Editor's Introduction

# Galileo in Context: An Engineer-Scientist, Artist, and Courtier at the Origins of Classical Science

> Andrea (in the door): Unhappy is the land that breeds no hero.
> Galileo: No, Andrea. Unhappy is the land that needs a hero.
> (*Life of Galileo*. Bertold Brecht)

The present volume documents recent attempts to explore the science of Galileo Galilei beyond its traditional perception as an isolated pioneering achievement into the intellectual, cultural, and social contexts that made it possible and that shaped it substantially. Three such contexts are singled out as having been of paramount importance for the genesis of Galilean science: the context of the engineer-scientists in which Galileo grew up and which provided his physics with much of its experiential basis; the closely related context of art which provided him not only with a model for his career as a courtier but also with the techniques of visual representation that he employed in his astronomical work; and finally, the context of contemporary power structures (including their ideological component), comprising those of the church as well as those of the courts and of the emerging scientific community. These structures determined not only Galileo's career but also the ways in which scientific information was produced, organized, and communicated in early modern Europe.

Several of the essays build on recent in-depth studies of Galileo's contexts that attempted also to develop new historiographical approaches. They range from an analysis of his relation to the church in terms of power-knowledge structures via a cultural anthropology of science under the conditions of patronage, and an examination of the formative role of representational techniques for scientific thinking, to a study of the knowledge structures common to the thinking of Galileo and his contemporaries and characteristic of "preclassical mechanics." These different perspectives are brought together here to show that, far from excluding each other, they in fact give rise to a surprisingly coherent new picture challenging the entrenched views of Galileo as a hero of science. That such a challenge might actually succeed in affecting the traditional image of Galileo is, however, rather unlikely, given the regularity with which historical research on Galileo tends to fall into oblivion under the spell of the Galileo myth.

Of course, the Galileo myth keeps changing with the changing images of science,

but what has remained is that, for more than three hundred years, his science and life have served as archetypes for the scientific enterprise: he is still widely recognized as the lonely founding hero of modern science who introduced the scientific method and, in defending it, became a victim of the repression of science by the Catholic Church. Yet concurrently, Galileo's science and life have also been an object of ever more extensive scholarly studies. When opening modern textbooks however, be they of physics or of the history of science, not to speak of encyclopedias or popular biographies, there can be little doubt: Galileo, the myth, has remained largely untouched by scholarly insights into his historical situation and role. Conversely, scholarly literature has often failed to dissociate itself from the myth and has hence unquestioningly accepted the paradigmatic role ascribed to Galileo. The specific contexts of Galileo's life and science hence often come into play only as attenuating or reinforcing factors in the development of this paradigmatic role and not as elements that make this development understandable in the first place. By focusing on a model scientist, scholars hoped to attain universally valid insights into the functioning of science and into its conflicts with power, independently of the specificity of the historical situation. Remarkably, this is not only the case for the older literature extolling the virtues of Galileo's experimental method, but also for more recent heterodox discussions in which the trustworthiness of his procedures is severely criticized — but still with the aim of showing the problematic character of scientific reasoning in general. Even the highly specialized recent Galilean scholarship is under the spell of the Galileo myth to the extent that research questions such as the sources of his scientific method, or the crucial experiments by which he supposedly made his decisive discoveries are pursued. Obviously, such questions presuppose that Galileo indeed introduced a novel scientific method guiding his research and that he indeed made crucial discoveries in the sense of later classical physics, issues on which some of the contributions to this volume throw a new light.

A volume on "Galileo in context" must challenge the notion of context as well as the traditional image of Galileo, if it is to undermine the Galileo myth. As long as putting Galileo's science into its historical contexts means only identifying "influences" or "conditions" affecting his actions and thinking and does not mean re-examining the traditional epistemological understanding of the cognitive core of the scientific enterprise, the Galileo myth will continue to haunt scholarship dedicated to early modern science. Instead of studying contexts in order to determine the supposedly decisive factors of Galileo's life and science, it seems more enlightening to take Galileo rather as a probe for exploring a *cultural system of knowledge*, that is, the shared knowledge of the time with its social structures of transmission and dissemination, its material representations, and its cognitive organization. The contexts of Galileo's science would thus no longer have to be interpreted as pointing to competing explanatory frameworks emphasizing for instance either social or cognitive factors of the development of knowledge, but rather as layers of the historical reality from which this cultural system of knowl-

edge would have to be reconstructed. Thus, truly putting Galileo's achievements into their historic contexts requires building up an epistemological framework wherein different contexts, whether referring to the social, material or cognitive dimensions of science are no longer fragmented and played off against each other but rather can be integrated so that the question "which context is relevant and why?" becomes answerable.

