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In the Orbit of the Sphere: Sacrobosco's De Sphaera Mundi in UPenn MS Codex 1881

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Abstract

Johannes de Sacrobosco's *De sphaera mundi* was the most popular astronomical text in Europe from the late thirteenth century to the late seventeenth, and a core component of the university curriculum. This essay is the first published study of a remarkable copy of *De sphaera* in a manuscript recently acquired by the University of Pennsylvania (MS Codex 1881), which includes an unedited commentary on *De sphaera* and a variety of diagrams. I begin by addressing the textual relationships between this codex and other fifteenth-century copies of the main text and commentary, including both manuscripts and incunables. I then evaluate its diagrams, which would have assisted readers in visualizing and memorizing topics introduced in the main text, and which range from simple geometrical volvelles to a compendious climata diagram. To conclude, I consider what MS Codex 1881 might offer twenty-first-century audiences, including my initial work on digital editions of its diagrams. As a useful case study for both research and teaching, this manuscript will likely benefit several areas of inquiry in medieval and early modern studies, including the history of science and the history of education.

Keywords

Astronomy, Fifteenth Century, History of Science, Johannes de Sacrobosco, Robert Grosseteste, Diagrams, History of Education, Digital Editing, Early Print, Manuscript Studies

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Reviews

In the Orbit of the *Sphere*: Sacrobosco's *De sphaera mundi* in UPenn MS Codex 1881

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University students today are typically advised to obtain the latest editions of required texts, often at a markedly higher cost. Even when a textbook's basic content remains unchanged, instructors may favor a new edition for logistical reasons: previous versions may contain different exercises, or the page numbers may have shifted, making communal reading challenging. In contrast, few instructors at medieval universities could have depended on students possessing identical copies of common texts, even when scribal errors were minimal. Manuscript textbooks were highly customizable, and the formats and paratexts of surviving examples often speak to their owners' needs, ambitions, and social positions. For example, Johannes de Sacrobosco's *De sphaera mundi* (or *Tractatus de sphaera*) was the most common astronomical text in Europe from the late

This article presents research that I conducted as a graduate fellow at the Schoenberg Institute for Manuscript Studies. I am very grateful to the Schoenberg Institute for supporting my project, to Lynn Ransom and Nicholas Herman for their ongoing mentorship, and to Amey Hutchins for proofreading my transcriptions.

thirteenth century to the late seventeenth.[1] Composed around the year 1230, this brief introduction to the Ptolemaic cosmos was soon in widespread use by teachers of the quadrivium, which all university students were expected to master before pursuing the higher faculties, such as law or theology. Yet manuscripts of *De sphaera* vary considerably with respect to their layouts, annotations, and illustrations. The characteristics of specific copies therefore grant insight into the uses of *De sphaera* in particular regions and periods, as well as the readers that it attracted.[2] In what follows, I present the first focused study of a remarkable copy of *De sphaera*, and situate its textual and visual features in the context of fifteenth-century astronomical literature.

In 2017, the Kislak Center for Special Collections, Rare Books and Manuscripts at the University of Pennsylvania acquired the manuscript now known as MS Codex 1881 (hereafter 1881) from Conception Abbey, a Benedictine monastery in northwest Missouri. Bound in modern parchment, this codex consists of ninety-three paper leaves measuring 307 × 205 millimeters, and contains several of the most influential astronomical texts of premodern

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1 For the standard edition and translation of *De sphaera mundi*, see Lynn Thorndike, *The "Sphere" of Sacrobosco and Its Commentators* (Chicago: University of Chicago Press, 1949). Extant manuscripts of *De sphaera* number in the hundreds; see Olaf Pedersen, "In Quest of Sacrobosco," *Journal for the History of Astronomy* 16, no. 3 (1985): 175–220 at 183. For an indication of its popularity as a printed text, see the database maintained by the Max Planck Institute for the History of Science, which includes 359 editions of *De sphaera* and related texts: Matteo Valleriani, dir., "The Sphere: Knowledge System Evolution and the Shared Scientific Identity of Europe," https://sphaera.mpiwg-berlin.mpg.de (accessed 20 December 2019). See also the list of 287 editions compiled by Roberto de Andrade Martins and hosted by the Grupo de História, Teoria e Ensino de Ciências: "Johannes de Sacrobosco: Editions of the *Tractatus de Sphaera*," http://www.ghtc.usp.br/server/Sacrobosco/Sacrobosco-ed.htm (accessed 20 December 2019).

2 *De sphaera* was translated into numerous languages, allowing it to reach individuals who were not studying at universities, including many women. See Kathleen M. Crowther and Peter Barker, "Training the Intelligent Eye: Understanding Illustrations in Early Modern Astronomy Texts," *Isis* 104 (2013): 429–70 at 431; Kathleen Crowther, Ashley Nicole McCray, Leila McNeill, Amy Rodgers, and Blair Stein, "The Book Everybody Read: Vernacular Translations of Sacrobosco's *Sphere* in the Sixteenth Century," *Journal for the History of Astronomy* 46, no. 1 (2015): 4–28.

Europe, accompanied by intricate diagrams and six intact volvelles.[3] Among these texts are the *Theorica planetarum*, a textbook describing epicyclic planetary motion (fols. 1r–14v);[4] the Alfonsine tables, a popular tool for calculating eclipses and planetary positions (fols. 40r–61v);[5] and a glossed, annotated, and illustrated copy of Sacrobosco's *De sphaera mundi* (fols. 15r–36v), making 1881 the fourth *De sphaera* manuscript at the Kislak Center.[6] Dated "1481" in a colophon at the end of *De sphaera* (fol. 36v), 1881 is written in a German Gothic cursive script, and the margins of the Alfonsine tables contain additional calculations for several European cities (Erfurt, Leipzig, Magdeburg, Mainz, Nuremberg, Paris, Prague, and Worms). One of these cities, Magdeburg, is transliterated into Hebrew near the end of the manuscript (fol. 95v), hinting at an origin in what is now northern Germany.[7]

Collectively, the contents of 1881 serve as a complete introduction to late medieval astronomy in both its theoretical and technical aspects, and many of its texts are complementary.[8] For instance, despite its clear explanations of the structure of the universe, the celestial sphere, the terrestrial climes, and the causes of eclipses, *De sphaera* contains little information on planetary motion. Many manuscripts and print editions therefore combined *De*

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3 Each volvelle consists of one (fols. 1v, 13v, 19v, 25v) or two (35r, 35v) paper or parchment disks attached to the page with thread. Fol. 20r contains traces of a volvelle that has been lost.

4 Incipit on fol. 2r of 1881: "[C]Irculus ecentric*us* dici*tur* vel egresse cuspidus vel egredientus centri . . . ." Often ascribed to either Gerard of Cremona (c. 1114–1187) or the thirteenth-century translator Gerardo da Sabbioneta, this *Theorica planetarum* was one of several treatises by this name. For an English translation, see Olaf Pedersen, trans., "The Theory of the Planets," in *A Source Book in Medieval Science*, ed. Edward Grant (Cambridge, MA: Harvard University Press, 1974), 451–65.

5 For an edition and commentary, see José Chabás and Bernard R. Goldstein, *The Alfonsine Tables of Toledo*, Archimedes 8 (Dordrecht: Kluwer Academic, 2003).

6 Other copies are found in LJS 26 (Italy, ca. 1225–1275, in Latin), LJS 216 (France, ca. 1256–1270, in Latin), and LJS 494 (Italy, ca. 1425–1450, in Hebrew).

7 Fol. 95v also includes a Hebrew alphabet and a handful of other words in Hebrew with Latin transliterations, including the name "Jacob Affraiim."

