

Galileo and the Others – Background to a Revolution in Astronomy

To mark the anniversary of Galileo's discovery of Jupiter's moons *Sterne und Weltraum* will publish a special issue.

By Jürgen Renn, Jakob Staude and Matteo Valleriani

Four hundred years ago, the first human peered into the night sky with the aid of a telescope. Forty years ago, the first man set foot on a foreign celestial body. From the earliest observations of the regularities of celestial movement to the development of astronomy and space travel, outer space has been part of our empirical world.

The astronomical observations and other scientific achievements of Galileo and his contemporaries contributed to the emergence of a new worldview during the seventeenth century. According to this worldview, the Earth was no longer the center of the universe, but rather orbited the Sun like the other planets. Events on our planet as in the heavens were subject to the same physical laws, and thus it was conceivable that other fixed stars were actually distant suns circled by planets of their own – celestial bodies that might also serve as a home

to other forms of life. A special research project at the Max Planck Institute for the History of Science is exploring the contexts and consequences of this epochal turning point in human history. The German-language magazine, *Sterne und Weltraum*, has chosen the anniversary of Galileo's decision four hundred years ago to turn his telescope to the heavens to highlight the results.

Copernicus succeeded in the mid-sixteenth century in simplifying the increasingly complex spheres model of the cosmos by placing

the Sun, not the Earth, at the center of the universe. Copernicus' scientific revolution was the result of a transformation of the astronomical knowledge that had been passed down to him. The empirical data and computation techniques were fundamentally preserved, whereas the organizational structure of knowledge was altered by the establishment of this new center.

The Copernican system emerged as a challenge to the geocentric worldview embodied in the dogma of the Catholic Church. In this world, man stood on a stationary Earth at the center of the cosmos. On Earth, birth and death, decay and growth were the order of the day. In the heavens, other laws applied, with the stars circling the Earth in eternal movement. This worldview was in accordance with proven physical ideas and experiences, none of which indicated the Earth's movement; on the contrary, they appeared to indicate that exactly this was implausible. Through the Church's assumption of Aristotle's natural philosophy, these two

challenges, the theological and physical, were closely linked. But as long as Copernicus' heliocentric system could be viewed first and foremost as a computation model for astronomical calculations, thus limiting its impact to a specific area of specialized knowledge, the explosive force of the new system remained obscured. This only changed with the invention of the telescope.

Exactly how did the invention of the telescope recast our view of the universe? Nine international historians of science answer this question in the latest issue of *Sterne und Weltraum*. Giorgio Strano and Matthias Schemmel show what astronomical knowledge had been gathered even before the invention of the telescope, drawing attention to the potential that had already existed to change the-then prevailing worldview. Kepler's discovery of the elliptical shape of planetary orbits, published in 1609 (the same year that Galileo pointed his telescope to the heavens) was based on observations that Tycho Brahe had carried out for decades with the naked eye and simple measurement devices. And some of the new phenomena that Galileo noted with his telescope had been suspected much earlier – or in some cases actually observed. Plutarch, for one, had speculated about mountains on the Moon, and the Middle Ages produced several reports about sun spots, as Horst Bredekamp makes clear in his essay. As Sven Dupré shows in his contribution, even the telescope itself had numerous antecedents. The first optical experiments and theories reach back to antiquity, culminating in highly specific reports about optical magnification instruments during the sixteenth century (Fig. 1). It remains an historical mystery, however, why the telescope be-



Fig. 1: For the production of his telescope lenses Galileo drew on the practical knowledge accumulated in the workshops of the spectacle makers. This depiction of such a workshop is taken from: Stradanus, "Nova reperta", 1584. Library of the Max-Planck-Institute for the History of Science.



”Tribuna di Galileo” (Sezione di Zoologica “La Specola” del Museo di Storia Naturale dell’Università degli Studi di Firenze), Photo: Saulo Bambi – Museo di Storia Naturale/Firenze

came such an important means of scientific research only at the beginning of the seventeenth century.

