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Galileo's *Trattato della sfera ovvero cosmografia* and Its Sources

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Résumé: Dans cet article nous étudions le *Trattato della sfera* de Galilée, écrit avant 1600. C'est un traité d'astronomie géocentrique qui suit la structure du *Tractatus de sphaera* de Johannes de Sacrobosco. Nous analysons quelques particularités du traité, en le comparant à d'autres travaux astronomiques du XVI^e siècle, et nous discutons ses sources probables. Nous soutenons que l'influence du commentaire de Christoph Clavius sur la *Sphaera* de Sacrobosco ne peut pas être considérée comme son influence unique ou principale. Le traité de Galilée était probablement inspiré par la *Sfera del mondo* de Piccolomini, un travail qui anticipait plusieurs particularités du *Trattato della sfera*. Cette influence est établie par de nombreuses annotations de Galilée trouvées dans un exemplaire du livre de Piccolomini.

Abstract: This paper studies Galileo Galilei's *Trattato della sfera ovvero cosmografia*, which was written before 1600. It is a geocentric astronomical treatise that follows the main structure of Johannes de Sacrobosco's *Tractatus de sphaera*. This paper analyzes some peculiarities of Galileo's treatise, comparing it to several other vernacular astronomical works of the sixteenth century and discussing its likely sources. Contrary to previous claims, we argue that Christoph Clavius' commentary on Sacrobosco's *Sphaera* cannot be regarded as its only or main influence. A likely inspiration for Galileo's treatise is Alessandro Piccolomini's *Sfera del mondo*, a work that anticipated several specific features of the *Trattato della sfera*. This influence is corroborated by Galileo's copious marginal notes found in a copy of Piccolomini's book.

1 Introduction

One of the earliest works attributed to Galileo is called *Trattato della sfera ovvero cosmografia* [Treatise on the Sphere, or Cosmography]. Its date of composition is unknown (probably before 1600) and it was published posthumously by the priest Urbano d'Aviso [Galilei 1656]. It is a short and elementary geocentric astronomical treatise. Its content and structure generally follow Johannes de Sacrobosco's medieval *Tractatus de sphaera*. A first look at the contents and style of the *Trattato della sfera ovvero cosmografia* (hereinafter called *Trattato* in brief) provides no internal evidence that it was written by Galileo. It includes no reference to Copernicus or his ideas; it accepts and defends the main geocentric astronomical ideas : that the Earth does not move in any way, that it is at the center of the universe, and that the Sun, the Moon, the planets and the stars move around it. Also, it contains no recent information that became available during the sixteenth century, such as new evaluations of the size of the Earth, the knowledge of stars visible from the Southern hemisphere, or the existence of people living in the tropical zone.

Due to its contents, it is understandable that after its publication the *Trattato* did not attract much attention, and up to the nineteenth century, there were strong doubts concerning its authenticity. Of course, it provides no information concerning Galileo's later ideas; however, it is an important source for studying his early acquaintance with the astronomy of his time.

2 Comparison between the *Trattato della sfera* and Sacrobosco's *Tractatus*

Most of the treatises belonging to the tradition of Sacrobosco's *Tractatus de sphaera* (or *Sphaera*, in short) contained the whole text of the medieval book, adding explanations, images, and new information. The original text was usually printed in a different (larger) typeface so that the readers would be able to identify it.

The *Trattato* cannot be regarded as a summary of Sacrobosco's work, as claimed by Wallace [Wallace 1977, 255]. The medieval *Sphaera* was a short work (about 9,000 words). The *Trattato della sfera* has nearly 16,000 words. For its size, it could comprise the whole content of Sacrobosco's work, as well as substantial explanations and additions. However, its author chose a different approach. It does not contain a translation of the *Sphaera*, and not even cites Sacrobosco's name.

Sacrobosco's work contains a preamble and four chapters. The *Trattato* begins with a long methodological introduction (with no correspondence in the *Sphaera*) followed by 24 small chapters. Generally, the chapters of the *Trattato* follow the order of the content of Sacrobosco's work. There are,

