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

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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.

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"Boundaries, Extents and Circulations: An Introduction to Spatiality and the Early Modern Concept of Space," in Boundaries, Extents and Circulations: Space and Spatiality in Early Modern Natural Philosophy, eds. Koen Vermeir and Jonathan Regier (Dordrecht: Springer, 2016), 1-32.

"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] – Francesco Patrizi, 1587.

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

[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.

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 **(FIGURE 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 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.

[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.

[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.

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]

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[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

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 (*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

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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."

[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.

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 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]

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[15] Scafi 2006.

[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

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

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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.

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]

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

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[21] Ibid., 45.

[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.

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]

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

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[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.

that parallel lines never cross. 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).

[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.

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 unextended measurer, that

[29] See e.g. Alder 2002, chapter 5.

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

[30] Sorabji 2004, 242.
[31] See Vincenzo de Risi's chapter in this volume, as well as Jean Seidengart's.

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

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[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.

and natural 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.

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

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

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, 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

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[35] See especially Grant 1979.

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

[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 & improprie extensiue […]" Bradwardine 1618, 179.

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]

The traditional narrative presents the development of absolute infinite space as a great revolution. Nevertheless, we should

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[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.

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,

[41] Cf. Grant 1981.

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]

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[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

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[44] Simon 2003.

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.

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

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[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.

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 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. **(FIGURE 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

[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.

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 (**FIGURE 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

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[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, chapters 4 and 5.

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

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 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

[54] Vanden Broecke 2000, 137. Also see Besse 2003, 123-129.

[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.

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

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[57] See esp. chapter 18 of Frisius 1530.
[58] Pogo 1935.
[59] Goldstein 1987, especially 173.

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 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

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

[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*.

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

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[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 Galileo's conservative position in the case of cometary parralax, see e.g. Gal and Chen-Morris 2013, chapter 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.

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, 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

[66] Euclid 1570, page 24 of Dee’s unnumbered preface.

[67] Apian and Frisius 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.

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 FIGURE 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

[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.

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.

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 **FIGURE 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 (**FIGURE 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]

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

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[70] See Connolly 1999 and Connolly 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.

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 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 **(FIGURE 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 **(FIGURE 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

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

[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 Jean-Marc Besse 2003, 91–96.

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

[77] Münster 1550, 1.

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 **FIGURE 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

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[78] Vogel 2006, 477-478.
[79] Ibid.
[80] Apian and Frisius 1564, 3r.
[81] See Besse 2003, 16.

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 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

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[82] Ptolemy 2000, 60.

[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.

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

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[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.

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.

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-

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

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.

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 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.

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

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[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.

mention is the anthropo-mystical maps of Europe drawn by Opicinus de Canistris in the fourteenth century; see **FIGURE 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.

