case there actually is a discrepancy between the two works (but see at any rate Mendell 1987), and none of the ancient commentators took notice of it. In the Middle Ages, however, the difficulty was explicitly noted, and many attempts, at times rather elaborate ones, were made to reconcile the two accounts. In the Fourteenth Century, however, an Averroist idea (not directly argued for by Ibn Rushd) gained ground: the claim that the *Categories* did not represent Aristotle's genuine account, but merely the common opinion. This is, for instance, the position of Buridan (see Grant 1981 and Algra 1994), but it was also held, precisely in the age of Patrizi, by Fonseca, *In metaphysicam* V, XIII, q. 7, s. 1 (vol. 2, p. 604). At any rate, it was no absurdity, in the Renaissance, to state that Aristotle himself had embraced, seriously or as a kind of joke, a theory of place as three-dimensional extension.

Classical Antique) conception of a world made up of particular substances, of which place is merely an attribute.[42] What was claimed, therefore, was that every body is located in a three-dimensional space. But this was a limited and particular space, the existence of which was conditioned by that of the body. On this account of things, spatiality would be attributed to the world (*qua* the totality of bodies) only *distributively*, and there would not yet be present any notion at all of an all-encompassing ambient space which would localize material bodies *collectively*, and which would thus be capable of existing independently of these latter.

Patrizi (just like Bruno and many of his contemporaries) could actually read in the ancient commentators on Aristotle, namely in Simplicius and, to an even greater extent, in John Philoponus, a considerably different conception of place as an all-encompassing ambient space.[43] These latter authors, who had remained unknown to Medieval and Scholastic thought, and had now been rediscovered and were read also in the Schools (and thus exerted a considerable influence on Sixteenth-Century Aristotelianism), in fact treated space as the three-dimensional extension of the whole cosmos; and admitted, if only problematically, the possibility of an empty space and thus of a spatial extension independent of body. It is not hard to recognize, however, that these authors ultimately remained indebted to the metaphysical conceptions of Classical Antiquity, and, if there was something unique to them, this was simply that they ascribed a single place (a local accident) to the world-complex as a whole (rather than a different place to each substance), without however claiming that space might have being independently of the being of the world. They claimed that a body's space can subsequently remain empty, or

[42]It seems to me that such a theory of place as the three-dimensional extension proper to each object can be found, for instance, in Scaliger's natural philosophy (see *De subtilitate*, V, 3). In fact, I would regard these doctrines as quite common and certainly not revolutionary.

[43]On Philoponus's spatial theories, which are principally to be found in the *Corollarium de loco* (or *Digressio de loco*, as it was called in the Sixteenth Century) of his commentary on Aristotle's *Physics*, see at least Sorabji (1988) and De Haas (1997). The *editio princeps* of Philoponus's commentary had been published in 1535, and translated into Latin in 1539. Both Bruno and Patrizi knew Philoponus's works very well, and Patrizi even translated his commentary on the *Metaphysics* (which, however, is probably spurious) in 1583, precisely in the years between the *Discussiones peripateticae* and the new theories of *De spacio physico & mathematico*. Bruno makes approving mention of Philoponus's account of space, especially with regard to the concept of a void (which, as we shall see, he accepts without reserve, with its strengths and weaknesses), in *De immenso*, I, VIII (*Opera*, I 1, p. 231). In any case, Philoponus's commentary on the *Physics* had a considerable influence in the Sixteenth Century; his anti-Aristotelian theories of space found a first application in Gianfrancesco Pico's *Examen vanitatis* from 1520 (that is, even before Philoponus's printed edition; cf. Book VI, pp. 176–179 in Pico), and continue to be mentioned and discussed (among others) by Cardano, Vimercati, Pandasio, and many Scholastic thinkers. It may well be that Telesio depended on them as well. On the spatial doctrines of Pico, who may have been an important source for Patrizi's *Discussiones*, see Schmitt (1968, pp. 138–144). On the diffusion of Philoponus's commentary in the Renaissance, see also the excellent article by Schmitt (1987), who however does not consider this doctrine to have exerted a major influence on Patrizi. In Footnote 14 above, I have already mentioned a passage in which the young Patrizi seemed to adopt Philoponian ideas.

at least that we can *think* of it as empty, even if the void does not actually exist in nature. In this sense, certainly, space does not depend on any single body; in fact, not even its *notion* depends on any single body; but it remains nevertheless an attribute and property of the world. Indeed, Philoponus's space is finite, just like his world, because space depends on the world.[44] Therefore, the consideration of space as a *hypostasis*, and a principle independent of the bodies, leads Patrizi to fairly radical advances over those ancient doctrines, which we can only appreciate if we grasp its evolution from the notion of quantified prime matter (which is precisely such a self-subsistent substrate).[45]

Moreover, the assertion that quantified matter is the paradigm for Patrizi's space does not only justify its autonomy from individual bodies or from the world as a whole, but, first and foremost, justifies the claim that space is essentially quantitative. Since however it does not *receive* quantity from the outside, as a form (as was the case with matter, which is in itself indeterminate and merely potential), but is rather that form *actu*, Patrizi affirms that space is not just (a certain) quantity in a categorial sense, but rather the source and origin (*fons et origo*) of quantity in general.[46] The latter claim is better understood in the light of Patrizi's definition of a material body, which is constructed, in a classical—more specifically, in a Plotinian—manner as an extension endowed with resistance to penetration

[44]The theory of place as extension in Philoponus descends at any rate from his theory of quantified matter, that is, from the idea that there can be a quantitative material extension independent of substance. This independence of extension from substance justifies in Philoponus's view the concept of extended space as well. But in no case is this space *really* distinct from matter and substance, and in fact it depends ontologically (though not logically) on the latter. On the relation between space and quantified matter, see Philop. *In phys.* 578–579; on the finiteness of space, due to that of the world, see *In phys.* 582–583.

[45]In the discussion on the primacy of space in *De spacio physico*, Patrizi makes this point very clearly and espouses, so to speak, Philoponus's doctrine only provisionally and in order to radicalize it. He starts off, namely, by showing that the *place* of a body (understood as its three-dimensional extension) is ontologically prior to the body itself and its accidents ("Corpora ergo qualitatibus suis sunt priora. Corporibus vero priores sunt loci", *De spacio physico*, p. 14r; *Nova philosophia*, p. 64v), and that a tree, for instance, can only exist if its place already exists. Now, this might count as a good portrait of the anti-Aristotelian theory characteristic of the Neoplatonism of late antiquity; but Patrizi then adds that the world (in its entirety) is prior to everything which it contains, that is, bodies, their accidents, but also their places; and concludes by adding that *space* is prior to the world itself (something which Philoponus would not have allowed), and thereby to places and to bodies too: "At cum entia nulla alia in natura sint praeter haec quatuor, spacium, locus, corpus, qualitas; corpus autem qualitate prius est; & corpore locus; & loco spacium, spacium nimirum rerum omnium primum est. Mundus itidem prior omnibus quae in eo sunt, locis, corporibus, qualitatibus est. Spacium autem ante quam mundus est: spacium nimirum mundanorum omnium primum erit" (*De spacio physico*, p. 14v; *Nova philosophia*, p. 65r).

[46]The claim that space is the origin of sensible quantity is of such importance that it appears immediately after its definition as a hypostasis: "Spacium ergo extensio est hypostatica, per se substans, nulli inhaerens. Non est quantitas. Et si quantitas est, non est illa categoriarum, sed ante eam, eiusque fons et origo" (*De spacio physico*, p. 15v; *Nova philosophia*, p. 65r).

(ἀντιτυπία).[47] In other passages, Patrizi even affirms that the essence of a body is just this impenetrability alone, which distinguishes it from space, whose essence instead consists in extension alone (i.e. would, for its own part, be in principle penetrable). From this it follows that body is extended and quantified not in itself, but because it is in space. This does not mean, of course, that there exist unextended bodies, because all bodies are in space; but it means that the *categorial* (that is, sensible) determination of quantity belongs to body only by virtue of space (which is thus its source and origin), and furthermore, that the quantitative properties of bodies depend only indirectly upon the bodies themselves, but directly and properly upon the space which they occupy and in which they are located.[48]

This *direct* quantification of space is absolutely unprecedented. I have already drawn attention to the fact that the earlier philosophical tradition had ascribed quantity and magnitude not directly to space or place, but rather to substance or matter. Quantity (like place, as we have seen) was always regarded as the *property* of an object, which possesses a certain magnitude; and most of all as an accident that must inhere in a substrate (a substantial one for Aristotelianism; a material one for Neoplatonism). Thus, for instance, the various criticisms leveled against the possibility of the void were based, at bottom, on the simple observation that the void would have had to be a quantity without a quantified subject. The same holds for the concept of space. As a consequence: either space itself (as the place of a single body or of the whole cosmos) was regarded as an attribute inhering in a (substantial or material) substrate, in which case it could be argued that such space is *indirectly* quantified (inasmuch as the substrate in which it inheres is quantified); or, alternatively, one could embrace the notion that space is by no means the

[47]On the penetrability of space, see *De spacio physico*, p. 13r; *Nova philosophia*, p. 64v. The definition of body as three-dimensional extension endowed with ἀντιτυπία is a very classical one (though not Aristotelian), and probably dates back to Democritus. It is attested to, for instance, in Sext. Emp. *Pyrrh. Hyp.* Γ 39 and *Adv. Phys.* B 257, or in Hero, *Def.* 11; the notion is also extensively discussed in Plot. *Enn.* II 6 [17], 2 and *Enn.* VI 1 [42], 26, and it is not unlikely that Patrizi took it from there. In Patrizi's natural philosophy, the impenetrability of bodies is a consequence of the elementary mixture of light and *fluor*. Later doctrines on the penetrability or impenetrability of space were, by contrast, to be rather varied; and several authors who certainly shared ideas similar to Patrizi's were to vigorously argue that space (as hypostasis and foundation of the sensible world) is impenetrable, and itself penetrates all bodies without its parts ever being separated. See for instance Bruno, *De immenso* I, VIII (*Opera*, I 1, p. 232); and in later ages Henry More, Joseph Raphson and many others.

[48]The statement that the essence of a body consists in impenetrability *alone*, whereas its dimensions are only accidentally acquired by virtue of its being in space, is explicit at least in this passage: "Proprium enim corpori naturali, qua corpus naturale est antitypia illa est, & quam vocant anteresim. Hoc est resistentia, & renitentia. Quae renitentia, trinon illo spacio opus habuit, ut subsisteret. Qua ratione tres distantiae, sunt fere corpori, tam alienae, quàm fuerant corporeis. Locus verò ita propriae sunt, ut ei non accidant, aut ei aliunde accidant, sed ipse locus, non sit aliud, quàm distantiae illae. Et spacium, verus sit locus. Et locus, verum sit spacium" (*De spacio physico*, p. 6v; *Nova philosophia*, p. 62v). Patrizi also restates the idea in the final revision of the *Nova philosophia* written for the Inquisition (see Puliafito 1993, p. 38).

attribute of an object (be it substance or matter), but rather a kind of autonomous metaphysical power wholly independent of matter and bodies, and thus insusceptible of being quantified. It is the latter option that is chosen by late Scholasticism which endorsed an anti-Aristotelian turn in the theory of space and chose to edify a concept of place upon the medieval notion of imaginary space, or space as mere negation; but this *spatium imaginarium* could not help but completely lack quantitative properties, since it was not a positive substrate capable of receiving accidents or determinations of any sort.[49]

The element of exceptional novelty in Patrizi's theory of space, namely, is that it envisages the idea of a quantitative extension without any substrate at all, neither substantial nor material. If we want to fully grasp the distinction between this conception and that of quantified prime matter (which may prima facie appear similar, since prime matter is completely indeterminate and thus does not seem to constitute a significant difference), we only need to observe that space is quantity and extension *alone*, whereas quantified prime matter takes up, successively, all the further forms of bodies and may only possess quantity as one attribute among many. In this sense, the quantity of matter is always at the same time the quantity of something (namely of the material object and its remaining properties). Space, by contrast, is a sort of *pure extension* which does not admit of further determinations apart from those of a quantitative (and thereby geometrical) nature[50]; and it is, as we have seen, a determinate and actual quantity—but not the quantity of anything. The formulation of such a concept by Patrizi was thus more likely to be due to a certain logical audacity and temerity, or to a relaxed conceptual carelessness, than to the full awareness of a new metaphysics; and Patrizi's notion of space, initially received only in the most nonconformist of Neoplatonic circles, had a difficult path towards becoming a paradigm. The School, indeed, refused for long years to accept those doctrines, which were plainly incompatible with the general foundations of classical metaphysical thought. But the boldest naturalism as well, and even Bruno's metaphysics, shied away from these conclusions, and Bruno still fluctuates with some ambiguity between a pure notion of space and the simple idea of a *material* (or ethereal) substrate that additionally, and extrinsically,

[49]The quantification of space is a result of the late Neoplatonic speculations of Philoponus and Simplicius, which had left no trace in the Medieval theories of ecological place or of imaginary space; it was also usually attacked by the Second Scholasticism. So, for instance, Fonseca in the aforementioned passage *In metaphysicam* V, XIII, q. 7, s. 1 (vol. 2, pp. 604–606) where he mounts a refutation of Philoponian space precisely because he wishes to affirm that imaginary space, being pure negation, cannot fall under the category of quantity. Note that Fonseca believed that, although he had to accept the Aristotelian notion of *place* as containing surface in the *Physics*, he could at the same time complement it with a (much more elaborate) doctrine of *space*, construed as the *spatium imaginarium* of the Medieval tradition, which is in fact independent of the existence of bodies and therefore shares (at least prima facie) some of the properties of Patrizi's "modern" space: though not quantification.

[50]Cf. one of the principles of the *Nuova geometria*: "Lo spazio è estensione, e la estensione è spazio" (p. 2).

functions as the place of bodies[51]; it is no surprise, indeed, that he refused to follow Patrizi in the edification of a geometry of space, and preferred to remain strictly faithful to the idea of a geometry of material magnitudes.

This ontological rarefaction of the quantified material substrate into pure spatial quantity is thus the genuine turning point of Patrizi's metaphysics.[52] Precisely because of its novelty, it is a very arduous task to identify its sources, and it seems that the Renaissance conceptions of space and quantified matter had by then simply moved so close to one another that all that was needed to weld them together was audacity enough to connect them, or carelessness enough to confuse them, with one another. However, we should mention that it is possible to find at least some *linguistic*, rather than theoretical, antecedent of the fusion of these concepts. I am thinking principally here of Marsilio Ficino's translation, with commentary, of the *Enneads*, which was published in 1492 and immediately became the reference text for Plotinus studies. Ficino, when tackling Plotinus's important discussion of quantified matter, correctly and naturally translates ὄγκος as *moles*. He

[51]See for instance *De l'infinito*, where the ambiguity clearly appears in the following passage, according to which space is (at least) *similar* to matter: "Lascio che il luogo, spacio et inane ha similitudine con la materia, se pur non è la materia istessa; come forse non senza caggione tal volta par che voglia Platone e tutti quelli che definiscono il luogo come certo spacio…" (*Oeuvres*, IV, p. 113; but cf. p. 69, also on the Platonists; and the *Acrotismus* in *Opera*, I 1, pp. 126–128). Other passages where Bruno seems to construct space as matter or aether occur at *De immenso*, IV, XIV: "Aether vero idem est quod caelum, inane, spacium absolutum" (*Opera*, I 2, p. 78). On the subject, cf. Amato (1997) and Giudice (2001).

[52]It must be admitted, however, that some fluctuation is still present in Patrizi as well, and that (as was noted by Grant 1981, pp. 386–387, n. 139) in the *Pancosmia* he reverts to a Neoplatonic emanationist account according to which the perfection and originality of a being is inversely proportional to its corporeality, so that space becomes the least corporeal and the *rarissimum* of elements, followed by the slightly more corporeal light, then heat, *fluor*, the aether, and so on to air and the other common elements. However, it seems to me that we should not take this scale of corporeal densities too seriously, since light is straightforwardly said to be incorporeal in other texts, and body is defined precisely as spatial extension endowed with the resistance to penetration. Still, it is a fact that Patrizi, even in the more cautious *De spacio mathematico* (p. 25v; *Nova philosophia*, p. 68r), paradoxically affirms that space is a *corpus incorporeum*. But there, as we shall shortly see, he needs the argument to prove that mathematics, the object of which is incorporeal (space as an ideal being), nevertheless applies to bodies, because they are in space. Moreover, Patrizi certainly owed the oxymoron of 'incorporeal body' to his Platonic studies, namely to the analogous characterization of χώρα offered by Calcidius (*In Tim.* §§ 319–320), as well as to Plotinus's *incorporeal* ὄγκος which is however at the same time σῶμα μαθηματικόν. We should finally observe that some interpreters (starting with Henry 1979; Deitz 1999 insisted on this point) have noted the affinity between Patrizi's views on Nature, especially his metaphysics of light, and Proclus's philosophy of space, which identified place with an immaterial body spread across the universe and probably identical with light (we owe this information to Simpl. *In phys.* 612; published in Latin in Venice in 1566, pp. 221–222). There is no doubt that Patrizi knew the work of Proclus very well: he had translated his *Elements* on physics and theology in 1583, and explicitly mentions many of his other works (the most relevant for our purposes being the commentary on Euclid); certainly Patrizi's emanationistic system retains some similarities to Proclus's, but not a great deal, since the latter is interwoven with Plato's and Ficino's: see Kristeller (1987). However, the actual similarities between the two concepts of space are rather scarce, and Proclus's meditations appear to extend no further than that very notion of corporeal (and finite) space which Patrizi aspires to transcend. On space in Proclus see Schrenk (1994) and Sorabji (1987).

must, however, have been aware that Plotinus's "mass" is in fact a rather unphysical thing, since it is a simple three-dimensional extension devoid of resistance, and is in fact characterized as an incorporeal *corpus mathematicum*. He was likely aware, then, that *moles* was not, in fact, the most adequate term to describe what was really at issue here, and in his lengthy marginal comment on this notion, he consistently refers to it rather by the name: *spatium*. This is, of course, a merely lexical innovation, since firstly, Ficino's account of place is straightforwardly Aristotelian (as, indeed, was the theory of place of Plotinus himself), and secondly, his mathematical ontology has nothing to do with space (being, in fact, entirely Platonic). However, one thing is certain: we find here in a text that was crucial for late-Renaissance Platonism (and for Patrizi and Bruno in particular) an explicit drawing of a connection between quantified matter—which was also the object of geometry—and space. It is not impossible, therefore, that Patrizi or others, seeking to discover, in the *Enneads* the unbroken thread of a thoroughly anti-Aristotelian ontology, may have found even in Ficino's merely fortuitous linguistic option a factor impelling them toward the identification of space with the properties of the material substrate.[53] In other contexts, the Medieval view concerning

[53]On Ficino's translation, see first of all Garin (1975), Wolters (1986), Saffrey (1996), Chiaradonna (2006). Ficino's edition of the *Enneads* was read and studied throughout the Renaissance and beyond. The *editio princeps* of the Greek text only appeared in 1580 (and was still presented along with Ficino's translation), so it is evident that most scholars continued, for many years, to rely on the only available translation. On the other hand, we know that Patrizi was in a position to inspect the Greek original before the appearance of the printed edition, because he owned a manuscript codex of the *Enneads* copied in 1563 (cf. Jacobs 1908; Muccillo 1993a). Ficino's commentary refers to Plotinus's crucial passages on ὄγκος in *Enn.* II 4 [12], 11, and in that passage he only uses the term *spatium* (Ficino, *Opera*, vol. 2, pp. 1949–1950). Even in translating the Greek original, on at least one occasion Ficino complements Plotinus's elliptic text with the alien notion of space; cf. the *incipit* of Ficino's translation of Chap. 12 in the above-mentioned treatise (ed. Perna, p. 166; it should be borne in mind that the subdivision into chapters of the treatises in the *Enneads*, still in use today, originates with Ficino), where he conjectures that the missing subject in the sentence in question is ὄγκος from the preceding discussion (it is the concluding word of Chap. 11), instead of ὕλη as is usually (and perhaps wrongly) assumed by modern translators: he thus decides to take advantage of the freedom offered by the text and to translate the term in question as *spatia*. Elsewhere, again, in *Enn.* II 4 [12], 11, Ficino renders with *spatium* the Greek word διάστημα. Patrizi never concealed his admiration for Ficino, and he even stated that his reading of the *Theologia platonica* had paved his way to philosophy (indeed, all his earliest works are variations on themes from Ficino): see the letter to Baccio Valori of 12 January 1587 (*Lettere*, p. 47); on Patrizi's Ficinianism, see Muccillo (1986). Furthermore and chiefly, as we have noted several times, the whole *Nova philosophia* abounds with genuinely Enneadic elements, especially when it comes to quantified matter or to quantity itself. As regards Bruno, it is very well known that his works display a widespread presence of Plotinian themes (see Chiaradonna 2011, who also gives some examples of Bruno's dependency on Ficino's interpretation—which is not the case, however, on the subject of matter); it should be noted, however, that in *De la causa, principio e uno* (*Oeuvres*, III, p. 237) Bruno mentions *explicitly* precisely the treatise on matter in *Enn*. II 4 [12], the one which contains the notion of ὄγκος and Ficino's remarks on space. A little later (pp. 249–251), he connects Plotinus's theory of ὄγκος to that of *dimensiones indeterminatae* (which in fact originates with later Neoplatonism, or even with Averroes). We can also note that in *De umbris idearum* (1582) Bruno not only made ample use of Plotinus, but also approved of his interpretation of matter as a mirror (which also played some role in the formation of the modern concept of space).

the indeterminate dimensions of prime matter had already, at times, been brought into close association—albeit only nominally—with the notion of space.[54] In any case, it is of prime importance to note that neither the notion nor the explicit theorization of a space which is quantified (and even quantifying) but at the same time autonomous from all corporeal substances were to be found anywhere prior to Patrizi. This, then, is the really original metaphysical element of his philosophy.

3.4 The Epistemology of Geometry

The principal element of originality in Patrizi's metaphysics of space consists, as we have just stated, in space's ontological independence from bodies and from matter, and in the fact that this space is quantified and is, in effect, the foundation of the quantification and extension of everything which exists in it. From this, clearly, it directly follows that mathematics must be concerned with space itself, rather than with bodies or with extended corporeal matter. It is thus no surprise that Patrizi was eventually to arrive at the formulation of a new epistemology of geometry as the science of space.[55]

The thesis that space is directly quantified but the matter located in it only indirectly so has vast implications for the general conception of science and nature. In particular, this leads to the idea that the world is mathematizable, and that it is possible to investigate its quantitative features precisely because it is in space. That is to say, geometry can be applied to the world because it can be applied to space, and space is the foundation of all bodies' extension. This is clearly an idea which

[54]For instance, we find that the *Filosofia naturale* (1560) by Alessandro Piccolomini, an author of major significance for Renaissance mathematical epistemology, discusses the theory of *dimensiones indeterminatae* (which Piccolomini attributes to Averroes) stating that matter can receive "spatio, & misura di quantità" independently of substantial form. Evidently, "space" here means simply extension and interval, and the text contains no theory of space as place (Piccolomini in fact espouses a perfectly Aristotelian doctrine of place), nor a theory of space as the object of geometry (Piccolomini in fact takes rather intelligible matter to be said object). However, it does contain the explicit contiguity of spatiality and quantified matter which may have precipitated the later theories of Patrizi and other contemporaries.

[55]We will discuss here only Patrizi's *geometrical* theories, not the arithmetical ones (which he, moreover, did not develop in much detail, and which he perhaps intended to work out completely in *De numerorum mysteriis*). It must, however, be borne in mind that space is the origin of quantity in general, continuous as well as discrete, and consequently the source of both extension and numbers (in terms of the Classical, Aristotelian division of the genus quantity). Patrizi thus claims that geometrical magnitudes and numbers are equally primitive and neither can be founded on the other (*De spacio mathematico*, p. 19v; *Nova philosophia*, p. 66v); moreover, he affirms (as we have seen) that "*le matematiche tutte*", and not only geometry, are founded on space (*Nuova geometria*, p. 2). He also claims, however, that geometry has a privileged connection with space; on this basis he affirms that arithmetic derives from geometry, which is the first mathematical science (*De spacio mathematico*, p. 25v; *Nova philosophia*, p. 68r). This is opposed to Aristotle's view of the primacy of arithmetic, but also opposed to the Pythagorean position.

was bound to enjoy a broad posterity. It was, indeed, to be readopted a few years later by Campanella and was eventually to pass down, through many other thinkers, to Kant (who was to try to prove it by way of a transcendental deduction). We witness here, so to speak, a kind of "dress rehearsal" of the epistemology of modern science. And even if Patrizi chose, in the end, to give himself over rather to the fantastical speculations of the Pythagoreans instead of pursuing the path of the exact measurement of phenomena, his theories can nonetheless be said to constitute an important step toward the modern theoretical justification of the sciences.

In any case, this is undoubtedly one of the first grand metaphysical attempts to justify the mathematizability of the world *as a whole*, whereas ancient epistemology primarily considered the applicability of mathematics to certain specific forms or substances (the heavens, for instance), without passing through the notion of a general space. The earliest attempts, likewise, to apply Plato's original epistemology of mathematics to a justification of the geometric study of the world were mostly limited to considerations of this type, and took the picture of the cosmos given in the *Timaeus* as an inspiration for the claim that divine wisdom had chosen to create the world according to number, weight and measure. No attempt was made, however, to show that the very essence of the sensible world as such (that is, irrespective of the contingent divine will) had to be quantitative and mathematical. But this is exactly what takes place in Patrizi's theory. It is clear, then, that at least two different paths were opening up in this period that led, potentially, to a Platonic epistemology of the new physics: one that closely followed Plato in affirming that God has organized, by means of mathematical Forms or Ideas, a matter which was in itself lawless (this was the path taken by Galileo); and another, peculiarly Neoplatonic, that attempted to establish an ontology whereby the essence of bodies is intrinsically quantitative and therefore subject to mathematical inquiry (this was the path taken by Patrizi and by later philosophical and idealistic constructions).[56]

[56]I think that the best example of what I call here the Platonic, but not Neoplatonic, theory of the mathematizability of the world can be found, in Patrizi's time, precisely in the work of his successor on the Roman chair, Jacopo Mazzoni. He was a proponent of a form of Platonism which insisted on the applicability of mathematics to the world and on the superiority of a quantitative study of this world (on the example of Archimedes, Ptolemy or the modern mathematician Giambattista Benedetti) over Aristotelian qualitative physics. Mazzoni, indeed, rejected that variety of Renaissance Platonism (championed for instance by Francesco Barozzi) that, on the basis of the epistemology of the *Republic*, defended the pure character of mathematics and its non-applicability; he based, instead, his interpretation of Plato on the *Timaeus* and on the mathematical structure of the cosmic elements which this work advocated. Mazzoni in fact regarded as his greatest exegetical rival precisely Plotinus, who had separated, with his new theory of matter, Plato from Aristotle and thereby from natural inquiry and had inaugurated the drift towards the radical, anti-"concordist" Neoplatonism which was eventually to lead to Patrizi's thought; for the same reason, Mazzoni deems it appropriate to reject the Neoplatonic Plato of Ficino's interpretation. These theoretical (and philological) moves were very common at the time, and if Giovanni Pico had already criticized Plotinus for his anti-concordism, Perna similarly undertook his Greek edition of Plotinus in 1580 because he wanted to free this latter writer from the interpretative superimpositions of Ficino's Latin version; still others attempted to make Plotinus, Plato and Aristotle consistent with one another (such as Gabriele Buratelli in 1573: see Muccillo 1994). However, as we have seen, it was precisely the Plotinian concept of a quantified matter (and ὄγκος) that gave birth to the long

We should also note that the Neoplatonic theory of quantified matter, that is, of quantity as the first categorial determination of sensible objects (prior to those of the other genera of being), was certainly the historical condition for the theory asserting the thorough geometrizability of the cosmos, but was in itself still insufficient to justify a mathematized natural philosophy. In fact, such an ontological construction was rather employed (at least in Patrizi's time) to discredit mathematics by denying its *exact* applicability to the world since, it was claimed, quantity is the poorest and basest determination of an entity and the one closest to the indeterminacy of matter. Therefore, mathematics is insufficient to the study of the sensible world, whose constitution by far exceeds its own quantitative features and rather finds its essence first in the qualities and finally in the substantial determinations of each being. As a consequence, mathematics can produce, at best, useful hypotheses, but falls short of the actual complexity of phenomena. It is merely the most basic abstractive product of natural philosophy.[57] In Patrizi, on the other hand, it is immediately clear that *space*, precisely because it is not indeterminate

Footnote 56 (continued)

intellectual tradition which finally arrived at the assertion that quantity is the essence of all bodies, and consequently paved the way for a (different, but very effective) epistemology of natural philosophy. It seems, at any rate, quite beyond doubt that Galileo's *Saggiatore*, with its "book of Nature" written in triangles and circles, descends to some extent from Mazzoni (and ultimately from the *Timaeus*); it is no surprise that Galileo was never greatly to appreciate the alternative attempt at justifying a mathematical knowledge of Nature carried out in his time by Campanella, on the same Neoplatonic and spatial foundations as Patrizi's. On Mazzoni and the Renaissance philosophy of mathematics, see Purnell (1972), who also discusses his relationship with Benedetti; and De Pace (2006a), who deals with the limitations of Mazzoni's concordism and his openings towards skepticism. By the same author, see also De Pace (1993), that suggests that Mazzoni (whose *Praeludia* date from 1597) might have been acquainted with Kepler's *Mysterium cosmographicum*, which had been published in the preceding year and immediately sent to Galileo in Italy, and which also contains an epistemology modeled on the *Timaeus* (and hostile, as we have seen, to Patrizi and his cosmological hypotheses); on the influence of Patrizi's metaphysics of light on Kepler, see Lindberg (1986). Finally, see De Pace (2006b), who, arguing against Hankins (2000), also finds an important difference between Galileo's Platonic epistemology and Ficino's Neoplatonism—even though along different lines than those sketched here.

[57]This devaluation of the cognitive value of mathematics was already marginally present in the late Greek commentators on Aristotle, that is, Philoponus and Simplicius, and is to be ascribed to the eclectic attitude of the latter authors, who inserted into the Neoplatonic conception of quantified prime matter the Aristotelian doctrine of mathematics as a product of abstraction; with the consequence that quantity, this primitive ontological determination of entities, instead of being considered as its foundation was regarded as its poorest and basest abstraction. From this it followed that mathematics could be applied to the world of corporeal substance only in the guise of a *hypothesis*, whereas only (qualitative) natural philosophy, which alone was concerned with substantial forms, could aspire to a non-hypothetical knowledge of Nature. These tenets, though variously extended and modified, had nonetheless reached and been absorbed by Renaissance Aristotelianism, and had been embraced by Piccolomini in *De certitudine mathematicarum*; in a period closer to Patrizi's, however, they were also propounded in Pereira's *De communis omnium rerum naturalium principiis*, published in Rome in 1576 and reprinted several times (for instance in 1585, around the very time that Patrizi composed his works). Patrizi vocally opposes these epistemologies of the world's (non)-mathematizability, and regards the attribution of quantity to space

matter but rather a hypostasis and foundation for bodies, contains precisely all the *essential* properties of the world, and those which best reveal its nature.

Moreover, the theory of quantified matter still admitted of an interpretation based on the usual Neoplatonic idea of a gradual loss of the formal properties in the course of their materialization. In short, one might well doubt that exact mathematical forms can really be found in Nature and suspect that matter (precisely by virtue of its being the principle of disorder and resistance to form) is never perfectly mathematizable—a position found in Cusanus and Bruno. On the other hand, Patrizi's space as a hypostasis and origin of quantity receives the geometric figures in the most perfect way. This immediately removed the various ontological problems connected to the Neoplatonic theories of imperfect mathematical objects. But most of all, it decidedly affirmed that the objects existing in space are themselves geometrizable in an exact manner, since the essence of each body is quantity (and impenetrability).

Yet another consequence was this: because geometry is the science of space, which in turn provides the foundation for physical Nature, mathematics must itself be understood as a more original science than natural philosophy, in short, as the most fundamental of sciences (after metaphysics).[58] Thus, the transition from quantified matter to quantified space also justifies this (quite widespread) modern epistemological claim. The transformation of the material substrate of geometry into space also has other far-reaching consequences for Patrizi's mathematical epistemology. Among the most relevant is the fact that (as we have already mentioned) he forcefully rejects Proclus's theory (revived by so many Renaissance and modern Neoplatonists) that geometrical objects are the product of projective imagination; in other words, that they are imaginary constructions that the mathematician draws intellectually on the screen of imagination. In fact, such an imaginative substrate was definitely characterized as matter, very often as "intelligible" or "imaginary matter", precisely because of its pure potentiality, indeterminacy and determinability on the part of the intellect. Such imaginary matter is nothing else than the ideal counterpart of the real matter of the world, in which the geometer draws his concrete diagrams and the Demiurge (or the World Soul, or God) draws the shapes and sizes of real bodies. On all these accounts, matter is regarded as perfectly indeterminate before the formal intervention

Footnote 57 (continued)

rather than to matter as the ontological foundation necessary to overcome the abstractionist theory and its consequences. In cosmology as well, in fact, he was a lively opponent of the view that astronomy deals with simple mathematical hypotheses rather than with the actual motions of the celestial bodies. Toletus, in fact, had already defended the nobility of mathematics against physics, and some years later (in 1615) Biancani was to claim that mathematics is more certain than natural philosophy since an accident is easier to know than a substance (thus, with an argument that Patrizi could not possibly have endorsed): see Biancani, *De mathematicarum natura*, p. 26.

[58]Patrizi thus revives the picture of mathematics as an intermediate science between metaphysics and the study of appearances, which can be, to some extent, traced back to Plato's *Republic*; he connects the intermediate position he assigns to mathematics with the analogous character of space, which is intermediate between the natures of (ideal) incorporeal objects and (phenomenal) corporeal things: "Eandem hanc rationem consequitur, ut mathematica anterior sit quam physiologia. Media quoque est, inter incorporeum omnino, & corporeum omnino, non qua ratione veteres dixere, per abstractionem a rebus naturalibus corpoream quasi fieri, sed quia revera spacium sit corpus incorporeum, & incorporeum corpus" (*De spacio mathematico*, p. 25v; *Nova philosophia*, p. 68r).

of the intellect and completely devoid of geometrical properties: geometrical shapes are present in it only potentially. Patrizi's space, on the contrary, is an actual substrate devoid of potentiality. This means that geometrical shapes, lines, triangles and circles, are in it from the outset and are not produced by the geometer's imagination. "First space" (as he calls it) contains *in actu* all figures; the mathematician, insofar as he does anything at all, can only direct his attention to some of these figures and separate them out (*desecare*) intellectually from the rest of the continuum so as to take them as the special object of his study. But the mathematician by no means *produces* them by this operation, nor has imagination any role to play in this intellectual act of separation.[59] For the same reason, Patrizi also attacks all the ancient and Renaissance theories which defined higher-dimension geometric objects in terms of the "flow" (ῥύσις) of lower-dimension ones—such as the theories which claimed that the line is the flow of a point, that a surface is generated by the flowing of a line, or that a body is produced by the flowing of a surface: since this flowing is nothing else than a movement of imagination (or was at least so understood), and imagination can have no place in geometry.[60] In order to fully grasp the many consequences of this last doctrine, we must first of all note that Proclus's theory of productive imagination in geometry was intimately related to the constructivist interpretation which he gave of Classical geometry. On this reading (to put it briefly), mathematical existence is

[59] I believe that this is the principal thesis of *De spacio mathematico*, which articulates in better detail the claim from the *Nuova geometria* (quoted above in Footnote 1) that the object of mathematics is neither abstractive nor imaginative: "Mentem nostram finita sibi in opus sumere, quae spaciis mundanorum corporum possint accommodari. A quibus corporibus non per abstractionem, mens ea separat, ut quidam contenderunt. Quoniam ea spacia non sunt primo, & per se in mundanis corporibus. Sed sunt ante corpora, actu in primo spacio. Neque etiam in phantasia, aut dianea nostra (ut quidam alij viri admirabiles tradiderunt) veluti in subjecto, dimensiones illae & quae inde formant reliqua, subsistentiam habent. Sed mens è spacio illo primo vi sua, ea partes desecat, quae sibi sunt, vel contemplationi, vel operi, usui futura" (*De spacio mathematico*, p. 24v; *Nova philosophia*, p. 68r). We ought to note that in Patrizi's vocabulary, "*mens*" is always equivalent to "intellect". A useful contrastive example is provided by comparing Patrizi's *desecare* with *designare* in Campanella, who was, a few years later, to propose another theory of the geometry of space while at the same time readopting the productive imagination of the Neoplatonic tradition: "Basis enim intrinseca sustentans omnia corpora est spatium incorporeum, in quo mens imaginatrix seu ideatrix omnia mathematica designat" (Campanella, *Mathematica*, p. 32).

[60] It is very important not to confuse this doctrine of ῥύσις as the flowing of geometrical objects with the theory of their (rigid) motion. The two concepts, of flow and of rigid motion, had already parted ways in Classical Antiquity, and the notion of ῥύσις was commonly employed in Neoplatonic ontology, where it had also usually been characterized in terms of a movement of imagination. In the modern era, the difference is clear in the case of Jacques Peletier: although he had criticized the use of "mechanical" motion in a pure science like geometry, he had nothing to object against defining a line as the continual flow of a point. Patrizi overthrows the usual positions, and admits rigid motion (as we have seen), while rejecting the flow: "Non ergo motus attingit punctum. Si non motus, nec productio. Si non productio, nec principium lineae punctus erit. Quid ergo linea a puncto non producitur, linea non erit? Erit sanè, sed non producta. Nec erit linea punctus fluens; quod veteres aliqui autumarunt. Quid ergo linea est? Pars ea spacij quae inter duo puncta interiacet" (*De spacio mathematico*, p. 19r; *Nova philosophia*, pp. 66r–66v). It is possible, however, that at the time of the *Nova philosophia* Patrizi had already moved beyond the opinions concerning rigid motion that he had endorsed in the *Discussiones*.

equivalent to the constructibility of the geometric object. Certainly, Proclus believed himself to have captured with this principle the spirit of the actual Euclidean procedures, with their constructive postulates and the geometrical problems of construction of one or the other figure. But in fact it can be doubted whether Greek mathematics as a whole had such a constructive character. It was, in fact, an intellectual phenomenon composite and complex enough to defy simple and general characterizations.[61] At any rate, it cannot be doubted that Renaissance mathematics saw itself openly confronted with non-constructive existence problems. The clearest examples are probably those from the theory of proportions, especially the question of the existence of the fourth proportional to three given magnitudes (which may turn out not to be constructible once certain constructive rules are defined). It is an important problem, because the existence of the fourth proportional is the foundation upon which Galileo was to base his whole theory of proportions, which he in turn took to be the only instrument capable of ensuring the actual mathematizability of Nature. However, in Patrizi's time many other similar instances of simply existential geometrical axioms or theorems could be found.[62]

For these reasons, a non-constructivist epistemology in mathematics was indeed able to justify a great mass of new results and thus contribute to a real evolution of geometric practice. I believe that this is a virtually unprecedented theoretical move[63]; and although Patrizi was, as we have already noted, too inept a

[61]The thesis of the constructivism of Greek geometry was put forward by the Neo-Kantian historiography of science in the second half of the Nineteenth Century, and certainly mirrored the epistemological concerns of the Critical Philosophy. To be sure, it cannot be doubted that Kant himself was inspired, as regards his philosophy of mathematics, mainly by the Neoplatonic tradition of productive (or projective) imagination which derived from Proclus's commentary on the *Elements*. A criticism of the idea of the constructive character of Greek mathematics is expressed in the now classical essay Knorr (1983); on the epistemological motivations behind Proclus's constructivist interpretation, see Harari (2008).

[62]Galileo devoted to the theory of proportions the (posthumous) *Fifth Day* of his *Two New Sciences*. For a general overview of the significance of that theory for Seventeenth-Century mechanics, and of the role of the existential assumption of the fourth proportional, see Giusti (1993). References to other non-constructive solutions in modern geometry can be found, among others, in Bos (2001). We can note in passing that Bruno accepts as an axiom the proposition of *Elements* V, 18, in which Euclid makes use of the fourth proportional; therefore he does not need to discuss the question in general (cf. *Articuli adversos mathematicos*; *Opera*, I 3, p. 10).

[63]What I mean is that the existential assumptions which were becoming more and more common in the late Renaissance were still completely lacking an epistemology and an ontology which could support and justify them. In Clavius's commentary on the *Elements*, for instance, the Jesuit mathematician states that the existence of the fourth proportional can simply be admitted because it does not contradict the other Euclidean principles (*Euclidis*, p. 221). This statement seems to identify mathematical existence with logical consistency *tout court*, but a general theory is lacking. It must in any case be noted that Patrizi's ontology could at most justify the existence of *geometrical* entities, whereas a relevant part of Renaissance and modern disputes revolved around the applicability of the theory of proportions (and its existential requirements) to magnitudes of any kind whatsoever, such as speed or force. In this sense, Patrizi's epistemology encouraged the geometrization of space and the corporeal world, but did not yet fully deal with the question of the applicability of mathematics to dynamic Nature as a whole (that is, to the study of motion).

mathematician to grasp all its consequences, the influence of his geometrical epistemology nonetheless extended as far as Newton, or even as far as Lambert (there was indeed, it must be stressed, not just influence but a direct filiation here). Patrizi's theories, in other words, eventually reached mathematicians who could really put these theories to good use.[64] Certain doctrines found in Patrizi surely stand at the origin of a long foundational tradition in this direction. For instance, he discusses Euclid's First Postulate, according to which *it is possible to draw* a straight line from any point to any other; and he immediately reinterprets this as the claim that, given two points, the straight line connecting them *actually exists*. Here, it is clear, the point is not to establish a result stating non-constructive existence, but rather to transform the foundations of geometric axiomatics, in a direction which these axiomatics were explicitly to take only many centuries later (namely, in Hilbert).[65]

Analogously, we ought to note that the Neoplatonic material substrate, precisely because it had inherited from the Aristotelian conception of matter the character of potentiality and pure receptivity, also had the drawback of being, though quantified, only indeterminately so. Therefore, it was stated that it was *indefinite* in its extension, but not actually infinite (this being so regardless of whether it be understood as a cosmological principle or considered as the simple substrate of the

[64]For instance, compare the text by Patrizi in Footnote 59 above with this famous passage from Newton's *De gravitatione* (which sounds, as it were, like an excerpt from *De spacio mathematico*) on the actual existence of figures in space, which are *delineatae* (that is, *desecatae*), but not produced, by the geometer: "Et hinc ubique sunt omnia figurarum genera, ubique sphaerae, ubique cubi, ubique triangula, ubique lineae rectae, ubique circulares, Ellipticae, Parabolicae, ceteraeque omnes, idque omnium formarum et magnitudinum, etiamsi non ad visum delineatae. Nam materiali delineatio figurae alicujus non est istius figurae quoad spatium nova productio, sed tantum corporea representatione ejus ut jam sensibus apparet esse quae prius fuit insensibilis in spatio" (*De gravitatione*, p. 100). But also Lambert's theory of geometry as the *anatomy* of space, that is, as the discipline concerned with "cutting out" geometrical figures from the ambient space assumed as existing, is certainly a late offspring of Patrizi's spatial conception.

[65]Patrizi believes himself to have proven the existence of the straight line between any two points of space in Proposition 11 of Book III (*Nuova geometria*, p. 34); and in Propositions 23–25 of the same Book, he proves its infinite extendibility (Euclid's Second Postulate). However, even this extendibility must be simply understood as the actual infinite extension of the straight line, rather than as the capacity to be prolonged in thinking or in drawing: "Lineam enim negamus, a nostra mente, aut arte in infinitum posse produci: attamen eam quae punctis finita est, iis liberata infinitudinem sui natura, fatemur subire" (*De spacio mathematico*, p. 20r; *Nova philosophia*, p. 66v). Let me note that this idea of a line infinite in nature but constrained by its endpoints in a bounded segment is also present in Proclus (*In Euclidis* 101), and this is certainly where Patrizi derived it from; in Proclus, however, the statement had an altogether different meaning, namely, that the line's boundaries (its endpoints) determine it as a definite magnitude, and in the absence of those boundaries it is mere potentiality, that is an *indefinite* (and certainly not: actually infinite) magnitude. See also *In Euclidis* 86; and, for a plain reading of these passages of Proclus in the late Renaissance, also Biancani, *De mathematicarum natura*, pp. 5–7. The change of perspective in Patrizi is very significant, and behind the same turn of phrase there lies hidden an altogether new mathematical epistemology. It is common to contrast the existential structure of Hilbertian axioms with the constructive one of Euclidean axioms: but as we see here, Hilbert's idea has a longer and more complex history.

mathematician's imagination). Patrizi's space, by contrast, is actually infinite. Now, this once again promised to have major consequences from the geometrical standpoint, because it was becoming clearer and clearer that a potentially infinite extension may fall short of providing a foundation for the principles and procedures of modern mathematics. It is true that Patrizi did certainly not grasp this point with full clarity, and that extensive discussions on the infinite in mathematics were to begin only in the second half of the Seventeenth Century. However, it is equally certain that with his theory Patrizi provided an ontology which was very well able to suit those more innovative infinitist mathematicians (such as Newton) who could not rest content with *dimensiones indeterminatae* (nor with their late developments, such as Descartes's *res extensa indefinita*) for their geometric and analytical investigations.

Patrizi, moreover, is not of the opinion that the Euclidean postulates, once transformed from constructive rules into existential propositions, should continue to serve as principles or axioms. Rather, he devises a (poorly executed) proof of some of them from the definitions of a point and a straight line. At this point it becomes clear, in a more general way, that the aforementioned "logicist" framework of Patrizi's *Nuova geometria* also derives from the adoption of space, rather than quantified matter, as the foundation of this science. Indeed, the system of Patrizi's principles can be reduced to a list of definitions which single out the various entities actually present in space; the existence of these entities (straight lines, circles, and so on) is simply entailed by the existence of space; and space is the subject of a metaphysical (no longer a mathematical) proof. Patrizi's geometry ultimately rests upon the metaphysical discussion of the nature of space. Its lack of further principles, apart from the definitions and from the sole existential assumption of space in general, can be explained precisely by his direct rejection of constructivism.[66]

[66]The complete system of principles of the *Nuova geometria* is actually slightly more complex than we have indicated. Patrizi lists five *Supposizioni*, eight *Diffinizioni*, and six *Axioms*. The suppositions, he says, have been proven in *De spacio mathematico*, and state that geometry is the science of space, that space is a quantitative extension with minima and maxima, and that it has three dimensions. The definitions, upon which the whole actual deductive procedure of the book rests, characterize the minimal, median and maximal space, then the point, the line, the surface, the (solid) body and the angle. In the course of his proofs, then, Patrizi assumes a few other definitions, such as that of parallel lines or that of a triangle, but he does not seem to regard them as genuine principles. The reason for this seems to be that he introduces these definitions only after having proven the existence of their object: that is, Patrizi first proves, for instance, that there can be three straight lines enclosing a two-dimensional space (*Nuova geometria*, Book XV, Propositions 1–7, pp. 211–216), and then calls this space a "triangle". On the other hand, the existence of minima and maxima, points, lines and surfaces, solids and angles, is never proven, but is rather assumed along with the existence of space and as a consequence of the metaphysical reflections on it (namely, those *Supposizioni* that characterized it as three-dimensional, and allowed for the existence of minima as shown in the *De spacio mathematico*). Patrizi's axioms, in turn, are nothing else than a version of Euclid's common notions, usually phrased in the form of other definitions (for instance: "Tutto, è quello che ha parti"), and concern general mereological and quantitative, but not strictly geometrical, concepts. They find actual application in the course of Patrizi's proofs, not unlike proper definitions. The system of Patrizi's geometrical principles thus ultimately comes down to the definitions of a few elementary objects (geometrical, as well as mereological or set-theoretical) and the assumption of their existence, while no operation on these objects is actually defined—as we could expect from a theory of demonstration incapable of dealing with a logic of relations. On science as the "*diffinizione dell'essenza*", also see the *Nuova geometria*, p. 1.

This very same epistemological position justifies the fact that in the course of its deductive march through the main results of the First Book of the *Elements* Patrizi's *Nuova geometria* devotes no attention to the many construction *problems* studied by Euclid, and that the whole discipline ultimately comes down to a collection of theorematic propositions. In the same way, the absence of constructions justifies to some extent the lack of diagrams in the proofs of the theorems. The rejection of imagination in mathematics has the immediate consequence that geometry, as the science of space, must certainly be understood as a purely intellectual discipline. To this extent, it must ultimately be reduced to a system of logical inferences essentially resistant to the intervention of that intuitive moment which is characteristic of diagrammatic demonstration.[67]

It is important to underline the novelty of this purely logical approach to geometry. It is very well known, in fact, that one of the most interesting consequences of the *quaestio de certitudine mathematicarum* in the mid-Sixteenth Century was precisely the appearance of the first treatises in elementary geometry, devised to constrain the Euclidean reasonings *in forma*, and thus to make sure that mathematical demonstration fell within the jurisdiction of classical logic.[68] These attempts at formalization, however, restricted the concept of demonstration to that particular stage of geometric proof which Proclus had called ἀπόδειξις proper, which follows the auxiliary constructions with compass and straightedge.[69] This entailed that a vast number of inferences (which the modern logicians and geometers, such as Hilbert, intended to formalize) were left to informal evidence and could be implicitly concluded on the basis of the actual configuration of the diagram. In this way, the theorematic proof still assigned an important function to intuition (or imagination), and to this extent it is no surprise that these Sixteenth-Century

[67]The definition of geometry as a purely intellectual science was, of course, very widespread in the Renaissance, and had originated in Plato (but had then been accepted by Aristotle, the Neoplatonists, and in the end by virtually everyone). The idea that geometrical axioms could be proven on the basis of definitions was a rather widely-held idea too. The novelty of Patrizi's approach consists therefore simply in the radicalization of this assumption, to the point of resolving the whole discipline into a chain of a priori reasoning free from any recourse to intuition.

[68]The principal result of this logical attitude towards geometry were the *Analyseis geometricae* by Herlinus and Dasypodius, published in 1566, which attempted a reduction of the first six Books of the *Elements* to syllogistic demonstrations. The underlying logic of the *Analyseis* also comprised other types of logical inference, including, of course, propositional logic and some principles on equality which, together with the usual diagrammatic inferences of classical mathematics, could lend to their endeavour at least a hope of success. There is no evidence, I believe, that Patrizi knew this work, and perhaps, if he had known it, he would have mentioned it; at any rate, it rested upon a Neoplatonic philosophy of mathematics (with a theory of magnitudes completely independent of space, and an extensive use of productive imagination) which Patrizi could not approve of. Herlinus's and Dasypodius's attempt, however, enjoyed wide resonance, and is deemed perfectly valid by Clavius (whose edition of the *Elements* enjoyed an enormous diffusion) and many other mathematicians after him (including Wolff, almost two centuries later).

[69]The division of the proof of a geometrical statement into six parts is given by Proclus, *In Euclidis* 203, and soon became the common property of mathematical epistemology.

mathematicians did succeed (for better or worse) in constraining and lacing the deductive richness of classical geometry into the Spanish boots of syllogism.

However, Patrizi insists on dispensing even with the important logical crutch of diagrammatic inference—an attempt which, I think, no one else made before the Nineteenth Century, with the exception of Leibniz. There are, to be sure, very good reasons for this. Leibniz himself, for all the efforts he devoted to the attempt at erecting a new logic of relations that could go beyond the syllogism, was far, in fact, from really already possessing the logical apparatus that his grand project of the formalization of geometry would have required[70]; Patrizi, who had no inkling of that new logic, and did not even exhaust in his book the entire resources of syllogistic logic or monadic quantification, and who merely resorted to some applications of propositional logic, was far from being in a position to prove rigorously even one single theorem of his new geometry, which in most cases remained little more than a childish exercise of empty formalization.[71]

It is difficult, then, not to share Leibniz's opinion about the *Nuova geometria*: namely, that it started with excellent premises but followed these up with a mathematical development that was simply "pitiful".[72] However, the book did lucidly indicate a direction for research and, as it were, a logical project—and this was no

[70]Leibniz struggled all his life to devise an adequate formalization of elementary geometry, for which he also designed peculiar symbols and appropriate logical axioms; this project went by the general name of *characteristica geometrica*. The ultimate aim of Leibniz's analyses, however, also came down to proving all of geometry by means of simple logic, starting from a general definition of space (which was very different from Patrizi's), while space itself was (as in Patrizi) assumed to exist on the basis of metaphysical arguments.

[71]Patrizi's deductive procedures are in fact completely inane, and one could criticize them in the same terms as those adopted in Lambert's later attack on Wolff's (similar) geometry, and say that it is *superdefinitory* and consists in nothing else than proceeding from names to other names, without ever coming into real contact with the concept. For instance, at the beginning of the First Book of the *Nuova geometria* Patrizi proves that, since the point is a minimum (according to his definition), it is also simple; and since it is simple, it is also indivisible; and since it is indivisible, it is not a whole; hence it has no parts; therefore it is not partible; hence it is not divisible; and in conclusion it has no quantity. Each of these passages consists of one or two theorems, which merely swap synonymous terms with each other, and it is very difficult to understand what their real advantage could be. The style of the demonstration is something of this sort: "Il punto, perché è semplice, è anche indivisibile. Dimostrazione: Perché se il punto non fosse indivisibile, sarebbe divisibile ne' suoi componenti; e perciò saria composto, e non semplice. Ma dimostrato s'sè, per la precedente, che il punto è semplice. Adunque il punto, perché è semplice, è anche indivisibile" (*Nuova geometria*, p. 5).

[72]Here the Leibnizian quote: "Je ne me souviens pas maintenant d'avoir veu un philosophe demonstrateur du siecle passé, si ce n'est que Tartaglia a fait quelque chose sur le mouvement, et Cardan parlant des proportions, et Franciscus Patritius, qui estoit un homme de belles veues, mais qui manquoit de lumieres necessaires pour les poursuivre. Il voulut redresser les façons de demonstrer des Geometres, il avoit veu en effect qu'il leur manque quelque chose, et il voulut faire autant dans la Metaphysique, mais les forces lui manquerent; la preface est admirable de sa Nouvelle Geometrie dediée au Duc de Ferrare, mais le dedans fait pitié" (*Projet et essais pour avancer l'art d'inventer*, in A VI, 4, n. 205, p. 966).

small merit for a work produced in the volcanic intellectual atmosphere of an era whose intellectual ferment was about to boil over into the Scientific Revolution.

3.5 The Geometry of Space

If we now choose to move from the purely logical or epistemological level to an evaluation of Patrizi's geometry proper, one last aspect, possibly the most important, remains to be considered: namely, the transformation of geometry from the science of quantified matter into the science of space. For practically the first time in history, geometry begins to deal with genuinely local and positional concepts. Greek geometry, to be sure, had, in some of its stages, theorized the use of certain notions which pointed to the localization and reciprocal situation of geometrical elements in a given configuration; for instance, Euclid's *Data* explicitly discussed the notion of θέσις (*positio*), and on some occasions short remarks were made about the order (τάξις) of the geometrical elements involved in a demonstration. These were, however, very marginal discussions, from which, it seems, very few further developments in Classical Greek geometry ensued and which disappeared almost completely in the later history of the discipline. Geometry became, quite rapidly, a *science of magnitudes*, the primary (though not the sole) concern of which was focused on the theory of measurement (of lengths, areas and volumes), and thus on problems of congruence.[73] The Aristotelian definition of geometry as a discipline concerned with continuous quantity, therefore, appropriately expresses the dominant tendency of Greek and Renaissance mathematics (a tendency still present in the Modern Age). However, if we identify *space* as the object of geometrical investigation, it is evident that the scope of this science immediately widens to all those local determinations of order and position which had been neglected for centuries.

This is a transformation of the greatest possible importance for modern geometry, which was, in the end, to lead to the birth of a geometry of position and a

[73]In most cases, moreover, the positional concepts did not become a stable part of the *definitions* of the geometrical objects of Classical Greek mathematics; as a consequence, although in Euclid's *Data*, for instance, a geometrical point can be "given in position" (Def. 4: τῇ θέσει δεδόσθαι λέγονται σημεῖα…), it is not defined in terms of this latter, and it is only a non-spatial object to which we later ascribe a certain position in a given configuration. There was, certainly, a genuine definition of point as a unity endowed with position, μονὰς θέσιν ἔχουσα, which Aristotle attributes to the Pythagoreans (*De an.* A 4, 409^{a}5–7; *Metaph.* Δ 6, 1016^{b}24–29; also cf. *An. post.* A 27, 87^{a}35–37, *Metaph.* M 8, 1084^{b}26–27). This definition was discussed throughout antiquity, but the addition of the point's positional character must have soon begun to appear as a philosophical whim devoid of mathematical significance, since no relevant consequence followed from it. Therefore Proclus (*In Euclidis*, 95–96) believed the Euclidean definition which makes no reference to θέσις to be perfectly correct. I think that this was also the usual attitude in the Renaissance, when geometers often stated the Pythagorean (or Aristotelian) definition for the sake of completeness, but then made no use of it.

projective geometry in the course of the following centuries, and later still to topology and to even more abstract disciplines. The general idea, at any rate, is that of freeing geometry from concerns of measurement, and establishing it as a science of *relations* and *structures*, removing it from the domain of quantity to connect it with logic or abstract algebra instead. This marks the most momentous revolution in the history of geometry and, so to speak, the great divide between ancient and modern geometry.

In Patrizi's time, there were many and various forces and factors that were prompting geometers to adopt positional and relational concepts within their science. The most evident and widespread example of this tendency is probably the enormous development of the geometric theory of perspective in the Sixteenth Century. This theory was gradually undergoing a transformation from a device which helped artists tackle their practical problems into an autonomous theoretical science, and it explicitly recognized a non-metric domain of mathematical inquiry. In the following century, the works of Desargues and Pascal on projections represented a fundamental step towards the elaboration of a science of spatial relations (partially) independent of the theory of measure; and later still, Leibniz's *analysis situs* (which depended on these developments in perspective theory) aspired to establish itself as a genuine geometry of space precisely because it understood space as a system of situational relations.[74] Another direction leading to a non-metric treatment of geometry was that marked by the earliest developments of combinatorial geometry, which however would only reap its first results much later (in Euler, for instance; but, once again, already in Leibniz).[75]

It is, indeed, hard to clearly recognize these developments as prefigured in Patrizi's *Nuova geometria*. His concept of space, as we have seen, remains undoubtedly anchored to the notion of quantity. Therefore Patrizi's geometry is still a simple science of magnitudes; that is to say, it differs from the Classical Greek theory only by the name of its object. Nor was Patrizi's mathematical vision sharp enough to enable him to innovate geometry from within in such a radical manner; nor does he appear to be aware of the advances which were occurring in the field of perspective in the same years. The birth of a genuinely positional geometry, in other words, was to take place precisely through the gradual transformation of the concept of space from one of merely quantitative extension (as it

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[74]On Leibniz's *analysis situs* as a geometry of space, see De Risi (2007). On the development of a geometry of space from the Renaissance writings on perspective, see De Risi (2012a).

