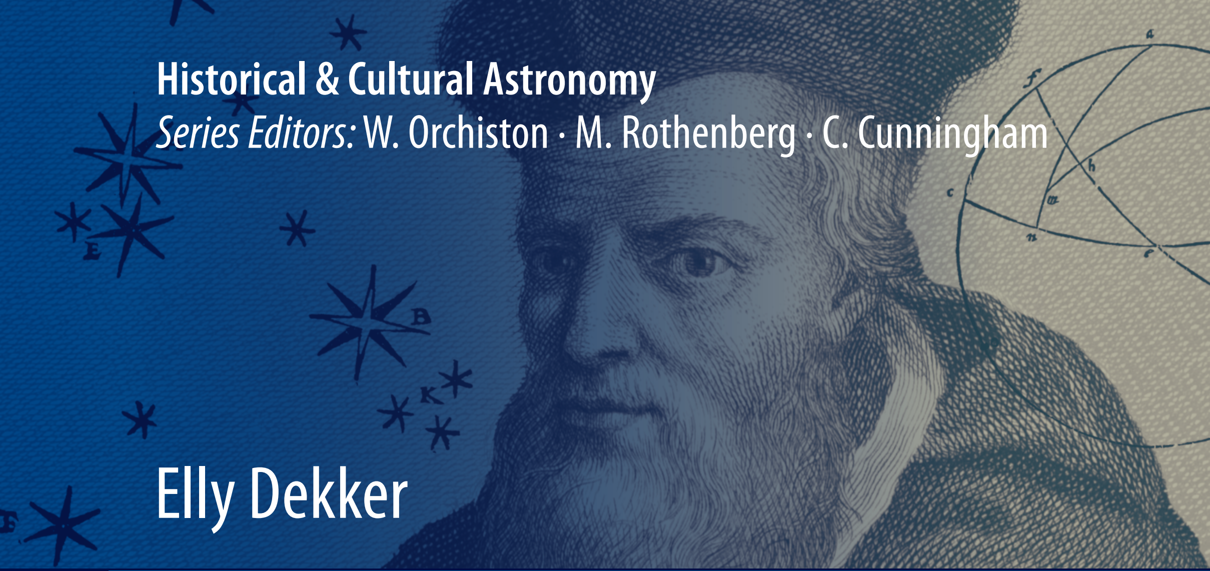

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Elly Dekker

Alessandro Piccolomini's Early Astronomical Works: II. An Examination of Their Scientific Content

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Portrait of Piccolomini with his map of Perseus and his sketch of spherical trigonometry.

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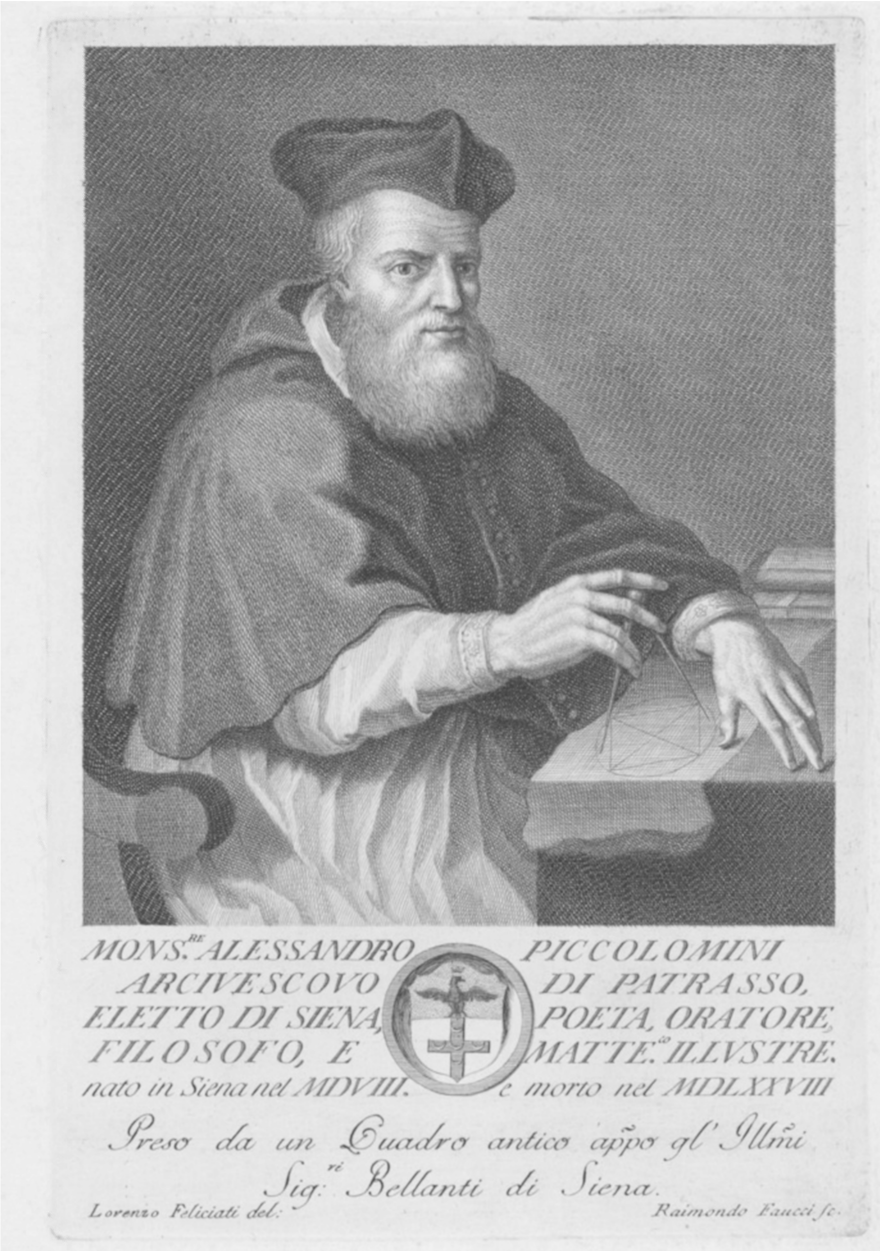

Alessandro Piccolomini, engraved by Raimondo Faucci after the original portrait by Lorenzo Feliciati, c. 1770. Amsterdam. Rijksmuseum

In loving memory of my mother

Preface and Acknowledgement

The Sienese polymath Alessandro Piccolomini (1508–1579) was one of the leading proponents of his day for making the natural sciences available to the lay reader in the vernacular. His earliest attempt is comprised of two works: *De la Sfera del Mondo* and *De le Stelle Fisse*, both of which were first printed in Venice in 1540.

The two treatises were dedicated to Laudomia Forteguerri, an accomplished Italian poet and a member of one of the most powerful families in the 16th-century Republic of Siena. In his dedicatory preface, Piccolomini stresses that they were written specifically to elucidate astronomy for someone who has little or no training in mathematics—'whether it be a man or a woman—so that he or she will be able to understand them very easily'.