however, important omissions and additions. At the end of the first chapter, the *Sphæra* describes the ancient measurements of the size of the Earth; this subject is lacking in the *Trattato*. Most of the content of the second chapter of Sacrobosco's book does appear in the *Trattato*, but in a different sequence; and it omits the final part of chapter two, about the five terrestrial zones. The third chapter of the *Sphæra* explains the several types of astronomical risings and settings; the *Trattato* omits this subject altogether. The rest of the third chapter is largely followed by the *Trattato*, but it adds a more detailed elucidation of latitude and longitude and describes 22 geographical climes, instead of the seven classical ones. The beginning of the fourth chapter of Sacrobosco's work explains the motions of the Sun and planets; the *Trattato* omits several parts of this content. The *Trattato* contains a description of the phases of the Moon and its visibility—subjects that do not appear in the *Sphæra*, although they are discussed in Sacrobosco's *De anni ratione* [Sacrobosco 1573, 211–214]. The final part of Sacrobosco's work expounds the miraculous eclipse of the Sun during Christ's passion; the *Trattato* does not refer to this miracle but includes a discussion of the motion of the 8th sphere and its trepidation that is lacking in the *Sphæra*. Of course, there are several other differences between the contents of these two works.

The editions and commentaries of the *Sphæra* frequently contained several illustrations. The *Trattato* contained only one single figure [Galilei 1656, 24]. Another curious difference is the complete lack of classical literary citations in the *Trattato*, whereas Sacrobosco's book contained several citations of Virgil, Lucan, and Ovid [Martins 2003].

The overall tone used in the *Trattato* is very similar to Sacrobosco's approach. It simply exposes accepted knowledge; there is no polemical character in any part of the book, in strong contrast with Galileo's later famous works. Notice that some former authors, such as Francesco Barozzi and Francesco Maurolico, had maintained a polemical attitude in their astronomical writings [Barozzi 1585], [Maurolico 1543].

3 Language and aim of the *Trattato della sfera*

Another relevant difference between the two works was their languages. Since the *Tractatus de sphæra* was used as a textbook in European universities, most of its versions were written in Latin. All of the 30 editions published during the fifteenth century, for instance, were in that language.¹ Among the 92 renderings of the *Sphæra* published between 1501 and 1550, we find 12 that

1. A survey of editions and commentaries of the *Sphæra*, produced by one of the authors of this paper (Martins) is available at <<http://www.ghtc.usp.br/server/Sacrobosco/Sacrobosco-ed.htm>>.

were not in Latin. The Portuguese and Spanish versions were produced for the use of pilots and other people involved in navigation; others were created for the general public, who was not familiar with Latin.

This raises a question concerning the aim and the target readers of the *Trattato ovvero cosmografia*. Galileo's teaching subjects at the universities of Pisa and Padua included Sacrobosco's *Sphæra* and the use of Latin in the lectures was obligatory [Favaro 1888, vol. 1, 177]. One of the reasons was that many of the students attending those universities came from other countries and the only *lingua franca* available at that time was Latin. Galileo must have used some Latin version of the *Sphæra* in his public teaching activities, and it would have been useless to prepare an Italian textbook for those students.

Stillman Drake and William Shea conjectured that the *Trattato* was composed for private teaching in 1586-1587 after Galileo left his medicine studies and before he became a professor at Pisa [Drake 1978, 12], [Shea 1990, 51]. However, there is no evidence that he knew or taught astronomy during this period [Favaro 1888, vol. 1, 15]. Also, Drake's claim that "it is safe to assume that Galileo's first-year lectures on astronomy were based on his *Treatise on the sphere*" [Drake 1978, 19] is groundless.

Besides his official duties at the universities, Galileo delivered private classes on several subjects, as a way to improve his financial income. It is certain that he taught astronomy to some students in the early years of the seventeenth century—at the time when the extant manuscript copies of the *Trattato* were produced. It is unlikely, however, that he wrote a textbook for those private lessons. Firstly, many of his students were foreigners. According to extant records, in the period 1601-1607, about 10 private students studied the sphere under Galileo. One of them was British, two were Hungarian and seven were Polish [Favaro 1888, vol. 1, 186-191]. It is doubtful whether they would have appreciated a textbook in Italian. Secondly, Galileo could deliver private classes on astronomy without the inconveniency of writing a textbook for his students: he could use any of numerous available treatises—both in Latin and in Italian.

Composing a new textbook would be understandable if Galileo intended to impart new knowledge, not available in the usual treatises. The *Trattato*, however, could not fulfill this purpose, as all its content could be found in works published one century earlier. It did not include updated information about the size of the Earth, or the stars visible from the Southern hemisphere, or the existence of people living in the Torrid Zone, for instance. It did not address the practical navigational use of astronomy that was very important during the sixteenth century, or the use of new astronomical instruments. Neither did it discuss recent astronomical theories (such as those of Copernicus and Tycho Brahe) or fresh observational findings (such as comets and Tycho's *nova*).

