

# Chapter 7

## Sacrobosco's *Sphaera* in Spain and Portugal



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**Abstract** This paper analyzes sixteenth-century commentaries on Johannes de Sacrobosco's *Sphaera* in Portuguese and Spanish. Between the fifteenth and seventeenth centuries, there were more translations of the *Sphaera* into Castilian and Portuguese than into all other European vernaculars combined. A major reason for the interest in *Sphaera* translations in Spain and Portugal was that the basic astronomical and geographical knowledge contained in this text could be used for navigation. Because of their enormous interests in overseas exploration and colonization, Iberian monarchs supported the development of cosmography, a subject that combined mathematics, astronomy, and geography. The astronomical information in the *Sphaera* was also valued on the Iberian Peninsula for its applications to astrology. Finally, the *Sphaera* was critical to a Christian education because it taught readers to appreciate the wonders of God's creation. Spanish and Portuguese commentaries on Sacrobosco's *Sphaera* reflect this mix of practical, political, and spiritual concerns.

### 1 Introduction

In 1792, French philosophe Nicolas Masson de Morvilliers (1740–1789) characterized Spain as “the most ignorant nation in Europe” (Navarro-Brotóns and Eamon 2007, 27). A weak and ineffective government, combined with a powerful and oppressive Catholic clergy and Inquisition, and a lazy and superstitious population meant that Spain was an intellectual backwater. “Spanish science” was an oxymoron. All the progress of the Scientific Revolution and the Enlightenment took place far away from the Iberian Peninsula and had limited impact there. This dismissive and caricatured view of Spain and its intellectual history is, of course, no longer tenable. Several generations of historians of Spanish science have made abundantly

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161

clear that early modern Spain and Portugal had a lively scientific culture (Portuondo 2017). This culture was distinctive, characterized by a focus on the practical problems and empirical evidence produced by voyages of exploration and colonization and often conducted in vernacular languages (Leitão and Sánchez 2017). But Spanish and Portuguese scientists were also active participants in European-wide natural philosophical debates and made distinctive contributions to the Scientific Revolution of the sixteenth and seventeenth centuries.

In this paper I examine a group of commentaries on Johannes de Sacrobosco's (died ca. 1256) *Sphaera* produced by Portuguese and Spanish authors. The *Sphaera* was one of the most popular scientific texts in early modern Spain and Portugal. In the sixteenth and seventeenth centuries there were at least ten printed *Sphaeras*, most with commentaries, in Spanish and Portuguese, and many more manuscript versions (Martins 2004, 371–73). The sheer number of *Sphaeras* with commentaries suggests that there was a lively conversation about astronomy and cosmology on the Iberian Peninsula. Close reading of some of these treatises helps to illuminate the scientific culture of early modern Spain and Portugal, and allows us to see the features that both distinguish this scientific culture from that of other parts of Europe as well as what connects it to the larger European intellectual scene. Although historians of science have by and large moved “beyond the Black Legend,” there is much about early modern Spanish and Portuguese contributions to and involvement with science that remain unclear, and Iberian science is still poorly integrated into larger histories of the Scientific Revolution. Analysis of *Sphaera* commentaries demonstrates that Spanish and Portuguese authors were engaged with a range of issues, practical, natural philosophical, and theological, that they were engaged with the work of scholars across Europe, and that their work was read far beyond the borders of Iberia.

## 2 The Iberian Context

Spain and Portugal were engaged in voyages of exploration and colonization earlier than the rest of Europe. A major reason for interest in the *Sphaera* in Spain and Portugal was that the basic astronomical and geographical knowledge contained in this text could be used for navigation (Martins 2004). Because of their enormous interests in overseas exploration, exploitation, and colonization, the Spanish and Portuguese monarchs actively supported the development of cosmography, a subject that combined mathematics, astronomy, and geography. These intellectual disciplines were vital to the success of colonial operations. Astronomical knowledge served vital state interests—and received state support—in a way that it did not in other parts of Europe.

The Portuguese were the first to venture into parts of the Atlantic Ocean not previously traversed by Europeans. The Portuguese voyages began with the conquest of the North African city of Ceuta in 1415. This military victory was followed by decades of exploration of the west coast of Africa sponsored by the Portuguese

monarchy, or more precisely, by Prince Henry the Navigator (1394–1460), younger son of King João I (1357–1433). In 1488, a voyage headed by Bartholomeu Dias (ca. 1450–1500) rounded the southern tip of Africa, the Cape of Good Hope, which gave the Portuguese access to the Indian Ocean and thus a maritime route to Asia (Leitão 2003, 229–30; Leitão 2009). The scale and scope of these voyages was unprecedented, as were the logistical, administrative, technological, and navigational challenges they posed. Sometime in the second half of the fifteenth century, the Portuguese Crown established the *Armazéns da Guineé Índia* (Storehouse of Guinea and the Indies) to meet these challenges. The *Armazéns* coordinated the African voyages and managed the flow of information, people, and objects coming from them. One responsibility of the *Armazéns* was the improvement of navigational tools and techniques as well as the training of navigators (Leitão and Sánchez 2017, 202–03). Much of this work involved the basic astronomical knowledge to be found in Sacrobosco's *Sphaera*. For example, between 1455 and 1475, the Portuguese developed a method for determining latitude at sea using measurements of the height of the North Star taken with a mariner's astrolabe (Leitão 2009, 30). The demand for men with training in practical mathematics and astronomy grew as the global reach of the Portuguese extended. In 1547, the Crown established the position of chief cosmographer, a man tasked with training pilots as well as examining nautical charts and instruments (Leitão 2003, 233).

The other major site for the teaching of astronomy and mathematics in early modern Portugal was the Jesuit Colegio de Santo Antão in Lisbon, which was established in 1553 (Leitão 2003, 234; Leitão 2007). At the request of King João III, the Colegio added the *Aula da Esfera* (Course on the *Sphaera*), a set of lectures on mathematical topics, in 1574. This course was initially only for Jesuit students, but became public in 1590. According to Carolino and Leitão, “great importance [was] attached to nautical questions: elements of cosmography, rules of nautical astronomy and navigation, uses of nautical instruments (astrolabe, quadrant, etc.), the design and construction of nautical charts and globes, etc.” (Carolino and Leitão 2006, 162). In keeping with its practical teaching agenda, instruction at the *Aula da Esfera* was in Portuguese, not Latin (Leitão 2006, 374).

In Spain, two state-supported institutions were established “to coordinate the colonization and exploitation of the New World: the *Casa de la Contratación* or House of Trade in Seville and the Council of the Indies” (Portuondo 2009, 4). The *Casa* was founded in 1503 to coordinate and regulate commerce and navigation to the Americas and the Indies (Portuondo 2009; Barrera-Osorio 2006; Sandman 2001). The *Casa* needed men who could prepare instruments and charts for navigation, teach methods of navigation, and make maps. The chief cosmographer at the *Casa* was responsible for licensing pilots and administered an exam to make sure they knew how to use navigational instruments. Cosmographers at the *Casa* produced numerous navigation manuals in Spanish for pilots and navigators in the first half of the sixteenth century (Portuondo 2009; Sandman 2001). Most of these manuals contained material either directly translated from or heavily based on Sacrobosco's *Sphaera* (Portuondo 2009; Martins 2004). The *Casa* brought together university-educated scholars and practically-trained navigators and sought to foster

cooperation between those with theoretical expertise and those with practical experience. However, the relations between these two groups were far from smooth. Cosmographers promoted the use of astronomical instruments—most notably the astrolabe, which was used to find latitude at sea. Navigators, on the other hand, preferred to use the compass and dead reckoning (Sandman 2001). Because Sacrobosco's *Sphaera* offered a basic introduction to astronomy, a number of cosmographers saw it as a valuable resource in convincing pilots, as well as royal and aristocratic patrons, of the usefulness of astronomical knowledge.