To date, neither volume has received more than cursory scholarly attention. The current study examines the scientific content of these two works, in particular that of *De le Stelle Fisse* because this book is, on the one hand, applauded as the first printed star atlas and, on the other hand, criticised for not meeting cartographic standards of those days. No attention has been paid to the actual purpose for which these maps were designed, namely as part of a method for teaching the constellations and their stars by observation at night instead of by book learning, maps or globes.

This volume was written in tandem with Dr Kristen Lippincott's examination of the historical and cultural background of Piccolomini's early astronomical treatises, and we planned our works as independent, but complementary investigations. I wish to take this opportunity to thank her for her on-going dedication to the project, for her generosity to let me freely use her English translations of Piccolomini's texts and for taking care of the administrative side of our project. I would like to thank libraries, museums and institutions for their permissions to use photographic material from their collections. My thanks also go to Giancarlo Truffa, Annelies Aerts and Jenny Boyle, who supported and advised me at the various stages of this study.

Linschoten, The Netherlands Elly Dekker

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About the Author

Elly Dekker (born 1943, Haarlem, The Netherlands) studied theoretical physics and astronomy at Utrecht University and obtained her PhD in 1975 at Leiden University on the dynamics of flat stellar systems. From 1978–1988, she was curator at the Museum Boerhaave in Leiden. After 1988, she worked as an independent scholar on the history of astronomical models and instruments. From 1993–1995, she was Sackler fellow of the Royal Museums Greenwich. She was awarded the Caird Medal for her work on the museum's globe collection in 1998.

Her books include *The Leiden Sphere. An exceptional seventeenth-century planetarium* (Leiden, 1987); with Peter van der Krogt, *Globes from the Western World* (Zwemmer, London, 1993); *Globes at Greenwich. A Catalogue of the Globes and Armillary Spheres in the National Maritime Museum, Greenwich* (Oxford, Greenwich, 1999); *Istituto e Museo di Storia della Scienza: Catalogue of Orbs, Spheres and Globes* (Florence, 2004); and *Illustrating the Phaenomena: Celestial Cartography in Antiquity and the Middle Ages* (Oxford, 2013). Her papers comprise studies on the discovery of the southern celestial sky, on mediaeval astrolabes and quadrants, on Renaissance globes and on the history of Renaissance celestial maps.

Chapter 1
De la Sfera del Mondo: An Exploration of Piccolomini's Universe

1.1 Introduction

Of the two treatises by Piccolomini, *De la Sfera del Mondo* is indebted to material already available in the university textbooks of his day. Piccolomini makes this debt clear at the beginning of the *editio princeps* of 1540. Thus, the title-page of *De la Sfera* announces its contents as 'not derived from the translation of any particular writer, but are derived in part from collecting the best [authors] and, in part, from producing new [material]'.[1]

Piccolomini does not enlarge on which of the pre-existing authors he considered 'the best', or on what he means by 'new material'. Broadly speaking, his *De la Sfera* reflects the Aristotelian, geocentric scheme of the structure of the world, as described in Sacrobosco's *De Sphaera*, which was the most widely-read textbook on astronomy in universities from the thirteenth to the end of the sixteenth century. More than 350 editions of Sacrobosco's *De Sphaera* are known, of which approximately two-thirds present an edition of the original treatise, usually together with additional material such as a commentary or supplementary texts, while the rest are adaptions.[2] Piccolomini's *De la Sfera del Mondo* can be regarded as an adaptation, in that it discusses more-or-less the same schematic structures as *De Sphaera* while adding a

[1] Piccolomini, *De la Sfera* (1540a), title-page: ... *i quali non per via di traduttione, nè à qual si voglia particolare Scrittore obligati: ma parte da i migliori raccogliendo; e parte di nuovo producendo.* English translation Lippincott (2024), Chapter 5, ESM 5.3 (https://doi.org/10.1007/978-3-031-56786-5_5#MOESM3).

[2] Valleriani (2020), pp. 5–7. Valleriani distinguishes five categories of printed works of Sacrobosco: (1) editions of the original medieval tract (ca. 15); (2) an edition of the original treatise with a commentary (48); (3) compilations with the original treatise and other treatises (45); (4) an edition of the original treatise with a commentary and other texts (125); (5) adaptions (124).

E. Dekker, *Alessandro Piccolomini's Early Astronomical Works: II. An Examination of Their Scientific Content*, Historical & Cultural Astronomy,
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number of arguments and topics.[3] An example of such an addition is Piccolomini's discussion of the arguments for and against the immobility of the Earth, in the section *Che la Terra non si muova circularmente*.[4] Central to this discussion is an idea not found in *De Sphaera*: that the motions of the stars and planets can be explained just as well by assuming that the Earth rotates on its own axis as by assuming it remains static. The possibility of a rotating Earth was first discussed in antiquity by Aristarchus of Samos and, although not regarded as a serious alternative to an immobile Earth in the centre of the universe, it was well known in the Middle Ages. The French astronomer Nicole Oresme (d. 1382) considered all the arguments for and against the rotation of the Earth in his commentary on Aristotle's *On the Heavens*, and, indeed, found that rotation presented a rational and simpler explanation of observable phenomena than immobility; but he ended by discarding that hypothesis since, as he reminded his readers, it is unsupported by the greater authority of Holy Scripture.[5] Piccolomini, by contrast, rejects the possibility of the Earth's rotation on the grounds that it is inconsistent with the observed phenomena.[6]

While Piccolomini's *De la Sfera* was not the first vernacular treatise adapting Sacrobosco's *De Sphaera*, it was preceded by only two others. The earliest, a Tuscan translation, was made in 1498 by Piervincenzo Danti (c. 1440–1512) for his children Teodora and Gulio. It is unlikely that Piccolomini ever saw Piervincenzo's manuscript, the text of which was printed much later by his grandson Egnatio Danti (1536–1586) in 1571.[7] He was, however, almost certainly aware of the first printed vernacular adaptation of Sacrobosco's work, Fra Mauro Fiorentino's *Sphera Volgare Novamente Tradotta*, which was published in Venice in 1537 by Bartholomeo Zanetti.[8] Fra Mauro's book contains far more material than Piccolomini's *De la Sfera*, encompassing not only a concise text on the main topics of Sacrobosco's *De Sphaera* but also treatises on related subjects of interest, such as cosmography and navigation. The two works differ both in organisation and in detail, but have a significant point in common, in that both reproduce exactly the same diagram to illustrate the structure of the universe. This diagram differs from those usually found in medieval versions of Sacrobosco's treatise, as is discussed further below. Another similarity between Fra Mauro's and Piccolomini's works is that both begin with a series of elementary geometrical concepts, which students will need before progressing to the main contents. It should be added, however, that the two authors could have each borrowed this idea independently from one of the Latin

[3] Lippincott (2024), Chapter 2, n. 18, for a detailed characterisation of Piccolomini's *De la Sfera* as an 'Adaptation (Treatise strongly influenced by the original tract').