Perhaps Galileo did not compile the *Trattato* for his students. It might be just a set of notes he wrote for himself, when he was learning the traditional astronomy he was going to teach in Pisa. William Wallace conjectured that it

was composed towards the end of 1590, when he wrote to his father requesting his copy of the *Sfera* [Wallace 1998, 35].² Maybe he used these annotations as guidelines for his classes, later; and he could have lent the manuscript to some students who wanted to copy it.

4 Suggested sources of the *Trattato della sfera*

Some authors have claimed that the main source of the *Trattato* was the famous commentary on Sacrobosco's *Sphaera* written by Christoph Clavius [Wallace 1977, 255, 257], [Wallace 1984, 257], [Lattis 1994, 5]. In the late sixteenth and early seventeenth centuries, Clavius' bulky book (about 500 pages and 170,000 words) was one of the most respected and widely used astronomical textbooks. After its first edition in 1570, it underwent successive improvements and was printed in 1575, 1581, 1585, 1591, 1593, 1594, 1596, 1601, 1602 (twice), 1603, 1606, 1607 (three times), 1608, 1611 and 1618.

Of course, most of the contents of the *Trattato* can be found in Clavius' book, or in some other large commentary on the sphere. Any generic textual parallel between the two works, such as the one published by Wallace is pointless [Wallace 1977, 258]. For deciding whether a specific work was the main source of the *Trattato* it is necessary to analyze some of its unusual features.

William Wallace and Alistair Crombie have noticed that part of Galileo's early manuscript on Aristotle's *De Caelo* (MS 46), might have been copied from Clavius' commentary on the *Sphaera* [Wallace 1977, 258], [Wallace 1990, 28], [Crombie 1996, 181], and this part is also similar to a section of the *Trattato*. They claimed that the methodological introduction of the *Trattato* was based on Clavius' book [Crombie 1996, 178]. However, in his later publications Wallace suggested that Galileo could have only indirect acquaintance with Clavius' work, through Mutius de Angelis [Wallace 1990, 36]. Stillman Drake, on the other hand, concluded that this introduction was added to the work at a later time (around 1602) and that Galileo's source for that part was Ptolemy's *Almagest* [Drake 1978, 52–53]. It might also have been derived from Caspar Peucer, a book owned by Galileo [Peucer 1573, 1–8].

One peculiarity of the *Trattato* is the inclusion of 22 geographical climes, supplying a table with their data. The descriptions contained in the table are in Latin, not in Italian, suggesting that it was copied from a Latin book. The declination of the ecliptic used for the computation was $23^{\circ} 29'$, a figure that was not very common during the sixteenth century. An almost identical

2. In november 1590 Galileo asked his father Vincenzio Galilei to send to him a few books, including a *Sfera* (notice that he did not call it "Sphaera") [Galilei 1890-1909, vol. 10, 44–45].

table can be found in Clavius' treatise [Clavius 1585, 429–430]. Hence, William Wallace concluded that it was copied from that book [Wallace 1977, 258], thus establishing a strong link between the *Trattato* and the famous commentary. However, this evidence is not conclusive, as we have already shown [Martins 2010].

In all editions of Clavius' commentary on Sacrobosco, beginning with the first one (1570), we do find a table closely similar to the one reproduced in the *Trattato*. All descriptions are in Latin; the declination of the ecliptic was also $23^{\circ} 29'$; and the numbers are almost identical to those reproduced by Galileo. However, there are a few numerical differences. Notice that Clavius' table is reproduced without any numerical change in the several editions of his book—we have compared the editions of Rome (1570, 1581, 1585, 1606); Venice (1591); Lyon (1593, 1594, 1602, 1607), and they are exactly equal. Three of the numbers that appeared in the *Trattato* are different from those of Clavius. These might be simply copying mistakes, but they could be due to his using a different source. Two of the three differences between Galileo's and Clavius' numbers also appear in the table published by Francesco Pifféri—and that cannot be ascribed to a mere coincidence [Pifféri 1604, 348–349]. It is significant that Pifféri was a mathematics professor at the University of Padua before Galileo and that the manuscript of his book could have been available several years before its publication, in 1604.