[75]A significant part of Leibniz's studies on the *characteristica geometrica* were in fact aimed at producing a combinatorial theory of the dispositions of points or lines; this is the main reason why some historians believed (a bit too generously, however) that they recognized in that Leibnizian theory the origin of topology—the same that was said of Euler's later theorems on polyhedra. We can note that Patrizi explicitly includes the combinatorial art in the number of the mathematical disciplines in *De spacio mathematico* (p. 26r = *Nova philosophia*, p. 68r), and that he seems to resort to arguments of this sort to justify the three-dimensionality of space (*De spacio mathematico*, p. 19v; *Nova philosophia*, p. 66v). In the latter case, these were probably Pythagorean arguments (briefly discussed by Aristotle); Leibniz himself discussed them at length in his own theory of dimensions (see again De Risi 2007).

is in Patrizi) to that of a relational structure, but would certainly never have been accomplished, had geometry persisted to operate with the old concept of quantified matter. Patrizi had made the very first step in this direction.

Moreover, though Patrizi always connects his concept of space with mere extension and continuous quantity, he is fully aware that space is also *place* and in fact possesses a *vis locandi*. Therefore Patrizi complements the quantitative properties of space with certain genuinely positional attributes. Thus, for instance, he emphatically insists that the geometrical *point*, which Euclid simply defined as that which has no parts, should rather be defined by the positive feature of situability, that is, of position in space. Patrizi will have surely noted in this definition a certain Pythagorean descent (a fact about which he must have been flattered), but he was well aware that it was a very novel use of the notion of *situation*, since his concept of space is itself very novel. He adds that no one among the ancients ever arrived at the idea of a *science of the point*, since this latter seemed to the Classical Age geometers to be just the purely negative concept of magnitude—that is to say, to be the "non-extended" by definition (and in Patrizi it similarly signifies a *minimum* of extension). However, the point's inclusion in space offers a positive, *not quantitative but rather local* determination of the point in question, which in turn makes it possible to prove theorems about said point and about its positional relations to other points and figures in space.[76]

To be sure, these are very humble beginnings, and Patrizi was unable actually to bring this geometry of position (or points) to any completion. However, the later developments towards a structural, rather than metric, geometry, all passed through this definition of the point as a *purely situational element*, which is already clearly stated in the *Nuova geometria*, and which was later to become a

[76]Patrizi defines the point as the minimum *in space* (*Nuova geometria*, p. 3), and then characterizes it on the basis of the local predicates which derive from that definition: "il punto, perché è nello spazio, ha sito. Il punto, perché sito hà, ha anche posizione, o positura nello spazio. Il punto, poiché positura ha, havrà anche riguardo ad altri uno, o più, e punti, e linee, e angoli, e superficie, e corpi, che nello spazio sono" (*Nuova geometria*, pp. 14–15). From these premises, Patrizi develops the whole theory of Book One, which is the science of the point which the "ancients" lacked (p. 16). It does not seem to me that any of the Classical authors actually claimed that there cannot be a science of the point, although this certainly followed from the definition of geometry as the science of magnitudes (since the point is not a magnitude); but the thesis was in fact maintained in the Middle Ages, and we find it, for instance, in a manuscript of *quaestiones* on mathematics, which states that "de puncto nulla passio probatur in tota geometria" (see Dell'anna 1992, p. 132; cf. pp. 141–49). The idea of the point's not being an object of science will have been transmitted to Renaissance Aristotelianism in this form. From a lexical standpoint, we can also note that θέσις did not necessarily have a local connotation and Aristotle claims, for instance, that mathematical objects can have θέσις without being in a τόπος. This mathematical θέσις was generally translated as *positio*. On the other hand, the term *situs* often had a geographical or cosmographical import, and was related to the regions of space (to indicate the different climatic zones of the world, and therefore sometimes even the customs of the peoples inhabiting them); the same was still to be true of Campanella, although he, for his part, was open to the notion of a geometry of position. Patrizi's terminological choice may therefore mirror the intent of distinguishing his own geometry of space from the simple geometry of position which had been conceived (and soon abandoned) in antiquity.

battle cry for Pascal and Leibniz.[77] It must also be borne in mind that Patrizi, as we have mentioned, espoused a theory of minima according to which spatial extension is not infinitely divisible, i.e. a theory in which the existence of indivisible lines must be admitted. By what means Patrizi intended to compose the continuum on the basis of minimal points and indivisible lines remains utterly obscure, and it can be doubted whether he would ever in fact have proven able to find the exit from the *labyrinthus de compositione continui* which he had imprudently entered. However, from the few remarks he develops, it seems that he hoped to find the way out precisely through the concept of situation, that is, through the different spatial configurations that the indivisible elements can assume.[78] I believe that the earliest mathematically informed developments in this direction (which was very promising, since it ultimately understood extension as a simple system of positional relations) are not to be found before Leibniz,[79] and that this very solution was made unavailable to Patrizi, firstly by his uncertainties in the field of geometry, and secondly by his metaphysical certainties as regards the originally

[77]The definition of the point in terms of situation became more and more usual during the Seventeenth Century, and precisely in those authors who were most engaged in the edification of a geometry of space. To mention a few, this is present in Campanella: "Punctum est unitas situalis, cuius ergo nulla est pars" (*Mathematica*, p. 37); then in Pascal: "Les points ne diffèrent que de situation" (*Introduction à la géométrie*, p. 87); and finally in Leibniz: "*Punctum est cujus pars nulla est*. Addendum est, situm habens. Alioqui et temporis instans, et Anima punctum foret" (*In Euclidis* πρῶτα, in GM V, p. 183), who also adds (just as Patrizi before him) that: "Ea est natura situs, ut omnia quae habent situm, habeant etiam situm inter se" (*Prima Geometriae Principia*, C 541).

[78]Book Three of the *Nuova geometria* is entirely devoted to the theory of lines, and in particular of indivisible lines. Patrizi tries to show there that it is possible that the reciprocal situation of two points may be such that their distance is the smallest of all, and that, posited in this way, they enclose a minimal space, which is an indivisible straight line. This is certainly one of the cases in which the work's deductive form lends an appearance of rigour to common-sense lines of reasoning (chiefly in Proposition 3, which proves that two points can enclose a minimal space simply because they can also enclose a medium or a maximal space), which then turn out to be fatal to the mathematical procedures. It is true, however, that the existence of indivisible lines, which taken all together constitute the continuum, should be founded on the situational relations of points. Since, however, the *Nuova geometria* confines its treatment to linear magnitudes, we do not know how Patrizi would have dealt with plane or solid minima (the existence of which he affirms in *De spacio mathematico*, p. 24r; *Nova philosophia*, p. 67v), nor how indivisible lines are supposed to constitute a tridimensional space. However, if we assume that he was simply following the Platonic tradition of the *De lineis insecabilibus*, the answer could be that he would have then theorized minimal triangles, and perhaps even the Platonic solids of the *Timaeus*, which consist of those triangles. If this were the solution, tridimensional extension would also arise from the combinatorics of situational relations between elementary objects.

[79]Leibniz's conception of space as the *order of situations*, that is, as a relational structure, was completely lacking in Patrizi. The fundamental idea of Leibnizian geometry is that of constructing the extension and quantity of space not as its principal attribute (as in Patrizi), but as a property which can be deduced from the set of situational relations. In this way, Leibniz could count on a pure concept of spatiality, whereas Patrizi was still employing a hybrid of the quantitative definition of space and the local properties which are attributed to it *subsequently* by virtue of its also being place (in the Classical sense). On the construction of extension on the basis of situational relations in Leibniz, see De Risi (2007).

extended nature of space. However, he certainly perceived the connection between positional concepts and the theory of minima which was to continue to escape so many authors well on into the Seventeenth Century.

Some further developments of a situational mathematics can be found in Patrizi's theory of the straight line, since he tries to characterize this thorny concept of elementary geometry (which seemed to defy any exact definition) by way of a series of properties qualifying the reciprocal position of its parts. In this way, he is able to avoid any recourse to the Archimedean *metric* theory, which simply characterizes the straight line as the shortest line between two points. In this case as well, several developments of the idea can be recognized in the more mature Seventeenth- and Eighteenth-Century foundational attempts, which definitely move in the same direction—that is, at a time when the idea of a geometry of space had already fully imposed itself.[80]

In other cases, our expectations are not met even on the simple level of a concept's definition and basic properties. For instance, the notion of parallelism, which was to play such a major role in the later elaboration of the (Euclidean and non-Euclidean) geometry of space, could be characterized precisely on the basis of certain intersection properties which are highly suitable for a positional and situational analysis. Euclid himself had made the first steps in this direction, but parallel lines had later been redefined as *equidistant* lines, in acknowledgment of the theory of

[80]The modern age's various attempts at defining the straight line represent one of the major foundational efforts in the history of geometry. Its definition as the shortest line between two points was widely accepted, but everyone would have preferred to simply take it as a characterization or a property of that line, and define the latter on the basis of formal and figural, rather than metric, properties (as Archimedes himself would most probably have understood this topic). Patrizi devotes the whole of Book Four of the *Nuova geometria* to the definition and characterizations of a straight line, and makes, in fact, some progress in this direction because he can count on positional relations. Thus, he tries to define the straight line through its situation in space (as a line that does not determine a plane or the whole space, but only, as we would say today, a one-dimensional subspace), and tries to deduce from this that it is the shortest (Proposition 1), that it lies evenly with the points on itself (the very obscure Euclidean definition; Proposition 2), and, most importantly, that it is *similar* to itself in all its parts (Proposition 8), that it is *uniform* (Proposition 11), and that any one of its parts is congruent with any other (Proposition 21). All these characterizations, in fact, were to be found once again in Leibniz's situational geometry, which was to take pains to define the straight line as an axis of rotation (that is, by way of its situation in the ambient space), as *linea brevissima*, as *linea sibi similis*, as uniform line, and finally as *self-congruent* line. The comparison of Leibniz's studies with Patrizi's certainly shows the wide abyss dividing the mathematician from the philosopher daring to take his first steps in a field foreign to him; and it makes clear how Patrizi's characterizations remain, for the most part, simply nominal (since he, for instance, never defines what similarity or uniformity are, and therefore moves from one definition to the other on a merely intuitive basis). However, it is still remarkable that the simple transition from a geometry of magnitudes to a geometry of space and situation can carry with it a whole world of new definitions and characterizations of the straight line (as well as of other geometrical objects) which can be found in the same terms, at least nominally, in these two authors. On the Leibnizian theory of the straight line see De Risi (2007, pp. 226–264); there is no trace, however, of a *direct* influence of the *Nuova geometria* on the development of Leibniz's *analysis situs*.

geometry as a science of measure. This was, however, definition which was completely inadequate from the foundational standpoint, and enormously compromised the development of a theory of space as structure. Now, Patrizi did not realize that a pure theory of intersection is possible precisely on the basis of the concept of situation, and simply persevered with the metric definition common in the Renaissance, which moreover deceived him into believing that he had proven, analytically (i.e. one paralogism after another), the famous Parallel Postulate.[81]

Patrizi's demonstrations do not extend far beyond his poorly-developed theory of parallel lines, and only sketch out a few initial theorems regarding triangles. I do not think that they contain any other significant idea, and in fact as we proceed further from the first definitions, Patrizi's logical method of proof, so patently faulty, shows more and more clearly its flaws. The further developments, had Patrizi tackled them, would have confronted him with even greater difficulties.[82]

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[81]The theory of the reciprocal situation of straight lines in the plane, and thus of parallelism, takes up the greatest part of the *Nuova geometria* (Books VI through XIV), and represents in fact a rather admirable attempt at a (non-metric) geometry of intersection. Precisely the definition of the parallels as equidistant straight lines at the beginning of Book VI (p. 82), however, perturbs the overall construction, and, in substance, assumes surreptitiously what would have to be proven in a demonstration of the Parallel Postulate (which eventually closes Book XIV). Patrizi's mathematical incompetence is most clear from Book VII, however, in which the usual logical procedure *in forma* once again conceals simple common-sense arguments which should not be admitted in geometry. Thus, the most delicate question in the whole parallel theory is whether two straight lines that approach each other must eventually meet, or whether there can be (as in hyperbolic geometry) asymptotic straight lines; a problem which, in fact, had been already formulated in Classical antiquity, and is attested to in Proclus (*In Euclidis* 192; 364–365). Patrizi does not appear to see the difficulty, and thus in Proposition 11 of Book VII, after having proven that certain pairs of straight lines approach each other more and more, he concludes simply that they meet, with an argument of this kind: "Perché se piu anche allungandosi, non concorressero finalmente, non sempre più s'appresserebbono. Ma per la precedente dimostrato si è, che allungandosi sempre piu s'appressano. Adunque due o piu rette linee inclinate, perche dalla parte ove meno distano allungandosi, sempre piu s'appreßano, finalmente concorreranno" (p. 98). Here we can only note, in partial defense of Patrizi's naiveté, that the possibility of asymptotic curves was still a matter of debate in the Renaissance, and was considered an "admirable" difficulty; by the time of the *Nuova geometria* it had been discussed by several authors, such as Peletier and Finé in France, and also in a very well-known booklet by Francesco Barozzi (whose contribution to Sixteenth-Century Platonic philosophy of mathematics is so remarkable), published in the same year 1586. Bruno was another author who denied the possibility of asymptotic curves, in the *De minimo*; on this point see Maierù (2012). Moreover, we must bear in mind that the general debate on the theory of parallels in the Renaissance starts, in substance, with the second edition of Clavius's commentary on the *Elements*, in which the great German mathematician extensively discusses the fallacious attempt at a demonstration of the Parallel Postulate, exposing to the eye all the usual paralogisms (including that of asymptotic straight lines); this second edition of Clavius's *Euclidis* was first to appear in 1589, and thus follows the *Nuova geometria* by two or three years.

[82]We have already mentioned the fact that Patrizi deemed it necessary to discuss the geometry of curves in the sequel to this work, which, in the end, did not actually write. It is not immediately clear how his doctrine of minimal (but extended) straight lines would have fitted together with a theory of curves, and it seems that Patrizi would have had to change something in the general structure of his new geometry to accommodate this latter.

Thus, Patrizi's geometry stood principally as a monument to futility; but it also indicated the way towards an actual reform of the discipline. It helped spread the ambition of establishing a perfectly formal mathematical science which would be able to dispense with any recourse to intuition. Furthermore, it allowed there to become visible the possibility of a geometrical investigation freed from the chains of the quantitative analysis of magnitudes and open to the consideration of position, order and structure. But most of all, it pointed the way towards a *geometry of space*, and was able to support this intuition with a new epistemology of mathematical thought and with a new ontology of physical space.

If, then, we admit that Patrizi was the first to explore this path, I think that we definitely ought also to acknowledge that he deserves an important place in the history of geometry, or at least in that of geometrical epistemology. It is still very difficult to establish whether his theories had fruitful consequences in the course of the later development of the discipline, or if the discipline attained maturity apart from Patrizi and by following paths very distant from those which he had himself pursued. Tommaso Campanella proposed a philosophy of space and a geometrical epistemology which have many features in common with Patrizi's, but which also diverge on many points and it is not immediately clear whether he really knew and appreciated the mathematical works of his predecessor; nor was he a much better geometer than Patrizi, nor a figure capable of better publicizing the promises of the possible fruits of a geometry of space.[83]

Indeed, the *Nuova geometria* does not seem to have enjoyed a wide reception; the book's print run must have been rather small (only a few copies have survived to this day) and the choice of the Italian language will not have helped its diffusion; moreover, the mathematical errors were so patent that a mathematician would probably soon have shut the book in disapproving disdain. Its Latin reworking in the *Nova philosophia*, by contrast, was in a better position to be read and appreciated. The substantial cuts were probably beneficial, as they eliminated so many poor demonstrations while preserving the fundamental methodological assumptions.

The reception of the *Nova philosophia*, in turn, is hard to evaluate, primarily because of its inclusion in the Index, which made it difficult, if not to obtain a copy of the work, then at least to refer to it explicitly. However, it seems that it was very widely read and much discussed, and that it enjoyed a wide circulation in spite of the prohibition. As late as 1640, in a cultural climate very different from that of Patrizi's own age (and in which, indeed, the new conceptions of space were widely gaining ground), the volume was reprinted in the guise of an anonymous treatise titled *Naturalis magia*, and certainly circulated further in this form.[84] In any case, Patrizi's theses were disseminated in Germany as early as 1593, thanks to Jessenius's *Zoroaster*, which probably influenced (among others) Daniel

[83] Campanella's main views on space and mathematics are to be found in his *Metaphysics*, published in 1638; but his essay on *Mathematica*, where he puts them to a concrete use in actual geometry (not unlike Patrizi's *Nuova geometria*) remained unpublished until a few years ago.

[84] On this clandestine edition of the *Nova philosophia*, see Zambelli (1967).

Sennert's important *Hypomnemata physica* (1636).[85] In France, his positions gained ground principally through the writings of Gassendi, who certainly makes a wide use of them (though without ever mentioning Patrizi) in the exposition of his theory of space, so similar to Patrizi's, in the *Syntagma philosophicum* from 1649.[86] Gassendi was also able to use these doctrines to attack the Cartesian metaphysics of extended substance, which represented the very antipodes of Patrizi's conception of space (and was in this respect closer to the Renaissance Aristotelianism of the Second Scholastic); on the other hand, Mersenne made the effort to mount a complete refutation of Patrizi's doctrines.[87] Most of all, however, Patrizi's metaphysics later gained currency in Great Britain, and Gilbert, Bacon, Fludd, Digby, and Harriot and Warner, were acquainted with him while Hobbes appreciated him highly; his good fortune, however, was chiefly due to the large numbers of English Neoplatonists who embraced his spatial theories enthusiastically: Herbert of Cherbury, Joseph Glanvill, and certainly Henry More.[88]

Nonetheless, although many of these authors accepted, or reworked, or rewrote the theories of *De spacio physico & mathematico*, only a few of them were persuaded of the necessity of a corresponding revision of the object of geometry. They were metaphysicians rather than mathematicians, and in any case conservative epistemologists who found ways of merely supplementing and complementing the

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[85]On Patrizi's influence on Sennert, and on Jessenius's book and its diffusion in German universities, see Zanier (2007).

[86]Gassendi's views on space are exhaustively expounded in the *Physica*, I, II, 1 and 6 (*Syntagma*, pp. 179–184 and 216–220; the intermediate chapters are devoted to the void). Here we can find the by now usual assertions that space is neither substance nor accident, that it is a three-dimensional and infinite quantitative extension which precedes bodies and can be empty, and the like. On the reception of Patrizi in Gassendi see Muccillo (2010); on Gassendi's spatial theory and its fortunes in the Seventeenth Century (and thus on Patrizi's indirect legacy in that century), see Lennon (1993). Moreover, Deitz (1997) also mentions a volume by L. Crasso, *Elogii d'huomini letterati* (1666), reprinted in French in 1715, that mentions Patrizi as a forerunner of both Descartes's and Gassendi's notions of extension.

[87]In his *Quaestiones celeberrimae in Genesim*, cc. 739–741; here Mersenne does not discuss space, however, but chiefly Patrizi's theory of light, which he intends to criticize (but Mersenne maintained a certain consideration for Patrizi's theories, and will recommend his works in the 1648 *Optique*).

[88]On the English reception of Patrizi, see Henry (1979). On the other hand, Henry (1982) points out that two copies of the *Nuova geometria* were in Henry Percy's library, and it is thus very likely that the work was known by Harriot and the circle of the Wizard Earl; on Patrizi's influence on Warner in particular, see Prins (1994). Henry More discusses the metaphysics of space in the *Enchiridium metaphysicum* of 1667; but he had also addressed the question in his *The immortality of the soul* (1659) which was certainly known to Newton, and especially in his correspondence with Descartes, which was published in 1655 but had enjoyed a certain manuscript circulation in earlier years (we know that Newton had already read it in 1654). Hobbes's conceptions seem rather different from Patrizi's, but see at any rate Schuhmann (1986). It is remarkable, however, that Hobbes possessed a copy of the *Nuova geometria* (that is, not only of Patrizi's treatises on spatial metaphysics). Note also that Berkeley still knows and quotes Patrizi with some admiration.

old opinions on the geometry of magnitudes and quantified matter with a new theory of space. Newton's mentor, Isaac Barrow, certainly held modern positions about space, but in geometry he remained a classical Neoplatonist.[89] On the other hand, Newton himself, who had studied all these English authors, especially More, and then Gassendi and scores of other readers of Patrizi, never once doubted that geometry is performed in space. Already his early writings betray a mathematical epistemology clearly Patrizian in spirit. Newton's extraordinary fame was certainly instrumental in the definitive acceptance of the geometry of space by mathematicians and philosophers.

In the same years, moreover, Leibniz was developing a different theory of space and of geometry, but certainly agreed that the two needed to proceed hand in hand. It is not easy to ascertain the influence of Patrizi's *Nuova geometria* on Leibniz's attempts to develop an *analysis situs*. We do know that Leibniz read, admired—but also in certain respects scorned—Patrizi's book; that he shared with him some epistemological views about mathematics; and that many geometrical concepts and definitions appear in almost identical forms in both works. We don't know, however, when exactly Leibniz read the *Nuova geometria* and whether he was actually influenced by it in the making of his own (far superior) geometry of space.[90]

Thus, although there still were some Cartesians who protested that only a *res extensa* can be mathematized, the Eighteenth Century began with a debate concerning which concept of space was the correct one, and thus which concept of geometry the right one. By this time nobody could any longer be in doubt that this latter science was indeed the science of space. Thus Patrizi's elaborate and brave metaphysical theory of space and place, which had played such a major role in the renewal and reconstruction of natural philosophy, began to seem to some to be almost as obsolete as the old Aristotelian doctrine against which Patrizi had fought. The idea of his geometry, however, (if not its execution) continued for a long time to appear as an idea in the bloom of youth and pregnant with the highest hopes.

[89]On Barrow's theories on space, see Lecture Ten in his *Lectiones mathematicae*, where however he repeats that space is not in itself quantity (and only acquires quantity through the bodies existing in it), so that geometry remains a science of magnitudes rather than of space.

[90]On Leibniz' opinion about the *Nuova geometria* see above Footnote 72. It is to be noted, however, that this is a text from 1688 to 1690, when Leibniz was already quite advanced in his own geometrical endeavors, and that there is not to be found any previous reference to Patrizi's geometry among his papers. We should also note that Leibniz was rather critical of Patrizi's metaphysics as well, as he considered himself to be a good Platonist and regarded this Late Renaissance Neoplatonism as a corruption of Plato's original philosophy: "Itaque saepe miratus sum nondum extitisse quendam qui systema philosophiae Platonicae sanioris daret, nam Franciscus Patritius, non contemnendi vir ingenii Pseudo-Platonicorum lectione animum praecorruperat" (*Ad constitutionem scientiae generalis*, in A VI, 4, n. 114, p. 479).

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Chapter 4
The Inception of the Concept of Infinite Physical Space in the Time of Copernicus and Giordano Bruno

Jean Seidengart

Abstract I propose an analysis of one of the principal steps in the formation of the concept of cosmic space at the very beginning of classical science. Following the Copernican reversal, the apparent movement of the sky became pure illusion, while even the existence of the sphere of fixed stars lost its self-evident character. From there, the ancient argument in favor of the finitude of the universe (according to which it is impossible that an infinite thing turn) lost all credibility and the question of whether the universe was infinite came to be asked anew. The infinitization of the universe achieved by Giordano Bruno made necessary a reworking of the concept of cosmic space. Thanks to his new conception of infinite, cosmic space (profoundly inspired by John Philoponus and Francesco Patrizi), Bruno was pleased to have escaped from the traditional difficulties of finitude. Paradoxically, it is this new concept of cosmic space that comes to counterbalance the dominant peripatetic cosmology. It constitutes a philosophical transition between perceptive space (qualified, heterogeneous, discontinuous, limited) and the space of classical science (homogenous, infinite, continuous) that would later be developed by Gassendi, Morus, Charleton and Newton.

4.1 Copernican Heliocentrism Partakes in a Cosmic Space Which Is Both *Immense* and *Immobile*

It has been known since Antiquity that one of the principal cosmological consequences of the heliocentric system is that it stretches the universe considerably, to such an extent that the distance separating the earth from the sun, large as it may be, ends up being incommensurable with the distance separating the sun from the

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"sphere of the fixed stars". The question had already been openly debated by Archimedes in his celebrated treaty, *The Sand Reckoner*. And even though Copernicus died just before Archimedes' works became available,[1] this in no way signifies that it was impossible for him to have been aware of them, since he takes up this very argument himself.

(1) The *Immensity* of the Heavens as Defined by Copernicus

In his *Almagest*, Ptolemy had already clearly demonstrated that the dimensions of the earth were negligible when compared to those of the fixed star heavens above:

> …the heaven is spherical in shape, and moves as a sphere; the earth too is sensibly spherical in shape, when taken as a whole; in position it lies in the middle of the heavens very much like its centre; in size and distance it has the ratio of a point to the sphere of the fixed stars; and it has no motion from place to place.[2]

Copernicus takes up Ptolemy's arguments, developing them drastically and with all the necessary geometrical rigor. His approach is twofold:

(1) he first demonstrates that "on the testimony of the senses the earth is related to the heavens as a point to a body"[3];
(2) following on, this argument carries *a fortiori* in the heliocentric perspective, since:

> In comparison with any other spheres of the planets the distance from the earth to the sun, has a magnitude which is quite appreciable in proportion to those dimensions. But the size of the universe is so great that the distance earth-sun is imperceptible in relation to the sphere of the fixed stars.[4]

The demonstration stems from a geometric perspective since it makes it understood that the earth's diameter becomes either negligible or else disappears (since unassignable) when placed before the diameter of the sphere of the fixed stars. This incommensurability of the dimensions of the sphere of the fixed stars relative to those of the earth is practically discernible to the naked eye, we need only think of the appearances of the twelve constellations of the Zodiac. From there, Copernicus arrives at the following conclusions:

> the heavens are immense <*immensum*> by comparison with the earth and present the aspect of an infinite magnitude <*infinitae magnitudinis*>, while on the testimony of the senses the earth is related to the heavens as a point to a body, and a finite to an infinite magnitude <*finitum* ad infinitum *magnitudine*>.[5]

[1]Indeed, the *princeps* edition wouldn't be published in Basel, by Thomas Gechauff Venatorius for Hervagium, until 1544. As for Commandino's translation, this appeared in Venice in 1558. On these matters, see Heath (1921), tome II, 25 sq.

[2]See Ptolemy (1984, 38).

[3]Copernicus (1978, Book I, Chap. VI).

[4]Copernicus (1978, Book I, Chap. X).

[5]Copernicus (1978, Book I, Chap. VI).

In other words, given the vantage point of a fixed star, the diameter of the earth would vanish as unto some practically imperceptible point. He simply makes us understand that, in terms of “the testimony of the senses”, what allows us to compare the immense and the infinite is, in both cases, the *absence of proportion* between the measure itself and what remains to be measured. The measure cannot in any way constitute an aliquot part of what is to be measured, or, if we prefer, the parts which should be employable as units of measure, strictly speaking, are of no determinate number.

Regarding the second point, Copernicus this time responds from his heliocentric perspective and shows that the great annual journey the earth undertakes in circling the sun changes strictly nothing for the problem of the *immensity* of the heavens, apart from increasing it considerably, so to speak, since the absence of an assignable annual stellar parallax teaches us that it is not only the earth’s diameter which is a mere dimensionless point in comparison to the immensity of the heavens, but the diameter of the earth’s annual orbit as well:

> The same may be said also about the position of the earth. Although it is not in the center of the universe, nevertheless its distance therefrom is still insignificant, especially in relation to the sphere of the fixed stars.[6]

What matters in astronomical measurement is the proportionality or commensurability of the magnitudes. Where incommensurability rears its head, all reference points disappear, since calculations become impossible and observation (to the naked eye at least) loses all semblance of significance. Clearly what comes into evidence here is that, with Copernican heliocentrism, the depth of the heavens is even more unfathomable than the geocentric tradition had ever imagined. In other words, Copernicus recognizes that the earth’s distance at the center of the world cannot serve as an adequate basis in determining, by triangulation, the distance of any of the fixed stars. The absence of stellar parallax implies only the material impossibility of undertaking a measurement to fathom the sheer depth of the heavens, from this point Copernicus does not conclude that the universe is infinite:

> For that proof establishes no conclusion other than the heavens’ unlimited size <*indefinitam magnitudinem*> in relation to the earth. Yet how far this immensity <*immensitas*> extends is not at all clear.[7]

Indeed, incommensurability can just as easily arise between two finite magnitudes as it can between a finite and an infinite magnitude. Besides which, Copernicus never made a secret of the fact that he leaned more towards a finite universe, closed and limited to the sphere of the fixed stars, as he states from the first lines of the *De Revolutionibus*: “that the universe is spherical”.[8] Despite its

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[6]Copernicus (1978, Book I, Chap. VI).

[7]Copernicus (1978, Book I, Chap. VI).

[8]Copernicus (1978, Book I, Chap. I). The original text in Latin says: “*Quod mundus sit sphaericus*”. I agree with Rosen’s translation, because “*mundus*” may also mean universe by synecdoche. The context of the chapter shows that it is the case here.

immensity, Copernicus' universe is finite (as it was for Ptolemy), but he does consider the sphere of the fixed stars to be *immobile*. By Copernicus' own admission, this does not make it impossible for the universe to be infinite, as he does not rule out this possibility. Moreover, he ceaselessly repeats that the matter is not resolved and that admitting its infinitude would do away with the aporia stemming from its limitation:

> But 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.[9]

Nevertheless, Copernicus thinks this question not to be within the remit of astronomy but to belong rather to natural philosophy. As he says:

> Let us therefore leave the question whether the universe is finite or infinite to be discussed by the natural philosophers <*physiologorum*>. We regard it as a certainty that the earth, enclosed between poles, is bounded by a spherical surface. Why then do we still hesitate to grant it the motion appropriate by nature to its form rather than attribute a movement to the entire universe, whose limit is unknown and unknowable?.[10]

Let us simply note that the observational ascertainment of the incommensurability or the immensity of the heavens when compared with the dimensions of the terrestrial orbit *necessarily* raises the question of cosmic infinity.

(2) The *Immobility* of the Sphere of the Fixed Stars in Copernican Heliocentrism

It is not only considerations of *immensity* which we feel were essential on the path which lead to the idea of cosmic infinity, but also the question of the *immobility* of the sphere of the fixed stars which is correlative to the earth's movements. Copernicus openly acknowledges this:

> For, the chief contention by which it is sought to prove that the universe is finite is its motion.[11]

From the moment Copernicus immobilized the sphere of the fixed stars and redirected the appearance of the starred heavens' diurnal motion to the axial rotation of the earth in the opposite direction, the principal prior argument in favor of universal finiteness lost all relevance. Despite everything, Copernicus remained attached to a certain cosmological finitism by basing himself on *geometric* arguments (the sphere seen as a geometrical invariant and as a shape comprising maximal capacity[12]), *physical* arguments (the natural tendency of bodies to amass

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[9]Copernicus (1978, Book I, Chap. VIII): "*Sed dicunt, extra caelum non esse corpus, non locum, non vacuum ac prorsus nihil, et idcirco non esse, quo possit evadere caelum*; *tunc sane mirum est, si a nihilo potest cohiberi aliquid*".

[10]Copernicus (1978, Book I, Chap. VIII).

[11]Copernicus (1978, Book I, Chap. VIII): "*Nam potissimum, quo astruere nituntur mundum esse finitum, est motus*".

[12]Copernicus (1978: Book I, Chap. I): "*quod ipsa capacissima sit figurarum*".

themselves spherically),[13] and *aesthetic/teleological* arguments (the perfection of the sphere is befitting of “heavenly bodies”[14]).

Of course, against Aristotle’s argumentation could have been objected that, although he clearly demonstrated a priori that what is infinite cannot partake in circular motion, this does not suffice in ruling out the possible existence of an *infinite* and *immobile* cosmic space. But this objection did not stand up in Aristotle’s view, as he took the sphere of the fixed stars’ motion of diurnal rotation to be an objective fact, without questioning the observational data:

> Moreover, the heavens certainly revolve, and they complete their circular orbit in a finite time. […] The revolving body, therefore, cannot be infinite.[15]

Once Copernicus had rejected the geocentric and geostatic appearances of things, this whole probationary apparatus collapsed of its own volition. Furthermore, this is what Bruno had very well understood, as he explains in his *De l’infinito*:

> But like a sophist he [Aristotle], taketh one part of his argument from the conclusion of his adversary; positing his own principle that the universe is mobile, also that it moveth and that it is of spherical form. […] [these] arguments are based on that presupposition, namely that his adversary asserteth the universe to be infinite and that he himself attributeth motion to this infinite body. Certainly this is foolish and absurd.[16]

Even though nothing could now be opposed, in any truly incontestable way, to the infinity of the universe, not since the “immobilization” and immense enlargement of the sphere of the fixed stars, Copernicus still refused to make the passage from the *immensity* to the *infinity* of the cosmos. The primary reason for his refusal is, it seems, an epistemological one. It relies on the unknowable nature of what may be found beyond the sphere of the fixed stars: “[the limit of the entire universe is] unknown and unknowable <*totus mundus, cujus finis ignoratur scirique nequit*>”.[17] However, the epistemological advantage, if not to say superiority, that Copernicus recognized in infinitism over finitism was that the notion of an infinite universe would dispense with the aporia related to its limitation:

> If the heavens are infinite, however, and finite at their inner concavity only, there will perhaps be more reason to believe that beyond the heavens there is nothing.[18]

Even though, for Copernicus, the *immensity* and *immobility* of the heavens rendered undecidable a clear distinction between the finite and the infinite, they

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[13]Copernicus (1978, Book I, Chap. I): “*quod hac universa appetant terminari, quod in aquae guttis caeterisque liquidis corporibus apparet*”.

[14]Copernicus (1978, Book I, Chap. I): “*talem formam divinis corporibus attributam*”.

[15]Aristotle (1922, I, 5, 272 b16–17).

[16]Bruno (1950), *Dialogo secondo*, 277.

[17]Copernicus (1978, Book I, Chap. VIII).

[18]Copernicus (1978, Book I, Chap. VIII): “*At si caelum fuerit infinitum, et interiori tantummodo finitum concavitate, magis forsitan verificabitur extra caelum esse nihil, cum unum quodque fuerit in ipso*”.

nonetheless constituted an inescapable piece of knowledge which raised the question of cosmic infinity with an acuity not previously matched. This was thus one of the factors which tipped the balance in favor of the elaboration of what we today call the "new image of the world".

4.2 From "Place" to Space in the Natural Philosophy of the Renaissance

(1) The Cosmological Inconsistencies of the Aristotelian Concept of "*Place*"

It would, for example, be in vain were one to seek a theory of space in Aristotle, who deploys all his ingenuity in avoiding any recourse to the Platonic Greek term for space or "*χώρα*" (excepting, of course, when he discusses Plato's theory), or again to the Democritean term "*κενόν*". This is a consequence of his bitter struggle against the Platonic conception of space which saw matter and extension as identical,[19] and against Democritean atomism which had allowed for the existence of empty space as the enabling condition for the motion of atoms and composed bodies.[20] Wherein springs forth the conception of place <*τόπος*> which is in total accord with Aristotelian physics while remaining closely harmonious with his cosmology. Having carefully distinguished and separated the idea of *place* from that of matter <*ὕλη*> or body, Aristotle shows that *place* is reducible neither to shape <*μορφή*> (which matches its content), nor to extension <*διάστημα*> (which separates the extremities of a body). Ultimately, there remains only the fourth and last possibility: *place* is itself identified with the *immediate unchangeable (immobile) limits or extremities of the container or envelope*:

> If, then, place is none of the three, neither the form nor the matter nor some extension […], it must be that place is the […] limit of the surrounding body <*τὸ πέρας τοῦ περιέχοντος σώματος*>. […] So that is what place is: the first (or immediate) unchangeable limit of that which surrounds <*Ωστε τὸ τοῦ περιέχοντος πέρας ἀκίνητον* πρῶτον, *τοῦτ' ἔστιν ὁ τόπος*>.[21]

In other words, the limits of the universe constitute *place* which encloses all things without itself being in turn surrounded or lodged within another *place*. Otherwise we would risk slipping into an infinite regression, as Zeno had already observed, in taking the Stagirite at his word.[22] So the universe is not *in* a place, it is the *place* of all reality belonging to the sub- or superlunary worlds; which is tantamount to saying that it is either self-containing or that it is nowhere:

[19]See, Aristotle (1983, 22–23).

[20]See, Aristotle (1983, Books III and IV, 7, 214a16 sq., 33).

[21]Aristotle (1983, Books III and IV, 4, 212a2–6; 212a20–21, 28 and 29).

[22]Aristotle presents Zeno's argument in the following way in Physics IV. Aristotle (1983, IV, 3, 210b22, 25): "Zeno's problem [states that] if place is something, it will be in something."

> the whole is not anywhere. […] But there is nothing besides the universe and the sum of things, nothing which is outside the universe; and this is why everything is in the world (or heavens). For the world is the universe. The place is not the world but a part of the world, which is an extreme and in contact with changeable (mobile) body. Hence the earth is in the water, the water in the air, the air in the ether, and the ether in the world, but the world is no longer in anything else. It is manifest from these considerations that all the problems, too, will be solved by this account of place.[23]

The Aristotelian conception of *place* is not a substitute for the theory of *universal space* and this is the reason it was impossible to partially rework or modify it in order to put a new vision of the universe into place. The Aristotelian theory of *place* is inseparable from his ontology, his qualitativist physics and his geocentric, finalist and finitist cosmology. This explains why all theoretical attempts aimed at rethinking the status of cosmic space have *ipso facto* been placed entirely *outside* of Aristotelianism. It is in this way that Platonism, atomism, Stoicism, Epicurianism, or Neo-platonism enabled, to a certain extent, the philosophers of the Renaissance and of the classical era to rethink the nature of cosmic space *differently*. But it would also be a mistake to forget the essential role played by the ancient and medieval *commentaries* on the Stagirite's works (principally, though not restricted to: Simplicius, Philoponus and Averroës) which had already long pointed out the internal difficulties harbored within these texts and the controversies they aroused.

(2) John Philoponus Substitutes the Concept of Space for the Aristotelian "Topos" *<τόπος>*

Although the Neo-platonic philosopher and Christian theologian John Philoponus[24] may not have constructed a new system of the world, neither did he content himself with merely criticizing the difficulties or incoherencies in Aristotle's philosophy, given that he proposed his own positive solutions to overcoming several of these, and not the least of them either. In this way, John Philoponus provided late Antiquity with its most aggressive and insightful critique of Aristotle's natural philosophy, which is surely how he attracted Bruno's attention, through his extremely incisive *Commentaries on Aristotle's Physics*.

Among John Philoponus' innovations, let us highlight the fact that he rejected the distinction between the sublunary and superlunary regions, and the existence of the fifth element as constitutive of the superlunary world, thus allowing him to assert that the universe contains stars composed of diverse elements, subject therefore to generation and corruption. He then affirms the unity of the whole universe by leaning, admittedly, on a religious creationist conception of things. He also rejects the Aristotelian idea of place, replacing it with an idea of *space* which serves as a formal framework to his new dynamics. So what is the other vision proposed by John Philoponus, whose Latin translations show him undertaking a

[23] Aristotle (1983, IV, 5, 212b13–21, 29 and 30).

[24] John Philoponus—or John the Grammarian—was born, it seems, in Caesarea around 490 and died in Alexandria around 575. He is thought to have been one of the last holders of the chair of [Neo-platonic] philosophy in Alexandria.

decisive passage from *place* <*locus*> to space <*spacium*> and by which Bruno was directly inspired (even if the Alexandrian philosopher dismisses any form of cosmic infinity)?

Even though the composition dates of several of John Philoponus' writings are unknown, we do know that he completed his *Commentaries on Aristotle's Physics* in 517 A.D. It is in reference to chapter 4 of Book IV of the *Physics*, entirely dedicated to the definition of the essence of place, that Philoponus presents his own conception of space. Having held Philoponus' original Greek up to the Latin translation[25] published during the Renaissance at the time of Bruno, I found the following affirmation emerged there:

> In truth, for these reasons we could therefore well consider that place <*τόπος*, *locus*> is not the limit <*τὸ πέρας τοῦ περιέχοντος*, *terminus continentis*> of the container. But it is said that place is a space <*τό διάστημα*, *spacium*> which is measured according to three directions <*τριχῇ διαστατὸν*, *trifariam dimensum*> and that it differs from the bodies which penetrate it and are found within it, because it is incorporeal by its very nature, and because it is but the dimensions devoid of any corporeality. (Since, in reality, place and void are one and the same <*ὑποκείμενον, subjecto*>) this is demonstrated by refuting all else. Indeed, if place is neither matter, nor form, nor the limit of the container, what remains is that it be space <*τό διάστημα*>. Undoubtedly, the same thing would be demonstrated by showing that space is something other than the bodies which penetrate it.[26]

It is interesting to note that Philoponus' cosmic space is entirely *immobile*, enabling it to fit perfectly with the Copernican world view. As Duhem quite rightly remarks, Philoponus thought therein to have resolved all the difficulties linked to the Aristotelian conception of place.[27] That conception was not abandoned, for it came back in force during the Renaissance.

(3) The Contribution Patrizi's Ideas Had on the Ontological Status of Space

The idea here is not to detail the doctrines of space which were novel to the Renaissance, this would fall under a very different objective to the one my contribution here aims for. I simply wish to show that the novel Brunian conception of space was not isolated but rather was part of a widespread return to the knowledge drawing-boards during that era, particularly in the domain of natural philosophy.

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[25]The Greek text of the *Commentaries on Aristotle's Physics* by John Philoponus was published in 1535 and its Latin translations appeared in Venice in 1554, 1558, 1569 and 1581. The scholarly edition of the Greek text was established by Vitelli in Philoponus (1887/1888, spec. 567–568).

[26]Philoponus (1581, 170, col. a–b): "Quod quidem igitur locus non sit terminus continentis ex his satis contueri possumus. Qui dicitur vero locus sit spacium trifariam dimensum diversum ab his corporibus quae ipsum incidunt, ac ingrediuntur quod sua ac propria ratione sit incorporeum, & solum sit ipsae dimensiones corporis vacuae. (Nam revera idem subjecto est vacuum & locus) demonstretur ex destructione reliquorum. Nam si neque materia, neque forma, neque terminus continentis est, restat locum esse spacium. Quod vero idem quatenus idem sit aliquod spacium omnino diversum ab his corporibus, quae in illo ingrediuntur demonstretur."

[27]Duhem (1913–1959, tome 1, 317).

Among Bruno's closest contemporaries, it is worth mentioning Francesco Patrizi who, in 1587, had published a brief memoir on natural philosophy[28] entirely dedicated to an analysis of the concept of space, which was as mathematical as it was physical, and where he openly asserts his infinitism: the *De rerum natura libri II priores*, whose conclusions were taken up in their entirety and then reinforced in the *Pancosmia* of his 1591 master work: *Nova de universi philosophia.*[29] Patrizi's natural philosophy, despite referring to Copernicanism in glowing terms (Copernicus is referred to as "*astronomus summus*"), does not align itself with it. Furthermore, whether it be the earth or the sun at the center of the system to which we belong, in Patrizi's book this changes nothing for the properties of space or for the question of its eventual infinity. In this respect, we can measure the gap which separates Patrizi and Bruno according to their respective rapport with Copernicanism.

For Aristotle's four elements, Patrizi substitutes four others: Space <*spacium*>, Light <*lumen*>, Heat <*calor*>, Fluidity <*fluor*>. In this regard, Patrizi is very close to the ideas of Bernardino Telesio, despite the fact that the latter denied the importance of mathematics in the study of natural phenomena, while Patrizi makes it the favored instrument of the natural sciences. Patrizi situates himself in a processional, Neoplatonic schema where the superior precedes and also determines the inferior: his point of departure is the unitotality of God, descending to the incorporeal and then on to the corporeal, that is to the space which is prior to and superior to the corporeal, just like in the relationship between the corporeal and its properties. This explains why the *Pancosmia* broaches the subject of space from its very first book entitled: *De spacio physico*. Here he sets forth his new conception of a cosmic space that is three-dimensional, absolute, void, precedent to all things, and whose infinity exists in act.

Patrizi shows that space is a veritable "substance apart" on the ontological level, to the extent that it is prior and exterior to Aristotle's categories, and that it is neither a material nor an immaterial reality. Space is not material, since it is devoid of the force of impenetrability <*antitypia*> which characterizes bodies; but neither is it immaterial, since it has extension, which is not at all the case for spirits:

> What is it then, a body or an incorporeal substance? Neither, but what is found between the two of them. […] It is an incorporeal body and not a corporeal body. And each of these determinations is subsistent of itself, existent of itself, and existent in itself.[30]

Space is therefore an eminently ambivalent substance: its "immateriality" gives reason to the fact that geometry is a wholly a priori science, but its affinity with

[28]Patrizi (1587).

[29]Patrizi (1591), Pancosmia, liber Primus: *De spacio physico*; 2ème éd. Venise, 1593.

[30]Patrizi (1591), Pancosmia, liber Primus: *De spacio physico*, 65c: "*Quid igitur corpusne est an incorporea substantia? Neutrum, sed medium utriusque. Itaque corpus incorporeum est et non corpus corporeum. Atque utrum* per se *substans,* per se *existens, in se existens*".

the corporeal world provides an explanation for its fertility in physics or in natural philosophy <*physiologia*>[31]:

> Therefore, no category encompasses space; it is before all of them, outside all of them. So what is it? It is *hypostasis, diastèma, diastasis, ecstasis, extensio, intervallum, capedo, and intercapedo*. […] [Space] is accidental to no worldly thing, whether this be a body or not, substance or accident, because it is before all these things. […] This is why we must philosophize on its subject in a different way to what befits the categories. Therefore, space is a hypostatic extension subsistent in itself, and not inherent to any other reality. It is not a quantity, and if it is a quantity, then it is not that of the categories, but it is beyond them and is at once their principle and their source.[32]

Let us point out that space becomes place (*locus*) when it is full, but void (*vacuum*) when it contains no body. This void exists in two forms: the extramundane and the intramundane. In this way Patrizi is quite close to Stoic cosmology. Indeed, he sees the world as designating our planetary system (whatever its structure may be, geo- or heliocentric) which stretches out to include the sphere of the fixed stars; beyond the world it is the infinite void which stretches out. The intramundane exists only in the form of minuscule interstices (*spaciola*) which make possible the rarefaction and condensation of bodies. The problem of the infinite thus arises only in relation to the extramundane spatial void:

> We who follow a different path, we say that the space which is outside of the world is at once finite and infinite. It is finite where it touches the most extreme surface of the world; not by virtue of any proper or natural boundary, but relative to the confines of the world. But where it departs from the world and leaves it far behind, it carries on to infinity. […] Consequently, since this space which stretches beyond the world is confined neither by the limits of a body, nor by those of another space, nor by its own, nor by incorporeal things, it must be concluded that it carries on to infinity and that it is infinite.[33]

[31]Patrizi (1591), Pancosmia, liber Secundus: *De spacio mathematico*, 68b.

[32]Patrizi (1591), Pancosmia, liber Primus: *De spacio physico*, 65b: "*Nulla ergo categoriarum spatium complectitur; ante eas omnes est, extra eas omnes est. Quid ergo est*? *hypostasis, diastema est, diastasis, ectasis est, extensio est, intervallum est, capedo est, atque intercapedo. Sed sunto categoriae in mundanis bene positae*; *spatium de mundanis non est, aliud quam mundus est*; *nulli mundanae rei accidit, sive ea corpus sit, sive non corpus, sive substantia, sive accidens, omnia haec antecedit, omnia illi uti accedunt, sic etiam accidunt*; *omnia illi uti accedunt, sic etiam accidunt*; *ita ut non solum quae in categoriis numerantur accidentia, verum etiam quae ibi est substantia, illi sunt accidentia. Itaque aliter de eo philosophandum, quam ex categoriis. Spatium ergo extensio est hypostatica* per se *substans, nulli inhaerens. Non est quantitas. Et si quantitas est, non est illa categoriarum, sed ante eam ejusque fons et origo*".

[33]Patrizi (1591), Pancosmia, liber Primus: *De spacio physico*, 64a-b: "*Nos alia ingredientes* via, *dicimus, spacium quod est extra mundum, & finitum esse et infinitum. Finitum quidem ea parte, qua mundi extimam superficiem contingit, non quidem proprio et naturali fine, sed mundi terminis. Qua vero digreditur a mundo, ab eoque procul abit, in infinitum transit* […]*Cum ergo, nec corporis terminis, nec spacii alterius, nec suis, nec incorporeis finiatur, necessario concluditur, spacium illud a mundo recedens, in infinitum recedere, & infinitum esse*".

Without going further into Patrizi's body of work here, let us simply say that he undertook, in the light of the Platonic and Stoic[34] traditions, the correction of certain deficiencies in the Aristotelian concept of place. In turn, Bruno, Campanella and Gassendi took up this concept of space, which we then find in Henry More[35] and Walter Charleton,[36] some of whose ideas found their way into Newton's natural philosophy.

4.3 Extensive Infinity and the Properties of Cosmic Space

(1) The Critique of Aristotelian Place in the *Acrotismus Camoeracensis*

Now let us move onto Giordano Bruno, who knew Patrizi's ideas quite well. However, whether he was indeed inspired by him, though this is not certain, he did unfortunately prove to be most unfair and even obnoxious towards him.[37] Nevertheless, Bruno had given himself to fierce criticism of Aristotle's natural philosophy even before the appearance of Patrizi's first writings on space. Indeed, it was in his *Acrotismus camoeracencis* of 1586 that Bruno delivered a highly detailed critical analysis of all eight books of Aristotle's *Physics* and also the four books which make up the *De coelo*.

Concerning place, Bruno showed that the four causes do not really allow for the definition of place and that a "fifth cause" must be put forward to show that it is sooner identifiable with *space*.[38] Subsequently, it could not be said, as Aristotle

[34]Admittedly, Patrizi makes reference here not only to Plato and Plotinus but also, and above all, to Marsilio Ficino's *De sole et lumine*, see, Ficino (1561, 965 sq).

[35]See, More (1671), Chap. VIII, § 8, 69: "When we shall have enumerated those names and titles appropriate to it, this infinite immobile, extended [entity] will appear to be not only something real but even something Divine[…]: One, Simple, Immobile, External, Complete, Independent, Existing in itself, Subsisting by itself, Incorruptible, Necessary, Immense, Uncreated, Uncircumscribed, Incomprehensible, Omnipresent, Incorporeal, All-penetrating, All-embracing, Being by its essence, Actual Being, Pure Act." Henry More was, in truth, steeped in the Jewish and Christian kabbalistic teachings which Christian Knorr von Rosenroth (1636–1689) had communicated to him. Indeed, for Kabbalists, it was generally accepted that God filled the world in the same way the soul inhabited the body; in other words, mundane space, which is genuinely distinct from corporeality, is but a manifestation of the Divine presence.

[36]Walter Charleton, author of the famous *Physiologia Epicuro-Gassendo-Charltoniana* (London 1654). According to Richard S. Westfall, Newton would have had a fair knowledge of this work from the time of his writing *Quaestiones quaedam philosophiae*, that is, around 1661. On this subject, see: Westfall (1971, 326–327).

[37]Hence, for example, in the *De la causa, principio e Uno*, Bruno (1996), *Dialogo Terzo*, 165–167: "un altro sterco di pedanti, italiano, che ha imbrattati tanti quinterni con le sue *Discussioni peripatetiche*".

[38]Bruno, *Acrotismus camoeracensis*, *Art.* XXVIII, in Bruno (1879), vol. I, part I, 123: "That place is space, corporeal transference shows it better than anything else. It is therefore the receptacle of bodies which possesses size, it is not reducible to any of the four causes but hearkens of itself to a fifth kind of cause".

claimed, that place is the "limit of the enveloping body", since it is, on the contrary, the body which limits space.[39] Unlike Patrizi, Bruno did not accept the existence of the void, that is to say, he did not accept that space was void. From this angle Bruno stands alongside those thinkers who conceive only of a filled universe:

> For our part, we do no posit the [existence] of an empty space, in the sense that there would be nothing in it that exists in act, but [we affirm] at least that space is that in which is necessarily contained sometimes one body, sometimes another, because we know full well that before all things it is filled with air. Indeed, it is our opinion that it is an infinite being, and there exists nothing within which there is not something. So then, we define the void as space or the boundary within which bodies exist; but it is not at all that which has nothing in it. Yet, when we say void of the place without bodies, we do not literally differentiate it from bodies, only abstractly.[40]

It is, moreover, for this reason that Bruno had previously declared that "there is no void which does not contain either air or else some other body".[41] Bruno stands alongside those thinkers who either do not separate space from corporeality or who conceive only of a filled universe. In this way we understand that for Bruno the terms space, void, air and ether are equivalent (in the sense he takes them to have at least), something he had already clearly shown in his Italian language writings.[42] It still remains for us to determine what the properties of cosmic space are.

(2) **The Properties of Cosmic Space According to Bruno**

The movement towards the infinitization of the universe in Bruno's thought could not truly establish itself without leading to the conceptualization of spatial infinity which "*contains all within itself, without however being in turn contained*".[43] In this way we understand that for Bruno the terms space, void, air and ether are equivalent in his *De immenso*, Book I, Chap. 8.[44] Quite astutely, Bruno begins by bringing to memory some great Peripateticians who had been lead to reject the antivacuism of their master; this was the case with John Philoponus:

> Several of the Peripateticians were incapable of accepting Aristotle's doctrine against the void; better than any other, Philoponus stood up with the most boldness against that

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[39]Bruno, *Acrotismus camoeracensis*, *Art.* XXIX, in Bruno (1879, vol. I, part I, 126): "But if this is so, it is what is localized which limits place, rather than place limiting what is localized. <*Quod si ita est, potius locatum terminat locum, quam locus locatum*>".

[40]Bruno, *Acrotismus camoeracensis*, *Art.* XXXIII, in Bruno (1879, vol. I, part I, 130–131).

[41]Bruno, *Acrotismus camoeracensis*, *Art.* XXVII, in Bruno (1879, vol. I, part I, 123).

[42]Cf. Bruno (2006), *Dialogo quinto*, 356–360.

[43]Bruno, *De immenso*, 1591, livre I, Chap. VIII, in Bruno (1879, vol. I, part I, 231): "extra et omnia corpora comprehendens, et incomprehensibiliter intus omnia continens".

[44]The Brunian conception of the properties of cosmic space has been dealt with several times since the nineteenth century by a number of commentators. Among them, we will do well to turn to Tocco (1889, 219–220), Cohn (1994, 131 sq.), Cassirer (1991, 236–241), Mahnke (1936, 48–59). Koyré (1994, Chap. II, 40–55). Grant (1981, Part II, Chap. VIII, 182–192), spec. 186–190. The special edition of the journal *Physis* dedicated to Bruno between science and philosophy, vol. XXXVIII (2001), Fasc. 1–2, Firenze, Olschki, spec. 135–389.

> [doctrine]. His whole argument involved that question <*causam*> of knowing what the particularity of natural bodies occupying the same space is, which must be something measurable <*dimensum*>, something distinct from all things.[45]

However, as we saw earlier, John Philoponus, strictly speaking, wasn't a "Peripatetician" but a Christian Neoplatonician who had leveled Antiquity's most cutting criticisms at the physics and cosmology of Aristotle. Bruno pays tribute to John Philoponus for having demonstrated, despite the overbearing prestige of Aristotle's teachings, the unity of the heavens and the earth and, consequently, the homogeneity of space which contains everything within itself. Better still, he congratulates him for having understood that the common characteristic of space and the bodies to which it serves as container is their three dimensional extension.[46] Alongside John Philoponus, Bruno too rejects the Aristotelian definition of place, according to which this would be the: "surface <*facies*> of the body which contains".[47] For, if that form was coincident with what is localized then it should, like the latter, be in motion, something which renders the motion of bodies both unintelligible and absurd. Nevertheless, the fact that John Philoponus' name is mentioned only once in the entire body of Bruno's work must be acknowledged. This occurs in the passage from *De immenso* which we shall now analyze. For this reason, it would not be fitting to overestimate his importance in the development of Bruno's philosophical ideas. Let us simply point out that several Latin translations of Philoponus' Greek text were published contemporaneously to Bruno's lifetime, which is the second half of the XVIth century in Venice.[48]

Saint Thomas' definition, stating that space is "what is interposed between the surface of the container and that of the contained", resolved the problem no better since it invokes the notion of term <*terminus*> and/or of an extreme boundary <*finis*> of space, something which implies contradiction from a Brunian point of view, since any bounding of the finite necessarily implies something other than itself.[49] In other words, the idea of an ultimate or absolute boundary is a contradiction in terms since a boundary unites what it separates.

From here comes a new definition of space that Bruno presents without taking any particular care to specify which parts of it were respectively due to John Philoponus and his own philosophy. This remark is not without importance to us because Bruno seems unaware that, in his doctrine, John Philoponus rejected the existence of the infinite in all its forms (as much the actual infinite as the potential infinite) by denouncing the paradoxes it lead to and using them to endorse his refusal of the very concept of infinity. The precise definition Bruno gives for

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[45]Bruno, *De immenso* 1591, Book I, Chap. VIII, Bruno (1879, vol. I, part I, 231).

[46]It seems Bruno had read John Philoponus' analyses through the intermediary of Simplicius and what he had related of them in his *On Aristotle's Physics*, 1331, 10.

[47]Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, poem, v. 6–7, 230).

[48]The Greek text of the *Commentaries on Aristotle's Physics* by John Philoponus was published in 1535 and its Latin translations appeared in Venice in 1554, 1558, 1569 and 1581.

[49]Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 230).

space, and which is as essential for the intelligibility of his doctrine as it is for the history of cosmological thought in general, is as follows:

> Space, therefore, is a certain continuous physical quantity consisting in a triple dimension, in which the magnitude <*magnitudo*> of bodies is captured, by nature before all bodies, and subsisting without <*citra*> all bodies; indifferently receiving all things, without conditions of action and passion, not intermingled with anything else, impenetrable, not formable, not locatable, exteriorily embracing all bodies, and incomprehensibly within, containing all bodies.[50]

Firstly, Bruno insists just as much on the three dimensional aspect as he does on the continuity of space, which he posits as a physical reality from the outset, thus ridding himself of abstract mathematical space. But, above all, this definition accentuates what we could call the *absoluteness* of space, that is the *independent* nature of the container in respect to everything it contains: "indifferently receiving all things <*indifferenter omnia recipiens*>".[51] The whole difficulty with this definition is conceiving of space as a physical reality which remains completely distinct from the reality of the material bodies it contains, in such a way as space is neither substance nor accident! The existence of space precedes even that of bodies and is exterior to them, "[is] by nature before all bodies <*ante […] et citra omnia corpora*>". This raises the question of knowing what its ontological status may be, for it even seems as though it may be space which confers three dimensionality upon bodies. Bruno gives particular insistence to this point and presents the *fifteen properties of space* one by one, providing, when necessary, explanatory remarks to confirm and expand his views all along the chapter. We will take the time only to look at the most important of the properties appearing in this long list.[52]

Among these properties, we see that Bruno evokes, though without dwelling on it, the *immobility* of space. However, this immobility of cosmic space results from the perspective opened up by Copernicus; yet Bruno does not seem to dwell on it, since the Copernican system is not analyzed before Book III of *De immenso*. Still, this immobility, and even the persistence of space independently of any body, is not sufficient in itself for conferring substantialness. In this regard, Bruno removes himself from the Epicurean perspective which, it seems, bestowed equal honor on both bodies and the void.[53]

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[50] Bruno, *De immenso* 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 231): "*Est ergo spatium quantitas quaedam continua physica triplici dimensione constans, natura ante omnia corpora et citra omnia corpora consistens, indifferenter omnia recipiens, citra actionis passionisque conditiones, immiscibile, impenetrabile, non formabile, illocabile, extra et omnia corpora comprehendens et incomprehensibiliter intus omnia consistens*".

