David Marshall Miller. *Representing Space in the Scientific Revolution*. Cambridge University Press 2014. 246 pp. $108.00 USD (Hardcover ISBN 9781107046733); $30.99 USD (Paperback ISBN 9781107624719).

'Space: the final frontier'. Contemporary philosophers should remember these words from *Star Trek*. Despite the great significance of the concept of space in natural knowledge, avoiding circularity in its definition is impossible. Modern physics does not prove very helpful for solving the problem; for example, the Theory of Relativity has denied the a priori representation of space and considered the dimensions of space and time as part of a four dimensional structure. In the author's mind, the shift from a centered to an oriented representation of space has characterized the emergence of exact science during the Scientific Revolution. He has overcome the difficulty of a proper definition of space. In fact, he takes into account spatial epistemology, and the set of coordinations arranging phenomena, without devoting attention to space as a metaphysical concept. In other words, leaving metaphysical concerns aside, the author lays stress on the representations of space and their being part of modern scientific theories.

It is broadly accepted that Copernicus' work constitutes a turning point in the history of science. Notwithstanding the difference between his astronomical system and Newton's, historians consider Copernicus' heliocentrism as a fundamental step toward the achievement of modern astronomy. In the 2nd century AD, Ptolemy had already provided the community of astronomers with detailed calculations, and the Copernican System did not offer much more accuracy in predicting planetary motions. The problems affecting the Ptolemaic representation of space led the Polish astronomer to choose an alternative way. More specifically, he inherited considerable doubts raised by Averroes and the Averroist tradition, the plurality of centers instead of a single center coinciding with the center of the earth being the most significant. Broadly speaking, despite empirical success in saving the appearances, equants, eccentrics, and epicycles could not account for the reality of heavenly motions. Averroes' criticism of Ptolemaic solutions exerted a considerable influence on some Renaissance astronomers, such as Domenico Maria da Novara, Copernicus' teacher at the University of Bologna. Copernicus did not reject Ptolemaic astronomy as a whole, as he wanted eccentrics and epicycles to be part of his own innovative and realistic theory. His own trust in geometrical finalism led him to believe in the physical plausibility of uniform rotations as the natural movement of celestial spheres. In any case, Copernicus adopted a multi-centered spatial model: the center of the earth for terrestrial phenomena, and the sun for heavenly motions. Furthermore, a duality affected terrestrial phenomena, such as free falling bodies: they cannot have a simple rectilinear movement towards the universal center, as they take part of the rotation of the earth too. This and other common phenomena caused a lot of problems that early Copernican astronomers were far from solving. Although Copernicus' intention was to agree with Aristotelian explanations, that multi-centered representation of space could not fit with Aristotelian physics. His leaving the third motion of the earth unexplained further complicated the ongoing debate on the lack of a physical ground for his system.

Gilbert's magnetic philosophy displayed much originality, although he could not demonstrate that magnetism is the reason of the terrestrial daily rotation. He expressed a typical Neo-platonic conception, in which a kind of magnetic virtue empowered our globe to rotate. Thus, every part of the rotating earth could benefit from the action of celestial bodies. He indicated the reason why the earthly axis constantly keeps its orientation in verticity, that is, the ability to align with a kind of universal magnetic virtue, called the Law of the Whole. In sum, a magnetic worldview founded upon a geographical representation of space allowed Gilbert to state the fixed orientation of the terrestrial axis.

The main characteristic of Kepler's view consisted in his own mystical fervor, which led him to believe in a world structured on perfect geometrical forms. What is astonishing about his research is the idea of the beauty of creation as the outcome of God's mathematical mind. Humans, made in image of the Creator, share a part of the divine mathematical knowledge, and that is why the German astronomer could not accept a planetary solution aiming only at saving phenomena. The theological ground of his mathematical realism implied the physical plausibility for astronomical calculations. Kepler was influenced by the rectilinearity of Gilbert's magnetic virtue; thus, the rectilinear representation of the cosmos was the best way to structure his model of the universe. Even if he preferred to keep the idea of a centered universe, where the sun occupies a focus of the elliptical path, his conception was a step further toward the adoption of a new spatial framework.