Besides that, the table published by Clavius was not original. An identical one was printed by Caspar Peucer [Peucer 1569, 268–269], one year before the first edition of Clavius' book. Other published books might also have tables very similar to those of Peucer and Clavius. Therefore, the description of the 22 geographical climes and the corresponding table appearing in the *Trattato* could have been copied from another work and they do not establish a strong connection with Clavius' book.

Another particularity of the *Trattato* is its description of the phases of the Moon and the condition of its visibility. Although these are elementary astronomical topics that could have been introduced by Sacrobosco in his *Sphæra*, he did not include them in that work, and Clavius' commentary also does not contain this subject. Therefore, his book could not be the source from which the *Trattato* drew its description of the phases and visibility of the Moon.

Analyzing further details of the *Trattato* we find several other relevant differences between its content and Clavius' work—for instance, some of the specific arguments concerning the immobility of the Earth [Martins & Cardoso 2008]. We may certainly reject the claim that the *Trattato* was a summary of Clavius' book. The general style of the *Trattato* and the very language that was chosen for its composition also suggest that its main source should be sought elsewhere.

5 Sixteenth-century Italian astronomical works

Taking into account its language, the *Trattato della sfera ovvero cosmografia* might have been inspired by some previous vernacular publication. The Italian versions of Sacrobosco's *Tractatus de sphaera* that were published before 1600 were those of Mauro Mattei, Antonio Brucioli, Piervincenzo Danti de' Rinaldi, and Francesco Giuntini. We have examined all of them, and their description will be presented in a forthcoming paper. None has many similarities to the *Trattato della sfera*.

During the sixteenth century, there appeared several astronomical books inspired by Sacrobosco's work but that did not follow it in a strict way. Most of them were in Latin, but there were also vernacular ones. The most famous one was Alessandro Piccolomini's *De la sfera del mondo*, first issued in 1540. This work was published again in 1548, 1550, 1552, 1553, 1554, 1558, 1559, 1561, 1564, 1566, 1573, 1579, 1584, 1595. It was translated into French and printed in 1550, 1608 and 1619; and a Latin version appeared in 1568.

The analysis of Piccolomini's work is particularly relevant for us because, according to Domenico Berti, Galileo wrote numerous annotations in a copy of Piccolomini's book on the sphere [Berti 1876, 100]. Antonio Favaro reported that Galileo had a copy of the 1572 edition of *De la sfera del mondo*, remarking that this was probably the copy that belonged to the library of Meucci [Favaro 1886, 251].³

Alessandro Piccolomini (1508-1578) was a famous humanist of the sixteenth century, born in Siena [Fabiani 1759]. He wrote poetry, plays, and books on philosophy, astronomy, and other subjects. He became a priest and later was nominated bishop of Patras (Greece), although he never visited that country. He belonged to a group of writers who defended the replacement of Latin by Italian (or, more exactly, the Tuscan dialect) as a scholarly language and he was one of the main writers who contributed to the early development of a vernacular scientific prose [Suter 1969, 210]. He lived for four years in Padua, where he attended the university. During this period he developed a strong interest in astronomy and published his famous treatise *De la sfera del mondo*, that was accompanied by his treatise *Delle stelle fisse*, the first celestial atlas presenting all the Ptolemaic constellations in their real configurations, with the indication of the magnitude of each star. The first edition was dedicated to a lady, Laudomia Forteguerri de Colombini. One of Piccolomini's purposes, in his vernacular works, was to make philosophy, poetry, and astronomy available to everyone (including women) who did not know Latin and who had no access to university courses.

Piccolomini did not regard the classics as sacred writings. He thought that the ideas contained in the old books were more important than their

3. There is no edition of 1572. Favaro was probably referring to the 1573 issue.

original language and for that reason, instead of producing rigorous and literal translations, he preferred to create vernacular paraphrases of Aristotle's *Rhetoric* and *Physics*, for instance. For the same motive, he produced his own vernacular books inspired by Sacrobosco's *Tractatus de sphaera* and by Peurbach's *Theorica planetarum*, rather than translating them to Italian.

The first edition of Piccolomini's *Sfera del mondo* had four parts or books. He kept improving it in the following editions, adding new topics and expanding his explanations. In 1564, he published his final revised and enlarged version in six books. It contained 252 pages and over 100,000 words—that is, it was more than ten times larger than Sacrobosco's *Sphaera*.

Alistair Crombie has already remarked that Galileo's style is somehow similar to Piccolomini's, from whom he borrowed some relevant phrases such as “sensate esperienze e certe dimostrazioni” [Crombie 1996, 236–237].