The present volume offers clues suggesting that a synthesis of different approaches to the question of the contexts of Galileo's science can actually succeed. The essays in this volume show Galileo not as a singular figure but as representative of the groups of actors who shaped the Scientific Revolution of the early modern period, ranging from engineer-scientists such as Guidobaldo del Monte, via philosophers such as Pierre Gassendi, to artists such as Ludovico Cigoli. This volume not only points to a great variety in the specific problems addressed by these actors, an equally great variety of the approaches taken in coping with them, and of the individual fates of these actors with regard to the success or failure of their contributions. It also suggests that the emergence and dissemination of the new sciences of Galileo's times were shaped by constraints that turn out to be surprisingly similar in spite of their individual variety. In fact, all of these actors were not only bound by similar social structures but also had to confront an array of *shared bodies and images of knowledge*, to use the terminology of Yehuda Elkana. The shared bodies and images of knowledge constituting the intellectual resources of early modern science ranged from the heritage of Aristotelian physics and ancient mechanics to the drawing techniques of contemporary art and engineering. The historical actors exploited these resources in their struggle with the *challenging objects* of the time, whether these were represented by the new technological achievements or by the newly discovered celestial phenomena. Taken together, these constraints and common challenges constitute the boundary conditions of a cultural system of knowledge which has to be reconstructed before one can truly understand individual intellectual trajectories such as that of Galileo as "science in context."

Approaches that focus on Galileo as an archetypical figure of modern science paradoxically lose sight of precisely what one might call "*the Galilean moment*" in the history of science. This Galilean moment may indeed be associated with a subversive power of knowledge, not in the sense of a clash between modern rationality and ancient dogmas, but in the sense of an explosion of technical and scientific knowledge so powerful that it unavoidably became central also to the symbolic politics of the time, deeply ingrained in canonized views of the natural world. It is the great paradox of the Galilean moment that this explosion of knowledge was not initiated by the birth of a new form of rationality but rather by the conflictual, yet productive, encounter of traditional bodies of knowledge such as the practical knowledge of the engineers and the theoretical tradition of the universities. This encounter was, at least in part, triggered by the great practical ventures of the time, from intercontinental navigation to large-scale engineering

projects. It took place within a setting where the advancement of science was regulated by mechanisms to which its intellectual achievements were, taken by themselves, of only limited relevance, being promoted or suppressed within a patronage system. Nevertheless, the impact of the resulting integration of heterogeneous strands of knowledge on the advancement of science was so powerful that it eventually led not only to the revision of traditional conceptual systems, but also to the creation of new social structures for the production and dissemination of scientific knowledge. Hence the role of "the social context" of scientific development would be underestimated were it considered solely as an external framing condition for a specific subculture of society. Instead, the development of scientific knowledge in the early modern era must be understood as an essential part of societal dynamics itself, namely as the self-reflection of an increasingly knowledge-based society.

Around the turn of the last century, there have been remarkable attempts to identify the specificity of Galileo's historical situation, beginning with Antonio Favaro's *Edizione Nazionale* of Galileo's works. By making the early, evidently Aristotelian writings of Galileo as well as his vast correspondence available, insights into Galileo's intellectual debts with regard to his antique and medieval predecessors, as well as to his contemporaries became inescapable. Among the first scholars to draw consequences from such insights, albeit in quite different ways, were Raffaello Caverni and Emil Wohlwill. They seriously confronted the challenge of making sense, not only of Galileo's major works such as the *Dialogue on the Two Great World Systems* and the *Discorsi on Two New Sciences*, but also of the numerous documents — unpublished manuscripts as well as letters — that show Galileo at work as one among many of his contemporaries struggling with the authority of Scholasticism, while still thinking in terms of Aristotelian notions (or polemically defending his inventions against competitors, occasionally maintaining his own priority only with the help of false pretenses). Caverni, in his six-volume *Storia del metodo sperimentale in Italia (History of the Experimental Method in Italy)*, and Wohlwill, in his two-volume biography *Galilei und sein Kampf für die Copernicanische Lehre (Galileo and His Battle for the Copernican System)* as well as in several of his book-length papers, were the first historians to examine Galileo's work also with an eye to his failure to attain crucial conceptual breakthroughs such as a general principle of inertia. Galileo's thinking thus emerged as much closer to that of his predecessors and contemporaries than the Galileo myth would have it, an insight that was also confirmed by the extensive studies of Pierre Duhem, Anneliese Meier, and Eduard Jan Dijksterhuis, in particular in his neglected masterpiece *Val en worp (Fall and Projection)*. It is a singular fact characterizing the present state of Galileo studies that thousands of pages written by authors circa 1900 on Galileo's science had no substantial impact — either on the public perception of Galileo or on the specialized scholarly literature.