In Portugal, astronomy and mathematics were neglected at the universities of Evora and Coimbra, although they were taught at the *Armazéns* and the *Aula da Esfera* (Carolino and Leitão 2006, 162). By contrast, in Spain astronomy and mathematics flourished at the universities of Salamanca, Valencia, Alcalá, and Seville (Navarro-Brotóns 2006). At all of these institutions the *Sphaera* was an important teaching text. The University of Salamanca was a key early site for the development of cosmography (Chabás 2006). The curriculum included subjects like cartography, and incorporated information from voyages to the West Indies and the Americas. Beginning in 1529, the university's statutes specified that the mathematics professor teach arithmetic, geometry, astrology, perspective, and cosmography. This statute was instituted because the Spanish Crown was concerned that there be enough men trained in cosmography, because the subject was critical for navigation and for the mapping of Spain's overseas possessions. The other three universities followed suit over the course of the sixteenth century. These statutes meant that university professors in Spain who taught mathematical subjects, including the *Sphaera*, taught a more diverse body of students than at other European universities. Their students included traditional university students, but also practical men training for careers in navigation and cartography. To accommodate both these groups, instruction in mathematical subjects was often in Spanish rather than Latin. In the sixteenth century, at the University of Salamanca, basic astronomy, including Sacrobosco's *Sphaera*, was taught in Castilian rather than Latin. In 1529, and again in 1538, the university statutes specified that all instruction should be in Latin, except for "grammar, music, rhetoric and astrology [i.e. astronomy]" (Gómez Martínez 2006, 205).

The astronomical information in the *Sphaera* was also valued on the Iberian Peninsula, as elsewhere in Europe, for its applications to astrology. Astrology was critical to medical practice, as well as to political and personal decision-making. Several professors at the Jesuit Colegio da Santo Antão in Lisbon taught courses on astrology as part of the *Aula da Esfera* (Leitão 2006; Carolino 2017). In Spain, astrology was taught at the universities of Valencia, Salamanca, Alcalá de Henares, and Valladolid from the late fifteenth to the early eighteenth centuries (Lanuza-Navarro 2017a, b, 413–18). It was also taught at the Casa de Contratación and the Academia de Matemáticas in Seville. Members of the Spanish royal family and court regularly consulted astrologers throughout the sixteenth and seventeenth centuries (Lanuza-Navarro 2007, 75–77). And in both Portugal and Spain, astrology was considered integral to medical theory and practice (Lanuza-Navarro 2006) (Chaps. 3 and 10).

Alongside a strong emphasis on the practical uses of astronomy and mathematics, Iberian scholars were also engaged with the same natural philosophical questions about the structure of the cosmos that preoccupied scholars in other parts of Europe. Some of their natural philosophical speculations were incorporated into commentaries on the *Sphaera*. Although, as noted above, the teaching at the *Aula da Esfera* was focused on the practical uses of astronomy and mathematics, it also “served as an exceptional channel of communication with the scientific centers of Europe” (Leitão 2003, 236). Two Italian Jesuits who taught at the *Aula da Esfera*, Cristoforo Borri and Giovan Paolo Lembo, both discussed Galileo’s telescopic observations of 1610 and 1611. Lembo carried out his own telescopic observations in Lisbon, and his lecture notes indicate that he “addressed the cosmological consequences of these new observations, discarding the traditional Ptolemaic system and proposing a semi-Tychonic system instead” (Leitão 2003, 236).

In Spain, new cosmological discoveries and ideas were discussed at both the universities and at the *Casa* and *Consejo*. For example, Jerónimo Muñoz (ca. 1520–1591), who taught astronomy and mathematics at the universities of Valencia and Salamanca, was one of the many European scientists to observe and write about the supernova of 1572. For Muñoz, the supernova challenged the Aristotelian notion that change was impossible in the celestial realm. In some of his unpublished work and letters to other European astronomers like Tycho Brahe (1546–1601), he espoused an understanding of the relationship between the celestial and terrestrial realms drawn from Stoic philosophers. He denied the existence of celestial orbs and instead asserted that the planets moved through the heavens like birds through the air or fish through the water. He also discussed Nicolaus Copernicus’ (1473–1543) heliocentric system with his students, although he did not endorse it (Navarro-Brotóns 1995, 57). In fact, as Victor Navarro-Brotóns has shown, “the work of Copernicus circulated freely in sixteenth-century Spain, where its technical and empirical aspects were greatly admired and used” (Navarro-Brotóns 1995, 63). In 1561, the statutes of the University of Salamanca specified that in the second year of the astronomy course the professor must teach either “the *Almagest* of Ptolemy, or its *Epitome* by Regiomontanus, or Geber, or Copernicus,” and that the students could vote on which text they wanted (Navarro-Brotóns 1995, 55). In 1594, these statutes were amended and the teaching of Copernicus was made mandatory, no longer subject to the vote of the students (Navarro-Brotóns 1995, 59). The 1594, statutes were reproduced with no change in 1625, despite the prohibition of Copernicus’ work by the Roman Inquisition in 1616 (Navarro-Brotóns 1995, 60). In fact, *De revolutionibus* was “never placed on any Spanish Inquisitorial index” (Navarro-Brotóns 1995, 63), which does not mean Spanish astronomers were free to adopt heliocentrism but does indicate that it was possible to teach and discuss Copernicus in Spanish universities. As Navarro-Brotóns notes, only one Spanish scholar, Diego de Zúñiga (1536–1597), is known to have actually endorsed the Copernican system. Others used the Prutenic tables, which were calculated using Copernicus’ mathematical models, and other parameters drawn from *De revolutionibus*, in much the same way that Copernicus was taught at the University of Wittenberg (Navarro-Brotóns 1995, 59; Westman 1975). Finally, interest in

Copernicus spread outside universities, because the Prutenic tables and other technical aspects of Copernicus' work had applications in navigation. For example, Juan Cedillo Diaz (ca. 1560–1625), who studied at Salamanca and became chief cosmographer at the *Consejo de Indias* and professor at the Mathematical Academy in Seville in 1611, made a free Spanish translation of the first three books of Copernicus' *De revolutionibus* sometime between 1620 and 1625 (Granada and Crespo 2019; Navarro-Brotóns 1995, 63; Esteban Piñeiro and Gómez Crespo 1991).

Beyond these practical and philosophical issues, there was a long tradition, going back to Plato, of regarding the study of astronomy as essential to the cultivation of virtue. For many medieval and early modern people, the *Sphaera* was critical to a Christian education because it taught readers to appreciate the wonders of God's creation. Spanish and Portuguese translations of and commentaries on Sacrobosco's *Sphaera* reflect this mix of practical, philosophical, and spiritual concerns.