8 Richard J. Oosterhoff describes this combination of *Theorica planetarum*, *De sphaera*, and *Tabulae* as "a complete set of astronomer's tools." See "A Book, a Pen, and the *Sphere*: Reading Sacrobosco in the Renaissance," *History of Universities* 28, no. 2 (2015): 1–54 at 4–5.

sphaera with one of several *Theorica planetarum* texts describing the movements of the planets, with the text in 1881 being the most popular.[9] Some of the texts in 1881 are also glossed or annotated; in particular, *De sphaera mundi* contains a complete commentary, written in a smaller size between sections of the main text, as well as interlinear glosses providing synonyms or definitions of difficult words. Perhaps most notable is the rich variety of diagrams in this manuscript, themselves often densely annotated. Figure 1 shows each of these components on the first page of the main text of *De sphaera*, which begins with a large initial "T" in the left column.

Students could therefore use this codex to gain a basic understanding of astronomical concepts and calculations without referring to additional texts or glosses. More advanced scholars could also use its paratext, particularly the *De sphaera* commentary, as a model for their own expositions, while its diagrams would have helped readers to visualize and memorize topics introduced in the main text.[10] In particular, these diagrams would have encouraged students to develop what Kathleen M. Crowther and Peter Barker call the "intelligent eye," or the capacity to progress from a two-dimensional astronomical drawing to a dynamic mental vision of the universe.[11] Taken as

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9 Olaf Pedersen, "The Origins of the *Theorica planetarum*," *Journal for the History of Astronomy* 12, no. 2 (1981): 113–23; Olaf Pedersen, "The *Theorica planetarum* Literature of the Middle Ages," *Classica et Mediaevalia* 23 (1962): 225–32. On the early modern legacy of the *Theorica planetarum*, see James Steven Byrne, "The Mean Distances of the Sun and Commentaries on the *Theorica planetarum*," *Journal for the History of Astronomy* 42, no. 2 (2011): 205–21; Isabelle Pantin, "The First Phases of the *Theoricæ planetarum* Printed Tradition (1474–1535): The Evolution of a Genre Observed Through Its Images," *Journal for the History of Astronomy* 43, no. 1 (2012): 3–26.

10 Both mental and physical images could function as mnemonic devices in the medieval *ars memoriae*, as Mary Carruthers demonstrates in two important monographs: *The Book of Memory: A Study of Memory in Medieval Culture* (Cambridge: Cambridge University Press, 1990), with a discussion of mental images at 21–24, and *The Craft of Thought: Meditation, Rhetoric, and the Making of Images, 400–1200*, Cambridge Studies in Medieval Literature 34 (Cambridge: Cambridge University Press, 1998), esp. 116–70. On the relationships between scientific texts and diagrams, see also J. D. North, "Diagram and Thought in Medieval Science," in *Villard's Legacy: Studies in Medieval Technology, Science, and Art in Memory of Jean Gimpel*, ed. Marie-Thérèse Zenner (Aldershot: Ashgate, 2004), 265–88.

11 Crowther and Barker, "Intelligent Eye," 430, 469–70. The authors focus on print editions of *De sphaera* and the *Theorica planetarum*, demonstrating the need for similar work on manuscripts.

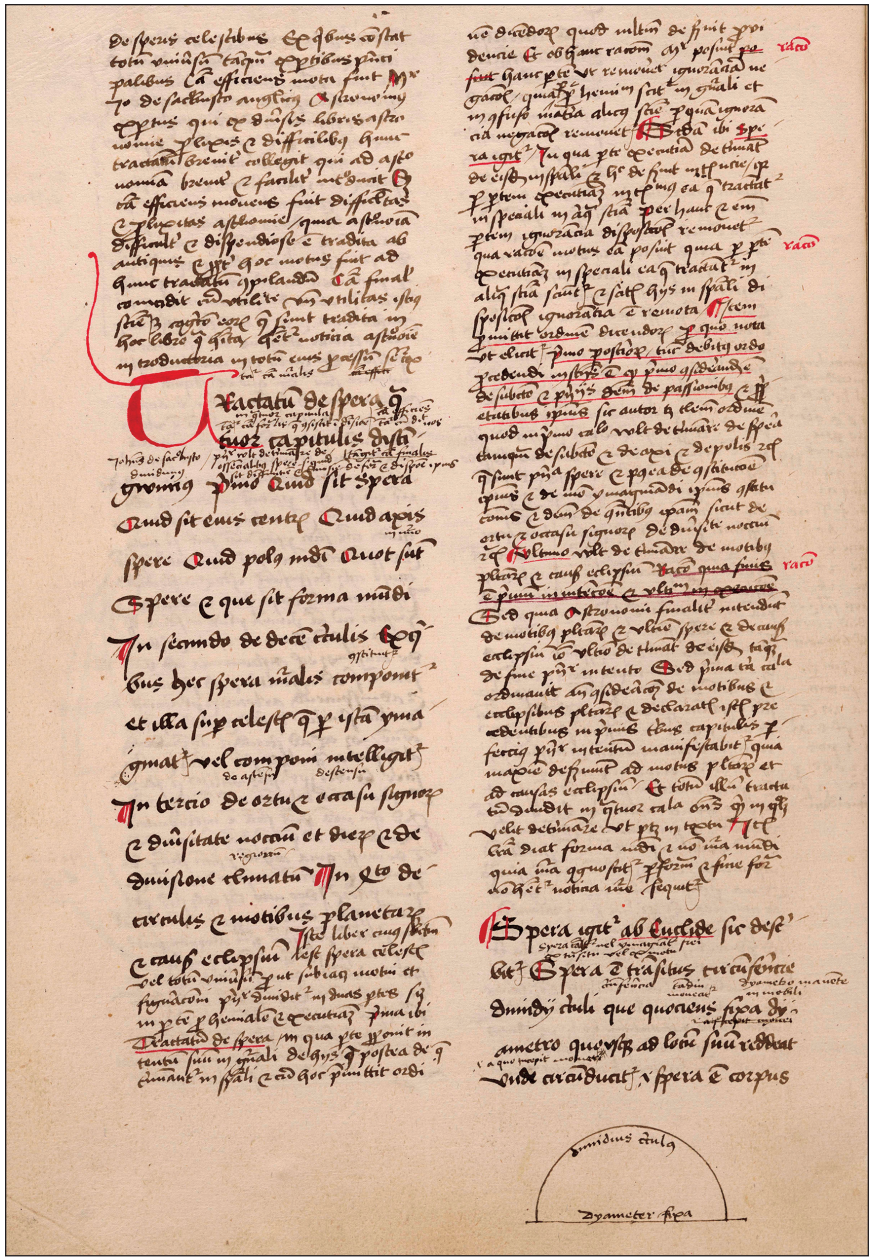

FIGURE 1. The opening of Johannes de Sacrobosco's *De sphaera mundi*, with main text, commentary, interlinear glosses, and a small marginal diagram. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 15v.

a whole, 1881 thus provides a snapshot of education in the late Middle Ages, as a manuscript that is broadly typical of its genre, but also—as the following analyses of the *De sphaera* section will show—exceptional in some of its textual and visual aspects.

Texts and Technologies: Annotating "De sphaera mundi"

Like all authoritative texts used in medieval universities, *De sphaera mundi* would generally have been taught alongside at least one commentary, often composed by the instructor.[12] The resulting profusion of *De sphaera* commentaries remains an under-researched subject, albeit one of significant importance for both the history of science and the history of education; as Richard J. Oosterhoff observes, studying the uses of "typical" textbooks can clarify the context from which the well-known works of Copernicus and Galileo emerged.[13] The earliest *De sphaera* commentaries include one ascribed to Michael Scot (early thirteenth century) that introduces fifty-three questions on Aristotelian natural philosophy, and the commentary by Robertus Anglicus (ca. 1271) that discusses the possibility of a world soul and cites the testimony of a spirit as proof of the equatorial region's habitability.[14] Perhaps most noteworthy is Cecco d'Ascoli's commentary (ca. 1322–24), with its allusions to necromantic texts and strategies for summoning demons. This commentary led to Cecco's condemnation by the Inquisition in 1324, after which he was banned from teaching astrology.[15] By the time that 1881 was copied in the late fifteenth century, commentaries on *De sphaera* had become an important medium through which astronomy

12 Byrne, "Mean Distances of the Sun," 206.

13 Oosterhoff, "A Book, a Pen, and the *Sphere*," 2.

14 Lynn Thorndike's *"Sphere" of Sacrobosco* includes editions and analyses of the commentaries by Michael Scot, Robertus Anglicus, and Cecco d'Ascoli, as well as selections from anonymous commentaries.