Figures

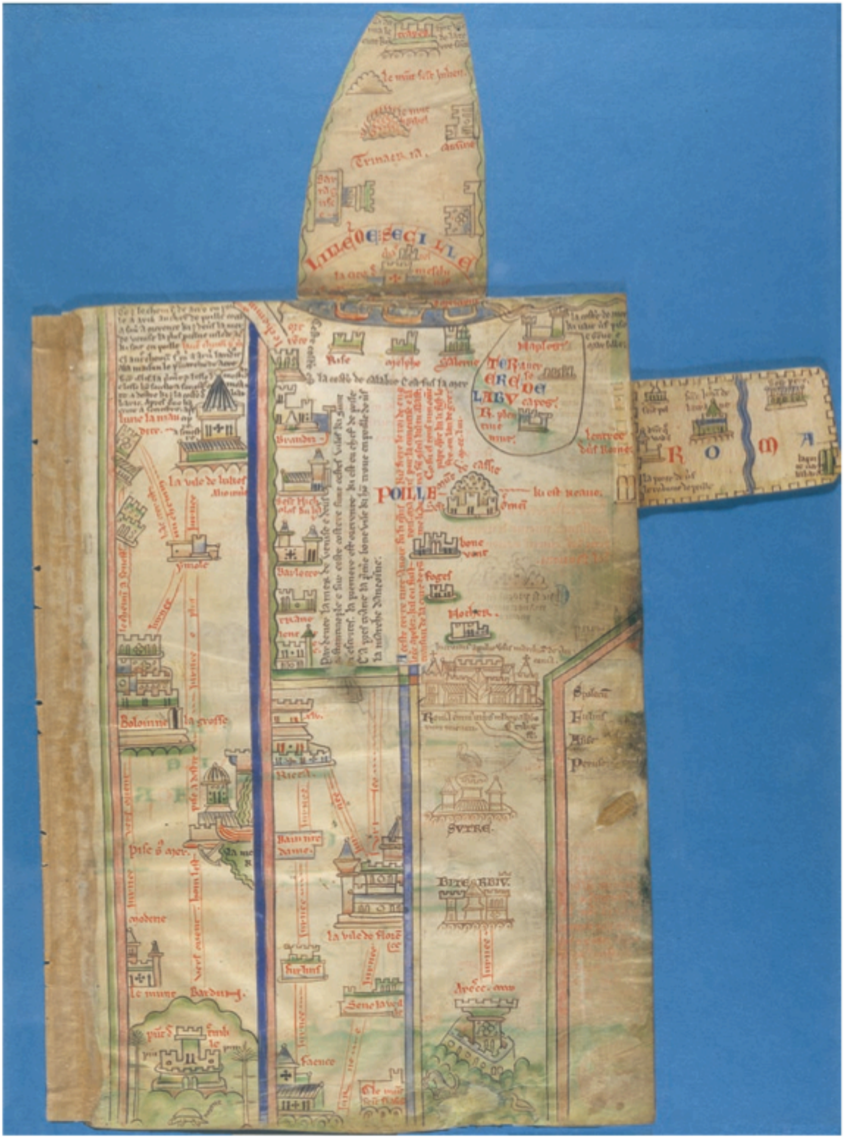

Fig. 1 Page from the itinerary from London to the Holy Land with images of towns, their names, and descriptions of places. From Matthew Paris, *Historia Anglorum, Chronica majora*, Part III, England (St Albans), 1250–1259, Royal 14 C. vii, f. 4r. Courtesy of the British Library

Fig. 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. 3 Peter Apian and Gemma Frisius, *Cosmographia*, Antwerp: Gregorius Bontius, 1550, f. 1v. Courtesy of the Max Planck Institute for the History of Science

Fig. 4 Peter Apian and Gemma Frisius, *Cosmographia*, Antwerp: Gregorius Bontius, 1550, f. 3r. Courtesy of the Max Planck Institute for the History of Science

Fig. 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 undique obductã & incluſam fuiſſe aquis maris, donec iuſſu creatoris aqua ab aliqua parte ſuperficiei terræ ſubducta, ſiccũ & cõmodum manſionis locum hominibus atq; animalibus terreſtribus reliquit, plantis quoq; unde omnia uiuentia uictitarent, firmum in ipſa arida adaptaretur fundamentum. Mare ergo ab illa die non obtinet naturalem ſuum ſitum, ſed quantum 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 aquarũ atq; profunditas imperſcrutabilis, qualis paſſim ultra Hiſpaniã, Iberniam, Scotiã, extremitatẽ Africę & in India inuenitur, ubi profunditas maris nulla induſtria humana indagari poteſt. Si enim iuxta philoſophorũ traditionem, elemen
a tum

Oceanus abyſſus magna.

Fig. 6 Sebastian Münster, *Cosmographiae uniuersalis Libri VI*, Basel: Heinrich Petri, 1552, 1. Courtesy of the Bavarian State Library

Fig. 7 Opicinus de Canistris, *Mappe*, 1296, Vaticanus latinus 6435, f. 84v. Courtesy of the Vatican Apostolic Library

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