## 2.1 Tractado da Spera (*Lisbon, 1510*)

In around 1510, an anonymous Portuguese translation of the *Sphaera* appeared in Lisbon (Bensaude 1914; Martins 2004, 371). This is the first printed *Sphaera* in any European vernacular, although there were certainly vernacular versions in manuscript both earlier and later. This Portuguese translation, titled *Tractado da Spera* (Treatise on the sphere), does not have a formal commentary in the academic sense, but it does have significant extra material attached to it. This *Sphaera* was appended to a treatise on navigation titled *Regimento do estrolabio & do quadrante pera saber ha declinaçam & ho logar do soll em cada hora in dia & asy pera saber ha estrella do norte* (Rules of the astrolabe and the quadrant to find the declination and the place of the sun every hour of the day and also to know the north [pole] star). This short treatise contained instructions for using a mariner's astrolabe and quadrant. It was one of the very first printed books to contain instructions for two new methods for determining latitude at sea: the first using the height of the North Star and the second using the height of the noon sun. As Leitão points out, both of these methods were devised by the Portuguese sometime in the second half of the fifteenth century to meet the challenges of exploring the west coast of Africa (Leitão 2009, 30–32). The practical information in this translation of the *Sphaera* summarized the results of several decades of collaborative scientific work to solve some of the problems of navigating into previously unknown waters. The book was published in a small handy format that could conceivably have been carried on a sea voyage. This Portuguese *Sphaera* stands at the beginning of a long line of navigational manuals that incorporate the *Sphaera*. Multiple versions of these manuals were produced in Spain and Portugal and subsequently the formula was copied in other countries (Leitão 2009, 36; Portuondo 2008, 63).

In addition to information on navigational instruments, this *Sphaera* includes a Portuguese translation of a letter originally written in Latin by Hieronymus Münzer (ca. 1447–1508) to King João II of Portugal (1455–1495) in the summer of 1493

(Pohle 2017, 63). Münzer was a Nuremberg physician, humanist scholar, traveler, and one of the authors of the famous *Nuremberg Chronicle*. In the letter of 1493, Münzer informs João II that the Holy Roman Emperor Maximilian I (1459–1519) recommended that João pursue a westward route to “Cathay.” He further recommended Martin Behaim (1459–1507), a German cosmographer already known to João (Pohle 2017), to lead this voyage. What Maximilian, Münzer, and Behaim had in mind was a westward passage across the Atlantic to China, but at a much more northerly latitude than the route Christopher Columbus (1451–1506) had taken in 1492. There was already doubt that Columbus had actually succeeded in finding a route to the Indies, although Columbus himself vehemently asserted that he had. It would not have been unreasonable for any of the people involved in this scheme to believe that a better route might be found (one that actually ended in the Far East) (Hunter 2011). Münzer visited João in 1494 as an emissary of Maximilian (Horst 2017, 18; dos Santos Lopes 2017, 77), and it seems likely he discussed the plan further with the Portuguese monarch.

The letter from Münzer to João II functions as a kind of commentary on the contents of the *Sphaera*. Münzer urges the king to take both ancient authorities and more recent experience into account in considering the feasibility of finding a new sea route to China. Münzer writes that Aristotle (348–322 BCE), Seneca (ca. 1–65), Pierre d’Ailly (1351–1420), “and many other illustrious men, have said that the beginning of the habitable Orient is very close to the end of the habitable West. The proof is in the elephants, which abound in these two places, and similarly in the reeds which the storm from the east throws on the coast of the Azores islands” (Bensaude 1914, 61). But he is also critical of the errors of ancient and medieval authorities and opposes their errors to recent experience, which must carry greater weight. “Do not let yourself be troubled by Alfraganus and others without experience,” he writes, “who say that only a quarter of the land is above the sea level, and that the earth in the other three quarters is drowned under the sea, because in things pertaining to the dwelling of the earth, we must believe rather the experience and probable stories than fantastic imaginations. You certainly know that many authoritative astronomers have denied that there is any habitable land in the tropics and in the equinoctial regions. But you have proved by experience that these things were false and foolish” (Bensaude 1914, 61).

We have evidence that this *Sphaera* was read outside of Portugal and by at least one humanist with interests in overseas exploration. There is only one extant copy of the book, in the Bavarian State Library (Bayerische Staatsbibliothek). This copy originally belonged to the German humanist Conrad Peutinger (1465–1547), who assembled one of the largest private libraries in Europe. At his death he owned around 200 manuscripts and 10,000 printed books. He collected many books and manuscripts having to do with geography, travel, and navigation, and was very interested in the overseas “discoveries” of the Portuguese in Africa and the “New World” (dos Santos Lopes 2017, 78). He had a number of Portuguese books and manuscripts in his collection. Peutinger had multiple connections to Portugal and multiple reasons for being interested in Portuguese voyages of exploration. Born into a wealthy Augsburg family, Peutinger was educated at the universities of Basel,

Padua, and Bologna, and he was acquainted with the leading humanist scholars of his age. He achieved a high-level administrative position in the city of Augsburg, and eventually became one of the Holy Roman Emperor Maximilian I's chief confidants, advisors, and diplomats. In this role, he may certainly have been aware of Maximilian's overture, through Münzer, to the Portuguese King João II, to convince him to support an expedition to China by sailing across the Atlantic Ocean. Peutingger had other reasons to be interested in and familiar with Portuguese voyages. He was married to Margarete Welser (1481–1552), member of a wealthy Augsburg patrician family. The Welsers were merchants with far ranging operations. They were the first Germans who, after the discovery of the Indies, established a sales office in Lisbon. They were also the first Germans who joined their ships with Portuguese fleets heading East (dos Santos Lopes 2017, 78).

Many of the Portuguese books in Peutingger's collection were sent to him by Valentim Fernandes, a German printer who moved to Lisbon and was active there from 1494 to 1518 (dos Santos Lopes 2012, 2017, 78; Hendrich 2017; Blackmore 2009, 25–26). Fernandes is a reasonable candidate for the printer of this Portuguese sphere although he is not identified on the title page. In this period there were only about eleven printers active in Lisbon. Fernandes published other books connected to exploration, including a translation into Portuguese (which he prepared) of the travels of Marco Polo (1254–1324) (*Livro de Marco Paulo*, 1502). Further, he had a close relationship with both the Portuguese court and with Germans resident in or visiting Portugal. He would certainly have been familiar with the representatives of the Welser family. When Hieronymus Münzer visited Lisbon in 1494 on a diplomatic errand for Maximilian I, Fernandes served as his translator. As noted, Fernandes had an ongoing relationship with Conrad Peutingger and sent him a number of Portuguese books. Although this *Sphaera* is small and unprepossessing, it reflects a dense network of connections between the Holy Roman Empire and Portugal in the early sixteenth century, and intense interest in voyages of exploration on the part of a wide variety of people—humanists, diplomats, monarchs, printers, and sailors (Horst et al. 2017).

## 2.2 *Francisco Faleiro, Tratado del esfera y del arte del marear (Seville: Juan Cromberger, 1535)*

Another translation of the *Sphaera* ostensibly aimed at navigators was Francisco Faleiro's *Treatise on the sphere and on the art of navigation*, published in Seville in 1535 (Faleiro 1535). Faleiro was a Portuguese cosmographer who came to Spain in 1518 and worked at the House of Trade from 1519 to 1532. Faleiro's text is, as the title suggests, two separate books: the first a partial translation of Sacrobosco's *Sphaera* and the second a treatise on navigation. The translation of the sphere contains numerous illustrations to facilitate understanding, and some commentary on the original text. In the treatise on navigation, Faleiro proposed a solution to a problem that plagued navigators, the magnetic variation of the compass (Collins 2013).