[4] Suter (1969), pp. 215–217. Suter presents an English translation of this text from the revised version, Piccolomini, *De la Sfera* (1566), pp. 51–53, but the discussion of the Earth's mobility can already be found in the first edition of 1540 on pp. 12v–13v.

[5] Grant (1996), pp. 114–116.

[6] Piccolomini, *De la Sfera* (1540a), p. 13r.

[7] Crowther et al. (2015), pp. 12–15.

[8] Fra Mauro (1537). As discussed further below, it is very likely that Piccolomini consulted Fra Mauro's work.

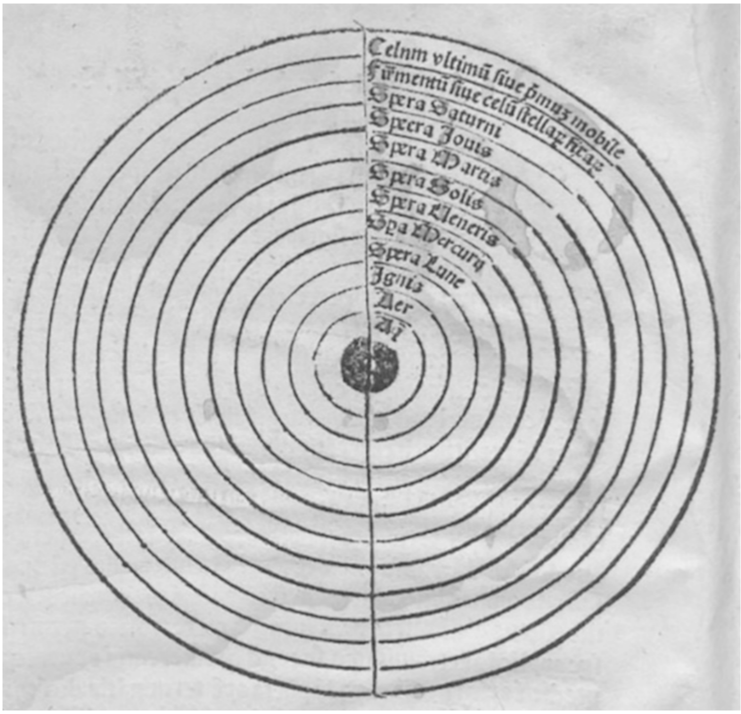


Fig. 1.1 The diagram from *Ioannis de sacrobosco anglici viri clarissimi spera mundi feliciter incipit,* Venice, [1478]. Staatsbibliothek zu Berlin - Preußischer Kulturbesitz, Berlin, Germany, Inc 3812.10

editions of Sacrobosco's *De Sphaera* printed in Venice in 1490, 1491 or 1513, all of which start with similar preliminaries.[9] In Piccolomini's case, he certainly would have become familiar with Sacrobosco's work as part of his studies at the University of Siena prior to his Paduan sojourn.

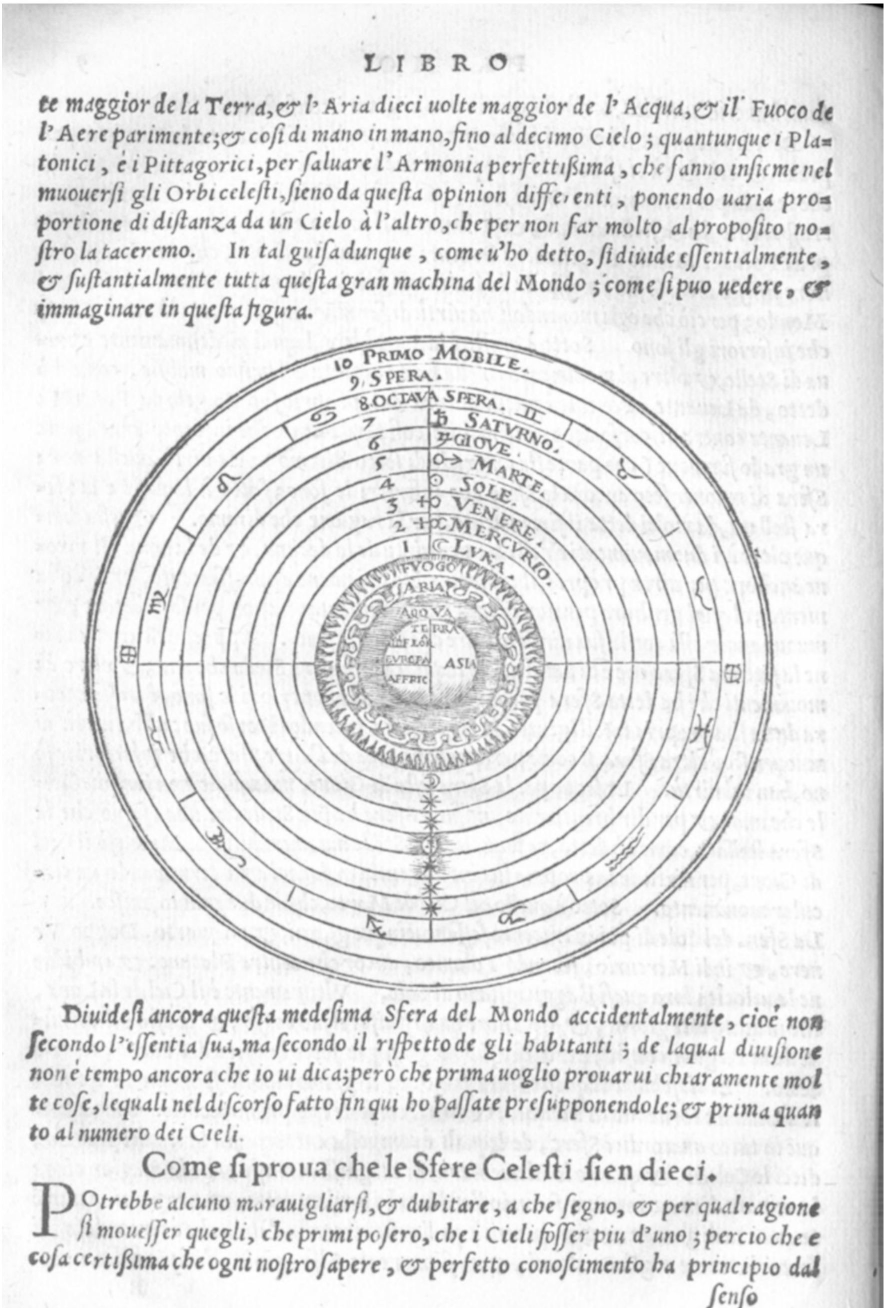
At the time Fra Mauro and Piccolomini were writing, the view that the structure of the universe is geocentric had yet to be challenged by Nicolas Copernicus, whose *De Revolutionibus* was published in 1543. Although there were various schools of geocentric astronomical thought, the main differences between them concerned the number of spheres the universe contained. Sacrobosco's model (Fig. 1.1) had four elemental spheres and, beyond them, nine celestial ones: seven containing each of the planets (including the Moon and the Sun), then a single sphere containing the so-called 'fixed stars' (since they appear not to move relative to one another), and, finally, an encasing outer sphere, the *Primum Mobile* ('First Mover'). The movement of the outer celestial sphere affects all the spheres within it.

