Biographical Encyclopedia of Astronomers

Cavalieri, Bonaventura (Francesco)

Born Milan, (Italy), circa 1590-1600

Died Bologna, (Italy), 27 December 1647

Bonaventura Cavalieri was a professor of astronomy at Bologna and one of the great mathematicians of the 17th century, credited for initial steps toward integral calculus. Cavalieri's date of birth and his Christian name (probably Francesco) are uncertain. Bonaventura was his father's name, which Cavalieri adopted in 1615 when he took the minor orders with the Jesuati (not Jesuits). In 1616, Cavalieri was transferred to the monastery in Pisa, where he met Benedetto Castelli, a mathematics lecturer in Pisa and friend of Galileo Galilei, who took him under his wing. Castelli introduced him to geometry and to Euclid, Archimedes, and Apollonius. In 1620, Cavalieri was called to Milan to teach theology at the monastery of San Girolamo, where he continued his mathematical studies. Because of Due to difficulties with his superiors, he applied unsuccessfully for the mathematics chair at Bologna, vacant upon Giovanni Magini's death. Cavalieri asked Galileo for support, having met him earlier in Tuscany. In 1621 he was ordained a deacon by Cardinal Federico Borromeo, who esteemed him and recommended him to Galileo for his extraordinary mathematical abilities.

During his stay in Milan, Cavalieri developed his initial ideas on the theory of indivisibles, and in 1622 he wrote his first observations, sending a copy to Galileo. This marked the beginning of their correspondence. (One hundred and twelve of Cavalieri's letters and two extant letters of Galileo's are in the *Works* of Galileo.)

Between 1623 and 1625, Cavalieri was prior of San Pietro in Lodi, near Milan. Following a short stay in Florence, he then went to Rome, attempting to obtain the chair of mathematics at Pisa and Rome. From 1626 to 1629, Cavalieri was prior of the monastery of San Benedetto in Parma. In the autumn of 1629, he was struck by an illness of the lower limbs, which would afflict him for the rest of his life. This period was nonetheless very profitable: he continued his studies on indivisibles and wrote his most important work, *Geometria indivisibilibus* (not printed until 1635). After turning his attention to astronomy, in 1629 Cavalieri became professor of mathematics at Bologna for a three-year trial period. He was simultaneously appointed prior at the Jesuit convent of Santa Maria della Mascarella in Bologna. He then became very productive, publishing some eleven books

The Bologna curriculum included Euclid's *Elements*, the *Theorica Planetarum*, and Ptolemy's *Almagest*, although each professor was free to teach appropriate subjects. Cavalieri, more mathematician than astronomer, focused on the science of numbers. He was one of the first professors at Bologna to disseminate Copernican theory, although he explained it strictly on a hypothetical level due to censorship. To be reconfirmed, Cavalieri published his *Directorium generale Uranometricum*, the exceptional logarithmic tables he had compiled. The work is divided into three parts, devoted to logarithms, plane trigonometry, and spherical trigonometry, respectively. In addition to noteworthy innovations in terminology, the work includes important demonstrations of John Napier's rules of the spherical triangle and of the theorem of the squaring of each spherical triangle that, attributed to Albert Girard, was later claimed by Joseph Lagrange His other works include *Nuova pratica astrologica*. The word "astrological" in the title should not be misconstrued, however, as Cavalieri was opposed to the practice of astrology. Under the pen name of Silvio Filomantio, he wrote *Trattato sulla Ruota planetaria perpetua e*

dell'uso di quella, which received mixed criticism. Cavalieri was accused of supporting the prejudices of judicial astrology. In reality, his work deals solely with astronomical, geographical, and chronological subjects, although he used astrological terminology.

Following Cavalieri's death, Bonardo Savi (an anagram for Urbano d'Aviso) printed the work *Trattato sulla Sfera*, which Cavalieri had left in manuscript. The treatise examines astronomical observations, in addition to discussions on the circulation of water and various atmospheric phenomena, which are of great interest at least from a historical standpoint

In the field of astronomy, we must cite Cavalieri's *Specchio ustorio overo trattato delle settioni coniche* on the properties of parabolic, hyperbolic, and elliptical mirrors, overlooked by his predecessor Magini in his work on spherical mirrors. The section of this work about their application includes new and original concepts: Spherical mirrors are used not only as optical instruments but also as acoustic ones. Moreover, Cavalieri explicitly states the equivalence of the dioptric system (with lenses) and the catoptric system (with mirrors): "If we combine the concave mirror... with the concave lens [diverging eye lens], we should achieve the effect of the telescope." Several scholars have credited Cavalieri with inventing the reflecting telescope before James Gregory and Isaac Newton

Afflicted with gout, in 1636 Cavalieri went to the health spas of Arcetri, where he spent the summer discussing mathematics with Galileo. Upon his return, his work suffered because of poor health, envy from other friars in his order, and the fact that the academic senate would have preferred that he compile ephemerides and study astronomy. Unwilling to leave Bologna, Cavalieri turned down the chair at Pisa that Galileo offered as well as Cardinal Borromeo's invitation to move to Milan as a doctor of the Biblioteca Ambrosiana.

Against his will, Cavalieri became involved in a dispute with Jesuit mathematician Paul Guldin, who accused him of appropriating several of Johannes Kepler's propositions and groundlessly contradicting some of Galileo's assertions To defend himself, Cavalieri wrote an (unpublished) dialogue, preferring to entrust his defense to his work *Trigonometria plana et sphaerica linearis et logaritmica* and to the third of his *Exercitationes geometricae sex*. The former was a pamphlet for students but was profitably consulted by scientists such as Giovanni Cassini because it summarized problems from his minor works. The latter is an appendix to *Geometria*, extending the method of indivisibles to a large number of applications, also arriving at decidedly original concepts. Examples can be found in the fourth exercitatio, where, in his discussion about squaring parabolas and cubing the bodies of revolution they generate, Cavalieri closely approaches the formula of integral calculus, while in his fifth exercitatio, he applies indivisibles to determine the centers of gravity of bodies with variable density.

Cavalieri extended the applications of geometry to mechanics, physics, and astronomy, propounding them in a series of connected works that, in Cavalieri's own words, were to be read simultaneously*: Compendio delle regole dei triangoli colle loro dimostrazioni; Centuria di vari problemi per dimostrare l'uso e la facilità dei loga-ritmi nella Gnomonica, Astronomia, Geografia ecc.; and Nuova prat-ica astrologica di fare le direttioni secondo la via rationale*, to which an Appendix was added. These works were then unified in a single volume, to which he added his *Annotations*

Cavalieri's chair was renewed in 1646, but he was unable to continue teaching for long. The problem with his legs became so severe that he could no longer walk when he died. Cavalieri was buried in the church of Santa Maria di Mascarella, where he is commemorated with a memorial tablet.

In addition to the recognition that the Senate of Bologna, Cardinal Borromeo, Pope Urban VIII, and Ferdinand II of Tuscany attributed to his work, we must also remember Galileo's profound esteem for the Milanese mathematician, referring to him as the Alter-Archimedes.

Fabrizio Bonoli

Selected References

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