Magnetic variation causes compass needles to deviate from true north. For navigation in smaller areas like the Mediterranean the deviation is not great enough to cause problems. But on long ocean voyages it is. As Maria Portuondo notes, "Navigation manuals became a forum for advocating different ways of coping with the problem, either by designing instruments that 'corrected' the compass reading or trying to use the needle's deviation as an indicator of longitude" (Portuondo 2008, 64).

Faleiro translated portions of the *Sphaera*, rearranged them, and added new material, reflecting the book's function as a teaching text for men who were going to sea. Indeed, like the Portuguese *Sphaera* discussed above, the text is small enough that it was conceivably taken to sea for use as a reference. However, despite this clearly practical context, Faleiro's *Sphaera* is notable for the repeated emphasis on the importance of cosmographical knowledge in cultivating Christian piety. In the introduction, Faleiro claims he has translated the *Sphaera* "for those like me who do not have polished Latin," so that they might be able to learn about "the admirable works and marvels of God."<sup>1</sup> Contemplation of the divine works of creation will lead the reader to a deeper knowledge and love of God. The Christian who learns about the heavens "will know much more clearly the greatness, power, and wisdom with which such work was made, and with much more understanding, joy and knowledge give praise to the Lord, as the psalmist says: The heavens declare the glory of God."<sup>2</sup>

Faleiro expanded on various sections of the *Sphaera* and cut others entirely. In his discussion of the planets he comments on their influences on human life and health. For example, he informs readers that Saturn is cold and dry, connected to the humor melancholy, and has a generally negative effect on human life. This was all quite standard astrological fare, but it was not in Sacrobosco's original text. Faleiro uses it to emphasize the interconnectedness of the heavens and the earth, and the magnificence of God's plan for the world. Faleiro cut out the last section of Sacrobosco's *Sphaera*, which introduced mathematical models for the motions of the sun and the moon. Perhaps he deemed them too technical and unnecessary for his projected audience.

Faleiro also corrected and updated Sacrobosco's original text by referring to knowledge gained through the recent experiences of Portuguese and Spanish explorers. For example, Sacrobosco had asserted that there were five climactic zones: a torrid zone around the equator which was too hot to sustain life, two frigid zones around the Arctic and Antarctic poles which were too cold to sustain life, and two temperate zones which were the right temperature to sustain life. Faleiro pointed out

<sup>1</sup>(Faleiro 1535, fol. a ii v): "...para que los que como yo no alcancaren la polida latinidad: a esta falta no dexen de saber algo por natural razon delas admirables obras y maravillas de dios."

<sup>2</sup>(Faleiro 1535, fol. a iii): "Mas el christiano que por todo esto passare contemplando y viendo como el esphera y la orden della es la mas excelente y admirable obra entre todas las obras despues de la que dios a su semejanca hizo: con mucha mas claridad conocera la grandeza / poder / y saber del que tal obra hizo: y con much mas conocimiento / gozo y saber dara loores al señor: y conel psalmist dira. Celi enarrant gloriam dei."

that Portuguese voyages to the Cape of Good Hope and Brazil demonstrated that no portion of the earth was uninhabitable. And far from being arid deserts, the equatorial regions were remarkably fertile. According to travelers's reports, "cucumbers and melons, pears, lettuce, eggplant, and many other fruits"<sup>3</sup> grew year-round in the torrid zone, rather than only in a particular season as in the temperate zone. However, the peoples of this region were sometimes strange—Magellan allegedly found people almost the size of giants on his voyages of 1520–1521. In general, Faleiro informs his readers, "The temperate zone is populated by the best part of people, most endowed with reason and of better understanding and more skill than people who inhabit the other zones."<sup>4</sup>

In this section, Faleiro uses Sacrobosco to represent received and authoritative knowledge, and he opposes this authoritative knowledge drawn from books with experience. But Sacrobosco's statement that the torrid and frigid zones of the earth were uninhabitable was by no means a universally accepted claim in antiquity or the Middle Ages. For example, in the 1260s Campanus of Novara (ca. 1220–1296) composed an astronomical textbook, one that Lynn Thorndike describes as "evidently...indebted" to Sacrobosco's *Sphaera*, in which he argued that the climate at the equator was temperate (Thorndike 1949, 28). Long before European voyages of exploration began in the fifteenth century, commentators on Sacrobosco's *Sphaera* refuted his claim that the torrid and frigid zones were uninhabitable, drawing on reason, experience, and authoritative texts. One of the earliest commentaries on the *Sphaera* is by Robertus Anglicus (13<sup>th</sup> cent.) and was composed around 1271 (Thorndike 1949, 28). On the subject of the torrid zone, Robert argued "that the equatorial region is habitable and not merely habitable but fine to live in" (Thorndike 1949, 239). He cited Avicenna (980–1037) and Isidore as authors who asserted that the torrid zone was habitable, but he also reasoned that since days and nights are always equal at the equator, the heat of the day would always be balanced out by the cool of the night, creating a temperate climate. Nevertheless, these passages on the climactic zones in Faleiro's *Tratado del esphera* reflect the high value he placed on experiential knowledge. He could have cited various ancient and medieval authorities who argued that the equatorial region was temperate, but he chose to highlight the reports of mariners. In so doing he created a sense of progress, of modern knowledge surpassing ancient wisdom. Many historians of Spanish and Portuguese science identify this kind of valorization of experiential and empirical evidence as a distinctive feature of "Iberian science" and a major contribution to the development of modern science (Leitão and Sánchez 2017; Portuondo 2009; Barrera-Osorio 2006). As Henrique Leitão and Antonio Sánchez write, "All Iberian literature connected to maritime discoveries in this period exhibits a vigorous and self-conscious departure from ancient authorities. The new knowledge was not acquired by logical

<sup>3</sup> (Faleiro 1535, fol. ciii): "...pepinos y melones / peras / lechugas / berenjenas: y otras muchas frutas...."

<sup>4</sup> (Faleiro 1535, fol. ciii): "Esta templada zona es poblada por la mayor parte de gentes mas acogidas a razon y de mejores entendimientos y mas abiles y para mas que las otras gentes de que son abitadas las otras zonas."

sylogisms and deductive reasoning, but by experience—i.e., by direct empirical evidence” (Leitão and Sánchez 2017, 208).

Faleiro is also concerned to explain how this newly acquired geographical knowledge can be incorporated into biblical interpretation. He concludes that Asia and Europe are in the temperate zone, while most of Africa is in the torrid zone. And it is in the temperate zone that all the important historical events have occurred. The first human beings were created and sinned for the first time in the temperate zone. Noah built his ark in the temperate zone. The twelve tribes of Israel were dispersed in the temperate zone. And so on. All the events of biblical and world history occurred in Europe and Asia. Africa was in this account devoid of history and significance (Faleiro 1535, fol. ciii–ciii v). It is worth pointing out that by the time Faleiro wrote, the Portuguese slave trade had been going on for almost a century and was one of the most lucrative aspects of Portuguese overseas operations (Saunders 1982). Faleiro's low estimation of the peoples of Africa must be seen in the context of ongoing efforts to provide legal, philosophical, and moral justification for human trafficking.