[9] Cozzoli (2011), p. 238 considers these geometric explanations a novelty.

The motion of the eighth sphere of the fixed stars in Sacrobosco's diagram is linked to the Ptolemaic theory of the precession of the equinoxes, as the slow but perceptible movement of the fixed stars around the poles of the ecliptic is called. This phenomenon was discovered by the Greek astronomer Hipparchus (fl. 130 BC), but his observations did not allow a quantification of this motion. Using new, additional observations, Ptolemy deduced that the fixed stars moved at a rate of one degree every 100 years. Ptolemy's theory was questioned when the observations of a group of astronomers working in Baghdad under the patronage of the Caliph Abū al-ʿabbās ʿabd Allāh al-Ma'mūn (813–833) showed that a number of Ptolemy's parameters, such as the obliquity of the ecliptic and the rate of precession, had changed between his epoch and their own. To account for the observed change in the Ptolemaic precession rate, a number of alternatives to Ptolemy's theory were proposed. For example, the Mesopotamian astronomer Muḥammad ibn Jābir al-Battānī (c. 858–929) advocated replacing the Ptolemaic precession of one degree in 100 years with the value of one degree in 66 years, but his way of quantifying the movement of the fixed stars remained almost unknown in the Latin West until the sixteenth century. Another theory, which reached the Latin West in the twelfth century through an anonymous Latin translation of an Islamic work, the *De Motu octave spere*, at the time (incorrectly) attributed to the ninth-century mathematician Abū al-Ḥasan ibn Zahrūn al-Ḥarrānī Thābit ibn Qurra, proposed to resolve the divergence by replacing Ptolemy's theory of precession by a motion of trepidation [*motus trepidationis*] or access and recess [*accessus et recessus*] of the eighth sphere.[10] Before long, this trepidation model was superseded in the Latin world by the Alfonsine precession theory, which incorporated a two-fold motion of the fixed stars: a constant, slow movement from West to East around the ecliptic poles; and a motion of access and recess centred on the first points of Aries and Libra. Although this theory is in essence arithmetical, and as such is included in the well-known *Alfonsine Tables*, later astronomers tried to provide a geometric basis for it. Each of the two motions was believed to be induced by a single sphere, which implied that an additional sphere to the nine of Sacrobosco's model was needed. It is this ten-sphere model of the structure of the universe that is represented in the diagram reproduced by Fra Mauro and Piccolomini (Fig. 1.2). The small circles in the ninth sphere at the first points of Aries and Libra are supposed to illustrate how the motions of the eighth and the ninth spheres are connected.

Yet, even though Piccolomini and Fra Mauro use the same diagram to show the structure of the universe, they disagree in their explanations of the two motions associated with the eighth and the ninth spheres. Fra Mauro ascribes to the ninth sphere a slow, constant motion at a rate of one degree in 136 years, based on a complete revolution in 49,000 years; and to the eighth sphere, which contains the

[10] The attribution of the treatise *De Motu octave spere* to Thābit is now known to be incorrect, see Nothaft (2017), p. 215.



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te maggior de la Terra, & l'Aria dieci uolte maggior de l'Acqua, & il Fuoco de l'Aere parimente; & coſi di mano in mano, fino al decimo Cielo; quantunque i Platonici, e i Pittagorici, per ſaluare l'Armonia perfettiſsima, che fanno inſieme nel muouerſi gli Orbi celeſti, ſieno da queſta opinion differenti, ponendo uaria proportione di diſtanza da un Cielo à l'altro, che per non far molto al propoſito noſtro la taceremo. In tal guiſa dunque, come u'ho detto, ſi diuide eſſentialmente, & ſuſtantialmente tutta queſta gran machina del Mondo; come ſi puo uedere, & immaginare in queſta figura.

Diuideſi ancora queſta medeſima Sfera del Mondo accidentalmente, cioè non ſecondo l'eſſentia ſua, ma ſecondo il riſpetto de gli habitanti; de laqual diuiſione non è tempo ancora che io ui dica; però che prima uoglio prouarui chiaramente molte coſe, lequali nel diſcorſo fatto fin qui ho paſſate preſupponendole; & prima quanto al numero dei Cieli.

Come ſi proua che le Sfere Celeſti ſien dieci.

POtrebbe alcuno marauigliarſi, & dubitare, a che ſegno, & per qual ragione ſi moueſſer quegli, che primi poſero, che i Cieli foſſer piu d'uno; percio che e coſa certiſsima che ogni noſtro ſapere, & perfetto conoſcimento ha principio dal

ſenſo

Fig. 1.2 The diagram from Piccolomini, *Della Sfera Del Mondo,* Venice, 1552, p. 9a. Private collection fixed stars, a motion of access and recess that concludes a full revolution in 7000 years.[11] In contrast to these values, Piccolomini connects the slow, constant motion of the ninth sphere to the traditional Ptolemaic value of one degree in 100 years, equivalent to a complete revolution in 36,000 years. He does not specify the rate of motion of access and recess of the eighth sphere and, indeed, declines to discuss this trepidation motion at all, claiming that it is of no importance.[12]

At the end of his *De la Sfera*, Piccolomini promises to explain the motions of the planets in detail in another vernacular work.[13] This subsequent astronomical treatise, entitled *La prima parte dele theoriche overo speculationi dei pianeti*, was duly published in 1558. In it, Piccolomini maintains his geocentric view of the structure of the universe and, in this case, draws mainly on a single existing source. Effectively, the work is an attempt to convey the ideas discussed in Georg Peurbach's *Theorica Planetarum Novae*, which was often published together with Sacrobosco's *De Sphaera* in the sixteenth century.[14] Peurbach's treatise was first printed in 1472, having originated in a series of lectures he gave in Vienna in 1454.[15] It soon became the standard university textbook on planetary motion, replacing the anonymous *Theorica Planetarum*, which is thought to have been written in the thirteenth century.[16] Peurbach's *Theorica Planetarum Novae* contains extensive explanations of physical models of the Sun, the Moon, the inner planets (Mercury and Venus) and the outer planets (Mars, Jupiter and Saturn). His principal intention was to overcome the conflict between Aristotle's insistence that planetary orbits must follow the laws of nature and Ptolemy's recourse to theoretical eccentrics and epicycles.[17] To that end Peurbach applied the 'orb-principle' that had pervaded the Latin West at the end of the fourteenth century.[18] Two classes of orbs are distinguished: an orb of the one class consists of a spherical shell of uniform thickness and an orb of the other class is a spherical shell of non-uniform thickness. How such orbs were employed is best illustrated by Peurbach's solar model:

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[11] Fra Mauro (1537). The table is in the first section and is labelled *Tavola delli moti, 10 sphere celesti, proprij*.

[12] Piccolomini, *De la Sfera* (1540a), p. 6r.

[13] Piccolomini, *De la Sfera* (1540a), p. 52r.

