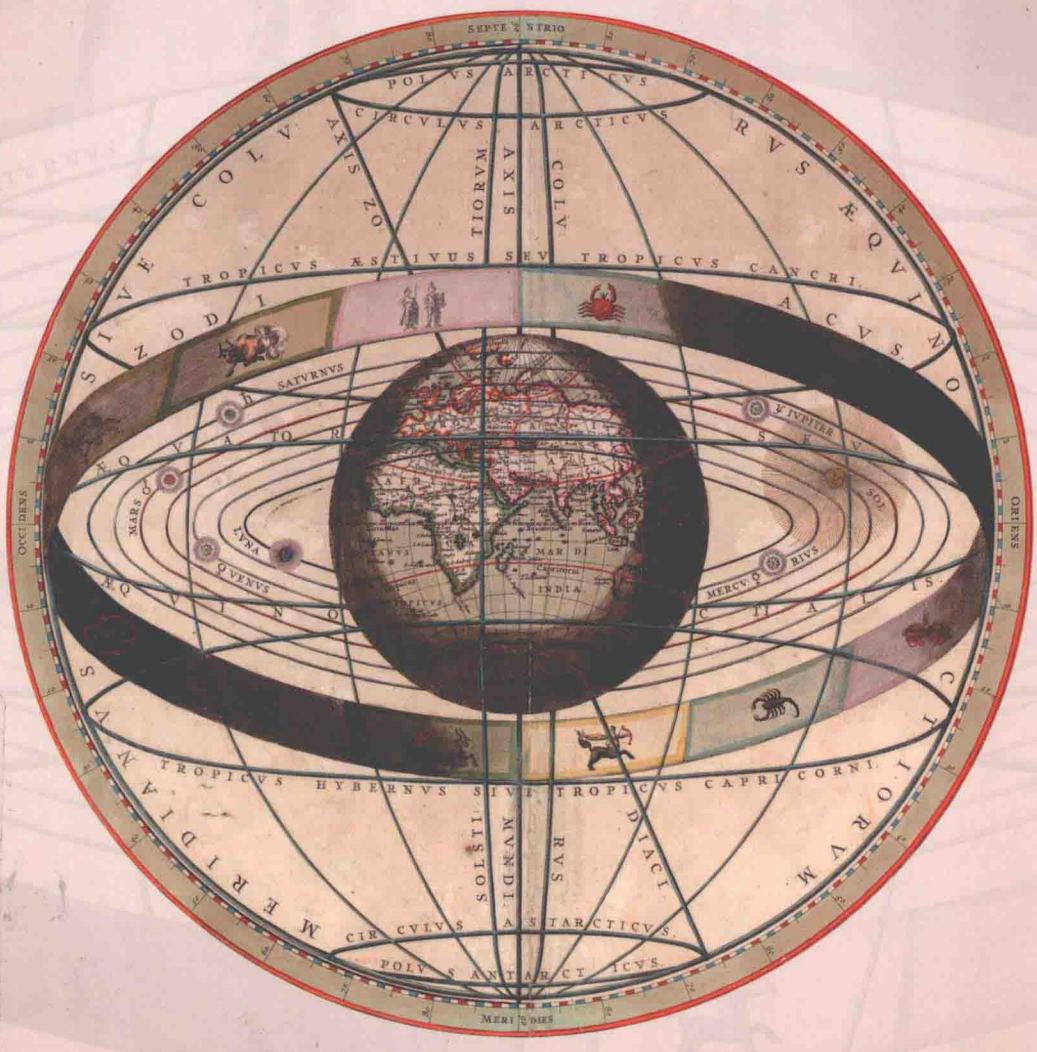
Representing Space *in the* Scientific Revolution



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REPRESENTING SPACE IN THE SCIENTIFIC REVOLUTION

The novel understanding of the physical world that characterized the Scientific Revolution depended on a fundamental shift in the way its protagonists understood and described space. At the beginning of the seventeenth century, spatial phenomena were described in relation to a presupposed central point; by its end, space had become a centerless void in which phenomena could be described only by reference to arbitrary orientations. David Marshall Miller examines both the historical and philosophical aspects of this far-reaching development, including the rejection of the idea of heavenly spheres, the advent of rectilinear inertia, and the theoretical contributions of Copernicus, Gilbert, Kepler, Galileo, Descartes, and Newton. His rich study shows clearly how the centered Aristotelian cosmos became the oriented Newtonian universe, and will be of great interest to students and scholars of the history and philosophy of science.