Significantly, there is very little in Faleiro's translation of the *Sphaera* that refers to the practical uses of astronomy in navigation. That is all reserved for the second half of the book, on the art of navigation. The material in the *Sphaera* was clearly necessary for the reader to make sense of the navigational tools and techniques described in the second part, but Faleiro cast his version of the *Sphaera* as a pious contemplation of the wonders of the cosmos God created and the unfolding of human history according to God's plan.

### 2.3 *Pedro Nuñez, Tratado da sphaera com a Theorica do Sol e da Lua (Lisbon: Germão Galharde, 1537)*

In 1537, Pedro Nuñez (1502–1578), one of the most prominent European mathematicians of the sixteenth century, published a Portuguese translation of the *Sphaera* with commentary (Nuñez 1537). Nuñez's book was called *Tratado da sphaera com a Theorica do Sol e da Lua* (Treatise on the sphere and *Theorica* of the sun and moon). It also included a translation of the first book of Ptolemy's (died 160) *Geography*, a translation of the chapters on the sun and moon from Georg Peurbach's (1423–1461) *Nova Theorica*, and two treatises on navigation (the first on “certain doubts about the navigation” and the second on the nautical chart). Nuñez was educated at the University of Salamanca and then the University of Coimbra in Lisbon. Between 1544 and 1562 he held the Chair of Mathematics at Coimbra, a position that required him to teach arithmetic, geometry, perspective, music, and astronomy (Leitão 2009, 81; Carolino and Leitão 2006, 159; Leitão 2002 15–27). Although he was a brilliant mathematician, he seems to have been an indifferent teacher. Carolino and Leitão comment dryly that his “classes in Coimbra seem to have been constantly plagued by lack of attendance, both by students and

by Nuñez himself” (Carolino and Leitão 2006, 159). In 1547, he was appointed to the newly created position of chief cosmographer, a position that gave him responsibility over navigators, cartographers, and instrument makers, as well as access to the royal court (Leitão and Sánchez 2017, 204; Leitão 2003, 233). Nuñez’s translation and commentary on the *Sphaera* reflects his multiple roles as university professor, royal adviser, and trainer of pilots. His book contained a great deal more theoretical information on astronomy and mathematics than did either of the two *Sphaerae* I have discussed so far. In the first half of the sixteenth century there was considerable disagreement about just how much theoretical knowledge navigators needed (Sandman 2001; Portuondo 2009; Almeida 2008). Some, like Nuñez, felt that navigators needed a very solid grounding in mathematics, astronomy, and cosmology to do their jobs safely and effectively. At the other extreme were those who were satisfied with rote memorization of rules and the use of tables. As Bruno Almeida notes, Nuñez distinguished between “*ars navigandi*” and “*ratio navigandi*.” The “art” of navigation was based on known sets of rules, procedures, and instruments.” “Rational” navigation, which Nuñez held to be far superior, was “based in the understanding and use of mathematical principles” (Almeida 2012, 462).

Nuñez, like Faleiro, referred to Portuguese voyages of exploration to refute the idea that there were parts of the earth that were uninhabitable: “The navigations of the Portuguese show us that there is no land so distempered by hot or by cold that it is not inhabited.”<sup>5</sup> In addition, he tried to introduce greater mathematical precision and rigor into Sacrobosco’s *Sphaera*. For example, he adds a reference to the spherical geometry of Theodosius (ca. 160–ca. 100 BCE) to Sacrobosco’s discussion of the movement of the sun and the unequal lengths of the day. The passage in Sacrobosco reads,

In the right sphere the horizon, since it passes through the poles of the world, divides all those circles into equal parts, whence the arcs of days are the same as those of nights for persons living at the equator. Hence it is evident that for persons living at the equator it is always equinox, wherever the sun may be in the firmament. (Thorndike 1949, 133).

Nuñez adds,

Theodosius, in proposition 19 of his first book, demonstrates that every major circle passing through the poles of another circle cuts it in two equal parts and right angles. And in [proposition] 18, he demonstrates that if you cut a minor [circle] in half, you must pass through the poles.<sup>6</sup>

Nuñez also includes a new mathematical demonstration about the climactic zones (Nuñez 1537, fols. c–ciii v). At the end of book three in the *Sphaera* Sacrobosco describes the seven climes into which the habitable portion of the earth

<sup>5</sup>(Nuñez 1537, fol. b): “As navegações dos portugueses nos a mostram que não ha terra tam destemperada per quente ne per fria em que não aja homes.”

<sup>6</sup>(Nuñez 1537, fol. Biii.): “Theodosio demonstrou a 19. proposição do seu primeiro livro que todo circulo mayor que passa pellos polos de outro circulo o corta en duas partes yguais e per angulos reytos: e na. 18. demonstra que se cortar a algum menor pella metade he necessario que passe pellos polos delle.”

was divided. Sacrobosco defines these by the average length of the longest day of the year in each, ranging from 13 h in the southernmost to 16 in the northernmost. The climes were of unequal size as well, ranging from 440 miles across to 185. In other words, the climes closer to the equator were wider, those closer to the north pole narrower. But Sacrobosco provides no rationale for these numbers. Nuñez proposes a mathematical demonstration of the varying width of the climate zones. Matteo Valleriani has traced the way in which this particular section was incorporated into a large number of subsequent *Sphaera* commentaries (Valleriani 2017). The French humanist Elié Vinet (1509–1587) translated this section of Nuñez's commentary into Latin and incorporated it into his own commentary on Sacrobosco's *Sphaera*. Vinet's commentary was reprinted numerous times, first in Paris and then in several major European cities. In this way, Nuñez' mathematical demonstration spread all over Europe.

#### 2.4 *Jerónimo de Chaves, Tractado de la sphaera que compuso el doctor Ioannes de Sacrobusto con muchas additiones (Seville: Juan de Leon, 1545)*

In 1545, Jerónimo de Chaves (1523–1574) published a translation of Sacrobosco's *Sphaera* with commentary (de Chaves 1545). Jerónimo de Chaves was a mathematician, astronomer, and cosmographer who held important positions at the House of Trades. He followed in the footsteps of his father, Alonso de Chaves (1492–1586), who was also a cosmographer at the House of Trades (Sánchez Martínez 2010; Martins 2004, 376; Sandman 2001). Jerónimo de Chaves's sphere was called *Treatise of the sphere composed by doctor Johannes de Sacrobosco with many additions*. His treatise contains more theoretical material and less practical material than any of the *Sphaeras* I discussed above. Chaves' translation of Sacrobosco's *Sphaera* contains a quite extensive commentary. However, despite his later role as a teacher of navigators, the commentary contains very little directly related to navigation. In the prologue, he claims that he chose to translate the *Sphaera* "for the pleasure and common usefulness of my country and my friends."<sup>7</sup> But he makes clear that he had far more in mind than the usefulness of this text as a basis for navigation. He claims that he wanted to make accessible to those who could not read Latin, "the most sublime science and art of Astronomy,"<sup>8</sup> which reveals the "Majesty, Wisdom and infinite Power"<sup>9</sup> of the creator (de Chaves 1545, fol. iii). Chaves' view of the "utility" (*utilidad*) of astronomy was quite broad (Omodeo 2017). He asserts that the material in Sacrobosco's *Sphaera* was essential for philosophers, physicians, and astrologers. It was also necessary if one wanted to comprehend "certain passages

<sup>7</sup>(de Chaves 1545, fol. iii): "...dela delectation y utilidad commun de mipatria y amigos...."