[14] Valleriani (2020), p. 6. Two early examples of Sacrobosco's text published together with Peurbach's *Theorica planetarum* are *Sphaera mondo compendium foeliciter inchoat*, Venice 1491; and *Sphera Mundis cum tribus Commentis*, Venice 1499. An English translation of Peurbach's treatise was published by Aiton (1987). For the history of printed editions, see Pantin (2012).

[15] Malpangotto (2020).

[16] Pedersen carefully examined a number of attributions but concluded that none was convincing. See Pedersen (1981).

[17] The conflict between these two conceptions of planetary motion became a major controversy among medieval astronomers. See, for example, Pedersen (1978), pp. 320–322. Ptolemy's approach was labelled 'saving the phenomena' by Duhem (1969). On that interpretation, see Goldstein (1997). On Ptolemy's attitude, see Toomer (1984), XIII.2.

[18] Grant (1994), pp. 281–282.

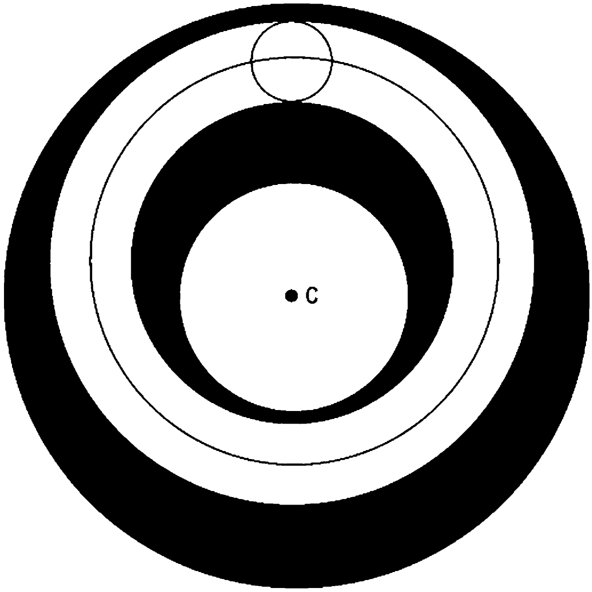

Fig. 1.3 Peurbach's three-orb system of the Sun. The point C marks the centre of the world

> 'The sun has three orbs, separated from one another on all sides and also contiguous to one another [Fig. 1.3]. The highest of them is concentric with the world on its convex surface, but is eccentric on its concave surface. The lowest, on the other hand, is concentric on its concave but eccentric on its convex surface. The third, however, situated in the middle of these, is eccentric to the world on both its convex surface and its concave surface.'[19]

Peurbach called the inner and outer orbs of unequal thickness *orbes augem solis deferentes*, the deferent orbs of the apogee of the sun. The apogee (in Latin *aux*) is the point in the solar orbit that is farthest removed from the centre of the Earth. As Peurbach expounds, these deferent orbs move together 'so that the narrowing part of the superior is always above the wider part of the inferior and go round equally fast, following the variations of the motion of the eighth sphere, concerning which we shall speak later'.[20] By 'later' he means the final chapter of his book entitled *De motu octave sphaerae,* which includes among others an account of the Alfonsine theory of precession. Following this theory, Peurbach assigns a threefold motion to the eighth sphere: the daily westward motion around the poles of the world, induced by the tenth or first movable sphere; a slow eastward motion around the ecliptic poles, coming from the ninth sphere which he calls the second movable; and the third

[19] Aiton (1987), p. 9.

[20] Aiton (1987), p. 9.

motion, called the motion of trepidation or approach and recession of the eighth sphere.[21]

Interestingly, Peurbach's discussion of the Alfonsine precession theory was probably influenced by the work of the Paduan astrologer Nicolò Conti (Nicolaus Comes de Comitibus, d. 1468), who, as it happens, also strongly influenced Federico Delfino (1477–1547), the professor of mathematics and astronomy at the university of Padua from 1520 to 1547.[22] Yet, despite the fact that Piccolomini appears to have known Delfino well, and occasionally refers to him in his astronomical works, there is very little evidence that he ever engaged seriously with the fundamental astronomical and cosmological issues that concerned Delfino and his contemporaries.[23] For example, Piccolomini does not appear to be aware of Delfino's treatise *De motu octavae sphaerae*, which describes the several theories of precession that had been proposed since Hipparchus discovered the phenomenon. Although Delfino's treatise remained unpublished until 1559, a close acquaintance would have surely known of it and would not have dismissed the motion of accession and recession as being of no importance.[24] Piccolomini's very confused account of the motion of the solar apogee in his treatise on the motions of the planets provides another example of his ignorance of Delfino's writings.[25]

1.2 Piccolomini and the Motion of the Solar Apogee

In his study of solar motion, Ptolemy concluded that the position of the solar apogee is tropically fixed: that is, its longitude as counted from the vernal equinox is constant in the course of time. Ptolemy's deductions were, however, shown to be faulty in the ninth century by the same astronomers who questioned his findings on the movement of the fixed stars. Instead, al-Ma'mūn's astronomers deduced that the solar apogee is fixed with respect to the stars. Therefore, its longitude varies with

[21] Peurbach's precession models are discussed by Swerdlow (1990), pp. 175–183. See also, Nothaft (2019).

[22] Nothaft (2019), p. 95, shows that Peurbach's discussion of the Alfonsine precession theory was very likely influenced by Conti's short treatise written in 1450, *De triplici motu octave spere*, in which he attempted to provide a physical model for the purely computational method underlying the Alfonsine theory. Conti's work survives in five manuscripts, one of which was owned by Delfino: Florence, Biblioteca Medicea Laurenziana, Ashburnham 208 (134, 140), pp. 407–417. For Delfino's teaching in Padua, see Grendler (2002), p. 417.

[23] For the little that is known about Piccolomini's relationship with Delfino, and his references to the older scholar in his writings, see Lippincott (2024), Chapter 1.

[24] Delfino's treatise was published posthumously in Venice in 1559 by the mathematicians of the Accademia Veneta (or della Fama), together with another one, *De fluxu et refluxu aquae maris*. See Bianca (1988).