DAVID MARSHALL MILLER is Assistant Professor of Philosophy at Iowa State University. He has published articles in journals including *Philosophy of Science* and *History of Science*.

For my family

Preface

This book pays homage to Alexandre Koyré, one of the founders of the intellectual history of science, who coined the term "Scientific Revolution," and whose work originally excited my own interest in the field. From its inception, this project has been motivated by a conviction that Koyré gave precisely the wrong answers to exactly the right questions. In particular, I have been fascinated by Koyré's idea, expressed in *From the Closed World to the Infinite Universe*, that changing conceptions of space were an essential catalyst of the Scientific Revolution. I was sure, though, that the story Koyré told about the metaphysics of space could not be correct. At bottom, this is an attempt to follow the trail Koyré blazed to a more satisfactory conclusion. The old questions are still worth asking.

Though it retains relatively little of the text, the ideas expressed in this book originated in my doctoral dissertation, written while I was a student in the History and Philosophy of Science department at the University of Pittsburgh. I am grateful for the guidance and support of my mentors, Peter Machamer and Ted McGuire. Through their eyes, I first discovered the lasting perplexity of the Scientific Revolution. Important inspiration also came from Hasok Chang and the late Ernan McMullin, who demonstrated how history and philosophy could be woven into scholarly material whose value transcends disciplinary bounds. John Norton, John Earman, Jonathan Hodge, Paolo Palmieri, Jonathan Scott, Zvi Biener, Greg Frost-Arnold, Jim Tabery, and Brian Hepburn also served as early interlocutors and made lasting contributions.

In the many years since, this project has had the support of many institutions and individuals, for which I am very thankful. I have worked on this book while affiliated with the University of North Carolina at Chapel Hill and Oxford College of Emory University. I was also a Mellon Postdoctoral Fellow in the Humanities at Yale University, where Matthew Smith, Barbara Sattler, Verity Harte, Michael Della Rocca, Ken Winkler, Tamar Gendler, and Sun-Joo Shin graciously offered comments and

counsel. At Duke University, I enjoyed the wisdom and friendship of Seymour Mauskopf and Andrew Janiak, both of whom provided invaluable comments on the completed manuscript, and without whom this book could never have been completed. In addition, I spent a productive summer at the Max-Planck-Institut für Wissenschaftsgeschichte as part of the Modern Geometry and the Concept of Space working group, led by Vincenzo De Risi, alongside Marius Stan, Delphine Bellis, Valérie Debuiche, and Michael Friedman, all of whom made significant and helpful suggestions, especially for the Descartes chapter. At the same time, I had the pleasure of discussing Galileo with Jochen Büttner, Rivka Feldhay, Alison Laywine, and Daniel Warren.

Along the way, I have benefitted immensely from generous criticism by Tad Schmaltz, Dan Garber, Maarten Van Dyke, Eric Schliesser, Michael McVaugh, Maurice Finocchiaro, Stephan Blatti, Patrick Boner, Adela Deanova, and anonymous referees. Samuel Schindler, Helge Kragh, and the science studies reading group at the University of Aarhus provided useful comments on the Copernicus chapter. Conversations with a multitude of audiences refined my thoughts and improved their expression. For particular points of assistance, I offer additional thanks in the footnotes to the text. I am also indebted to my wonderfully excellent colleagues at Iowa State University, particularly Jonathan Tsou and Patrick Connolly.

With guidance from Owen Gingerich and translation assistance from Nicholas Jardine and Paolo Palmieri, a version of the Kepler chapter was published as "*O Male Factum*: Rectilinearity and Kepler's Discovery of the Ellipse," *Journal for the History of Astronomy* 39 (2008), 43–63. I am grateful to Michael Hoskin and Science Publications Limited for permission to reproduce that material here. Thanks are also due to Hilary Gaskin, Kanimozhi Ramamurthy, and all those working with Cambridge University Press for their extraordinary care in seeing this book through publication.

Finally, I owe the deepest love and appreciation to my family. My parents, grandparents, and brother offered a remarkable and mystified enthusiasm that buoyed me over innumerable obstacles, while my four-legged relations reminded me that naps and walks are what are really important. Above all else, there is Dana LeVine, whose support of me and my obscure toil has long been steadfast. She is a model of dedication, energy, sympathy, and caring. I could never thank her enough.