Several characteristics of Piccolomini's work have counterparts in the *Trattato*. First of all, the use of Italian as a language for exposing astronomical knowledge. Secondly, the absence of a rigid correspondence between Piccolomini's composition and Sacrobosco's *Sphaera*. Thirdly, a preoccupation with epistemological and methodological issues. Fourth, the inclusion of the phases of the Moon among its topics, adjacent to the explanation of the eclipses. Both treatises lack the discussion of the miraculous eclipse at the time of Christ's passion. Another curious similarity is the deficiency of citations of the classic poets in the *Sfera del mondo*. Perhaps Piccolomini dropped out most of the quotes that appeared in Sacrobosco's work because of his campaign for Italian (not Latin) as the preferred language.

6 Galileo's annotations in Piccolomini's *Sfera*

In 1886, when Antonio Favaro wrote his work on Galileo's library, he was not sure about the location of the copy of Piccolomini's book containing Galileo's annotations, although he thought that it might belong to the Meucci library. He wrote to Ferdinando Meucci, on January 6th 1890, asking him if he had that work or if he knew who owned it. Meucci answered to Favaro on the following day, telling him that he did have the book.⁴ We have obtained no information about further contacts between Favaro and Meucci concerning this copy of Piccolomini's *Sfera del mondo*.

4. Museo Galileo. Carteggio Meucci I : Carteggio cronologico. 1865-1893. Lettere (1890) I, 1890, #3. We are grateful to Mrs. Alessandra Lenzi, librarian of the Museo Galileo, for providing copies of those two letters (private communication, November 14, 2015).

It is known that Favaro asked Ferdinando Meucci to bequeath some of his books to the National Library of Florence.⁵ It is also known that Meucci had a copy of Nicolò Tartaglia's *La Nova Scientia* with marginal notes by Galileo [Favaro 1886, 268], and that this copy now belongs to the library of the Museo Galileo (shelfmark MED 0976/01).⁶ A heavily annotated copy of the 1573 edition of Piccolomini's *De la sfera del mondo* now belongs to the library of the Museo Galileo (shelfmark MED 0719). This specific item was displayed at the 1929 *Prima esposizione nazionale di storia della scienza*, in Florence (registration number 6952). Although the staff of the Museo Galileo was not aware that this item was the one containing Galileo's notes described by Favaro,⁷ it is fairly probable that it was. One important evidence is the comparison between the leather book covers of MED 0976/ 01 (Tartaglia's book) and MED 0719 (Piccolomini's book). The design of both book covers, in blind stamping, is identical, although they were printed by different publishers. This shows that both belonged to the same library. They also have identical stamps at the title page : one from the Laboratorio di Fisica in Arcetri; the other one from the Museo degli Strumenti Antichi di Astronomia e di Fisica, R. Istituto di Studi Superiori, Firenze, with the handwritten number 31 in the case of Piccolomini's book, and number 32 for Tartaglia's book. Since Tartaglia's book came to the Museo Galileo through Meucci's library, it is highly probable that Piccolomini's book had the same origin.

Favaro suggested that the marginal notes of this copy of Piccolomini's work could have been made by Galileo, but at that time he had not been able to examine its handwriting. Following our contact with the library of the Museo Galileo, Dr Patrizia Ruffo inspected that book and concluded that the annotations might indeed have been made by Galileo.⁸

A detailed analysis by one of us (Walmir Cardoso) has shown that the calligraphy of the marginal notes found in the 1573 copy of *De la sfera del mondo* belonging to the library of the Museo Galileo displays striking similarities and no conspicuous differences when compared to several samples

5. See, for instance, Favaro's letter to Meucci, March 29, 1890. Museo Galileo. Carteggio Meucci I : Carteggio cronologico. 1865-1893. Lettere (1890) I, 1890, #14.

6. We are grateful to Mrs. Alessandra Lenzi for calling our attention to this book (private communication, November 10, 2015).