This new scientific knowledge also spread to teaching, even as far as Asia, with Jesuit scholars making decisive contributions. At the same time, a conflict arose between science and the dogmas of the Catholic Church. In 1600, Giordano Bruno was burned at the stake, and in 1633 Galileo was forced to recant his belief in Copernican teachings and placed under house arrest by the Inquisition, offering another example of the intellectual clash that shocked contemporaries. Yet this conflict, as Rivka Feldhay and Elio Nenci discuss, was less the starting point for an early modern scientific revolution, but rather the product of a conflict fomented by the rapid dynamics of this era. Fueled by the accumulation of knowledge, these dynamics were in fact part of a broader social development, one that yielded a new social

stratum of engineer-scientists during Europe’s early modern era. Their task was to conquer major technical challenges of the time, from architecture to shipbuilding to artillery, mobilizing all available knowledge assets toward solutions. To this end, the engineer-scientists drew on knowledge that had been passed down to them from antiquity, as well as artisanal knowledge from their own time. These individuals thus shaped the comprehensive integration of technical knowledge, and in doing so, overcame traditional boundaries, placing the major challenges of their era, such as the determination of the trajectory of a cannon ball or latitude at sea, in direct relation to theoretical knowledge passed down since antiquity (Fig.2). Matteo Valleriani interprets Galileo himself as a typical representative of this group of engineer-scientists, one who, like many of his contemporaries, spoke a new language of science, a language both ground in Aristotelian principles

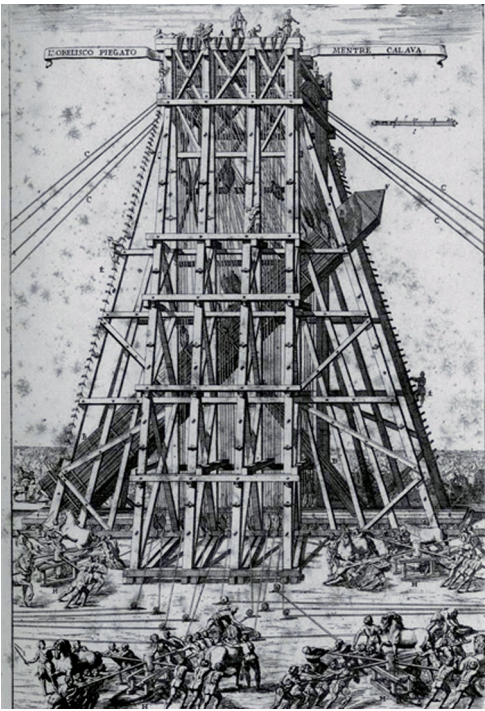


Fig. 2: Throughout Europe large-scale technical projects fostered the development of the engineering sciences and were a motor for the transmission of knowledge. This example shows the erection in 1590 of the Vatican Obelisk by the architect Domenico Fontana on what is today St. Peter's square in Rome. Library of the Max-Planck-Institute for the History of Science.

and containing anti-Aristotelian elements, one that placed in clear view for all to consider the value of practical knowledge. All attempts to explain Galileo's successes by

reference to a particular scientific method, a unique style, strategy, or skill, remain unsatisfactory. As Jürgen Renn concludes, the novelty of the new science did not stem from external sources, such as a new idea or attitude toward nature. Instead, scientific novelty at this time emerged via transformation of knowledge that had been passed down across many centuries, a knowledge structure that, similar to the Copernican system, was the result of yet another reorganization of traditional knowledge. As Jochen Büttner points out, Galileo's physical ideas remained anchored in Aristotelian natural philosophy, and it was from this starting point that classical Newtonian mechanics emerged with its uniform explanation of terrestrial and celestial movements. Without stellar observation, an interest many regarded as esoteric, we would have neither modern physics nor any of its manifold technical applications.

This special issue of *Sterne und Weltraum* will be available on December 1, 2009.

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