[25] Piccolomini, *La prima parte* (1558a), p. 8v: *Come per il primo modo et via si può salvare la prima apparentia del Sole. & del sito, & movimento de l'Auge di esso Sole*.

precession, as do the longitudes of the stars.[26] Peurbach, in his treatise, adhered to the same assumption and, accordingly, discusses the motion of the solar apogee in his last chapter *De motu octavae sphaerae*. Piccolomini, on the other hand, treats this motion in his chapter on the Sun and not in a separate chapter. Piccolomini starts by relating that diligent observations in his own time have located the solar apogee in the beginning of Cancer (Cnc 0°).[27] Then, he claims that in Ptolemy's days the apogee was observed in a location eleven degrees further back, at nineteen degrees in Gemini (Gem 19°), and that therefore 'it is concluded that the two orbs that hold the eccentric orb in the middle, have a particularly slow movement by which they are moved in hundred years about one degree, following the direction of the signs – that is, [from] Aries towards Taurus [. . .]'.[28] He finishes by saying that it is not surprising that Ptolemy placed it [that is, the solar apogee] in the nineteenth degree of Gemini (Gem 19°) whereas now, 1200 years later, it is located at the beginning of Cancer (Cnc 0°).[29]

In commenting on this passage, it can be observed first that is it not clear why Piccolomini thought that there were 1200 years between Ptolemy's time and his own. The epoch recorded in the standard recension of Ptolemy's *Almagest* is the beginning of the reign of Antoninus (20 July, 137 AD), which is 1400 years before the time that Piccolomini was writing.[30] Secondly, there is no known source for Piccolomini's statement that the position of the solar apogee in Ptolemy's time was in Gem 19°. According to the *Almagest*, the solar apogee was in 137 AD approximately 24½° in advance of the summer solstice—that is, in Gem 5.5°—a considerable distance from Piccolomini's position.[31] The possibility that he derived his data from the *Alfonsine Tables* can also be discounted. There, the Ptolemaic epoch is taken to be 16 AD, and the longitude of the solar apogee at that time was Gem 11.5°, again far from close to Piccolomini's figure.[32] Only one of his numerical statements is discernible: his reference to the movement of the solar apogee around the zodiac at

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[26] Chabás and Goldstein (2010), pp. 47–52.

[27] Piccolomini, *La prima parte* (1558a), p. 10r: *Hanno ancora per diligenti osservationi osservato che l'Auge nei / tempi nostri vien sotto quasi il principio del Cancro: & l'opposto de /l'Auge si truova sotto quasi il principio del Capricorno* [. . .].

[28] Piccolomini, *La prima parte* (1558a), p. 10v: *Et perche ai tempi di Tolomeo su osservato esser l'Auge undeci gra/di indietro da quell che gli è hoggi, cioè sotto quasi il decimo nono gra/do de Gemegli, si è concluso che li due orbi, che l'orbe Eccentrico in /mezo tengano, habbiano un movimento particolare tardissimo, per il / quale si muovino in cento anni quasi un grado secondo l'ordine de se/gni, cioè da l'Ariete uerso 'l Tauro, [. . .].* English translation Kristen Lippincott, private communication.

[29] Piccolomini, *La prima parte* (1558a), p. 11r: *consequentemente non è da maravigliarsi se havendo Tolemeo po/ sta la detta Auge sotto'l decimo nono grado de li Gemegli, noi hog/ go, che piu di mille dugento anni siamo doppo di lui, intorno al prin/ cipio del Cancro la collochiamo.*

[30] Toomer (1984), VII.4, p 340.

[31] Toomer (1984), II.4, p. 153. For the longitude of the solar apogee, see also Neugebauer (1975), pp. 57–58.

[32] A useful introduction to the *Alfonsine Tables* is offered in Wegener (1905), pp. 129–185. See also Bianchini (1495).

a rate of one degree in 100 years. Here, he seems to be citing the Ptolemaic precession rate which he ascribes in his *De la Sfera* to the ninth sphere. However, he makes no mention of the motion of access and recess which he connects in that treatise to the eighth sphere.[33]

In the revised and extended edition of his *De la Sfera*, first published in 1566, Piccolomini makes two minor adjustments to the cursory discussion of precession in the 1540 edition.[34] He maintains his assertion that the ninth sphere moves one degree every 100 years, but adds that this motion is transferred to the apogees of the planets as he has explained in his *Teoriche de i Pianeti*.[35] The motion of access and recess of the eighth sphere is no longer claimed to be of little importance, but the reader is referred to his *Teoriche de i Pianeti* for an explanation.[36] Any reader who follows his referral will, however, be disappointed, since the issue is conspicuous by its absence in that book. Piccolomini may have intended to include a chapter on trepidation in a second part of the work, which he had announced as forthcoming in the address to the reader of the 1558 and 1563 editions of the *Teoriche de i Pianeti*, but the second part—if ever written—was never published.[37]

[33] Cozzoli (2011), p. 242, interprets Piccolomini's discussion of the solar apogee as reflecting the conflict between ancient conceptions of planetary motion: *sur la question de la précession des équinoxes, Piccolomini expose les deux manières de sauver les apparences*.

[34] Piccolomini, *De la Sfera* (1566).

[35] Piccolomini, *De la Sfera* (1566), p. 33: *Et quell ch'io dico del primo mobile, rispetto à tutte le stelle, intendo parimente della Nona sfera: poscia che ella ancora serve assai col suo movimento alle stelle fisse & ai pianeti ancora per li Augi loro, come ho dichiarato nelle mie Teoriche de pianeti*.

[36] Piccolomini, *De la Sfera* (1566), p. 34: *Questa olta li due movimenti, ch'ella ha per virtù della sfera decima, & della nona, si muove ancora per virtù propria: movendo in gran parte insieme con la medesima virtù le sfere che le son sotto. Il cui movimento chiamano gli Astrologi appressamentoi, & discostamento. La dichiaratione del quale appartiene alle Teoriche de i Pianeti, & noi quivi n'habbiomo trattato.*

[37] Suter (1969), p. 212. Piccolomini, *La prima parte* (1558a), address to the reader: *Ne laqual seconda parte, hò riserbato à trattar quelle cose che appartengano ali movimenti, che importano nei Pianeti larghezza dai loro Eccentrici; & specialmente in Venere, & in Mercurio: come sono restessioni, deviationi, inclinationi & simili. Hò riserbato parimente la dichiaratione dei termini, ò ver nomi tabulari, & le lor cause: come sono veri mouimenti, veri luoghi, veri Augi, veri argomenti, vere equationi, movimenti meziani, luoghi meziani, Argomenti, & Augi mezane, & simili, come cose mezane à far conoscere & trovar le vere. Appresso di questo si è pur à quella seconda Parte riserbato il dichiarare quali sieno le Equationi, quali li Equanti, quali sieno le lincee che cotai luoghi, augi, argomenti cosi veri, come mezani demonstrano: & molte altre cose in somma che al complemento di cotal notitia dele Theoriche de Pianeti appartengano.* The 1563 edition of *Teoriche de i Pianeti* is a reprint of the1558 edition which, as noted above, does not mention the motion of access and recess.

