PREFACE

This book is a historical-epistemological study of one of the most consequential breakthroughs in the history of celestial mechanics: Robert Hooke's (1635-1703) proposal to "compoun[d] the celestial motions of the planets of a direct motion by the tangent & an attractive motion towards a central body" (Newton, *The Correspondence* II, 297. Henceforth: *Correspondence*). This is the challenge Hooke presented to Isaac Newton (1642-1727) in a short but intense correspondence in the winter of 1679-80, which set Newton on course for his 1687 *Principia*, transforming the very concept of "the planetary heavens" in the process (Herivel, 301: *De Motu*, Version III).

It is difficult to overstate the novelty of *Hooke's Programme*[1]. The celestial motions, it suggested, those proverbial symbols of stability and immutability, were in fact a process of continuous change: a deflection of the planets from original rectilinear paths by "a centrall attractive power" (*Correspondence*, II, 313). There was nothing necessary or essential in the shape of planetary orbits. Already known to be "not circular nor concentricall" (*ibid.*), Hooke claimed that these apparently closed "curve Line[s]" should be understood and calculated as mere effects of rectilinear motions and rectilinear attraction. And as Newton was quick to realize, this also implied that "the planets neither move exactly in ellipse nor revolve twice in the same orbit, so that there are as many orbits to a planet as it has revolutions" (Herivel, 301: *De Motu*, Version III). Far from "being exceedingly well ordered in heaven," as Kepler was still very much certain they were (*New Astronomy*, 115), the planetary trajectories, according to *Hooke's Programme*, represented nothing but a precarious balance between conflicting tendencies.

Culminating in this paragon of abstract celestial mechanics, however, the traces of Hooke's construction of his *Programme* lead through his investigations in such practical, earthly disciplines as microscopy, practical optics and horology. Similarly, the mathematical tools Newton developed to

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[1] *Hooke's Programme* is a modern title, coined, to the best of my knowledge, by S. I. Wawilow in 1951: "Die *Prinzipien* konnte im 17. Jahrhundert niemand ausser Newton schreiben. Aber man kann nicht bestreiten, dass das Program, der Plan der *Prinzipien*, zum erstenmal von Hooke entworfen wurde" (cited by Lohne, 42).

realize *Hooke's Programme* appear no less crafted and goal-oriented than Hooke's lenses and springs. This transgression of the boundaries between the theoretical, experimental and technological realms lends philosophical significance to Hooke's free excursions in and out of the circles occupied by gentlemen-philosophers, university mathematicians, instrument makers, technicians and servants. Tracking these forays thus becomes more than just a survey of the epistemic activities of late seventeenth century English savants. Rather, it presents an opportunity to examine the epistemological categories embodied by Hooke and Newton, and the suspicion that much of these categories is nothing but a reflection of the social divisions, relations and hierarchies that separated Hooke's diverse acquaintances and collaborators. This examination is undertaken in three historical chapters with two philosophical interludes in between.

The book opens with the correspondence between Hooke and Newton in 1679-80. The *Introduction* suggests a reading of the correspondence as one continuous text with two authors. It explores the manner in which communication was established, common grounds for exchange were laid down, and complex working relations were created, relations whose fruitfulness was a product of suspicion and careful positioning no less than of polite collaboration. The *Introduction* then proceeds to question the historiographical and epistemological merit of the common practice among historians of seventeenth century science to juxtapose Hooke, the "mechanic of genius, rather than a scientist" (Hall, "Robert Hooke and Horology," 175) with "the genius of Sir Isaac Newton" (Westman, in Lindberg and Westman, 170).

Chapter 1 is dedicated to Hooke's depiction of planetary trajectories as curved from rectilinear paths into closed orbits due to an external, rectilinear 'power' (Hooke's term). References to Kepler, Descartes and Borelli highlight the surprising originality of this portrayal, which Hooke first introduced in his 1666 *Address* to the Royal Society, further developed in his 1674 *Attempt to Prove the Motion of the Earth*, and brought into fruition in the correspondence with Newton. Two tools used by Hooke in his 1666 *Address* hint at the motivations underlying his reformulation of the question of planetary motions and the means by which he achieved it. The first is a new theoretical term—'inflection'—signifying the gradual curving of a rectilinear trajectory. The other is an experimental design: a conical pendulum mechanically embodying the hypothetical configuration of motions and attractions in order to demonstrate its basic feasibility. The chapter follows these clues to reveal Hooke's techniques and procedures of knowledge production, in which material and theoretical artifacts are closely intertwined.

Chapter 2 focuses on the unique concept of 'power' with its relations to motion that Hooke brings to the correspondence. This chapter offers an interpretation of Hooke's 1674 Cutlerian Lecture *Of Spring*, the locus of his celebrated Spring Law—the single one of Hooke's accomplishments that still carries his name. It explicates the original oscillatory theory of matter that Hooke constructs in this lecture, and analyzes the complex relations between Hooke's Law, the theory in which it is embedded, and Hooke's work on springs—work that sought to develop a spring watch for marine navigation. If the first chapter reveals Hooke's use of theoretical artifacts in the production of material ones, this chapter uncovers his use of material objects for linguistic-theoretical purposes. It demonstrates, among other things, that not only is Hooke's law far from being the paradigm of 'empirical generalization' that it is generally held to be, but its import within Hooke's theoretical apparatus defies the commonly assumed distinctions and relations between the empirical and the theoretical.

