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

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

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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MANUSCRIPT STUDIES

A Journal of the Schoenberg Institute for Manuscript Studies

VOLUME	5,	NUMBER	1

Yemeni Manuscripts Online: Digitization in an Age of War and Loss	
Nancy Um	1
Opening the Text in the Floreffe Bible (London, BL Add. MS 17738): From Ways of Seeing to Ways of Touching	
Dominic Marner	45
<i>Litterae florissae</i> in English Manuscripts in the Late Twelfth/ Early Thirteenth Century	
Sara Charles	79
The <i>Durham Latin Prose "Brut"</i> to 1347 with a Continuation to 1348: A Nationalistic Chronicle of England and Its Manuscripts	
Trevor Russell Smith	120
A Brief Introduction to Seventeenth-Century Military Manuscripts and Military Literacy	
Lucian Staiano-Daniels	142
Annotations	
How Many Glyphs and How Many Scribes? Digital Paleography and the Voynich Manuscript	
Lisa Fagin Davis	164
In the Orbit of the <i>Sphere</i> : Sacrobosco's <i>De sphaera mundi</i> in UPenn MS Codex 1881	
Aylin Malcolm	181

iv | Journal for Manuscript Studies

Reviews

Erik Kwakkel and Rodney Thompson, eds. <i>The European</i> <i>Book in the Twelfth Century.</i>	
Joanna Fronska	203
Paul M. Love, Jr. Ibadi Muslims of North Africa: Manuscripts, Mobilization, and the Making of a Written Tradition.	
Amanda Propst	206
Jeffrey F. Hamburger, Robert Suckale, and Gude Suckale- Redlefsen, eds. Painting the Page in the Age of Print: Central European Manuscript Illumination of the Fifteenth Century.	
Gregory Clark	210
Erik Kwakkel, ed. <i>Vernacular Manuscript Culture, 1000–1500.</i> Hannah Morcos	214
Gaudenz Freuler. The McCarthy Collection, Volume I: Italian and Byzantine Miniatures.	
Bryan C. Keene	218
List of Manuscripts Cited	223

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

> AYLIN MALCOLM University of Pennsylvania

NIVERSITY 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.

182 | JOURNAL FOR MANUSCRIPT STUDIES

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

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.

Malcolm, Orbit of the Sphere | 183

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*

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 ecentricus dicitur vel egresse cuspidus vel egredientus centri" Often ascribed to either Gerard of Cremona (c. 1114–1187) or the thirteenthcentury 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.

184 | JOURNAL FOR MANUSCRIPT STUDIES

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

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.

Malcolm, Orbit of the Sphere | 185

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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.

186 | JOURNAL FOR MANUSCRIPT STUDIES

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 fiftythree 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.

Malcolm, Orbit of the Sphere | 187

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 presens scientia est introductoria ad Astronomiam videlicet per totum eius processum

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).

188 | JOURNAL FOR MANUSCRIPT STUDIES

Ideo p*ri*mo vidend*um* est in generali de Astronomia Quid sit & de eius diuisione....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 cuius subiectum est spera celestis vel totum vniuersum²¹ prout subiacet motui et figuracioni principaliter diuiditur in duas partes scilicet in partem prohemialem & executivam²² prima ibi <u>Tractatum de spera</u> / in qua parte proponit in tentum suum in generali de hiis quae postea de quae terminantur in speciali & cum hoc premittit ordi nem dicendorum quod multum definit providencie Et ob hanc racionem Magister posuit po suit hanc partem vt remoueret ignoranciam negacionis / quia \per/ prohemium scitur in generali et in confuso materia alicuius scientie per quam ignoran cia negacionis remouetur. . . .

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.

Malcolm, Orbit of the Sphere | 189

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

190 | JOURNAL FOR MANUSCRIPT STUDIES

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).

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).

Malcolm, Orbit of the Sphere | 191

Sciendum est²⁶ quod tam inspera recta quam obliqua / ascendit equinoctialis circulus²⁷ / semper vniformiter scilicet in
temporibus equalibus / equales arcus²⁸ ascendunt / Motus enim celi vniformis est / et angulus quem
facit²⁹ equinoctialis cum orizonte obliquo³⁰ non diuersificatur in aliquibus horis³¹ / Partes vero zodiaci³²
non de necessitate habent³³ equales ascensiones in vtraque spera³⁴ / Quia quanto aliqua pars³⁵ rectius
oritur / tanto plus temporis³⁶ ponitur³⁷ in suo ortu / huius³⁸ signum est / quia sex³⁹ signa oriuntur in longa
vel breui die artificiali similiter & in nocte⁴⁰

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

- 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.

²⁶ est] 26: tamen, 4350: igitur.

²⁷ circulus] 26: arculus.

²⁸ arcus] 4350: partes.