7. Mrs. Alessandra Lenzi, librarian of the Museo Galileo ; private communication, November 10, 2015.

8. "La dott.ssa Ruffo ha fatto una prima analisi sulla calligrafia delle postille del nostro MED 0719 e secondo lei potrebbero in effetti essere autografe di Galileo" (Mrs. Alessandra Lenzi, private communication, November 14, 2015). We have been informed that Ilaria Poggi and Patrizia Ruffo plan to transcribe those annotations and to publish them in a future update of the National Edition of the works of Galileo; and that Patrizia Ruffo and Michele Camerota began a comparison between those annotations and the *Trattato della sfera* (Mrs. Alessandra Lenzi, private communication, November 28, 2015). We have no further information about their work, which was prompted by our interaction with the librarian of the Museo Galileo.

of Galileo's handwriting (letters, manuscripts, and marginal annotations) around 1590. A small part of the available evidence is presented here.⁹

Galileo owned and made annotations in a 1570 copy of Piccolomini's *De le stelle fisse* [Favaro 1886, 251–252]. This item belonged to the National Library of Florence and can now be found in the Museo Galileo (shelfmark Rari 111/02). Let us compare some of those marginal notes to the ones found in the 1573 copy of *De la sfera del mondo*.

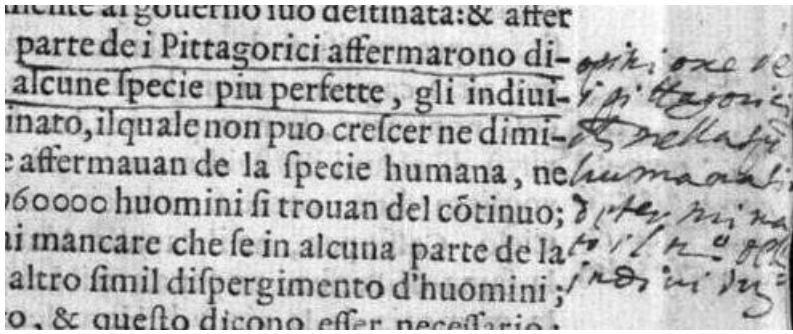


FIGURE 1. Detail of Galileo's annotation at fol. 2r, *De le stelle fisse* [Piccolomini 1570]

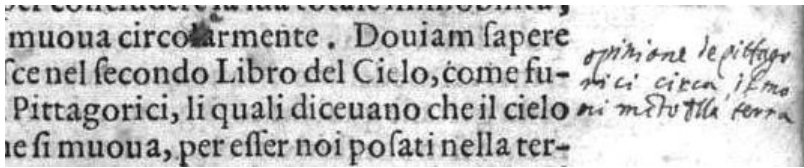


FIGURE 2. Detail of annotation at p. 51, *Sfera del mondo* [Piccolomini 1573]

It is possible to notice the strong similarity between Galileo's authentic calligraphy¹⁰ in Fig. 1 ("opinione de i pittagorici") and the notes on the *Sfera del mondo*, Fig. 2 ("opinione de pittagorici") and Fig. 3 ("ragione de pitagorici").

Galileo's notes to the preface of *De le stelle fisse* present three times the word "opinione" (Figs. 1, 4, 5). In all of them, the word is broken twice, opi-ni-one, and the letter "n" after the break has a characteristic drawing. We

9. All images reproduced here are details of page scans available at the website of the Museo Galileo, *De le stelle fisse*, 1570 : <http://bib-dig.museogalileo.it/Teca/Viewer?an=323989>; *La sfera del mondo*, 1573 : <http://bib-dig.museogalileo.it/Teca/Viewer?an=300237>.

10. We have used the marginal annotations to the preface of the 1570 copy of Piccolomini's *De le stelle fisse* (fols. 2r, 2v), because Antonio Favaro explicitly recognized them as authentic [Favaro 1886, 251–252].

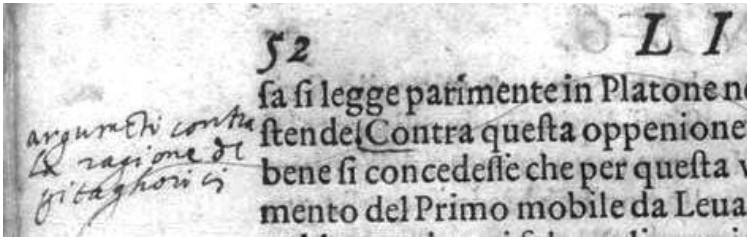


FIGURE 3. Detail of annotation at p. 52, *Sfera del mondo* [Piccolomini 1573]

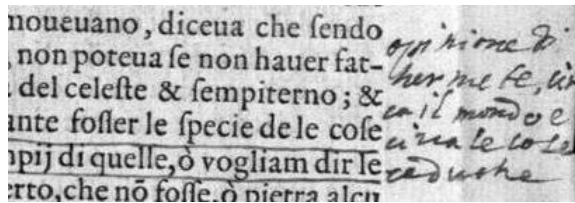


FIGURE 4. Another detail of Galileo's annotation at fol. 2r, *De le stelle fisse* [Piccolomini 1570]