The unassailable character of the Galileo myth has many roots, among them the

disciplinary splintering of studies dealing with the development of scientific knowledge. In particular, the analysis of the emergence of early modern science at large, in its nature an undertaking involving epistemological, historical, and sociological dimensions, has been, to a considerable extent, pursued separately from the study of Galilean science in the sense of a highly specialized sub-discipline of the history of science, comprising careful editions, detailed commentaries, and subtle interpretations of historical sources. For example, in the early twentieth century, historians such as Edgar Zilsel and Leonard Olschki drew attention to the context of contemporary engineer-scientists and to their role in the genesis of modern science. Their studies began to shed some light on the structural characteristics of early modern science, emphasizing its dependence on the social and material working conditions of engineer-scientists and, in particular, its roots in the social and cognitive integration of various traditions of knowledge. But these early pioneers succeeded only to a limited degree in linking their questions with a detailed examination of the historical material that was gradually becoming available through editions, commentaries, and specialized studies. As a consequence of the disciplinary separation of philological, historical, philosophical, and other approaches, this material thus remained largely unexploited for answering theoretical questions related to the emergence of early modern science.

Galilean studies in the philosophical tradition often exploited historical sources merely as a quarry from which to pick and choose, instead of systematically confronting their theoretical claims with the wealth of extant sources. In fact, even philosophers who extensively discussed Galileo, as did Natorp, Cassirer, or Husserl, hardly took the results of the historical research on Galileo by Wohlwill and others as a serious challenge to their philosophical views. Cassirer, for instance, claimed that Galileo deduced the principle of inertia in his *Discorsi* and, with only a few words, rejected objections based on Wohlwill's detailed historical research to this interpretation as being philosophically irrelevant and as illuminating "only the historical difficulties" presenting themselves to the achievement of the new insight. Koyré claimed that Galileo's mathematical Platonism was crucial for the success of the new science on motion, denying the relevance and even the existence of experiments on motion performed by Galileo. He effectively ignored the numerous references to experiments in Galileo's published and unpublished writings and concentrated his textual analysis instead on those passages supporting his opinion. The overwhelming richness of sources on Galileo's science may have even appeared as irrelevant to Koyré since his primary aim was not to reconstruct a sequence of historical events. He attempted instead to identify mental attitudes characteristic of the historical actors. This approach was possibly related to that of contemporary students of "collective representations" such as Durkheim or Lévy-Bruhl, as has been recently suggested by Paola Zambelli. In fact, however, the "collective" of Koyré's actual historical studies of Galileo's science remains essentially restricted, not only to a small intellectual elite, as Yehuda Elkana sees it, but actually to a single individual, Galileo himself. Koyré's identification of mental attitudes, such

as his characterization of Galileo as a physical thinker in contrast to that of Descartes as a mathematical thinker, thus fails to achieve the historical contextualization of Galileo's science for which he is often credited.

Given the one-sidedness of Koyré's interpretation and his highly selective treatment of historical sources, it was not difficult for another towering figure of Galileo scholarship in the twentieth century, Stillman Drake, to challenge this interpretation and to identify documents favoring instead his view of Galileo as the first modern experimental physicist. Projecting his own opposition to philosophy on Galileo, Drake saw himself as a pioneer in opening up the study of Galileo as a working scientist, a claim that is justified by his extensive studies of Galileo's manuscripts on mechanics and numerous other contributions. But Drake's publications hardly take into account the substantial earlier research on Galileo's science, both in history and philosophy. Drake's own preconceived opinions, less reflective than those of the philosophers, shaped his historical work all the more strongly, as may be illustrated by occasional misleading quotations, twisted translations, or suitably arranged cut-and-paste editions that can be found alongside the lasting achievements in Drake's work. While his translations and editions considerably widened the scope of the historical documentation available to the English-speaking world, his leading role in Galileo scholarship contributed at the same time to the oblivion of the earlier historical and philosophical research, which seemed to be superseded.

