

CONTENTS

Introduction	1
1 Sacrobosco and His World	7
2 The Medieval Cosmos	24
3 Scribes and Artists	49
4 Printing the <i>Sphere</i>	76
5 Commenting on the <i>Sphere</i>	93
6 Copernicus and the <i>Sphere</i>	112
7 Galileo and the <i>Sphere</i>	126
8 Astrology in the <i>Sphere</i>	149
9 Physicians Read the <i>Sphere</i>	164
10 Flirting with Demons	179
11 The Regiment of the North Star and the Sun	189
12 Christopher Columbus and the <i>Sphere</i>	207
13 Into the Torrid Zone	224
14 A Christian Cosmos	238

viii CONTENTS

15	Sacrobosco in New Spain	255
16	Sacrobosco in China	275
	Conclusion	294

Acknowledgments 299

Notes 303

Bibliography 339

Image Credits 355

Index 357

Introduction

WHAT DO you see when you look at the night sky? On most nights, clouds permitting, you can see the moon and stars. The particular stars that you see will vary depending on your geographical location and the time of the year. On some nights, you can see one or more planets as well. Occasionally you might see even rarer phenomena like shooting stars, a comet, or an eclipse. How do you make sense of what you see? You have probably learned something about the structure and nature of the universe from school, science museums, independent reading, television, the internet, or some combination of these, and you interpret your observations of the night sky to fit what you have learned. For example, you most likely believe that night and day are caused by the rotation of the Earth on its axis, and not by the motion of the sun around the Earth. Depending on your background and inclinations, you may see other things when you look at the night sky. You may see the immense power and goodness of a Creator God. You may see the vastness of the universe and the cosmic insignificance of human beings. You may see the beauty that has inspired poets and artists, or the unsolved mysteries of the cosmos that have inspired scientists.

If you lived in Europe before about 1600, you would have seen the same things in the night sky, but you would have interpreted your observations very differently. Instead of an infinite universe and a moving Earth, you would have imagined that the cosmos was a sphere—an enormous sphere, but a finite one—and that the Earth you were standing on was a tiny point at the center of this sphere. The cosmos consisted

of a nested set of hollow, transparent spheres, rather like an onion, if an onion were a perfect sphere and each of its layers was also perfectly spherical. All these spheres were centered on the Earth. The stars that you saw in the night sky were all embedded in the outermost of the hollow spheres—or orbs—that made up the cosmos. The five planets visible to the naked eye (Mercury, Venus, Mars, Jupiter, and Saturn), the sun, and the moon were each embedded in different orbs. All the orbs rotated around the Earth, creating the cycle of night and day, seasons and years, past, present, and future. Further, you would almost certainly have believed that the universe was the beautiful, orderly, law-like creation of a benevolent God. And this would be true whether you were Christian, or a member of one of the two significant minority religions in Europe: Islam and Judaism.

If you lived any time after about 1250, most likely you would have learned about the cosmos by reading a book called the *Treatise on the Sphere*. The *Sphere* was written around 1230 by Johannes de Sacrobosco, who taught mathematics and astronomy at the University of Paris. He composed the *Sphere* as an introductory textbook for his students. The book rapidly became the most popular and widely used astronomy text of the medieval and early modern period. There are at least one hundred surviving manuscripts of the *Sphere*, and over three hundred different printed editions between the 1470s and the 1660s. The majority of these were in Latin, but there were also versions in German, English, French, Italian, Spanish, Portuguese, and several non-European languages. For four hundred years, men and women across Europe and beyond learned about the cosmos from Sacrobosco's *Sphere*. At a very conservative estimate, more than one million Europeans read the *Sphere* during the four centuries it was in circulation. Only a fraction can be identified with certainty, and of that number, a mere fraction left any account of why they read Sacrobosco's *Sphere* and what they thought about it. Nonetheless, even this tiny percentage reveals that a surprisingly wide variety of people in medieval and early modern Europe were interested in astronomy.