²⁹ facit] 26: tangit.

192 | JOURNAL FOR MANUSCRIPT STUDIES

aftenfios Er Bore mont lu Equit De ozter et var fu figze mus loques De prefu fatho put formut after norm 2 pus m pera vita Notande aut go orty mis m libra Sofus equorale Direns No oblig meat ner 2 onafris alun furm muhil alund Band zections post Brozping of qui illam ptem equopialis stiri gozit on illo figno moie Gaut airs Donat (na toa lu Raint affrica inber lento Sile te alten Dete for orizonte vel Mam ptem equinoarate bande Deze pikes par nemb couron Caur Sunt Carting (2 Dem on maring azi que saider ai allo fugno saide 955 caloa's noplus leo a molling offe te i tendente monafu fuben Vina his Just friday guod or ple cancer riteori zonte Bugun aut vierte orizi Quat fon que a º2 ps eque aialis Acntibus inbequorali figna For the series of the series o

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*.

Malcolm, Orbit of the Sphere | 193

23ñ Lucanus fic inquit. Tunc nor theffalicas vrgebat parua fas gittas. Eliacus oztus: five folaris: eft quando fignú vel ftella vide ri poteft per elongatione folis ab illo: qo prius videri ino poterat folis ppinquitate. Exemplu buius ponit Duidius in libro de fat ftes fic. Jam leuis obliqua fubfedit aquarius vrna. Et 2Jirgili? in georgicis. Enoliags ardentis vescendit stella corone. Que insta fcorpione existens no videbat: oum fol erat i fcorpione. Decalus eliacus c:quado fol ad fignu accedit: z illud fua prefentia z lumi/ nolitate videri no pmittit. Duius exemplu eft in versu premillo. (c3. Taurus z aducrfo cedens canis occidit aftro. Deortu zoccasa fignoz rum secundu astrologos. I Sequit de ortu ? occasu lignoz put sumut Aftronomi: 2 prius in fpbera recta. Sciendu e o tam in fpbera recta of obliqua alce dit equinoctialis circulus femp vniformiter:fcs in teporbus equa libus gquales arcus afcendunt. 2/Jotus eni celi vniformis e: z an gulus qué facit equinoctialis cu bozizonte obliquo no oiuerlifica tur in aliquibus bois. partes vero zodiaci no be neceffitate bas bent equales alcéliones in vtrags fphera:q2 quato aliqua 30diaci pars rectius outur: tanto plus tepozis ponit i fuo oztu. Duius fi/ gnum eft:q2 fex figna oziunt in longa vel breui die artificiali. fimi liter 7 in nocte. I Notandu igit op ortus vi occasus alicuius figni nibil aliud eft q3 Illa pte equinoctialis oziri que ozitur cum illo fit gno oriente: vel afcedente fupra borizonte: vel illam partem equi/ noctialis occidere que occidit cu altero figno occidente. id e tende

te ad occafum fub bosizonte. Signum autem recte osiri olcitur cũ quo maios pars equinoctialis ositur: obliqué vero cũ (quo minos Similit etiam intelligendũ é de occafu. Et ch feiendũ qu i fpbe/ ra recta quattuos zodiaci inchoate quattuos pūctis: dob? fc3 fol/ ficialibus z duob? equinoctialib? adequant fuis afcélionib?. id é quantum temposis confumit quarta zodiaci in fuo ostu: 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.

194 | JOURNAL FOR MANUSCRIPT STUDIES

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

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.

Malcolm, Orbit of the Sphere | 195

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.

196 | JOURNAL FOR MANUSCRIPT STUDIES



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.

Malcolm, Orbit of the Sphere | 197

fut civelis a comoda 3" voe nereffitate ques fi mous cfet alting forme qua votide f that true govelanie vel intelatric fiquet = of aliquis lorus effetta formes a low five waste a costa

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 "vacuum" 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

198 | JOURNAL FOR MANUSCRIPT STUDIES



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.

Malcolm, Orbit of the Sphere | 199

low ybi physioz e dies 12 hozp et qite ptforg bore c chuat 60 20 20 polus 21 goun 2 Inmigy g st quarta pmus wallis A20 62 11120 marta Kobis Maridies S uperfines Civali Eginomalis 721CNS Intabilis ypter Mapimu Calorem Solis Allopadia fila Ba avalua E convers at Clima Aruns " Septemtrip

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.

200 | JOURNAL FOR MANUSCRIPT STUDIES

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

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.

Malcolm, Orbit of the Sphere | 201

uperfinalis Mare mediterraneum Mediterranean Sea Zuarta Robis Incognita Meridies . Civruli En unomalis uperhous rucus ibitabilis apter Mapimi Calorem Solis

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 highquality objects, produced using the most advanced printing techniques of

202 | JOURNAL FOR MANUSCRIPT STUDIES

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).