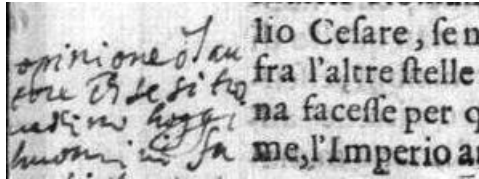


FIGURE 5. Detail of Galileo's annotation at fol. 2v, *De le stelle fisse* [Piccolomini 1570]

find the same characteristics in the marginal notes on pages 51 and 74 of the *Sfera del mondo* (Figs. 2 and 6). Other significant features are Galileo's way of writing "che", "del", and letters "q", "d" and "z".

These and other traits establish such a strong similarity between Galileo's authentic calligraphy of *De le stelle fisse* and the handwriting of the marginal notes at *Sfera del mondo* that they leave no doubt that the later ones were also written by Galileo, probably around the same time.

The comparison with other autograph writings by Galileo, of the period from 1588 to 1597, strongly suggests that he wrote the marginal notes to Piccolomini's *Sfera del mondo* around 1590—that is, about the same time when he requested his father to send him his copy of the *Sfera*. Additional evidence will be published by us in a forthcoming paper.

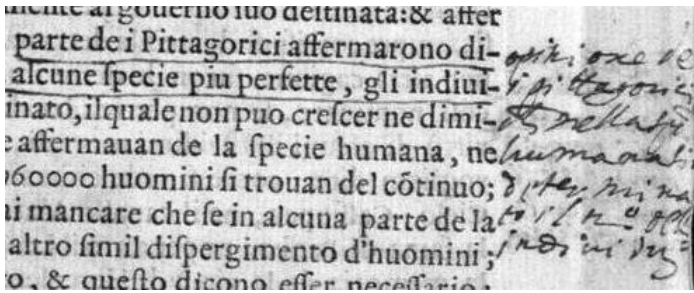


FIGURE 6. Detail of annotation at p. 74, *Sfera del mondo* [Piccolomini 1573]

7 The influence of Piccolomini's *Sfera* on Galileo

Galileo's marginal annotations to Piccolomini's *Sfera del mondo* do not contain any discussion, criticism, or comparison with other works, nor any original matter. For the most part, Galileo underlined or otherwise marked parts of the book that seemed relevant to him, and wrote at the margins some words or sentences that replicate information contained in the printed text itself. This characteristic way of making notes suggests that, at that time, Galileo was just beginning to learn the foundations of astronomy and that Piccolomini's work was one of the first (or the very first) astronomical treatises he ever studied. Therefore, the marginal remarks can show which specific topics and ideas called the attention of the young Galileo.

The only marginal note found in the first book of Piccolomini's treatise appears at page 23 (chapter 9), where the author discussed the circles on a sphere and states that two maximum circles cannot be parallel. There are no other annotations in the first book, most of which contained geometrical prerequisites to the study of astronomy. Galileo had studied Euclid under Ricci, before 1590. It seems likely that he thought that the first book of the *Sfera del mondo* did not contain anything new for him. However, chapter 9 did contain an important description of the sphere, its diameter, hemisphere, as well as the axis and poles of a rotating sphere, corresponding to the very beginning of Sacrobosco's *Sphaera*. This elucidation is noticeably absent in the beginning of the *Trattato*, although it is seldom missing in any other elementary astronomical treatise of that time.

Galileo's first annotation in the second book is found at page 44 (chapter 7), which discusses the position of the Earth in the universe. Piccolomini's original presentation of the proofs for the central position of the Earth is different from Sacrobosco's. They were already contained in the first edition of his work (1540) and later appeared in Clavius and Giuntini's treatises. The *Trattato*

also presented a condensed version of those arguments [Galilei 1891, 220]. At page 47 we find an annotation of Galileo stressing another argument for the central position of the Earth : if it were not in the middle of the universe, the eclipses of the Moon would not occur when the Sun and the Moon are in diametrically opposite directions. This was not a new contention since Piccolomini himself ascribed it to Ptolemy and Averroes ; but it was a rather unusual one and it was reproduced in the *Trattato* [Galilei 1891, 221].