<sup>8</sup>(de Chaves 1545, fol. iii): "...tan sublimada sciencia y arte de la Astronomia...."

<sup>9</sup>(de Chaves 1545, fol. iii): "...su Magestad, Saber, y infinito Poder...."

and obscure verses of poets.”<sup>10</sup> Here he seems to have had in mind primarily Virgil (70–19 BCE), whose *Georgics* is cited throughout the commentary, as well as Lucan (39–65). Navigation only comes in at the end of Chaves’s list of reasons for learning astronomy. There are only a couple of references in the entire book to “those who sail the Atlantic.”<sup>11</sup> Very little material in the book touches on problems of navigation or cosmography relevant to exploration of the “New World.” Chaves includes a discussion of the location of the meridian at the “Fortunate Isles” (or the “Canaries”), a topic of much contention between Spanish and Portuguese cosmographers (Sandman 2001). He includes a table of the positions of fixed stars but does not include any “new” stars or constellations, like the Southern Cross (de Chaves 1545, fol. xlviij v). Similarly, he includes a table of the longitudes and latitudes of various places, but all in Spain, nothing in the “New World” (de Chaves 1545, fol. l v–li).

While Chaves’s translation of Sacrobosco’s *Sphaera* may well have appealed to people who could not read Latin (or who could not read Latin well), he had a more learned audience in mind as well. He claimed that his version of the *Sphaera* had more extensive commentary, including “many demonstrations, figures and supplementary tables,”<sup>12</sup> than most other editions of Sacrobosco, even those in Latin. And indeed, his explanations and expansions on Sacrobosco’s original text are long and detailed, and his text is richly illustrated. Much of his commentary engages with natural philosophical issues that concerned his contemporaries, both in Spain and in other parts of Europe. For example, he discusses celestial orbs in much greater detail than Sacrobosco did. In his commentary on Sacrobosco’s first book, Chaves explains the difference between an orb and a sphere and includes a picture of an orb whose concavity has a different center than its outer surface. This material was certainly not necessary for navigation, but it was an important prelude to a discussion of the structure of celestial orbs in the more advanced astronomy text by Georg Peurbach, the *New Theorica* (Crowther and Barker 2013). Chaves wrote this in a period when European astronomers, including Spanish astronomers like Jerónimo Muñoz, were debating whether celestial orbs existed or not, and if they did, what their internal structure was (Barker 2011) (Chap. 6). Chaves also discusses the phenomenon of trepidation (de Chaves 1545, fols. xiii, xvii) and debates about the number of celestial spheres (de Chaves 1545, fol. xv v). Again, none of this material was necessary for navigation, but it was all part of learned discussions of astronomy in this period.

Chaves updated Sacrobosco’s original text with new information gained from the Portuguese and Spanish voyages of exploration. For example, he explains how to determine the longitude of a place using the timing of lunar eclipses (fol. xlviij), a method much discussed by cosmographers interested in mapping Spain’s overseas possessions. Another good example is in the section on the five climactic zones, which Chaves, like Faleiro and Nuñez, notes are all both habitable and inhabited.

<sup>10</sup>(de Chaves 1545, fol. iii v): “...algunos lugares y versos oscuros de Poetas...”

<sup>11</sup>(de Chaves 1545, fols. xxvii v, xxx): “Los que navegan el mar Oceano...”

<sup>12</sup>(de Chaves 1545, fol. iii–fol. iii v): “...muchas demonstraciones, figuras y tablas supputatorias...”

Like Faleiro, Chaves comments on the supposed characters of people in the different climactic zones. According to Chaves, the people in the torrid and frigid regions were wilder and more animal-like than the inhabitants of the temperate zone. People in the torrid region were exposed to excessive heat “which burns their bodies, and blackens them, and dries the humors, and bakes their faces, and weakens their limbs.”<sup>13</sup> Their hair is “black and frizzy” (*negros, y crespos*) and their social customs are “wild and without temperance” (*silvestres y sin temperamento*). People in the frigid zones are very pale, with red hair and large soft bodies. They too are savage and uncivilized. Chaves claims, “There are in these lands or cold areas, men who eat human flesh, and drink blood: as there are also in the torrid zone.”<sup>14</sup> The torrid and frigid zones are full of “evil people, and devils, and beasts who are inimical to human nature.”<sup>15</sup> By contrast, the inhabitants of the temperate zone are “better and healthier men.”<sup>16</sup> These passages show how *Sphaera* commentators corrected Sacrobosco's text, but also how they fit new information into pre-existing intellectual frameworks, in this case climactic theories of human difference that were derived from Hippocrates (ca. 460–ca. 370 BCE). And as I commented in reference to Faleiro's text, by the time that Chaves wrote this, the Portuguese slave trade had been underway for a century and there were several 1000 men, women, and children of African origins, both enslaved and free, living in Portugal and Spain (Saunders 1982). Chaves did not so much “observe” these people as reproduce racial and ethnic stereotypes that had been prevalent in Europe for centuries. The description of Africans as “black” and of blackness as physically, morally, and spiritually inferior to whiteness long predates voyages of exploration (Heng 2011). The thirteenth-century encyclopedist Bartolomeus Anglicus (1190–1250) also described the people of Africa as black, frizzy-haired, cowardly, and full of guile in his *De proprietatibus rerum* (Heng 2011, 316). As in Faleiro's case, Chaves's comments on racial differences need to be seen as part of a justification for enslavement and colonization.

## 2.5 *Martin Cortes. Breve Compendio de la Esfera y de la Arte de Navegar (Seville, 1551)*

One of the most successful translations and commentaries on Sacrobosco's *Sphaera* produced in Spain was the *Brief Compendium of the Sphaera and of the Art of Navigation* by Martin Cortes (1510–1582), published in 1551 in Seville (Cortes 2003). Martin Cortes taught cosmography and navigation to pilots in Cadiz and was

<sup>13</sup>(de Chaves 1545, fol. liiii v): “...les quema sus cuerpos, y los ennegresce, y desecca los humores, y assa les los rostros, y enflaquece sus miembros.”

<sup>14</sup>(de Chaves 1545, fol. liiii v): “Y hallanse enestas terras ò zonas frias, hombres que comen carne humana, y beven la sangre: segun que tambien se hallan enla torrida zona.”

<sup>15</sup>(de Chaves 1545, fol. liiii v): “...malignos, y diablos: y crianse bestias que son empecientes a la naturaleza humana....”

<sup>16</sup>(de Chaves 1545, fol. liiii v): “...los hombres mejor y mas sanos....”

at some point royal cosmographer (Barrera-Osorio 2008). Cortes's book is divided into three parts. The first is heavily based on Sacrobosco's *Sphaera*, the second contains material from Sacrobosco's *Sphaera* along with navigational material, and the third is instructions on the construction and use of navigational instruments (Martins 2004, 378). The translation of the *Sphaera* is indebted to Jerónimo de Chaves's earlier translation, and parts of the sections on navigation are copied from Pedro Medina's (1493–1567) *Art of Navigation* of 1545. Cortes, however, claimed great originality for his book. In his dedicatory letter to the Spanish king Charles V, Cortes claims to have been "the first person to reduce navigation to a brief compendium, setting out infallible principles and clear demonstrations, writing the practice and theory of it, giving the true rules to sailors, showing the way to pilots, making them instruments to know how to take the height of the sun, to know the ebb and flow of the sea, ordering charts and compasses for navigation, advising them of the course of the sun, the movement of the moon, and a clock for the day so true that in all the lands it indicates the hours without any defect, another clock infallible for the nights, discovering the secret property of the stone magnet, explaining the [deviation] of their needles."<sup>17</sup>

Although the claims of originality are greatly overstated, the third part of the book does indeed contain instructions for making and using sea charts (fols. lxi v–lxviii), measuring the height of both the North Star and the sun in order to determine one's longitude at sea (fol. lxxiii), as well as the construction and use of the mariner's astrolabe (fol. lxxv v–lxxviii) and other nautical instruments.