Galileo Galilei's contribution to mathematical science is undeniable. The characterization of Galileo as the father of modern science is due to the innovative dimension of his approach to natural investigation. In his early works on the motion of bodies, the Italian scientist essentially maintained the Aristotelian principles of natural and forced movements. Even the introduction of the concept of neutral motion did not alter his physical view. His adhesion to the Copernican theory made him deal with all the questions connected with the heliocentric hypothesis; more specifically, he trusted in the Copernican idea of a multi-centered space in which the circular motion of the earth does not interfere with specific phenomena. However, despite the evolution of his research on the movement of bodies, he did not renounce the idea of a conserved circular motion.

The merits of René Descartes as a scientist include the employment of the parallelogram rule, depending on an oriented representation of space, in kinematic researches. The reduction of the empirical world into the conservation principle was the main goal of his physics; however, the inclusion of a wide range of phenomena, including living things, in a broader metaphysical arrangement, determined the inaccuracy of his explanatory apparatus. In the beginning of his scientific inquiry, he assumed an oriented representation of space. Rays follow straight lines, and he combined that presupposition with his geometrical view, in which priority was assigned to straight lines, with no reference to centers. His mechanical conception of the universe and straight lines formed part of a broader metaphysical arrangement. This kind of worldview, deeply discussed in the XVII century, was affected by a merely qualitative approach to phenomena. Straightness, indeed, is a simple idea. Moreover, in the Cartesian system, the straight motion was the simplest way adopted by the divine creation, and its apprehension by the human intellect is unquestionable. Nevertheless, when Descartes started dealing with large-scale phenomena, as in the case of vortices, he shifted to a centered arrangement of space, while some of his collaborators and interlocutors applied an oriented spatial representation in their works.

The pivotal role played by Newton in the achievement of modern science is beyond doubt, as he was the first scientist who embraced an oriented spatial framework for the explanation of planetary motions. The combination of gravity and inertia in the parallelogram rule represents the core of his universal synthesis. In the early phases of his research, he tried to describe heavenly motions with a centered representation of space. Following a suggestion proposed by Hooke, who had already understood the inadequacy of Cartesian vortices, Newton became aware that corpuscles and planets share the same basic laws. He was more skilled in mathematics than his colleague, and his mathematical ability was the key factor for the solution he found. So, the association of the conservation principle with an oriented model of space, and its application to astronomy, marked a decisive turning-point in modern celestial mechanics. Newton's synthetic worldview, based upon the belief in an oriented representation of space as a common ground for both celestial and terrestrial movements, definitively abolished the idea of a unique geometrical and physical center, dating back to the Aristotelian tradition.

The conclusions drawn by the author in the final chapter inspire additional reflection. Representations of space surely constitute an original point of view for highlighting the evolution of science in the modern age. Moreover, one can agree with the necessity to integrate history and philosophy of science. That integration, indeed, can overcome the striving to remain faithful to a pre-determined conceptual apparatus. As a consequence, on one side the author is right in pointing out that historians of science are not forced to appeal to social concerns; on the other, however, a common ground can be found in the cultural milieu in which the main protagonists of modern scientific thought acted. Their firm belief in a world as a mathematical harmony created by God is a key factor for the emergence of exact science, which presupposes the universe as a coherent totality of interacting phenomena. 'But you have disposed all things by measure and number and weight' (Wis 11, 20). Galilei's grand book of nature, Keplerian geometrical archetypes, and Newtonian absolute space-time, can be seen as clear instances of a vision of the world as the outcome of the divine creation. In other words, only a conception of the universe as a harmonic creature brought about a more scientific and coherent explanation for space.

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