Chapters 8, 9 and 10 of the second book are particularly noteworthy [Piccolomini 1573, 48–55]. They present proofs for the immobility of the Earth—a subject that would later become the center of Galileo's interests. There are altogether fourteen marginal notes on these pages, disclosing the strong appeal of this subject for young Galileo. Among the several arguments, Piccolomini discussed the vertical motion of a stone, comparing it to what supposedly occurs when the person throwing the rock is moving in a ship [Piccolomini 1573, 52]. The ship argument was rather uncommon and it was not reproduced by Clavius. It was annotated by Galileo (“very beautiful reason to prove that the Earth does not move circularly”) and appears in the *Trattato* [Galilei 1891, 224].

There are many other peculiar topics in Piccolomini's work that called the attention of Galileo, as shown by his marginal notes. Most of them have a correspondence in the text of the *Trattato*, as we will disclose in a forthcoming paper. This fact suggests that Galileo was strongly influenced by Piccolomini's *Sfera del mondo* and that it was a major source of the content of the *Trattato*. Of course, many of those points also appear in other astronomical treatises of that time—such as Clavius' book. However, there is no known copy of Clavius' work with annotations by Galileo. Hence, there is no direct evidence that Clavius' commentary on Sacrobosco was read by Galileo and influenced him before the time when he wrote the *Trattato della sfera*.

8 Other sources of the *Trattato della sfera*

Although the influence of Piccolomini's *Sfera del mondo* upon the composition of the *Trattato* might have been very strong, it certainly could not be the only source used by Galileo. Indeed, there are some features of the *Trattato* that did not appear in Piccolomini's work. The very title *Trattato della sfera ovvero cosmografia* was extraordinary and implied an equivalence between astronomy and cosmography that was not acceptable to most authors of that time—including Piccolomini. Galileo might have been influenced by Oronce Finé's *De mundi sphaera, sive cosmographia* or by Francesco Barozzi's *Cosmographia*, a commented version of Sacrobosco's *Tractatus de sphaera*. Barozzi's *Cosmographia* is especially relevant since Galileo had a copy of this book [Favaro 1886, 260], and some parts of the *Trattato* may have been inspired by this work [Martins & Cardoso 2008].

The methodological discussion at the beginning of Galileo's work is different from Sacrobosco's first chapter, but similar accounts were published by Francesco Barozzi, Oronce Finé, Francesco Capuano and Christoph Clavius [Martins & Cardoso 2008]. A similar treatment also occurs at the beginning of Peucer's work owned by Galileo [Peucer 1573, 1–8]. Perhaps he was familiar with one of those sources when he wrote the *Trattato*.

Galileo did certainly study Georg Peurbach's *Theorica planetarum*, because he taught it at the universities of Pisa and Padua. In Peurbach's work, we find some subjects that were not discussed in Sacrobosco's *Sphæra* but are contained in the *Trattato*, such as the phases and visibility of the Moon [Peurbach 1569, 95]. Galileo could also have used instead Barozzi's *Cosmographia* for this part of his work [Barozzi 1585, 288, 295, 300].

The declination of the ecliptic presented in the *Sfera del mondo* was 24° [Piccolomini 1573, 94, 101]—a rather unusual value; the *Trattato* used 23.5° [Galilei 1891, 230, 233] and therefore this figure was copied from another source. Another relevant difference is the treatment of longitude and its determination by observations of the eclipse of the Moon, described in the *Trattato* [Galilei 1891, 241–242] in a way clearly independent from Piccolomini's exposition [Piccolomini 1573, 110–115].

Although we have no information about the time when Galileo studied Clavius' commentary on Sacrobosco's *Sphæra*, its influence upon the *Trattato* cannot be excluded, since several of its passages exhibit strong similarities to Clavius' work [Martins & Cardoso 2008].

9 Final remarks

This paper analyzed some peculiarities of Galileo's treatise, comparing it to several other vernacular astronomical works of the sixteenth century and discussing its likely sources. Contrary to previous claims, we argued that Christoph Clavius' commentary on Sacrobosco's *Sphæra* cannot be regarded as its only or main influence. A likely inspiration for Galileo's treatise is Alessandro Piccolomini's *Sfera del mondo*, a work that was carefully studied by Galileo and that anticipated several peculiarities of the *Trattato della sfera*. Our claim for this influence is strengthened by our analysis of Galileo's copious marginal notes found in a copy of Piccolomini's book. We admit, however, that there are features of the *Trattato* that have no counterpart in the *Sfera del mondo*. Therefore, the issue of Galileo's sources is very complex and has not been completely solved.

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