In Galileo scholarship, the opposition between Koyré and Drake has taken on an almost archetypical role in shaping the historical questions, the controversial issues, as well as the literary style of many contributions, even critical ones. Nevertheless, this limitation of the intellectual horizon of Galileo studies has, over the years, gradually been undermined by the research of scholars such as Thomas B. Settle, Pierre Souffrin, and Winifred Wisan, who also saw the necessity of looking back to Favaro, Wohlwill, and Caverni. The widened scope of Galileo scholarship is, in fact, becoming visible in recent work such as that collected in *The Cambridge Companion to Galileo*, edited by Peter Machamer. There still remains, however, a considerable gap between systematic epistemological questions, for instance concerning the role of shared knowledge for the emergence of early modern science, and thorough historical research, identifying such shared knowledge with as much empirical rigor as historians expect from reconstructions of Galileo's individual contributions. Closing this gap will make it necessary to overcome traditional boundaries of specialization by means of new forms of collaboration between scholars and new ways of making historical documents available, in particular by exploiting the potential of the Internet. Meanwhile, it is the aim of the present volume to survey recent approaches to Galileo scholarship that, particularly when taken together, offer perspectives on the potential outcome of such a joint effort, that is, an *historical epistemology* of early modern science.

The essays of the first section, "The Context of the Practitioners: Mechanics and its New Objects," deal with the relationships between practical and theoretical

knowledge in the emergence of classical mechanics. They show that neither the reliance on experiments, nor the continuity of theoretical traditions, nor the social context, taken by themselves, sufficiently account for the eventual success of Galilean science. The studies of the first section rather suggest that *challenging objects* which entered the intellectual horizon of the new engineer-scientists from outside the dominating academic traditions triggered the transformation of scholastic physical concepts towards classical mechanics. The origin of these objects in the accumulated *shared knowledge* of the practitioners and engineers of the time reveals their role as important and irreducible mediatory instances between early modern science and its social and technological context.

The essays of the second section, "The Context of the Artists: Astronomy and its New Representations," deal with another mediatory instance between early modern science and its social and technical contexts, *visual representations*. They also illustrate the extent to which the distinction between the history of science and the history of art is an artificial one when it comes to the early modern period. Artists and engineer-scientists not only shared similar career-patterns in the fragile social environment of patronage but also a common curriculum of learning that equipped them with similar techniques for addressing similar problems, the challenges of design involved in practical tasks such as those of architecture and the challenges of visual representation when confronted with the new experience of the age. The essays of the second section open a wide field of questions, worthy of being followed up in future studies: Which precisely were Galileo's artistic tools and in which tradition do they stand? How did these artistic traditions affect the perception and representation of the objects of his science? What was the function of Galileo's artistic production for his social role and its advancement, so similar to that of contemporary artists? How did Galileo's representations of the moon contribute to the dissemination and acceptance of his scientific results and their intellectual provocation? And more generally: Which role do visual representations play as mediatory instances between observation and theoretical convictions?

The essays of the third section, "The Contexts of Church, Patrons, and Colleagues: New Science and Traditional Power Structures," show how social, material, and cognitive factors act together in shaping the collective processes of the production, dissemination, and transmission of knowledge. By focussing on the dissemination and transmission of Galileo's contributions, the studies of this section provide general insights into the dynamics of the *cultural system of knowledge* constituting early modern science. As the essays of this section indicate, this dynamics is characterized by an economy of credit and disclosure due to the patronage system of early modern science, by the determining role of the Church in the institutionalization of teaching and learning, and by the potential of early modern science to undermine the dominant worldview of the Church. Early modern science results from an integration of disparate contributions, such as the theoretical knowledge of Scholasticism and the practical knowledge of the engineer-scientists, into the emerging framework of classical science.

The essays of this section make it clear to what extent such an *integration of knowledge* and its results are dependent on the historically contingent infrastructure of the shared knowledge of the time.

In order to encourage modern readers to make use of the forgotten treasures of Galileo scholarship from the turn of the last century, the present volume includes as an appendix essays in English translation by Favaro, Caverni, and Wohlwill which form part of a controversy on the origins of Galileo's great achievements in mechanics, traditionally identified with the discovery of the law of free fall and of the parabolic shape of the projectile trajectory. Naturally, the three essays can hardly provide more than a glimpse into the wealth of sources, contexts, and interpretations offered by the three masters of Galileo studies. The essays here published for the first time in English translation are prefaced by biographical introductions placing the pioneering works of Favaro, Caverni, and Wohlwill within the context of the historical scholarship of their period.

The roots of this volume go back to a workshop on new trends in Galileo scholarship, held in January 1996 at the ETH Zurich, and organized by Yehuda Elkana and Helga Nowotny. Without their encouragement this volume would not have been realized. Giuseppe Castagnetti played a crucial role in editing the Appendix. Support which helped to complete this volume was furthermore offered by Jochen Büttner, Peter Damerow, Lorraine Daston, Gideon Freudenthal, Wolfgang Lefèvre, Simone Rieger, Urs Schoepflin, Petra Schröter, Matteo Valleriani and other colleagues from the Max Planck Institute for the History of Science in Berlin.

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