15 The Inquisition sentenced Cecco to be burned at the stake with all copies of his published works in 1327, but many manuscripts of his texts survive. On his *De sphaera* commentary, see Thorndike, *"Sphere" of Sacrobosco*, 52–55.

developed and expanded, as rising academic stars sought to build their reputations by criticizing and improving upon this text.[16]

The commentary in 1881 is anonymous and unedited, but not unique. Thus far, I have located similar texts in three other manuscripts. All three date from the fifteenth century, and all contain free-standing commentaries, in contrast to the interwoven main text and commentary of 1881.

- Freiburg, Universitätsbibliothek Freiburg i. Br. / Historische Sammlungen 57, fols. 16r–31r. Dated "1409" on fol. 120v. Also contains an incomplete copy of *De sphaera* (fols. 1r–9r) and a copy of Sacrobosco's *Algorismus* (fols. 105r–112r).[17]
- Vatican City, Vatican Apostolic Library, Vat. lat. 3097, fols. 82r–102r.[18]
- Vienna, Österreichische Nationalbibliothek, Codex Vindobonensis 5145, fols. 72r–94v. Also contains a second commentary on Sacrobosco's *De sphaera* (fols. 12r–28r).

In 1881, this commentary begins on folio 15r, before the opening of the main text. Of the other three copies, only the Vienna manuscript includes this prefatory section:

Quia p*rese*ns sci*enti*a
e*st* introductoria ad
Astronomia*m* vi*delice*t
p*er* totu*m* eius p*r*ocessu*m*

16 For a summary of commentaries on *De sphaera* and their role in disseminating new astronomical theories, see James M. Lattis, *Between Copernicus and Galileo: Christoph Clavius and the Collapse of Ptolemaic Cosmology* (Chicago: University of Chicago Press, 1994), 41–45. On vernacular print commentaries, see also Crowther et al., "The Book Everybody Read," 4–28. A relevant collection edited by Matteo Valleriani, *"De sphaera" of Johannes de Sacrobosco in the Early Modern Period: The Authors of the Commentaries*, is forthcoming from Springer in 2020.

17 A digital facsimile of this manuscript is available on the Digital Collections Freiburg website: http://dl.ub.uni-freiburg.de/diglit/hs57/0030 (accessed 20 December 2019).

18 A digital facsimile is available on the DigiVatLib website: https://digi.vatlib.it/view/MSS_Vat.lat.3097 (accessed 20 December 2019).

Ideo p*ri*mo videnda*um*
e*st* in g*ene*rali de A-
stronomia Quid sit & de eius diuisio*ne*. . . .[19]

The Freiburg (fig. 2) and Vatican manuscripts open with variants of a passage occurring after the beginning of the main text in 1881 (fol. 15v):[20]

Iste liber cui*us* s*ubiectu*m
est spera celest*is*
vel totu*m* vniu*ersu*m[21] p*ro*ut subiac*et* motui et
figura*cio*ni p*rincipalite*r diuidit*ur* in duas p*ar*tes sc*ilicet*
in p*arte*m p*ro*hemiale*m* & executi*v*am[22] **p***ri*ma ibi
Tractatu*m* de spera / in qua p*ar*te p*ro*ponit in
tentu*m* suu*m* in g*ene*rali de hiis q*uae* postea de q*uae*
t*er*mi*n*ant*ur* in sp*eci*ali & cu*m* hoc p*re*mittit ordi
ne*m* dice*n*dor*um* quod m*ult*um definit p*ro*vi-
dencie **E**t ob hanc rac*ione*m M*agiste*r posuit ~~po~~
~~suit~~ hanc p*arte*m vt remou*eret* ignora*n*cia*m* ne-
gac*ionis* / quia \p*er*/ p*ro*hemi*u*m scit*ur* in g*ene*rali et
in *con*fuso mate*r*ia alic*uius* sci*enti*e p*er* qua*m* ignora*n*
cia negac*ionis* remouet*ur*. . . .

19 This is a semi-diplomatic transcription of the text in 1881. All transcriptions in this essay use the following conventions: abbreviations are expanded with supplied letters italicized and superscript letters lowered. Rubricated letters in the manuscript are in bold. A forward slash indicates a virgule in the manuscript, and an ampersand (&) indicates an abbreviated "et."

20 The Freiburg manuscript contains the same text with minor variations. The Vatican text diverges after a few initial phrases, and its relationship to 1881 may be more distant.

21 The incipit "Iste liber cuius subiectum est totum universum" appears in Lynn Thorndike and Pearl Kibre, *A Catalogue of Incipits of Mediaeval Scientific Writings in Latin* (Cambridge, MA: The Medieval Academy of America, 1937), 788(1). Thorndike and Kibre link this incipit to the Vatican and Vienna manuscripts; the latter is incorrectly listed as Cod. 5154, fols. 12r–28r, although the other Sacrobosco commentary in the Vienna manuscript is correctly indexed under 498(3), "Elye est civitas illa ubi presides philosophi fuerunt."