Although written in Spanish for the ostensibly practical purpose of instructing navigators, the *Breve compendio* bristles with references to ancient, medieval, and modern writers, including Aristotle (passim), Lucretius (fol. xiii), Pliny (fol. xxi), Albertus Magnus (fol. xii), Avicenna (fol. xii), Averroes (fol. xi), Alfonso X (fol. xv), Arzachel (fol. xv), Regiomontanus (fol. xxvii), Faber Stapulensis (fol. xx), and Franciscus Capuanus de Manfredonia (fols. xvii, xxxi).<sup>18</sup> And Cortes addresses a number of natural philosophical questions that would not have had practical implications for navigators, including debates about the number of celestial spheres (fol. xii v) and the phenomenon of trepidation (fol. xv v). He also raises the "Pythagorean" argument for a moving earth, if only to reject this idea. Cortes offers both physical and scriptural evidence that the earth is stationary (fols. xiii–xiii v).

Like many other Iberian authors, Cortes incorporates information gleaned from voyages of exploration into his commentary on Sacrobosco. While his citations to a

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<sup>17</sup>(Cortes 2003, fol. ii v): "...mas digo aver sido yo el primero que reduxo la navegacion a breve compendio / poniendo principios infalibles y demonstraciones evidentes / escribiendo pratica y theorica della / dando regla verdadera a los marineros / mostrando camino a los pilotos / haziendoles instrumentos para saber tomar el altura del sol / para conoscer el fluxu yre fluxu del mar / ordenarles cartas y bruxolas para la navegacion / avisandoles del curso del sol / movimiento de la luna / relox para el dia y tan cierto que en todas las terras señala las horas sin defecto alguno / otro si relox infalible para las noches / descubriendo la propiedad secreta dela piedra yman / aclarando el nordestear y norvestear / delas agujas."

<sup>18</sup>On Francesco Capuano da Manfredonia's commentary on *De sphaera* see (Chap. 4).



variety of authors demonstrate his erudition, he consistently valorizes experience over texts and describes the knowledge of his contemporaries as superior to that of earlier generations. “Navigation, as well as the other arts..., has been increasing little by little until it has come to perfection,”<sup>19</sup> he writes in his dedication letter to Charles V. He uses the evidence of recent voyages to refute Sacrobosco's statement that the torrid and frigid zones are uninhabitable (fols. xxi–xxii), and also notes that it was the moderns, not the ancients, that discovered the West Indies (fol. iiiii).

Finally, Cortes sets astronomical and navigational knowledge in an explicitly Christian framework. He begins the book with a chapter on the creation of the world, which starts, “The great God is the beginning and cause of the entire universe,”<sup>20</sup> and goes on to detail the different aspects of creation and the special place of human beings. And in his discussion of the solstices and equinoxes, Cortes states that Jesus Christ was conceived on the vernal equinox and born on the winter solstice, while John the Baptist (first cent. BCE–ca. 28) was conceived on the autumnal equinox and born on the summer solstice (fols. Xxxi–xxxii v). In this way, the solar year is connected to salvation history. Cortes's *Breve compendio* was even more popular in England than it was in Spain. It was translated into English and went through nine English editions between 1551 and 1630 (Martins 2004, 377). This text was one of the means by which a great deal of new information and technology relevant to navigation was disseminated from the Iberian Peninsula to other parts of Europe.

## 2.6 *Rodrigo Saenz de Santayana y Spinosa, La Sphaera de Iuan de Sacrobosco (Valladolid: Adrian Ghemart, 1567)*

One of the largest and most extensive *Sphaera* commentaries in Spanish is the edition published by Santayana y Spinosa 1567 in Valladolid (Santayana y Spinosa 1567). Very little is known about this author, other than that he was born in about 1540 and was a member of the nobility (Martins 2007, 331). Santayana y Spinosa asserts that knowledge of God's creation, and especially knowledge of “the composition and order of the celestial machine, the movements and courses of the circular spheres, the virtues and influences of the stars and celestial constellations”<sup>21</sup> will bring the pious Christian to a deeper knowledge and love of the God. On the frontispiece, there is a line from Psalm 19: “the heavens declare the glory of God; and the firmament sheweth his handywork.” Throughout the text the emphasis is on contemplating the wonders of God's creation. However, Santayana y Spinosa does

<sup>19</sup>(Cortes 2003, fol. iiiii): “La navegacion asi como las otras artes de cada dia se ha ydo augmentando y poco a poco ha venido a tener su perfection....”

<sup>20</sup>(Cortes 2003, fol. ix): “El immenso dios principio y causa de todo el universe....”

<sup>21</sup>(Santayana y Spinosa 1567, fol. 1): “...la compustura y orden de la machina celestial, los movimientos y cursos de sus circulares Spheras, la virtudes e influencias de las Estrellas y constellaciones celestiales....”

assert that understanding the heavens is crucial to understanding life on earth, because the heavenly bodies influence earthly bodies, including the human body. As he puts it, “He who knows [astrology] can avoid many influences of the stars, because he knows his own nature, and he can prepare beforehand.”<sup>22</sup> Only a man who actually understood how he was influenced by the stars could take charge of his destiny. Santayana y Spinosa includes a significant amount of astrological material in his commentary, including a spirited defense of the utility and validity of astrology, complete with references to Thomas Aquinas (1225–1274), Pedro Ciruelo (1470–1554) (Chap. 3), Albumasar (787–886), and Cecco d’Ascoli (1269–1327) (Martins 2007, 332).

Santayana y Spinosa includes natural philosophical speculations about the cosmos in his commentary on Sacrobosco’s text, including consideration of the heliocentric system of Nicolaus Copernicus. In one section of the *Sphaera*, Sacrobosco explains that the earth is at rest in the center of the cosmos, and he briefly gives some Aristotelian arguments about why this must be the case. Santayana y Spinosa, like a number of sixteenth-century commentators on Sacrobosco, expanded on this, clearly in response to the newly proposed heliocentric system. Although Santayana y Spinosa does not refer to Copernicus by name, he refers to “Pythagoreans” (Santayana y Spinosa 1567, fol. 20), a common designation of Copernicans in the period. Of course, when Sacrobosco wrote the *Sphaera* in the first half of the thirteenth century, there was little reason to question this view. But after the 1543 publication of Copernicus’ *De revolutionibus orbium coelestium*, some *Sphaera* commentators felt the need to address the question of the motion or rest of the earth in more detail. Most, including Santayana y Spinosa, did not accept Copernicus’ admittedly rather weak arguments for a moving earth, but it is nonetheless interesting that they were clearly aware of Copernicus’ book and expected that at least some of their readers were as well. Santayana y Spinosa explains that the earth must be immobile because “every heavy body naturally desires the lowest and deepest place, and this is the center and middle of the entire Firmament.”<sup>23</sup> And because it is “the natural place of the [element] earth, [thus once it reaches this place] it remains in firmness and stillness.”<sup>24</sup> Any movement of the earth away from the center “would be by violence and not naturally.”<sup>25</sup> This reiterates an argument found in Aristotle’s *De caelo*, and was one of the standard objections to the physical reality of the Copernican system.