Note on texts

For quotations from well-known texts, I have provided references to standard translations. In cases where a text is not well known, I have cited both the translation quoted and the original source, in most cases including the latter in a footnote. Where no translation is available for a text, I have provided my own, citing the original and including it in a footnote.

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CHAPTER 1

Introduction: centers and orientations

The historiographical problem

It is something of a commonplace to say that the seventeenth century witnessed a shift from viewing the natural world as fundamentally spherical to viewing the universe as fundamentally rectilinear. This move toward rectilinearity is evident in the emergence of all the hallmarks of "classical" science. The dissolution of the heavenly spheres, the replacement of equilibrium by collision as the model of mechanical interaction, the abandonment of Aristotelian natural place, and the all-important development of rectilinear inertia to supplant natural motion and impetus all display the general trend. Nevertheless, while these developments have been extensively studied individually, the conceptual shift common to all has not been satisfactorily addressed. Though most scholars would immediately recognize and acknowledge the existence and importance of the adoption of a rectilinear framework in the early modern physical sciences, none has satisfactorily detailed how this came to pass.

Many scholarly studies have sought answers to this question in the metaphysical understanding of space during the period.[1] According to these accounts, a rectilinear framework was somehow adopted alongside a shift in the understanding of space considered as a substantial thing. Their focus, therefore, is on the history of debates about space's ontological properties – its infinitude, eternality, vacuity, absoluteness, and so on. However, as I argue more extensively below, this emphasis is misplaced. Abstract speculation about the nature of space was too divorced from the changing explanations of the behavior of bodies that formed the physical core of the Scientific Revolution. The move toward rectilinearity was a change in the understanding

[1] Classic treatments include Jammer (1954), Koyré (1957), Grant (1981). See also Burtt (1954), Butterfield (1957), Dijksterhuis (1961),Toulmin and Goodfield (1961), Koestler (1968), Huggett (1999), Barbour (2001). To be fair, Jammer's treatment of the ancient and medieval periods focuses on the epistemic import of space. In fact, Jammer's work constitutes an appropriate prelude to my own. Nevertheless, his treatment of the early modern period veers toward the metaphysical.

of phenomena *in* space, not the nature of space itself. For example, sometime in the early modern period, authors decided that rectilinear translations were instances of uniform change. This decision was not determined by their views about the plenitude or immobility of space. Rather, it came about in their construction of theoretical knowledge about the behavior of physical objects. What is needed, then, is not another history of spatial ontology, but a history of spatial *epistemology*. This is what I attempt in the following.

In particular, this book will argue that *representation of space* is the appropriate unit by which to analyze the development of rectilinearity in classical science. As will be expressed more precisely below, a representation of space is part of a descriptive framework by which spatial properties and relations are described and explained. Thus, the "something" that changed during the seventeenth century was the prevailing representation of space. The shift that accompanied the emergence of modern science can be described as a move from a centered representation of space to an oriented representation of space. Authors described and explained spatial properties spherically, in relation to centers, at the beginning of the period and rectilinearly, in relation to orientations, at its end.

So baldly stated, this thesis seems blatantly and perniciously anachronistic. It imputes a contemporary notion of my own devising into the work of historical authors, and thus threatens to distort the resulting historical account. I am compelled, therefore, to offer a preliminary defense of the analytical frame I use to approach the history of the Scientific Revolution. The thoroughgoing argument in favor of my approach will be the analysis itself. The coherence and accuracy of the account presented in the rest of this volume will be the justification of my claims and the measure of their success. In the meantime, however, I must show that the authors here examined made use of what I am calling representations of space, such that they are appropriate objects to seek and characterize in historical work, and not mere anachronistic figments. There are two ways I might accomplish this task. The first is to identify pieces of text in which authors explicitly state their representations of space. This path is not available, since explicit expressions of a representation of space are very rare, though not entirely absent, in the work of early modern natural philosophers. This is not surprising. Indeed, it will be argued below that explicit statements regarding representations of space should not be expected of *any* author, since a representation of space comprises commonly held, "ordinary" concepts that seem obvious in most contexts. Hence, authors usually do not need to elaborate a representation of space in order to effect meaningful communication.