22 The text in the Vatican manuscript diverges from 1881 at this point.

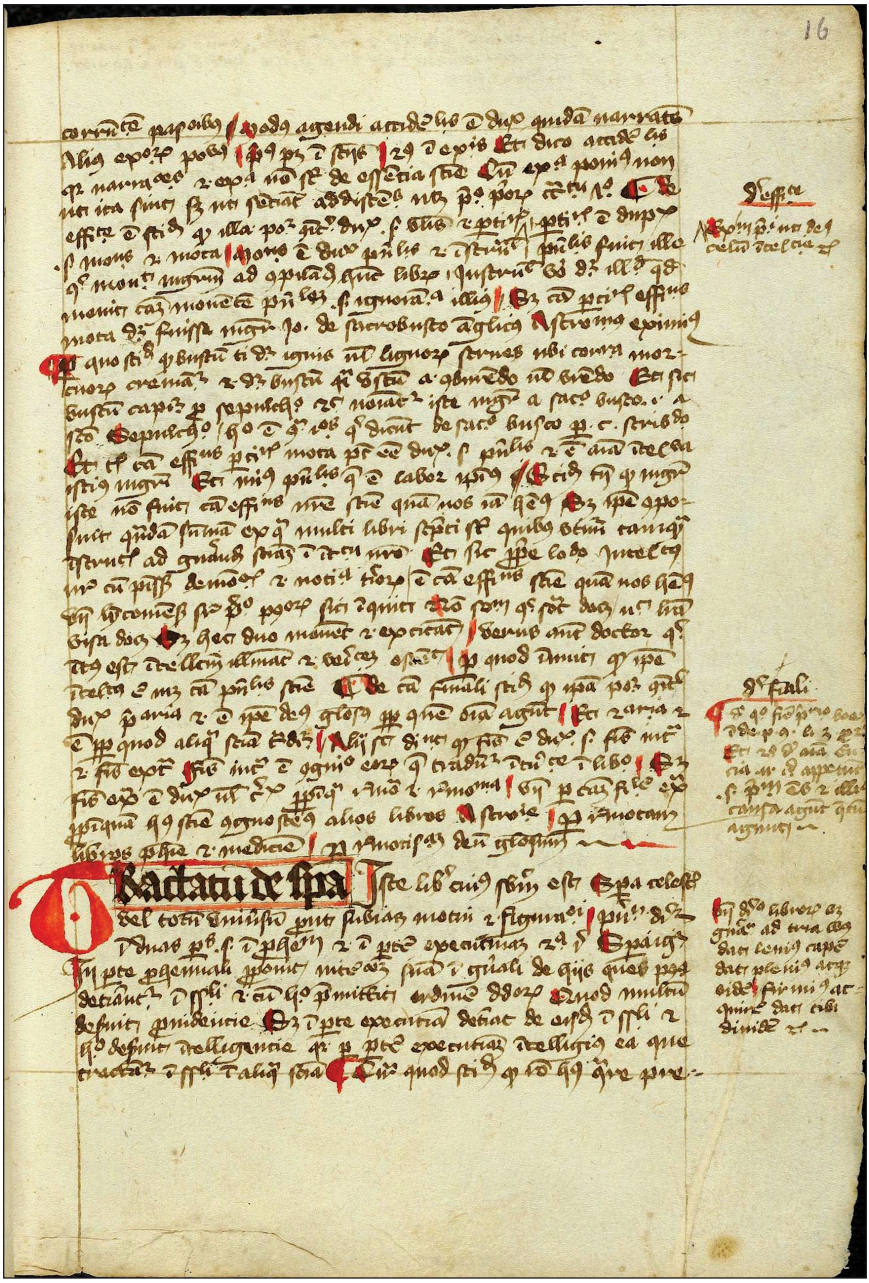

FIGURE 2. Beginning of the commentary on *De sphaera mundi*. Universitätsbibliothek Freiburg i. Br. / Historische Sammlungen 57, fol. 16r.

Further research on this commentary stands to enhance our understanding of the ideas in circulation at the end of the medieval period, when the first print editions of *De sphaera* were emerging from Italy and Nicolaus Copernicus (1473–1543) was a young child.

If the *De sphaera* commentary tradition was continually developing, 1881 also demonstrates that *De sphaera* itself was not a stable object. One intriguing case of textual fluidity is a passage that has been added at the bottom of folio 28r and marked for insertion into Chapter 3 of the main text, in a discussion of the different modes of rising and setting of the signs.[23] This passage does not occur in any of the thirteen manuscripts on which Thorndike bases his edition, and of the fifteen other Latin *De sphaera* manuscripts that I have consulted, it appears in only two, both copied in Italy: UPenn LJS 26 and Oxford, Bodleian Library, MS Digby 215.[24] Yet it is remarkably similar to a passage typically appearing in Chapter 3 of Robert Grosseteste's *De sphaera*, an early thirteenth-century introduction to astronomy with many similarities to Sacrobosco's text.[25] To illustrate this resemblance, I have compared the following transcription of the addition in 1881 with both LJS 26 (designated as "26" in notes) and the copy of Grosseteste's *De sphaera* in London, British Library, Harley MS 4350, fols. 10v–11r ("4350" in notes).

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23 For an edition and translation of the main text, see Thorndike, *"Sphere" of Sacrobosco*, 97–98 and 130–31.

24 In addition to these two manuscripts, I have consulted three at Yale University (Beinecke MS 335, Beinecke MS 797, Yale Medical Library MS 22), five at the Bodleian Library (MS Additional A. 2, MS Ashmole 1285, MS Bodley 491, MS Canon Misc. 561, MS Digby 93), four at the British Library (Additional MS 31046, Arundel MS 268, Harley MS 531, Royal MS 12 C XVII), and UPenn LJS 216.

25 Ludwig Baur noted that this passage occurs in manuscripts of both authors' texts; see *Die Philosophischen Werke des Robert Grosseteste, Bischofs von Lincoln* (Münster: Aschendorffsche Verlagsbuchhandlung, 1912), 64*. For general comparisons of the content and phrasing of these two texts, see Matthew F. Dowd, "Astronomy and Compotus at Oxford University in the Early Thirteenth Century: The Works of Robert Grosseteste" (PhD diss., University of Notre Dame, 2003), 195–98, and Thorndike, *"Sphere" of Sacrobosco*, 10–14. For an edition of Grosseteste's *De sphaera*, see Cecilia Panti, ed., *Moti, virtù e motori celesti nella cosmologia di Roberto Grossatesta* (Florence: SISMEL: Edizioni del Galluzo, 2001).

Sciendu*m* est[26] q*uod* tam inspera r*e*cta q*ua*m obliq*ua* / ascendit eq*ui*noctial*is* cir*cu*lu*s*[27] / s*em*p*er* vniformit*er* sc*i*lic*et* in temporib*us* eq*ua*lib*us* / eq*ua*les arc*us*[28] ascendu*n*t / Motus e*ni*m celi vniformis est / et angul*us* que*m* facit[29] eq*ui*noctialis cu*m* orizonte obliquo[30] no*n* diu*er*sificat*ur* in aliq*ui*bus hor*is*[31] / Partes vero zodiaci[32] no*n* de necessitate habent[33] eq*ua*les ascensio*ne*s in vtraq*ue* spera[34] / Quia q*ua*nto aliq*ua* p*ar*s[35] rectius orit*ur* / tanto plus t*em*p*or*is[36] ponit*ur*[37] in suo ortu / hui*us*[38] signu*m* est / quia sex[39] signa oriu*n*t*ur* in lo*n*ga vel breui die artificiali si*mili*te*r* & in nocte[40]

At present, it is difficult to determine whether this passage is original to Sacrobosco, to Grosseteste, or to another writer entirely.[41] What is clear is that it was eventually incorporated into many print editions of *De sphaera*. Although it is absent from the earliest edition (Ferrara: Andreas Belfortis, 1472; ISTC no. ij00399600), it appears in all five of the Venetian editions

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26 est] 26: tamen, 4350: igitur.
27 circulus] 26: arculus.
28 arcus] 4350: partes.
29 facit] 26: tangit.
30 obliquo] 26, 4350: aliquo.
31 horis] 4350 *adds* Arcus itaque de equinoctiali circulo qui ascendit cum aliqua parte zodiaci dicitur ascensio eiusdem partis.
32 zodiaci] 26 *adds* equales.
33 habent] 26 *om.*
34 in vtraque spera] 4350 *om.*
35 pars] 4350 *adds* zodiaci.
36 plus temporis] 26 *om.,* 4350: maius tempus.
37 ponitur] 26, 4350: ponit.
38 huius] 26 *adds* autem.
39 sex] 26 *adds* quia.
40 huius signum est . . . similiter & in nocte] 4350 *om.*
41 Scholars have yet to reach a consensus about which of the two *De sphaera* texts was composed first. Dowd, "Astronomy and Compotus," 197–98.