[51] Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 232).

[52] Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 231–233).

[53] Epicurus, Letter to Herodotus § 39, Epicurus (1960, 38): "Further, the whole of being consists of bodies and space <*σώματα καί κενόν*>. […] And if there were no space (which we call also void and place and intangible nature) <*χώραν καί ἀναφῆ φύσιν*>, bodies would have nothing in which to be and through which to move, as they are plainly seen to move".

(1) Therefore, this physical container (properties 4 and 5) must not be conceived in the manner of a *substance* (see n. 15), for space is not a physical substrate from which things may be drawn, since it is not possible to put a form to it (unlike raw matter, see n. 9), nor to wholly encompass it to define its boundary (see n. 12) or to localize it (see n. 10), which in any case would have necessitated that it be capable of undergoing alteration (see n. 6). Remaining without of all things (n. 11), it could therefore not be mixed (n. 7) with anything.

(2) Neither is it an *accident*, as, were this the case, it would have had to be linked to a substance, be inherent to a substance, which is absurd since, on the contrary, all things are within it. For Bruno, space is ontologically undefinable, or at least with the *genus proximum* it is, because it is: "something which is beyond class <*extra genus*>".[54] Which is tantamount to saying that space transcends the classes of being: it is indeed a kind of transcendental, in the Scholastic meaning of the term. Yet, this peculiar status that space has, which now remains ontologically undefinable, appears by means of the negative, or at least aphairetic, character of the terms employed in the naming of its properties. This long list of its properties is intended to elevate us, progressively and in a negative fashion, to an intuitive grasp of spatial infinity in its positivity and ontological specificity, since this is nowhere expressed in a direct and ostensive manner.

Space is the "*incomprehensum*": it is what nothing can encompass, enclose or surpass; but it is still necessary that we manage, some way or another, to comprehend this "incomprehensibility". All that remains is the method by negation, understood as the negation of any boundary which by its content purports to be affirmative, even though it presents itself discursively in the form of negative judgments and apophatic arguments. Space is what remains when we disregard all material content and all specific predicative determination which could come and cut down thought in its flight towards continuous, infinite magnitude.

Nevertheless, one difficulty remains with the property previously mentioned, that is *impenetrability*. Indeed, if space is a container, then it would be difficult to immediately imagine it as impenetrable, considering it is "that in which things are locally <*localiter*>"[55] (n. 15). This difficulty seems to intensify when we remember that Bruno had in no way mentioned this impenetrability in his Italian dialogue *De l'infinito*. There he conceived of infinite space as an empty container, or rather as a region of the ether:

> Besides the four elements […] there is a vast <*immensa*> ethereal region, […], in which they all move, live and grow: the ether which envelopeth and penetrateth all things.[56]

[54] Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 233).

[55] Ibid.

[56] Bruno (2006), *Dialogo Quinto*, 356; English trans., by Bruno (1950, 372). Similar ideas are to be found in *La cena de le ceneri*, 1584 in Bruno (1994), *Proemiale epistola*, 16–17, *Dial III*, 138–139 and *Dial V*, 238–239.

The question of impenetrability seems then to be a late addition to the Brunian doctrine of space.[57] Bruno associates impenetrability (see n. 8) with *unmixability* “because mixing <*mixtio*> is the particularity of bodies which exchange their parts in turns” (see n. 7). In both cases Bruno brings out the unity and the simplicity of space. It is because space has no parts that it escapes all mixing and that it cannot be penetrated, because: “penetrable only is that whose parts can be further separated <*distantiores fiunt*>”.[58] Simplicity thus eliminates the composed or discontinuous aspect of space. In simple space Bruno sees a first nature (see n. 3) whose existence precedes that of its material content, a content to which parts belong, “such parts could not belong to space, by reason of their secondary condition”.[59] Ultimately, cosmic space does not so much possess a chronological precedence as it does an ontologically superior consistency over its content. Furthermore, Bruno wanted to avoid the classical paradoxes of the infinite at all costs; to that end, he had taken great care to specify in his *De l’infinito*: “it is different to speak of parts *within* the infinite, and parts *of* the infinite”.[60] Despite everything, the difficulty remains, because we cannot fathom how the impenetrable space of the *De immenso* I, VIII can contain within itself those bodies who circulate and “change place alternately”.[61]

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Ultimately, it is generally accepted that philosophy of nature was, at the time of the Renaissance, the melting pot for new concepts which contributed significantly to what is neatly referred to as the “scientific revolution”. Nevertheless, it befits us in this regard to draw some precise conclusions from our analyses.

Firstly, the authority of Stoic physics and cosmology gave Patrizi’s and Bruno’s natural philosophy what they needed to counteract the overbearing influence of the Peripatetitian tradition, without getting confined within antiquarian atomism, whose vision of the world had been marginalized by the pagan tradition and then utterly condemned by the church.

The infinitization of cosmic space allowed Bruno to avoid the aporia of limitation while also expanding the Copernican system to infinity. From that moment on, the concept of world was reduced to being no more than one element within the more encompassing concept of *universe*, since the latter has the capacity to contain a plurality of worlds, or even an infinite multitude. The universe embraces the totality of all worlds.

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[57]This property was not present either in the *Acrotismus camoeracensis*, Wittenberg, 1588, or in the *Articuli centum et sexaginta adversus Mathematicos et Philosophos*, Prague, 1588.

[58]Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 232).

[59]Bruno, *Ibid.*

[60]Bruno (2006), *Dialogo Secondo*, 164; English trans., Bruno (1950, 295).

[61]Bruno, *De immenso*, 1591, Book I, Chap. VIII, in Bruno (1879, vol. I, part I, 231).

This new concept of cosmic space constitutes a kind of *philosophical transition* between perceptive space (heterogeneous, limited and discontinuous) and the space of classical science (homogeneous, infinite and continuous) which made the geometricization of physics possible.

In the end, this new concept of cosmic space developed by Patrizi, Bruno and several others, was still in a very fragile state at the end of the XVIth century, in so far as it could no longer receive the support of the official philosophy of the day, but neither could it yet find its necessary guarantee from within classical science, which did not yet exist. Despite its fragility, it must be recognized that this new concept of infinite cosmic space played an epistemic role which was fundamental to the building blocks of what would become classical science.

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Chapter 5
The Perception of Spatial Depth in Kepler's and Descartes' Optics: A Study of an Epistemological Reversal

Delphine Bellis

Abstract This paper is devoted to the explanation of the location and distance of objects in three-dimensional space through vision in the work of two major opticians of the 17th century, namely Kepler and Descartes. I show that, in his *Dioptrique*, Descartes took up from Kepler's *Ad Vitellionem Paralipomena* a psychological procedure involved in vision and consisting in a trigonometric operation. But, whereas Kepler had resorted to this procedure to account for the illusory, imaginary location of objects seen through reflection or refraction, Descartes applied it to the perception of distance in non-deceptive direct vision. This brings about a complete shift regarding the epistemological value of the psychological operations involved in vision. I indeed show that this displacement reveals that Descartes saw his natural geometry of vision as an epistemological foundation for the integration of sense perception into his physics.

Optics in the narrow sense of the word first includes a geometrical conception of space, since a certain kind of space is implied by theories relying on rays propagating rectilinearly from one point to another, or from one object to another, or being reflected and refracted. This is Euclidean, geometrical space, in which it is possible to draw rectilinear lines corresponding to the passage of the visual ray (and later on of the light ray) outside the eye. But if we consider optics from a historical perspective, we realize that it also implies a psychological treatment of spatial data, which gives rise to space as perceived by the observer through the sense of sight: how do we perceive things with the dimension of depth? Belonging to a more psychological realm, this conception of space is linked to the capacity of our eyesight to give perception of spatial depth. When opening our eyes, we do not only see patches of colored shapes in two dimensions, but objects in a three-dimensional space. Through vision, we are able to distinguish different objects and their spatial

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relationships. But how can what is purely external to our body and soul be seen in our thought as it is in extended space? From antiquity to the 17th century, this perceived dimensionality of space was not conceived as something purely external to extended space through which rays travel. I want to question, from a historical point of view, how these two ways of conceiving visual space are articulated. To that end, I intend to concentrate on two major figures of early modern optics, namely Kepler and Descartes. Theoretical connections between the approaches adopted by both authors have already been noticed in the available scholarship.[1] And they are mainly substantiated by the fact that Descartes himself declared, in a letter to Mersenne, that Kepler was his "first master in optics."[2] But the studies that emphasize this link have concentrated on what appears more "modern" in the optics of the two scientists, that is to say the analysis of the eye as an optical instrument and the function ascribed to the retinal picture in the process of vision. However, other studies have also emphasized that Kepler's theories remained much more embedded in an older framework.[3] Unlike Kepler, Descartes, as far as optics is concerned, is often seen as belonging to the modern part of science.[4] It might be due to his one and only success in demonstrating a law that is valid for contemporary optics, the law of refraction. It might also be due to his mechanization of light, which breaks away from the Scholastic as well as the Neo-Platonic conceptions of light. Or it could come from the mechanization of the physiological processes involved in vision going from the retina to the optical nerve, the chiasma and the brain. But as far as Kepler is concerned, things appear much different in the historiography. Some, like David Lindberg, consider Kepler as belonging to the tradition of perspectivist optics (beginning with Roger Bacon in the 13th century and based on the optics of Ibn Al-Haytham or Alhazen).[5] Others, like Stephen Straker or Raz Chen-Morris and Ofer Gal, insist on the very modern dimensions of his optics centered on the sole study of the rectilinear propagation of light rays (and thereby rejecting theories of *species sensibiles*).[6] What has rarely been noticed is that the picture becomes more complicated when one notices that Descartes also takes up another major dimension of Kepler's optics that is precisely not the one concerned with the study of the propagation of light according to optical principles inside the eye, but is rather concerned with a kind of psychological procedure to determine the distance at which objects seen are evaluated by eyesight.

[1]See for example Simon (1997).

[2]Descartes to Mersenne, 31 March 1638, AT II 86.

[3]See for example Lindberg (1976, 1986).

[4]See for example Simon (1975).

[5]See Lindberg (1976, 86, 122, 205, 207–208; 1978, 354). For a similar position, see Buchdahl (1972).

[6]See Straker (1971, vi–vii and *passim*; 1976); Gal and Chen-Morris (2010). A. Mark Smith proposes a more balanced interpretation: see Smith (1998, 13, 39, 42).

In order to account for this seemingly unexpected connection and to explain its significance, this paper will deal with two apparently different but ultimately intertwined, issues: (1) one is that of the evaluation of the distance of objects perceived by sight; (2) the other is that of the location of a reflected or refracted image. I shall simultaneously treat these two issues throughout this paper because I want to show that Descartes dealt with the first one in the way that Kepler dealt with the second one. Therefore the *terminus ad quem* of this paper is mainly the first issue as it is dealt with by Descartes. But to understand the deep epistemological reversal Descartes effected with regard to the Keplerian procedure, I will have to locate the latter procedure in its historical background and give insight on the status of reflected and refracted images and their location in visual space in the optical tradition from Euclid to the perspectivists. This will enable me to show that, while Kepler introduced a psychological procedure to account for the perception of what he considered to be errors concerning reflected or refracted images, Descartes took up this very procedure and transferred it to non-deceptive direct vision.

5.1 Perceiving Distance and Spatial Properties in Optics Before Kepler

It would be an anachronism to think that optics, since antiquity, has been a modern discipline insofar as it apprehended the external world only by means of mathematics. Indeed, from its very beginning, optics had never been independent from philosophical considerations that have had considerable consequences on its epistemology. This is mainly due to the fact that optics, at first, did not deal only with light but with the visible.[7] The fact that "optics" (in Greek *optica*) is derived from *ops* (the eye) clearly suggests that the reference-point of the discipline was the eye, not light. But since the eye, as the percipient organ, is not in direct contact with the objects seen, optics had to account for what could be called "the problem of vision": namely the fact that we do not see distant objects as being in our mind or in our eye but in the extended external world. The perception of visual space was therefore at the core of its interests.

For Euclid, this problem was solved by simply assuming that visual rays issue from the eye, forming a cone whose base is the object seen and whose vertex is the eye. Perception of distance was then just a question of interpreting line segments according to their apparent magnitude.[8] And this depended, for Euclid, on the

[7]This is one of the main theses defended by Gérard Simon: see Simon (1988).

[8]See Euclid (1945, def. 1–2, 4, 357).

magnitude of the visual angle (that is to say, the aperture of the visual cone). As a consequence, equal lines that are located at different distances do not appear as being the same size. Euclid's theory consisted of interpreting the appearance of real spatial configurations in a geometrical perspective.[9]

Ptolemy took up the theory of the visual ray and cone and directly applied it to the perception of distance, as sensed by the length of the visual rays. But, contrary to Euclid, Ptolemy did not limit himself to the perspective interpretation of apparent magnitudes and shapes and tried to account for the perception of three-dimensional objects.[10] The perception of the location and distance of objects in Ptolemy's *Optics* mainly relies on the capacity the visual rays have, within a continuous visual cone, to sense their own length.[11] This is an important difference with Euclid's optics in which only the aperture of the visual angle was taken into consideration to determine the size and distance of objects. Ptolemy's more realistic account of three-dimensional properties of bodies suggests that he was aware that the visual perception of space did not only consist in a perspective representation that one would have to account for afterwards, in terms of objective spatial properties, but that it was, right from the start, an interpretation of visual elements in three dimensions. One does not find a whole psychology of vision in Ptolemy,[12] but one should note that it is not really required since the visual ray, insofar as it is a mix of psychic and spatial reality, "inhabits," as it were, the external world.[13] The evaluation of the depth of the visual space ultimately relied on this projection of the soul into spatial reality (for example, this is required to understand how, for Euclid, the percipient can have knowledge of the width of the visual cone corresponding to the visual angle). Therefore, according to Gérard Simon, the question of the visual perception of space was not a real problem for Ptolemy's optics and it only became a problem in the Middle Ages.[14]

[9]Euclid (1945, 357): "Of equal spaces located upon the same straight line, those seen from a greater distance appear shorter"; Euclid (1945, 358): "Objects of equal size unequally distant appear unequal and the one lying the nearer to the eye always appear larger".

[10]On the visual perception of space (including location, size, shape, and motion) in Euclid's and Ptolemy's optics, see Lejeune (1948, 85–123).

[11]Ptolemy (1996, II 26, 81–82): "The visual faculty also discerns the place of bodies and apprehends it by reference to the location of its own source-points [i.e. the vertices of the visual cones]…as well as by the arrangements of the visual ray falling from the eye upon those bodies. That is longitudinal distance [is determined] by how far the rays extend outward from the vertex of the cone…whatever is seen with a longer ray appears farther away…".

[12]On the psychological elements present in Ptolemy's *Optics* to perceive the size, shape, location, movement and other properties of objects, see Smith (1988).

[13]See Simon (1994).

[14]See Simon (1981, 311).

Indeed when, with Alhazen's optics, the visual ray was replaced by the light ray between the object seen and the eye[15]; the former solutions based on visual rays devised to account for the sense of depth and distance in vision could no longer stand.[16] Alhazen's doctrine was known in western Christendom through the Latin translation of his optical work under the title *De aspectibus*. It was integrated by Roger Bacon, John Pecham and Witelo within the so-called perspectivist tradition which was to be the basis of Kepler's examination of optical matters.[17]

As opposed to the visual ray, the light ray could not possess self-knowledge of its own length. With the visual ray, emission theory endowed the eye with sensitivity of direction and depth: the object could be located in space thanks to the direction and length of the visual ray terminating on it. By rejecting emission theory, Alhazen had to do without the directional sensitivity it involved: the crystalline lens could only sense the presence of light, but no indication was given regarding where it came from.[18] Moreover, since light diffuses in every direction, the eye received on each of its parts overlapping light rays coming from various points on the object seen. It was thus hardly understandable how different parts of the perceptual space could ever be distinguished through this resulting confusion. However, Alhazen considered that the visible form of the object was impressed on the crystalline lens through the selection of light rays that were perpendicular to the surface of the eye and therefore not refracted and were the only ones to be sensed.[19] This allowed a one-to-one correspondence between the form sensed in

[15]Simon (1992, 213): "L'enjeu est de remplacer, par la propagation rectiligne *de la lumière*, l'antique rectilinéarité prêtée aux rayons *visuels* issus de l'œil." ("What is at stake is to replace, through the rectilinear propagation *of light*, the ancient rectilinearity that was attributed to the *visual* rays coming from the eye.") Lindberg (1967, 323): "*every visible object* is seen by the emission of its own light…Light and color remain the primary visible intentions, and the others are perceived through their mediation." Alhazen (2001, I 5, Sect. 27, vol. 2, 347): "the form of the visible object that sight perceives depends entirely upon the light possessed by that visible object, as well as upon the light that shines upon the eyes when that visible object is perceived, and upon [the light that illuminates] the aerial medium between the eyes and the visible object." Alhazen (2001, I 7, Sect. 1, vol. 2, 355): "it is a property of light to affect sight, whereas it is in the nature of sight to be affected by light." Alhazen (2001, I 7, Sect. 6, vol. 2, 356): "sight senses the light and colors that are in the surface of the visible object and…they pass through the transparency of the tunics of the eye." Alhazen, who would be followed by Witelo, clearly rejected visual rays: see Alhazen (2001, II 3, Sect. 71, vol. 2, 449); Witelo (1991, III 5, 111–112). Even if Roger Bacon and John Pecham would follow Alhazen on most topics, they would nevertheless maintain the hypothesis of visual rays as complementary to light rays in the process of vision. See Pecham (1970, I 67, 143); Lindberg (1967, 326, 339–341).

[16]As A. Mark Smith rightly notes, "the visual perception of the spatial characteristics of things is not immediate in the way our tactile perception of those things seems to be. The ulterior implication of the arguments is that there is absolutely nothing intuitive about spatial perception; it is an entirely inferential process" (Alhazen 2001, vol. 2, 543n.81).

[17]See Lindberg (1976).

[18]See Lindberg (1967).

[19]However, one must acknowledge that Alhazen and the perspectivists also tried to take into account to some extent the peripheral rays in the process of vision. The focus on the selection of the perpendicular rays comes largely from Kepler's criticism.

the crystalline lens and the object seen. At any rate, and even if the selective sensitivity of the crystalline lens prevented any optical confusion, the eye received only the forms of light and color, not the form of distance or of location. This means that Alhazen had to explain how three-dimensional vision was possible from this set of colored and luminous patches deprived of any spatial depth.[20] On the purely optical level, Alhazen considered images coming from each point on the object, (*optical forms* radiated in every direction from every point on the object) rather than a replica of the whole object.[21] As a consequence, the psychological process is meant to bridge the gap between a punctiform, purely geometrical analysis of the visual space (which can be analyzed into points) and a more "phenomenological" conception of space filled with objects distinct from one another and set in different positions relative to each other (and apprehended through a global *resultant psychological form* of the object).[22]

From the eye to the brain there is a continuous transmission of forms from the crystalline to the optical nerves, to the imagination, until the *ultimum sentiens* (last sentient). Then the faculty of judgment (*virtus distinctiva*) distinguishes and compares the different colors, the similarity or difference, and the relations between different parts (what Alhazen calls *intentiones visibiles*, including distance).[23] The outcome of this process is the production of a clear perception of the composition of the whole object. This results in the conception of an implicit judgment based on processes of recognition, differentiation, and deduction. But these processes

[20]However, note that the form received by the crystalline was not a real picture, as Kepler's retinal picture would be, but a purely sensorial form.

[21]Admittedly, Alhazen considered that the "form" of light and color was transmitted to the eye. But this word is not to be understood as a strict equivalent of the *species* which will be introduced in perspectivist optics only by Roger Bacon and Witelo. Neither can the form of light be strictly assimilated to the Aristotelian form which transports the appearance of the whole object. Indeed, even if Alhazen did not define the term in his *Optics*, the form of light emanates from point-sources and not from the visible object as a whole. See Sabra (1989, 116): "he proposed to subject form to geometrical analysis, something which no Aristotelian before him had thought of doing…" This form is only related to light and illuminated color, and not to the other properties, be they also visible like shape, of the object. Sabra (1989, 119): "Form in this sense is not to be confused with visible shape or figure or appearance; it simply refers to the light and colour themselves as physical properties of the luminous and coloured object." See also Smith (1981, 587) (for a different interpretation which associates Alhazen's form to Aristotle's, see Lindberg (1967, 335; 1976, 78–79). The selection of perpendicular rays by the crystalline then gives rise to an optical form which is an optical array, a pattern of light and colors from which the form of the object will be perceived (see Sabra 1978, 169, 173). One can therefore distinguish at least between three levels of form: the punctual form of light and color radiating from the object to the eye, the optical form sensed by the crystalline and the form of the object as it is perceived by the process of visual perception (for a similar analysis see Sabra 1989, 129–131). The form of light is thus expressed by the word *ṣūra* in Arabic (translated by *forma* in Latin, but never by *species*), whereas light as considered as an intention (that is to say as discerned by judgment) is referred to by the word *ma'nā*. See Sabra (1989, 117n.4).

[22]See El-Bizri (2005).

[23]On the perception of distance, see Alhazen (2001, II 3, Sects. 67–93, vol. 2, 448–457).

occur so quickly and are so customary that they are rarely ever noticed as such.[24] The intentions of distance and location are not transferred to the percipient by the forms of light and colors received in the crystalline and therefore must be elaborated by a kind of reasoning. The evaluation of distance (that is to say of the extent of space between observer and object[25]) by sight relies on an evaluation of the size of objects and intermediary spaces that are in a more or less continuous and ordered range between the percipient and the remote object.[26] The perspectivists took up this way of conceiving the evaluation of distance by sight. Roger Bacon included it among the things that can be perceived by means of syllogism.[27] Pecham emphasized that "the distance [from the observer] to the visible object is not perceived by sight, but is determined by reasoning [*ratiocinatione*]…"[28] Witelo kept Euclid's evaluation by the magnitude of the visual angle[29] but added the assistance of a *virtus distinctiva* inherited from Alhazen.[30]

5.2 The Status of Reflected and Refracted Images in Optics Before Kepler

I now turn to the second topic of inquiry of this paper that will ultimately return to the first, namely that of the evaluation of the location and distance of an object seen by reflection or refraction. For Ptolemy, it was not enough to account for vision as it enabled us to see objects as they were. But a good deal of the optics of the time was also meant to account for perceptual illusions and errors. Given the fact that visual rays were conceived as the externalization of our sense organs, it became indeed intriguing that we sometimes did not see objects where they were or in their true shape or colors. The study of reflected and refracted images was included in this analysis of perceptual errors, insofar as they implied that the

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[24]See Alhazen (2001, II 3, Sects.16–42, vol. 2, 431–438). See Sabra (1978).

[25]See Alhazen (2001, II 3, Sect. 68, 448).

[26]See Alhazen (2001, II 3, Sects. 72–77, vol. 2, 449–452). Alhazen (2001, II 3, Sect. 80, vol. 2, 453): "sight does not perceive the magnitude of the distance of a visible object unless its distance is spanned by a continuous, ordered range of bodies, and unless sight perceives those bodies and determines their measures accurately".

[27]See Bacon (1996, II 3.3, 207–213). Bacon notes that "distance can be grasped and certified if it is moderate, through the continuity of sensible bodies intervening between the eye and the distant object." (207) He adds that "distance is grasped…when a sequence of bodies is arranged continuously between the eye and the object, provided that the distance is moderate and that the eye will have inspected those bodies and certified their magnitudes" (211).

[28]Pecham (1970, I 63, 141). Proposition 64 is entitled "The magnitude of a distance is certified by the resolution of the intervening space into magnitudes of exactly known measure" (Pecham 1970, I 64, 141).

[29]See Risner (1572, Witelo IV 7, 120).

[30]See Risner (1572, Witelo, IV 9–10, 121–122).

visual ray was broken and thus impeded in seeing the object where it was. That means that reflection and refraction were not mainly conceived as natural phenomena produced by physical laws, but primarily as errors of sense perception where the percipient was misguided in identifying the object in the wrong place (for example in the case of an image reflected by a mirror or refracted in a transparent medium) or with a wrong shape or wrong color (when the object was seen through a colored glass for example). However, such illusions were considered to obey some principles that could be made explicit by optics. This led Ptolemy,[31] in the case of images reflected in a mirror, to formulate the *cathetus* rule: the object whose image is reflected in a mirror is seen at the intersection of (1) the visual ray drawn from the observer's eye to the point of reflection in the mirror and (2) the perpendicular dropped from the object to the mirror.[32] This rule initially based on visual rays was adopted by Alhazen[33] and taken up by the perspectivists Roger Bacon,[34] John Pecham,[35] and Witelo,[36] even if they considered that vision occurred exclusively or mainly by way of intromission. Pecham considered that this was rendered possible by the fact that "the length of rays are perceived by the eye,"[37] thus returning to Ptolemy's optics. Bacon, in his *Perspectiva*, was even more explicit, stating that "vision occurs by extramission."[38]

[31]This rule was also formulated in the pseudo-Euclid's *Catoptrics*.

[32]Ptolemy (1996, III 3, 131): "The first of these principles asserts that objects seen in mirrors appear along the extension of the [incident] visual ray that reaches them through reflection, the resulting line-of-sight being determined by the placement of the pupil with respect to the mirror. The second principle asserts that particular spots [on a visible object] seen in mirrors appear on the perpendicular dropped from the visible object to the mirror's surface and passing through it [i.e., the cathetus rule of reflection]." The third principle states the equality of the angles of incidence and of reflection.

[33]See Alhazen (2006, V 2, vol. 2, 385): "The image-location of any point is the point where the line of reflection intersects the normal imagined [to extend] from a point on a visible object to the line tangent to the common section of the surface of the mirror and the plane of reflection, or [to the common section] of the plane that coincides with [the plane of the] mirror and the plane of reflection".

[34]See Bacon (1996, III 1.2, 261–263).

[35]See Pecham (1970, II 19–20, 169–173).

[36]See Witelo (1983, V 37, 120–122). This proposition is entitled "The locus of the image of an object seen in any mirror must lie on the point of intersection of the line of reflection and the cathetus of incidence".

[37]Pecham (1970, II 20, 171).

[38]Bacon (1996, 261–263): "Along with these matters, it must be known that an object seen by reflection does not appear in its true place, because sight is accustomed to seeing by means of straight lines and [to judging] visible things to be at the extremities of these lines, and therefore it does not perceive the bending that occurs in reflection. Consequently, it judges the visible object always to be on [the rectilinear extension of] the visual ray, and the place of the image, which we call the 'appearance of the object', to be at one of its points. This is possible because vision occurs by extramission, and therefore vision judges the object to be in the direction of the species issuing from the eye. Although the object does not always appear in the same place, in most cases it appears at the intersection of the visual ray and the cathetus (the perpendicular drawn from the visible object to the mirror)".

5.3 The Perception of the Location and Distance of Reflected and Refracted Images in Kepler's Optics: An Approach Between Physics and Psychology

The historical background for the perception of distance and for the location of reflected images that I have presented will enable me to show first how Kepler's criticism of perspectivist optics on the issue of reflection remained nonetheless largely dependent on a number of conceptions that were to be found in the works of perspectivist opticians, and second how Descartes, by appropriating Kepler's analysis of the location of reflected and refracted images ended by transferring it to the problem-context of distance perception, thereby producing an important epistemological reversal.

In the 17th century, Kepler and Descartes completely reinvented optics and gave it a new foundation. The perception of spatial depth was affected by this reinvention. Now, Kepler and Descartes each appealed to a procedure of triangulation in order to account for the distance of what is seen. But Kepler did not apply the process of triangulation to exactly the same object as Descartes. It is therefore crucial to identify the functions the two authors gave to that process in their optics and in their theories of vision. Specifically, the idea of the evaluation of distance by a psychological process seems a bit alien to a modern optics centered on an analysis of light propagation. As we have seen, this had been a common approach in optics at least since Ptolemy and the solutions that were formulated relied heavily on various conceptions of the process of vision. Thus, what can Kepler's and Descartes' approaches teach us?

In his *Ad Vitellionem Paralipomena quibus Astronomiae Pars Optica traditur*, Kepler refuted the perspectivist theory of vision, in particular the privilege given to perpendicular light rays in the transmission of visible forms.[39] Kepler wanted to show that all light rays were transmitted through the eye but were refracted in such a way as to produce a punctiform picture of what is seen on the retina.[40] All along until the retina, light rays remain light rays and are not coupled with a parallel form that could be assimilated by the soul. As a consequence, through his new theory of light transmission, Kepler conducted a reform of optics that induced a new definition of its boundaries. Optics became mainly a science of light.[41] But the study of light rays could go no further than the opaque screen of the retina, after which the rays could no longer travel in a transparent media.[42] As a consequence,

[39]See Kepler (2000, V 4, 220) (KGW II 183).

[40]For a presentation of the demonstration of the formation of the retinal picture from light rays by Kepler, see Lindberg (1976, 193–202).

[41]See his preface to the *Dioptrice*, KGW IV 340, 22–23.

[42]See Kepler (2000, V 2, 180) (KGW II 152).

it seems impossible, according to Kepler's requirements, to explain how vision, in the mental sense of the term, occurs from the impression of the reversed and inversed picture of the outer world on the retina. This belongs to the work of "*Physici*" (natural philosophers).[43] It is thus with an analogical relation, expressed in a very elliptic way, between the retinal picture and the vision of the external world that Kepler formulated a potential explanation which eventually amounted to a refusal to enter into any explanatory process: "*Nam ut pictura, ita visio*"[44] However, we do not see the external world as if it were a painting. Except in the case of a perfectly made trompe-l'œil, we can always distinguish between the real spatial depth of the external world and the flatness of a painting. Consequently, by refusing to account for vision on the basis of the retinal picture, Kepler seemed to deprive optics of its psychological dimension. For, contrary to what the perspectivist theories proposed, what was transmitted through the eye onto the retina remained a purely luminous entity and was not coupled with a form of the visible realm that could be assimilated by the mind.

Now, despite this seeming exclusion of psychological considerations in optics, in the third chapter of his *Ad Vitellionem Paralipomena* dealing with reflected and refracted images, Kepler introduced a type of optical entity, *imago*, distinct from *pictura*,[45] and involving a clear psychological dimension. *Imago* was defined as follows:

> The Optical writers say it is an image [*imaginem*], when the object itself is indeed perceived along with its colors and the parts of its figure, but in a position not its own, and occasionally endowed with quantities not its own, and with an inappropriate ratio of parts of its figure. Briefly an image is the vision of some object conjoined with an error of the faculties contributing to the sense of vision. Thus, the image is practically nothing in itself, and should rather be called imagination [*imaginatio*]. The object is composed of the real form of color and light and of intensional quantities.[46]

[43]Kepler (2000, V 2, 180): "How this image or picture is joined together with the visual spirits that reside in the retina and in the nerve, and whether it is arraigned within by the spirits into the caverns of the cerebrum to the tribunal of the soul or of the visual faculty; whether the visual faculty, like a magistrate given by the soul, descending from the headquarters of the cerebrum outside to the visual nerve itself and the retina, as to lower courts, might go forth to meet this image—this, I say, I leave to the natural philosophers to argue about" (KGW II 151–152).

[44]Kepler (2000, V 4, 223): "For as the picture is, so is the vision." Kepler reached this formula after having stated that the function of the crystalline is not to enlarge the painting on the retina, but to make it clearer. The object painted on the retina should not "occupy a greater quantity on the retina than is correct" (KGW II 186).

[45]For the genesis of the distinction between these two types of images, see Dupré (2008, 2012). In the last article, Dupré shows that Kepler appropriated some innovations found in 16th century treatises of mathematical optics but aimed to give the physical causes of optical phenomena and acted as a natural philosopher in optics.

[46]Kepler (2000, III 2, def. I, 77) (KGW II 64).

Whereas colors were seen as they were in the object, spatial properties like size and shape, but also distance as we will see shortly, could be altered in the *imago*.[47] The opposition between *imago* and *pictura* was clearly expressed by Kepler:

> Since hitherto an Image has been a Being of the reason, now let the figures of objects that really exist on paper or upon another surface be called pictures.[48]

By opposition to the *pictura* which had an almost material existence (as it is the case with the retinal picture), but was only distinctly visible on a screen on which it was projected, the *imago* or *imaginatio* was, for Kepler, an entity visible per se, perceived by the eye, but which did not have the physical reality of the *pictura*.[49] It was a mix of physicality and subjective intentionality. To this kind of optical entity belong the images reflected in mirrors or seen by refraction. Kepler's approach to the status of reflected and refracted images is therefore in the line of ancient and perspectivist optics.[50] Now Kepler addressed the problem of the perception of location and distance through vision precisely when he dealt with these *imagines* in Chap. 3 of his *Paralipomena*. Kepler sought to determine where the perceived image was located, that is to say where vision located the object seen by a reflected or refracted image.[51] For that purpose, he appealed to a kind of geometry of the triangle and the process involved a psychological approach to vision:

> Thirdly, since to each animal a pair of eyes is given by nature, with a certain distance between them, by this support the sense of vision is most rightly used to judge [*iudicandas*] the distances of Visibles […]. For here it is simply the geometry of the triangle […].
>
> *For, given two angles of a triangle, with the side between them*, the remaining sides are given. In vision, the *sensus communis* grasps [*tenet*] the distance of its eyes through becoming accustomed to it, while it takes note of the angles at that distance from the perception of the turning of the eyes towards each other.[52]

While this geometry of the triangle did not essentially rely on a mental calculation or on determinate psychological faculties, it presupposed that the percipient had knowledge of the distance separating his eyes and the sensation produced by the rotation of his eyes orienting towards the object seen. This enabled the

[47]As I shall show, this is precisely the contrary in Descartes' optics where colors, as we perceive them, are not part of reality, whereas the properties of extension have a stabilized ontological status.

[48]Kepler (2000, V 3, def., 210) (KGW II 174).

[49]Simon (1979, 465): "l'image n'est rien d'autre que ce que l'on *voit*, elle n'a pas par elle-même une existence indépendante de *chose*." ("the image is nothing else than what is *seen*, it does not have by itself the independent existence of a *thing*.").

[50]Simon (1981, 306): "ce non-être existe dans notre imagination, mais projeté hors de nous, ce n'est qu'un fantôme. Voir une image, c'est voir la chose, mais là où elle n'est pas." ("this non-being exists in our imagination; but given that it is projected without us, it is only a phantom. Seeing an image is seeing the thing, but where it is not.") This statement is about Ptolemy's optics but can apply as well to the perspectivist tradition.

[51]On that aspect of Kepler's *Paralipomena*, see Simon (1979, 464–477).

[52]Kepler (2000, III 2, prop. VIII, 79) (KGW II 66).

observer to evaluate the two angles and the length of the intermediate side of a triangle formed by his two eyes and a point on the image of the object. By what resembles a calculation but which is not really one because it is more intuitive,[53] one could therefore determine the length of the two other sides, that is to say the distance between the percipient and the object.

As we have seen, the perspectivists gave a mainly psychological explanation of depth perception, but resorted to the cathetus rule to determine the locus in which the reflected or refracted image of an object is seen. Yet as Kepler showed, this rule was not valid for non-plane mirrors. Kepler's triangulation was therefore meant to replace the cathetus rule. He criticized the cathetus rule because it relied on a finalist principle.[54] Indeed, according to Witelo, "the object must appear on the perpendicular since we know…that this represents the shortest distance from either the surface of the mirror from which reflection is produced to the eye or the surface that forms its continuation. And along this perpendicular the object of sight maintains a uniform situation with respect to the mirror, and consequently the form of the object takes the designation of 'image' as we said before."[55] Kepler, on the other hand, considered that what was to be taken into account was the shape of the mirror at the point of reflection and the position of the two eyes in relation to this point. Since the eye has no possibility to determine where the ray comes from beyond the point of reflection, the sense of vision *imagines* that the object seen is located in the continuation of the reflected ray.[56] Kepler thus considered that the image of a point was located at the intersection of the reflected or refracted rays that would eventually reach the eyes. It is particularly noteworthy that Kepler then reintroduced the vocabulary of the visual ray: "And the genuine place of the image is that point in which the visual rays from the two eyes meet, extended through their respective points of refraction or reflection…Therefore,

[53]The mode according to which distance is apprehended through vision is expressed by the Latin verb *tenere*. This verb refers more to an act of grasping than to a step by step calculation. This is even more obvious in the passage on the triangle based on one eye where Kepler opposed grasping (*tenere*) and numbering (*numerare*), rejecting the latter: see below.

[54]Kepler (2000, III 1, 75): "[Alhazen] nevertheless seems to be implying that this location of the image on the perpendicular was long ago thus established by God the Creator because it would be best so, and no more fitting place could be given to the image…And in fact all these affects are consequences of vision by material necessity, where considerations of purpose or beauty have no place." (KGW II 63) On Kepler's criticism of the cathetus rule, see Chen-Morris and Unguru (2001).

[55]Witelo (1983, V 37, 122).

[56]Kepler (2000, III 2, prop. XVII, 85): "First, the sense of vision [*visus*] errs in direction…: it imagines for itself [*imaginatur sibi*] an object in the same direction whence the refracted or reflected ray approached. Next, the sense of vision also errs in the angle. For it imagines for itself that the inclination by which the refracted or reflected rays proceed all the way to the centers of the two eyes, is also the same as the inclination or angle by which proceed those rays which approach from the radiating point to the points of the reflections or refractions, corresponding to the eye…" (KGW II 72).

since the place of the image is in the meeting of the visual rays [*radii visorii*],…it will be in the meeting of the surfaces of refraction or reflection of the two eyes."[57] The visual ray is defined as "the luminous line drawn out by the imagination from the eye continuously through the point of reflection or refraction."[58] The light ray is thus extended by imagination beyond the point of reflection as if it were a visual ray. The capacity to locate images in the visual space therefore depends on the ability the imagination has to project, in a representative way, imaginary lines from the eyes to the point of reflection or refraction and beyond it in the visual space opened by the mirror or the refractive lens. Moreover, Kepler mentioned the *sensus communis* in the procedure of triangulation, a notion coming from Scholastic psychology and which seems here to refer to a function of the mind not assigned to a specific part of the body. One has to notice that in the analysis of depth perception for objects indirectly seen through *imagines*, Kepler did not appeal to imagination as a specific faculty, integrated in an ordered, multileveled psychological system in which it would be attributed a particular cognitive function (as this was the case in Scholastic and in the perspectivist traditions). For Kepler, imagination was on one hand the image seen, that is to say an object of vision, and on the other hand the activity of the sense of sight (and not so much of a proper faculty that would be called "imagination") when it illusorily locates the object of the image produced by reflection or refraction.

Now, in propositions 9–14 of Chap. 3, Kepler presented another way to evaluate distance that implied only one eye and that relied on a psychological function which can be considered as assigned to a part of the body. This second way of evaluating distance relied on a type of psychology immanent to the eye. Kepler considered that, depending on the distance of the image, a more or less dense quantity of light (that is to say more or less dispersed by a more or less wide beam)[59] entered the eye and was projected on the back of the eye. This projection would be more or less wide and therefore more or less dense depending on the quantity of light reaching the eye. The further away the object seen, the narrower the *pictura* projected on the retina.[60] The eye could then sense the density of light,[61] the size of this projection, as well as the geometrical configuration linking the extremities of this projection to the edges of the pupil. By being extended, these lines intersect in a point that indicates the distance at which the point on the object seen is located. Even though Kepler denied that the retina could "see" the retinal *pictura*, he considered that the eye could sense the density of light, the

[57]Kepler (2000, III 2, prop. XVII, 85) (KGW II 72).

[58]Kepler (2000, III 2, prop. XVII, 85) (KGW II 72).

[59]Kepler (2000, III 2, prop. XIII, 82): "For while light passes through this depth, it is spread out in a certain proportion…" (KGW II 69).

[60]Kepler (2000, III 2, prop. XIV, 83) (KGW II 70).

[61]Kepler (2000, III 2, prop. XI, 81): "it is fitting that there be in the eye the power of measuring either the density or rarity of both the air and the light." (KGW II 68); Kepler (2000, III 2, prop. XII, 82): "therefore, *the eye too will perceive the density of light*" (KGW II 69).

width of the retinal projection,[62] the distance between the retina and the pupil, and the pupil's diameter.[63] He endowed the eye as a whole and in a vague way[64] with a sensorial power of which he had precisely deprived the retina as a clearly identified physiological element. In other words, with the triangle based on one eye and not on binocular vision, as well as on the movement of the eyes turning towards each other to aim at what is seen, Kepler reintroduced a sensorial faculty in a diffuse way in the body, or at least in that part of the body which is the eye,[65] in a way similar to that of the perspectivists. It is important to note, especially in view of a clear difference with Descartes, that Kepler considered that the evaluation of the lengths of the sides of the triangle giving the distance of the point on the object in space was not subject to a calculus, but to an observation of the eye.[66] Kepler therefore assigned to multiple more or less decentralized instances the sensitive power which could be disseminated through various parts of the body.[67] This means that his psychology of vision was not a thoroughly coherent and centralized one.[68] This would also amount to an important difference with Descartes for whom the soul, and not the body, was the sensorial agent.[69]

[62]Kepler (2000, III 2, prop. XIII, 82): "we attributed to it a perception of the quantity of the surface touched by light." (KGW II 69) In proposition 61 of his *Dioptrice*, Kepler defined vision as "the sensation of the affected retina which is full of visual spirit; or seeing is sensing the retina being affected insofar as it is affected." (KGW IV 372: "Visio est sensio affectae retiformis spiritu visivo plenae: sive, Videre, est sentire affectam retiformem, quatenus affecta.").

[63]See Kepler (2000, III 2, prop. XIV, 83) (KGW II 69).

[64]Kepler's indecision is manifest in proposition XII. Kepler (2000, III 2, 82), my emphasis: "why therefore should *the eye or sense of vision* in general not also receive something contrary from this density of light, likewise in relation to its own density?" (KGW II 69).

[65]Kepler (2000, III 2, prop. X, 80–81): "For this faculty of setting up the measuring triangle is common to the two eyes together and to each eye separately" (KGW II 68).

[66]Kepler (2000, III 2, prop. XIV, 83): "it will consequently observe αη and αϑ, not, indeed, by numbering but by comparing the distances of the object through this habit, as it were, with the powers of its body, and the extension of hands and of paces" (KGW II 70).

[67]Simon (1979, 562): "[Kepler] multiplie les facultés psychiques ou leurs équivalents à l'intérieur du globe oculaire." ("[Kepler] multiplies the psychological faculties or their equivalents inside the eyeball.").

[68]Simon (1979, 563): "son panpsychisme lui permet, dans chacun des cas, de multiplier à sa convenance les zones et les formes de sensibilité, il le conduit à atomiser le sujet de l'acte de vision: au fil de la plume, ce qui 'sent', ce qui 'connaît', ce qui 'mesure', ce qui 'perçoit', ce qui 'compare', ce qui 'a l'habitude', ce qui 'estime', ce qui 'juge', est indifféremment une membrane de l'œil, l'œil lui-même, le sens commun ou la faculté visuelle, quand ce n'est pas tout simplement (et c'est le plus fréquent) *visus*, la vue." ("his panpsychism allows him, in each and every case, to multiply the areas and forms of sensibility as he wishes; it leads him to atomize the subject of the act of vision: in the course of writing, what 'senses,' what 'knows,' what 'measures,' what 'perceives,' what 'compares,' what 'is accustomed to,' what 'estimates,' what 'judges' is indifferently an eye membrane, the eye itself, the common sense or the visual faculty, when it is not very simply (and this is the most frequent case) *visus*, eyesight.").

[69]See Descartes (1984–1991, I, 164) (AT VI 109: "c'est l'âme qui sent, et non le corps").

Even if the eye was not able to perform a real calculus, Kepler conceived it, as is manifest in his analysis of images, as endowed with a power to recognize some mathematical relations in space. This means that, in Kepler's theory, there is no actual explicit inferential procedure. In that case, how is it possible for the eye or the sense of vision to "sense" or imagine these spatial mathematical relations? One possible answer lies in Kepler's theory of knowledge insofar as it aimed to renew the relations between sense perception and mathematics.[70] This is more explicit in Kepler's theory of harmonies: the human mind does not abstract mathematical ratios from the sensible but is itself endowed with mathematical knowledge. In his *Harmonice mundi*, Kepler thus wrote: "Proportions are entities of Reason, perceptible by reason alone, not by sense, and to distinguish proportions, as form, from that which is proportioned, as matter, is the work of the mind."[71] The key to such mechanisms resides in the fact that "the soul has knowledge of mathematics by instinct."[72]

> Indeed to the human mind and to other minds quantity is known by instinct, even if for this purpose it is deprived of all sensation. Of itself it understands a straight line, of itself an equal distance from a given point, of itself it forms for itself from these an image of a circle. If so, it can much more readily find the construction by means of that, and so perform the function of the eye in seeing the diagram (if there is nevertheless a need for one).[73]

This mathematical instinct seems to exclude any properly discursive reasoning (and it is common to human beings and to animals here designated as "other minds"). This is certainly a reason why it involves an imagining activity rather than the intellect.[74] The soul can spontaneously construct the image of a circle.[75] It can also, by imagination, take on the function of an eye contemplating a diagram. Moreover, the eye can only see the geometrical diagram because it was conceived in conformity with the soul. The eye sees because it is functionally patterned on the soul, and in particular on the soul's capacity for inner visualization. In other words, the eye was patterned on imagination. To summarize, visual perception works in a way that depends on the mind, which itself is imprinted with mathematics. The eye is meant to be used by the mind in order to recognize mathematical entities in nature:

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[70]On this topic in general, see Chen-Morris (2001). This article gives a thorough analysis of this question in relation to its Aristotelian background. I rely on it in order to link this topic to the evaluation of the distance of images in Kepler's optics. See also Escobar (2008).

[71]Kepler (1997, III. I, 150) (KGW VI 107).

[72]Kepler (1997, IV. I, 303) (KGW VI 223: "Anima habet scientiam Mathematum ex instinctu").

[73]Kepler (1997, IV. I, 303–304) (KGW VI 223).

[74]We shall see that the involvement of imagination in the Cartesian natural geometry obeys a quite different logic (since it is reserved for human beings).

[75]In the *Harmonice mundi*, Kepler indeed claims that the circle is like the form of the created soul: see KGW VI 277 ("ut forma quaedam ipsius Animae"); Kepler (1997, 373).

> Certainly the mind itself, if it never had the use of an eye at all, would demand an eye for itself for the comprehension of things which are placed outside it, and would lay down laws for its structure which were drawn from itself…For the recognition of quantities, which is innate in the mind, dictates what the nature of the eye must be; and therefore, the eye has been made as it is because the mind is as it is, and not the other way round.[76]

By means of sensation, the soul recognizes in the world its own nature, what properly belongs to it, that is to say mathematical entities produced by the imagination.[77] The human mind can thus see itself reflected in sensible perceptions insofar as it informs the sensorial faculties. One understands then the possibility the mind has to project visual intentional rays in visual space so that it can recognize there the mathematical relations that will allow it to determine the location of an *imago*.

In the two ways of evaluating distance by sight, Chap. 3 of the *Paralipomena* brought into play a physiological and psychological dimension of vision, before Kepler dealt with the eye and the *modus visionis* in this chapter. Kepler thus rejected the cathetus rule but conserved an intentional dimension to the perception of the distance of refracted or reflected images that came from perspectivist optics. This dimension is mostly manifest in the mention of visual rays and in a judgment performed by the sense of vision. On the contrary, Kepler gave a mostly physical account of the *pictura* by searching to locate the source of divergent light rays that produce this kind of image.[78] *Imago* and *pictura* therefore gave rise to two distinguished optical explanations. The psychological account of the distance of reflected or refracted images was developed within a theoretical framework which obviously escaped from Keplerian optical reform based on the theory of retinal picture formation. If both images involved a geometrical analysis, the *pictura* referred to physical reality,[79] whereas the *imago* was no more than an illusion with respect to the real situation of the object in space. This disjunction shows that Kepler, from that point of view, remained the heir of a traditional optics which considered that reflected or refracted images showed objects where they were not,

[76]Kepler (1997, IV. I, 304) (KGW VI 223).

[77]See Claessens (2011).

[78]For the posterity and the reinterpretation of these two dimensions of Keplerian optics into real and virtual images, see Shapiro (2008).

[79]The retinal picture can be analyzed in geometrical terms and is liable to geometrical definition through the very way it is formed from light rays being refracted in the eye. This mathematical dimension explains why it can faithfully reproduce the external world: see Malet (1990). J.V. Field even goes as far as to claim that Kepler's confidence in the fact that physical things behave like mathematical ones can account for his adoption of a reversed and inversed retinal picture as what provokes vision: see Field (1986). The mathematical dimension is also central to Kepler's analysis of reflected and refracted images, but it involves an intentional dimension that makes it less certain and more liable to errors.

that is to say fell under visual illusions.[80] The evaluation of the distance of these images in a kind of virtual, purely visual, space could therefore not be confused with the evaluation of the distance of objects in their true place and in their true spatial properties.[81] This is indeed very telling that, when Kepler dealt with the evaluation of distance by direct vision in his *Dioptrice*, he mainly remained within the theoretical framework of traditional optics, taking into consideration the visual angle, as in Euclid, and the relation between the size attributed to the object and its unknown distance, but appealing to no operation of triangulation as Descartes would do.[82] Moreover, for Kepler, even the rules according to which the distance and location of reflected and refracted images could be determined were liable to errors.[83] In Kepler's optics, the psychological process of distance measuring by triangulation could in no way constitute the basis of an epistemological foundation of vision. In the final part of this paper, I want to show that Descartes precisely took up the Keplerian distance-measuring triangle, but applied it to another subject: not to the distance of images but to the distance of objects themselves as they are seen through direct vision. This brought about an important epistemological reversal in Descartes' theory of vision.

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[80]For example, Pecham defined the images reflected in mirrors as follows: "What then is an image [*ydolum*]? I say that it is merely the appearance of an object outside its place [*apparitio rei extra locum suum*]…it is the object that is really seen in a mirror, although it is misapprehended in position [*in situ erratur*] and sometimes in number…"(Pecham 1970, II 19, 171).

[81]Simon (1979, 584–585): "Tant que, derrière la distinction entre *pictura* et *imago*, se profile le réalisme intellectualiste de la pensée médiévale, l'image étant due à un jugement reste une entité psychique, et ne peut, comme effet d'un rayonnement, matérialiser fictivement une origine extérieure: sa 'virtualité' est dans la tête de l'observateur, non dans l'espace qui lui fait face." ("As long as the intellectual realism of medieval thought looms behind the distinction between *pictura* and *imago*, the image arising from a judgment remains a psychological entity and cannot, as the effect of light radiation, materialize its outward origin in a fictitious way: its 'virtuality' resides in the observer's head, not in the space facing him.").

[82]See *Dioptrice*, propositions 67–68, KGW IV 376–377.

[83]Hamou (1999, 215): "[Kepler chercha à] lui substituer une règle d'assignation de la distance et de la 'quantité' (grandeur) de l'image qui met en jeu le facteur intentionnel…(l'œil est attiré spontanément vers la lumière et juge de la direction des objets en fonction de celle des rayons qui lui parviennent) et un jugement trigonométrique implicite…Cela étant, la règle de localisation des images proposée par Kepler…ne permet pas de comprendre l'image vue par réfraction comme pourvue d'un lieu géométrique réel. Non seulement la localisation est l'effet d'un jugement où intervient une connaissance naturalisée, une habitude, et donc est éminemment susceptible d'erreur, mais, comme le montre l'étude 'phénoménologique' des *Paralipomènes*, il y a plusieurs circonstances qui font que la règle parfois ne s'applique pas." ("[Kepler sought to] replace [the cathetus rule] with a rule by which to assign the distance and 'quantity' (magnitude) of the image involving an intentional factor…(the eye is spontaneously attracted to light and judges of the direction of objects according to that of the rays that reach it) and an implicit trigonometric judgment…That being so, the rule of localization of images proposed by Kepler…does not allow one to understand how the image seen through refraction could be located in a real geometrical locus. Not only is the localization an effect of a judgment involving some naturalized knowledge, some habit, and is therefore eminently liable to error, but, as shown by the 'phenomenological' inquiry of the *Paralipomena*, in several circumstances the rule sometimes does not apply.").

5.4 The Perception of Distance Through a Natural Geometry in Descartes' Optics

Descartes, who was usually very reluctant to acknowledge his sources, did not hesitate to declare to Mersenne that Kepler was his "first master in optics."[84] Descartes' *Dioptrique* indeed took up Kepler's account of the retinal image and attempted to determine the conditions that enabled it to be as accurate and complete as possible. But, what really mattered for Descartes was not so much the retinal picture itself as the judgment produced in sense perception out of which we determine, from what we see, that the external object located in space is endowed with a given property (among which that it is situated at such a distance and possesses such a shape).[85] But the optical analysis of the retinal picture did not suffice to account for all the dimensions of the bodies perceived. In particular, the problem of the perception of spatial three-dimensionality remained to be solved. For that purpose, Descartes appealed to a procedure which did not belong solely to physical optics. Within the realm of the latter, one could at best have explained through which procedures we could perceive a picture of colored spots in two dimensions that would be similar to the retinal picture.[86] But how could one account for the sense of spatial depth which is always associated with our visual perception? How could one explain that the light rays that reach the eyes also make us see the shape of the object in three dimensions?

Descartes added to his mechanical optics (according to which a picture is imprinted, after several refractions, on the retina and movements are transmitted to the brain and the pineal gland) a *natural geometry* required to make us access the visual perception of shape, distance and depth. In Discourse VI of his *Dioptrique*, he gave a specific treatment of the situation, distance, size and shape of the bodies as they are perceived through vision. He used the expression "natural geometry" only to describe the evaluation by sight of the distance at which bodies are situated:

> In the second place, we know distance by the relations of the eye to one another. Our blind man holding the two sticks AE and CE (whose length I assume he does not know) and knowing only the distance between his two hands A and C and the size of the angles ACE and CAE, can tell from this knowledge, as if by a natural geometry, where the point E is. And similarly, when our two eyes A and B are turned towards point X, the length of

[84]Descartes to Mersenne, 31 March 1638, AT II 86.

[85]On this topic, see Descartes' *Replies to the Sixth Objections* (AT VII 436–439; AT IX-1 236–238) and my comment in Bellis (2010, 376–401).

[86]I am not here saying that Descartes conceived of the retinal picture as giving rise to a kind of rough sensation of colored spots in two dimensions that would be elaborated upon by a psychological process. Actually, for Descartes, our sensations always involved, right from the start, the perception of three-dimensional space. In his *Reply to the Sixth Objections*, Descartes seemed to distinguish between these two levels of sensation, the more complex one involving a judgment. But, as I have shown elsewhere, the distinction is only the result of an analytical explanation that was not intended to give a genetic account of sense perception. See Bellis (2010, 383–387).

> the line AB and the size of the two angles XAB and XBA enable us to know where the point X is…And this is done by a mental act which, though only a very simple act of the imagination, involves a kind of reasoning quite similar to that used by surveyors when they measure inaccessible places by means of two different vantage points.[87]

This natural geometry relies on a distance-measuring triangle very similar to that of Kepler's *Paralipomena*[88] and consists in a kind of calculation. But Descartes displaced the field of application of this psychological procedure from reflected and refracted images to bodies seen by direct vision. As a consequence, natural geometry does not only refer to a question of psychology, but also to a question of epistemology, since what is at stake is to know whether and under which conditions vision can allow us to situate objects in space according to their true distance, location, size, and shape.[89] From that epistemological point of view, the very idea of a geometry is revealing since natural geometry ought to have its principles and rules, just like mathematical geometry. Both were instituted by God, either through the institution of Nature (as the term "natural" qualifying this geometry suggests), or through the free creation of eternal truths.[90] In the case of natural geometry, its principles correlate the distance between our eyes—a distance which is inscribed in our body—and the movement of the eyes required to see an object situated in a determinate part of the visual space with the distance at which this object is situated. There is almost a kind of mathematical relation between bodily data and objective properties of the material extended reality. The idea of a natural geometry also suggests that this psychological process is based, as geometry in general is for Descartes, on innate ideas. These are the bases for natural geometry, enabling us to recognize geometrical figures in space.[91]

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[87] Descartes (1984–1991, I, 170; AT VI 137–138).

[88] See de Buzon (1991, 98–99 n. 21)

[89] The determination of the shape and size of bodies indeed ultimately relies on that of distance and location: see below. My epistemological interpretation of the natural geometry therefore differs from Celia Wolf-Devine's interpretation: see Wolf-Devine (1993, 76–77). It also opposes Malet's skeptical reading of the power of the senses as presented in the *Dioptrique*: see Malet (2001). Instead of considering that "Descartes held our eyes to be hardly reliable at measuring distances" (Malet 2001, 129) because he stated that the various procedures at hand were reliable only below certain distances, I think that Descartes precisely gave the restricted conditions under which it is possible to see the spatial properties of things as they are. This restriction is not a skeptical perspective, but rather the establishing of the conditions under which eyesight faithfully gives us access to the spatial properties of extension. That optics in the early modern period involved important epistemological stakes can be seen for example in the way optics was defined as "the art of seeing well," which means that its aim was to judge of the truth or of the fallacy of what is seen. This statement is found in Risner. Risner (1606, 3): "Optica est ars bene videndi. Optica suo fine definitur, qui est bene videre, id est, de veritate & fallacia visibilium accurate and exquisite judicare." ("Optics is the art of seeing well. Optics is defined by its aim which is seeing well, that is to say judging precisely and in a thought-out way the truth and falseness of visible things.").

[90] See Descartes to Mersenne, 15 April 1630, 6 May 1630, 27 May 1630, AT I 145–146, 149–150, 151–153.

[91] See Descartes' *Reply* to Gassendi's *Fifth Objections*, AT VII 381–382.