Chapter 3 examines *Hooke's Programme* through the difference it made to the work of Isaac Newton. The new knowledge that arose from the correspondence between Hooke and Newton—the *Programme* as it came to function in Newton's 1680s manuscripts on celestial mechanics—is analyzed as a product of both men's skills, tools and techniques. The treatment of planetary motion that characterizes Newton's *Kepler Motion Papers* and *De Motu* is compared to his own early (1660s) formulations of the question, as well as to those of Huygens, and its main novelties are crystallized and traced back to the correspondence. This allows a re-evaluation of Newton's indebtedness to Hooke. The historiography of the relations between the two protagonists has been dominated by the question of the credit Hooke deserved for such notions as universal gravitation and the replacement of centrifugal force with centripetal force, and, primarily, for the discovery of the inverse square law of gravitation. The comparison in this chapter reveals that such questions of credit and priority are badly misleading, not least because none of these concepts constitutes *the* breakthrough enabling the *Principia*. What distinguishes Newton's later work is not the introduction of a new concept or the discovery of a particular universal constant. Rather, it is a new image of the "planetary heavens" coupled with a new task for celestial mechanics: the analysis of the forces produced by given orbits in Newton's (and Huygens') early work is replaced, following his correspondence with Hooke, with a calculation of the parameters of the rectilinear motions and rectilinear attractions by which precariously closed and stable orbits are created.

The three historical chapters attempt to account for the production of each and every facet of *Hooke's Programme*—theoretical or experimental, mathematical no less than technological—through reference to the art and craft of Hooke, Newton and their contemporaries. This goal gives rise to some grave epistemological challenges, which are partially addressed in two short interludes between the chapters. Pretending to be neither a survey of contemporary epistemology, nor a coherent alternative, these discussions critically examine the adequacy of available epistemological categories for the task. The presentation in the first and second chapters of the problem concerning the distinction and relations between theoretical and experimental knowledge is linked by an account of one important attempt to address this tension; Ian Hacking's 1983 *Representing and Intervening*. The second and third chapters highlight the peculiarity of the historiographic categories by which Hooke and Newton are traditionally judged and compared, and are linked to one another by a discussion of Richard Rorty's critique of the epistemology supporting these categories as developed in his 1979 *Philosophy and the Mirror of Nature*.

This book is the product of an attempt to write a history and philosophy of science as though it were a single discipline with a coherent set of norms, issues, rules of conduct and standards of integrity. Some ten or fifteen years ago, this integration seemed just around the corner. The very fact that I had to separate historical chapters from philosophical interludes testifies that it never happened. In this sense, the book may have become old-fashioned even as it was attempting to be avant-garde, which should explain the relative intellectual isolation in which it was written. This makes me all the more grateful to those people and institutions that offered me their generous help during my years of research and writing. The project began as research for a dissertation in the Department of History and Philosophy of Science at the University of Pittsburgh, under the instruction of J. E. McGuire, a scholarly role model and friend, to whom I owe special debt of thanks. Peter Machamer, Friz Ringer, Robert Olby and Bob Brandom were the other members of an encouraging dissertation committee. I had the important benefit of participating in seminars given by other members of the department: John Earman, Bernie Goldstein, Jim Lennox, John Norton and Merrilee Salmon, and of invaluable discussions with my colleague students, especially Jonathan Simon, Michel Janssen and Bill Sutherland. The administrative staff, headed by Rita Levine, always provided a cheerful and supportive environment. The research for *Chapter 3* was conducted in the Max-Planck-Institut für Wissenschaftsgeschichte in Berlin, where I benefited greatly from taking part in a reading group on the history of mechanics led by Wolfgang Lefèvre, Peter Damerow and Jürgen Renn. I am especially grateful to Professor Renn, the Rector of the Institute, who was the one to suggest that I turn my research into a book and submit it for publication with Kluwer. My debt to my friends and colleagues there, Serafina Cuomo, Cristoph Luethy and Sophy Roux, is clear to both them and me. The library staff of the Institute, and especially its head, Urs Schoeplin, was enormously helpful, even after I left the Institute, and I cannot overstate my thanks. I conducted most of the final research, editing and preparation for publication in the particularly pleasant and enlightening atmosphere of the Philosophy Department in Ben-Gurion University of the Negev in Israel, first as a Kreitman postdoctoral fellow and then as a lecturer and Alon fellow. Thanks go to Yehuda Elkana for his enduring support, to Rivka Feldhay, Gideon Freudental, Raz Chen, Shaul Katzir and Hanan Yoran for their attentive ear, to Ruth Freedman, who edited the style and language of the final manuscript, and also to the anonymous Kluwer reader for important comments. A version of *Chapter 1* was published in *Studies in the History and Philosophy of Science* 27.2 (1996), and I am thankful to Elsevier Science Ltd for their permission to use it.