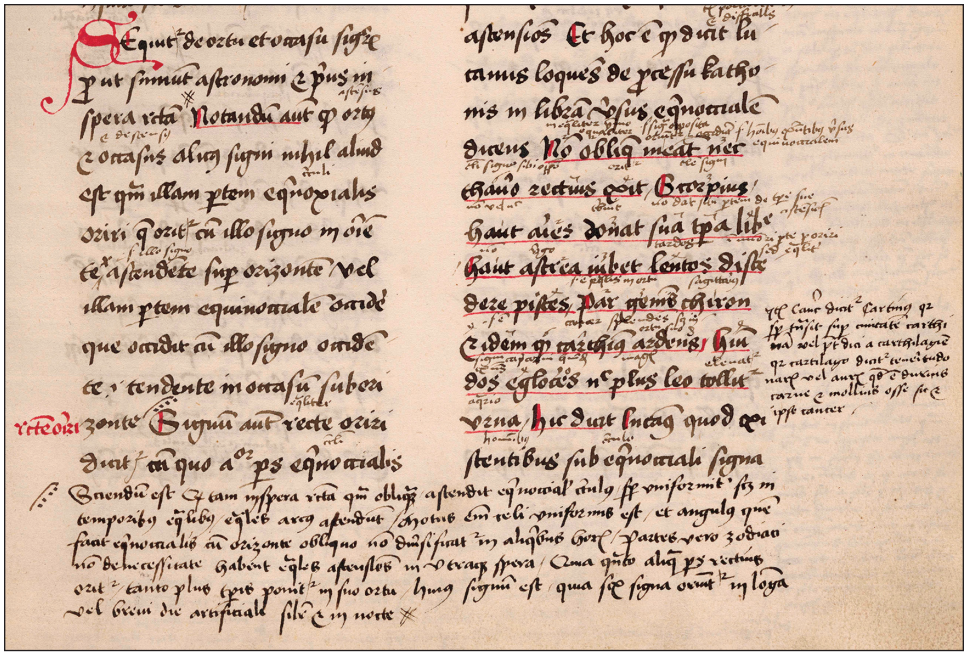
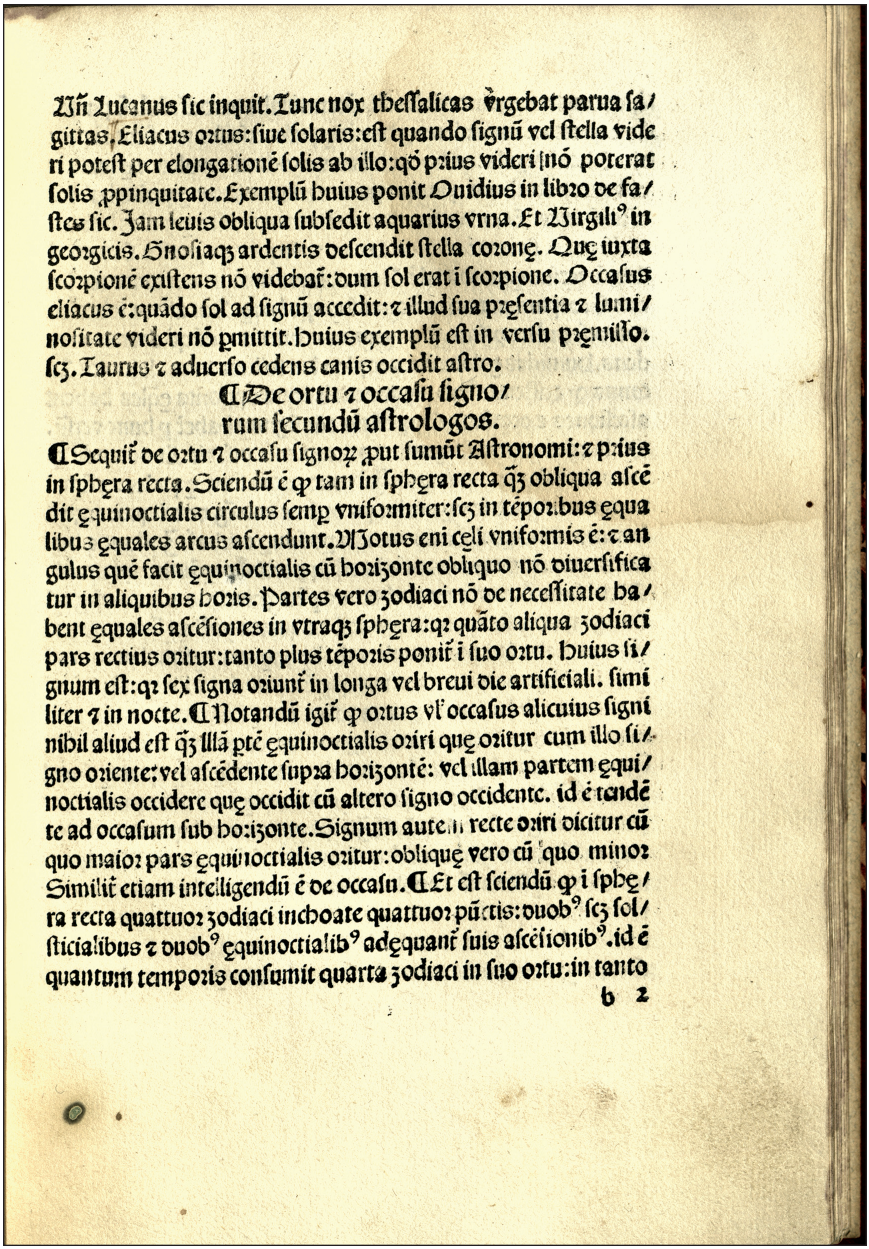


figure 3. Addition to the third chapter of *De sphaera mundi*. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 28r.

from the first decade of *De sphaera*'s print history, added to the main text before "Notandum autem quod ortus et occasus . . ." (fig. 4).[42] We can therefore speculate that 1881 was copied from a version of *De sphaera* lacking this passage and updated using another version—which may well have been a print edition.

42 These Venetian editions were published in 1472 (printed by Florentius de Argentina; ISTC no. ij00400000), ca. 1476 (Filippo di Pietro; ISTC no. ij00401000), 1478 (Franz Renner; ISTC no. ij00402000, ca. 1478 (Adam de Rottweil; ISTC no. ij00403000), and 1482 (Erhard Ratdolt; ISTC no. ij00405000). Like the 1472 Ferrara edition, the editions printed by Florentius de Argentina (i.e., Strasbourg) and Franz Renner include the *Theorica planetarum* attributed to Gerard of Cremona, which Ratdolt's edition replaces with Georg von Peurbach's *Theoricae novae planetarum*.



Vñ Lucanus sic inquit. Tunc nox thessalicas vrgebat parua sa/
gittas, Eliacus ortus: siue solaris: est quando signū vel stella vide
ri potest per elongationē solis ab illo: qō prius videri nō poterat
solis ꝓpinquitate. Exemplū huius ponit Ouidius in libro de fa/
stes sic. Jam leuis obliqua subsedit aquarius vrna. Et Virgili⁹ in
georgicis. Hoc iaqz ardentis descendit stella coronę. Quę iuxta
scorpionē existens nō videbat: dum sol erat i scorpione. Occasus
eliacus ē: quādo sol ad signū accedit: z illud sua p̄sentia z lumi/
nositate videri nō pmittit. Huius exemplū est in versu p̄emillo.
scz. Taurus z aduerso cedens canis occidit astro.

¶ De ortu z occasu signo/ rum secundū astrologos.

¶ Sequit̄ de ortu z occasu signoꝝ ꝓut sumūt Astronomi: z prius
in sphęra recta. Sciendū ē q⁹ tam in sphęra recta qz obliqua ascē
dit equinoctialis circulus semp vniformiter: scz in tēporibus equa
libus equales arcus ascendunt. Motus eni celi vniformis ē: z an
gulus quē facit equinoctialis cū horizonte obliquo nō diuersifica
tur in aliquibus horis. Partes vero zodiaci nō de necessitate ha/
bent equales ascēsiones in vtraqz sphęra: qz quāto aliqua zodiaci
pars rectius oritur: tanto plus tēporis ponit̄ i suo ortu. Huius si/
gnum est: qz sex signa oriunt̄ in longa vel breui die artificiali. simi
liter z in nocte. ¶ Notandū igit̄ q⁹ ortus vl' occasus alicuius signi
nihil aliud est qz illā ptē equinoctialis oriri quę oritur cum illo si/
gno oriente: vel ascēdente supra horizontē: vel illam partem equi/
noctialis occidere quę occidit cū altero signo occidente. id ē tandē
te ad occasum sub horizonte. Signum aute⁊ recte oriri dicitur cū
quo maior pars equinoctialis oritur: obliquę vero cū quo minor
Similit̄ etiam intelligendū ē de occasu. ¶ Et est sciendū q⁹ i sphę/
ra recta quattuor zodiaci inchoate quattuor pūctis: duob⁹ scz sol/
sticialibus z duob⁹ equinoctialib⁹ adęquant̄ suis ascēsionib⁹. id ē
quantum temporis consumit quarta zodiaci in suo ortu: in tanto

b 2

FIGURE 4. A section from the third chapter of *De sphaera mundi* in an early Venetian edition, including the passage added on fol. 28r of 1881. Johannes de Sacrobosco, *De sphaera mundi* (Venice: Erhard Ratdolt, 1482), B2r. Bryn Mawr College Libraries, Special Collections Department.