However, does the percipient actually appeal to an effective geometry or is this only an analogy? In the *Dioptrique*, just as in *L'Homme*,[92] the expression was used about the blind man holding two sticks and came into play within a comparison ("*as if* by a natural geometry"). At first sight, it is an analogy within an analogy, or a second-order analogy. As a consequence, what importance should we give to such a notion? Is a true geometry really involved in sensation? Is natural geometry really a geometry? I shall argue that this is really the case, but precisely insofar as this geometry falls under the institution of nature. By this institution, our physiological mechanism is constituted in such a way that it makes the soul sense the essential properties of the bodies seen, on the basis of a correlation between on one hand a modification of the pressure exerted on the optical nerve, the movements of the small strings enclosed in the nerves, the position of our eyes and of our body in space, etc., and on the other hand what our soul senses in terms of the distance of the object perceived. For Descartes, God has imprinted in our body and in our soul a certain type of reaction according to the data linked to the position and shape of our body (or of some of its parts) and the surrounding bodies.

But a "reasoning" is also involved. Through natural geometry, Descartes wanted to conceive a psychological procedure by which the percipient could sense the spatial three-dimensionality, and not only rough two-dimensional visual data made of colored and luminous spots. The introduction of a natural geometry signifies that, for Descartes, sensing spatial depth did not fall under raw visual data. It also means that it was not obtained through an inference that would associate, on the basis of repeated experiences, the vision of two-dimensional luminous and colored spots, or the sensation of ocular movement, with the evaluation of distance through, for example, the displacement in space of a subject who would, afterwards, touch objects where they actually stood. Vision in perspective is not the result of an apprenticeship correlating plane vision and touch, but it is produced thanks to bodily conditions and to a trigonometric reasoning, thus to geometrical notions.[93]

In the *Dioptrique*, natural geometry was one of three ways to determine the distance at which an object is seen.[94] However, the whole of the psycho-physiological processes at stake in vision eventually relied on a natural geometry. Indeed, according to Descartes, the determination of the shape and size of bodies

[92]See AT XI 160.

[93]Simmons (2003, 398): "These judgments effectively recover the three-dimensional properties of objects and explain perceptual constancy: they explain why things look to have constant shapes and sizes despite the fact that the portion of the visual field they fill is constantly changing as we move through the environment".

[94]The two others respectively rely on a change in the shape of the eye (accommodation) and on the more or less important degree of distinction and of luminosity of the sensible representation: see AT VI 137–140.

ultimately relied on the determination of the situation and distance.[95] Regarding the evaluation of situation, it might first appear as a purely bodily, thus mechanical, process: "Our knowledge of it does not depend on any image, nor on any action coming from the object, but solely on the position of the tiny parts of the brain where the nerves originate."[96] But the following part of the text indicates that this operation goes beyond mere mechanism, insofar as it implies a geometrical understanding of visual space inherited from the Euclidean tradition (including what the visual ray aims at):

> For this position changes ever so slightly each time there is a change in the position of the limbs in which the nerves are embedded. Thus it is ordained by nature to enable the soul not only to know the place occupied by each part of the body it animates relative to all the others, but also to *shift attention* from these places to any of those lying on the straight lines which we can *imagine* to be drawn from the extremity of each part and extended to infinity.[97]

This geometrical structure of visual space by rectilinear projection is the result of a quasi-intentional activity of the mind by which an object is aimed for within a natural geometry.[98] On the one hand, light acts upon the eye according to physical rays which are nothing else than the communication, in a continuum of subtle matter, of the pressure coming from the movements of particles of the first element in the Sun to the observer, these rays being liable to reflection or refraction through their encounter with visible objects. These rays correspond to the lines along which a real physical action is produced. On the other hand, the imagination can trace in the surrounding extension some imaginary, mathematical and not physical, lines by which thought can situate objects in space, in relation to my body and to other bodies. The analysis of vision that Descartes proposed thus effectuates an organization of material reality according to geometrical lines which correspond to a physical reality as well as to a psycho-spatial reality. Admittedly, these lines are not perfectly identical, since the physical lines ultimately refer to invisible corpuscular phenomena by which light rays are propagated, and the geometrical lines correspond to the sensible grasp of the external spatial reality. Moreover, even if one considers light propagation in straight lines at the macroscopic level, imagination goes past the geometrical line followed by the reflected ray of light and extends the imaginary line beyond the object. This enables the percipient to locate

[95] Descartes (1984–1991, I, 172): "Concerning the manner in which we see the size and shape of objects, I need not say anything in particular since it is wholly included in the way we see the distance and the position of their parts" (AT VI 140).

[96] Descartes (1984–1991, I, 169); AT VI 134.

[97] Descartes (1984–1991, I, 169, my emphasis); AT VI 134–135.

[98] Hyman (1986, 160): "…the situation of an object or a part of one is naturally identified by means of a deictic gesture, by pointing, and not by means of a description, and so the visual perception of situation is perfectly attuned to the walking-stick analogy".

Fig. 5.1 The blind man and the perception of distance (AT VI 135), in *Renati Descartes Specimina Philosophiae*, Amsterdam: Blaeu, 1685, p. 87 (reproduced with kind permission of the University Library of the Radboud University Nijmegen)

the object in extended space in general, and not only according to the punctual spatial relation of my body to this object (Fig. 5.1):

> In the same way, when the blind man, of whom we have already spoken so much, turns his hand A towards E, or again his hand C towards E, the nerves embedded in that hand cause a certain change in his brain, and through this change his soul can know not only the place A or C but also all the other places located on the straight line AE or CE; in this way his soul can turn its attention to the objects B and D, and determine the places they occupy without in any way knowing or thinking of those which his hands occupy.[99]

Natural geometry thus allows us to access a whole perceptual space with multiple relations. The lines in the perceptual space are drawn by the imagination which also locates objects within this space. By opposition to Kepler's triangulation in Chap. 3 of his *Paralipomena*, here the imagination allows the mind to project itself in a non-illusory way in real extended space (and not only in an imaginary or virtual space opened by the mirror). Admittedly, the location and distance of objects is evaluated in relation to my own body.[100] But Descartes here suggests that imagi-

[99]Descartes (1984–1991, I, 169); AT VI 135.

[100]Simmons (2003, 400): "What Descartes and Malebranche are latching onto here is the fact that in sensory experience the perceiver's body effectively fixes the origin and the axial symmetries of the space within which objects appear to be located: my body is always located as *here* and objects appear as situated *around me*, at some distance and direction from here." But Simmons does not take into account the capacity of projection of the imagination beyond the punctual spatial relation of my body to the object aimed at by eyesight. Moreover, the fact that the operation by which I locate objects in space is always made from a specific point of reference does not constitute, for all that, a hindrance in gaining access to the objective space through eyesight. This objectivity is precisely guaranteed by natural geometry, in the same way as a two-dimensional painting seen from a given point of view constitutes a basis from which I can reconstitute a three-dimensional landscape whose dimensions do not depend only on my particular situation in relation to the painting.

nation is endowed with a capacity to overstep the mere relation of my body to the object that I see by projecting itself in extension beyond a given object.

As Descartes intimates as a possibility in the text of the *Fifth Meditation*, I can indeed project the essence of matter (that is to say extension or geometrical space) into my sensations by means of imagination. Geometrical extension is present in my mind as an innate and imaginable idea. Therefore, I can reconstruct the material objects as they are perceived in vision thanks to this faculty of projection which lies in the imagination. Imagination is the mode of thinking by which I represent to myself the "'continuous' quantity as the philosophers commonly call it," that is to say "the extension of the quantity (or rather of the thing which is quantified) in length, breadth and depth."[101] If imagination is required in natural geometry, this is because it is required to represent spatial depth in general, but above all the particular aspects of spatial depth:

> I also enumerate various parts of the thing, and to these parts I assign various sizes, shapes, positions and local motions; and to the motions I assign various durations.
>
> Not only are all these things very well known and transparent to me when regarded in this general way, but in addition there are countless particular features regarding shape, number, motion and so on, which I perceive when *I give them my attention* [*attendendo percipio*]. And the truth of these matters is so open and *so much in harmony with my nature* [*naturae meae consentanea*], that on first discovering them it seems that I am not so much learning something new as remembering what I knew before; or it seems like noticing for the first time things which were long present within me although I had never *turned my mental gaze on them* [*in illa obtutum mentis convertissem*] before.[102]

Instead of giving an almost Platonist interpretation of this passage, I propose to interpret it as echoing the Cartesian theory of natural geometry. Admittedly, mathematical ideas are innate in our mind. But the application of the mind's attention can here be interpreted not only according to pure intellection, but also as the specific effort of the mind that is proper to imagination. Moreover, if the particular truths I discover about numbers, shapes, and movements are "in harmony with my nature," this is because these mathematical truths are *mentibus nostris ingenitae*.[103] But these "particular features" are also imprinted in our body—even if this body's existence has not yet been established at this moment of the *Meditations*. These features are perceived by vision through a process of projection of the imagination in spatial extension thanks to which we measure and locate the various parts of the surrounding bodies. In this process, no iconic element is presupposed as a prerequisite to effective vision (as was the case with Scholastic *species*). On the contrary, in vision the mind itself depicts the visual picture. And imagination comes into play precisely at this level. In other words, the imagination's activity replaces the images-species' objectivity. Apart from the soul, there is only body and body cannot project itself into space, except physically by motion. The Cartesian conception of vision is therefore not deprived of intentionality but the latter is performed by

[101] Descartes (1984–1991, II, 44); AT VII 63.

[102] Descartes (1984–1991, II, 44 my emphasis on the English translation); AT VII 63–64.

[103] Descartes to Mersenne, 15 April 1630, AT I 145.

imagination which is the mode *par excellence* of spatial representation. Mathematical imagination possesses a dimension of intentionality insofar as it allows the mind, in visual sensation, to hone in on corporeal extension in its particular features, but also in its more general features, since Descartes considers that it is possible to imagine lines "extended to infinity." Thanks to the role played by imagination in vision, vision is not a truncated representation of spatial extension, but encompasses it as an infinite potential space.

Thus, there exists in the *Dioptrique*, apart from the mechanical processes linked to the tendency to motion of the subtle matter exerted on the eye, another aspect of vision, which is not purely mechanical but is nevertheless geometrical. Whereas Kepler subordinated the psychological dimension of vision to the identification of the cause of our perceptual errors concerning reflected or refracted images, Descartes fully endorsed that, in non-deceptive direct vision, a psychological dimension, in addition to the purely physical dimension, comes into play. This does not mean that Descartes just came back to the theories of the visual ray or to the perspectivist or Scholastic theories which analyzed vision on the basis of species, a mix of physical and psychological reality that transported the object's resemblance and made it visible as it is.[104] There is no confusion any more between the study of the propagation of light and the theory of vision. However, the visible and, in particular, the spatial depth, became subjected to a mental reconstruction that involved the psychological activity of the subject. This psychological dimension does not appear as an obvious component that naturally accompanies the transmission of light and species, but as a required dimension of vision, *additional* to the study of light propagation which, because it has become in the meantime autonomous, cannot account anymore for spatial depth. Because of the real distinction between the soul and the body, Descartes claimed: "it is the soul that has sensory perceptions, and not the body."[105] There is now one psychological instance involved in the process of vision, the soul. This marks a noticeable difference with Kepler who multiplied the sentient instances.[106] This is the reason why Descartes, if he took up Kepler's triangulation, did not take up the distance-measuring triangle based on only one eye, but instead displaced the eye at two different points of observation (which amounts to reconstituting binocular vision in the imagination).[107] The Keplerian explanation supposed that the eye itself evaluated the width of the luminous projection on the retina—which Descartes would

[104]See Hamou (2002, 39–44).

[105]Descartes (1984–1991, I, 164) (AT VI 109: "c'est l'âme qui sent, et non le corps").

[106]Simon (1979, 570): "La sensibilité indistincte et instruite dont on parsemait quasi par inadvertance les organes des sens jusqu'à leurs plus infimes parties, a définitivement disparu." ("The indistinct and informed sensibility that was diffused, almost inadvertently, throughout the sense organs unto their most minute parts has definitively vanished.").

[107]See AT VI 138.

exclude[108]—and perceived lengths. For Descartes, that would then amount to assuming that the eye, in a way, thinks, which was impossible for him.

Descartes' natural geometry represents a new step in the conceptualization of the evaluation of distance by eyesight. By distinction with Alhazen, the reasoning implied in the natural geometry of vision is clearly embedded in bodily capacities (since it is based on the distance between the two eyes and the movement of rotation of the eyes). This will open the way to Malebranche's "natural judgment."[109] But at the same time, it relies on a centralized psychological instance that effectuates all the operations of sensation, imagination, and reasoning. This sets Descartes apart from the perspectivist and the Keplerian psychology of vision, even if they all considered that a kind of judgment was involved in the process of perceiving distances.

5.5 Conclusion

Descartes therefore applied to vision (understood as the mental representation of an object located in three-dimensional space) a type of explanation that Kepler applied to images that had mainly a mental reality in virtual space. Descartes took into full consideration the psychological dimension of direct vision and reintegrated it into a theory which aimed to account for, not illusory images, but images corresponding to real extended space. The procedure that guarantees the correspondence between vision and reality belongs to what, for Kepler, was illusorily projected by the mind in visual space. Descartes relied on Kepler to produce an epistemological reversal as to the reliability of vision. For Descartes, an object is seen in the way an *imago* was seen for Kepler.[110] The displacement operated by Descartes not only implies a new psychology of vision, but also an epistemological foundation of vision that attempts to bridge the gap between the thinking subject and the extended world, or between visual space and extended space.

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[108]Descartes (1984–1991, I, 167): "Now, when this picture thus passes to the inside of our head, it still bears some resemblance to the objects from which it proceeds. As I have amply shown already, however, we must not think that it is by means of this resemblance that the picture causes our sensory perception of these objects—as if there were yet other eyes within our brain with which we could perceive it" (AT VI 130).

[109]See Hamou (2002, 120–122).

[110]Opticians after Descartes will rather accomplish an inverse move in considering that an image is perceived as an object that is to say at the place where the light bundle seems to diverge. See Shapiro (2008).

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Chapter 6
Experimental Cartesianism and the Problem of Space

Mihnea Dobre

Abstract Notoriously, Descartes does not have a concept of space. Or more precisely, he takes space as indistinguishable from matter or extension. Yet, to some of his contemporaries, his physics was successful at providing mechanical descriptions of the natural world. In this paper, I discuss the problem of "space" within a larger Cartesian framework, focusing on a case of an experimentally-minded Cartesian who took up the challenge provided by Descartes's restrictive ontology and tried to accommodate it to experimental trials. One of the most famous debates of seventeenth-century natural philosophy concerns the existence of the vacuum. New instruments were built with the specific purpose of providing clear evidence to support this claim. While a large secondary literature has been devoted to this problem, we still lack a study of the Cartesians involved. Most of the time, Descartes's followers are taken to merely repeat his words about the contradictory nature of the vacuum, hence their experiments are portrayed as rather misplaced practices. At most, one would find in the literature a discussion about the pedagogical value of these experiments. The consequence is that new experimental approaches provided by Cartesians after Descartes's death in 1650 are, unfortunately, neglected. By building upon a recent volume, *Cartesian Empiricisms*, my aim in this paper is to explore the notion of space within Cartesian experimentalism. In doing so, I shall refer to the works of Burchard de Volder, Jacques Rohault, and Samuel Clarke's annotations of Rohault's text. Some of the questions I would like to address are as follows: why would a Cartesian natural philosopher perform experiments that are clearly connected to a concept of independent space? What would be the expected outcome? How does the theory (in this case, the Cartesian matter theory) relate to empirical evidence? And how would the latter influence the former? Such questions are relevant for the history of experiment in the early modern period. At the same time, they offer more insights into one of the most intricate problems of Cartesian philosophy, the relation between metaphysics and physics.

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When Isaac Newton drafted his *De gravitatione*, he referred to "quantity," "duration," and "space" as "[terms] too well known to be susceptible of definition by other words."[1] Of course, in *De gravitatione*, as well as in the *Principia*, Newton opposed René Descartes's views by claiming that space is independent from bodies and, hence, bodies change or remain in the same place; with "place" understood as a part of space. A consequence of this view is that empty spaces are possible; in other words, void spaces are likely to exist in nature. But Newton's theory was advanced after the great debates concerning the existence of the vacuum that marked the natural philosophy of the 1650s and 1660s. The main figure in these debates was Robert Boyle, who directed the discussion from metaphysical issues to experimental trials. After denouncing "the controversy about a vacuum [as] rather a metaphysical, than a physiological question; which therefore we shall here no longer debate" (Boyle 1772, 38), Boyle turned to experiment. At the heart of those debates was the use of a so-called *philosophical instrument*, the air-pump, which quickly became associated with the Royal Society and experimental philosophy.[2] The air-pump was the successor of other devices derived from the famous Torricellian experiment of 1644 and replicated with great success by several French natural philosophers.[3]

On June 11, 1644, Evangelista Torricelli conducted an experiment with a glass tube filled with mercury. Sealed at one end of the tube and with the open part temporarily blocked by the experimenter's finger, the tube was placed vertically, with the open end at the bottom, into a larger vase that also had mercury.[4] To everyone's surprise, not all the mercury from the tube descended into the larger recipient, but only a small part of it did. The tube remained occupied with mercury and the height of the liquid was the same when the experiment was tried again. Two issues were raised: why the mercury stayed at that particular level and what was in the upper part of the tube.[5] Regarding the latter, the main question was whether the empty part of the tube was still holding some matter or was completely devoid of bodies. The experiment had been reproduced by other natural philosophers and some of them tried to improve it

[1] See *De Gravitatione* in Newton (2004, 12–13). Later in the manuscript, he discusses "space" in close connection to Descartes's views. However, this comparison is beyond the scope of this chapter. For such a discussion, see Slowik (2002, 2013).

[2] See Shapin and Schaffer (1985), van Helden (1991). In this chapter, I am not discussing the air-pump experiment, but other pneumatic experiments. It is, however, important to note the role of instruments in the context of the "experimental philosophy."

[3] Even before Torricelli, there were prior experiments performed with water in a so-called weather-glass, which were quite similar to the one described here. See for example Borrelli (2008). For the French context of the reception of Torricelli's experiment, which is relevant for the topic discussed in this chapter, see Taton (1963).

[4] A very nice multimedia description of Torricelli's experiment is provided at the virtual exhibition of the Galileo Museum of Florence. See (Museo Galileo). For a thorough discussion of Torricelli's experiment see Shank (2013).

[5] In a famous letter to Michelangelo Ricci, Torricelli draws two conjectures derived from this experiment: that nature does not abhor a vacuum and that air has weight. See Torricelli (1975).

by using newly designed devices, as happened with Blaise Pascal or Gilles Personne de Roberval.[6] Moreover, the original experiment was complemented by additional pneumatic or baroscopic observations, which included variations in the length and thickness of the tube, replacing the mercury with other liquids, and using other instruments to illustrate the same effect (e.g., aspiration pumps, syringes, etc.). Anyway, it is not the purpose of this chapter to reiterate the history of such instruments or the general debates they caused. Rather, I would like to examine how this experiment (or variations of this experiment) was (and were) translated into the Cartesian philosophical framework and forced some of Descartes's followers, who were committed to experimentation, to use the concept of space in their physics. In order to analyze the experimental work of such Cartesians—which I exemplify here only with the case of Jacques Rohault—I shall begin with an account of Descartes's views about 'space', 'place', and the impossibility of vacuum. Most of the scholarship on this subject has focused on Descartes's passage from metaphysics to physics and emphasized the role of the metaphysical foundations for general physics. Edward Slowik and Jonathan Bennett have discussed such issues in detail and I complement their analyses with an account of space in the experimental context of Cartesian philosophy.[7] I discuss how Descartes's views were received by his most prominent seventeenth-century follower, Jacques Rohault. By moving my focus from Descartes to Rohault, I shall briefly refer to Descartes's reaction to Pascal's vacuum experiments. Most of that part will rely on recent accounts of the episode, most notably those provided by Daniel Garber and Sophie Roux; yet, such a discussion is needed for the question on the use of space in Cartesian physics.[8] I point to an apparent tension between Descartes's metaphysical rejection of void space as a contradictory notion and his reaction to Pascal's Puy-de-Dôme experiment, claiming that the latter reaction should be discussed outside the metaphysical constraints of general Cartesian physics.[9] This does not mean that Descartes's physics is free from metaphysical constraints. I do share with most of the current Cartesian scholarship the view that Descartes's metaphysics is foundational for his general physics (i.e.,

[6]The literature is rather large and its focus ranges from the geographical contexts to particular early modern figures. For some examples connected with the topic of this chapter, see Adam (1887, 1888), Mouy (1934), Rochot (1963), Shapin and Schaffer (1985), Gorman (1994). For a general overview, see Grant (1981).

[7]See Bennett (1999), Slowik (2002). Bennett and Slowik, as most of the scholarship on Descartes's views concerning "space," were interested in the articulation of the Frenchman's metaphysical claims, thus in his metaphysics of space. I propose here a change of perspective, by reversing the area of inquiry; so, instead of trying to reduce Descartes's (general) physics to its metaphysical foundations, I examine how the concept of "space" that is presented in Cartesian (general) physics works in particular (experimental) cases.

[8]See Garber (1992), Roux (2000).

[9]For some recent discussions of the intricate problems of Descartes's passage from metaphysics to physics, see Garber (1992), Roux (2000), Dobre (2010).

Principles I for *Principles* II), but I am not going to discuss this issue here.[10] Instead, I focus on how Descartes's concept of space is discussed in the case of a particular experiment. In other words, I discuss the *use* of "space" outside of general physics, in the particular case of the glass-tubes experiment and other variations of the Torricellian experiment. While a discussion of the experiment had already been opened by Descartes—something convincingly argued by the scholars referred above—I claim that one can better grasp the problem of space by looking at the way in which the Torricellian experiment was appropriated by Cartesian (i.e., Descartes's followers) natural philosophers. I argue that Cartesian explanation of the phenomena produced by various pneumatic devices unfolds as if bodies are *contained in space*. My claim is that after Descartes's death, some of his followers (in particular Jacques Rohault, for the case discussed here) were less concerned with providing a metaphysical foundation for their ontological principles. Instead, they focused more on the mechanical structures of matter, which, in the case of particular experiments, departed even more from the core claims of Descartes's general physics (i.e., Descartes's metaphysically-grounded principles for his general physics developed in the second part of the *Principles*). Such a move from the metaphysical principles (e.g., matter is identified with space under the attribute of extension) to physical principles (e.g., movement and change are governed by the mechanics of subtle particles) had two types of consequence. On the one hand, it drew the Cartesians closer to the taxonomy of their contemporaries, who were describing the phenomena as taking place *in space*. On the other hand, it made looking for a thorough reduction of physics to metaphysics less relevant for the physicists involved. Thus, an experimentalist would cease using the terms in the *proper* or *metaphysical* sense. By deriving this conclusion, I would like to sketch a further consequence, namely that some of the main concepts involved in the Cartesian description of experimental activity should be taken in a weaker sense than what Descartes gives for their "metaphysical" definitions. Thus, I argue that "space" is among other concepts, such as "motion" or "body," defined by Descartes's general physics but capable of having a less strict meaning when they are used to describe observations and experiments. Without doing so, Descartes's and the Cartesian physics, in general, would not be possible, as it would succumb to metaphysical constraints imposed by the system.

[10]By Descartes's "general physics," in this chapter, I understand the physics presented in the second part of the *Principles of philosophy*. Briefly put, general physics would be rooted in the metaphysics of the *Principles* I and will share some elements with Descartes's metaphysics (most notably, his identification of body, matter, and space). At the same time, his general physics would allow the development of particular areas of natural philosophy, including the use of experiment and observation. In modern terms, this difference would be expressed by the terms theoretical and experimental physics.

6.1 Descartes on Space and Void

I begin with a general description of Descartes's views on matter, body, space, and motion. This will provide the background for the debate between Descartes and Pascal discussed in section two and for Rohault's pneumatic experiments examined in section three.

In 1644, Descartes published the *Principia philosophiae*, a book aimed at replacing the Scholastic textbooks with a complete philosophical system.[11] Descartes divided his book into four parts: metaphysics, physics, an explanation of the heavens, and of the earth. According to the plan, the book should have included other sections, on animals and humans, but these were not developed.[12] In the second part of the *Principles*, Descartes deals with the general structure of matter, the fundamental notions of his physics (e.g., body, motion), the laws of nature, God's relation to these laws, and the rules of collision.[13] Presenting everything in an orderly manner, Descartes begins with an argument for the existence of bodies, which is derived from his prior metaphysics. To put it briefly, since one perceives the existence of something external and since it is not in one's power to cause those sensations (and God is not a deceiver), there follows "the unavoidable conclusion,…there exists something extended in length, breadth and depth and possessing all the properties which we clearly perceive to belong to an extended thing" (AT VIIIa 41; CSM I 223). This something that exists outside of the philosopher's mind is nothing else than "body" or "matter." As Descartes will explain a few paragraphs later, "the nature of body consists not in weight, hardness, colour, or the like, but simply in extension," or, in other words, "we shall perceive that the nature of matter, or body considered in general, consists not in its being something which is hard or heavy or coloured, or which affects the senses in any way, but simply in its being something which is extended in length, breadth and depth" (AT VIIIa 42; CSM I 224). Thus, the only property Descartes accepts for bodies is extension.[14] But this does not mean that extended bodies are contained in space, as Descartes hastily denounces the two prejudices that can impede one from grasping the true nature of body. Hence, in paragraph five of the *Principles* II, he claims that ordinary views about rarefaction and empty spaces forbid one's access to understanding the nature of body as extension.

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[11]In order to refer to (Descartes 1964–1974), I shall use AT, followed by the volume number and the page. For the English translation, (Descartes 1984–1991), I shall use CSM followed by the volume number (for the first two volumes) and the page and CSMK for the third volume, followed by the page number.

[12]For a lengthier discussion of Descartes's project in the *Principles*, see Gaukroger (2002).

[13]A very good account of the second part of the *Principles* is in Buzon and Carraud (1994). For Descartes as the paradigmatic case of the metaphysically-minded natural philosopher of the early modern period and for a discussion of the articulation of physics and of the general principles of his physics in the metaphysics, see Hatfield (1985, 1990).

[14]As in many other cases of Descartes's philosophy, this problem has been thoroughly discussed in the literature. See for example, Garber (1992), Lennon (1993), Des Chene (1996), Bennett (1999), Roux (2000), Schmaltz (2009), Zepeda (2009).

And indeed, at stake is the body as extension, with extension describing anything to which dimensions are ascribed, space included. He characterizes the second issue in the following manner: "if we understand there to be nothing in a given place but extension in length, breadth and depth, *we generally say not that there is a body there, but simply that there is a space*, or even an empty space; and almost everyone is convinced that this amounts to nothing at all" (AT VIIIa 42–43; CSM I 225, emphasis added). Space cannot be empty of bodies, because both 'space' and 'body' are conceived as extended, so they are identical. The French philosopher will expand this conclusion in paragraph 10 of the *Principles* II:

> there is no real distinction between space, or internal place, and the corporeal substance contained in it, the only difference lies in the way in which we are accustomed to conceive of them. For in reality the extension in length, breadth and depth, which constitutes a space is exactly the same as that which constitutes a body. The difference arises as follows: in the case of a body, we regard the extension as something particular, and thus think of it as changing whenever there is a new body; but in the case of a space, we attribute to the extension only a generic unity, so that when a new body comes to occupy the space, the extension of the space is reckoned not to change but to remain one and the same, so long as it retains the same size and shape and keeps the same position relative to certain external bodies which we use to determine the space in question (AT VIIIa 45; CSM I 227).

By saying that space and body are 'not different in reality', but only in the way they are 'conceived by us', Descartes points to his prior distinctions from the metaphysical section of the *Principles*.[15] This would be Descartes's view about the metaphysics of space. However, it is not my purpose to trace the argument back to its metaphysical roots, but only to mark the difference between *reality* and the way one *describes* that reality. "Descartes's subtle distinction between what people judge and how they conceive or represent things" has been briefly noted by Jonathan Bennett (Bennett 1999, 3). Yet, Bennett does not deal with this distinction, as his focus is on the metaphysical concept of "space." By moving the focus from metaphysics to physics, as I argue later, the distinction becomes crucial especially in the experimental context. Descartes's strategy is to make an *analysis* of the ordinary *description of body*, in order to grasp the true, philosophical, nature of it. This I take to be what Daniel Garber called "the argument from elimination," which is a reduction of all properties that are commonly ascribed to body to the property of extension only.[16] By anatomizing the idea of body (Descartes takes the

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[15]For Descartes's "real," "modal," and "conceptual" distinctions, see *Principles* I 60–63, AT VIIIa 28-30; CSM I 213–215.

[16]See Garber (1992, 77–80). Similar conclusions are expressed in other studies. For example, Sophie Roux links Descartes's argument with his rejection of void space, something that is particularly relevant for this chapter. Thus, Roux says, "the main claim of Cartesian physics, which was perhaps never proved, is that matter is something extended. And the impossibility of the void is nothing more than this claim, presented as a double negation—it is impossible that non-being exists" ("la thèse, fondamentale dans la physique cartésienne, et peut-être jamais démontrée, que la matière est chose étendue. Et l'impossibilité du vide n'est jamais que cette thèse, considérée sous la forme d'une double négation—il est impossible que le non-être soit") (Roux 2000, 236).

example of a stone), he finds "that nothing remains in the idea of the stone [i.e., of a body] except that it is something extended in length, breadth, and depth" (AT VIIIa 46; CSM I 227). But these are the same properties that space has and the only difference between body and space is that, if the first is commonly referred to as a particular (which obviously comes with a bunch of other properties that mind has to differentiate in order to provide the analysis of the *true* idea of body), the latter is a general term in no need of further philosophical analysis.[17] Thus, extension, taken in general, gives the idea of *space*, while when it is taken in particular it reveals relations between different bodies (in other words, different particular extensions). The latter is called "place" and mainly refers to the situation of a body within a specific configuration, as in Descartes's example of a stone.[18] Now, this seems to suggest that bodies can easily be identified in Descartes's physics, yet this is not the case.[19] Moreover, Cartesian *res extensa* is all that exists in nature, as Descartes states in his reinforced rejection of void space: "The impossibility of a vacuum, *in the philosophical sense* of that in which there is no substance whatsoever, is clear from the fact that there is no difference between the extension of a space, or internal place, and the extension of a body" (AT VIIIa 49; CSM I 229–230, emphasis added). But what about *the non-philosophical sense*, when the objects of discourse are bodies of physics and not substances of the metaphysics? I argue next that Descartes leaves open the possibility of taking a less philosophical stance toward bodies and space in his physics. And I link this question to the above distinction between reality and the way one describes or conceives that reality.

In the next section of the chapter, I argue that, in particular cases of his physics, Descartes is not concerned with the thorough philosophical analysis of the concepts involved in the experimental reports, but uses them in the same way as his contemporaries would. The case in point for the current chapter is that of "space"—which, I claim, is a rather vague term that can even be translated into a

[17]See Descartes's discussion in the *Principles* II 12. He expands on the prior example of the stone that can be moved, so he claims that when one sees the stone removed from its place, "we think that the extension of the place where the stone used to be remains, and is the same as before, although the place is now occupied by wood or water or air or some other body, or is even supposed to be empty. For we are now considering extension as something general, which is thought of as being the same, whether it is the extension of a stone or of wood, or of water or of air or of any other body…" (AT VIIIa 46–47; CSM I 228).

[18]For Descartes's use of the concepts of the 'internal' and 'external' place of a body, see especially Garber (1992), Des Chene (1996).

[19]Problems with the individuation of body in Descartes's physics have been discussed starting from the seventeenth century. For example, Géraud de Cordemoy denounced Descartes for failing to provide a good criterion for individual bodies. See, Cordemoy (1666). A disturbing consequence is that a body at rest would lose its individuality. For some recent discussions of these problems, see Garber (1992), Roux (2000), Dobre (2011).

non-Cartesian use—but this can be seen in other cases as well.[20] To put it more bluntly, Descartes's attempt at providing a very sharp distinction between the fundamental entities of his physics creates a tension between the metaphysical ambitions implied by this strategy (his metaphysics of space) and the possibilities for developing a natural philosophy that would eventually include observational and experimental reports. The case of void space provides a great example of this tension and, as I argue below, even if traces of it can be observed in Descartes, the experimental attempts of his followers (Rohault in particular) shed a better light on the relation between Cartesian ontology and experimental practice.

6.2 Pascal and Descartes

My aim for this chapter and for this section in particular, is twofold: to argue that Descartes did not perceive the experiment—and other variations of the Torricellian experiment—as dangerous for his views about matter and that he was using the terms 'space' and 'void' both in the strict (philosophical) and in the common (non-theoretical or non-metaphysical) sense. While my intention is to discuss how Pascal's experiments were appropriated by the Cartesian Jacques Rohault, I need to offer some details about the context first. By giving a brief outline of Descartes's views concerning experiments with mercury and his reaction to Pascal's famous experiments, this section will provide the framework for my case study.[21] Although most of the things covered in this section have been discussed in the literature, there is an important shift in the type of question addressed with respect to the Cartesian concept of "space." Instead of analyzing the metaphysical concept of space and testing the coherence of Descartes's general physics (i.e., enquiring from Descartes's general physics back to his metaphysics), my question concerns the *use* of "space" in the Cartesian description of experiments (i.e., asking about the relation of Descartes's general physics with particular experiments of his physics). At least three important new points are worth stressing. First, the

[20]See for example Descartes's use of "body" and "motion," which considered in the strong sense, reveals a circularity in Descartes's definition. As I have pointed above in the footnote about individuation of bodies in Descartes's philosophy, the two terms are clearly linked, such that if one aims to speak philosophically, one would be forced to abandon any claims that a system of physics can follow from these concepts. Only by speaking "as if," one would be able to advance in the study of physics. For more about this, see the references provided above, especially Garber (1992), Grosholz (1994), Dobre (2011). Another interesting case is that of the tension between kinematic and dynamic in Descartes; see Slowik (2002).

[21]The debate between Descartes and Pascal has been covered in several studies. See for example the classic studies of Charles Adam, (Adam 1887, 1888) or the more recent accounts of Garber (1992, 136–143) and Roux (2000). In order to achieve my first aim for this section, it is sufficient to sketch the context and complement the seminal accounts of Adam and Garber with only a few details. Related to Roux's account, there are other significant differences with respect to my main question (what would be the difference in the use of "space" in Cartesian general physics and in experimental reports?) that will receive a larger discussion in the chapter.

difference discussed in the previous section, between the philosophical and the common (non-metaphysical) way of speaking. The second point is that Descartes was also involved in some experimental activity with glass tubes filled with mercury and he discussed the experiments *as if* an empty space would have been actually possible. I do not want to claim that he replicated Pascal's experiments, nor discuss the more general problem of Descartes's attitude toward experiments in natural philosophy, but only to point to the experimental approach that developed within the Cartesian philosophical framework, from Descartes to Rohault. The third point (which is mainly based on the first) is that Descartes did employ terms in their *common* usage, which would further indicate a shared vocabulary with seventeenth-century experimentalists and experimental culture. Moreover, this vocabulary would reflect a use of terms independent from strict philosophical analysis, something that, if one would be allowed to connect with the recent literature in the history and philosophy of science, would express a kind of "trading zone" that mediates between pure metaphysics and experimental practices.[22] While principles of Cartesian general physics would have to employ terms accordingly to their proper meaning, in experimental practice the same terms are less likely to be rigidly used, so they would be more autonomous. The case in point is Descartes's request to Mersenne to perform experiments "in the vacuum." As I argue in my conclusions, these points provide a new emphasis on the problem of space within Cartesian philosophy, which complement the existing scholarship.

In the *Principles*, Descartes acknowledges that:

> *In its ordinary use* the term 'empty' [Lat., "vacuum"] usually refers not to a place or space in which there is absolutely nothing at all, but to a place in which there is none of the things that we think ought to be there….a space is called 'empty' if it contains nothing perceivable by the senses, despite the fact that it is full of created, self-subsistent matter (AT VIIIa 49; CSM I 230; emphasis added).

So, when one sees an empty vase, Descartes claims that it simply means there is nothing perceptible (i.e., to be seen) in that container, since it is filled with air. For this reason, one would have to correct sensory impressions with philosophically adjusted judgments. But again, this is done by the philosophically minded physicist, not by the average observer of nature. As Descartes puts it,

> if someone asks what would happen if God were to take away every single body contained in a vessel, without allowing any other body to take the place of what had been removed, the answer must be that the sides of the vessel would, in that case, have to be in contact. For when there is nothing between two bodies they must necessarily touch each other. And it is a manifest contradiction for them to be apart, or to have a distance between them, when the distance in question is nothing; for every distance is a mode of extension, and therefore cannot exist without an extended substance (AT VIIIa 50; CSM I 231).

From the metaphysical point of view, it is obvious that God would not contradict the laws of nature, so even the situation described at the beginning of this

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[22]For the concept of "trading zone," see Galison (1997, 781–844). I would like to thank Koen Vermeir for suggesting this connection to me.

passage (i.e., "if God were to take away every single body contained in a vessel"), would never be actual. How then does this thought experiment work in an experimental scenario? An illuminating case is Descartes's reaction to Pascal's experiment from the Puy-de-Dôme.

On August 17, 1649, Descartes wrote to Carcavi in order to thank him "for the trouble…taken to write and tell me about the success of M. Pascal's experiment with mercury, showing that it rises less in a tube on a mountain-top than in one lower down." He continues by saying that he not only suggested the experiment to Pascal, but that he did so in the light of the principles of his physics:

> I had some interest in learning this because it was I who had asked him to try the experiment two years ago, and I had assured him of its success, as it agrees completely with my principles; without these principles he would not even have thought of it, since he was of the opposite opinion (AT V 391; CSMK 380).

A modern reader might be puzzled by Descartes's optimism, but as the intricate history of the Puy-de-Dôme experiment and Descartes's relation to Pascal reveal, there are several aspects that can justify this attitude. This has been noted in the literature, as for example in Daniel Garber's enquiry: "why did Descartes and Pascal draw such different conclusions from the Puy-de-Dôme experiment?…Was he [Descartes] simply being dogmatic in refusing to concede Pascal's argument?" (Garber 1992, 139). Garber offers a convincing reconstruction of what Descartes might have seen in Pascal's attempt to refute an explanation in terms of plenum and subtle matter.[23] Sophie Roux shares similar concerns with Garber:

> Why would he [Descartes] write that the Puy-de-Dôme experiment 'pourrait grandement servir à vérifier' his physics, or, to pick up some of its future usages, that it 'accorde fort facilement avec [s]es principes', or that it is 'entièrement conforme à [s]es principes'?… Pascal's experiment proves the principles of Cartesian physics because it ascribes some effects not to the weight of the air, but to the fear of vacuum.[24]

For Roux, the contrast between Descartes and his contemporaries who were performing experiments to question the nature of void is crucially described by their use of the *principles of general physics*. In this way, her argument yields the conclusion that Descartes (and, we might add, his followers—including Jacques Rohault) is always forced to return to the general principles of his philosophy:

> Descartes was not convinced by experiments that the top of the tube was empty, yet he found them important for concluding that weight of the air is a physical agent… the role and degree of certainty ascribed to principles overcomes pure sensible experience…For

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[23]For a discussion of the entire episode, see Adam (1887, 1888), Garber (1992), Palmer (1999), Roux (2000). For my purposes in this chapter, it is sufficient to point to Garber's and Roux's detailed analyses. However, at the end of this section, I add some details that were not discussed in the literature.

[24]See Roux (2000, 245–246): "Pourquoi cependant écrit-il que l'expérience du Puy-de-Dôme 'pourrait grandement servir à vérifier' sa physique, ou, pour reprendre certaines ses formulations ultérieures, qu'il l' 'accorde fort facilement avec [s]es principes', ou qu'elle est 'entièrement conforme à [s]es principes'?…L'expérience de Pascal est conforme aux principes de la physique cartésienne parce qu'elle conduit à attribuer certains effets non à la pesanteur de l'air, mais à l'horreur du vide."

> Descartes…, these principles are the first truths inscribed by God in our souls, and one would not be able to establish a strong physics without taking them as foundational; in this sense, and this sense only, Descartes could be called a metaphysician and dogmatic.[25]

In contrast to Descartes's metaphysical foundation of general physics, Roux portrays the Frenchman's contemporaries as choosing between the metaphysical and the experimental discussion of void:

> For the savants concerned with the problem of vacuum in the years 1647–1648, the question regarding the nature of vacuum pointed to the principles of general physics; knowing the cause that explains certain effects would also point to physics, but to an experimental physics: these two facets of physics could coexist without necessarily connecting to each other.[26]

The current section of this chapter aims at providing some evidence that such a clear-cut distinction between metaphysical foundations and experimental practices is difficult to draw, even in Descartes's case. I argue that Descartes was using the concept of space in both ways, as a term from general physics and as a term from experimental natural philosophy. In the next section I extend this argument to Jacques Rohault and, in contrast with a more recent study of Sophie Roux (Roux 2013), I argue that Cartesian experimentalism shows notable developments that can be better understood if they cease being perceived solely through the metaphysical lenses of Descartes's system.

Back to the Pascal-Descartes case. The conclusions derived by Garber and Roux about this episode are sufficient proof that Descartes was still entitled to write that experiments verified his theory. In fact, Descartes himself gives an answer in a letter to Mersenne from December 13, 1647:

> I am surprised that you have kept this experiment secret for four years, as has the aforementioned M. Pascal, without ever reporting anything about it to me or telling me that you had begun it before this summer. For as soon as you told me about it, I reckoned that it was important, and that it could strongly verify what I have written on physics (AT V 100; CSMK 328).

The discussion about the existence of a vacuum in the tubes helps Descartes in his claim that subtle matter is responsible for the visible phenomenon. Thus, Descartes could not have reacted negatively to such experiments, as for him they would have been good illustrations of the hidden mechanisms he had postulated in

[25]See Roux (2000, 247): "Descartes n'a pas été convaincu par les expériences que le haut du tube était vide, mais il les jugeait d'importance pour établir que la pesanteur de l'air est un agent physique….la fonction et le degré de certitude qui sont attribués aux principes dépassant la pure expérience sensible….Pour Descartes…, ces principes sont des vérités premières que Dieu a inscrites dans nos âmes, et nous ne pourrons établir de physique solide si nous ne les prenons pas pour fondement; en ce sens, mais en ce sens seulement, Descartes peut être dit métaphysicien et dogmatique."

[26]See Roux (2000, 244): "Pour les savants qui s'occupent du vide dans les années 1647–1648, la question de la nature du vide relève des principes de la physique générale; savoir quelle est la cause qui explique certains effets, cela relève aussi de la physique, mais d'une physique expérimentale: et ces deux aspects de la physique peuvent coexister sans être nécessairement articulés l'un à l'autre."

nature. However, given the subsequent advancements of the experimental philosophy in the second half of the seventeenth century, Descartes's opposition to Pascal might look odd and this is why an examination of the experimentalism of some of Descartes's followers will give one a more nuanced picture. But I leave that discussion for the next section of the chapter, and I focus now on another important consequence of Descartes's discussion of Pascal's experiments, which will complement the argument of the previous section, that Descartes uses some of the main terms of his physics—"space" and "void" included—in both *philosophical* and *common* (non-theoretical/non-metaphysical) way.

An important source is to be found in Descartes's aforementioned letter to Mersenne from December 13, 1647. There, Descartes acknowledged that he had read Pascal's *Experiences nouvelles touchant le vide* (1647), which he appreciated. He recognized Pascal's opposition to the Cartesian explanation in terms of subtle matter, yet he confessed his eagerness to get more arguments from Pascal, since the ones published in the treatise were not very convincing. After this introduction, Descartes adds a baffling paragraph, where he tries to downplay his knowledge of the experiments at stake: "You ask me to write something on the experiments with mercury, and you neglect to inform me about them, as if I were to guess what they are" (AT V 98-99; CSMK 327). A few lines later, Descartes would say "I had advised M. Pascal to do an experiment to see whether the mercury rises as high on the top of a mountain as at the foot, and I do not know whether he has done it" (AT V 99; CSMK 328). But if Descartes did not know about "experiments with mercury," how on earth could he advised Pascal to try the experiment at different altitudes? This blend between claiming not to know about such experiments and (rather) accurate descriptions of trials with tubes filled with mercury represents the content of this letter. For example, Descartes asks Mersenne to perform experiments in order to measure the change of weather, and he describes a scale to use for calibrating different instruments:

> to enable us to know also whether a change in the weather or place has any effect on the result, I am sending you a piece of paper 2 ½ feet long, on which the third and fourth inch beyond 2 feet are divided into lines; and I am keeping an exactly similar piece here so that we might see if our observations agree (AT V 99; CSMK 328).

Moreover, he sends his experimental reports expecting reciprocity ("to encourage you to inform me plainly what you observe") and even supplementary reports from Mersenne ("I would also like you to try to light a fire in your vacuum, and observe whether the smoke goes up or down and what shape the flame is"). The latter request is due to the limited experiments Descartes was able to perform, as one can see in his wish for lighting a fire in the vacuum: "You can do this experiment by suspending a bit of sulphur or camphor at the end of a string in the vacuum, and lighting it through the glass with a mirror or a burning glass. I cannot do that here, because the sun is not hot enough, and I have not yet been able to adjust the tube and the bottle" (AT V 100; CSMK 328). This is a remarkable passage, as it reveals at least two important traits of Descartes's attitude toward the experiments concerning vacuum. First, it shows that Descartes was involved in a form of experimental activity, trying to reproduce (at least) the simplest observations of the variation in the length of the column of mercury.[27] Second, it sheds a new light on Descartes's approach to the problem of vacuum. From the philosophical point of view, the entire experiment is contradictory, as one should not forget that Descartes rejected void space as a contradictory notion. So, why bother now with experimental trials *in a vacuum*? Descartes explicitly asks Mersenne to do the experiment *in a vacuum*—and not in rarefied air—which is a nice illustration of the change of language from when he speaks metaphysically (or even when he uses the term in the proper sense discussed in his general physics) to when he discusses about particular experiments. In the latter case, Descartes uses the terms just like his contemporaries. Thus, experiments come to play a new role in Descartes's physics through the experimental reports which are given in *common* language, without a philosophical analysis of the terms (e.g., of "space" and "void" in this case). This does not contradict other prior analyses of Descartes's approach to space and void, or his discussion of Pascal's experiments, but shifts the focus from the foundations (and the coherence) of Descartes's philosophical views to experiment itself. In her study of Descartes's theory of matter, Sophie Roux concluded:

> the main lines of interpretation proposed by Descartes for the experiments with vacuum are clear: the height of the mercury is determined by the weight of the air, the upper-part of the tube is filled with subtle matter; it is the physicist's task to ask what is the nature of that something that is in the upper-part of the tube, but there is nothing that experiments can teach us—by definition, they do not deal with the existence of pure or absolute vacuum.[28]

Roux seems to take Descartes's approach to the pneumatic experiments as good cases illustrating how his general physics works, even if these experiments cannot enjoy any other explanation other than the metaphysics of space contained in Descartes's general physics. Moreover, these experiments are presented as if without consequence for Descartes's physics. But if this were the case, then Descartes's own experiments with mercury tubes would have been made only to illustrate to what extent (subtle) matter can be observed. Likewise, his request to Mersenne to perform a trial in a vacuum would simply be absurd or, at most, puzzling. In contrast, if one shifts the focus from metaphysics and general physics to particular problems in physics, as I have argued above, one finds other consequences of the experimental approach, most notably that Descartes's way of discussing these experiments with the vacuum shows that he was not committed to the strict philosophical use of these terms. As I show further down, this reading

[27]This activity is connected with instrument, on the one hand ("I have not yet been able to adjust the tube and the bottle") and with weather conditions, on the other hand, as Descartes denounces the difficulties of performing the required experiment in Dutch conditions ("the sun is not hot enough").

[28]See Roux (2000, 245–246): "les grandes lignes de l'interprétation que propose Descartes des expériences du vide sont claires: la hauteur du mercure est déterminée par la pesanteur de l'air, le haut du tube est plein de matière subtile; il revient au physicien de se demander quelle est la nature de ce qu'il y a dans le haut du tube, mais il n'y a là rien que les expériences puissent nous apprendre—elles ne concernent par définition pas l'existence d'un vide pur ou absolu."

has important consequences for the way Cartesian experimentalism is discussed in the literature, which I shall exemplify with a recent study by Sophie Roux.

In the light of what I have presented in the first part of this chapter, I conclude this section with the claim that Descartes is entitled to speak about vacuum, because when he does, he takes the term in the ordinary (non-metaphysical) sense.[29] It is the same sense in which one would describe the top of the glass tube as showing an empty space during the Torricellian experiment (something Rohault would later do). But what if one examines the Cartesian reaction to other experiments, as in the pneumatic experiments of the 1650s and 1660s? Of course, Descartes was not around to discuss them, but some of his followers were deeply involved in experimental activities. In the next section, I shall refer to two such cases, which are traditionally taken as illustrative examples of Cartesian experimentalism, Burchard de Volder and Jacques Rohault.

6.3 Cartesian Experimentalism and the Problem of Vacuum

In a recent work on *Cartesian Empiricisms*, Tammy Nyden offers a reconstruction of Burchard de Volder's program of experimental physics at the University of Leiden by discussing "De Volder's Cartesian Physics and Experimental Pedagogy." From the philosophical point of view, De Volder was a Cartesian, yet in his physics courses, he performed experiments.[30] He initiated (with great success) the implementation of the first university *Theatrum physicum*. This happened in Leiden, in January 1675, after de Volder took a trip to England in 1674. But one should not draw a quick conclusion about that trip and claim that de Volder had been converted to experimentalism when he came into contact with the experimental practices of the English natural philosophers.[31] As odd as it

[29]Eric Palmer explained Descartes's multi-layered strategy, by drawing a distinction between the arguments for the so-called "philosophical vacuists" (to which he would respond with conceptual analysis) and the physical arguments that he employed in cases such as his discussion with Pascal. In the latter case, at stake is matter's mechanical behavior. See Palmer (1999, 38). This reading is consistent with my argument from the first section that Descartes operates with two different sets of concepts, philosophical and physical.

[30]For de Volder, see Nyden (2013), Bunge (2013). For a general discussion of the historiographical tensions between Cartesianism and experimentalism, with an attempt at correcting it, see Dobre and Nyden (2013). I start this section with de Volder—who was active at a later time than Rohault—because his case offers a nice introduction to the issues raised by experimental activity. At the same time, de Volder provides a good case for the pedagogical value of Cartesian experimentalism and, since I am not going to focus on that aspect, I prefer to leave more space for discussing Rohault.

[31]Both Tammy Nyden and Wiep van Bunge make this point to reject the rather traditional narrative held by Gerhardt Wiesenfeldt that de Volder abandoned his early Cartesian convictions in order to pursue the experimental program that he learned from the other side of the channel. See Nyden (2013), Bunge (2013).

seems, de Volder started as a Cartesian who heavily relied in his teaching on Robert Boyle's experimental philosophy, but, at some point, he switched to Jacques Rohault's physics.[32] Before discussing Rohault's experiments, there is an important aspect of de Volder's work that I would like to emphasize here. This is the pedagogical value of teaching physics in a laboratory, which has been convincingly presented by Nyden. Students were able to witness and discuss phenomena produced in the university laboratory; and hence, they learned physics not only from textbooks, but also from experiments. Seen in this respect, any experiment is a good way to introduce students (and the general public) to natural philosophy. But the question then is whether any experiment would fit with a given natural philosophy. Is, for example, Torricelli's experiment a good case for any natural philosophy? And what about experiments with air-pumps or other similar devices? What would be the expected outcome of these trials? In other words, why would a Cartesian natural philosopher choose to perform experiments that are connected to a concept of independent space? Would it be sufficient to say that Cartesians were doing such experiments just because their contemporaries were working with new instruments, as in the case of the pneumatic devices? And one can ask further, were such experiments and new instruments modifying the Cartesian notion of space?

In order to answer such questions, I turn now to the main case study of this chapter: the experimental physics of Jacques Rohault. This looks like a more puzzling example than the aforementioned Descartes-Pascal case. First, because when Descartes was replying to Pascal—or even asking him to perform the experiment—pneumatic observations were only just beginning, so many issues were still under debate. Second, when Descartes performed experiments with mercury in glass tubes, the instruments were rather basic. Third, when Rohault published his treatise on physics in 1671 (Rohault 1671), the experimental activity with air-pumps, syringes, and other pneumatic devices had already been firmly established, clarifying some of the theoretical problems and solving most of the instrumental challenges.[33] Fourth, unlike de Volder, Rohault was not a university professor, but, like de Volder, he was giving public lessons that involved experimentation.

[32]For de Volder's switch from Boyle to Rohault, see Nyden (2013, 228n3). This is a point worth stressing, because de Volder makes an unexpected move, at least from the perspective of a modern reader familiar with the traditional history of the scientific revolution. Thus, his change in teaching from Boyle (an acclaimed experimental philosopher and one of the prominent members of the Royal Society) to Rohault (a Cartesian) does not fit well with our histories about the decay of Cartesian Rationalism and the emergence of British Empiricism in the late seventeenth century. As I argue further, Sophie Roux would also consider this as a move in the opposite direction, although she examines a different context—that of Parisian *salons* of the 1660s; see Roux (2013).

[33]E.g., see the discussion about the leakage of the pump in Shapin and Schaffer (1985). The evolution of the instrument is, however, not that important for the current paper. As I argue next, Rohault's original experimental work is at the end of the 1650s and early 1660s.

During the 1660s, Rohault became a well-known Cartesian natural philosopher.[34] His fame came from hosting a *salon* where he and other invited speakers gave lectures on various subjects. These conferences were known as Rohault's "Wednesdays" and attracted all sorts of men and women in Paris.[35] Timeframe is particularly relevant for the discussion, as these activities began in the late 1650s—first with Rohault offering his lectures in the Montmor academy, then at his own residence—and continued throughout the entire 1660s, up to his death in 1672. As I have argued elsewhere, the publication of his *Traité de physique* in 1671 was effectuated because unofficial written versions of his conferences had been circulating for a while.[36] Various notes from his conferences were available and some of these were gathered in the form of a book, as happened with the *Physique nouvelle* (1667). A comparative study of the early evidence we have (Rohault 1660–1661, 2009) and the official text of the *Traité* reveals only small differences, especially when it comes to the experiments performed. It looks like Rohault specialized in performing some experiments and he repeated those to his weekly audience. This would also explain why after stirring great interest among his fellow natural philosophers at the end of the 1650s, Rohault became less interesting for the same *savants*. For example, Christiaan Huygens attended some of the conferences organized by Rohault and when he was back in the Netherlands, he discussed with his brother, Lodewijk (who was still in Paris), the possibility of commissioning an air-pump from Rohault.[37] When Oldenburg visited Paris, he witnessed several experiments performed by the Frenchman, including public demonstrations with magnets and Rohault's use of a large-scale model of the human eye to explain vision. Moreover, in the preface to Blaise Pascal's *Traitez de l'équilibre des liqueurs, et de la pesanteur de la masse de l'air* (1663), Perier gives Rohault (this time spelled "Rho") as an example of a great experimenter, able to imagine and to explain new experiments (Pascal 1663, unpaginated preface). In particular, his work with small tubes is highlighted as a great achievement. This would be Rohault's experimental investigation of the phenomena of capillarity, which was—at that time—on the research agenda of all newly founded research academies in Europe. Furthermore, a brief note in the *Journal des*

[34]For a discussion of Rohault's natural philosophy, see Dobre (2013). For other studies on Rohault, see Balz (1930), Mouy (1934), Milhaud (1972), McClaughlin and Picolet (1976), Clair (1978), McClaughlin (1976, 1996, 2000), Vanpaemel (1984), Des Chene (2002).

[35]For a discussion of the Wednesday conferences hosted by Rohault and how popular they were, see Clair (1978), McClaughlin (2000), Roux (2013), Dobre (2013).

[36]I have discussed this point at length in Dobre (2013). I need to reassess it here, because it sheds more light on the type of experimentation that Rohault was doing. It also explains a possible objection derived from Roux (2013), that especially after 1664, the experiments performed in other Parisian academies were of a different type ("radical experimentalism") than what one can find in Rohault.

[37]For the correspondence between the Huygens brothers, see Huygens (1890–1891). Particularly important are letters no. 823 (December 18, 1660), 924 (December 7, 1661), and 952 (January 4, 1662). In this correspondence, Rohault's name is spelled "Rohaut." I shall return shortly to Christiaan Huygens's correspondence.

Sçavans of April 26, 1666 concerning the history of pneumatic experiments lists Rohault (with his name spelled "Roho," this time) among the main experimenters, such as Petit, Pascal, Mersenne, and Auzout:

> What the English journal calls Baroscope or Barometer is not something new in France, where it is almost as old as the suspension of Mercury in the vacuum experiment that was invented in Italy by Galileo and Torricelli, [it] was done for the first time in France in 1646 by Petit, the Intendant des Fortifications, as it seems from the tratise he has published in 1647 at Seb. Cramoisy. It was followed and improved by Pascal and by many others, who let the Mercury stay in the tubes in the so-called continuum experience [on void], in order to see the changes in the height of Mercury with respect to different moments and seasons. It is over 19 years since Mersenne had done one [experiment] and by the testimony of Pascal's treatise on the *Equilibre des liqueurs*, one can see that [he] perfomed the same experiment in different places, which was continued at different moments and is still performed by Auzout and Roho. However, as no one has managed yet to establish with certainty a rule for [explaining] the changes in the height of mercury following changes in the air, no one had seen fit to publish anything on this.[38]

What is curious about this memo in the French *Journal* is that in 1666, Roho (i.e., Rohault) was still remembered for his pneumatic experiments. While this is not the place to explore the biography of Rohault as a Cartesian experimentalist, it is useful to stress the fact that for several years at the end of the 1650s and the early 1660s, he was considered a reputed performer of some experiments. Among the experiments Rohault was remembered for are his explorations of the properties of air. A sign of this recognition is in the name given to a device invented by him—"la chambre de Rohault"—which is a variation of similar devices that Pascal and Roberval had previously used in their own experiments.[39] With these preliminary remarks, I can return to the set of questions listed above and reassess them as a rephrased question: what was Rohault trying to achieve with his experiments?

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[38]This is a brief note in the *Journal des Sçavans* about the pneumatic experiments, with an emphasis on the seventeenth-century French tradition of experimentation for finding the properties and nature of air (G.P. 1666): "Ce que le Journal d'Angleterre appelle Baroscope ou Barometre, n'est pas une chose nouvelle en France, où elle est presque aussi ancienne que la suspension du Mercure pour l'experience du vuide, qui ayant esté inventée en Italie par Galilée & Toricelli, fut faite pour la premiere fois en France en 1646 par M. Petit Intendant des Fortifications, comme il paroist par le discours qu'il en fit imprimer chez Seb. Cramoisy en 1647. En suitte elle fut augmentée par M. Pascal & par plusieurs autres, qui laisserent le Mercure suspendu dans le tuyau en experience, comme ils appelloient, continuelle, pour voir le changement qui arriveroit à la hauteur du Mercure selon la diversité des temps & des saisons. Il y a plus de 19 ans que le P. Mersenne en avoit une, & par le recit qui est dans le traité de M. Pascal de l'Equilibre des liqueurs, on voit qu'en 1649. on a fait la mesme experience en plusieurs endroits, qui a esté continuée icy en divers temps & l'est encore presentement par Mess. Auzout & Roho. Mais n'ayant jusqu'icy pû trouver aucune regle certaine de la difference qui arrive à la hauteur du vif-argent suivant les changemens de l'air, ils n'avoient pas jugé à propos d'en rien publier." See Gallica, http://gallica.bnf.fr/ark:/12148/bpt6k581215/f212.highres.