Table 1.1 Distances from the Earth to the planets and to the eighth and ninth Spheres, in Piccolomini's *De la Sfera*

Celestial object	D_s	D_o
	Italian miles	e.r
Moon	160,427	33
Mercury	316,528	64·17
Venus	831,826	167
Sun	6,058,289	1210
Mars	6,108,409	1220
Jupiter	44,472,625	8876
Saturn	72,178,444	14,405
Eighth sphere	100,766,199	20,110
Ninth sphere	201,537,409	40,220

D_s = Distance from the Earth's surface in Italian miles
D_o = Distance from the Earth's centre in units of the radius of the Earth (e.r)
1 e.r. = 5011 Italian miles

1.3 The Sizes of the Planets and Their Distances from the Earth

Although the extent of Piccolomini's understanding of precession must be seriously doubted, he shows a better grasp of the literature on another aspect of the universe. He provides detailed information about the sizes and distances from the Earth of the seven planets, as well as for the celestial spheres beyond them, which complies (for the most part) by using the standard reference books on cosmic dimensions. Calculations of sizes and dimensions of celestial spheres were based on the nesting-sphere principle. The idea is that the greatest distance from the Earth's centre reached by a planet equals the least distance from the Earth's centre of the adjacent planet, confining a planet's motion spatially to a spherical shell. This theory was proposed by Ptolemy in his *Planetary Hypotheses*, a work known only from an Arabic translation. The nesting-sphere principle and a scheme of corresponding cosmic dimensions that became known in the Middle Ages stems from Latin translations of a work by the ninth-century Arabic astronomer from the Abbasid court in Baghdad, known in the West as Alfraganus. He is referred to by Piccolomini as 'Alfagranio', and his full name was Abū al-ʿAbbās Aḥmad ibn Muḥammad ibn Kathīr al-Fargānī (800–870).[38] Al-Farghānī's scheme of cosmic dimensions, as laid out in his *Kitāb fī Jawāmiʿ ʿIlm al-Nujūmi* (*Elements of Astronomy on the Celestial Motions*), is found in the Latin West from the thirteenth century onwards, for example, in Roger Bacon's O*pus Maius*, composed in 1266. Sacrobosco's *De Sphaera* did not include a section on cosmic dimensions, but sizes and distances are discussed by some of his medieval commentators. The cosmic dimensions in al-Farghānī's scheme, expressed

[38] Van Helden (1985), pp. 28–40.

Table 1.2 Distances from the centre of the Earth in e.r. to the planets and to the eighth and ninth spheres, as given by al-Farghānī, Fra Mauro and Piccolomini

Celestial object	al-Farghānī	al-Farghānī	Fra Mauro	Fra Mauro	Piccolomini
	Greatest distance	Least distance	Greatest distance	Least distance	Least distance
Moon	64·17	33·55	64·17	33	33
Mercury	167	64·17	167	64·17	64·17
Venus	1120	167	1120	167	167
Sun	1220	1120	1220	1120	1210
Mars	8876	1220	8876	1220	1220
Jupiter	14,405	8876	14,405	8876	8876
Saturn	20,110	14,405	20,110	14,405	14,405
8th sphere		20,110	40,220	20,110	20,110
9th sphere				40,220	40,220

in units of the Earth's radius (e.r.), were often converted into miles. Piccolomini gives cosmic distances in Italian miles (see Table 1.1).[39]

Unique to Piccolomini's data is that his distances are counted from the surface of the Earth (D_s), instead of from the centre (D_o) as in other accounts. For the sake of comparison, they are expressed in Table 1.1 according to both systems, thus providing Piccolomini's D_s values in Italian miles, and D_o values in units of the Earth's radius (e.r.). (This straightforward conversion from Piccolomini's figures is achieved by first adding the Earth's radius in Italian miles, 5011, to the values of D_s and then divide the sum by 5011.)

In the absence of a systematic study on the transmission of al-Farghānī's scheme of cosmic dimensions and possible adaptations, the present comparison of Piccolomini's distance values is limited to al-Farghānī's original data, as published by Albert Van Helden, and those given in Fra Mauro's *Sphera volgare* of 1537 (see Table 1.2).[40]

Al-Farghānī and Fra Mauro provide slightly more information than Piccolomini does, as they record both the least and the greatest distance of a planet to the Earth's centre, which mark the boundaries of the spherical shell to which a planet's motion is confined. In contrast, Piccolomini's distances indicate only the least distance of a planet to the Earth. Given that this equals the greatest distance of the previous planet, however, the boundaries of the spherical shell of each planet can be readily obtained. In Table 1.2, all distances are given in e.r. and Piccolomini's figures have been adjusted to give distances from the centre of the Earth (D_o).

The most striking feature in Table 1.2 is the degree of correspondence of the least distances given by al-Farghānī, Fra Mauro and Piccolomini. However, there are two

[39] Piccolomini, *De la Sfera* (1540a), pp. 51v–52r.

[40] Van Helden (1985), p. 20. The table on p. 30 contains an error in the least distance for the Moon, which is corrected in a later table published by Van Helden (1989), p. 107.

notable deviations. One is Piccolomini's value of the least distance for the Sun, 1210 e.r., which contrasts with al-Farghānī's and Fra Mauro's 1120 e.r. The most likely reason for this discrepancy is that it arose from an error.[41]

The other variation in Table 1.2 is in the least distances of the Moon, for which both Fra Mauro and Piccolomini depart from al-Farghānī's value. In this case, Piccolomini describes how he arrived at his figure. He asserts that al-Farghānī's value is *quasi 33* and that he reduced this number to 32 before converting it to Italian miles, which gave him the figure of 160,427 Italian miles, representing the distance of the Moon as measured from the surface of the Earth (see Table 1.1).[42] But 32 times 5011 is 160,352, so Piccolomini's rationale is contradicted by his result. Actually, Piccolomini's value 160,427 differs from Fra Mauro's figure precisely by 5011.[43] This strongly suggests that Piccolomini did not calculate the distance of the Moon by converting al-Farghānī's figure as claimed, but copied Fra Mauro's figure in miles instead.

Fra Mauro and Piccolomini also list a value of the least distance for the ninth sphere, which is, of course, missing in al-Farghānī's data. Their common source need not have been a very modern one: for example, they could have used an amended edition of al-Farghānī's treatise printed in Ferrara in 1493. The data in that treatise are given in e.r. and in miles (using 1 e.r. = 3250 miles).[44] The greatest distance of the eighth sphere containing the fixed stars is given as twice its least distance, so, according to the nesting-sphere principle, the least distance of the ninth sphere is equal to twice the least distance of the eighth sphere.[45] This is exactly what Fra Mauro's and Piccolomini's figures show and could explain how they reached them.

Al-Farghānī's scheme also includes data for the diameters and volumes of the planets and the stars of six brightness classes, expressed in magnitudes (1,. . .,6).[46] Fra Mauro and Piccolomini list only volumes. Table 1.3 expresses the planetary and

[41] Piccolomini's value of 1210 e.r. for the Sun equals that of Ptolemy for the *mean* solar distance, but this is cannot explain Piccolomini's number because his list shows only the *least* distances of the planets, see Van Helden (1985), p. 27.

[42] Piccolomini, *De la Sfera* (1540a), p. 51v.

[43] Fra Mauro's value of the least distances of the Moon is 165,438 Italian miles. In his treatise the size of the Earth's radius (1 e.r.) equals 5011 + 4/11 Italian miles. Using these data he computes a value of the least distance of the Moon of 33 e.r., see Fra Mauro (1537).

[44] The value used by al-Farghānī for 1 Earth radius, 3250 miles, is based on value of the length of a degree measured by al-Ma'mūn's astronomers , see Van Helden (1985), p. 30.