Compendious and Interactive Diagrams

Diagrams were an integral component of medieval astronomical pedagogy, assisting students in developing mental images of the universe.[43] Since it was impossible to observe the entire cosmos in motion, students were trained to construct images that they could visualize and—crucially—manipulate in the mind.[44] Basic textbooks often instructed readers to imagine rotating or otherwise moving the diagrams provided, and this skill was essential for more advanced astronomy; indeed, Crowther and Barker show that both Copernicus and Galileo presumed that their readers could create and manipulate mental images.[45] However, the diagrams in *De sphaera* manuscripts remain under-studied, with most scholars having focused on print editions of this text.[46] Even the number of illustrated *De sphaera* manuscripts is uncertain; only seven of the manuscripts used in Thorndike's edition contain diagrams, but their consistency suggests that, as Isabelle Pantin states, "a kind of iconographical tradition . . . had been established as early as the second half of the thirteenth century."[47]

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43 For an overview of late medieval astronomical diagrams, see Bruce Eastwood and Gerd Graßhoff, "Planetary Diagrams—Descriptions, Models, Theories: From Carolingian Deployments to Copernican Debates," in *The Power of Images in Early Modern Science*, ed. Wolfgang Lefèvre, Jürgen Renn, and Urs Schoepflin (Basel: Birkhäuser, 2003), 197–226 at 212–17.

44 Crowther and Barker, "Intelligent Eye," 436–38, 470. As Mary Carruthers observes, this skill was fundamental to the medieval curriculum; indeed, "almost every medieval diagram implies some degree of mental manipulation on the part of the student using it." See "Moving Images in the Mind's Eye," in *The Mind's Eye: Art and Theological Argument in the Middle Ages*, ed. Jeffrey Hamburger and Anne-Marie Bouché (Princeton: Princeton University Press, 2006), 287–305 at 294.

45 Crowther and Barker, "Intelligent Eye," 448–51.

46 See, for example, Owen Gingerich, "Sacrobosco Illustrated," in *Between Demonstration and Imagination: Essays in the History of Science and Philosophy Presented to John D. North*, ed. Lodi Nauta and Arjo Vanderjagt (Leiden: Brill, 1999), 211–24. Franz Renner's 1478 edition was the first to include diagrams, followed by the editions of Erhard Ratdolt (1482, ISTC no. ij00405000; 1485, ISTC no. ij00406000) and Johannes Santritter (1488, ISTC no. ij00407000).

47 Pantin, "First Phases," 3, 22 n. 1; Thorndike, *"Sphere" of Sacrobosco*.

Yet whether one compares this codex with other manuscripts or with print editions, the number of images in 1881 is unusually high, and many of these images contain unusually large amounts of text. Nearly every page of *De sphaera* includes one or more diagrams, ranging from marginal sketches to detailed figures occupying half a page. Some concepts are associated with multiple images; thus in addition to the large diagram of the celestial spheres on folio 17r (fig. 5)—a typical feature of astronomical textbooks in general and of *De sphaera* in particular—folio 18v features a

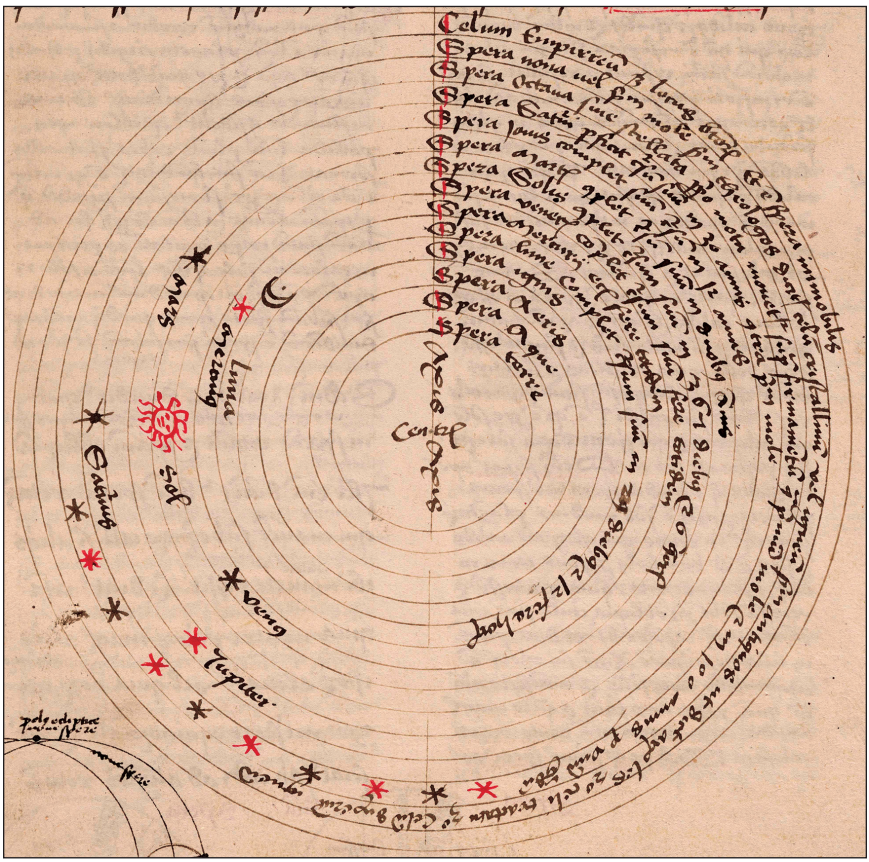

FIGURE 5. Diagram of the elemental and celestial spheres. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 17r.

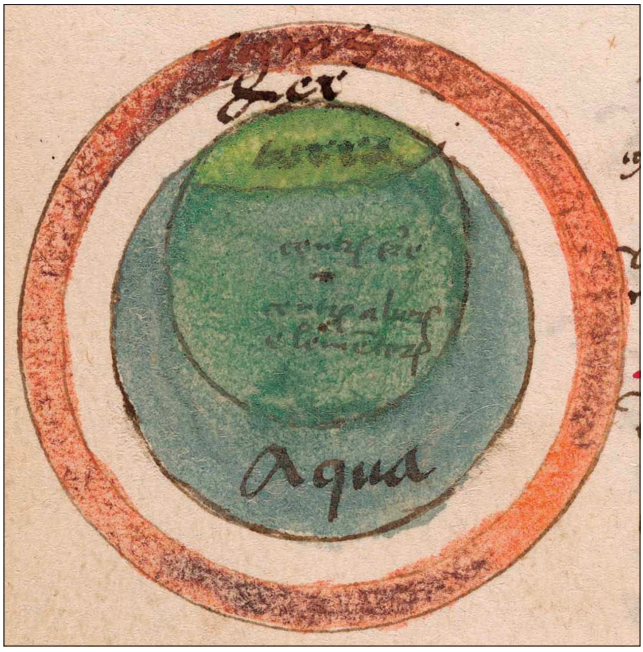

figure 6. Diagram of the elemental spheres. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 18v.

diagram of the elemental spheres in the left margin (fig. 6).[48] The darker ink of many marginal drawings suggests that they were added later, possibly by a student attempting to commit an exemplar to memory.[49]

This copy of *De sphaera* also includes four of the six intact volvelles in 1881 (fols. 19v, 25v, 35r, and 35v). Beyond their function as attractive decorations, these model how a reader might mentally rotate static images presented elsewhere in the text. For instance, a simple triangular volvelle on folio 19v, occurring next to a similar static image, illustrates the necessity for a spherical universe: by rotating this diagram, the viewer perceives that

48 On the uses of this "cosmic section" diagram in *De sphaera*, see Crowther and Barker, "Intelligent Eye," 453–55.

49 On this practice of copying diagrams to assist with memorization, see Oosterhoff, "A Book, a Pen, and the *Sphere*," 21–36.