[39]For a comparison between the three devices, see Mouy (1934, 126–132). This would reflect an evolution in the instrumental apparatus. It is unimportant that Rohault did not use an air-pump, as he was still using and improving other devices.

The question is reinforced by the observation that Rohault builds his natural philosophy in a way similar to Descartes's. He announces that he takes "Matter as extended into Length, Breadth, and Thickness; as having Parts, and those Parts having some Figure, and that they are impenetrable" (Rohault 1987, 23). Matter has precisely the same sort of properties as in Descartes and this is made clear in the opening article of chapter eight, where Rohault states "from what we have now laid down concerning the Essence of Matter, we infer in the first place, that what the Philosophers call a Vacuum cannot possibly be" (Rohault 1987, 27). As in Descartes's case, for Rohault, the problem is "what the Consequence would be, if God should annihilate the Air in a Room?"; to which he offers the expected answer: "the Walls would approach one another so near, that there would remain no Space betwixt them" (Rohault 1987, 28). Despite some important differences between the two, Rohault's natural philosophy is built on the same Cartesian foundation that does not allow for this concept. Vacuum is simply defined as "a Space void of all Matter" and matter should always be present in what one commonly calls "empty space."[40]

Thus, when Rohault announced in the title of his twelfth chapter that he would deal experimentally with "such Motions as are commonly ascribed to the Fear of a Vacuum," the appeal to empirical test—with the obvious connection to Pascal's famous experiments—confused some of his contemporaries. This might have been the case of P. Galloys, who signed the review of the *Traité de physique* in the *Journal des Sçavans* and claimed that "Le XII. Chapitre peut passer pour un des plus curieux" (Galloys 1671, 27). For Galloys, the main traits of Rohault's chapter were the expansion of Pascal's experiments concerning the weight of the air to a large variety of instruments and the rejection of the fear of vacuum explanation. If one looks at Rohault's text, one can see that his argumentative strategy is twofold: on the one hand, he establishes the theoretical framework for his explanation (that includes the rejection of the fear of vacuum theory and the emphasis on local motion, as the sole explanatory principle for the observed phenomena) and, on the other hand, he performs and describes a series of experiments in order to explain the properties of the air.[41] In his explanation, Rohault describes several possible scenarios for the motion of the piston in a syringe. These scenarios are of the type "what would happen if the mouth of the syringe is open/blocked and one tries to move the piston" and find their ultimate ground in the Cartesian theory of matter. Of course, he accepts the Cartesian plenum, something also noted by Samuel

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[40]This would be the metaphysical concept of space discussed above. I move next to discuss how "space" fits into Rohault's experimental practice. The point is to see if the above distinction between metaphysical vs common (physical) concepts of space can be found in Rohault's experiments.

[41]For a lengthier discussion of Rohault's argumentative structure, see Dobre (2013). With respect to Rohault's use of "space," one can count four occurrences of the term in chapter twelve, see Rohault (1671, 72, 83, 84, 97).

Clarke.[42] But the issue is not at all Cartesian plenum theory. Regardless of the way one conceives the distribution of matter in the world, one should be able to give a description of the structure of matter in a particular experiment. My goal, then, is to examine how Rohault's experimentalism fits with his strong Cartesian commitment concerning the properties of matter. More precisely, I am interested in the role of experiment in the context of a very restrictive ontology and I take Rohault's various trials described in chapter twelve to reflect a significant progress from Descartes's own interest in experiments with mercury. This would be something more than Roux's recent conclusion:

> What happens in Rohault's physics is simply a translation or a change of language: to the description of experiment in terms of objects perceived by the senses is added the description of a matter that would by its properties be able to produce the experiment that is perceived by the senses. The problem of the translation proposed by Rohault is that the second description offers nothing more than the first.

In the light of what I have presented so far in this chapter, I argue that Rohault's change of language has some consequences for Cartesian natural philosophy. Most notably, this translation weakens the philosophical understanding of "space" and allows experimental reports describing the structure of matter *in space*. It is the common (non-metaphysical) usage of the terms vacuum, space, and empty that one can find in Rohault's chapter and not the proper (philosophical) meaning of these terms. In the previous sections, I claimed that a dual use of the terms was already in Descartes and now I argue that Rohault builds his physics in a similar manner. After he gives a brief description of the core principles of physics—including the proper, philosophical, definition of some terms—his attention shifts to the experiment itself and to the use of instruments.[43] It is precisely in his experimental reports where one can find a loose use of the terms, especially "space." Moreover, Rohault's emphasis on experiments and his downplay of the metaphysical foundations reveals a remarkable departure from Descartes: the common usage of terms, such as "space," increases the tension between metaphysics and physics already introduced by Descartes. Thus, in contrast to Roux's conclusion, a change of language in Rohault's physics has an important impact upon natural philosophy and opens Cartesian physics to experiment.

In article 9 of his twelfth chapter, Rohault comes to an intermediate conclusion for his prior scenarios involving the maneuverability of the syringe:

> In order to know whether the Sucker of the Syringe can be drawn when the Hole at the lower end is stopped; we must first know, whether the Syringe or the Sucker have any Pores in

[42]Samuel Clarke produced a Latin translation of Rohault's *Traité*, which he appended with comments. These comments changed with new editions and eventually reached a final version in 1723, when the first English translation of the text (provided by John Clarke) was printed. For Samuel Clarke's annotations, see Hoskin (1961), Schüler (2001). Interestingly, Clarke would agree with Rohault's conclusion about the motion of the piston as a valid deduction, but would deny the truth of the main premise (that the world is a plenum).

[43]Rohault does not mention the air-pump, although he refers in passing to an "experiment from England" that he could not replicate. It is important, however, that Rohault tries to address the problem in an experimental setting, including by using some recent devices, such as the double-chambered instrument he designed.

> them or no; and after that, whether there be any Particles in the Air subtil (sic) enough to enter in at these Pores; For according to one or other of these Suppositions, will the Thing be possible or not possible. And because neither of them can be determined by our Senses or by Reason, and there being no Contradiction in either, it must be decided by Experience; now we find by Experience, that, if the Syringe be not too thick, we can draw the Sucker without much Difficulty; from whence it is evident, that there are Pores either in the Syringe, or in the Sucker, or rather in both of them; and that amongst the gross part of the Air, there are some so fine, as to pass through the Pores of most terrestrial Bodies (Rohault 1987, 58).

Rohault combines here explanations, experiments, and description of some possible scenarios for the motion of the syringe. Remarkably, he appeals to experience, because neither reason nor senses can directly inform one about the structure of matter (e.g., of the existence of pores in bodies and of the nature of subtle matter). But the question addressed here is important: can experience help one decide about the acceptable conjectures? Rohault makes a full turn to experience indeed, something similar to Boyle's experimental strategy. And the Cartesian philosopher approaches this with a new instrument—*la chambre de Rohault*—that would eventually solve some of the problems:

> Some have imagined it impossible to make any observation by which it should appear, that Reason and Experience agree in this Particular; because there is no Mountain high enough to carry us up to the upper Surface of the Air; and because, if there were, the Air would be so thin, that we could not breath in it. But I thought of a Means to remove these two Difficulties, and by which the Thing might easily be effected; and that was, to prepare some small Room, with transparent Walls, which one might stand without and look upon, without any Danger from what might happen within… (Rohault 1987, 73).

The connection with Pascal's experiment is obvious. However, there is some novelty, which clearly sets Rohault among the contemporary debates. A glimpse at how his activity was perceived is possible if one looks at Huygens's journal. On November 13, 1660, Christiaan Huygens writes,

> At Rohault's house, saw the experiments with mercury that completely verified the weight of air and how the air that surrounds us springs continuously. flat [sic] carp bladder swells in the vacuum for this reason. It is easy to create a great vacuum in a vase placed at the top of a house, to which would be attached a narrow tube of tin of 36 feet or thereabouts, as all the water will flow out of the vase. Carcavi and Auzout and many others were at Rohault's house. His room was really well equipped and his vases and tubes [were] fit for excellent experiments.[44]

[44]See Huygens (1890–1891, vol. 22, 536): "Chez M. Rohaut veu faire les experiences du vif argent qui verifient tout a fait le poids de l'air, et comment celuy qui noys environne fait toujours ressort. vessie de carpe platte s'enfle dans le vuide pour cette raison. Il est aisè de faire un grand vuide dans un vase au haut d'une maison, auquel seroit attachè un canal estroit de fer blanc de 36 pieds ou environ, car toute l'eau s'ecoulera hors du vase. Chez Rohaut estoyent Carcavy et Auzout et quantitè d'autres. Sa chambre estoit fort bien meublée et ses vases et tuyaux pour les experiences fort propres." One should note the timeline here. As I have remarked earlier, Rohault's experiments were almost the same through the 1660s, so he was not taking advantage of the new devices (e.g., the air pump). However, he built instruments, as is the case with the *chambre de Rohault*, which improved earlier devices of Pascal and Roberval. Moreover, in his discussion of the properties of air, Rohault uses a number of instruments, ranging from the syringe and the Rohault's chamber that I mentioned in the text, up to mercury tubes of various lengths, cupping glasses, bladders, etc. In this respect, Rohault's experiments are a clear departure from Descartes's limited trials with mercury tubes described in the previous section.

This rather short note by Huygens gives us some hints about both the experiments performed and the equipment of Rohault's laboratory. But, to return to Rohault's explanation, the scenarios described by him (his so-called "conjectures") are all given in terms of motion of small particles. At the same time, there is no reference to space as identical to matter, or to any similar metaphysical claim that might have come from Cartesian metaphysics. Instead, Rohault gives a description of what any witness to the experiment would perceive:

> *it is easy to see that this Space is not full of common Air*; for if the Tube be not quite filled with Quicksilver, but an Inch or two be left for Air, and stopping the End of the Tube with our Finger, it be inverted; we observe that the Quicksilver descends slowly, and we have time to see the Air ascend in the Form of Drops (Rohault 1987, 65, emphasis added).

Someone reading these passages can easily imagine the small particles in a container-space, which would provide the same explanation as the one offered by Rohault. Of course, in such a reading, the container space would be filled with matter to satisfy the plenum theory; but that is not important for the current discussion. The consequence of such a reading would be that "space" (in the philosophical sense) becomes less important, since all the focus would be on the mechanical structures that can accommodate an explanation of the observed phenomena. And, in this respect, the opponents of Cartesian explanations are in no better a position, because they would all describe a container space that has a different arrangement of matter (e.g., with places that are not occupied by matter at all). But any of these choices could not be affected by such experiments, because pneumatic devices deal with something that cannot be perceived by the senses.

In this respect, it would be too hasty to conclude that Rohault was building a "speculative" explanation, while other natural philosophers were open-minded "experimental philosophers." By sharing the use of "space" in their discussion of experiments, Cartesian explanations and those provided by their opponents fit well in Descartes's metaphor from the end of the *Principles*, where two clocks having the same exterior and showing the same time are built differently in the interior. They provide an explanation of the observed phenomena (both clocks show the same hour), but they have different ontological commitments (different internal structures of the two clocks). If I may be allowed to push Descartes's metaphor further, I would conclude that the inner mechanism of any clock cannot be accounted for only by an outside look at the device, which means that other perspectives should be acknowledged. This would be the meaning of Samuel Clarke's reaction to Rohault's argument. As far as one works with sound arguments and the conclusions are reduced to the ontological premises of one's system, what would be debatable is precisely the status of their starting assumptions. Yet, the new experiments are required to illustrate the (theoretical) premises and more experiments are encouraged to force the theoretical framework and to find additional support or counter-examples for the theory. The theory (in this case, Cartesian general physics) and experimental practice would evolve autonomously, with the latter adapting to the language of other experimentalists. This reading further answers my initial question about Cartesian experimentalism and the concept of space, because it points to a rather neglected part of Cartesian natural philosophy. Instead of testing the (metaphysical) coherence of the main concepts Descartes and his followers employed for space, place, motion, I argue that it is equally important to examine how these concepts were integrated in experimental practice. The problem is, thus, no longer in the foundation of Cartesian metaphysics of space—not even in the difficult passage from metaphysics to physics—but in the way one would describe the empirical outcome of an experiment. And this would not be subject to the "philosophical distinctions" discussed by Descartes, to which I have referred in the first section of this chapter. It would rather reflect a common use of experimental language—as in the second and the third sections—when, even if not explicitly stated, matter can easily be taken as contained in space. And neither space, nor matter, quality or motion would require a definition anymore. They would be taken for granted, just like Newton states in *De gravitatione*, as "too well known" to be defined. But this would mark a gap between the "philosophical" and the "common" (non-metaphysical/non-theoretical) way of talking about physical terms. Concepts such as motion, body, and space would have a different use in physics, especially when they are employed to describe experiments. This does not take away from the merits of Cartesian metaphysics and of the "proper" way of using those terms, but moves the focus from Cartesian metaphysics to Cartesian experimentalism, which has been neglected in recent scholarship on Descartes and his followers.

6.4 Conclusions

The larger picture of the change described here would be similar to the recent discussions in the philosophy of science where experiment is taken to have "a life of its own."[45] If experiments, theories, and instruments develop at different paces, then some of the terms they use will change as well. This will create, in some cases, a gap between the ascribed theoretical ("proper" or "metaphysical," to use Descartes's taxonomy) use of a given term and its approximations derived from experimental practice. In this chapter, I illustrated such a departure with a discussion of the problem of space in Cartesian natural philosophy. I argued that by moving from the metaphysics of space in Descartes's identification of space and matter, to the problem of why a Cartesian would be interested in experiments that use the concept of space as independent from body, one can get a better grasp of the evolution of Cartesian physics, which allowed Descartes's followers to appropriate experimental practices. My suggestion is that "space" does not represent a problem for Cartesian experimentalism. Once the concept of "space" is discussed in the general part of Cartesian physics (in order to identify it with body and matter and to receive, thus, a metaphysical underpinning), it does not play any additional role when one performs experiments in natural philosophy. This would express the transition from the philosophical (metaphysical) use of space to the common (non-metaphysical) way of talking about space found in any description

[45] See Hacking (1983), Galison (1987).

of experimental results. Moreover, the emphasis on structures and mechanical models postulated at the invisible level of nature can take various forms, including the use of space as a "container" for the moving matter.[46] An additional consequence is that Descartes's own move from metaphysics to physics and the more explicit commitments of his followers to experimental physics reveal a different use of concepts, which is most of the times weakened. In this particular respect, one should look at the difference between speaking philosophically about a subject and talking in a rather ordinary (non-metaphysical) sense. In section one, I have applied this distinction to Descartes's commitment to "space." By moving from metaphysics to physics, one gets less certain knowledge (something that Descartes acknowledged himself at the end of the *Principles*). As long as the subject is physical space, Cartesian natural philosophers are able to accommodate their explanations to the same phenomena that are commented on and experimentally examined by their opponents (and by the participants in the experimental trials of de Volder and Rohault). They are creating a "trading zone" for exchanges with their contemporaries. The focus is no longer on the translation of particular experiments in the (strict) language of general Cartesian physics, which would further be reduced to its metaphysical roots. Quite to the contrary, general physics would be adjusted to the needs of particular experiments, as in Galison's explanation of the "trading zones" between theory and experiment in the modern physics.[47]

This means that Cartesian experimentalism is not endangered by allegedly "speculative philosophy."[48] In this respect, their commitment to a restrictive ontological framework is not an impediment to doing experimental research, because they can work with a less strong concept of *space*, as I have tried to show in this chapter. Such a conclusion would allow a change of perspective with respect to Cartesian philosophy. By switching the focus from metaphysics and from general physics to experiments in physics, one will be able to do further research of the various threads of Cartesianism in the second half of the seventeenth century, including experimental Cartesianism.

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[46] This would be the weaker sense of "container-space" that was mentioned by Edward Slowik when he discussed the views presented by Jonathan Bennett. Slowik refers to "some primitive notion of space as a 'container'" (Slowik 2002, 139). For Bennett's views and his rejection of a metaphysics of space as a container, see Bennett (1999). Both Slowik and Bennett reject the "container" view for Descartes's metaphysics of space. However, neither of them was concerned with the way "container-space" might have worked in the experimental context and this chapter aimed to fill in that gap.

[47] See Galison (1997).

[48] For a discussion of the relation between "speculative" and "experimental" philosophies of the early modern period, see Anstey (2005), Anstey and Vanzo (2012). For an attempt to give a more nuanced view of this distinction, see Dobre and Nyden (2013).

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Chapter 7
Putting the Devil on the Map: Demonology and Cosmography in the Renaissance

Thibaut Maus de Rolley

Abstract This chapter explores the conceptions and representations of space in early modern demonology, focusing on the contribution brought by cosmographical knowledge to demonology in the Renaissance. I start by examining the conception of the devil as an inhabitant of the air, free to invade the world of the living: a fundamentally mobile creature, the devil possessed a mastery of the sublunar world that made him akin to cosmographers. I then assess the extent to which demonologists incorporated geographical information into their treatises, and in particular material related to the new worlds discovered overseas. I argue that the publication of Olaus Magnus's *Description of the Northern Peoples* (1555) marked a critical moment in the construction of this "cosmography of the devil," and analyse one of its most striking examples: Le Loyer's *Discours et histoires des spectres* (1605). The diabolical world map outlined by demonologists was a dynamic one, across which demons moved according to the flow of history. It expressed an anxiety beyond that of the fear of witchcraft: what is at work here is the idea of Europe being contaminated by the New World.

The question that I propose to examine is that of the geography of witchcraft, but approached here from a rather unusual angle: not from the point of view of witchcraft historians (Where did the witch-hunts take place?), but from the point of view of sixteenth- and early seventeenth-century "demonologists." How did specialists on witchcraft and demonism in the Renaissance map the activity of the devil in the world? Where did they situate demons within geographical space? To ask this question is to explore to a certain extent the wider question of the conceptions and representations of space in early modern demonology. It is also a means of bringing together demonological and geographical literature, two bodies of writing that correspond to two major upheavals in the history and culture of the

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period. Geographical literature, as we know, flourished in the Renaissance alongside the European exploration and colonization of newly discovered lands, and the emergence of a new geographical concept of the inhabited Earth.[1] The sixteenth century—and more precisely the later sixteenth century—witnessed an increase in the publication of travel accounts, geographical treatises and atlases, and a growing interest, among European readers, in material related to the new worlds encountered overseas.

But if the Renaissance was the Age of Discovery, it was also the Age of Demonology. Indeed, without being a direct product of the persecution of witches, nor its essential cause, demonological literature developed and prospered at the time of the great European witch-hunt: roughly, from the mid-fifteenth to the mid-seventeenth century. Deeply rooted in classical and medieval thought, demonology was an extensive network of theoretical discourses found in treatises, tracts, pamphlets and even literature, whose object were the related (but not necessarily linked) topics of demons, witchcraft, magic, ghosts and spirits. It was a composite and cross-disciplinary field of knowledge, touching on theology, law, medicine, history, natural philosophy—and, as this chapter argues, cosmography. In spite of these uncertain boundaries, it may be said that the "science of demons" affirmed itself in the Renaissance as an identifiable shared discursive field, whose importance in the intellectual history of the period has been fully demonstrated by Stuart Clark's magisterial study, *Thinking with Demons* (1997).[2]

In the Renaissance, the exchange between demonologists on the one hand, and cosmographers and travellers on the other, operated in both directions. This chapter, however, is largely concerned with one particular pathway in this interaction: the contribution brought by cosmographical knowledge to demonological discourse. As such, the inverse flow—for example, the way that demonology influenced how European travellers of the Renaissance perceived the territories, societies and beliefs that they encountered—will not be examined in any detail here.[3] Rather, I will embark upon on a reconstruction of representations of the presence of the devil in geographical space, as they occur in early modern demonological treatises. This involves an assessment not only of the extent to which demonologists incorporated geographical information into their treatises, but above all, an examination of the way in which the revival of this knowledge, in an age of "cosmographic revolution,"[4] changed the way that demonologists thought about the devil and his powers, and about the nature of his interactions with mankind. This approach also lends itself to an evaluation of the revitalising impact of

[1]See Lestringant (1994), Besse (2003).

[2]On the uncertain boundaries of the demonological corpus, and the debatable connection established by social historians between demonology and witch-hunting, see also Chesters (2007), and Machielsen (2015, 5–8). For general presentations of this corpus, see Clark (2006), Williams (2013).

[3]On this question, see Shapiro (1987), Bernand and Gruzinski (1988), MacCormack (1991), Cervantes (1994), Mello and Souza (2003), Holtz and Maus de Rolley (2008), Holtz (2010).

[4]Lestringant (1994, 59).

geographical knowledge upon demonological *writing* itself, notably in the emergence, within this vast and complex discursive field, of a category that may be referred to as the "cosmography of the devil."[5]

And finally, a third figure must yet be introduced into this exchange: that of the humanist. For, if the Renaissance was the golden age of the devil, and of cosmographers, it was also—primarily—the age of the humanist. What, then, do we learn about humanism in discussing demonological discourse on the cosmography of the devil? To ask this question, in a way, is to reexamine the classic tricolon which characterized for sixteenth-century humanists themselves the age in which they were living: namely, the gunpowder, the nautical compass and the printing press.[6] Gunpowder, according to Rabelais and others, is the diabolical element amongst the three.[7] What I would like to show, through this exploration of the Renaissance diabolical *mappa mundi*, is that the devil may also lurk in the compass (in the "discovery" of the New World), as well as in the printing press (in the "rediscovery" of Antiquity).

7.1 The Devil, Prince of This World

In the Renaissance, the devil and his demons were not cloistered in hell. Far from being secluded in an Other World on the margins of our own, evil spirits were believed capable of invading the world of humans and moving through it as they wished. This was precisely what made them so disturbing for the living. According to Alain Boureau, the emergence of a Christian science of the devil in the medieval West corresponded to a "liberation of demons" into earthly realms.[8] The "demonological turning point" that Boureau dates to the early 14th century, during the pontificate of John XXII (1316–1334), mainly consisted, he argues, in a release of demons from the "tight prison" constructed by Thomas Aquinas. Let loose from the subterranean or supralunar spaces where they had previously been confined, demons could henceforth make contact with men, conclude pacts with them, tempt and hassle them, creep inside them, and even physically transport them from one point in space to another. This conception of the devil was further reinforced in following centuries by the crystallisation, in the first half of the fifteenth century,

[5]I owe the phrase (and much more) to Chester's stimulating pages on Le Loyer's "cosmography of the spectre." See Chesters (2008) and Chesters (2011, 154–163).

[6]The presentation of these three inventions as emblems of modernity can be found throughout the period in the works of authors such as Rabelais, Fernel, Cardano, Bodin, Le Roy, Frobisher, etc.

[7]Rabelais's *Pantagruel* (1532), Chap. 8: "Printing likewise is now in use, so elegant, and so correct that better cannot be imagined, although it was found out but in my time by divine inspiration, as by a diabolical suggestion on the other side was the invention of Ordnance." (Rabelais 2005, 161) This opposition between the "divinely inspired" printing press and the "diabolical" art of artillery is also a humanist commonplace: see Hale (1966).

[8]Boureau (2006, 93–118).

of the stereotype of satanic witchcraft. In other words, by the emergence of the belief in the existence of a conspiratorial sect of witches, who would gather at night in huge assemblies (the Sabbat), in order to worship the devil and perform a series of diabolical rites.[9] For a good two centuries, hell was unleashed upon the earth. If early modern demonologists are to be believed, there was no need to venture into the bowels of the earth to find the devil. It was enough to simply apply ointment, mount a broomstick and let oneself go, up the chimney and out into the air, until one reached the witches' Sabbat. What's more, whether it was far or near, across the oceans or on the outskirts of a village, the Sabbat was an outpost of hell very much belonging to this world. Held on the same ground and under the same sky as our own, it occupied a tangible geographical place.

Demonologists were, for that matter, not particularly interested in hell. Or, more precisely, they were not concerned with discussing the exact location, nature, structure or organisation of the underworld. Early modern demonology did not offer visions of the Other World, or accounts of journeys to infernal realms: the reader would find no means of getting there in thought alone. In this way, the demonologist parts company with a Dante, or a Faust. We know that Faust was presented from the beginning—that is, from the anonymous *Historia von D. Johann Fausten,* which appeared in Frankfurt in 1587, onwards—as a personification of curiosity.[10] A sort of Menippus reborn, Faust plagues Mephistopheles with questions, particularly about hell, until the magician finally demands to see it for himself, after eight years of fruitless theological debate. As Walter Stephens notes in his discussion of Marlowe's version of the legend, "Faustus' ideal is a round-trip ticket to hell."[11] The interest of demonologists centred rather on the Sabbat, a hell on earth just as terrifying but, in appearance at least, more accessible. That is not to say that hell is absent from their works. But the subject (or even the word itself) appears only in passing, for example when discussing ghosts, or the possibility of souls returning to earth after death: thus, in relation to the scope for communication between this world and the next.[12] There is greater concern with hell in texts dealing with demonic possession, particularly in the accounts of exorcisms. The exorcist, after all, shared with Faust a rare privilege: the ability to commune with the devil, using the demoniac as sole intermediary, thus gaining access to the mysteries of the great beyond. This was, in any case, a selling point of

[9]On the emergence of this "cumulative concept of witchcraft," see Levack (2006, 32–51). For early fifteenth-century representations of the Sabbat, see Ostorero et al. (1999). Although absent from early treatises such as Kramer's influential *Malleus maleficarum* (1486/7), the Sabbat becomes a central feature of demonology a century later. Even then, however, exists a body of demonological writing indifferent to the subject of witchcraft, and thus to the Sabbat: see Chesters (2011).

[10]On Faust and curiosity in the first printed versions of the legend, see Maus de Rolley (2011, 510–523).

[11]Stephens (2002, 353).

[12]On this important question and its theological implications, see Chesters (2011), and Lecercle (2011).

published accounts of exorcisms: they reveal many "otherwordly things" ("choses de l'autre monde"), advertises Jean Le Normant in his book on the Lille possession cases of 1613.[13] However, if demons happened to shed light upon the tortures endured in hell, descriptions by demoniacs of visionary journeys to the Other World comparable to those experienced by divinely possessed mystics remain rare.[14] A subject as composite as demonological discourse hardly invites generalisation. Nonetheless it may be said that the greatest preoccupation of early modern demonologists (and particularly those concerned with the witches' Sabbat) was the question of the presence and actions of the devil within the earthly realm: how he entered into interaction with man ("the association of spirits and men" to use Jean Bodin's phrase[15]), how he intervened in the natural world, and how he threatened church and state.

The reason for the demonologists' lack of interest in the Other World also lies in the fact that subterranean hell (hell as "underworld") was not necessarily understood as the home of demons and their only, or even principal, residence. Indeed, in Renaissance as in medieval conceptions of hell, the abyss was in competition with the atmosphere. Certainly the location of hell in the bowels of the earth was largely accepted by medieval theologians, despite the theoretical difficulties posed by the association of a physical space with spiritual beings.[16] However, the devil was also conceived as the "Prince of the Air," following St. Paul in his letter to the Ephesians (Ephesians 2:2 and 6:12). St. Paul identifies the aerial region—between the earth and the heavens, in the cosmological system inherited from Ptolemy and Aristotle—with the realm of darkness to which, according to the Old Testament, the legions of Satan had been relegated after their uprising against God. The Church Fathers picked up on this placing of demons in the atmosphere. Indeed, similar discussion can be found in Tertullian, St. Hilary, St. Jerome, and above all in St. Augustine: "The devil was expelled, along with his angels, from the lofty abode of the angels, and was cast into darkness, that is to say into our atmosphere, as into a prison."[17] In presenting demons as "sky-birds" (*volatilia caeli*) or "aerial powers" *(aereas potestates*), the Church Fathers christianized the Platonic image of the demon developed in the works of Apuleius or Plutarch, since Platonic *daimones* were, as we know, intermediary powers for good or for evil, placed in the

[13]Le Normant (1623, 303).

[14]For a description of the punishments of hell, see the exorcism of Louise Capeau on 14 December 1611 in Michaëlis (1614, 72–74). In the account of her demonic possession (published 1586), Jeanne Féry briefly narrates a visionary journey to hell (Buisseret 1586, f. 46 v°). For a similar account in a case of divine possession, see Thérèse d'Avila (1601, Chap. XXXII).

[15]Bodin (1580), f. 7 r°.

[16]Vacant (1903–50), IV, 1, col. 28–120; Baschet (1993, 33–59).

[17]Augustine, *Enarratio in Psalmum CXLVIII*, cited in Cohn (1975, 66).

air as mediators between heaven and earth, between gods and men.[18] Despite the growing distinction made in the Middle Ages between celestial, divine space on the one hand, and the infernal underworld on the other, this doctrine was largely accepted by later theologians. Not universally accepted, however, was Augustine's contention that demons would be thrown into hell only at the Last Judgement, until which point they would remain at large in the air so as to better tempt and torment mankind. As far as the Venerable Bede, Honorus of Autun and Thomas Aquinas were concerned, some demons were in hell already, torturing condemned souls and being tortured themselves.[19]

Demonologists of the late Renaissance occasionally returned to these debates about the fate of demons after the Fall, including Sébastien Michaëlis (1587), Taillepied (1588), Maldonado (1607) and Lancre (1612), to mention but a few.[20] In any case, the aerial location of demons was brought up again and again in treatises of the time, though not as a matter for real debate, even when the author sought to reconcile it with the popular taxonomy of spirits established by the Byzantine Michael Psellus in his *Dialogue on the Operations of Demons* (*Peri energeias daimonon dialogos*), translated into Latin by Marsilio Ficino in 1497.[21] Psellus/Ficino filled the elementary world with swarms of spirits, divided into hierarchical categories: igneous, aerial, aquatic, earthly and subterranean. (The sixth category, the dreadful *lucifugus*, was defined by fear of light rather than by habitat.) In the eyes of early modern demonologists, this Neoplatonic extension of the domains of demons merely enriched the Christian idea of the devil as an inhabitant of the air, without undermining it. According to the demonological doxa, therefore, the majority of demons, if not all, could be found in the air, or more precisely in its middle region, where clouds, wind, rain and storms were supposed to take formation. This middle region was, effectively, the sky's obscure zone, as Pierre Crespet explained in his *Deux livres de la hayne de Satan* (1590), following St. Jerome: the sun's rays pass through it without encountering any solid matter which could reflect light.[22] This aerial location of demons gave them unequalled mastery of sublunar space. The devil could, quite literally, bring rain or shine to the earth. Occupying the centre of winds and clouds, demons were imbued with the power to summon rain and storms, a power which underpinned that of weather magicians and witches. Above all, demons could appear almost instantaneously in any place. Despite the Fall, they effectively retained their angelic qualities: power, agility, speed. As such, as Tertullian had it in a passage of his *Apology* (XXII, 18) much glossed by Renaissance demonologists: "In a moment, they are everywhere. To them the whole world is one place." As Pierre

[18] On Platonic demonology, see Timotin (2010). On the confusion between *daimones* and demons, see Boureau (2006, 131).

[19] Vacant (1903–50, IV, 1, col. 321–409).

[20] See Michaëlis (1587, 65–68), Taillepied (1588, 200–202), Maldonado (1607, ff. 82 v°–92 v°), Lancre (1612, 15).

[21] On this work and its influence on late Renaissance demonology, see Chesters (2011, 175–185).

[22] Crespet (1590, f. 15 v°).

Le Loyer wrote in his *Discours et histoires des spectres* (1605), no place was forbidden to them: "The particular places that these Spirits enjoy and look for are almost infinite, for no sublunar place is inaccessible to them. Demons are aerial spirits, and the air is diffuse everywhere in the inferior world: thus they are everywhere in the lower universe."[23] Demons were no more restricted to their aerial realm than they were imprisoned in the underworld. Before the Last Judgement and their final, total liberation, God would allow them to go forth unfettered into the world, in order to bait and torment mankind. In a sermon of 1332, John XXII emphasised the freedom of demons before the Last Judgement: "Indeed, the damned, that is, demons, could not tempt us if they were secluded in hell. That is why one must not say they reside in hell, but in fact in the entire zone of dark air, whence the path is open to them to tempt us."[24] Or, as Marlowe's Mephistopheles puts it: "Hell hath not limit, nor is circumscrib'd/In one self place, for where we are is hell/And where hell is there we must ever be." (*Doctor Faustus*, II, 1)

For Le Loyer, the devil was therefore in constant motion: "The devil never stops running and wheeling across the whole earth, and circles it endlessly […] to seek out the sinner his prey, to take him unawares, swallow him up and devour him."[25] Le Loyer explained, however, that the devil's earthly freewheeling was not entirely born of his duty to hound human souls. It was also because he found a paradoxical respite in motion. The devil's ceaseless movement was perpetual suffering; but he took pleasure in this torment nonetheless, to the extent that he was enraged by the magicians who, in summoning him, wrenched him from his wandering:

> That is his rest, his daily pastime, his mobile base, his shifting, turning bedstead, his coach, his litter, his carriage, where he is shifted and shaken ceaselessly, and from which he would never willingly be wrested. And he is angered when the magician disturbs and assails him with his charms and importunate words, and forces him away from his delightful business by conjuring him up and tearing him from the place in which he was settling down to work.[26]

The same image of the devil encircling the earth in flight is found in Pierre de Lancre, where he appears as a bird of prey, keen eyes fixed on his next victim:

[23]Le Loyer (1605, 340): "Et pour les lieux particuliers que ces mesmes Esprits aiment & cherchent, ils sont presque infinis, pour n'estre les Demons exclus de lieu quelconque qui soit sous le cercle Lunaire. Aussi qu'ils sont Esprits de l'air, & comme au monde inferieur l'air est diffus par tout, de mesme les Demons sont diffus par le bas univers."

[24]Cited in Boureau (2006, 25).

[25]Le Loyer (1605, 786): "Le diable ne cesse de tracasser et courir par toute la terre, et circuit icelle […] afin de chercher sa proye, qui est le pêcheur, le surprendre au despourveu, l'engloutir et devorer."

[26]Le Loyer (1605, 786): "C'est son repos que cela, c'est son exercice coustumier, c'est la place mouvante, son lict branlant et tournoyant, son coche, sa litiere, son carrosse où il est branlé et agité dans cesse, et dont il ne voudroit estre osté, et se fasche contre le Magicien qui par ses charmes et paroles importunes le trouble et travaille, ce luy semble, en luy faisant quitter son travail qui est delectable, et l'excitant et arrachant du lieu où il estoit occupé."

"[The world] is the globe and ring that this bloody beast keeps circling, in a ceaseless quest to fill this hell which never says 'enough'."[27] Besides this, Lancre indicated that if demons had a horror of returning to hell, though this was their "principal residence" ("principal manoir"), that was precisely because it entailed the loss of their "freedom to roam" ("liberté de vaguer").[28] Sébastien Michaëlis confirmed this: as a result of their spiritual nature, demons were fundamentally mobile creatures who could not bear to be restricted to one place—when thus, they suffered as birds trapped in a cage.[29] His extreme mobility clearly made the devil dangerous: because his hunting ground was as wide as the earth itself, and he circled it unrelentingly; because he could sweep up humans while in flight, paying mind to neither obstacles nor distances; because he could also breach the threshold of exterior and interior space by creeping inside a body and possessing it. In the latter case, the devil's territory was less the world map, so much as that other "diabolic atlas" (as Michel de Certeau put it) that is, the very body of the demoniac.[30]

But if the devil's mobility made him dangerous, this was also because it gave him access to knowledge of the world far superior to that of man. Demons, Lancre noted, knew the elementary world as no one else could. In a passage that echoed humanist discourses praising the limitless powers of the human mind, Lancre evoked how demons were free to come and go as they pleased, across the surface of the globe, through the clouds, or in the depths of the earth: "These spirits roam above and below our hemisphere; they go to the centre of the Earth, searching all its corners and bowels; they climb up to the clouds, raise thunderstorms, tempests and rain—and all by natural means, with the permission of God."[31] The devil, in particular, was able to explore territories still unknown to men, or at least to Europeans. I will return to this point below, but offer one example in the interim: that of Robert Anglicus's *Commentary* on the *Sphere* of Sacrobosco (1271). Here, we learn how an Englishman in the know could get ripe figs in every season thanks to an obliging demon who picked them for him in the equatorial region,

[27] Lancre (1612, 13): "C'est [= le monde] le Globe & le cerne que ceste beste sanglante va tournoyant estant tousjours en queste dequoy elle pourra remplir cest Enfer qui ne dict jamais (c'est assez)."

[28] Lancre (1612, 20).

[29] Michaëlis (1587, 68).

[30] I do not develop here these two questions of demonic possession and demonic "transvection" (i.e., the devil's ability to transport bodies across space). For the former, see Certeau (2000), Caciola (2003), Ferber (2004), Levack (2013). For the latter, see Stephens (2002, 125–144), Maus de Rolley (2011, 412–539).

[31] Lancre (1612, 278): "Ces Esprits courent par tout au dessus & au dessous nostre Hemisphere, vont au centre de la terre, fouillent tous les coings & entrailles d'icelle, montent aux nues, font foudroyer, tempester & plouvoir, le tout par les agents naturels, ainsi que Dieu le permet." Compare with the praises of astronomy and cosmography quoted in Maus de Rolley (2011, 101–106).

well beyond the limits of the *oikoumene*.[32] This amusing anecdote reappears in the 1587 German *Faustbook* and its first translations, where it enters Faust's repertoire of tricks; it is also present in Marlowe's *Doctor Faustus* (IV, 3). However, in Robertus Anglicus's *Commentary*, the anecdote does more than merely divert the reader: it also permits the commentator to argue that the torrid zone is inhabitable. Here, then, the devil's travels helped overcome lacunae in geographical knowledge. Moreover, this mobility, alongside the ability to observe the world from an aerial vantage point, gave the devil a kind of ersatz omniscience, an all-seeing, all-powerful gaze, not dissimilar to that of the cosmographer.[33] The devil was therefore able to anticipate future terrestrial events and so pass himself off as a soothsayer. Sébastien Michaëlis illustrated this in his *Pneumalogie* (1587):

> Noticing that it is already raining in the Indies, and that the weather is likely to carry those clouds towards Egypt, the devil informs his oracles that it will soon rain in Egypt; and when he sees that a great amount of snow melted on the mountains, or has started to melt, he predicts, too, that the Nile or another great river will soon overflow its banks, so that he tells nothing but what he sees.[34]

Thus we imagine the devil leaning over the world, tracking depressions and anticyclones, preparing forecasts on behalf of soothsayers: a devil who is as much meteorologist as cosmographer. This figure of the devil as cosmographer appears elsewhere, in fictions of the late sixteenth and early seventeenth centuries: in the German *Faustbook* and in Kepler's *Somnium* (posthumous 1634) it was the devil—or at least, in Kepler's case, a demonic figure—who enabled the hero, and thus the reader, to gain the cosmographer's vantage point, and so access a vision of the earth as seen from the sky.[35]

7.2 New Horizons

The devil, then, could be everywhere in cosmographical space. This must be understood in the sense that he could go anywhere on the globe, not that he was considered present everywhere at all times. The devil in fact occupied a determined point in space—or rather, the devil and his numerous but finite legions of demons occupied determined points in space. The devil did not have the gift of

[32] Thorndike (1949, 239–240).

[33] On the cosmographer's "all-powerful gaze" ("regard tout-puissant"), see Lestringant (1994, 19–26).

[34] Michaëlis (1587, 84): "Comme voyans qu'il pleut desja aux Indes, et que le temps est disposé pour porter les nuees vers les quartiers d'Egypte, [le diable] fait sçavoir à ses oracles qu'il pleuvra en bref en Egypte, et quand il voit que grande abondance de neige a fondu aux montagnes, ou commencé à fondre, il predit aussi que le Nil, ou autre grosse rivière débordera, mais il ne dit sinon ce qu'il voit."

[35] For a reading of these demonic voyages, see Maus de Rolley (2011, 510–539).

ubiquity, a miracle reserved for God alone, just as he could not cause two bodies to occupy the same place.[36] That would go against the fundamental laws of nature to which, according to the overwhelming majority of demonologists, the devil remained subject.[37] If the devil could, in theory, be located in space, this raises the question of where early modern demonologists placed him on the world map. In their view, were demons always in motion and incapable of staying fixed in a precise place, or did they have favourite lodgings, or predilections for certain territories? And what was the influence of the geographical knowledge brought by the Age of Discovery and the cosmographic revolution on this cartography of the devil's dominions?

Demons, as Pierre Le Loyer explained, settled in specific "lands, regions and countries" ("pays, régions & contrées"). But before that, they were attached to "particular places" ("lieux particuliers"), in other words, particular kinds of spaces and environments, rather than geographical places as such.[38] These were wild, deserted, uncivilised places marked by death or the idea of wandering: crossroads, cemeteries, forests, deserts, mountains, ruins and abandoned mines. This proposition of Le Loyer's was not especially original. In any number of treatises, in fact, one can trace a fairly homogenous "poetics of diabolical space" (in Bachelardian terms[39]) that contains little unexpected material, being strongly rooted in a well-established literary and cultural tradition. The diabolical landscapes outlined by demonologists did not always correspond with those emerging from testimonies gathered in trials and inquisition tribunals, where the accused often pointed to nearby, familiar spaces, on the outskirts of the village, rather than to far-flung places, on mountaintops or in the depths of the desert.[40] But the landscapes described, both in treatises and in trials, were overwhelmingly rural. Lancre explained that one had to venture into the countryside in order to run into the devil: it was necessary, then, to *travel*. In a passage that recalls the diatribes of those travellers to the New World pillorying the armchair adventurers who

[36]For an example of these discussions, see Weyer (1998, 201–202).

[37]For virtually all demonologists, true miracles were reserved to God alone. The devil could not overrule the laws of nature, and achieved most of his wonders by manipulating nature and its occult properties. His domain was not that of the supernatural, but of the preternatural, i.e., the realm of deviant and prodigious phenomena that were yet within nature. See Clark (1997, 151–178).

[38]Le Loyer (1586, 485).

[39]I am thinking here of Bachelard's "Poetics of Space" (*Poétique de l'espace*, 1957).

[40]The fact is noted by Lancre (1612, 68–69) but also by modern historians. See Roper (2004, 109): "At the height of the witch craze, when accused witches described the dances, the sites they described were often tucked away locally, by the mill perhaps, a place associated with boundaries between the wild and the settled, and situated usually on an isolated area or at the edge of habitation; or in the woods." See also Roper's remarks on the "narrowness of [village witches'] geographical imagination" in sixteenth-century Germany: Roper (2013, 6).

sensibly stayed in their comfortable libraries, the judge-demonologist similarly attacked the "delicate mind" ("esprit délicat") who

> has never left his town, has seen nothing but what is seen in large companies, and knows about demons only what can be found in books. […] It is not amidst the pleasures of a great and mighty city that demons can be seen, or their presence been felt: the infinite multitude of people, the churches, devotion and conversation usually chase them out.[41]

Lancre's remark is somewhat at odds with the accounts of mass demonic possessions that started to flourish in France in the years of the publication of his treatise, or even those that could already be found in earlier works, such as Weyer's *De praestigiis*.[42] These events showed that demons could sometimes desert their moors and mountains to creep into convent walls, in the heart of towns, before invading the bodies of young nuns. However, in the dramatic seventeenth-century French cases, the Sabbat remained often at the centre of the exorcists' preoccupations and writings: the "affaire Gaufridy" (Aix-en-Provence 1611), in particular, reinforced the myth of the Sabbat and the representations of diabolical space commonly attached to it.[43] The landscape, for demonologists such as Lancre or Le Loyer, was also a factor in explaining sorcery, in the sense that the presence and activity of devils and witches could be understood via the nature of the spaces in which they were found. This kind of geographical determinism is developed in Le Loyer's discussion on Endor, where a medium (the Witch of Endor) conjured up the ghost of the prophet Samuel at the request of King Saul (I Samuel 28). That land of moors, prairies and hills, Le Loyer argued, could not but attract witches, and the devil too.[44] Lancre similarly explained the abundance of witches in Labourd—the part of the Basque region where he launched a brutal witch-hunt in

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[41]Lancre (1622, 629–630): "l'esprit délicat qui n'a jamais bougé d'une grosse ville, et n'a jamais rien veu, que ce qui se voit à grosses troupes, qui n'a rien ouy des Demons, que ce qu'il en a peu apprendre dans les livres. […] Ce n'est pas dans les delices d'une grosse et puissante Cité où les Demons se font voir ou sentir: la multitude infinie du Peuple, les Eglises, la devotion, la conversation, chassent ordinairement tout cela." Compare for instance with Léry (1990, 21–22). For a reading of Lancre's *Tableau de l'inconstance* as a narrative of discovery, similar to those written by travellers back from the New World, see Jacques-Lefèvre (2008).

[42]Moshe Sluhovsky has demonstrated that the outburst of mass possessions cases in seventeenth-century France and Europe had a rich "pre-history". Most of the sixteenth-century cases, though, remained "cloaked in silence," some of them being known to us only from a list compiled by Weyer in the 1568 edition of his treatise. See Sluhovsky (2002, in particular 1385–1386). On the possession at Aix-en-Provence, see Ferber (2004, 71–88).

[43]See Michaëlis (1614) and Ferber (2004, 70–88).

[44]Le Loyer (1605, 702): "En ce cartier d'Endor ou Fribolet y avoit force bois, force landes et pastures, force collines, outre les monts Tabor et Gelboé, qui en estoient proches. Et cecy je ne le dis point pour neant, parce qu'aux femmes simples qui gardent leurs bestes és pastures et colines, et aux pasteurs et bouviers des champs les Diables s'insinuent plus facilement qu'à d'autres qui ont plus de ruse et se sçavent mieux garder des embusches Diaboliques. Davantage parmy les landes, prairies, collines, montagnes, pastures, forests y a plus de Sorciers et Sorcieres qu'és villes et villages, esquels hantent et frequentent les hommes."

the summer of 1609—by the geographical characteristics of the place ("la situation du lieu"): a poor, rural country between sea and mountain, a liminal land at the intersection of three kingdoms (France, Spain, and Navarre).[45]

Beyond the question of the devil's *places*, what did demonological treatises say about his favorite *regions*, to take Le Loyer's distinction between the two? Here, a diachronic approach is useful. Before 1550, demonological literature only rarely made reference to a diabolical "elsewhere," by which I understand far-flung, exotic lands believed to be under the devil's mastery. The crimes of the devil and of witches, and in particular the holding of Sabbats, took place in a circumscribed, familiar geographical frame—one that was most often part of the world to which the authors and their sources belonged. Anecdotes reported by early witchcraft theorists were, in fact, often based on information gathered from trials held in their own region, or on the testimony of local informants. For example, the stories reported by the Dominican Jean Nider in Book Five of his *Formicarius*, or 'Anthill' (composed 1436–37, and published in Cologne around 1480), largely took place in the region of Bern and Lausanne, although events in Basel, Strasbourg, Colmar, Nuremberg, Cologne and Vienna were also mentioned; these were either the home towns of his informants, or were visited by Nider over the course of his career.[46] Similarly, the anecdotes in inquisitor Heinrich Kramer's *Malleus maleficarum* (*The Hammer of Witches*, 1486) map contemporary witchcraft, broadly speaking, onto southern Germany: an area stretching from Alsace to the Tyrol, via the Rhineland Palatinate and Bavaria, with nods to Rome or Cologne on the way.[47] Another example of this tendency is the Italian demonologists of the early sixteenth century whose sources had a strongly Italian weighting: Girolamo Visconti (1490), Bernardo Rategno da Como (1505–10), Prierias (1521), Bartolomeo Spina (1523) and Paolo Grillando (1536).[48] It should be noted that in general, geographical indications are rare in these early treatises: the Sabbat, for example, is described as near or far, usually without more precise location. This is not to say that precise locations are never given. Among the Italians, for instance, there is frequent mention of the "Noce di Benevento," the Benevento walnut tree near Naples, that these works contributed to establish in the demonological imagination as a hot spot of satanic witchcraft.[49] (There are other examples of similar places in the period, such as the Venusberg evoked by Nider, or, later, the German Blocksberg.)[50] For the readers of these early treatises, then, witchcraft was fundamentally a European phenomenon. It was Europe that was under the sway of the

[45]Lancre (1612, 31). On Lancre's imagination of space, see Houdard (1992, 161–226).

[46]On the imagination of space in Nider's *Formicarius*, see Céard (2008).

[47]See the maps in Kramer (2009, viii).

[48]Most of these treatises have been compiled in Abbiati et al. (1984).

[49]See Bonomo (1985), Portone (1990).

[50]On the Venusberg, see Zika (2007, 103–106). On the Blocksberg (or Brocken), known in the seventeenth century as the setting for the Walpurgis Night, see Becker (2006), and Roper (2012, 40–43).

devil, and witches in flight, supposedly travelling (according to commonplace formulas) "across great distances" or "to faraway, foreign lands" actually rarely seemed to venture beyond Christendom.[51] Rather, witches travelled, as Martin le Franc (author of *Le Champion des Dames,* c. 1440) wrote, "From Rome to Metz, from Britanny to Lombardy" ("De Rome à Metz/Ou de Bretagne en Lombardie").[52] Even if a few exceptions could be found, it remained unusual, overall, to find precise references to contemporary witchcraft outside Europe in the treatises published up to 1550.[53]

I emphasise this point to demonstrate the extent to which Olaus Magnus's *Historia de gentibus septentrionalibus* (*The Description of the Northern Peoples*) constituted a striking novelty for demonologists upon its publication in 1555. Archbishop of Uppsala, Olaus Magnus was driven from Sweden by the Reformation, so it was from exile in Rome that he published this monumental natural and moral history of the Nordic territories and peoples, accompanied by illustrations from the *Carta Marina*, a map of Scandinavia that he had previously published in Venice in 1539. The work was a great success, quickly translated, often in abridged form, into vernacular languages (Italian, German, French, Dutch, English).[54] In 1555, the Far North (the "Septentrion") very much represented a new world for the inhabitants of more southerly climes: a *terra incognita*, or at least a fairly unknown territory.[55] And the land revealed to continental Europe in Olaus Magnus's work was to a considerable extent a diabolical one. In Book II (II, 23), the reader learnt, for instance, that Mount Hekla in Iceland was one of the gates of hell, and that witches were in the habit of taking themselves to the peak of another mountain, on a Baltic island (the isle of Jungfrun, also known as Blåkulla) to worship the devil and cast malevolent spells. In Book III, "On the superstitious worship of demons by the people of the North" (a demonological work in the true sense, then) Olaus Magnus evoked idolatrous cults; human sacrifices; the nocturnal dance of the elves where ghosts and witches came together; magicians who harnessed and controlled the winds; witches capable of bodily metamorphosis; magicians who fell into a cataleptic trance and travelled in spirit form; ghosts and revenants; a magician bound by a spell to the depths of a chasm, like Satan in the pit of hell, etc. Finally, in Book XVIII, three chapters were dedicated to

[51]See for instance Castañega (1994, 22): "Tierras remotas y estrañas." These stereotyped formulas recall the mention, in the famous *Canon Episcopi* (10th century), of the "great spaces of earth" (*multa terrarum spatia*) supposedly traversed "in the silence of the dead of night" by the wicked women seduced by the illusions of Satan. (Translation and presentation in Kors and Peters (2001, 60–63)).

[52]Le Franc (1999, IV, vv. 17842–17843).

[53]The most notable exception would be Castañega's reference to idolatrous cults in New Spain: Castañega (1994, 26–27).

[54]For a presentation of Olaus Magnus and his work, see Foote (1996), Johanneson (1991).

[55]Lestringant (2004, 45).

lycanthropy and the werewolves who, according to Olaus Magnus, abounded across Prussia, Lithuania and Livonia.

For the "southern" European readership, this was much of a revelation, even if some elements were already known thanks to Saxo Grammaticus's *Gesta Danorum* (13th century) or Albert Krantz's *Chronica regnorum aquilonarium* (1546). It was also a confirmation of demonological theory. Readers believed that the *Historia de gentibus septentrionalibus* contained evidence of practices and beliefs similar to those that had been described in demonological treatises for a good century, especially concerning nocturnal assemblies of elves and witches. As such, Bodin made reference to the "assemblies and ordinary dances of sorcerers" described by Olaus Magnus, and Le Loyer explicitly related the Nordic dance of the elves to the witches' Sabbat ("infernal dances held at night, like the Sabbats of the witches").[56] The diabolization (and thus christianization) of Nordic beliefs was not the doing of the demonologists alone. It was greatly facilitated by Olaus Magnus himself, who emphasised the role played by the devil in these varied wonders. He associated Nordic witches with contemporary European ones, and scattered numerous clear visual references to witchcraft as it was recognised elsewhere in Europe in the illustrations of his work: witches' cauldrons, winged demons, and witches lifted into the air by the devil.[57] Olaus Magnus did not explicitly cite demonological works, but we cannot rule out his having some knowledge thereof. Besides, it would seem that certain of these Nordic beliefs were well and truly indebted to European conceptions of witchcraft. The nocturnal assemblies of Blåkulla, in particular, might in this way be read as the product of a meeting between native traditions and the Sabbat as it was developed in the continental European imagination.[58] The "assimilation" of satanic witchcraft and Nordic sorcery, practised by demonologists or by Olaus Magnus himself, might not, therefore, have been entirely without foundation.

It should be noted, however, that the many demonologists who cited Olaus Magnus's works during the second half of the century did not pay particular attention to the parts of the text dealing most explicitly with the witches' Sabbat, such as Blåkulla and the conventicles of devil-worshipping witches. In general, what they took from the *Historia de gentibus septentrionalibus*, and especially from Book III, were the descriptions of idolatrous worship, the marvels effected by Nordic magicians, weather magic, werewolves, and the ecstatic journeys of Lappish sorcerers. Above all, the fundamental idea taken from Olaus Magnus, recurring in treatise upon treatise, was that the Septentrion was infested by devils and sorcerers. The Far North was the "primary residence of demons" wrote

[56] Bodin (1580, f. E1 v°): "assemblées et danses ordinaires des sorciers." Le Loyer (1605, 328): "danses infernales qui se font principalement de nuit, comme les Sabaths des Sorciers."

[57] Zika (2007, 224–226).

[58] Mitchell (1997).

Antonio de Torquemada (1570), among others.[59] In the *Historia de gentibus septentrionalibus*, many found confirmation of biblical prophecies of the devil reigning over the Septentrion (Isaiah 14:13; Jeremiah 1:13). But in doing so, these demonologists were actually breaking faith with Olaus Magnus, who was attempting to refute these very prophecies.[60] Olaus Magnus was, in fact, mostly writing about the past, and the practices he described were presented as those of a bygone era: the return of the devil was certainly an ever-present threat (I will return to this in a moment), but demons had been triumphantly driven from most places by Christian evangelization.[61] And yet, few were the authors, with the possible exception of Weyer, who did not substitute the present tense for the past when quoting the *Historia de gentibus septentrionalibus*, and who did not consider the phenomena recalled from the ancient past by Olaus Magnus as part of a contemporary reality.[62]

The *Historia de gentibus septentrionalibus* put a new continent on the demonologists' diabolical map of the world. I would suggest that this therefore marked a critical moment in the construction of a "cosmography of the devil" in the Renaissance, and so in the evolution of demonological writing. As is demonstrated by the regularity with which his work was cited by later demonologists, Olaus Magnus made a decisive contribution to the conception of the devil and witches as being active elsewhere, on the edges of the world map. This in turn contributed to the opening of demonology to new horizons. Olaus Magnus was not, of course, the first to point to the presence of the devil on Europe's peripheries, and the extension of the diabolical world map in the second half of the century was also a consequence of the increase of publications on the New World, and the interest that travellers and cosmographers themselves took in the devil, in idolatry, and more

[59]Torquemada (1982, 444): "la principal habitacion de los demonios." Torquemada's *Jardín de flores curiosas* (1570) is a miscellaneous book in six treatises (hence its French title, *Hexaméron*) which could hardly be described as a demonological work as a whole; however, its third treatise, on demons and ghosts, is a demonological discourse in the true sense. Besides, demons, ghosts and witches reappear in parts V and VI, two cosmographical treatises on the Far North heavily indebted to Olaus Magnus. As such, Torquemada's *Jardín* played an important part in the diffusion of Olaus Magnus's discourse on Nordic superstitious beliefs, especially in France, where Gabriel Chappuys translated it in 1579.

[60]Foote (1996, xxxviii–xxxix), Johanneson (1991, 178).

[61]See for instance Magnus (1996, III, Preface, 147): "I must tell how the malignity and craft of the devil have for so many past centuries held that country [Lithuania] in frightful delusions (as indeed ever other nation), until in recent years it has been summoned to the communion of the Catholic faith. […] [Lithuania is] freed now from the worship of demons." Lestringant argues that Olaus Magnus's discourse is somewhat more ambivalent, caught between the desire to exalt the marvels of the Far North and the necessity to denounce the progress of evil in those regions (Lestringant 2004, 51).

[62]See for instance Bodin (1580, f. 90 v°), Le Loyer (1586, 495), Le Loyer (1605, 327), Crespet (1590, f. 32 r°).

generally in religions and beliefs of newly discovered people who, moreover, they themselves frequently identified as diabolical practices and beliefs.[63] This new knowledge made progressive incursions into demonology: in the second half of the century, especially from 1580, references to geographical literature and travel writing became more numerous. In 1563, Johannes Weyer makes comparative little use of it, referring only—and usually briefly—to Cortez, Varthema, André Thevet, Leo Africanus and Pierre Belon. Bodin, whose particular interest in cosmography is well-known,[64] cites similarly few such sources in his *Démonomanie des sorciers* (1580): Olaus Magnus provided the majority of his cosmographical material, topped up by a certain "History of the West Indies" (probably Lopez de Gomara's, translated into French in 1569), and allusions to Thevet. In 1599, Martín Del Río presents some exotic *exempla* found in Jesuit letters from the New World.[65] But it was in the work of Pierre Le Loyer more than anyone else that travel narratives and cosmography became a major source of demonological information. In the 1586 edition of his treatise (*Quatre livres des spectres*) they were still in short supply: Leo Africanus, Pomponius Mela, Marco Polo and Olaus Magnus rub shoulders with Fernández de Oviedo, Ca' da Mosto, Ludovico Varthema and André Thevet. But in the expanded edition of 1605 (*Discours et histoires des spectres*), Le Loyer's frame of geographical reference took on a whole new dimension. In this later work, the following names (by no means an exhaustive list) were added to those mentioned above: Pierre Martyr, López de Gómara, Antonio Pigafetta, Nicolò de' Conti, Giovanni Maffei, Giovanni da Verrazzano, Thomas Harriot, José de Acosta, Vasco da Gama, Thomas Lopez, Guillaume Postel, Jacques Cartier, René de Laudonnière and Jean de Léry. Other French demonologists followed Le Loyer's example, such as Crespet (1590) who, moreover, shamelessly plagiarised the *Quatre livres des spectres*. Following this, Serclier (1609) and Pierre de Lancre in his second demonological treatise, *L'incrédulité ou mescreance du sortilege* (1622), also engaged with this cosmography of the devil.