[45] Alfraganus (1493), chapters 21 and 22. For example, the least distance of the Moon is given as 109,037 miles, a value also quoted by Fra Mauro (1537). To convert this figure into e.r., one divides it by 3250 miles, which gives 33·55 e.r. The greatest distance of Saturn is given as 65,357,500miles, and the outer boundary of the sphere of the fixed stars is given as 2 × 65,357,500 = 130,715,000 miles, which is 2 × 20,110 = 40,220 e.r.

[46] The brightness of a star as recorded in the Ptolemaic star catalogue is classified using a range of six magnitudes: the brightest stars are said to be of the 1st magnitude (m = 1); those less bright of the 2nd magnitude (m = 2) and so on; the weakest stars are said to be of the 6th magnitude (m = 6).

Table 1.3 Volumes in v.e. of the planets and of the stars with six magnitudes (m = 1–6), as given by al-Farghānī, Fra Mauro (1537) and Piccolomini (1540)

	al-Farghānī	Fra Mauro	Piccolomini
Moon	1/39	1/39	1/39
Mercury	1/22,000	7/22,000	1/3143
Venus	1/37	1/37	1/37
Sun	166	166	166
Mars	1+(1/2)+1/8	1+(3/4)	2
Jupiter[a]	95	95	91
Saturn	91	91	95
stars, m = 1	107	115	115
stars, m = 2	90	90	86
stars, m = 3	72	70	72
stars, m = 4	54	50	50
stars, m = 5	36	36	36
stars, m = 6	18	18	20

[a]In Piccolomini's revised edition of 1566, the value of Jupiter is 89

stellar volumes in units of the volume of the Earth (v.e.) of al-Farghānī and Fra Mauro and the corresponding values derived from Piccolomini's data.

An oddity in Piccolomini's scheme is in his volumes of Jupiter and Saturn, which are identical to al-Farghānī's and Fra Mauro's volumes of Saturn and Jupiter, respectively. In the revised edition of his *De la Sfera* (1566), he changed the value of Jupiter into 89 but maintained the value of 95 for Saturn. More interesting are the values for the volume of Mercury. Piccolomini's value is, in fact, the same as Fra Mauro's, because 22,000/7 equals 3143. Piccolomini's manner of expressing it is more direct, telling the reader clearly that 3143 volumes of Mercury fit into one volume of the Earth. What is curious is that, as Fra Mauro's number of the volume makes plain, it is seven times greater than al-Farghānī's volume. The origin of this change is as yet unknown, but the precedence of Fra Mauro's treatise, and the coincidence of Piccolomini's value with his, could perhaps suggest, again, that Piccolomini borrowed Fra Mauro's data. Fra Mauro and Piccolomini also present different figures for the volume of Mars – which is strange for these authors agree on the values of the distances of Mars.

Further deviations from al-Farghānī's values occur in the volumes of the stars. Al-Farghānī lists the volume of a first magnitude star as 107 times the volume of the Earth.[47] His data for the volumes of stars with magnitudes 2,.. . . .,6 are computed by dividing the volume of the first magnitude by 6, making the difference between consecutive magnitudes equal to 18. Fra Mauro and Piccolomini list a value of the volume of a first magnitude star as 115 times the volume of the Earth. Unfortunately, neither Fra Mauro nor Piccolomini explain how they arrived at this data, nor what principle they used to calculate the volumes of stars with magnitudes 2, . . ., 6. Only three of their volumes for the stars are identical, suggesting that they may have used different source data.

[47]Van Helden (1985), p. 30.

1.4 Concluding Remarks

Overall, the similarities between Fra Mauro's *Sphera volgare* (1537) and Piccolomini's *De la Sfera* (1540) are sufficiently numerous to make a link between them almost certain, even though Piccolomini does not mention consulting the Florentine's recently published vernacular work, which (like his own) was printed in Venice. He uses the same diagram as Fra Mauro to illustrate the structure of the universe and, like the Florentine, includes a chapter on cosmic dimensions. Moreover, as the previous discussion has shown, most of his values for the distances of the planets from the Earth and the volumes of planets and stars are exactly the same as those we find in Fra Mauro's *Sphera volgare*. Yet, despite the many correspondences between Piccolomini's and Fra Mauro's treatises, the two works depart markedly from one another in both style and in scope. Fra Mauro's concise treatise is aimed at practicians, such as navigators and surveyors. Piccolomini, by contrast, addresses his book to a group of amateur readers, albeit well-educated, who had no professional or academic interest in the topic of astronomy.

Piccolomini's motives in addressing a wider public are convincingly expressed in 1558, in a letter to the readers of his book about the planets. Piccolomini explains:

> Most gracious readers, who desire to read the writings of others, more out of a desire to learn than to criticize and malign; you have always been the only audience for my works [. . .] I want to warn you of certain things. Firstly, you must know that in all the works I have written until now, my primary intention has been to write as clearly as possible: seeking in every study to present the subjects to other intellects in a manner so plain, so accessible and free of difficulty, that not only fine intellects but also average ones can learn them. [. . .] I have always judged either envious or uncultured those who, the more the subjects they have set themselves to dealing with are wrapped in obscurity, the more instead of shedding light upon them, they seek, either with excessive brevity, or with words that are not well known, or with arrogant affected elegance, or, finally, by representing, while translating from one language to the other, things they do not understand, adding difficulties and hoping in this way to appear more scholarly. [. . .] for this reason, I have tried to make the subjects accessible with known vocabulary and familiar expressions, stating, replying and exemplifying to shed light upon them: so that for this reason many times I have chosen to adopt a lower style, and a turn of phrase that is perhaps too domestic; because it did not seem to me useful for the Readers to do the opposite and leave things obscure.[48]

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[48] Piccolomini, *La prima parte* (1558a), letter to the readers: *Benignissimi Lettori, & desiderosi di leggere gli altrui scritti, più per desiderio di sapere, che per voglia di riprendere, & malignare; a voi soli ho io scritto sempre le opere mie [. . .] voglio voi d'alcune cose avvertire. Primieramente voi havete da sapere che in tutte quelle opere che io ho scritte fin qui, ho havuto più che ad altro intentione a scrivere con quella maggior chiarezza, che è stato a me possibile: procurando con ogni studio di mettere innanzi agli altrui intelletti le materie così piane, così agevolate, & sciolte di difficultà, che non solo li sottili intelletti, ma li mediocri ancora le possino apprendere. [. . .] ho io sempre giudicato, o invidiosi, o poco dotti coloro, li quali, quanto più li soggetti di cui han preso a trattare sono involti di oscurità, tanto più in cambio di dar lor luce, si ingegnano, o con troppa brevità, o con vocaboli poco noti, o con soverchia affettata elegantia, o finalmente con depingere, da una lingua transportando nel'altra, le cose che non intendano, aggiugnere difficultà, sperando forse per questo parer più dotti. [. . .] per queta cagione ho cercato di aprire le materie, & con vocaboli manifesti, & modi di dire familiari, dichiarando, replicando, & esemplificando dar*