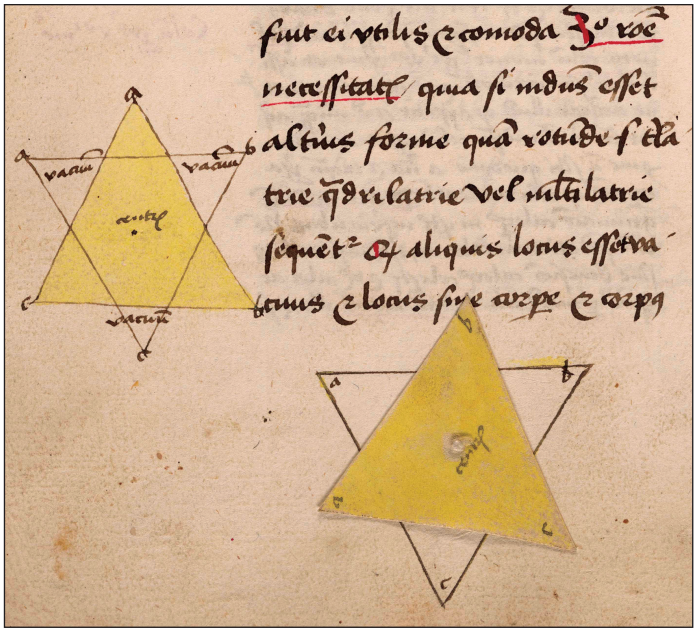

FIGURE 7. Triangular volvelle complementing a passage on the shape of the universe. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 19v.

a triangular universe would create empty spaces as it rotated, identified as "vacuu*m*" in the static image (fig. 7). Although these diagrams may seem basic, they prompt readers to develop the movable mental images required for more complex astronomy: as the volvelle rotates on the page, so readers must learn to rotate the nearby static image in their minds. The volvelles found later in *De sphaera* are more sophisticated, such as the diagram on 35v, which uses an asymmetrical upper disk to depict the conditions under which an eclipse will occur, including the positions of the earth, sun, and moon (fig. 8).[50]

50 The phrases "caput draconis" and "cauda draconis" (head and tail of the dragon) on this diagram denote the intersections of the lunar deferent (a large circle around which the center of the moon's epicycle moves around the earth) and what Sacrobosco calls the lunar equant (a circle concentric with the earth in the plane of the ecliptic). A lunar eclipse would occur only

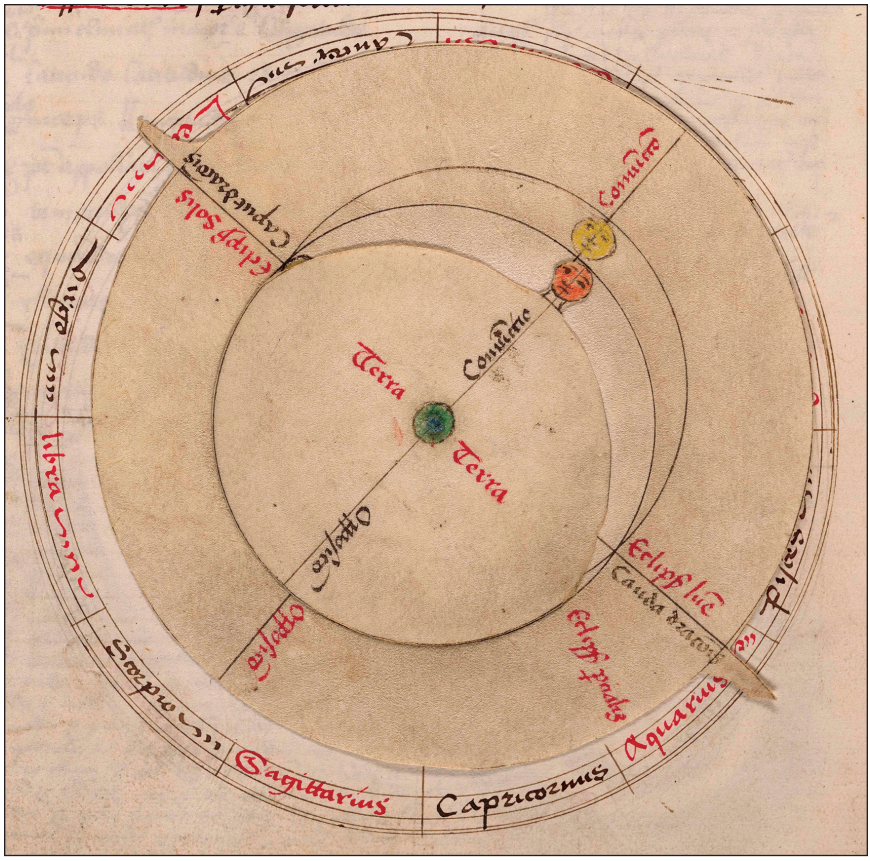

FIGURE 8. Volvelle illustrating the conditions required for eclipses to occur. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 35v.

Perhaps the most striking diagram in this codex is an image of the *climata*, or the seven climatic zones of the earth. MS Codex 1881 contains two *climata* diagrams, the smaller of which merely provides the names and dimensions of each clime (fol. 33r). In contrast, the larger *climata* diagram (fol. 33v) is essentially a world map: here, the scribe has copied out dozens of place

when the full moon was at one of these two points; thus Sacrobosco accounted for the fact that eclipses did not occur at every full moon.

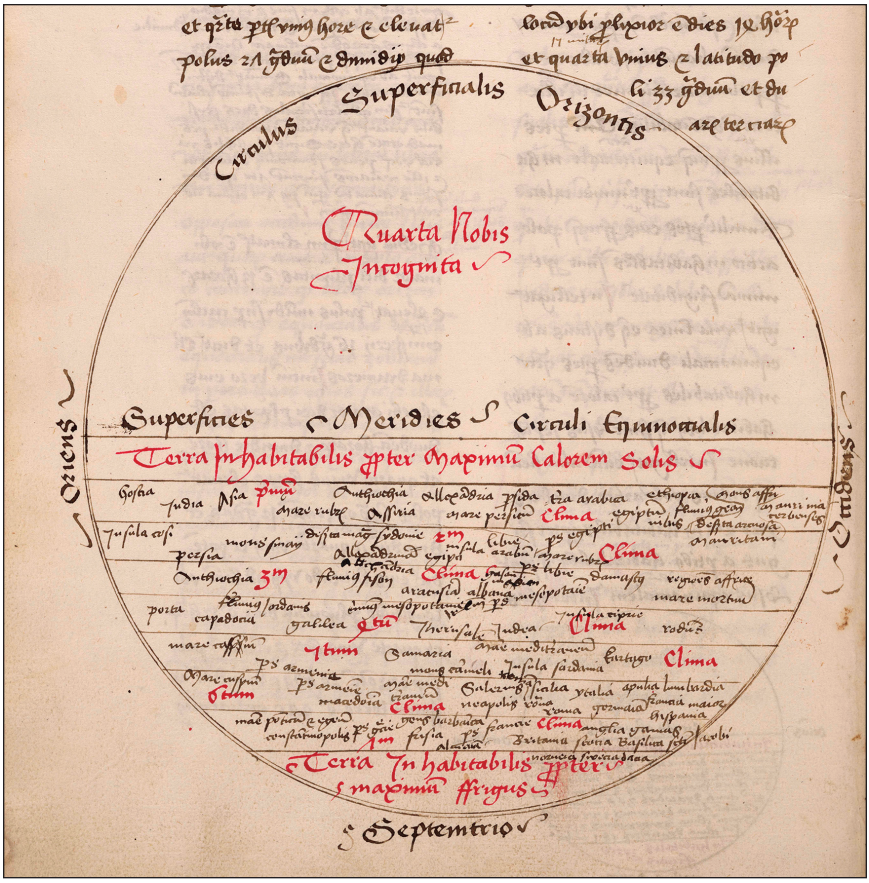

FIGURE 9. Diagram of the seven *climata*. University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, MS Codex 1881, fol. 33v.