Santayana y Spinosa was only in his mid-twenties when he published his translation and commentary on the *Sphaera*. Unlike the other authors I have discussed in this paper, his motivations were unclear—he was not affiliated with a university or

<sup>22</sup>(Santayana y Spinosa 1567, fol 1 v): “Porque el que es sabio...puede evitar muchas influencias delas Estrellas, conociendo su naturaleza, y preparar se antes de su venida.”

<sup>23</sup>(Santayana y Spinosa 1567, fol 19 v): “...que todo cuerpo pesado naturalmente desea el lugar mas baxo y mas hondo, y este es el Centro y medio de todo el firmament....”

<sup>24</sup>(Santayana y Spinosa 1567, fol 19 v): “Y por ser aquel el natural lugar de la tierra, permanece en firmeza y quietud....”

<sup>25</sup>(Santayana y Spinosa 1567, fol 19 v): “...lo qual seria por violencia y no naturalmente....”

with the Casa de Contratacion. Further, as Roberto de Andrade Martins has pointed out in his analysis of Santayana y Spinosa's *Sphaera*, the man's grasp of astronomy appears rather weak at points. He makes a number of basic errors, including confusing the phases of the moon with eclipses, misstating Aristotelian arguments for the rotundity of the earth, and misunderstanding the concepts of the horizon and the major circles (Martins 2007, 333–34). Further, parts of the text appear to have been copied from Chaves' translation (Martins 2007, 335). While it is impossible to draw any firm inferences from Santayana y Spinosa's translation and commentary on the *Sphaera* since so little is known of his life and career, his enthusiastic if naïve text seems to indicate interest in astronomical and cosmological knowledge beyond the circles of university professors, cosmographers, and navigators.

## 2.7 *Diego Pérez de Mesa, Comentarios de Sphaera (1596)*

The last *Sphaera* commentary that I will discuss is one by Diego Pérez de Mesa (1563–ca. 1632), composed sometime around 1596. According to Víctor Navarro-Brotóns, Pérez de Mesa studied at the University of Salamanca under Jerónimo Muñoz, arguably the most famous Spanish astronomer of the period. Muñoz was then chair of astronomy and mathematics. He wrote a widely read work on the supernova of 1572. As I noted before, several Spanish universities of the period specified that Copernicus either could or should be taught by the professor of astronomy. Muñoz discussed Copernicus' work in writing and with students, although he did not endorse heliocentrism. After studying in Salamanca, Pérez de Mesa took up the chair in astronomy at Alcalá de Henares. In 1595, at the request of the King Philip II, Pérez de Mesa moved to Seville. Here he took up a position newly created to train navigators and cosmographers. He taught both university students and men training to be pilots, giving classes on arithmetic, algebra, geometry, astrology, and navigation. All his classes were in Spanish. Although he wrote several books, most, including his *Comentarios de Sphaera*, remained in manuscript (Navarro-Brotóns 2006, 92–93).

In his preface, he describes cosmography as “a science of the heavens and the world” (*una ciencia del cielo y mundo*). It concerns practical subjects like geography and navigation, but it also engages “many beautiful questions of philosophy, such as whether the fourth element fire is in the concavity of the moon, and if it is possible that the earth and the celestial bodies move together, and if the stars move by themselves or together with their orbs.”<sup>26</sup> Pérez de Mesa's commentary ranges over all of these natural philosophical questions and more, as well as practical applications of astronomy. Pérez de Mesa also wrote separate treatises on navigation and

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<sup>26</sup>(Pérez de Mesa 2009, fol. 1): “...muchas questiones hermoissimas de la misma filosofia como es hay fuego quarto Elementi en el concavo de la luna puesto si es posible que se muevan juntamente la tierra y los cuerpos celestiales y si se mueven las estrellas por si solas o juntamente con las orbes....”

astrology. Both of these, like the *Comentarios*, remained in manuscript. His work reflects familiarity with authors both ancient and modern. Among the moderns, he cites Nicolaus Copernicus, Girolamo Cardano (1501–1576), Francisco Valles (1524–1592), and Jerónimo Muñoz. He includes discussion of Copernicus’ heliocentric system, devoting a section to arguments for and against a moving earth. He also incorporates new information gleaned from voyages of exploration into his philosophical discussions. A particularly striking example of this is in his discussion of the four elements. He begins, conventionally enough, by stating that “earth has the lowest place of all the elements.”<sup>27</sup> Earth is the heaviest element and it naturally moves down to the center of the cosmos. Here he notes that this is an objection to the Pythagoreans, Aristarchus (310–230 BCE), and Copernicus, all of who would “put the earth among the stars.”<sup>28</sup> This is an argument that comes straight out of Aristotle and would have surprised no one. His discussion of the element water, however, is considerably less conventional. Water is the second heaviest element, according to Pérez de Mesa, and it covers the earth. But unlike earth, which moves in straight lines, water has a circular motion: “water moves in circles over the surface of the earth.”<sup>29</sup> His evidence for this position, which he acknowledges is a controversial one, is “the experience and certain reports of all navigators.”<sup>30</sup> Sailors, he writes, know that ocean currents move in circles. He gives multiple examples of this phenomenon, ranging from the Pacific Ocean, the Indian Ocean, the Atlantic Ocean, the North Sea, and the Mediterranean.

In addition to his discussion of natural philosophical questions, Pérez de Mesa includes practical uses of astronomy. For example, when he discusses the meridian, which Sacrobosco defined as “a circle passing through the poles of the world and through our zenith,” he explains how to calculate one’s longitude using a table of the height of the sun at midday. His commentary, like Nuñez work, is full of mathematical demonstrations that lend greater rigor and precision to Sacrobosco’s text.

### 3 Conclusions

My goal has been to demonstrate the rich variety of Iberian treatises of *De sphaera* in the sixteenth century, and to examine what they can tell us about scientific culture on the Iberian Peninsula in this period. The seven treatises that I have described are different in tone, format, and content. Some were aimed at practical men—pilots and navigators who would need to use cosmographical knowledge at sea. But most also included considerable information relevant to astrology, history, and religious

<sup>27</sup>(Pérez de Mesa 2009, fol. 4): “La tierra tiene el lugar mas baxo de todos los Elementos....”

<sup>28</sup>(Pérez de Mesa 2009, fol. 4): “...las quales la ponía entre las estrellas....”

<sup>29</sup>(Pérez de Mesa 2009, fol. 4): “...el agua se mueve sircularmente sobre la superficie de la tierra....”

<sup>30</sup>(Pérez de Mesa 2009, fol. 4): “...la espiencia y siertas rrelaciones de todos los navegantes....”

piety. Some commentators, like Chaves and Santayana y Spinosa, situated astronomical knowledge in a religious and moral context rather than a practical context, although they too included some information about astrology and navigation. These texts were aimed at more elite, highly educated readers who might be more interested in natural philosophical questions. But what is distinctive and fascinating about Spanish and Portuguese science in this period is that the boundaries between these groups—practical and elite—were much more porous than they were in other parts of Europe. It is also the case that many Spanish and Portuguese treatises of *De sphaera* were read and used all around Europe.

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