7.3 Analogies

For these authors, the West and East Indies competed with the Septentrion, and perhaps even supplanted it as the devil's chosen lands. More fundamentally, it was in their works that the cosmography of the devil truly became a discernable category within demonological discourse. In order to demonstrate the universal presence of the devil on earth, these demonologists-turned-cosmographers compiled

[63] I do not develop here the question of the influence of demonological thought on early modern travellers and, more generally, on the European perception of the New World. For elements of analysis, see the references listed above in Footnote 3.

[64] See Lestringant (1985).

[65] Machielsen (2015, 255).

and compared information provided by geographical literature regarding religious belief and practice of the peoples of the world. In this way, these demonological treatises may be considered important vehicles for the development of comparative ethnography in the Renaissance. But their contribution entailed an approach that entirely excluded any cultural relativism, and flattened the singularity of those exotic belief systems without a second thought. After all, these authors were invested in demonstrating that the apparent diversity of religious belief and practice across the world was no more than a diabolical decoy. The many names of the pagan divinities were simply pseudonyms adopted by the devil as a means of concealing the extent of his hold on the world; their varying appearances were only masks hiding the true face of Satan with various levels of success; the worship of such gods, in its many guises, was nothing but a blasphemous parody of Christian worship, just like the Sabbat.

Even if his ethnographical references remained limited, Weyer nonetheless devoted a whole chapter to the discussion of "One and the same form of worship of the devil in the most widely separated regions" (I, 9).[66] For his part, the supremely erudite Le Loyer demonstrated an impressive capacity to track the mark of the devil across the entire known world, along with a review of the beliefs of Ancient and New World societies concerning ghosts, angels, ecstasies, the immortality of the soul, and the practice of ritual sacrifice. Crespet, Serclier and Lancre, who made liberal use of José de Acosta's *Natural and Moral History of the Indies* (1590, translated into French in 1595) in turn emphasised the parodic elements of pagan worship. The devil, puppet-master of the pagan cults, merely aped the rituals and mysteries of Christian worship (baptism, confession, Communion, charity, the existence of a clergy, the belief in paradise, in the Trinity and the Virgin Mary, etc.).[67] Demonologists, as Grégoire Holtz puts it, were effectively possessed by the "demon of analogy," as were many travellers of the time, themselves influenced by demonological discourse.[68] By reducing the unknown to the already known, analogies made it possible to "translate alterity;" but the analogies drawn in these writings between Catholic and idolatrous cults were above all a means to denounce the evil nature of the latter. It should be noted that this "demon of analogy" operated not only on a horizontal axis (that is, in space) but also on a vertical axis: in chronology and in history. Demonologists weaved a web of analogies between the modern and ancient world, between contemporary witchcraft (whether from Europe or the New World) and ancient paganism. The demonologists, who were also often humanists of note (one thinks of Le Loyer, or Bodin), launched a veritable diabolization of antiquity, particularly of Greek and Roman antiquity, which they populated, post hoc, with devils and sorcerers. It is tempting

[66]Weyer (1998, 22).

[67]For detailed lists of these parodic elements, see Lancre (1622, 460–461), Serclier (1609, 511–513 and 525–31). On these demonic analogies between Christianity and heathen religions, see also Ossa-Richardson (2013, 65–73).

[68]Holtz (2008).

to see in this process the expression of a certain (paradoxical?) anxiety among humanists about ancient texts and knowledge. In a way, the demons who troubled demonologists were as much the classical ones being resurrected thanks to the printing press, as the contemporaneous demons that one might encounter at the Sabbat or that haunted the New World. This discourse is already discernable in Giovanni Pico della Mirandola's *Strix* (published 1523), which underlined the fundamentally demonic essence of the ancient gods, and expressed a corresponding mistrust of a certain humanistic paganism.[69] It can also be found in the *Historia de gentibus septentrionalibus*, when Olaus Magnus aligns, for example, Nordic elves with the fauns, satyrs and nymphs of antiquity, with reference to Virgil, Ovid, Horace and Pomponius Mela—although in this case one can see more an attempt to present the Nordic peoples in a more distinguished light, than a concerted diabolization of antiquity or a simple strategy for explaining the unknown by reference to the known. The people of the Far North might have been idol-worshippers, but after all, so had the Egyptians, Greeks and Romans, "the most judicious men of all"…[70] This marriage of antique paganism and contemporaneous witchcraft was widely reinforced by demonologists of the second half of the century who developed a concomitant interest in the manifestations of the devil across space and historical time. But the principle was always the same. It was necessary to show that the devil was *everywhere* and *always* the same: "Since the creation of the world, Satan has always remained similar to himself, and the same as he is today," wrote Lambert Daneau.[71] This is also why one can characterise Weyer and Bodin's approach as cosmographical, despite the rarity of their references to geographical literature. Weyer's aim, in the first part of his treatise—and this aim was truly original—was to sketch a history of the devil, and locate this within a history of idolatry and pagan beliefs. The central idea of this first book was very much that, for *all time,* up to the present day, "the Devil contrived that one and the same form of worship of him should be observed in the most widely separated parts of the whole world."[72] The same is true of his rival and opponent, Jean Bodin, for whom the demonologist's vocation was to bring the universal consistency of witness testimony into relief, across the centuries as well as through space.[73] In this way, his aim was that of "universal," or "cosmographical" history: a history which "took into account all known societies, past and present."[74]

[69]See Pic de la Mirandole (2007, 24–27).

[70]Magnus (1996, 155).

[71]Daneau (1579, 26): "Car Satan a de tout temps depuis le monde creé, esté semblable à soy-mesme, & tel qu'il est aujourd'huy."

[72]Weyer (1998, 22).

[73]Bodin (1580, f. E^4 v°): "Je deduiray en son lieu la convenance et accord perpétuel d'histoires semblables des peuples divers, et en divers siecles rapportées aux actions des Sorcieres, et à leurs confessions."

[74]Lestringant (1985, 140). On Bodin's conception of "universal history," see also Couzinet (1996, 146 *sq*).

I now wish to look in closer detail at a few particular moments where the demonologist turned cosmographer. As it happens, these moments occur in two chapters of the *Discours et histoires des spectres*, Le Loyer's (1605) reworking of his earlier treatise. In Book IV, Le Loyer devoted a whole chapter to the question of diabolical geography, in other words to mapping the devil's chosen haunts, or, as the title of the chapter puts it, "Of the lands and regions haunted and visited by the devils, and where they make themselves visible" ("Des païs & regions où hantent & frequentent les Diables, & se monstrent visibles," IV, 11).[75] Le Loyer reminded his readers that the devil could be anywhere and everywhere, with no place on earth foreign or unreachable for him. However, he had his favourite spots: regions where he preferred to exercise his tyrannical powers, or where he could do so more easily. In fifteen particularly dense pages, this chapter presented an overview of all the devil's earthly dominions. They were divided into three: firstly the Septentrion, explored from west to east, from Scotland to Tartar lands via Scandinavia, Poland and Russia; then the East and West Indies; and finally Africa. Christian Europe, then, was not discussed, but much space was given to the world opened up by the Age of Discovery—territories that would comprise the section *Tabulae modernae* in a sixteenth-century atlas. Throughout this long tour of the world map, Le Loyer adopts the rhetoric of cosmographers and periegetes, mimicking the journeys described, and inviting the reader to cross the seas in company with him: "But enough about Scotland: let us now cross the sea, and enter the lands of Denmark and Norway"; "Now that we have talked about the East and West Indies, let us turn sail towards our hemisphere, cross the Atlantic and reach Africa, leaving the Cape of Good Hope behind"; "I shall now depart from Africa, and crossing the Gibraltar strait, rest a moment on the island of Cephalonia, like I first did on the island of Scotland."[76] The lesson in demonology thus became a geography lesson as well, bringing into disturbing communion the figures of cosmographer, demonologist… and the devil. For what this chapter shows is that all three shared the same vantage point over the globe, and the same power to transport themselves across the map, paying no mind to distances or obstacles. Just as, in the words of Tertullian, the devil experienced the world as "one place" easy to explore and possess, so in fact did the cosmographer who could look across the whole world and soar above it on the wings of his mind, and so too did the demonologist who borrowed the cosmographer's knowledge. Thanks to cosmography, then, it was possible to beat the devil at his own game. Demons might well go

[75]Le Loyer (1605, 326–340).

[76]Le Loyer (1605): "C'est assez parlé de l'Ecosse, passons la mer, et entrons au pays de Dannemarch et de Norvège" (328); "Mais ayans parlé des Indes Orientales et Occidentales, tournons voile vers nostre Hemisphere, et dessus l'Ocean et Mer Atlantique, voguons jusques en l'Afrique, laissans derriere nous le Cap de Bonne Esperance" (338); "Je laisseray l'Afrique, & passant le destroict de Gibraltar, je me reposeray en l'Isle de Cephalenie, comme j'ay commencé par l'Isle d'Escosse" (339). On the rhetorics of the *periegesis*, see Jacob (1981).

freewheeling around the globe, but the demonologist-cosmographer, endowed with the same powers of flight, could chase them in turn.[77]

This cosmographical method is employed in several other chapters in which Le Loyer tried his hand at comparative ethnography, and attempted to show the universal presence of the devil within apparently diverse beliefs and practices. As such, in a chapter concerning the various names of demons ("Of demons and their names in diverse languages," III, 5),[78] Le Loyer started by noting the infinite diversity of diabolical names, equal to the diversity of peoples, nations and languages. And the chapter is, in fact, a formidable inventory of demons' names: ancient Greek, Roman, Egyptian and Hebrew demons alongside demons from the New World and demons among the "European peoples." These diabolical names appear alongside the equally exotic names of people and places that cascade across the page:

> East Indians have their own devils, Goya, Permal, Haminant, Muthiam. Japanese name their human-shaped devils Goquis, and in the West Indies, those living in Santa Cruz, near Peru and Paraguay, have their devil Toboroccoce, Peruvians have their Xixarama and Noachah, Floridians have their Aignan, the Tupinamba their Kagerre or Forest Demon, Caribs and Cannibals their Chiappan, those in Canada and Hochelaga their Gougou and their Cudruagny, who they represent, according to Jacques Cartier, exactly as we draw demons here, with a pair of horns on their forehead.[79]

The impact of such an accumulation suffices in itself to convey the omnipresence of the devil, the breadth of his dominion, and his capacity for metamorphosis which entailed not only constantly changing his name, but also his appearance. The devil—"The Ape of God," according to the commonplace expression—could take the form of man, cockerel, wolf, snake or dragon, depending on where he was; and sometimes all these at once. These pages paint a portrait of a devil whose constant shape shifting made him impossible to catch. Impossible for everyone, that is, except the demonologist, who was able to carefully gather these deliberately fragmented forms on a single page, along with the many local and singular beliefs that would otherwise operate in isolation. For these demons were in fact nothing more than the multiple guises of a single character, the devil: not *our* demon or *their* demon ("*their* Xixarama," "*their* Aignan," "*their* kagerre," etc.), but *the* devil, one and unique. In short, the demonologist collected and unified

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[77]On the figure of the cosmographer as aerial traveller, see Maus de Rolley (2011, 371–408).

[78]Le Loyer (1605, 194): "Des Demons, et de leurs noms et appellations, qui se remarquent en diverses langues."

[79]Le Loyer (1605, 207): "Les autres Indiens Orientaux ont leurs Diables, Goya, Permal, Haminant, Muthiam. Les Japonais appellent du nom de Goquis les Diables qui leur apparaissent en forme humaine: Et en l'Inde Occidentale, ceux de la province de Saincte Croix, voisine du Peru & Paragay ont leur diable Toboroccoce, les Peruviens leur Xixarama, & Noachah, les Floridiens ont leur Aignan, les Taopinambaux, leur kagerre ou Demon Forestier, les Caribbes ou Canibales leur Chiappan, les habitans de Canada, & Hochelaga leur Gougou, Diable femme & une autre Lamie, & leur Cudruagny, qu'ils peignent, ce dit Jacques Cartier, ni plus ni moins que nous peignons les Diables avecques deux cornes en teste."

everything that the devil had taken care to divide and dissipate across historical time and geographical space. While one cannot help but think that Le Loyer was himself in a way bewitched by this incredible diversity, and took a certain scholarly pleasure in competing with the devil by bringing it to life on the page, his work nonetheless consisted of thoroughly weaving a thread that the devil had tried to unravel; of elucidating analogies that the devil had wanted to camouflage.

The devil betrayed himself by his appearance: for example, the Iroquois Cudruagny had "two horns on its head" which, through kinship with Christian representations, signalled its diabolical nature. There were also hidden links in the names themselves. In his reading of Varthema's much-commented description of a cult practised in Calicut,[80] Le Loyer did not have to try hard to reveal the devil behind the terrifying hindu deity with three crowns. For a start, the disguise fooled no one; and furthermore the name of this god, "Deumo" was a clumsy anagram of the word "Demon," as their simple juxtaposition made clear ("Deumo, or Demon"). Within a letter of each other, *Deumo* or *Demon* were the same thing. Equally, as far as Le Loyer was concerned, *Tuira*, the name of a spirit who spoke to the Cuna-Cueva of Urabà (in modern-day Panama), came directly from the Hebrew word *Saïrim*, via a simple "swapping of letters" ("échange de lettres").[81] The inquiry into the names of demons was thus conducted on an etymological basis: not only did *Tuira* come from Hebrew, but the name Cemis (or *Zemis*) given to the idols venerated by the Taino in the Caribbean could "derive"—wrote Le Loyer—from an Arabic word meaning "angel, or minister," just like those of the Javanese divinities Sutanaoch and Settam.[82] For Le Loyer, this was no coincidence. Rather, the linguistic analogies allowed genealogies to come to light. Le Loyer considered that if exotic names could be read as corrupted versions of semitic divinities, this was because all pagan gods, whether ancient or modern, from the New or the Old World, had a common origin. Just as the Greek gods were derived from their Egyptian counterparts, the New World deities, spawned in the cradle of the Mediterranean, had been displaced over the course of history with the migration of both peoples and the devil. We know that this hypothesis, based on the then widely held idea that the New World peoples had European ancestry, was being put forward at the same time by the mythographer Lorenzo Pignoria in his work on Mexican and Japanese gods.[83] It was therefore the history of the devil that demonologists were recalibrating in this way: a devil who had started out under the name of Pan, worshipped by ancient Brahmins, and who would later reappear as the Deumo venerated by the Zamorins of Calicut.[84]

[80]For other demonological readings of this episode, see Holtz (2008, 172–177).

[81]Le Loyer (1605, 207).

[82]Le Loyer (1605, 207).

[83]Mac Cormack (1995, 87–88).

[84]Le Loyer (1605, 207).

7.4 Demons on the Move

What is clear to the reader of these chapters of Le Loyer's *Discours des spectres* is that the devil's dominion was an empire in motion. The diabolical world map outlined by demonologists was in no way static: it was dynamic, always subject to change, a map across which demons moved according to the flow of history. The devil might in theory have been able to be in any place at any time, but demonologists were in broad agreement that his inhabiting of the earth was not necessarily balanced or uniform. This is certainly something that came across strongly in Olaus Magnus's *Historia de gentibus septentrionalibus*. We have noted that, as far as Olaus Magnus was concerned, the Septentrion had largely been purged of the devil by the propagation of the Catholic faith. Of course, at the time he was writing, the devil was regaining lost territory, but for centuries Satan had nonetheless been well and truly driven out of the majority of the land.[85] The presence of the devil in the Far North thus depended on historical circumstance. Here, then, was an apologetic discourse that must be understood in the context of a struggle with a religious adversary: the demons that came and went were evidently Lutherans, those devils in disguise. But the idea of the devil migrating across the map occurred beyond the framework of confessional polemic. Jean Bodin, for example, suggested in his *Démonomanie des sorciers* that the New World had served as a refuge for the devil after the coming of Christ. As Bodin reminded his readers, the coming of Christ was thought to have considerably weakened Satan's power.[86] But this was only the case in Christian Europe: the devil, wrote Bodin, had been able to "maintain" ("entretenir") idolatry in the New World, at least until the Spanish conquest.[87] In short, the devil was able to pursue in the Americas the crimes he had committed in the ancient world before the establishment of Christianity (idolatrous worship, human sacrifice, oracular practice, etc.). Bodin's numerous analogies between Ancient and New World religions, like those of many travellers, reinforced the idea that there had been a kind of diabolical *translatio* to the New World at the start of the Christian era. José de Acosta made just this point ten years later, at the start of the fifth chapter of his *Natural and Moral History of the Indies* (1590) which discussed Indian customs and beliefs: "Once idolatry was rooted out of the best and noblest part of the world, the devil retired to the most remote places and reigned in that other part of the world [=the Indies], which, although it is very inferior in nobility, is not in size and breadth."[88] As such, the New World, as the devil's territory, offered a glimpse of what Europe would have become

[85] Lestringant (2004, 53).

[86] Bodin (1580, f. 120 r°): "La publication de la Loi divine a bien fort diminué la puissance de Satan."

[87] Ibid., f. 14 v°.

[88] Acosta (2002, 254).

without Christ. The discovery of the Americas was therefore another kind of rediscovery of the ancient world; an ancient world, however, from whence the demons had not been driven; an antiquity that had stayed pagan, and where the devil had flourished.

But the devil was, in any case, winging his way back to Europe. According to many demonologists, the fact that modern times had witnessed a resurgence of witchcraft in Europe and the disunity of the Church was a sign that battalions of demons were returning to Europe from the New World. The lawyer Pierre Massé wrote in 1579 that: "Chased away by the predication and reception of the Gospel, the devils flee the new lands where they were staying, and come back to these lands from where they had in times past been driven out."[89] The devil, he added, "returns [in Europe] as if *postliminium*" (the right to recover a vessel or property that has fallen into foreign hands).[90] Pierre Crespet confirmed this: "the devil thrust himself freely into France from the very moment faith was planted in these new and foreign lands."[91] Moreover, the devil himself had said it: Crespet cited, without specifying his exact source, a possessed man from Soissons ("un démoniaque de Soissons") according to whom more than fifteen thousand demons driven out of the Indies were seeking refuge in France.[92] Crespet actually discovered this "revelation" in the account of the exorcism of one Nicolas Facquier, exorcised in Soissons on the 15th of June, 1582. Cramoisy, the demon who had possessed the unfortunate Facquier, introduced himself as one of the hordes who had returned from America: "We are fifteen thousand and eighteen hundred that went out of the Indies, and four hundred here by the command of God."[93] Thirty years after that exorcism, in a famous passage of his *Tableau de l'inconstance des mauvais anges et demons* (1612), Pierre de Lancre evoked in turn the transatlantic migration of the devil: English and Scottish travellers whom he had encountered in Bordeaux declared that they had seen "large troups of demons in the guise of dreadful men cross over to France."[94] The *Tableau de l'inconstance* actually ended with an epic and dramatic account of the progression of the devil's army across southern

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[89] Massé (1579, f. 49 v°): "Les diables fuient des terres neuves où ils estoient, chassés par la prédication et réception de l'Evangile et reviennent en ces terres ici dont ils avoient esté autrefois chassés."

[90] Massé (1579, f. 49 v°): "[le diable] retourne [en Europe] comme *post liminium*, c'est-à-dire par droit de recouvrance."

[91] Crespet (1590, f. 194 v°): "[le diable] s'est venu fourrer parmy la France dés lors que la foi a esté plantée és terres neuves, & pays estranges."

[92] Ibid.

[93] Blendecq (1582, f. 102 r°): "Nous sommes quinze mille dix huict cens qui sommes sortis des Indes, dont les quatre cens sont en ce pays par le commandement de Dieu."

[94] Lancre (1612, 80): "de grandes troupes de démons en forme d'hommes épouvantables passer en France."

France. After invading Provence, Guyenne and Labourt, the devil, announced Lancre, had laid siege to Bayonne, conquered the moorlands of Bordeaux, crossed the Garonne and sent his werewolves up through the North Dordogne.[95] The devil would soon reach Paris…

Once again, it is possible to place this discourse within the framework of religious polemic. For the Catholics Massé and Crespet, these migrations were at once proof of the efficacy of Jesuit missions to the New World, and a sign that Christianity was weakened in its heartlands by protestant heresy. Parallels between the threats of witchcraft and heresy were often established by Counter-Reformation demonologists.[96] There was also an eschatological angle: the return of the devil (once and for all?) to the centre of the Christian world could be understood, both from Catholic and Protestant viewpoints, as a sign of the end times approaching, and the imminent triumph of the Antichrist.[97] But this discourse, as I suggested in relation to Bodin, exceeds the category of religious controversies, which were in truth of minor importance to authors such as Bodin, Pierre Le Loyer, and even Pierre de Lancre. Descriptions of demons crossing the oceans to return to Europe undoubtedly expressed a profound anxiety about the dangers posed by witchcraft and heresy to Christianity. However, they also betray a further anxiety, this time prompted by geographical discoveries: what is at work here, I would argue, is the idea of Europe being contaminated by the New World. This contagion anxiety surfaced at other moments of the treatises, in the way in which, for example, witches and heretics were sometimes presented as "European Indians,"[98] domestic savages who had to be confronted just like the inhabitants of the Indies,[99] and who furthermore owed their cruelty in some cases to the contact that they had had with the New World. The most striking example of this would be the Basque witches interrogated by Pierre de Lancre, who, according to the demonologist, would swoop across the Atlantic to Newfoundland to be reunited with their husbands who had gone whaling and cod fishing.[100] But one may also refer to Pierre Massé's discussion of the way that Europeans, under the influence of demons returning from the Americas, became contaminated by cannibalistic violence ("the cruelty of man-eating cannibals is transferred [into atheists]," wrote he[101]), or to the (more anecdotal) account cited by Michel de Certeau of a

[95] Lancre (1612, 569–570).

[96] Machielsen (2015, 214–215). On heresy and witchcraft, see also Clark (1997, 526–546).

[97] On demonology and eschatology, see Clark (1997, 335–345).

[98] The phrase is used by a "Spanish Catholic theologian" quoted by Roper (2004, 27).

[99] On this point, and more particularly on "the conflation of witchcraft with Amerindian cannibalism," see Zika (2007, 219).

[100] Lancre (1612, 99, 129 and 136).

[101] Massé (1579, f. 49 v°): "La cruauté des Canibales mang'hommes se transfere."

possessed woman suddenly speaking Tupinambá, as though she had been possessed by a "americanized" demon, just back from Brazil.[102]

The question thus raised by the demonologists was this: had the discovery of the New World not set the devil free to roam once more among Europeans? And in doing so had it not in fact ensured their own downfall? In short, demonological discourse on the "cosmography of the devil," and particularly the narrative that they built of the devil's past and present colonization of the world, expressed an anxiety beyond that of the fear of witchcraft for its own sake. Rather, it put into question the elements that, for the humanists themselves, defined the age in which they lived: the compass, that opened the path to the New World, and—as we have seen—the printing press, which resuscitated ancient texts. By discovering the New World, early modern Europeans had probably released the devil once again, as they had resurrected the devil by resurrecting Antiquity. In other words: because of the Renaissance, Europe had been contaminated, once again, by the devil. "Where is the devil?" Perhaps he was lurking, all along, in the heart of humanism itself.

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[102]Certeau (2000, 121).

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Chapter 8
All Space Will Pass Away: The Spiritual, Spaceless and Incorporeal Heaven of Valentin Weigel (1533–1588)

Alessandro Scafi

Abstract The cosmology of Valentin Weigel (1533–1588) offers an example of the changing understanding of space and the universe between medieval and modern times. The aim of this essay is to explore his discussion of the nature of space in the treatise *Vom Ort der Welt* (*On the Place of the World*, 1576) in relation to his views concerning the Christian heaven and the resurrected body. Adopting the distinction between "locative" and "utopian" tendencies in religion drawn in the field of religious studies by Jonathan Z. Smith, Weigel's views on earthly space and historical time in relation to heaven and eternity bear the hallmark of a utopian vision. Weigel was an advocate of the true Christian faith—received as a gift of the Holy Spirit acting within the soul and forming a spiritual brotherhood—as opposed to the visible and organised Church, and combined mystical, Lutheran and Paracelsian theories to provide an original way to envisage the relation between time and eternity, space and infinity, human realm and divine dimension. He envisioned the material and visible world as floating against the infinite abyss of God, saw the Kingdom of Heaven as accessible from within and radically opposed spirit and matter, light and darkness, freedom and bondage.

It is well known that an epochal shift in the conception of space occurred in Western Europe during the late Middle Ages and the Renaissance, when the Aristotelian model of the universe was challenged by advances in astronomy and

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geographical discoveries.[1] The cosmographical ideas held by the German theologian and mystical writer Valentin Weigel (1533–1588) provide a good opportunity for assessing the interaction between these changing views concerning space and religious belief.[2]

Edward Grant has described the paradigm shift from the medieval debates on cosmography to early modern views of space and pointed to the introduction, between the fifteenth and sixteenth centuries, of atomistic and Hermetic concepts as well as Stoic ideas about an infinite space beyond the cosmos.[3] The cosmology of Valentin Weigel, who was not included by Grant in his study, offers an important case study in which one can find an example of the changing understanding of space and the universe between medieval and modern times. Weigel was still entrenched in the medieval mindset of a geocentric cosmos, but he envisioned the material and visible world, with the planets and the sun revolving around the earth at their stationary centre, as floating against an overpowering background of infinite nothingness, offering an intriguing cosmographical vision in the age of the Copernican revolution. His cosmological views, however, were heavily informed by his religious and mystical thought. Weigel was the Lutheran Pastor of Zschopau, in Saxony, and explored the subject of the world's position in space and time as part of his interest in the Bible and as an advocate of the true Christian faith, which required, in his view, "accepting Christ … as a model and pattern for our lives."[4] Following like-minded spiritualists such as Sebastian Franck (1499–1542) and Caspar Schwenckfeld (1489–1561), Weigel argued for the autonomy of the individual conscience enlightened by the Holy Spirit, in contrast to the increasingly authoritarian and dogmatic Lutheran Church. In a Lutheran world shaken by doctrinal controversies Weigel was divided between the loyalty to Luther's faith,

[1]I am grateful to Teresa Monachino and Guido Giglioni for their advice and to the editors and anonymous readers for their precious criticism.

There is, of course, a vast bibliography on the subject. See for example, Cosgrove (2007, 55–98), Harries (2001), Randles (2000, 1999), Koyré (1957). On Aristotelian cosmology see Grant (1994), and on the challenge to the Aristotelian model, his Conclusion there, 675–79. Edson (2007) has studied the impact of the changing world view between the Middle Ages and the Renaissance on maps. For the reaction to these changes in humanistic circles, see Clough (1994, 291–328), and Wuttke (2007).

[2]An introduction to Weigel is provided by Weeks (2000) and Koyré (1930), reprinted in Koyré (1971, 81–116). For an useful account and bibliography, see the entries on Weigel by Pfefferl (2003), Weeks (2005) and Telle (2011). See also Odermatt (2008). A discussion on Weigel's and Pseudo-Weigel's writings is found in Pfefferl (1991), Lieb (1962) and Zeller (1965). Earlier studies include Israel (1888), Opel (1864) and Aarsleff (1976).

[3]Grant (1981, esp. 182–213).

[4]Weigel (2014b, 14–15): "der wahre glaube erfodert Christum anzunehmen, nicht alleine zum geschenke, oder gabe, sondern auch zum fürbilde und Muster unseres Lebens;" English translation in Weeks (2000, 88).

the commitment to pastoral duties, and a covert antiauthoritarian dissent.[5] He strongly believed that Christ could be born in each human soul and envisioned the invisible brotherhood of all good Christians sharing in such an inner Kingdom of God, universally present, as opposed to the visible, formal and organised Church, the *Mauerkirche*, the church made merely of stone.[6]

The aim of this essay is to explore his discussion of the nature of space in the treatise *Vom Ort der Welt* (*On the Place of the World*, composed in 1576) in relation to his views concerning the Christian heaven and the resurrected body.[7] These views are of great interest, as they prove Weigel's originality in the way in which he handled in a modern context the old issue of how to conceive of a human perfection in heaven, while his thinking about Spirit and the universe bears witness to the long-standing tendency in Western Christianity to spiritualise and de-individualise heavenly bliss.

8.1 A Fundamental Dichotomy: Locative and Utopian, Bodily and Spiritual

The centuries-old Christian debate about heaven and the resurrection of the body is of great complexity and only a detailed study of the individual authors would do justice to the topic. Generalisations are always somewhat risky. For the purpose of this essay, however, it will be helpful to look briefly and in general terms at the Christian attitude towards the complementary opposites of matter and spirit, body and soul, heaven and earth. In doing so, we will be able to identify the main issues involved and to appreciate Weigel's position against the backdrop of major attitudes that emerged along the centuries in Western Christianity in the debate about heaven and its relation to the earth.

The Christian tradition is rich in warnings about the transitory nature of the material world. As Saint Paul noted, the only permanent dwelling is heaven and Christians are encouraged to concentrate their minds on heavenly thoughts, and therefore not concern themselves with earthly matters (Colossians 3.2: "Set your affection on things above, not on things on the earth"). The Christian approach to

[5]See Pfefferl (1993/94).

[6]The term was used by Paracelsus in his *De septem puncti idolatriae christianae* (1525) to mean the "brick-church" of Rome, see Gilly (1998, 152). It was adopted by dissenting Lutherans to refer to their Church: Goodrick-Clarke (2008, 89). On Weigel see Koyré (1971, 86–88, 101); Weeks (2000, 103–114).

[7]I shall refer to the recent Pfefferl edition: Weigel (2014a); for the transmission of the text and a bibliography see the Introduction, XV–XIX, and XXXIII–XXXIV; I use here the English translation by Andrew Weeks in Weigel (2003).

earthly space and historical time, however, is not quite so simple. For Christians, the hope in an eternal heaven is founded on an essentially historical faith and the incarnation of Christ and His redeeming sacrifice on Golgotha have sanctified earthly space and historical time once and for all. Thanks to Christ and the sacramental life of the Church, the heavenly Kingdom of God has already been established on earth. Yet, for Christian teaching the visible universe, in which man can contemplate the invisible God and where Divine Providence directs salvation history, is destined to be replaced by a new heaven and a new earth at the end of time.

This complex and seemingly contradictory attitude can be viewed adopting a terminological distinction drawn in the field of religious studies by Jonathan Z. Smith, who has contrasted "locative" and "utopian" tendencies in religion.[8] According to this distinction, "locative" refers to a vision that emphasises place and installation within the world, with a stable and closed space focussed on a centre, while "utopian" refers to a more open view that recognises the problematic nature of existence and seeks absolute freedom and transcendence. This latter tendency is usually characterised by a rebellious impulse to break limits and boundaries. Smith explains that by "utopian" vision of the world he means a vision appreciating the value of "being in no place," thus using the term in its strict sense.[9]

Of course, the issue whether to assign positive or negative value to the world of the senses, appreciating settlement on earth or seeking transcendence in heaven, has a long history, with a great variety of ways to imagine the material world as a manifestation of spiritual truths: as old as Plato and Plotinus, it has been a central issue in Greek-pagan philosophy and religions and has permeated the history of Christianity, with its recurrent gnostic tendencies. Already André-Jean Festugière, for instance, when studying Hermetic literature recognized two contrasting attitudes in the Hellenistic religious philosophy: an optimistic line of thought—that he termed *gnosis optimiste*—pleased about the beauty and the order of the world, and a pessimistic one—*gnosis pessimiste*—troubled by the evil, chaos and corruption prevailing in the human condition.[10] Smith's designation adapts a new cloth to a well-known philosophical divide and traditional body of thought, but the interest

[8]Smith (1978, XI–XV, 67–207), and (1990, 121–43). See Markus (1994, esp. 264–266).

[9]Smith (1978, 101): "In my own writings I have toyed with the distinction centrifugal and centripetal, central and peripheral, considering adopting Bergson's classic distinction between the closed/static society and the open/dynamic one, or Eric Voegelin's contrast between a 'compact' and 'differentiated' experience of the cosmos. With some hesitation I have settled for the present on the dichotomy between a *locative* vision of the world (which emphasizes place) and a *utopian* vision of the world (using the term in its strict sense: the value of being in no place)."

[10]Festugière (1967, 28–87, 1990, X–XI); see Bos (1994, 2–3).

and significance of his terminology is that it enables the acknowledgment that in Christianity these two contrasting world views have coexisted and dynamically interacted as part of a fundamental dichotomy (interestingly, Festugière also noted his two tendencies merging in some treatises of the Hermetic Corpus). Christian doctrine endorses a utopian world view inasmuch as it points to the heavenly fatherland and to a mysterious God who is equally present in all places at any time and is to be found in our innermost depth. As Christ Himself taught, God does not dwell in any particular spot and is to be worshipped in spirit and truth (John 4.23–24: "But the hour cometh, and now is, when the true worshippers shall worship the Father in spirit and in truth: for the Father seeketh such to worship Him. God is a Spirit: and they that worship Him must worship Him in spirit and in truth"). The "utopian" Christian challenge to transcend the world, however, has always coexisted with a keen interest in the beauty and variety of that world. Christian teaching points at the frailty of the human condition to call the faithful to eternal life, but also to a world created by a benevolent God and to a history set in motion by Him. A geo-history of salvation may include the holiness of specific moments and particular places and allow mankind to lead a holy and devout life on earth. Holy places on earth feature in Scripture, and throughout history the Church has often marked the spot and recorded the moment when the divine dimension has broken through into the human world, acknowledging in this way the sacrality of life itself in present historical time and actual geographical space. In Christian tradition, the argument has swung back and forth between these two different discourses along the centuries.

A similar dichotomy could be appreciated when looking at the diverse Christian ways of envisaging human perfection in heaven and at the different approaches to Scripture adopted throughout the centuries. The same paradoxical attitude that we have seen towards the material world and human life on earth can also be detected in the Christian idea of a fallen human nature that preserves some of the glory of God's image and yet will be restored to its full perfection only in the afterlife.

But what kind of human life is to be expected for the blessed in heaven? A fundamental element in Christian doctrine is that life in heaven must include a restoration of the whole psycho-physical organism. Man was created by God to be and to remain an embodied spirit. At the Second Coming of Christ, departed souls will be restored to a bodily life. Moreover, the acceptance of the Aristotelian tenet that the soul was the form of the body gave philosophical justification for the belief that the resurrection of the body was necessary for a full human life in the world to come. The boundary, however, between spiritual and material has always appeared to be rather imprecise.[11]

How then to affirm the identity of the individual in heaven? How to account for a change into changelessness? How to keep both transformation and identity,

[11] In the present discussion of these issues, I have made use of Bynum (1995).

which requires integrity of bodily structure and material continuity? Was resurrection a collection and revivifying of the material particles of the same dead body? Or was perhaps the resurrected body something completely new and spiritual, like a seed changing into a tree? In the first letter to the Corinthians, Saint Paul maintains that the resurrected body will be a body of a new order, the perfect instrument of the spirit, raised above the limitations of the earthly body (1 Corinthians 15).

Mainstream Christian theologians, starting with Jerome and Augustine, have always clung to a literal notion of the resurrection of the flesh, despite the paradox of imagining a changeless physicality and an incorruptible body, and insisted on the preservation of the individual identity in heaven. In their view, continuity of earthly life in heaven had to be clearly asserted. Belief in the immortality of the soul (sometimes thought of as material and somatized) was combined in different ways with the notion that the body was essential for the survival of the person in heaven. Augustine's emphasis on the integrity of personal characteristics in heaven shaped later medieval discussion. Borrowing from Augustine, medieval writers such as Peter Lombard emphasized the material and formal continuity of the resurrected and glorified body with the body on earth. Everything intrinsic to what a man and a woman are must reappear in the resurrected body. Thomas Aquinas, for example, claimed that at the end of time all men and women shall rise from the dead in their own bodies and in their youthful age to be immortal; in his view, at the resurrection all things, including human nature, will be perfectly restored by God. Significantly, most of the thinkers coming from this mould advocated an historical and literal reading of Scripture. As a result, the Garden of Eden was understood as the original paradise described in Genesis and as a real place on earth, while Adam and Eve were thought as having been created perfect by God in their physical bodies. It was also common to take in a literal sense all biblical references to bodily resurrection in heaven, seen as the ultimate paradise, neatly distinguished from the original Eden on earth. These authors tended to appreciate the uniqueness of human history and saw it as a process directed by God Himself to culminate in the final and eternal paradise. The tendency to include corporeal and individual bodies, however spiritualised and made eternal, within the heavenly perfection and to project onto the screen of eternity the recognisable features of an earthly humanity may be seen as paralleling the "locative" propensity to value the contingent and the particular on earth.

Another line of thought, imbued with Platonic philosophy, laid emphasis on how human nature was destined to undergo a radical transformation in heaven, to take on the spiritual, angelic, and godlike nature of eternal life. For many Christian writers, such as Origen and Clement of Alexandria in the early centuries, and later on John Scotus Eriugena and Giovanni Pico della Mirandola, to mention just a few, human nature in heaven coincided in all aspects with divine being. For these authors, resurrected humans would become beautiful angels. Again, it is significant that the exegetes who adhered to this line of thought attempted to reveal deeper meanings hidden in the biblical text and equated the original perfection in Eden with the final bliss in heaven as a bodiless, immaterial, divine state outside time and space, and akin to Plato's realm of ideas. For them, history was the result of some cosmic fall and the visible world a mere reflection of a higher and eternal reality, while human life on earth, contrasted with heavenly perfection, was intrinsically imperfect. They viewed true human nature as godlike and the earthly man, confined within a physical body, as sinful and corruptible. Man, for these authors, had the task to return to his original and spiritual perfection. For instance, Origen maintained that human nature had originally been created as an "angelic" spirit, "in the image of God," in order that it could contemplate forever divine wisdom, but in some way humankind became separated from the Supreme Being and acquired the solid flesh of the human body. Therefore the physical body was not part of man's original state of perfection and surely was not going to be included in any heavenly condition. The spiritualising approach to human perfection in heaven was usually paired with an exclusively allegorical understanding of the Bible, and we may safely associate it with the typical utopian attitude of relativizing any earthly particular or historical uniqueness.

In Christian theology and exegesis the literal approach to the biblical account, focussed on earthly history, was challenged by an allegorical reading of Scripture inspired by Greek philosophy and seeking human perfection only in heaven. Bodily and spiritual as well as locative and utopian discourses coexisted and interacted in Christian tradition throughout the centuries. Their interplay also point to the inextricable link between body and place.

8.2 On the Place of the World: A Locative Start for a Utopian Argument

When we consider the swinging pendulum between the locative and the utopian within the Christian tradition, Weigel's thought definitely moves towards the "utopian" extreme. He declares the aim of his treatise *Vom Ort der Welt* (*On the Place of the World*) at the very beginning. It is very important for each individual to consider the foundation of the visible world, reads the title of Chap. 1.[12] Directly after these lines, Weigel introduces his readers to the paradox of a visible world, within which material places stand and human beings move, but which, although

[12] Weigel (2014a, 4): "Daß es einem jeden Menschen nützlich sey zu bedencken/worauff die Welt stehe/daß sie nicht falle;" Weigel (2003, 68): "That it is useful for each human being to consider upon what sort of foundation the world stands so that it may not fall."

knowable in space and time, hovers “in no place.”[13] The argument intends to urge the readers to keep in mind their heavenly fatherland:

> And in as much as the human being has been made from the clump of earth of this world and has been placed into the middle of this world, in order to dwell within it until his appointed time, it is appropriate for him to regard and contemplate his place and fatherland, in which he has his home in such time; [that is,] in accordance with his mortal body [only], so that he might be forewarned that is eternal and in heaven, for which he was created in the beginning.[14]

Weigel argues that, according to the body, the human being needs a location in this time, but according to the spirit, the human being is in a real “utopian” condition, in need of no place:

> …in accordance with the spirit, he is in need of no place, for the spirit possesses no place [and] occupies no space [and] does not admit of being enclosed or locked into any place. Whoever considers and properly understands these things strives to walk in accordance with the spirit in Christ [and] to remain in the Kingdom of God, so that he may at last leave behind this narrow and pitiful wretchedness and come to his Father in heaven in the eternal expanse. For he sees clearly with what drudgery his mortal body transports itself from one place to another; how it is driven hither and yonder by men and by beasts, by fire and water, by hunger and by thirst, by heat and cold, through day and night, summer and winter; and how it is at last entirely consumed by death and reduced to nothing.[15]

After introducing, in this manner, a sharp contrast between body and spirit, between the material world—mankind’s temporary dwelling place—and his heavenly homeland, Weigel declares the rather “locative” intention to describe in detail the physical world as it falls under the senses. This “locative” enterprise, however, serves to develop the very “utopian” argument that the contemplation of the physical universe, composed of heavens and earth but standing in no place, should remind men and women of their homeland in heaven.

Out of the 29 chapters of the treatise, eight (from Chaps. 2–9) are devoted to the exploration and illustration of the structure of the physical universe. Such a

[13]Weigel (2014a, 4): “an keinem Orte;” see Weeks (2000, 107).

[14]Weigel (2003, 68, 2014a, 4): “Und dieweil der Mensch aus dem Erdenkloß dieser Welt gemacht ist/und ist gesetzet mitten in die Welt/darinne zu wonen biß auff seine bestimpte zeit/ so gebühret jhm gar wohl/anzusehen und zu betrachten seinen Ort oder Vaterlandt/da er in dieser Zeit seine heymat *hat*. Nach dem sterblichen Leibe/auff daß er sich ermahne/wie er in dieser Welt keine bleibende Statt habe/er muß bald darvon und diese Welt verlassen/er gehöret in ein ander Vaterland/das ewig ist im Himmel/zu welchem er anfenglich geschaffen ist.”

[15]Weigel (2003, 68–69) (with modifications); Weigel (2014a, 4): “Aber nach dem Geist bedarff er keines Ortes/denn der Geist besitzet keine statt/nimpt keinen Raum ein/lesset sich an keinen Ort nicht schliessen noch einsperren. Wer das bedencket und wohl erkennet/der trachtet in Christo nach dem Geist zu wandeln/ | im Reich Gottes zu bleiben/auff daß er endlich aus diesem engen erbärmlichen Elend komme/in die ewige Weite zu seinem Vater in den Himmel. Denn er siehet wohl/wie müheselig sein sterblicher Leib von einem Ort zum andern beweget werde/hie und daher getrieben von Menschen und Thieren/vom Fewr und Wasser/vom Hunger und Durst/ von Hitz und Kälte/durch Tag und Nacht/durch Winter und Sommer/und endlich durch den Todt wird er ganz verzehrt und zu nichte.”

universe is likened to an egg, Weigel says, with the heavenly spheres and the air that surrounds the earth and the sea at the centre, as the albumen and yoke. Weigel then discusses the division of the earth into five zones (two frigid, two temperate, and a torrid zone along the equator); the division of the firmament into ten astronomical circles (Horizon, Meridian, Equator, Zodiac, Tropic of Cancer, Tropic of Capricorn, the Equinoctial and the Solstitial Colures, the Arctic and Antarctic Tropics); the twelve signs of the Zodiac; the four parts of the world (Europe, Asia, Africa, and America), with all their regions; the calculation of latitude and longitude; the orientation according to the height of the Northern Pole; the form of the earth and the four winds; the measurement of the earth and the seas. Finally, in Chap. 9, Weigel discusses the stable position of the earthly globe at the centre of the universe.[16]

This first part of Weigel's treatise demonstrates the considerable progress achieved by geographical and cosmographical knowledge during his time. The great age of geographical discoveries, started in the early fifteenth century, was in full swing in the second half of the sixteenth century. In 1569, only a few years before Weigel compiled his *On the Place of the World*, Gerard Mercator (1512–1594) had drawn the famous world map based on his new projection.[17] Among the sources of Weigel's cosmographical account we find the *Abacus* by the German scholar Petrus Apianus (1495–1552) and the *Weltchronik* by Sebastian Franck, which included America in the description of the world.[18] Weigel, however, adopts advanced contemporary geographical knowledge to make a religious point: notably the range of his sources includes not only geographers and cosmographers, but also mystical writers. In addition to Paracelsus (1493–1541), Schwenckfeld and Franck's writings, Weigel's sources consist of the mystical late thirteenth-century treatise *Theologia Germanica* and the writings of Boëthius (480–524), Hugh of St. Victor (1096–1141), Meister Eckhart (1260–1327), Johannes Tauler (c. 1300–1361), Nicholas of Cusa (1401–1464).[19]

In his treatise Weigel concedes that it is important to know how to discover a route from one location to another, but he also points out that the position or proportion of any physical place on earth is relative to the dimensions of the world itself, and that the finite world is incomparable to the infinite abyss of God:

> This visible world stands in itself, and in accordance with its external aspect it stands in the depths, within the abyss of infinity [*abysso infinitudinis*], a depth that is in height without end and in breadth without end and in length without end and in depth without end. In such a nothingness the world stands, for no one can in all eternity fathom, plumb, comprehend, or conceive the same [nothingness]. Whether in height, depth, breadth, or width, no end to it shall ever be found. All physical things are enclosed and comprehended in this

[16] Weigel (2003, 70–88, 2014a, 6–27).

[17] On Mercator, see the bibliography in Crane (2002, 331–38).

[18] Weigel (2003, 78, 82, 2014a, 17, 18, 20, 21). See Weeks (2000, 107).

[19] See Weeks, Introduction, and R. Emmet McLaughlin, Preface, in Weigel (2003, 32–42 and 6–8), Koyré (1971, 81–87). On Weigel and Paracelsus see Pfefferl (1995, 1988).

> visible world; outside of the world there is no physical thing, thus neither is there any location or place. Locations and places are only internal to the world.[20]

> The world is nowhere, for outside of the world there is no place, neither under it nor above it.[21]

> Now, great as the earth is, yet compared to the firmament, it is a centre or minute point, just as this entire world with earth and heavens, great as it is, is nonetheless similarly small, indeed nothing whatsoever, compared to the incomprehensible depths. A droplet of water compared to the great sea has a relation or comparison, for both are *finita*, that is, finite and comprehensible. But this entire world is not only small, it is like nothing at all compared to the depths. For how should one compare the finite with the infinite?[22]

Christian association with the intellectual world of Platonic and Neoplatonic tradition stands out in Wegel's work; here, however, we find a clear conceptual connection with Aristotelian lore. Aristotle had conceived of a nothingness beyond the finite and material dimension of the world, where no void, no place, no time exist:

> This world is one, solitary and complete. It is clear in addition that there is neither place nor void nor time beyond the heaven; for (*a*) in all place there is a possibility of the presence of body, (*b*) void is defined as that which, although at present not containing body, can contain it, (*c*) time is the number of motion, and without natural body there cannot be motion. It is obvious then that there is neither place nor void nor time outside the heaven, since it has been demonstrated that there neither is nor can be body there.[23]

Aristotle envisioned the existence, beyond the last celestial sphere (the sphere of the fixed stars), of a transcendent world without space or time where immaterial and eternal realities are found. The term he uses, τἀκεῖ ("those [things/beings]

[20]Weigel (2003, 89) [following the suggestion of one of the anonymous readers, I have replaced Week's translation of Weigel's original German text "in einem solchen nichts" as "in such a void" with "in such a nothingness"]; Weigel (2014a, 28): "Diese sichtbare Welt stehet in jhr selbst/und nach ihrer Außwendigkeit stehet sie in der Tiefe, in *Abysso infinitudinis*, welche Tieffe ist nach der Höhe ohne Ende/und nach der Breite ohne Ende/und nach der Lenge ohn Ende, und nach der Tieffe ohn Ende/in einem solchen nichts stehet die Welt/da niemand in Ewigkeit dasselbige erfahren/ergründen/begreiffen noch bedencken kan/es sey in die Höhe/Tieffe/Breite oder Lenge/so findet man alle zeit kein Ende. Alle leibliche Ding seynd in diese sichtbare Welt geschlossen und gefasset/unnd ausserhalben der Welt ist kein leiblich Ding/also auch keine Stelle noch Ort. Stellen und Oerter sind nur inwendig in der Welt." See Koyré (1971, 99–103).

[21]Weigel (2003, 93, 2014a, 33): "die Welt ist nirgends/denn ausserhalben der Welt ist kein Ort/ weder uber sich noch unter sich."

[22]Weigel (2003, 96, 2014a, 35–36): "Nun wie groß die Erden ist/dennoch gegen dem Firmament gehalten/ist sie ein *Centrum* oder kleines Punct/eben also auch diese gantze Welt/als Erden und Himmel/wie groß sie ist/dennoch ist sie so klein gegen der unbegreifflichen Tieffe/ja sie ist gar nichts dargegen. Ein tröfflein Wasser gegen dem grossen Meer hat eine Vergleichung oder *Collation*, denn beyde seynd *finita*, das ist/endlich und begreifflich/aber diese gantze Welt ist nicht alleine klein/sondern auch wie nichts gegen der Tieffe/dann wie wil man vergleichen das *finitum* mit dem *infinito*?"

[23]Aristotle, *On the Heavens* I.IX.279a.11–16 (1939, 90–91).

over there"), has been variously translated and interpreted by scholars who wondered whether Aristotle was speaking of some kind of transcendent divine realm.[24]

A particular point made by Aristotle in this context seems to echo in Weigel's vision. For Aristotle the place of a body is defined by the inner surface of its surrounding body.[25] Outside the cosmos, however, there is no matter nor body, just nothing. Thus the material cosmos, filled everywhere with extended bodies, lacks a containing body with which it is in contact, and this is why it cannot have a place, an idea akin to Weigel's statement that while all things are enclosed in the visible world outside it there is no location and the world, enclosed in no place, stands in nothing.[26] Surely Weigel read Aristotle[27]; for example he quotes him in *The Golden Grasp*, written just a couple of years after *On the Place of the World*, when, discussing the emergence of everything out of nothing, he rejects Aristotle's claim that the rain comes from earthly vapours.[28] However, he does not explicitly refer to him here.

What lies at Weigel's heart is the idea that the world in its geographical extension and historical development is little and insignificant when compared to the divine infinity; as he put it, "in the spiritual invisible being greatness and smallness are the same thing."[29] However, it is precisely the finitude of the world of the senses, and the relativity of place in it, that point to the inward realm of the spirit. In this sense, in Weigel's view, the place of the world is symbolic.[30]

The "utopian" character of Weigel's vision becomes evident when he states that God created the material and visible world from nothing, in other words, without any material and from that which is invisible, which Weigel identifies with the water beneath the heavens, mentioned in the Book of Genesis (1.7). In his view, the entire visible and corporeal world was formerly invisible and incorporeal in God and to this invisible and divine condition is ultimately destined to return. All corporeal creatures were first invisible and angelic, and they owe their being to the divine source.[31]

Weigel also appropriates and interprets the alchemical theory by Paracelsus, who regarded the three principles of Sulphur, Mercury and Salt as images of the Trinitarian nature of God inhabiting all corporeal things. Like Paracelsus, he saw

[24]Elders (1966, 143–145); Bodeus (2000, 18–20); Keizer (1999, 84–85, note 101).

[25]Aristotle, *Physics* IV.4.212a.5–6, (1929, 310–313).

[26]See notes 20 and 21 above. On Aristotle's concept of void space and the infinite see Grant (1981, 5–8) and Solmsen (1960, 160–173, esp. 169 note 39).

[27]Weigel (2000, 10).

[28]Weigel (2003, 151).

[29]Weigel (2003, 95, 2014a, 35): "Jm geistlichen unsichtbaren Wesen ist die Grösse und Kleinheit ein Ding."

[30]Weeks (2000, 108–110); Weeks, Introduction, in Weigel (2003, 9–10).

[31]Weigel (2003, 97–98, 2014a, 37–38). See Weeks (2000, 110).

these principles working in material nature, which at the beginning had been created from nothing and will return to nothing at the end of time.[32]

The treatise begins with the account of how humans survey the space of the world to conclude that the very concept of place is an illusion and that the spirit cannot be located. The heavenly condition is not bound to place, person, gesture, external liturgy, but rather stands free in spirit and faith. Valentin Weigel, defined as "the last of the German Reformation Spiritualist" who, as a ghost, "haunted the Lutheran Church,"[33] proves his "utopian" attitude in his theory about the place of the world, consistent with his radical dismissal of external rituals (belonging to the material dimension) for the sake of the most inner religious experience (the work of the Spirit), not to be subjugated by priestly power.

8.3 From a Space Hovering in no Place to a Utopian Heaven: Nothing to Nobody

The entire material world, according to Weigel, is nothing; created out of nothing, it will return to nothing. At the centre of *Vom Ort der Welt* is the notion that the world is floating in a spatial-temporal abyss, against the backdrop of infinity. As Andrew Weeks has pointed out, such a central concept in Weigel's work corresponds to his "darkening mood of the mid to late 1570s," when the Lutheran pastor committed to tolerance and spiritual freedom, and eager to seek the Kingdom of God within the human heart, found himself surrounded by devastating religious conflicts and escalating violent persecutions. Echoing the notion of the material world as nothingness and the call to return to the divine dimension of the Spirit, man's condition of exile on this earth is also a recurrent motif of *On the Place of the World*.[34] The idea, of course, is found in the centuries-long Christian tradition, but we can appreciate here its "utopian" character.

Weigel interpreted the duality of the Christian attitude towards life on earth by making the concept of spiritual exile and withdrawal from the world a foundation of his religious thought. In the words of the twelfth-century theologian Hugh of St. Victor, an author Weigel read and used,[35] perfection is to live as if the entire world were "a foreign land," achieving a state of detachment from any particular place:

[32]Weeks, Introduction, in Weigel (2003, 21–22, 35), Weeks (2000, 111–114).

[33]McLaughlin, Preface, in Weigel (2003, 1).

[34]Weeks (2000, 104–105).

[35]Weeks, Introduction, in Weigel (2003, 37).

> The man who finds his homeland sweet is still a tender beginner; he to whom every soil is as his native one is already strong; but he is perfect to whom the entire world is as a foreign land. The tender soul has fixed his love on one spot in the world; the strong man has extended his love to all places; the perfect man has extinguished his.[36]

Weigel takes up this sense of being lost in a journey away from God into a condition of exile far distant from Him as he sees humans as homeless "exiles" bound to this world:

> Oh, how wretched are the human beings who seek satisfaction and their good life in the world hither and yonder. They seek in vain and remain exiles even in a kingdom.[37]

Our real home is not any particular place on earth, writes Weigel, out of which we can always be expelled by violence or banishment, as was all too frequently happening around him in those troubled times. Our real home is rather within us, a spiritual dwelling from which no one can ever chase us:

> Our home or fatherland is not outside of us but rather inside within the spirit. Hence we are not at home in Spain or Germany or in Leipzig, or in this or that house, and so forth. For whence another mortal can chase and drive me out is not really my home. It must be such a place or home from which neither man nor animal nor worm can chase or expel me in eternity.[38]

In Weigel, the utopian attitude takes the shape of a radical opposition between spirit and matter, light and darkness, freedom and bondage. The being of God is contrasted to the nothingness of the creature, which is called to become like God. Significantly, like other Christian exegetes inclined towards the "utopian" pole on the Christian grid, Weigel practices a mystical interpretation of Scripture, in particular of the first three chapter of Genesis, seen as suggesting "the macrocosm of nature and the microcosm of the human being."[39]

Weigel was an isolated radical and dissenting reformer, influenced by the Spiritualists Caspar Schwenckfeld and Sebastian Franck (mentioned above) in contrasting the Spirit, a Christian version of the immaterial Neoplatonic mind (νοῦς), to the material world.[40] He was profoundly critical of the ecclesiastical Lutheran establishment that he served with great commitment throughout all his

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[36]Zinn (2005, 88); Hugh of St. Victor, *Didascalicon*, III. 19, (1939, 69): "delicatus ille est adhuc cui patria dulcis est; fortis autem iam, cui omne solum patria est; perfectus vero, cui mundus totus exsilium est. Ille mundo amorem fixit, iste sparsit, hic exstinxit."

[37]Weigel (2003, 94, 2014a, 34): "O wie Elend seynd die Menschen/so da in der Welt hie und da jhre genüge suchen/und jhr gutes Leben/sie suchen vergebens/und bleiben *Exules* auch bey einem Königreich."

[38]Weigel (2003, 115, 2014a, 54): "Unsere Heymat oder Vaterlandt stehet nicht ausser uns/sondern inwendig im Geiste/darumb seynd wir noch nicht daheime in Hispania oder Germania/oder zu Leipzig/oder in diesem oder jenem Hause/etc. Denn daraus mich ein ander sterblicher Mensch jagen und stossen kan/das ist noch eigentlich nicht meine Heymat. Es muß ein solcher Ort oder Heymat seyn/daraus mich kein Mensch noch Thier noch Wurm jagen oder treiben können in Ewigkeit."

[39]Weeks, Introduction, in Weigel (2003, 23–30).

[40]Koyré (1971, 1–43, 81–107).

life, and laid emphasis on the inner life of the faithful to call for a truly spiritual Church, based on the spiritual knowledge of Christ. Just as the spiritual realm was opposed to the physical world, Weigel, as we have seen, contrasted the true, mature, interior faith to the state-imposed, puerile and external Church of the sacraments, and even to Scripture. Faith had to be cleansed of any dross of worldliness, and the faithful was called to receive a celestial and spiritual body in this life to be then saved in the next.[41]

Weigel therefore adopts the notion that "the Kingdom of God is within you" found in the Gospel (Luke 17.20–21) to imagine heaven as a spiritual reality within the individual believer that can be seen with the eye of faith. Thanks to the power of the Spirit of God, any human being can imitate the spiritual rebirth of Nicodemus (John 3.6), renouncing self-will to access divinity itself. The Kingdom of Heaven is thus accessible from within.[42]

Given Weigel's views about spirit and matter, it is no surprise that the eternal heaven in the other world is conceived as a spiritual and divine dimension where there will be no conditioning of space and time and no natural body that occupies a place. Only supernatural celestial bodies will be in this "utopian" heaven, where there will be no need of external place:

> in that [other] world we must have invisible, spiritual, celestial, supernatural bodies that are in no need of an external place or reservation, neither of air nor light of the sun nor anything natural, but rather it [the body] must be celestial and angelic, so that we might also dwell with God in ourselves upon the eternal expanse, where no end is to be found or seen or imagined in eternity, neither below nor behind nor in front of oneself.[43]

Weigel's vision is that at the end of time the natural and physical world will cease to exist and will be replaced by the supernatural Kingdom of God. Nothing natural or material will be present in heaven, notably no earthly bodies:

> In this expanse we will hover in God, not with a natural, comprehensible, elemental body, but rather with a supernatural, new, celestial, clarified body, which is no longer in need of any external place or element. But what else is a new supernatural body but a spiritualized and deified one that has grown from the new birth, from the flesh of Christ, and not from Adam.[44]

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[41]McLaughlin, Preface, in Weigel (2003, 1–8).