names, including cities, bodies of water, and landmarks (fig. 9). Although some late medieval *climata* diagrams are purely schematic, it was not uncommon for these diagrams to include the names of the climes and certain representative place names.[51] However, the encyclopedic character of the 1881 diagram is unusual, as is its tendency to repeat place names across multiple

51 For a schematic *climata* diagram without text, see University of Pennsylvania, Kislak Center for Special Collections, Rare Books and Manuscripts, LJS 216, fol. 16v.

climes; this repetition of names could have been inspired by the actual boundaries of regions such as Egypt or Libya, but it is surprising that some cities occur in multiple climes (e.g., Alexandria and Antioch), suggesting that the creator may have been compiling from several sources and registering their disagreements.[52] Faith Wallis has described how *computus* tables could be transformed into diagrams through the imposition of a geometric form, producing figures that depict "relationships and patterns that are visually satisfying and evocative."[53] The large *climata* diagram in 1881 is a similar hybrid figure, though likely the outcome of an opposite process: by filling this conventional image with text, the scribe has arguably made its visual unity secondary to its data. The result is a compendious diagram that condenses a large amount of geographical knowledge into a compact form.

The substantial range of subjects covered by these skilfully executed diagrams makes 1881 a valuable case study of late medieval astronomical illustration. I am therefore working to produce interactive online editions of some of its images, as well as rotatable digital versions of both its static diagrams and its volvelles.[54] Figure 10 shows an edition of the larger *climata* diagram, created using the Omeka application and the Neatline plugin. The user can hover over a place name to view a semi-diplomatic transcription (including all variants of this name in the diagram) or click to view an English translation. This digital resource therefore joins a long tradition of

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52 Another detailed *climata* diagram from the fifteenth century, though lacking the repetition of place names in 1881, is the seventh figure in Pierre d'Ailly's *Imago mundi*. For a reproduction, see Pierre d'Ailly, *Imago mundi*, ed. Edmond Buron, 3 vols. (Paris: Librairie orientale et américaine Maisonneuve Frères, 1930), 1:140. Available on Gallica at https://gallica.bnf.fr/ark:/12148/bpt6k6572456q (accessed 20 December 2019). See also Alfred Hiatt's discussion of its relationship with the lost *climata* diagram described in Roger Bacon's *Opus maius*: *Terra Incognita: Mapping the Antipodes before 1600* (Chicago: University of Chicago Press, 2008), 145–46.

53 Faith Wallis, "What a Medieval Diagram Shows: A Case Study of *Computus*," *Studies in Iconography* 36 (2015): 1–40 at 32. According to Wallis, a diagram is a "primarily geometrical . . . representation of an abstraction or concept," while a table "is not structured by geometrical relationships; instead, its structure is determined by the data it contains"; see pages 3–4.

54 For the full series, see Aylin Malcolm, *The World of the Sphere: Diagrams from "De sphaera mundi,"* http://aylinmalcolm.com/sacrobosco.

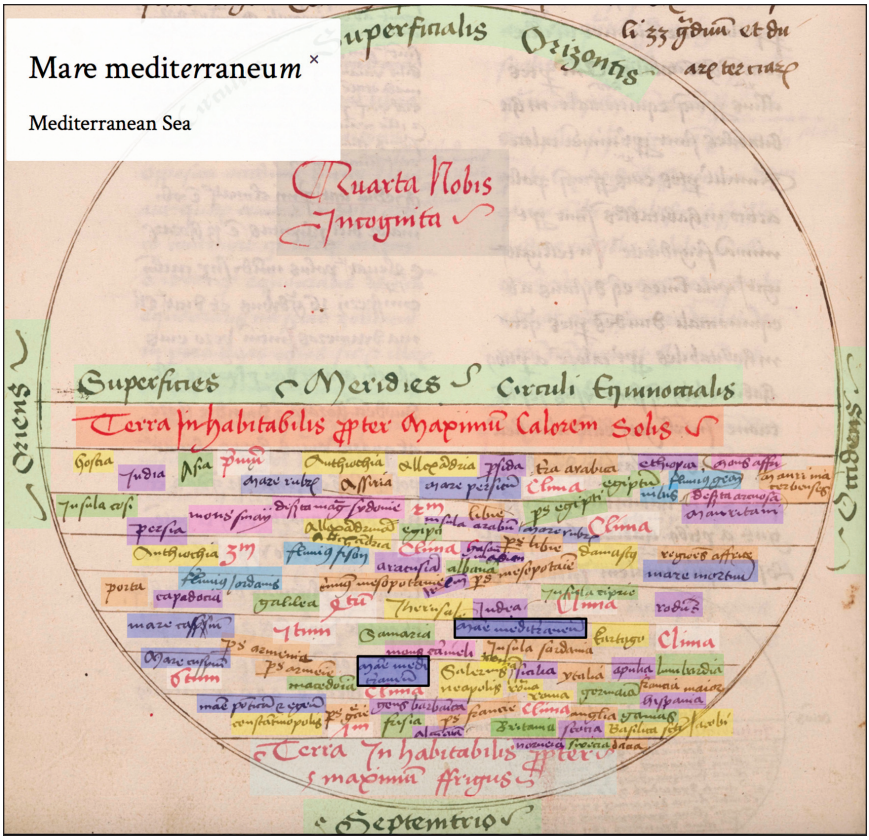

FIGURE 10. Digital edition of the *climata* diagram from MS Codex 1881, fol. 33v, created using Omeka and Neatline. The user has clicked on one of the two instances of "Mare mediterraneum." Available at http://aylinmalcolm.com/sacrobosco.

commentary on *De sphaera*. By inviting users to manipulate these diagrams—not in the mind, nor on the page, but onscreen—I hope to update them for a twenty-first-century audience while preserving a sense of their original purposes.

With its layers of text and commentary and its detailed diagrams, MS Codex 1881 exemplifies the affordances of hand-copied codices and the reasons for which scientific manuscripts continued to circulate well after the advent of print. Although some astronomical incunables were high-quality objects, produced using the most advanced printing techniques of

their period, manuscripts remained a practical alternative until the sixteenth century, since handwritten texts could effectively convey hierarchies within the text and allowed for illustrations with complex annotations and color schemes.[55] MS Codex 1881 might be considered both an ordinary and an extraordinary example of these later astronomical manuscripts, as a codex containing a typical selection of popular texts accompanied by unusual diagrams and an understudied gloss on *De sphaera*. It therefore stands to benefit both research and education today. Though it has long been obsolete as a textbook, the emergence of low-cost, accessible digital technologies suggests that this particular codex could gain a larger sphere of influence than ever before.

55 A leading figure in early scientific printing was Erhard Ratdolt, whose numerous innovations included tricolor diagrams in his 1485 edition of *De sphaera* (ISTC no. ij00406000).