[42]Weigel (2003, 140–142, 2014a, 82–83). See Weeks, Introduction, in Weigel (2003, 24–27, 39, 43). The same theme is developed by Weigel in his *Dialogus de Christianismo*, see Odermatt (2008, 213–234), and Koyré (1971, 88–93).

[43]Weigel (2003, 69, 2014a, 5): "wir in jener Welt unsichtbare/geistliche/himlische/ubernatürliche Leibe haben müssen/die da keines eussern Ortes oder *Reservaculus* bedürffen/weder Lufftes noch Liechtes der Sonnen/oder etwas natürliches/sondern es muß Himlisch und Englisch seyn/ daß wir auch mit Gott wohnen in uns selbst auff der ewigen Weite/da kein Ende weder uber sich noch unter sich/weder hinder sich noch vor sich zu finden/zu sehen/noch zugedencken ist in Ewigkeit."

[44]Weigel (2003, 121–22, 2014a, 62): "Jn dieser Weite werden wir schweben in Gott/nicht mit einem natürlichen greifflichen Elementirten Leib/sondern mit einem ubernatürlichen newen himlischen verklerten Leibe/welcher keines eussern Ortes noch Elementes mehr bedürfftig ist. Was ist aber ein newer ubernatürlicher Leib anders/als ein vergeistet und vergottet Leib/der aus der newen Geburt/aus dem Fleische CHRJsti gewachsen ist/und nicht aus Adam."

The entire material world will disappear. Everything temporal or spatial, natural or earthly will be excluded from such "utopian" heaven, where we will be as God, who "is and remains a spirit in eternity,"[45] we will be able to behold Him face to face (1 Corinthians 13.12). Of course, Weigel specifies that this does not mean that we shall see God "externally, with physical eyes, in a particular place, but rather in ourselves, face to face."[46] Nothing related to natural life (seeing, talking, hearing, eating, sleeping, moving from one place to another) will be part of the final spiritual bliss. Weigel shows his dualistic bent when he explicitly denies the resurrection of the flesh, excluding from the heavenly bliss the mortal body of Adam, made of the clay of the earth, to include in the final perfection only the authentic human being, which is, in his view, the spiritual, inner and godlike human nature, the new flesh of Christ.[47]

Moreover, in heaven, as announced by Saint Paul (1 Corinthians 13, 8–9), there will no longer be any kind of knowledge or scholarship. The arts, the study of languages, the practice of prophecy, even Scripture will cease. Everyone will be instructed within directly by God. Significantly, before the Fall, Adam too had no need of languages or arts as he lived as an angel. It was only after sin that man fell out of the spirit into the flesh, and acquired a natural body, heralding the origin of the visible world, which did not exist before the Fall. The spiritual condition that existed before the visible world will return again once this visible world is dissolved.[48]

Consistently with his political and religious thinking, Weigel also insists that in the Kingdom of Heaven there will be no ruling authority nor political or religious power. There will be no priests, no bishops nor kings, but only God as the only Lord of all. All ethnic or national distinctions will also disappear.[49] Most notably, Weigel also emphasises that no name will remain in the future world, as names apply only to temporal contexts and to earthly and mortal bodies, which are the lowest part of the human being, and not to the inner and spiritual human nature. This constitutes a significant challenge to the preservation of individual identities in heaven: "The soul or the spirit has no name. It is called spirit and soul, and not Conrad, Peter, Andrew, Martha, Catherine, Anna, or the like."[50]

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[45]Weigel (2003, 122, 2014a, 63): "Gott ist und bleibet ein Geist in Ewigkeit." A good account of Weigel's metaphysics is found in Koyré (1971, 103–107).

[46]Weigel (2003, 122, 2014a, 63): "wir GOtt nicht von aussenzu mit leiblichen Augen sehen an einem gewissen orte/sondern in uns von Angesicht zu Angesicht."

[47]Weigel (2003, 122–25, 2014a, 62–64).

[48]Weigel (2003, 125–28, 2014a, 65–67).

[49]Weigel (2003, 128–31, 2014a, 68–70).

[50]Weigel (2003, 131, 2014a, 71): "Die Seele oder der Geist hat keinen Namen/er heisset Geist und Seele/und nicht Conradus/Petrus/Andreas/Martha/Katharina/Anna/etc."

8.4 Conclusion

For Weigel the sensible world is not the creation of an evil principle or an inferior divinity (as in gnostic dualism), but of God himself.[51] It is possible, however, to identify in his thought some aspects that Festugière would name as belonging to a *gnosis pessimiste*, for example in his negative evaluation of the sensible world, seen as a place of exile, and his evaluation of otherworldliness as our true fatherland, a future residence, which can nevertheless be "actualized" in this life through "spiritual or intellectual life," according to true Christianity or philosophical contemplation.[52] Adopting the terminology we discussed at the beginning of this essay, we can say that Weigel's views on earthly space and historical time in relation to heaven and eternity bear the hallmark of a utopian vision. He rejects everything corporeal, spiritualises all of creation and de-individualises the human creature. Nevertheless, to confirm the dynamic interaction between locative and utopian world views in Christian teaching also mentioned above, it is possible to detect in Weigel's work some hints at the idea of the ultimate unity of the universe and of a close association between matter and spirit.[53] *On the Place of the World* may be seen as providing an original way to envisage the relation between time and eternity, space and infinity, human realm and divine dimension, by combining mystical, Lutheran and Paracelsian theories. Significantly, Weigel draws from Paracelsus the idea of an immaterial spirit permeating and giving life to the universe, the same spirit that the alchemists attempted to distil from matter.[54]

The utopian search for complete transcendence and the radical opposition between matter and spirit also parallel, in Weigel's thought, the acknowledgment of a process of emanation, from the eternity of God into the angels through the Creator Logos, then to the invisible four elements and the invisible stars, finally to the visible world. At every level of emanation each thing is in its own way all things, and the human being and the visible world are perceived as made in the image of God.[55] All corporeal things are a kind of "excrement" expelled from the invisible stars that will all pass away. The world that hovers in infinite nothingness hovers also in time between nothing and nothingness.[56] The realm of the angels,

[51]Koyré (1971, 85), claims that Weigel did not support "a gnostic dualism," but just insisted on the need of a spiritual rebirth of the individual.

[52]As one of the anonymous readers has remarked, this line of thought is found in the German mystical tradition mentioned above (note 19) and in Giordano Bruno, who also quotes the Gospel passage about the Kingdom of God within (Luke 17. 20–21; *Eroici furori*, I, 4) to refer to the union with God through philosophical contemplation, in line, through the Averroistic tradition, with Plato and Aristotle.

[53]On Weigel's general views concerning the relationship between God and the world, see Koyré (1971, 108–115). See also Zeller (1979, 105–124).

[54]Weeks, Introduction, and McLaughlin, Preface, in Weigel (2003, 35 and 6–7).

[55]Weeks (2000, 110–14).

[56]Weigel (2003, 97–98, 2014a, 37–38).

however, which as the paradise within represents the divine dimension, is invisibly present in this world.

Weigel begins his treatise discussing the earthly space as known to the senses, precisely measured by latitude and longitude, showing how to locate different places on the vast stretch of space of the visible universe. Soon, however, he "theologises" his own cosmographical discourse and the vastness of the visible universe looks to him infinitely small when compared with its background of infinite nothingness. It should be borne in mind, however, that this infinite background is not to be thought spatially. The infinity of the weigelian *Nichts*, in which the sensible world floats, is not infinite space in the line of Bruno or of Newton. It is just "nothing," with no matter, no time, no space, and, in Weigel's view, the visible universe stands in no place precisely because outside it there is no extent of space and thus no physical place nor material location. The reader is presented then with a vision of immeasurable vastness and infinite abyss. Crucially, Weigel sees a relation between this cosmic infinite and spaceless expanse and the spiritual inner world, not enclosed into any place. Hence the fundamental message in his description of the outer world, which is directed to the inner spirit: the human nature that possesses a soul remains free to renounce selfhood and always able to access the paradise within, as it longs to return to God. The Kingdom of Heaven where the spirit dwells is not bound to places and occupies no space. It is the omnipresent inner world of the divine and the eternal.

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Chapter 9
‘Borders,’ ‘Leaps’ and ‘Orbs of Virtue:’ A Contextual Reconstruction of Francis Bacon’s Extension-Related Concepts

Dana Jalobeanu

Abstract Francis Bacon’s natural philosophy contains a whole series of interconnected concepts related to extension, such as “borders,” “leaps” and “orbs of virtue.” These Baconian concepts are still not fully understood and are in need of a detailed analysis. They do not derive from a general conception of physical or mathematical space, and are not explainable in terms of parts of matter and aggregates. Instead, they are somewhat mysteriously defined in terms of limits and boundaries of action. This article offers a contextual investigation of Bacon’s extension relating concepts. I show that in adopting a particular strategy of deriving spatial properties and extension related concepts from a theory of action and force, Bacon follows in the footsteps of Gilbert’s magnetic philosophy. However, in contrast to the more traditional approaches of William Gilbert, Giovan Battista della Porta and Johannes Kepler, Bacon strips his extension-related concepts from most natural philosophical content and argues for a methodologically driven approach, leading to operational definitions.

9.1 Introduction

Francis Bacon’s natural philosophy contains a whole series of interconnected and insufficiently investigated concepts related to extension. Such concepts as “limits,” “borders,” “leaps,” “measures of space,” and “orbs of virtue” abound in Bacon’s

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explanations of the structure of the universe,[1] body-body interactions, local motion, action at a distance, etc.[2] They do not derive from a general conception of physical or mathematical space; they are not explainable in terms of parts of matter and aggregates of parts. Instead, Francis Bacon's extension-related concepts express limits and boundaries of action; as well as limits and boundaries of perception. More precisely, his general claim is that there are such natural limits and boundaries in nature; that

> […] virtues and motions of things operate and work over distances which are neither indefinite nor random, but finite and certain, so that in the particular natures under investigation to grasp and take these distances into account, is of the greatest importance for practice.[3]

Faced with this situation, the investigator of nature has to find ways to discover these natural boundaries and limits, or the specific "orbs of virtue," for all the "virtues and motions of things."

My purpose in this article is to offer a contextual investigation into the questions and challenges raised by this way of thinking. I show that in developing some of his extension-related concepts, Bacon follows the strategy developed by Gilbert and other proponents of a magnetic philosophy to define, describe and chart "orbs of virtue," i.e., the space "effused" and organized by certain virtues. In the first part of the paper I attempt to reconstruct the problematic background of Gilbert's attempt to devise a "science of the orb themselves,"[4] and its sequel in Kepler's endeavours to generalize it from the case of magnetism to the more general case of a central force. In the second part of the paper I deal with Bacon's specific attempts to generalize and operationalize the "orbs of virtue." I show that Bacon goes a step further than Della Porta, Gilbert and Kepler in the attempt to disentangle the natural philosophical content from the operational content of this concept. My claim is that Bacon's definitions of "orbs of virtue" as "measures of

[1]For Bacon, the universe is made of regions and layers endowed with dissimilar properties. Change mostly happens (and is especially easier to see) at the "borders" between these regions (OFB VI 123ff; 145, 149, 177). On Bacon's cosmology, see Rees (1975a, b, 1996), Manzo (2006). On the relative stability of the regions and the activity at the borders see OFB VI 137, 145. See also Rees (1979, 204). These "natural borders" are sometimes described in terms of "leaps." Thus, Bacon claims that there are great leaps "from the region of the air to the region of the Moon, and similarly there is an enormous leap [*saltus*] from the heaven of the Moon to the heaven of the stars." (OFB VI 177).

[2]For Bacon, each individual body contains spirits, or pneumatics, endowed with "the appetite and faculty of constantly generating, multiplying and spreading themselves in all directions […] of mutually attacking and invading one another" (OFB VI 231). More generally, bodies exhibit virtues operating by contact, but also at a distance (OFB XI 369); also, most bodies emit both tangible and pneumatic effluvia (SEH II 643–645).

[3]OFB XI 369.

[4]Gilbert (1893, 304, 1600, 205).

space"[5] and "limits of perception"[6] successfully avoid most questions concerning the nature of action and perception and their respective mechanisms of operation. Instead, they can be used as general, operational definitions, embedded into a sophisticated strategy of experimental inquiry.

9.2 The "Orbs of Virtue" in Magnetic Philosophy: Natural Philosophical and Operational Aspects

Scholars have already noted that in devising the notion of "orbs of virtue" Bacon borrowed a natural philosophical concept already formulated by Gianbattista della Porta and William Gilbert, and he generalized it, so that it extends beyond mere magnetism, to all natural virtues and actions.[7] However, the details of Bacon's strategy were never subjected to a thorough scrutiny. This is partly due to the realization that there is a certain degree of latitude and confusion in how Della Porta and Gilbert used this term. A thorough history of the natural philosophical significations of the "orbs of virtue" for the proponents of magnetic philosophy still waits to be written.

The purpose of this section is to set the background for a more thorough investigation into Bacon's strategy of generalization and clarification. I begin by discussing the problems encountered by various attempts to give a natural philosophical significance to this concept. Then, I address the challenges and difficulties facing Gilbert's attempt to construct a "science of the orbs themselves."

Terms like "sphere of influence," "sphere of activity," "orbs of effluvia," and "orbs of virtue" abound in sixteenth century; they are usually employed to express the belief in a radiative nature of bodies. Giovan Battista Della Porta claims that bodies radiate "beams of virtue," which means that they can act at certain distances upon similar objects, with a force often described in terms of concord, "love" and sympathy. Magnetic attraction is a special form of this more general sympathetic attraction.[8] Each magnet has a sphere of activity, or an "orb of virtue,"

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[5]In the ANN, Bacon proposes an inquiry into the "measure of distance or the orb of virtue [*mensura spatij, sive the orbe virtutis*]; this is the distance which the powers of bodies may travel to, stop at, build up and die down from." OFB XIII 211.

[6]The same ANN contains a second definition of the orbs of virtue, in terms of "the distance that perception reaches to;" OFB XIII 195. I discuss Bacon's definition of "perception" in the second part of this paper.

[7]Rees (1979) and Kelly (1965). On the sphere of activity and the orb of virtue before and after Gilbert see Ugaglia (2006), Parigi (2011), Pumfrey (2002) and Hesse (1960a, b).

[8]Della Porta describes a radiative process in which the magnetic virtue emanates within a certain orb of virtue. See Porta (1658, 199, 203). Porta's explanation of magnetic coition is formulated in terms of an "active" and a passive form of sympathy: the magnetic virtue excites a response in other magnets (because of similitude of substance) and iron (which has some form of passive or potential magnetic virtue). As a result, attracted bodies "run" towards the attractive, "to meet it, to be embraced by it" (Porta 1658, 201). For a discussion of Porta's descriptions of magnetism see Kodera (2014).

and within that sphere, it can impart some of its virtue to other magnets, or to pieces of iron. The magnetic force spreads in space in very much the same manner in which light spreads around a light-source; it decreases with the distance, and the limits to which these emanations can extend determine "the orb of virtue."[9] Della Porta's explanations of magnetic attraction are not specific to magnetism; they can be easily generalized to other forms of sympathies.[10] Meanwhile, Della Porta's treatment of the "sphere of activity" has a distinct operational feature: he is less interested in the natural philosophical mechanism of magnetic activity than in questions regarding the possible ways of determining with accuracy, charting and extending the given sphere of activity of one magnet.

At the first sight, William Gilbert's approach, in *De magnete,* is very different. After all, Gilbert offers an extensive natural philosophical explanation of magnetic attraction in terms of matter theory and within the larger framework of a magnetic cosmology. He divides bodies into electrics and magnetics:[11] electrics emanate spheres of effluvia, a material medium responsible for various forms of attractive effects.[12] By contrast, the propagation of magnetic virtue is a form of action-at-a distance; it does not require a medium, and permeates through matter without material contact.[13] Magnetic virtue does not reside in space—there are no orbs of "permanent essential virtue spread through the air"[14]—but is constitutive for each

[9]Porta (1658, 199). See also Porta (1589, 305).

[10]This is how some of Della Porta's medicines are supposed to work. See Book 8, Porta (1658).

[11]As it has been shown, Gilbert attempted to construct a comprehensive, "cosmological" theory on the basis of this division. Gilbert also claims that there are only two kinds of attraction, magnetic and electric. Gilbert (1893, 170). On Gilbert's cosmology, see Freudenthal (1983). For a more general discussion of Gilbert's theory in context see Hesse (1960a, b).

[12]The distinction between electrics and magnetics is made in terms of matter theory: electric bodies are those containing "humours;" while magnetics contain "earth." Both electrics and magnetics have attractive powers, but the mechanisms of attraction are different. In the case of electrics, material effluvia produce attractive effects. Gilbert (1893, 340). See Pumfrey (1989, 48). See also Pumfrey (1987, 92 ff). On the discussion of the difference between virtues propagated through effluvia and the propagation of magnetic virtue, see Gilbert (1893, 107 ff).

[13]Gilbert (1893, 123–124). See also Henry (2001). In *De mundo* Gilbert claims that the orbs of effluvia around planets are small, while the interstellar spaces are void. Light and magnetic virtue can "travel" through empty space. See *De mundo* Book II Chaps. 25–27. Gilbert (1651, 212–214). For Gilbert, the nature of magnetism is similar to that of the (animal) soul. Like soul, magnetic virtue is a specific, active form of a body, possessing natural motion. It can exist in a dormant form in iron and steel, and in a more actualized, perfect form, in magnets, magnetized iron and in the celestial bodies. Gilbert's model is the world soul or the celestial intelligences of the planets; each great globes has its own "soul" (animate force/vigour), those of the Sun and stars being "superior" to those of smaller globes. See Gilbert (1893, 308).

[14]Gilbert (1893, 123).

magnet, for which it defines fixed points (the poles), directions of spatial organization (the magnetic axis, but also directions such as "away" from the magnet and "towards" the magnet) and other symmetries.[15]

Gilbert uses emanationist language to describe how magnetic virtue is "effused" throughout each orb of virtue; how "in all globes the effused forms reach out and are projected in a sphere all round," and how the soul-like magnetic powers of each celestial globe "extend an unending action, quick, definite, constant, directive, motive, imperant, harmonious, through the whole mass of matter."[16] Meanwhile, while describing how such effects happen in laboratory conditions, Gilbert adopts an operational language and a methodologically-driven strategy, while the elements of his matter theory are much less present in the explanation.[17] For example, Gilbert explains magnetic interaction in terms of a step-by-step process. When a bar of iron is brought in the orb of virtue of the *terrella*, its dormant magnetic virtue is first "awakened," then "endures," and "by its very act gives back the force again."[18] At the second step, the newly magnetized object "orients" itself within the orb of virtue of the *terrella*, rotating until it becomes "well disposed" with respect to it.[19] It is only in the third instance that attraction (or, in Gilbert's term "coition") manifests itself. The strength of coition varies with the distance,[20] the quality of magnetic substance, the particular geometry of the magnet,[21] and the particular configuration (and geometry) of matter in which the magnet is placed. Because, for Gilbert, anything that contains solid

[15]More on the ways in which magnetic virtue is constitutive of spatial organization in the next section.

[16]Gilbert (1893, 308–309, 311). Similarly, Gilbert claims that the Sun has the power to incite motion in the celestial globes, causing them "to advance in their courses […] by sending forth the energies of his spheres." Gilbert (1893, 333). Although it is usually said that Gilbert only acknowledges the cosmological implications of his magnetic philosophy in book VI of *De magnete*, there are numerous passages throughout the other books as well which ascribe celestial motions to magnetic energy and talk about the "law of the whole," or about the "ordering and planning of the universe and the earth." See Gilbert (1600, 41, 44). For a discussion of Gilbert's "cosmic magnetic field" see Miller (2014).

[17]This does not mean that Gilbert abandons the matter theory of the "electrics" and "magnetics" (although *De mundo* might be said to qualify it significantly). It merely means that he adopts a phenomenological strategy, in the attempt to operationalize some of the elements of the explanation.

[18]Gilbert (1893, 150–151).

[19]Gilbert (1893, 130). See also Gilbert (1600, 82).

[20]See for example Gilbert (1893, 161–163). Gilbert distinguishes clearly between the variation of the "strength" of coition (which strongly decreases with the distance) and the variation of the direction, orientation and rotation in the magnetic field, which have more complex forms of variation. See Georgescu (2014).

[21]On the dependence of the strength of attraction on the qualities of matter see Gilbert (1893, 167–169). However, the more important variable seems to be the geometry of the magnet, which determines both the geometry of the orb and the strength of attraction. For example, elongated magnet "attracts best at the vertex." Gilbert (1893, 122).

matter is, at least, potentially magnetic, most magnets are already in the orb of virtue of other magnets, as well as in the larger, all-encompassing orb of virtue of the Earth.[22] As a result, their magnetic virtue is often "altered, changed, incited, renewed and driven out,"[23] but can be also strengthened and multiplied. Gilbert is particularly interested in the experimental investigation of particular situations of magnetic union.

> Pieces of iron in the presence of a loadstone, though not in contact with it, come together, eagerly seek and seize one another, and when in conjunction are, as it were, glued together. Iron dust or iron reduced to a powder, packed in paper tubes, and placed on the meridian of a loadstone or merely brought near it, coalesces into one mass, and in an instant the many particles come together and combine: and the multitude of united grains act on a piece of iron and attracts it, as though they formed but one continuous rod if iron, and take the north and south direction when laid on a loadstone.[24]

Magnetic union creates a solid bond between bodies, and it is produced by an attraction stronger than mere coition. If two pieces of iron are placed in the orb of virtue of a loadstone,

> […] likeness of substance becomes decisive and iron gives itself up to iron, and the two pieces are united by their most like (identical) and homogeneous forces. This is effected not only by coition, but by a firmer union.[25]

Incidentally, it is this stronger bond of magnetic union which explains how "the foundations of the earth are conjoined, connected, held together magnetically."[26]

Thus, Gilbert's natural philosophical and experimental investigations disclose the complexity of magnetic interactions. He shows that magnetic philosophy has to deal with a number of forces and motions,[27] as well as with complex spatial

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[22]Gilbert (1893, 136): "[…] here on earth, naught can be held aloof from the magnetic control of the earth and the loadstone and all magnetic bodies are brought into orderly array by the supreme terrene form, and loadstone and iron sympathize with loadstone though solid bodies stand between." See also Gilbert (1893, 212–213). Gilbert claims that "the matter of the entire orb conspire[s], produces verticity in bodies" (Gilbert 1893, 216). Thus, one standard procedure for fabricating a magnet recommended by Gilbert and his followers is to heat up a piece of clay and cool it down oriented in the lines of the Earth's magnetic field.

[23]Gilbert (1893, 209). Gilbert discusses in Book III many examples of multiple magnetic interactions, showing how changes in verticity occur, or how magnetic power can be renewed, diminished and lost as a result of these interactions. These kinds of loss of magnetic powers do not happen in magnets, however, because in the loadstone force is "innate" and "inhere more closely, nor do they easily retire from their ancient seats." (Gilbert 1893, 209).

[24]Gilbert (1893, 142).

[25]Gilbert (1893, 150–151).

[26]Gilbert (1893, 142). Magnetic union is not only a property of loadstone and iron but seems to be a much more widespread property. For example, Gilbert gives an example of grafting: if a branch is cut into two halfs, one cannot graft another branch on the upper part, but only on the lower part. This is because, Gilbert claims, "the vegetative force […] tends in a fixed direction." Gilbert (1893, 200).

[27]Gilbert distinguishes between four different magnetic motions: coition (attraction, verticity, declination and magnetic dip).

configurations. One of Gilbert’s attempts to clarify the matters is to multiply the orbs and spheres of activity, by distinguishing between a smaller orb of coition, and a larger orb of virtue. This allows him to classify magnetic attraction and magnetic disposition according to their range of action; magnetic union and coition happen within the smaller, orb of coition, while disposition, orientation and rotation take place within the larger orb of virtue. However, the difference between the two orbs is not merely one of dimension, but also one of symmetry. Magnetic attraction has a radial symmetry; and the orb of coition is spherically diffused. By contrast, the orb of virtue has a much more complex symmetry; it has fixed points and a definite direction (the north-south axis); and magnetic orientation and “verticity” have different strength and directions at various points within this orb of virtue.[28]

In fact, the symmetry and spatial organization of the orb of virtue is so complex that it led Gilbert to the understanding that magnetic philosophy needs to provide a “science of the spheres themselves” [*novam & admirabilem … orbium ipsorum scientiam*],”[29] i.e., a description of the geometry, symmetries and the transmission of magnetic powers within the orbs of virtue.[30]

9.3 Spatial Organization: Limits, Orientation and Symmetries

For Gilbert, each orb of virtue has a particular geometry and a determinate structure, partly dependent on the geometry of the magnet,[31] partly due to the “strength” of magnetic vigour and the ways in which it is “effused” around the magnet.[32] One of the main aims of *De magnete* is to map these orbs of virtue, at

[28]Gilbert (1893, 125). Gilbert claims that the poles of a magnet are fixed (within the orb of virtue); they are said to be “the citadel, the judgment seat of the whole region.” (Gilbert 1893, 131). They are said to be “reference points of direction and of position.” (Gilbert 1893, 129).

[29]Gilbert (1893, 304, 1600, 205).

[30]Laura Georgescu claims in a recent paper that Gilbert’s main contribution to the development of magnetic philosophy lies in shifting the interest from the phenomenon of attraction to the orientation in space, spatial distribution and symmetries. See Georgescu (draft).

[31]The geometry of the orb of virtue corresponds to the geometry of the magnet; orbs are only spherical around spherical magnets; they are oriented according to the magnet’s axis and have, similarly, “fixed poles.” In the case of the Earth, Gilbert emphasizes time and again, that poles and the magnetic axis are “permanent, and fixed, and natural.” (Gilbert 1893, 67).

[32]For example, an elongated magnet creates an elongated orb and concentrates the magnetic forces at the poles. As a result, Gilbert claims, “the force supplied by other parts [of the magnet] […] are better massed and united, and thus united they are stronger and greater.” (Gilbert 1893, 131). See also Miller (2014, 74).

least in the relatively simple case of a spherical magnet.[33] The way to do this is with the help of a small magnetic needle which, placed in different points around the magnet, is led to "follow" the directing force of the magnetic virtue, disclosing borders, limits, directions and hidden symmetries of the orb. In Book VI of *De magnete*, Gilbert generalizes his findings; first, to the orb of virtue of the Earth and then to the universe as a whole. He claims, for example, that the Earth's axis of rotation points always in the same direction (towards the Ursa Minor) and that, if it were deflected from this direction, it would naturally return to this former orientation.[34] However, this direction is not a general direction in space; it is not established by the pre-existing geometry of celestial orbs. Quite on the contrary; the direction of the Earth's magnetic axis is determined by the "forces […] implanted in the earth."[35] These "forces" and virtues of each magnet are "poured forth and diffused beyond their superficies spherically, the form being exalted above the bounds of corporeal nature."[36] In this way, properties of the solid, magnetic bodies are extended to the orbs, while the shape and structure of the orb is indicative of the direction and strength of magnetic motions.[37]

Again, one can distinguish in Gilbert's attempt of mapping the orbs of virtue a distinctive operational drive. In describing the result of this mapping for small spherical magnets (the *terrellae*), Gilbert brackets most questions regarding the mechanism of action and transmission of virtue. Instead, he claims that the orb itself, i.e., the space around the spherical magnet, has certain properties of symmetry.[38] For example, Gilbert claims that at various distances along the same radii, the magnetic needle has the same orientation. He also claims, against Della Porta, that the center of the magnetic movements is not at the poles, but in the center of the magnet (or the center of the earth), while disposition and orientation are governed by their relation with the North-South axis. This means that, at various points within the orb of virtue, the magnetic needle is both attracted (towards the

[33]David Marshall Miller has suggested that Gilbert replaced the traditional spherical representation of space with a "geographical representation" of space and that this geographical framework is essential for understanding Gilbert's descriptions and explanations of magnetic phenomena. However, unlike the geographer's spatial representation, Gilbert's geographical representation corresponds to the physical properties of the magnet and its surrounding space. The magnet "sets" and "defines" the spatial properties of the orb of virtue. As Marshall has convincingly shown, Gilbert is using this particular spatial (geographical) representation to discuss limits and symmetries of the orb of virtue (Miller 2014, 70–73).

[34]See also the passages of Book III, Gilbert (1893, 180–181).

[35]Gilbert (1893, 329). Gilbert also claims that the revolution of the Earth around the sun is determined by the same "innate energy," plus a law of necessity which is responsible for the cosmic harmony of planetary motions. Gilbert (1893, 333).

[36]Gilbert (1893, 304).

[37]For example, an elongated magnet creates an elongated orb and concentrates the magnetic forces at the poles. As a result, Gilbert claims, "the force supplied by other parts [of the magnet] […] are better massed and united, and thus united they are stronger and greater."(Gilbert 1893, 131). See also Miller (2014, 74).

[38]For details of Gilbert's construction and reasoning see Georgescu (2014).

center of the magnet), and "controlled," disposed and "rotated,"[39] according to the inner directions (and symmetries) of the orb itself, i.e., towards the poles of the magnet.[40] The strength of attraction decreases along the radius of the orb of virtue; but at each point along the same radius, the directive power maintains the same direction.[41] In Gilbert's terms:

> […] everywhere at equal distances from the centre or from the convex circumference, just as at one point it seems to attract in a right line, so at another it can control and rotate the needle, provided only that the loadstone be of not unequal power.[42]

Thus, the orb of virtue contains concentric spherical surfaces where the strength of magnetic attraction has the same value, while magnetic disposition differs from one point to the next.[43] However, Gilbert claims that this variation of direction is not random but "continuous," so that if a magnetic needle is moved on any spherical surface inside of the orb of virtue, it "rotates completely twice, in one circuit around his center, like an epicycle around his center."[44]

A more thorough discussion of Gilbert's views on such inbuilt symmetries is beyond the scope of the present paper. For my purpose it suffices to have shown that there is in Gilbert a constant preoccupation for a "science of orbs themselves," i.e., for an attempt to show how the emanation of magnetic virtue is constitutive of a spatial distribution and spatial symmetries around each magnet. Discovering the symmetries of this "spherically effused magnetic vigor" leads to the discovery of the properties of physical space, such as direction, situation, orientation etc.,[45] at least, in the case of an isolated magnet. However, as we have already seen, in Gilbert's magnetic cosmology there are hardly such things as isolated magnets. When mutual influences are taken into consideration, Gilbert's theory is confronted with insurmountable difficulties, as I will show in the next section.

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[39]See for example (Gilbert 1893, 150–151). Gilbert claims that the force of attraction (coition) emanates "from the whole mass" of the magnet. In this way, the magnetic attraction has a radial symmetry. Meanwhile, the rotation and orientation towards the poles are directed by a different kind of symmetry. The two superposed symmetries describe the spatial distribution (orientation) around a magnet.

[40]In modern terms, Gilbert maps separately the strength and the direction of the magnetic field.

[41]Gilbert (1893, 151). Gilbert claims that, in principles, "forces are the same on the same parallel," at least unless there are no variations produced by the "inequalities" of the magnet.

[42]Gilbert (1893, 150).

[43]Gilbert (1893, 151).

[44]Gilbert (1893, 307). It is not clear how this particular property is derived from Gilbert's empirical construction or from his "diagrammatic reasoning." Here, most probably, considerations of symmetry play a more important part in Gilbert's reasoning than empirical considerations. Most probably, Gilbert's reasoning is motivated by his interest in planetary motion.

[45]Although magnetic virtue propagates spherically through space, the magnetic action is oriented along (or parallel) to the magnetic axis. For a discussion of Gilbert's "oriented space" see (Miller 2014, 99–100; 103–105).

9.4 Operational Drive and Natural Philosophical Difficulties: Perception, Collaboration and the Common Good in Gilbert' and Kepler's Magnetic Philosophy

Gilbert's magnets are not isolated bodies. Magnetic needles, iron bars or artificially devised *terrellae* are already disposed and oriented towards each other, as well as within the larger orb of virtue of the Earth. Since a magnetic substance is very common, orbs of virtues are practically everywhere. And this extends to the universe as a whole[46]: Gilbert does not exclude the possibility of mutual magnetic influences among planets, claims the existence of a universal, active virtue, effused by the Sun[47]; and raises the issues of a cosmic "orb of orbs," and a direction "common to the whole universe."[48]

Explaining these complex mutual interactions poses a number of problems. First, it led Gilbert to appeal to concepts such as the "collaboration" between magnets, the "general benevolence" [*benevolentia*] among like substances, and a common good of the Universe.[49] Second, in order to explain individual behavior of

[46]Some scholars have attempted to limit Gilbert's magnetic philosophy to the Earth, claiming that one can separate book VI from the rest. This type of interpretation was widespread amongst Gilbert's own contemporaries and is nicely exemplified in the debate between John Barlow and Mark Ridley. See Barlow (1616) and Ridley (1613, 1617). In fact, Gilbert's cosmology is not limited to book VI; statements regarding the cosmological significance of magnetism abound. And Gilbert often refers to the "ordering and planning of the universe and the earth," (Gilbert 1600, 44) or to the fact that magnetic planetary globes take position (are ordered) in the universe according to a "law of the whole" [*totius normam*.] (Gilbert 1600, 41). For a more general discussion of Gilbert's magnetic cosmology in terms of a "cosmic magnetic field" see Miller (2014, 66–71).

[47]See for example Gilbert (1893, 332–333). Also, Gilbert claims that all planets are in the "orb of influence" of the Sun. It is not entirely clear from this context whether this is the magnetic orb, or the orb of virtue of Sun's light. But the Sun is said to be "the chief inciter of action in nature," and the cause of planetary motions. Gilbert (1893, 333, 1600, 224). While planets are said to be situated "within the sphere of Sun's forces." (Gilbert 1893, 344).

[48]Gilbert (1893, 308–309): "[…] each homogenic part tends to its own globe and inclines in the direction common to the whole world, and in all globes the effused forms reach out and are projected in a sphere all round, and have their own bounds—hence the order and regularity of all the motions and revolutions of the planets, and their circuits." In a similar passage in which he describes the orientation of Earth's magnetic axis, Gilbert proposes a "primary soul" (of the world). (Gilbert 1893, 329).

[49]See for example Gilbert (1893, 310–311). "Therefore the bodies of the globes, as being the foremost parts of the universe, to the end they might be in themselves as in their state endure, had need of souls to be conjoined to them, for else there were neither life, nor prime act, nor movement, nor unition, nor order, nor coherence, nor *conactus*, nor *sympathia*, nor any generation, nor alternation of seasons, and no propagation; but all were in confusion and the entire world lapse into chaos, and, in fine, the earth were void and dead and without any use."

magnetic globes, Gilbert had to introduce supplementary concepts, such as "perception," "imagination," and "judgment."[50] His planets are endowed with souls and have both an "impulse of self-preservation," and a capacity to "perceive" and recognize a common good, in order to act accordingly.[51]

Moreover, vitalist concepts are not reserved for the planets only. All magnetic bodies are ultimately animated by "mutual love" and "undying good-will" to bring about "the true and genuine conformance of magnetic bodies in nature."[52] In terms of particular interactions, this is spelled out as a form of mutual collaboration towards a common good:

> The weaker loadstones are refreshed by the stronger ones, and the less vigorous bring no damage to the more vigorous. Yet a strong loadstone exerts more attraction in another strong one than in one that is feeble, for a vigorous stone contributes forceful action, and itself hastes, flies to the other, and solicits it vehemently; accordingly there is cooperation, and a clearer and stronger cohesion.[53]

One can take all these vitalist concepts to be the result of Gilbert's prior, metaphysical commitments. My suggestion is to regard them as resulting from Gilbert's attempts to solve the problem of mutual, body-body interaction. However this may be, these and like concepts prevent the operational drive from getting very far and reintroduce natural philosophical explanations in Gilbert's experimental philosophy.

The case of the Earth-Moon system is representative of the difficulties Gilbert runs into when attempting to describe mutual interactions in the physical universe.[54] Both Earth and Moon are magnetic globes; they have a natural circular motion. This natural, circular magnetic motion of the Moon is hindered by its presence in the Earth's orb of virtue; and thus the Moon is "the prisoner to the Earth," tied magnetically to it.[55] Meanwhile, if the Moon does not spontaneously rotate around its axis, it does revolve around the Earth; and this happens, according to Gilbert, because of its own celestial energy and power. The Moon's motions are the result of two impulses: its own magnetic energy and its perception of the Earth's orb of virtue and willingness to "collaborate" with it. Meanwhile, the Moon also exerts "astral influences" upon the Earth; these exercise, for example, a form of attraction upon terrestrial waters, producing tides. However, according to Gilbert's own theory of magnetic interaction, such a form of attraction is not possible. The Moon's orb of virtue is smaller than the Earth's, and her orb of coition

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50 Gilbert (1893, 311–312).

51 Gilbert (1893, 308–309, 1600, 210). See also Gilbert (1893, 329).

52 Gilbert (1893, 186). He also seem to claim that there is a "natural position" of magnets within the orb of virtue of the Earth, as well as a more "constant and permanent station and position in the system of nature." (Gilbert 1893, 182–183).

53 Gilbert (1893, 147–148). See also Gilbert (1893, 186): "Magnetic bodies seek formal unity, and do not so much regard their own mass;" and Gilbert (1893, 344).

54 Significantly, this case is not treated in *De magnete* but in Gilbert's unpublished *De mundo*.

55 This is why, according to Gilbert, the Moon always turns the same face toward the Earth; Gilbert (1651, 186–187).

is smaller still. Thus, Gilbert's suggestion is that Moon-Earth attraction is a combination of magnetic and electric interaction, i.e., that the Earth is within the Moon's orb of *effluvia*. Electric effluvia travel from the Moon towards the earth and exercise a form of attraction upon Earth's (electric) waters.[56] Thus, what looks like a mutual attraction between the Earth and the Moon is, in fact, the result of a complex interplay between electrics, on one hand (water and the electric component of Moon's matter), and magnetics, on the other.[57] Meanwhile, it is clear that these effects cannot be neatly separated; in *De mundo,* Gilbert also claims that "the Earth colludes with the Moon," and that that "the effused lunar powers" and "the Earth's magnetic virtues," "unite in a joint action," and "act in unison."[58] Moreover, he claims that the respective powers of the Moon and Earth can be "increased" by the influence of the Sun, i.e., by effluvia, powers and virtues coming from the Sun. Similarly, in *De magnete*, references to planetary and astral influences abound, and it seems to be left open whether they refer to light, magnetic virtues or other effluvia. They can be taken to express the same general, theoretical difficulties to describe mutual influences in terms of properties of orbs, or orbs-within-orbs.

To conclude: one way to understand Gilbert's introduction of concepts such as "perception," and "collaboration" is to see them as a response to the abovementioned difficulties. In order to describe the mutual body-body interaction, Gilbert assigns "perception" and "intellection" to the magnetic souls of the planets. This is what allows smaller magnetic bodies to orient themselves within complex situations (such as orbs-within-orbs) in a way so as to "give way" to stronger magnets, but also to "collaborate," or to follow the common good.[59] This also allows planetary soul to receive effused celestial virtues which can add or subtract from their own powers.

Gilbert was not alone in facing such difficulties. One can recognize the same problems in Kepler's attempt to place a "celestial rooftop upon Gilbert's magnetic philosophy."[60] In the *Astronomia nova*, Kepler follows in the footsteps of Gilbert in distinguishing the orienting power of the magnetic force, from the mere attractive force of magnets. Moreover, he makes an interesting distinction between two magnetic faculties present in each body:

> In applying the magnetic example, I suppose two faculties in both the planet and the magnet, one of direction and the other of appetency. The magnet is directed towards the pole,

[56]Water, in Gilbert's theory, is among the electrics, and so it is air or atmospheric vapors. The problem with this explanation is that one has to suppose that material effluvia extend all the way to the Moon which is, of course, a serious problem. See Freudenthal (1983, 31–33).

[57]Gilbert claims, in *De mundo*, that there are orbs of effluvia around every planet, i.e., that each planet has a natural magnetic motion and a natural sphere of activity. That is each planet is composed of a mixture of electric humors and magnetic "earth." See Gilbert (1651, 109).

[58]Gilbert (1651, 187). See also Pumfrey (1987, 51ff).

[59]At least for the motions of the celestial globes, Gilbert claims that "connate in them are reason, knowledge, science, judgment."(Gilbert 1893, 312, 344).

[60]Kepler's letter to Georg Brengger, 30 November 1607, JKGW vxi 86.

and seeks out iron. Just so, the globe of the planet is directed with respect to the fixed stars, and seeks out the sun.[61]

Both faculties have a directive capacity; and both are used to describe the way in which the magnet, or the Sun, can organize the space in which they are placed. The appetitive drive of the planet towards the Sun is not an attraction, but the "orientation" of the planetary soul in such a way that the body of the planet remains "close to the zodiac.[62]" Kepler describes planetary motion in terms of a clash between these two faculties. The planet's orientation with respect to the fixed stars is partially deflected by its own appetitive faculty to "seek out" the Sun, "just as a magnet directed towards the pole is nonetheless somewhat deflected by iron and nearby mountains."[63] In many places throughout *Astronomia nova* Kepler claims that the recourse to examples coming from the magnetic philosophy is more than mere analogy; and that Gilbert "the Englishman" really proved that "there are magnets in the heavens."[64] Meanwhile, Kepler is ambivalent with respect to the nature of these magnetic faculties. They are said sometimes to be corporeal; other times they are said to require a (planetary) mind.[65] In the case of the Sun, a supplementary, vital faculty is postulated.[66] Again, I suggest that one can see Kepler's wavering as arising, at least in part, from Kepler's unsuccessful attempt to give operational definitions of magnetic interactions.

There is a clear operational drive in Kepler's attempts to describe Sun's orb of virtue and its properties. Like Gilbert, Kepler attempts to map the solar orb, and to find quantitative correlations between different positions within the Solar's vortex and the behaviour of the bodies situated in those particular positions. By claiming that the sun acts "like a magnetic body,"[67] Kepler claims, in fact, that: (1) The Sun is itself in a (magnetic) motion of spontaneous rotation[68]; (2) That this motion is

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[61]Kepler (1992, 101), KGW iv 51.

[62]Kepler (1992, 398), KGW iv 251.

[63]Kepler (1992, 52), KGW iv 52.

[64]Kepler (1992, 390–391), KGW iv 246.

[65]As Bruce Stephenson has pointed out, in Chap. 57 of *Astronomia nova*, Kepler offers two theories to account for the planet's libration. One of these theories attempts to give an explanation in terms of a quasi-magnetic force. The other presupposes the reintroduction of a planetary mind. See Stephenson (1994, 120–121).

[66]Kepler (1992, 68), KGW iv 35.

[67]A lot has been written on the status of Kepler's analogy. For the purpose of the present paper, it is less important whether Kepler really states that the Sun is a magnet or that the *anima motrix* is a species of the same genus as magnetic force. In both cases, the types of conceptual difficulties he is facing are very similar to Gilbert's own difficulties in explaining mutual magnetic interaction. For a discussion see Barker and Goldstein (2001, 109–110), Voelkel (2001, 237 ff).

[68]One of the clearest statements of this point can be found in the letter to Maestlin, March 5 1605, KGW vol. XV 172. The Sun is said to be a "circularly magnetic body," rotating "in its place [by virtue of a *facultas animalis* already found in Plato], whereby it carries around its *oribis virtutis* with it." In the same letter, Kepler emphasizes the fact that Sun's magnetic virtue is not attractive but "directive," organizing the space around the Sun in such a way that the planets are moved "more slowly" or "more quickly" according to their position in the orb of virtue. See also Chaps. 33, 34 and 58 of *Astronomia nova*.

concomitant with the emission of "immateriate species," from the body of the Sun; (3) that these "immateriate species," imagined as a sort of magnetic filaments, or fibers, are describing a *vortex* around the sun[69]; (4) that this orb of virtue has a certain geometry, orientation and directionality, i.e., contributes to the orientation and motion of surrounding planets.[70]

Kepler attempts to describe the strength of magnetic virtue in terms of a radial distribution and "density" of immateriate species emitted by body of the Sun. This "density" differs from one region to another, within the solar vortex, and this is what, according to Kepler, makes Sun's "grasp" upon the planets "stronger or weaker, according to the law governing its diffusion."[71] Moreover, unlike light, this virtue is diffused "unequally:" the "species […] descending near the pole is less well adapted to the motion carrying the planets along."[72] In this way, the Sun's magnetic orb is endowed with a particular geometry. Kepler claims that this diffusion of species is responsible for "indicating" the poles of the zodiac and the dimensions and inclination of the ecliptic, "thus furnishing a natural cause for these astronomical entities."[73] Thus, magnetic virtue organizes the space, endowing it with certain geometrical symmetries. This spatial organization of Sun's orb of virtue is said to be the cause of why planets do not move "indiscriminately in all directions," but are confined to the ecliptic plane.[74] This is also, at least partially connected with the particular trajectories and speeds of planetary motions. Later, in the *Epitome of Copernican astronomy*, Kepler would claim that "the virtue flowing from the body of the Sun" is "corporeal" and it is gradually "dispersed and thinned out."[75] In other words, the very composition and structure of the Sun's orb of virtue is responsible for guiding and directing planets along specific paths, and with particular speeds.

Meanwhile, Kepler also sees that the organization of Sun's vortex is only a part of the problem. In fact, he claims that if the Sun would be solely responsible, the motions of the planets would be uniform. In other words, "the approach and recession of a planet to and from the sun arises from that power which is proper to the

[69]Kepler, AN 176; KGW III 355. For a discussion on Kepler's immateriate species see Rabin (2005), Dupré (2012). In *Astronomia nova* Kepler makes clear that such *species* are not only ascribable to the Sun, but also to the earth, which moves the moon "through its *species*." (Kepler 1992, 391).

[70]See KGW III 355. The Sun does not "attract" planets, but has only a "directing force [*vis directoria*]." In addition, this directing force acts within the plane of the ecliptic. It is worth emphasizing that, for Kepler, both magnetic and gravitational attraction always take place in the orb of virtue.

[71]Kepler (1992, 68), KGW iv 35.

[72]Kepler (1992, 399), KGW iv 252.

[73]Kepler (1992, 387), KGW iv 243.

[74]Kepler (1992, 398), KGW iv 251.

[75]KGW vii, 302; for a discussion on the nature of Kepler's immateriate *species* see Rabin (2005, 53–54).

planet."[76] Thus, this re-configuration of the notion of "orb of virtue" leaves open most of Gilbert's own problems regarding the mutual effects of magnetism (and gravitation),[77] such as the problem of the accord between the Sun's magnetic virtue and the respective magnetic virtue of each planet. Kepler's suggested solution is very similar to Gilbert's: namely, he distinguishes between the motive power (of the Sun) and the perceptive faculty (of the planet). Following Gilbert, he deems them both magnetic[78]; however, the two powers refer to two very different motions. The spontaneous rotation of the sun "generates" an organized and oriented space, in which planets are disposed, and directed. The magnetic intellective faculty of each planet "perceives" the properties of this orb of virtue, and tends to react accordingly, for example, by preserving the orientation of its magnetic axis in alignment with the fixed stars. However, in this attempt, the directive magnetic faculty of each planet is hindered by both its own, appetitive virtue, which directs it to "seek" the Sun, and by its own (corporeal) inherent force, which tends to "keep it at rest,"[79] or even to "flee" the orb of virtue of the Sun.[80] As a result, Kepler sees the resulting motion of a planet as the result of an inner "wrestling match" between various faculties ascribed to each planet: some corporeal, and some intellective.

Thus, Kepler's cosmological generalization of Gilbert's magnetic philosophy does not sort out the question of mutual interactions.[81] Despite the operational drive clearly present in Kepler's treatment of the Sun's "orb of virtue," various natural philosophical difficulties prevent the formulation of operational definitions. Instead, the explanation of magnetic interaction has to deal with traditionally difficult subjects, such as the nature of planetary souls, and their various animal and intellective faculties.

9.5 Francis Bacon's Operational Treatment of the Orbs of Virtue and the "Measures of Space"

By contrast with Della Porta, Gilbert and Kepler, Francis Bacon has a slightly different way of tackling the same problems. First, he generalizes the concept of the "orbs of virtue" to apply to all virtues whatsoever. Second, he constantly brackets questions regarding the nature of virtues and their respective mechanisms of interaction, aiming to formulate operational definitions and methodologically driven

[76] Kepler (1992, 407), KGW iv 256.

[77] For a more general discussion see Krafft (1991).

[78] The planet's libration is the effect of its own magnetic faculty; however, Kepler agrees that this is a complex motion and he ascribes it to the planet's capacity to perceive the angular size of the sun and thus, to know its distance from it and to regulate its own motion. See Voelkel (2001, 179).

[79] One of Kepler's fundamental axioms is that "a body of a planet is inclined by nature to rest in every place where it is put by itself." (Kepler 1992, 407), KGW iv 256.

[80] For a discussion of Kepler's understanding of inertia see Krafft (1991, 215).

[81] Here I agree with Krafft's conclusion, namely that "the idea of a general mutual gravitation" never came to Kepler's mind. See Krafft (1991, 218).

strategies of experimental inquiry. As a result, he is able to push the operational drive much further than Gilbert. My claim is that one can see in Bacon's strategy of experimental inquiry an attempt to disentangle completely the natural philosophical content from the operational content of the "orbs of virtue."

A word of caveat might be useful here. When I say that Bacon managed to successfully operationalize the treatment of the "orbs of virtue," I do not mean to assert that he also abandoned his appetitive metaphysics, or his pneumatic matter-theory. I merely claim that he devised a strategy to keep apart, in his experimental inquiries, the operational content from a deeper level of metaphysical and natural philosophical content.[82] This allowed him to formulate successful operational definitions and to devise strategies of measurement before having a clear theoretical grasp of the entities subject to measurement.[83]

In what follows I show that one can distinguish, in his writings, two attempts to formulate an operational definition of the "orbs of virtue." The first is connected with a classificatory concern: Bacon repeatedly used the orbs of virtue as an instrument of classifying actions in terms of their range. This led him to discuss "natural limits," boundaries, borders and other extension-related questions in terms of a definition of "orbs" as "measures of space" for a given action. A second attempt to find an operational definition is in terms of a universal property of matter he calls "perception." However, unlike for Gilbert and Kepler, Bacon's perception is not a faculty of the planetary soul but a universal quality of matter. Again, Bacon circumvents the natural philosophical discussions on the nature and mechanisms of perception and merely classifies bodies as more or less perceptive, claiming that the range of their "perception" can be the subject of experimental investigation. This is precisely Bacon's second operational definition: orbs of virtue are the distances to which a certain perception extends. This definition opens the possibility of constructing "perceptive" instruments which can experimentally map the space around a certain body, determining its structure, its hidden limits and symmetries.

9.6 Classifying Actions and the "Measure of Space"

Bacon claims that every natural virtue has its own, characteristic, "orb," which designates its range of action and the limits to which it can act, under given circumstances. However, unlike Della Porta, Bacon does not conflate all effluvia

[82]Incidentally, this also raises the question of the entangled and extremely interesting interrelation between theory and experiment in Bacon's inquiries. In other papers, I suggested that Bacon's speculative natural philosophy plays the role of a background theory in the formulation of his experimental investigations. (Jalobeanu 2013).

[83]I have discussed this strategy more extensively in Jalobeanu (2015a). Here, the discussion will be limited to one example, that of the "orb of virtue".

under a generic term. He clearly distinguishes between different kinds of effluvia, either in terms of "subtlety,"[84] or in terms of range, and mechanisms of interaction. For example, in *Sylva sylvarum*, Bacon discusses eight different types of effluvia, (he calls them "transmission of spirits"), extending from the "most corporeal," such as "odours" and "infections," to the "least corporeal," such as the astral "influxes" and the operations of sympathy. In between these extremes, Bacon arranges various types of attraction and "consent."[85] All these actions, he claims, produce their effects at a distance, in ways too "subtle" to be fully understood.[86] Therefore, Bacon does not attempt to discuss and classify them in terms of their respective mechanisms of propagation. Instead, he proposes a classification based on two parameters: the range of action, and the role played by the intervening media. Some of the eight types of effluvia are short ranged; others can act at considerable distances. In some cases, the action is strongly dependent on the intervening medium (as in the case of light and sound). In some other cases, "emissions of spirits and immateriate powers and virtues," "work by the universal configuration and sympathy of the world:"

> Of this kind is (as we suppose) the working of the load-stone, which is by consent with the globe of the earth: of this kind is the motion of gravity, which is by consent of dense bodies to the globe of the earth: of this kind is some disposition of bodies to rotation, and particularly from east to west: of which kind we conceive the main float and refloat of the sea is, which is by consent of the universe, as part of the diurnal motion. These immateriate virtues have this property differing from others; that the diversity of the medium hindered them not; but they pass through all mediums; yet at determinate distances.[87]

Thus, from the perspective of the investigator, the major difference between the "materiate" and "immateriate" powers and virtues is that the latter can be investigated without taking into consideration the action of the intervening media in widening or shortening the range of action.[88] By contrast, electric action and other forms of sympathy depend on the medium in which bodies are placed[89]; and that

[84]"Subtlety" is a technical term in Bacon's vocabulary; it describes the multiple and complex ways in which the fundamental processes taking place in nature escape the senses. See for example OFB XI 211, 347, SEH II 602. For a discussion see Rees (1980) and Jalobeanu (2015a).

[85]SEH II 602.

[86]It is tempting to read Bacon's types of effluvia in corpuscular terms, and his classification as one of substances made of increasingly smaller corpuscles. However, this is not Bacon's definition of subtlety. Subtlety refers to perception; it is a generic name for describing the multiple and complex ways in which fundamental processes taking place in nature escape the senses. See OFB XI 347.

[87]SEH II 644.

[88]In *Sylva Sylvarum* Bacon extensively discusses the role of such intervening media, such as the air, in the transmission of odours and diseases. He is also interested in natural magic tricks of extending the "natural range" of human imagination. More experiments on the role of the media in electric attractions can be found in Bacon (1679, 140–151).

[89]Sympathetic attraction comprises "the attraction in gold of the spirit of quicksilver;" "the attraction of heat at distance, and that of fire to naphta; and that of some herbs of water, though at distance; and divers others." See SEH II 644.

means that by operating on the medium, the investigator can obtain a wider-ranged action, or a less powerful attractive effect.[90]

Similar classifications of actions and virtues in terms of their range of action can be found in *Novum organum* and *Abecedarium novum naturae*. In *Novum organum,* Bacon proposes a tripartite classification of virtues: some operate by contact, others at small distances,[91] and others at large and very large distances. In each case, regardless of the actual mechanism of interaction, the range of action, or the "orb of virtue," is determinate.

> […] virtues and motions of things operate and work over distances which are neither indefinite nor random, but finite and certain.[92]

Thus, Bacon claims that there are "natural limits" and orbs of virtue, not only for magnetic and gravitational virtues, but for every each action, virtue and motion. The same tripartite classification is applied, in the *Abecedarium novum naturae*, to simple motions. Bacon distinguishes wide-range motions, whose orb of virtue is the "sphere of the universe," from middle and short-ranged motions.[93]

Thus, Bacon's first operational definition of the orbs of virtue is in terms of a *measure of space*. The "orb of virtue," he claims,

> […] is the distance which the powers of bodies may travel to, stop at, build up to and die down from - whether the operation occur by contact alone, or at a [greater or] lesser distance […].[94]

This operational definition provides the ground for a more accurate classification of actions and motions in terms of range. It also opens up the possibility of experimental investigations of these measures of space in particular circumstances. The experimental investigation of such measures of space is taken to reveal natural limits, "borders" and "boundaries" around particular bodies. Bacon claims that

> […] there is a kind of *No further* which varies according to the mass or quantity of bodies, or the strength and weakness of virtues, or the helps and hindrances of the media, all of which ought to come into the reckoning and to be noted down.[95]

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[90] See also Bacon (1679, 150–151).

[91] Bacon's list of short-ranged actions contains quite diverse items: instances of electric attraction, but also "bubbles" in water, "merging when they come together." Instances of action-at-a-distance properly speaking comprise gravitation, magnetic attraction, but also the particular form of consent through which plants attract water, even at a distance, etc. Bacon also opens the possibility of very long, cosmic "orbs of virtue" in the case of magnetic disposition (orientation) and gravitational effects.

[92] OFB XI 369.

[93] OFB XIII 195; see also the next section. The unfinished *Filum labyrinthi sive Inquisitio legitima de motu* proposes another classification of simple motions in terms of categories such as space, time and alteration. SEH III 630; it is worth emphasizing that in this classification, the motions "with respect to space" cover very diverse tendencies of a body to avoid the void (*motus nexus*) to avoid interpenetration by other bodies (*motus plagae*); to keep within the limits of its own sphere (*motus libertatis*) and to change its sphere (*motus hyles migrantis, sive ad sphaeram novam*).

[94] OFB XIII 211–213.

[95] OFB XI 371.

In the experimental investigation of the orbs of virtue, one has to take into consideration three parameters: the "quantity" or bulk of the bodies involved, the "strength" of a given virtue, and the intervening action of the media. The experimental investigation aims to establish a correlation between these parameters in particular circumstances. Mark that, again, the actual mechanism of action is circumvented. What the experimenter attempts to do is map the space around a body, looking for how the effects of a particular action take place at various distances within the orb of virtue. In each case, the effects of the action are said to be "confined within the orb of its own virtue."[96]

In the light of all this, one can more easily understand Bacon's interest for borders and limits; his numerous examples of bodies changing their behavior when moving from one "orb" to another and his constant preoccupation to determine the "natural limits" and the range of action of each virtue. In his preface to the *Historia gravis & levis* Bacon clearly states that

> […] it is quite certain that a body is not affected except by another body, and that no local motion occurs which is not prompted either by the parts of the moving body itself; by adjacent bodies, be they contiguous or close at hand; or at least by ones within their orb of virtue.[97]

Thus, for Bacon, heavy bodies are not heavy because they tend towards the center of the earth; they are heavy because they happen to be in the orb of virtue of the Earth. The further away from the Earth, the less heavy they are; and at the borders of the Earth's orb of virtue, they would simply "hanging there like the Earth itself and not fall down at all."[98] By way of consequence, we can imagine similar limiting cases for each virtue. Hence, the experimental investigator can "map" the space around bodies for similar cases of strange behavior in bodies. Such "leaps" in the regular behavior of a body or another can mark the natural limits, or the orbs of virtue of a particular action, or motion.

9.7 Perception and "Perceptive" Instruments: Mapping the Orbs of Virtue

The experimental determination of these "measures of space" is fraught with difficulties. Bodies are endowed with multiple virtues, each with its own orb. For example, Bacon criticizes Gilbert for over-simplifying "the matter of magnetic

[96] OFB VI 157; OFB XI 317–319; OFB XI 329–331.

[97] OFB XII 133; *Historia gravis et levis* was one of the six natural histories Bacon planned to write in the last five years of his life. Its manuscript has not survived.

[98] OFB XI 329. Bacon claims that this is the case of the lower comets, but also that of large clouds over the seas. See also OFB XI 317–319. Bacon also suggests various ideas for experiments attempting to find a quantitative relation between weight and the actual position in the orb of virtue. See SEH II 353–354.

powers" by reducing the number of magnetic motions, and by confining them to the loadstone.[99] By contrast, Bacon claims that there are many more magnetic motions[100]; and that at least some of them are universal, simple motions, that can be found in each body, tangible and pneumatic.[101] More generally, Bacon's appetitive metaphysics postulates that there are complex configurations of motions in each single body.[102]

> […] all bodies, by the manifold consent of things are also endowed with many motions, some ruling, others submitting, others again lying hidden unless excited; and there are no proper motions of things other than specific measures and modes of general motions.[103]

Each of these simple and composed motions has its own range of action, or "orb of virtue." In some cases, these orbs can be very large, no less than the whole "sphere of the universe [*spheram universi*];"[104] this is the case of motions taking place by the "common bond of the system, or cosmical consent."[105] It is clear, especially from Bacon's earlier, unfinished texts, that he hoped to turn these estimative classifications into proper inquiries into the "nodes and spheres" of every motion, "the times and moments wherein motions work, and which is the more swift and which the more slow."[106] However, for such an investigation to work,

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[99]OFB XII 133.

[100]For example, a series of experiments in *Sylva sylvarum* attempts to determine four magnetic motions in the Moon: the "drawing forth of heat; the inducing of putrefaction; the increase of moisture; the exciting of the motions of spirits." (SEH II 636). All these magnetic motions are instances of action-at-a-distance; and some of them are classified as instances of the "simple" magnetic motion. In addition, the Moon has the (magnetic) virtue to "lift up the waters," to "make moist bodies swell or inflate," etc. Bacon also mentions repeatedly the magnetic virtue of the Sun, which "holds" Venus and Mercury very close to the Sun's orbit. OFB XI 399. It is worth noting that in classifying magnetic phenomena, Bacon moves certain magnetic motions from one class of simple motions to another. See for example OFB XI 397–401; OFB XIII 197–198.

[101]Bacon uses the term "magnetic motion," or motion of congregation [*motum magneticum sive congregativum*]; or "great magnetic motions," for all mutual attractions where masses of matter are involved (bodies tending to unite with great masses of connaturals). See OFB VI 193; OFB XIII 195. This also extend to purely pneumatic matter, such as the celestial fire.

[102]Bacon's bodies are configurations of matter in motion; and he attempts to explain these perceptible motions in terms of a small, fixed number of simple motions. Bacon has various lists of such simple motions. There are interesting differences between one list and the other, both in terms of the number of simple motions and in terms of the actual description of one motion or another. On Bacon's doctrine of simple motions, see Manzo (2006), Rusu (2013), Weeks (2007) and Jalobeanu (2015a).

[103]OFB VI 189.

[104]OFB XIII 195. The orb of virtue for this motion can also be very large. In *Novum organum* Bacon claims that this motion arises "from a certain harmony and consent of the world," a type of consent which manifests itself at distances greater than the orb of virtue of the Earth. This marks the particular place Bacon gives to verticity which, he claims, is simply the way in which solid, "robust" bodies participate in the cosmic, diurnal motion of the universe (SEH V 455).

[105]OFB VI 193.

[106]SEH III 627.

one would need rules of composition of simple motions into sums of motions, as well as ways to compare the "strength" and weakness of various motions.[107] Bacon's abstract physics does not provide such general rules.[108]

On the other hand, his experimental program suggests a possible alternative direction for such an investigation. One can, in principle, begin with an experimental inquiry which attempts to map the space around a particular body, in the hope of determining certain natural borders and boundaries. The mark of such natural borders would be a "leap" in a variation of a particular property; or simply the change in the behavior of an instrument that is "subtle" enough to "perceive" the border, or to register the leap. I suggest that this is the motivation behind Bacon's formulation of a second operational definition of the orb of virtue, as "the distance that perception reaches to."[109]

At first sight, Bacon's move looks deceptively similar to what we have seen in Gilbert and Kepler, i.e., introducing yet another natural philosophical concept in order to account for the apparently mutual character of magnetic (and gravitational) interactions. And indeed, Bacon introduces perception as a universal property of matter.

> It is certain that all bodies whatsoever, though they have no sense, yet they have perception: for when one body is applied to another, there is a kind of election to embrace that which is agreeable, and to exclude or expel that which is ingrate: and whether the body be alterant or altered, evermore a perception precedeth operation; for else all bodies would be alike one to another. […] And this perception also is sometimes at distance, as well as upon the touch; as when the loadstone draweth iron; or flame fireth naphtha of Babylon, a great distance of.[110]

However, Bacon does not elaborate a natural philosophical explanation of perception. In most cases, he treats it as yet another operational concept to be applied in further experimental investigations. For example, his *Inqusitio de magnete* contains a series of experiments intended to prove that even if, by laboratory manipulations, one can destroy the active power of a magnet, its "passive power" of perception cannot be destroyed.[111] Thus, loadstone burned, or reduced to powder is still attracted by magnetized iron, appearing "to retain its passive virtue in some degree."[112] Perception is thus considered to be a fundamental property, prerequi-

[107]Bacon calls these rules "cannons of ascendency," and discusses some of them among the instances of special powers of the *Novum organum*. OFB XI 413–417.

[108]His ANN can be read as an unfinished, sketchy attempt to provide such rules of composition, with the intention of bridging the gap between his request of experimental investigation and what looks like a metaphysics of schematisms of matter and simple motions.

[109]OFB XIII 195.

[110]SEH II 602.

[111]SEH V 403–305.

[112]SEH V 405.

site and preliminary to all action. This means that, each time a body is placed within the orb of another body, perception is the first "activated," and can be followed (or not) by action. Bodies can be more or less perceptive; and the detection and mapping of more subtle effluvia require very perceptive bodies.

Defining perception in this way allows a fully operational, experimental approach to body-body interaction. By placing suitable "perceptive" bodies close to one another one can detect various changes of behaviour. And since bodies are always acted upon by other bodies (either directly or through the emanation of subtle effluvia), one can consider that ensuing, observable motions arise as the result of a body's "labour for configuration relative to another body."[113] The motions thus observed can be manifold: attraction and repulsion, but also subtle, or less subtle changes of virtues.

This means that one can "map" the space around a given body by placing suitable "perceptive" bodies in certain configuration around it. Such bodies can perceive some of the borders, limits and boundaries of virtues and actions in the first body.

In practice, the experimenter meets with several different situations in this process of "mapping." The simplest situation is when the simple motion or the particular configuration of motions is already given. This is the case of "mapping" the variation of weight with distance.[114] Bacon claims that the weight of a body decreases with hight and suggests a series of experiments intended to map this gradual decrease.[115] The case of magnetic virtue is slightly more complicated, because it involves at least three different simple motions (coition, verticity and the motion of situation).[116] Even more complex are the cases in which one does not know the prevailing configuration of motion. Bacon formulates an experimental investigation of this type in Century IX of *Sylva sylvarum*: a complex series of experiments intended to map "the inequalities of the air" in a given region. Without knowing what produce these inequalities, and without actually discussing what these "inequalities of the air" are, the investigation attempts to find limits,

[113]OFB VI 267: "For place has not power, and body is not acted upon save by body, and all the haste of a body which seems to be aimed at positioning itself somewhere, it longing and labour for configuration relative to another body, and not relative to a mere location or position." Bacon also claims that in addition to mutual motions there is a "cosmical" motion of rotation; but even that is a motion received "by consent" with the whole universe and not a self-motion properly speaking. See OFB VI 180–181.

[114]This is a simple situation because, in Bacon's view, motions of major congregation (the great magnetic motion) always prevail in competition with other motions. This is why one can investigate weight and the motion of gravity independently of any other motion. OFB XI 417.

[115]OFB XI 329; SEH II 353–354.

[116]Most of the time, any assessment of the orb of magnetic virtue has to take into consideration weight as well. Bacon usually gives examples where magnetic virtue "gives way" to gravitational attraction. However, in the *Inquisitio de magnete* there are also cases where the experimenter screens off the gravitational attraction in order to concentrate on either coition or verticity.

borders and leaps in a given region with the help of very perceptive instruments, such as a weather glass or an improvised hygrometer.[117] These instruments record "changes" in the "inequalities of the air," and can be used to "map" a given region, for a given time. The recording of certain "leaps" in the behaviour of instruments is taken to be indicative of the discovery of natural limits and borders in nature. In this case, Bacon claims that the accuracy of this "mapping" depends primarily on the "subtlety" of the perception of the particular body used as an instrument.[118]

Again, one can read Bacon's introduction of "perception," and the associated strategy of determining boundaries, limits and leaps of the orbs of virtue as a generalization and operationalization of the same kind of concepts and questions one can find in Gilbert and Kepler. In contrast to his predecessors, however, Bacon brackets completely such concepts from their natural philosophical context, anchoring them firmly in methodological formulations of laboratory procedures.

9.8 Conclusion

My purpose in this paper was to investigate Francis Bacon's particular strategy of defining extension-related concepts in terms of "limits" and "borders" of action, i.e., "orbs of virtue." I have shown that, in formulating this kind of approach, Bacon was freely borrowing terms from magnetic philosophy and natural magic, building up on a series of questions and challenges already contained in Gilbert's proposal for a "science" of the "orbs of virtue." However, in his characteristic fashion, Bacon radically transformed both the meaning and the use of the borrowed concepts. I have shown that in his treatment of the "orbs of virtue," Bacon repeatedly circumvented all discussions about the nature and mechanisms of actions and the nature and mechanisms of perception. Instead, he formulated abstract, operational definitions, in terms of "measures of space (distance)" to which an action can extend; and in terms of (spatial) limits of "perception." He used these two operational definitions to devise experimental strategies of investigation for detecting natural limits and borders of actions and virtues, and for the classification of the (unknown) actions and virtues in terms of their range. Clearly, Bacon's approach is more than a mere "generalization" of concepts borrowed from natural magic and magnetic philosophy. In many ways, it marks a conceptual breakthrough and opens up new possibilities of proper, quantitative measurement, in actual, experimental investigations.

[117]It is important to note that Bacon is not only interested in finding instruments that are "subtle" and "perceptive" enough, but also in devising and inventing them, i.e., using very perceptive bodies as instruments in a given situation (Jalobeanu 2015b, 2013).

[118]The accuracy of mapping also depends on the application of the proper methodology of experimentation (Jalobeanu 2015a, b).

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Abbreviations

SEH	Bacon, Francis. 1857–74. *Works*, 14 vols. Edited by James Spedding, Robert Leslie Ellis and Douglas Denon Heath. London: Longman repr. Stuttgart-Bad Cannstatt: Frommann, 1961–63
OFB IV	Bacon, Francis. 2000. *Advancement of Learning*, ed. by Michael Kiernan. Oxford: Oxford University Press
OFB VI	Bacon, Francis. 1996. *Philosophical Studies c.1611–c.1619*, ed. by Graham Rees and Michael Edwards. Oxford: Oxford University Press
OFB XI	Bacon, Francis. 2004. *The Instauratio Magna Part II: Novum Organum and Associated Texts*, ed. by a Graham Rees and Maria Wakely. Oxford: Oxford University Press
OFB XII	Bacon, Francis. 2007. *The Instauratio Magna Part III: Historia Naturalis et Experimentalis: Historia Ventorum and Historia Vitae et Mortis*, ed. by Graham Rees and Maria Wakely. Oxford: Oxford University Press
OFB XIII	Bacon, Francis. 2000. *The Instauratio Magna*: *Last Writings*, ed. by Graham Rees. Oxford: Oxford University Press

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Chapter 10
The Circulating Structure of Cosmological Space in the Seventeenth Century Chemical Tradition

Luc Peterschmitt

Abstract I propose following one of the major themes in chemistry from the end of the sixteenth century to the beginning of the eighteenth: the circulation of seeds. My goal is not only to bring forward the longevity of this tradition—this is self-evident. Instead, I want to show how under diverse forms, the thesis of circulation allowed one to understand of how space was organized. In particular, I will look at the work of Joseph Duchesne (Quercetanus), Pierre-Jean Fabre and Herman Boerhaave. I will consider these three chemists as three moments in the history of chemical cosmologies that allow us to see how the spatial structure of the world has been considered.

Alchemists do not examine the nature of space. Certainly, space is not a concept that belongs to chemical[1] theory. Chemists meet the question or the problem of void only incidentally, for example. Moreover, the problems raised by the dimensions of bodies, their position and motion in space do not really concern chemists. At least, these issues are not essential to a chemical theory, which can be built without even addressing them. Indeed, they do not concern the core of chemistry: the explanation of the composition and qualities of bodies. However, this does not mean that nothing is said about space in chemical theories.[2] Indeed, till the beginning of the 18th century, alchemy also had a cosmological scope. If the chemist

[1]In this paper, I use "alchemy" and "chemistry" synonymously, as they were used during the 17th century—see Principe and Newman (1998).

[2]Thus, in this paper, I am not concerned with the question of "space" in the microstructure of a chemical substance and between its particles, but with cosmological space as discussed by chemists. The problem of the existence of interstitial void exceeds chemistry properly speaking, since it concerns every natural philosophy.

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works in a laboratory, his aim is to unveil nature as a whole, that is, to show what happens outside the laboratory. This issue could take many different forms. For example, one crucial question was to know to what extent artificial operations (which might result in products that do not exist naturally) were also natural. But more deeply, the aim of the chemist was to build a natural philosophy. Pierre-Jean Fabre expressed this goal in a quite striking way: "Alchemy is the true and only natural philosophy and it understands the whole of nature".[3] This means that, according to Fabre, alchemy allows one to know "all natural things" or that "it gets into the whole of nature"—that is to say minerals, animals, vegetables, and even Heaven. Alchemy aims to know the core of nature: the spirit of life that rules over the production of all natural things.[4]

Such declarations indicate that alchemy should also provide a cosmology. In this paper, my aim is to examine the structure of some alchemical cosmologies. However, it is evident that there are as many chemical cosmologies as chemical theories that sustain them. I will follow one question and examine it in three chemists: how do their cosmologies account for the unity of the world, beyond the crucial affirmation of the unity of divine creation? Nature is divided into regions or parts: what makes these parts into a harmonious whole? I will examine the following hypothesis: these essentially and spatially distinct parts of the world are united by a constant circulation. It remains to be seen what passes from one region to another. The question of *what* is transmitted will be another goal of my paper, and I would like to show how chemists passed from a metaphysical understanding of this circulation to a quasi mechanical interpretation of it. To show this evolution, I will focus, as I said, on three chemists: Joseph Duchesne (Quercetanus), Pierre-Jean Fabre and Herman Boerhaave. My aim is not to establish any relation between them; I will not consider the question of whether Duchesne had an influence or not on Fabre and Boerhaave. It would not change my claims if Fabre had never read Duchesne or if Boerhaave had never heard of Fabre and Duchesne. For my purposes, it is enough that they explicitly acknowledge belonging to the same tradition or history—chemistry—and that they take a position regarding Paracelsus, even a critical one. I will consider these three chemists as three moments in the history of chemical cosmologies that allow us to see how the spatial structure of the world has been considered.

10.1 Duchesne and Spiritual Circulation

In the first section, I will examine Joseph Duchesne's doctrine. Duchesne or Quercetanus was born around 1546 and he died in 1606. He was a Protestant; he was a military surgeon, and he became a physician in Geneva, were he became

[3]Fabre (1636, 8): "Que l'Alchymie est la vraie et unique Philosophie naturelle et qu'elle comprend en soy toute la nature" (all translations from French into English are mine).

[4]Ibid., 9–10.

acquainted with Paracelsians. However, if Duchesne was a Paracelsian, he remained moderate. His main goal was to defend the use of chemistry and chemical remedies in medical practice. In the end, he built his own cosmology and never felt the need to sustain Paracelsian thought as a whole. These few biographical features are sufficient for my purpose. My aim is mainly to underline that Duchesne belongs to the Paracelsian tradition, without being a strict follower of Paracelsus. The last important point about Duchesne is the following: during the 17th century, his treatises were best-sellers.[5]

Even if Duchesne was a Paracelsian physician and intended to defend the use of chemical remedies, this led him to a far more ambitious aim: his *Grand Miroir du Monde*, published in 1587 and in 1593 indicates that he built a kind of cosmology. My goal is to show the structure of the world according to Duchesne.[6] He divides the world into three parts: the Intellectual part, the Celestial one, and the Elementary part. Examining the Intellectual part is beyond the scope of the present paper; it is only necessary to keep in mind that it is constituted by "spiritual beings" (angels and so forth). It is a part of the world in the sense that it has been created. It is interesting to note that Duchesne thinks that he has to say something as an alchemist about this part of the world. Since the Intellectual part is created, a complete natural philosophy, exactly what alchemy aimed for, should deal with it.[7] Anyway, Duchesne describes the two other parts of the world as follows:

> In the fourth [book], I deal with the Celestial world, dealing with the matter and form of the Heavens, along with their accidents and number; with celestial images and shapes; with their aspects and influences. With the birth and death of things; with their sympathy and antipathy, proceedings from celestial aspects. In a word, I deduce the most necessary issues in these questions. In the fifth [book], I proceed to the Elementary world; I begin, following Aristotle's *Metaphysics* by dealing with agents or principles of everything. After having described the natured nature, I build this lower universe on the four elementary pillars, which I ground on the most solid Philosopher's arguments.[8]

Duchesne adds a second division to the simple division of three parts: the notion of natured nature entails a distinction between principles or agents and the elements properly speaking (all of them belonging to the Elementary world):

> That which I endow you now, natured nature, of such powers with which we see you. You are the principle of every motion and rest, not at once but successively; Spring of the

[5]Regarding Duchesne, see especially Kahn (2007). Also see Kahn (2004) and Hirai (2010).

[6]For all that follow, I will rely mainly on Hiraï (2005).

[7]Thus, it does not mean that alchemy is a kind of spiritualism and even less a mysticism.

[8]Duchesne (1587), préface (n.p.): "Au quatrième [discours], je viens au Monde Céleste, discourant de la Matière et de la Forme des Cieux, de leurs Accidents et dénombrement; des images et figures célestes; de leurs aspects et influences. De la naissance et mort des choses: de leur Sympathie et Antipathie procédant des aspects célestes; et déduis en somme les questions les plus nécessaires à cette matière. Au cinquième [livre], je descends au monde Élémentaire, que je commence (suivant Aristote en sa Métaphysique) par les agents ou principes de toutes choses. Après la description de la nature naturée, je viens bâtir ce bas univers sur les quatre piliers des Éléments, que je fonde sur les plus fermes arguments des Philosophes."

> Universe, Mother of time, author of years, months, days and hours, of number already counted, of passive measures, wife of work, widow of idleness, the mirror in which Great God's Goodness shines.[9]

The natured nature makes the elements act and play their role in the constitution of the world and in its course. Natured nature is but a reflection of God—that is to say, as we will soon see, of naturing nature. Thus in the elementary world, there are traces or images of what rules over it by transcending it. If the parts of the universe are clearly distinguished, they are not completely separated. At least one link between them is given by the notion (maybe the metaphor) of mirror or reflection.

Duchesne proposes other distinctions that concern naturing nature. In a first sense, naturing nature may refer to God. But there is a second sense of naturing nature, which is in turn divided into universal and particular. The universal naturing nature is identified with the soul of the world or the heaven that contains everything. In other words, universal naturing nature is but the celestial world. Thus, the celestial world is what is acting in everything and what makes everything act; it produces and supports natured nature. Particular naturing nature refers, then, to the particular form of things—we will come back to it later.

All these distinction show what is the first bond of the universe:

> For as the universal frame of this world is divided into these three parts, namely intellectual and elementary, the mean between which is the celestial, which does couple the other two, not only most divers, but also clean contrary, that is to say, that supreme intellectual wholly formal and spiritual, and the elementary material and corporeal: so in man the like triple world is to be considered, as it is distributed into three parts, notwithstanding most straightly knit together and united: that is to say, the head, the breast and the belly beneath. The which lower belly comprehends those parts which are appointed for generations and nourishment, which is correspondent to the lower elementary world. The middle part, which is the breast, where the heart is seated, the fountain of all motion of life, of heat, and of all motions: in the which the Sunne has the preeminence, as the heart in the breast. But the highest and supreme part, which is the head or the brain, contains the original of understanding, of knowledge and is the seat of reason, like unto the supreme intellectual world, which is the angelical world. For by this part man is made partaker of the celestial nature of understanding, of the feeling and vegetating soul, and of all celestial functions, formal and incorruptible: when as otherwise his elementary world, is altogether crosse, material and terrestrial.[10]

I pass over the analogy between world and man. For my purpose, it is enough to note that it signifies the fundamental unity of the universe in all its parts. The passage shows clearly that the celestial world is the bond of a universe made up of essentially different parts. Duchesne's object is the unity of the universe, which he

[9]Duchesne (1587, V, 156): "Ca que j'enrolle donc, Nature naturée/Tant et tant de pouvoirs dont l'on te voit parée./Tu es de tout repos et de tout mouvement/Principe, non à coup, ains successivement;/Source de l'Univers, sa laitière Nourricière, sa charitable sœur sa soigneuse tutrice …/ Mère du temps, l'auteur des ans, mois, jours et heures,/Des nombres ia contés [sic], des passives mesures,/Épouse du travail, veuve d'oisiveté,/le miroir où reluit du grand Dieu la bonté."

[10]Duchesne (1605, I, XV) (n.p.).

takes to be analogous to man's unity. As we have seen, the universe is composed of three parts: the intellectual, elementary and celestial—this last one linking the first two. The elementary world (or belly) contains all that concerns growth and food; the Sun in the Celestial region is as the heart in the human breast; lastly, the intellectual (or angelical) world is like reason. The celestial region is necessarily the middle part, which links the others. Thus, this region is the source of life and motion, tying the universe together or uniting the parts that compose it. Now the question is: how does the celestial world play this role? It can do so thanks to its middle situation, which indicates its intermediate ontological status. On the one hand, the celestial world dispenses the universal power of God. Since the celestial world is created (it is a part of universe), the fact that it may receive this power is not really a problem. The question is: how can it distribute the spiritual power to the elementary world? Answering such a question amounts to examining how the celestial world makes nature act—since the celestial world, as we have seen, is the principle of all motion. This means that the celestial world is the principle of natured nature.

Duchesne explains this link in his theory of seeds. Elements are the receptacles of seeds, which are spiritual in their essence. Duchesne describes their constitution as follows:

> This incorruptible balm is to be found enduring with all the secondary corruptible seeds of things. Here what Aristotle says holds true: 'that the corruption of one thing is the generation of another', because the seed, being thrown into the earth, it rots or at least it is corrupted, that is to say it digests and dissolves; but its radical and balsamic substance, which, before, was hidden and idle in a certain vital and spiritual humidity and in which the virtue that is the seed's power was vigorous, begins now to appear. Thus, it appears evidently that this balsamic substance, which, as we have said, is incorruptible, is not corrupted; but it is made perfect and it produces a new body. If it appears that nature may by herself perform such things and that she may separate what is spiritual from what is corporeal, what is incorruptible from what is corruptible, what is invisible from what is visible and finally what is pure from what is impure, what would she be able to do with the help and the dexterity of art?[11]

Duchesne distinguishes two kinds of seeds. Secondary seeds are like the material or corporeal envelope of the primary seeds (or seeds properly speaking since only they are really producing). Secondary seeds carry the primary ones; primary

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[11]Duchesne (1676, 15–16): "Ce baume incorruptible se trouve et conserve sur les corruptibles et secondes semences des choses. Et c'est ici principalement qu'a lieu le dire d'Aristote: *Que la corruption d'une chose est la génération d'une autre*, car la semence étant jetée en terre, elle se pourrit bien aucunement ou pour le moins se corrompt, c'est-à-dire digère et résout; mais la radicale et balsamique substance d'icelle qui auparavant demeurait cachée et oisive en certaine humidité vitale et spirituelle et dans laquelle était en vigueur la vertu, puissance de toute la semence, vient maintenant à se faire paraître; De sorte que de là même il paraît assez évidemment qu'icelle substance balsamique, laquelle nous avons dument qualifiée incorruptible ne se corrompt, mais se parfait et produit un corps nouveau. S'il appert que la seule nature peut de soi effectuer de telles choses et que par son seul moyen on peut séparer le spirituel du corporel, l'incorruptible du corruptible, l'invisible du visible et finalement le pur de l'impur, que pourra-t-elle faire étant aidée par le moyen et la dextérité de l'art?".

seeds separate from secondary seeds when the latter become rotten in the elementary world. Primary seeds are nothing other than the balsamic substance that is the vivifying force, which is spiritual, incorruptible and pure. Sometimes, Duchesne describes this balsam as an astral or celestial matter. Proceeding from the celestial world, it feeds the elementary world (in which it constitutes or serves as the essence of secondary seeds).

However, this substance does not only come down from the celestial to corporeal world. It keeps the mark or image or even memory of its origin. This causes seeds to return to their origin. As H. Hiraï has observed, there is a "circulatory life of seeds… by this perpetual circulation, heaven is married to the earth and the lower elements are linked to the higher".[12] In order to give a representation of this circulation, Duchesne uses the model of exhalation:

> And this is the perpetual circulation, by which the heaven is married to the Earth, and the inferior elements do combine with the superior. For the continual vapours arising from the center of the earth, being expulsed into waters, and being carried from waters into air, by the attraction of the celestial stars: and also by the force and appetite of the inferior Elements to bring forth issue, and to conceive from heaven, the seeds passing too and again, as the last elements return to their parents full and impregnated with celestial forms and do there nourish their seeds, until at length they bring forth in due season and do exclude their generation. The which impregnation comes from no other than from those astral seeds, and those three several beginnings, Mercury, Sulphur and Salt, furnished and fulfilled with all science, properties, virtues and tinctures.[13]

The elements can produce only if they are filled with this celestial substance, that is to say the seeds. Only such a union constitutes secondary seeds, which are fruitful. But this supposes that the celestial substance circulates.

Now the question is: what, precisely, circulates? Celestial seeds attract exhalations from the earth. Thus, what goes up to the heavens before going down to the earth are the material elements. But during such a circulation they are vivified, because they are impregnated with "forms". Thus there are two circulations: on the one hand, secondary (or material) seeds circulate; on the other hand, there is also, precisely speaking, a circulation of formal principles. When a body is destroyed, its form goes up to heaven, where it stays before it impregnates another secondary seed. Thus the formal principles pass from one seed to another. Their circulation is deeply important and constitutes the bond of the universe.

This circulation of spiritual seeds cannot be construed as the local motion of bodies or material elements. I propose to term it a "spiritual" circulation.[14]

> Finally, it is called the Philosopher's Heaven, because it surpasses by far the nature of elements. They can also rightly call this matter a balm, since it is a radical matter, spring of actions and fruitfulness, by means of which elements are appropriately melted and linked one to another: the true and universal remedy of all disease, the recovery of health, the renewing

[12] Hiraï (2005, 280); Hiraï uses a formula from Duchesne—see quotation below.

[13] Duchesne (1605, I, IV).

[14] Describing it as circulation of spirit would remain ambiguous, since, as we shall see, Fabre considers that spirits are purely material: their circulation, according to him, is not to be distinguished from the circulation of bodies.

> and conservation of bodies lie in its power and virtue. And even if this spiritual, celestial, invisible, occult matter, and consequently more noticeable to reason than to the senses, can hardly be found separately, yet it exists and may be found by a true Philosopher.[15]

Certainly, the notion of spirit should not be misinterpreted. The word may refer to the last product of distillation (in this sense, spirit is a very subtle matter). But according to Duchesne, balsamic substance is so spiritual that it does not seem material—at least, not in the same sense as bodies, since it is celestial, invisible and occult (to the senses). Indeed, the balsamic substance "surpasses by far the nature of elements", as if it were not of the same kind. As N. Emerton notes, "spirit [seems] to occupy the border line between corporeal and incorporeal existence".[16] More precisely, the nature of spirit is intermediate between (pure) matter and (pure) spirit (or intellect). Duchesne seems to hesitate about its true nature. Spirit is "matter"; but Duchesne stresses the difference between matter and spirit:

> The Heaven, albeit it is most simple does consist of those three beginnings [that is to say Salt, Sulphur and Mercury conceived as Principles] but of the most pure and most spirituous, and altogether formal.[17]

Spirit is "altogether formal". This implies a crucial difference between spirit and matter, and it explains why spirit remains occult to the senses[18]: it is confounded with form. But forms are the result of the "Spiritual Idea endowed with spiritual essence"[19]: spirit is not corporeal. The fact that it is constituted by the three "beginnings", as all bodies are, means that spirit is created, and it explains why forms can be diffused into material bodies. Thus, spirit partakes of the pure nature of form and of matter.

There is a constant circulation between the heavenly and elementary worlds. Elements are exhaled from the bowels of the earth; elements attract celestial forms that vivify them; then they carry along the celestial forms in their descent back to the earth, in a perpetual circulation. But Duchesne stresses the difference between form and matter. Thus he is led to consider a particular kind of circulation, distinct from material motion and circulation. This circulation of forms or this spiritual circulation is, according to Duchesne, the true bond if the universe.

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[15]Duchesne (1676, préface, 14–15): "Finalement, elle se nomme Ciel des Philosophes, pour autant qu'elle surpasse de beaucoup la nature des éléments. C'est aussi à bon droit qu'ils appellent baume cette matière, vu que c'est une nature radicale source des actions et de fertilité, par le moyen de laquelle les éléments sont convenablement mêlés et liés ensemble: en la faculté et vertu d'icelle consiste aussi la vraie et universelle médecine de tous les maux, la restauration de la santé, le renouvellement des corps et leur conservation. Bref, c'est ce qui donne vigueur et puissance d'agir à toutes choses naturelles. Et combien que cette matière spirituelle, céleste, invisible, occulte et par conséquent plus notoire à la raison qu'au sens ne se puisse à peine trouver séparément, si est-ce qu'elle a existence et se peut trouver par un vrai Philosophe, comme par raisons certaines et évidentes nous prouverons et montrerons."

[16]Emerton (1984, 179).

[17]Duchesne (1605, I, XII).

[18]It means that form is the origin of the qualities but not the qualities themselves. For example, form in Salt principle has no savour, but it is the origin or the cause of savour—see Duchesne, *Practice* I, 10.

[19]Duchesne (1605, I, X).

10.2 Material Circulation

We move on now to the second chemist I will consider, Pierre-Jean Fabre. He was born in 1588 and died in 1658; he belongs to the generation that immediately follows Duchesne's. He studied medicine at the University of Montpellier, where he discovered alchemy and Paracelsus. Because of his Paracelsianism, his thesis in medicine was refused for a while. But when he came back home in the South–West of France, this did not hinder him from practicing chemical medicine. However, quickly enough, his work began to extend far beyond medicine *stricto* sensu: as we have mentioned in the introduction, his aim was to build a complete natural philosophy.[20]

Since both Fabre and Duchesne are Paracelsian, their doctrines share a lot of common features. Yet there are some crucial differences. One of these differences lies in cosmological structure. Fabre develops a firm "materialist" understanding of natural philosophy.[21] Of course, Fabre was not a radical materialist: he still considers a spiritual God as the Creator of the universe. But God's presence in Fabre's philosophy does not extend beyond the act of creation. Fabre proposes a materialist conception of chemistry insofar as he considers only materialist explanations, and much more firmly than Duchesne.

Like Duchesne, Fabre considers that Heaven is the center of the world:

> It is necessary to know and understand how all these principles and elements [...] are united together and make and constitute a general spirit of the world, which is the general and universal food for everything, where the whole of nature is united and gathered with all its parts and its true center; from this center, infinite lines are drawn. The further from the center they are, the more they diverge and the more they are different; the nearer from the center they are, the more they are united, till they form but one homogeneous point, alike in all its parts. Thus, the Heaven, with all the elements together, constitutes a liquid humor, where all the natural virtues of the Heaven and of the elements are united by the same means that unites and gathers all the virtues and energies of the parts of a body in its seed; thus, this liquor is the seed of the world.[22]

That Heaven is the center of the world has different meanings. But it cannot be understood literally: Fabre's cosmology is a geocentric one. Firstly, it means that

[20]For more biographical details, see Joly (1992).

[21]On Fabre's materialism, see Joly (2012); I will dwell on Joly's comment on Fabre.

[22]Fabre (1636, 111–112): "Il est donc nécessaire de savoir et comprendre comment tous ces principes et tous ces éléments … s'unissent entre eux et font et constituent un esprit général du monde, qui est l'aliment général et universel de toutes choses où toute la Nature est unie et rassemblées en toutes ses parties comme en son vrai centre, duquel se tirent des lignes infinies, qui tant plus elles sont éloignées du centre tant plus elles sont discordantes et différentes; et tant plus elle sont proches du centre, tant plus elles sont unies, jusqu'à ne faire qu'un seul point homogène et semblable en toutes ses parties. Le Ciel donc, avec les éléments tous ensembles constituent une humeur liquide où toutes les vertus naturelles du Ciel et des éléments se trouvent unies par le même moyen que toutes les vertus et énergies des parties d'un corps se trouvent unies et assemblées dans sa semence; ainsi cette liqueur est la semence du monde."

Heaven is the nourishing center of universe. Heaven is the ontological ground of the world, since it is but the seed of the world. More precisely, the substance of Heaven seeds the world and makes it live. This is not just an analogy or a comparison—I will come back to this point later. For the moment, let us note that Fabre gives a spatial figuration for the central "situation" of the Heaven. It is a point wherefrom infinite lines are drawn in all directions. This amounts to making Heaven the center of the world—which is physically impossible for Fabre.[23] In fact, he tries to figure out how everything is related to Heaven and how a simple substance may have different and even completely opposite effects. It does not matter whether these lines are real or metaphorical. In any case, they indicate what links Heaven and the rest of the universe (that is to say mainly earth). Heaven sends its seeds in the elements or mixed bodies, which are only matrices:

> The elements that we see are like the matrices of everything, because the general and seminal spirit lies in them. This spirit fathers and produces in all the elements; and the elements are nothing else than the places and matrices of production and generation. The rest is but a vital spirit or excrement of this spirit, which gives form, makes act and vivifies the elements; otherwise, they are only lifeless, vain and useless bodies, as the *Scriptures* say. Indeed, what is said of an element, *i.e. Terra est inanis et vacua*…["and the earth was without form, and void"], holds true for the other elements as well, since they were useless before the Creator of all things put in them the spirit of life that vivified them all.[24]

This substance, Fabre adds, is "the principle of motion and action that makes the whole created nature produce and generate everything". However, this spirit of life cannot be separated from the elements in which it lies. This is the ultimate sense of the notion of heaven as the center of the world. Heaven is (in) the center of everything, because it is the origin of everything. Thus, it is to be found in things themselves, innermost and inseparably tied to them.

This cosmology can be compared to Duchesne's. The spirit of life infuses everything. Fabre describes this dispensing of spirit as a circulation. His materialism is revealed here. The spirit circulates; during its fall from the heaven, it gets dirty

[23]Fabre provides an argument taken from the principles of chemistry to prove that Earth is in the center of the universe. He considers that light is the principle of motion and darkness is the principle of rest; therefore, as Earth is dark, it must be at rest. Fabre (1646, 237).

[24]Fabre (1636, 43–44): "Les éléments que nous voyons sont pareillement les matrices de toutes choses, car en iceux gît l'esprit général et séminal de toutes choses, qui est celui qui engendre et produit tout dans les éléments et les éléments en sont que le lieu et la matrice des productions et générations, le reste n'est qu'esprit vital ou excrément de cet esprit qui informe, actue et les rend pleins de vie, autrement ce sont des corps sans vie, vains et inutiles, comme il est dit dans la sainte Écriture. Car ce qui est dit de l'un des éléments, à savoir *Terre est inanis et vacua* … s'entend aussi des autres éléments, lesquels étaient tous inutiles avant que le Créateur de toutes choses y eut mis cet esprit de vie qui les vivifia tous."

and rougher and eventually tumbles down to earth; there, it retakes the body it had possessed before it was transformed into a vapor when the body died:

> From that, a perpetual and blind circulation follows. The going up from earth to Heaven and the falling down from Heaven into earth, in order to be resolved and coagulated into the seed and spermatic body of everything, and to be resolved into a very subtle vapor, yet full of life and full of natural and celestial fire; yet the most coagulated parts, which tend to be fixed, remain in earth, where they produce the most precious things if these parts fall down into pure places and if they are purified at the highest degree, by means of the long and continuous sublimation that occurs in this matter night and day in this vast and huge vessel of the universal world.[25]

We should keep in mind that this text is not metaphorical. The circulation is real. Fabre describes it following the model of a continuous distillation made in a pelican (an alembic so shaped that the product of distillation falls down and is distillated again and again). The comparison between the world and an alembic is not new—Duchesne uses it as well. However, Fabre admits all its consequences: the circulation that is the bond of universe is purely material.

To stress this last point, it is necessary to examine Fabre's notion of spirit more precisely. Once again, the notion is ambiguous. Duchesne seems to hesitate, since he attributes "ideas" to this spirit which bears "forms". These hesitations disappear in Fabre's doctrine. Even if he considers that reason alone can know spirit, which remains unperceivable. It is nevertheless material:

> The Heaven itself, which is above our corporeal senses, which can be understood only by the intellectual operation of the soul, cannot be excluded from the realm of Alchemy. Indeed, as Alchemy deals with the incorruptible matter of lower things, the matter which is in their center, it sees and touches the superior and celestial matters. By the very same means and way, alchemy sees that the lower matters are like the superior and celestial ones; that their substance is the same and that their difference is due to the degree of purity or impurity that is to be found in their individuals.[26]

[25]Fabre (1636, 162–163): "D'où s'ensuit cette perpétuelle et indésirante circulation, de monter et descendre de la terre au ciel et du ciel en la terre, pour se résoudre et se coaguler en semence et corps spermatique de toutes choses et se résoudre en vapeur très subtile, pleine toutefois de vie et de feu naturel et céleste; et cependant les parties les plus coagulées et tendant à fixion [sic] demeurent dans la terre et là produisent les choses plus précieuses, si ces parties tombent dans des lieux purs, et qu'elles mêmes soient dépurées à dernière purification, par la longue et continuelle sublimation qui se fait de cette matière nuit et jour dans ce grand et vaste vaisseau du monde universel."

[26]Fabre (1636, 10): "Le Ciel même qui est par-dessus nos sens corporels, que nous ne pouvons comprendre que par l'opération intellectuelle de notre âme ne peut être exclu du domaine de l'Alchymie; puisque par la matière incorruptible des choses inférieures qui se trouvent en leur centre, elle voit et touche les matières supérieures et célestes; et voit par même moyen et même voie, les matières inférieures être semblables et de pareilles substance que les supérieures et célestes et que leur différence est seulement par le pur et l'impur qui se trouve en leurs individus."

Fabre is clear enough. The celestial substance can give form to the elements because it is itself material.[27] As a consequence, the circulation described by Fabre is purely physical. Four vehicles bear the spirit of life: heaven's rays, air, water and earth. The elements bear this subtle substance: they are able to fix the spirit so that they can carry it with them.

What is circulating? Duchesne thought the forms were circulating. If he gave a chemical analysis of them, he mainly intended to show that the "spirit" is contained in the Principles (Mercury, Sulfur and Salt) and that it gives them life (or makes them active beings). As for Fabre, he gives a proper chemical analysis of spirit. He affirms its material composition. According to Fabre, seeds circulate and tie the world together by relating all the world's parts to its center. The chemical analysis makes sense, because forms themselves are material. Fabre uses three principles to account for the constitution of seeds, although we must remember that the Principles are not separable in reality. In short, Fabre's account runs as follows:

(a) Sulfur is a "vital and invisible fire, principle of every motion and action"[28]; Sulfur fills Heaven, it is nothing other than light. This "vital fire protects forms". Given these properties, Fabre reinterprets ancient philosophy:

> This explains that all the ancient Philosophers have written that the main nature of lower things, which they say to be their form and their true essence, depends on Heaven. Indeed, they asserted that they are fathered by the celestial fire as the particular forms of every elementary individual. The celestial fire gets into the lower seeds and raises up the inner form and makes it appear from the very deep heart of matter, with all its ornament and *équipage*.[29]

[27]For example, Fabre writes: "Who knows and understands the generation of one vegetable only may from it know the generation and production of all others, because their matter is unique and alike in all, the only noticeable difference between all these individuals coming from the particular form which is in them, which makes and causes in them all these particular and individual differences. But this form proceeds and is drawn from the very deep heart of matter, which has in itself the property and the virtue to produce these forms; and these forms are not different from matter, since they come from it and proceed from it; but they are an active matter, full of virtues and energy." Fabre (1636, 340–341): "Qui sait et comprend la génération d'un seul végétal peut d'icelui savoir la génération et la production de tous les autres, puisque la matière est unique et semblable en tous, la seule différence qu'on remarque à tous les individus de ce genre dépend de la forme particulière qui est en eux, qui fait et cause en tous ces particulières et individuelles différences. Mais cette forme procède et est tirée du centre et du profond de cette matière, qui a la propriété et vertu en elle-même de produire ces formes et ces formes ne sont point quelque chose de différence (*sic*) de la matière, puisqu'elles en sortent et en procèdent; sinon que c'est une matière pleine de vertu et d'énergie."

[28]Fabre (1636, 18): "Feu vital et invisible, principe de tout mouvement et de toute action"; "il protège les formes".

[29]Fabre (1636, 20): "D'où vient que tous les anciens Philosophes nous ont laissé par écrit que l'être principal de toutes choses inférieures qu'ils disaient être leur forme et leur vraie essence était dépendant du Ciel car ils ont assuré que sous les formes particulières de tous les individus élémentaires, elles étaient produite et engendrées par ce feu céleste, qui, s'introduisant dans les semences inférieures suscite et fait paraître la forme intérieure du plus profond de la matière, avec tout son ornement et son équipage."

(b) Mercury: it is the radical humidity, on which the universal seed acts in order to give Mercury its particular form.

(c) Salt: it is the "third part which comes from the action of the two others [i.e. Sulfur and Mercury], by means of which they become a visible and tangible body".[30]

Thus, bodies are constituted by the union of the Principles; but this is possible only because the principles are material—even if they are not immediately sensible by themselves (it is only their union in the production of the body that makes them sensible).

From Duchesne to Fabre, materialism becomes firmer. According to both chemists, the circulation of seeds is the bond of the universe, because it relates everything in the universe to its center or origin. Both try to understand physically this circulation and both rely on the model of exhalation. However, they do not construe what circulates in the same fashion. The object of disagreement is the notion of form. Of course, Duchesne and Fabre consider that spirit is insensible; only reason can know it. This does not hinder them from affirming that spirit is material. However, in Duchesne's doctrine, this "matter" is able to bear or to support forms which are spiritual (or even intellectual) entities. Thus, spirit is a kind of intermediate reality between pure matter and pure mental realities. Such features totally disappear in Fabre's doctrine of forms: he affirms quite vigorously that forms are material entities. Thus, according to Fabre, the structure of universe is purely material. It seems that the conception of space has been modified. Fabre describes circulation as taking place within a physical space. Fabre thus progresses toward adopting a space which is nothing else than what contains material bodies and in which they circulate.

10.3 Mechanical Circulation

I come now to my third chemist, Herman Boerhaave. He was physician and chemist at the University of Leydenin at the beginning of the eighteenth century.[31] His most important contribution to chemistry is his book, *Elementa Chemiae*, published in 1732.[32]

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[30]Fabre (1636, 26): "La troisième partie qui procède de l'action de ces deux, au moyen de laquelle ils prennent corps visible et sensible"; on Fabre on Salt, see R. Franckowiak, *Le développement des théories du sel dans la chimie française de la fin du XVIe à la fin du XVIIe siècle*, Thèse de doctorat, Université Lille 3—Charles de Gaulle, 2002.

[31]See Knoeff (2002), Powers (2012), and Lindeboom (1967).

[32]Some papers on mercury published in the *Philosophical Transactions* are important too—see Powers (2007); the *Elementa chemiae* are constituted by the lessons given by Boerhaave at Leyden. He published his book in 1732 because an unauthorized version was already circulating, especially in English, entitled *The New Method of Chemistry*, translated by Peter Shaw, published in 1724.

Boerhaave's project is clearly at odds with Duchesne's and Fabre cosmological aims. Boerhaave does not consider chemistry to be the one and only natural philosophy; according to him, chemistry should be a Baconian natural history,[33] dealing with experimental facts:

> But then this science became most perplexed when these Artists began to introduce their disputations into it, came to coining their general principles and went about to explain the causes of the different appearances they met with.
>
> These difficulties however may in some measure be removed, by collecting together the genuine experiments, which have been performed in this Art; from thence deducing some general rules, and then disposing those rules the most to advantage (…)
>
> Nor indeed in this art do we allow of any other theory, than what is built upon such general propositions, as have first been deduced from many common undoubted chemical Experiments, from which as they always succeed in the same manner, some general truth may be fairly inferred.
>
> We must take care however, not to carry this rule any farther, than simply to apply it to such particular bodies, as we evidently discover to be perfectly of the same nature.
>
> For it is certain that the powers of some particular bodies, frequently produce such effects as could not possibly have been foreseen, from any general theorem, in as much as they depend purely upon the peculiar nature of those bodies, which perhaps may be different from all others.[34]

This does not imply a clash with preceding theories or chemical doctrines. On the contrary, Boerhaave knows the chemical tradition perfectly well; and he very seriously takes into account what he calls alchemy. Even if he considers that "alchemy" is chemistry of the past, this does not mean that alchemy should be banished to the limbo of error and illusion. According to Boerhaave, at least some so-called alchemists were great chemists and they gave accurate observations of nature.[35] Boerhaave discusses alchemy; and he often gives his own interpretation of alchemical themes, as in the case of the circulation of seeds.

It is highly significant that Boerhaave reinterprets the two themes I have examined in Duchesne's and Fabre's doctrines: the theory of elementary Fire and the theory of seeds. However, it is also significant that he completely separates them. Boerhaave develops a very long theory of pure Fire—this is clearly his main topic, since he devotes one third of the *Elementa Chemiae* to it; the two-thirds that remain are devoted to a short history of chemistry, natural histories of Air, Water, Earth, solvents and then a description of the instruments and of chemical operations. On the other hand, he considers the theory of seeds as a part of alchemy. By separating the theory of seeds and the theme of circulation, Boerhaave opposes the chemical tradition that closely associated them. Indeed, Boerhaave's conception of the circulation of seeds is correlated with a crucial shift in the conception of Fire.[36]

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[33] See Peterschmitt (2005).

[34] Boerhaave (1735, I, 1–2).

[35] See quotation below for an example of such declarations.

[36] See Love (1972).

According to Boerhaave, Fire cannot be a spirit (or seed) of the world—because there is no spirit (or seed) of the world. But this, in turn, implies a "new" conception of space: Fire (whatever it may be) cannot remain the "spiritual" (in any sense) bond of the universe. Fire is a body that circulates in a neutral and homogeneous space; and Fire acts as a body in the universe—it does not bear formal principles and it is perceivable (its presence may be shown by the dilatation of bodies).

At first glance, Boerhaave deals with the theory of seeds very quickly.[37] He examines it when he tries to show that chemistry might be useful to alchemy. Clearly enough, his main aim is to criticize alchemy by assessing its claims from the point of view of true chemistry. In this context, Boerhaave recalls quite generally the alchemical notion of seed: according to the alchemists—as he reads them—there is in every body a very subtle vapor or spirit. Under the title "The Spiritus Rector of the Alchemists in compound bodies", Boerhaave writes:

> It appears then at length by the help of the chemical Art only, that there really is in every single Animal, and Vegetable, a kind of *Aura*, or Vapor, that is proper only to that particular body; and that this is so subtle a nature, that it discovers itself only by its scent, taste or some peculiar effects. This Spirit expresses the true Genius of the Body in which it resides; and it is this chiefly that accurately distinguishes it from all others. The infinite fineness of this Vapour makes it invisible to the eye, though assisted by the most perfect glasses; nor can the most exquisite Art detain and collect it by reason of its vast volatility: When it is pure therefore and separated from every thing else, it grows impatient of rest, flies off, and mixes with the Air, and so returns to the grand Chaos of all volatile bodies. There, however, it still retains its own proper nature, and floats about till its descends again with snow, hail, rain or dew. It then sinks down into the bosom of the Earth, impregnates it with it prolific seed, mixes it with its fluids, and so at last unites itself again with the animal and vegetable juices; and thus by this revolution returns into new bodies, in order to govern them and render them active. This Spirit, from its vast penetrability, exquisite subtlety, and prodigious volatility, the ancient Alchemists, who were certainly top masters of the Earth, and the most consummate Examiners of natural bodies, called the *Spiritus Rector*, or Governing Spirit.[38]

Boerhaave thinks along with the alchemists that such a spirit really exists. He even tries to locate it (for example, he proposes an analysis of cinnamon that confirms the alchemical doctrine). However, he makes some reservations concerning metals and metallic seeds:

> The masters of this Science who have been most happy in their discoveries tell us that they have seen these Spirits even in Metals and every kind of Fossil; that they are locked up in their proper bodies and confined there in their fixed Sulphur; and that whenever they can extricate themselves from their fetters and become free, then they grow vastly active, insinuate themselves into other kind of bodies, and are exceedingly efficacious in the cure of diseases. But enough of this; if your curiosity about these things leads you any farther, consult the Adepts in these mysteries. For my own part, I don't choose to say anything more upon this head, lest I should be suspected of recommending, and imposing on others, those things to which I am myself not equal.[39]

[37]The main passage is to be found in *Elements*, I, 72–75.

[38]Boerhaave (1735, I, 47).

[39]Boerhaave (1735, I, 49).

This passage gives some interesting indications about Boerhaave's conception of seeds. (a) Seeds are active substances which can be chemically identified. Boerhaave does not say a word about the way they are acting. But it is doubtful that they bear "forms"—Boerhaave does not use such a vocabulary. In fact, he considers that seeds are but certain parts or elements of bodies (which means that they are corporeal and endowed with corporeal qualities only). The only point he is willing to make is to establish their activity, leaving (maybe in a Newtonian fashion) aside the explanation of this activity. Boerhaave gives the example of the analysis of cinnamon. After a few operations on cinnamon he extracts a red oil that contains its spirit (it retains the virtues of cinnamon and especially its scent). There remains only something that perfectly resembles cinnamon but which has lost its properties. Boerhaave concludes: "hence it is evident that all the proper aromatic virtue of Cinnamon resides in a very small quantity of Oil, and that even of this, it constitutes but an infinitely small part. And this particular demonstration will almost universally hold good".[40] (b) Seeds are spirits or a subtle vapor; they are not made of elementary Fire: they are bodies of the very same kind as the body to which they give birth. (c) Boerhaave mentions the circulation of seeds only in the section that he devotes to the study of Air. This means that he does not consider that this circulation may link earth with a fiery Heaven or celestial world.

It is necessary to insist on this last remark: the seeds are examined in the context of his study of Air. According to Boerhaave, elementary Air should be distinguished from atmosphere. The latter is made of elementary Air, that is to say pure elastic aerial particles, and of all that is exhaled by terrestrial bodies. Seeds are parts of such exhalations. They move to and fro, according to the oscillations of atmosphere (these oscillations are partly due to the essential elasticity of elementary Air), and they act where they are mechanically moved (if they meet the conditions in which they can act). Boerhaave considers that atmosphere is but a chaos in which many events may happen:

> Thus then, Gentlemen, the few things I have laid before you, are sufficient to instruct us in our chemical Inquiries, what notion we ought to form of the Air. In reality, it is to be considered as a true Chaos of all things intermixed and compounded together. For in it there float up and down the attenuated particles of all bodies whatsoever. And since the little corpuscles are always in motion, they may, by running among one another in this aerial space, produce all the wonderful operations of nature, which are owing to the efficacy of particular bodies. But these are almost infinite.[41]

[40]Boerhaave (1735, I, 49).

[41]Boerhaave (1735, I, 289); note that this may explain the alchemical conception of seeds and especially the metallic ones: "That surprising phenomenon which in all ages has been observed by miners, seems likewise to be owing to the residence of these metallic parts in the Air, viz. That the fossil glebes, when they are dug out of the Earth, and are exposed to the Air, are affected by it in a very extraordinary manner. How frequently it is seen, that Marcassites, the Pyrites, vitriolic Stones and metallic substances that are quite exhausted are so acted upon by the Air, that they increase, come to maturation, are changed, renewed and afresh impregnated and become again enriched with a true metallic Offspring. In reality, the Air seems to be the grand universal distributer of the seeds of bodies, which being plentyfully stocked with every kind of matter, commits to the Earth the Elements of Bodies it has received from it and thus generates most kinds of Bodies, rather by means of a revolution than a new production" (*Elements*, I, 288–289). In all this passage, Boerhaave takes some alchemical themes and deals with them in the same "mechanical" fashion—see especially what he says about dew and its effects, *Elements*, I, 273 sq.

Thus, according to Boerhaave, the circulation of seeds does not extend beyond the limit of terrestrial space (that is, Earth and its “atmosphere”—Boerhaave does not provide any notion of distance here, and certainly what he calls atmosphere should not be confused with our conception of it). Moreover, such a circulation concerns only bodies that the chemist is able to isolate (even if, due to their extreme degree of subtlety, it is impossible to keep them in a vessel). Boerhaave is able to show experimentally some effects of such a circulation. It appears that this circulation does not structure space and can no longer serve as the bond of the universe. On the contrary, the circulation of seeds happens *in* space, which supposes that space is a neutral place for the seeds to circulate (or for anything else that may happen in it). Space is but the indifferent container of motion.

I will dwell on this last point by quickly examining Boerhaave’s theory of Fire. Fire is no longer a spirit comparable to Fabre’s or Duchesne’s Fire; there is no Heaven in Booerhaave’s cosmology that could be the nourishing center of the world. Once again, seeds circulate only in a purely mundane or terrestrial space. According to Boerhaave, Fire is only a medium in which everything in the universe floats. Fire is corporeal, even if it is not heavy; it is extended, impenetrable, mobile, and as simple a body as can be. In this sense, it may be compared to the alchemist’s pure Fire or Sulfur—and it is beyond any possible doubt that Boerhaave retains something from the alchemical tradition. For example, he considers that Fire and light are one and the same thing. But this affirmation is not necessarily identical with what the alchemists would have said—because Boerhaave entertains a Newtonian conception of light (in particular, he holds white light to be composed, which explains why Fire is not absolutely simple or homogeneous). In the same fashion, Boerhaave considers that Fire causes heat as soon as it is applied to an object; and thanks to its heat, it may join or disjoin the bodies—which is a most traditional conception of the action of Fire. But Boerhaave also considers that Fire does not perform anything outside of joining and disjoining. Lastly, Fire’s action is both universal and necessary. By its action (that is by its heating of bodies), Fire vivifies; a moderate heat is a condition for the development of bodies (including living bodies, but also minerals and metals). Indeed, where there is no Fire, an absolute cold reigns; there, nothing can happen (everything is absolutely frozen and immobile, particles cannot move and bodies cannot grow). But to perform its task, Fire need not be the bearer of forms or qualities as the alchemists thought. Last but not least, Fire is a medium. Boerhaave describes its universal presence as follows:

> In the first place, then, by what we already know of Fire, it appears that it must be always present in every part of space, though we are not at all times able to discover it, if we search for it only in the common methods […] Nor does Fire thus exist only in every part of space, but it is likewise equally diffused through every body, the most solid, as well as in the rarest […] I have not therefore, hitherto been able to discover, that in all nature there is any part of space, in which there is not Fire. Nor yet has it ever appeared to me after the most laborious inquiries, that there is any kind of body, that has a power implanted in it by the Divine Being by which it is able to attract this Fire thus equally diffused, and so unite it to itself, as to make the excess discernible to our senses. On the contrary, all the observations that I have had an opportunity of making seem to evince, that

> where there is neither any degree of attrition, nor motion from the mixture of various bodies together, there Fire is most equally distributed through every part of space. Nor does it in the least signify whether these spaces are empty or full or with what kind of bodies they are filled.[42]

Moreover, Fire is always in motion. But the way in which Boerhaave describes this motion is crucial:

> If Fire, explain'd as above, and now known by its power of rarefying, putting in motion, and insinuating itself into every kind of natural bodies, is collected in any Space, or body, so that it becomes perceptible to our senses, it then immediately begins to move by itself every way from the center of this space, or body.[43]

The motion of Fire is a tendency. Note that Fire does not necessarily depart from the very center of the universe; any body may be a source for its diffusion. This implies that there is no privileged place in the universe. A few lines below the quotation above, Boerhaave gives a last description that highlights his conception of space:

> It appears therefore, that this is the property of Fire, that its parts, whilst they expand or move themselves, tend equally towards every part of space and consequently are not determined to one point more than to another. This, I confess, seems somewhat surprising and not easily intelligible; and indeed, this idea differs very little from the idea of rest. I'll endeavor therefore, by a simple example, to explain what I mean, a little more clearly. Suppose a hollow sphere perfectly empty, and then conceive another sphere a hundred times less placed in the center of it, and its parts to have such a power, that by equally receding one from another, they may perfectly fill up the larger sphere. By this means then, you will have a true motion in all the parts and yet the whole mass thus mov'd, will be perfectly indifferent and indetermined to any particular side.

Curiously enough, Boerhaave fears that his conception of the diffusion of Fire could be misunderstood, because it may be difficult to conceive it. However, imagining the dilatation of Fire is not really a problem (there is no difficulty in imagining, as Boerhaave suggests, a sphere of which the radius is increasing). The difficulty lies in fact in what distinguishes his conception of pure Fire and the alchemical concepts. It concerns especially the fact that Fire cannot be, according to Boerhaave, the center of the universe, because there is nothing like a center: space is perfectly homogeneous, and Fire is equally diffused in all directions in it.

Boerhaave's doctrine indicates that the representation of the world has been deeply modified since the time of Duchesne and Fabre. The conceptions of space underlying the chemical cosmologies give us an insight with which to assess this evolution. In Duchesne's cosmology, the universe is divided into three heterogeneous parts, which implies that space itself is not homogeneous. The universe is tied by an essential circulation: immaterial forms pass from one seed to another in order to make the world fertile. In Fabre's cosmology, even if the universe is still divided, its structure is less organized (or even organic). Certainly, space is structured by what circulates in it. But since the Principles are material, according to Fabre,

[42] Boerhaave (1735, I, 113).

[43] Boerhaave (1735, I, 123).

space seems to be nothing other than what contains the circulation. Boerhaave seems to put an end to this evolution: he admits into chemistry a conception of space, as a neutral, undifferentiated place for anything. There is no center in the universe: no nourishing center nor even a purely geographical center. The universe is no longer divided into regions or parts, ontologically distinct, that must be tied or linked together by a spirit in order to form one universe. Thus the notion of circulation loses the crucial importance it had in Duchesne's and Fabre's cosmologies.

Certainly, the universal presence of Fire in Boerhaave's cosmological doctrine might be taken as a trace of alchemical cosmologies. But this is a vanishing trace. The unity of the universe is not really a problem anymore; it is the pure unity of God's act of creation. As a consequence, the space of chemistry is considerably modified. Chemistry can no longer be a complete natural philosophy. Fabre's claim to account for every phenomenon in nature does not make any sense for Boerhaave. Chemistry is but the experimental study of a certain range of phenomena in the universe.

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