Why was an astronomy text written in the 1230s still being published and read four centuries later? Why was a text that described a geocentric

cosmos still in circulation long after Nicholas Copernicus proposed that the Earth circled the sun and Galileo Galilei pointed his telescope at the heavens? Why was a text that described planets as embedded in crystal-line spheres still being taught long after Johannes Kepler asserted that planets move freely through space in elliptical orbits? Why was a text that claimed part of the globe was too hot to sustain life still being read long after the European voyages of exploration had found the tropics full of life? The longevity of the *Sphere* might seem to be evidence of the intellectual stagnation that is so often imputed to the Middle Ages. But tracing the history of this book and its readers shows exactly the opposite. It reveals a lively curiosity about the universe, a keen interest in new discoveries and new ideas, and a willingness to question authoritative sources of information.

Far from remaining static for four centuries, the *Sphere*—in both manuscript and print—was generally accompanied by additions, corrections, and commentary. From the moment he wrote it, Sacrobosco's short, simple text was seen as a starting point for inquiry, not an endpoint; the first step on a journey, not the destination. His readers were skeptical and critical, not credulous. Through the centuries, readers chose which aspects of his original text to accept, which to modify, and which to reject. What the *Sphere* offered was a framework for investigations of the cosmos, a set of questions rather than a set of authoritative answers.

The *Sphere* appeared as a textbook in introductory astronomy classes at universities throughout Europe from the mid-thirteenth to the mid-seventeenth century. Astronomy was part of the basic liberal arts curriculum that all students were required to complete before advancing to any of the higher faculties, and as a result, a very high percentage of university-educated men read the *Sphere*. This includes men who went on to the higher faculties of medicine, law, or theology, as well as those who left after a few years without completing a degree. The *Sphere* was used by tutors who offered private instruction to children of the wealthy—both boys and girls. It was studied in monasteries and convents by monks and nuns, and by the children who attended monastery schools but never took vows. Mastery of the contents of the *Sphere* was

part of what it meant to be an educated person in medieval and early modern Europe. Without a basic understanding of the cosmos, one would not be able to understand the numerous references to stars, planets, and celestial phenomena that were ubiquitous in art, poetry, and literature. When William Shakespeare has Romeo say of Juliet,

Two of the fairest stars in all the heaven
Having some business, do entreat her eyes
To twinkle in their spheres till they return. (*Romeo and Juliet*,
act 2, scene 2)

he understood—and he counted on his audience understanding—that stars were embedded in solid, crystalline spheres rotating around the Earth. Most would have attained this knowledge from reading an edition of Sacrobosco.

The structure of this book is not linear and chronological. Rather, it is circular and recursive, like the structure of the universe described by Sacrobosco. In this cosmos, the Earth is at the center—tiny in relation to the vastness of the heavens, and motionless as the moon, sun, planets, and stars circle around it in an endless, complex dance. Sacrobosco and his *Sphere* are the small, still point at the center of this narrative. Around them swirl spheres of culture—science, religion, politics, and economics. In chapter 1 we meet Johannes de Sacrobosco, a young Englishman newly arrived at the University of Paris in the early thirteenth century. Although we have only fragmentary information about Sacrobosco's life, we can reconstruct the milieu in which he composed his *Sphere*. The newly established University of Paris was an intellectual center, drawing students and teachers from all parts of Europe. And this was an exciting time to study astronomy. In the generation before Sacrobosco, a flood of translations of Arabic astronomical works had dramatically expanded and improved European understandings of the cosmos, and he eagerly shared this new material with students in his lectures and in his textbook. In chapter 2 we turn to the contents of Sacrobosco's *Sphere*, using it as an entrée into the medieval cosmos. The *Sphere* details the structure of the heavens, but more than that, it shows us how astronomy fit into medieval

culture. Laced with Latin poetry and biblical allusions, the *Sphere* offered readers a specifically European and Christian view of the cosmos.

Chapters 3 and 4 move beyond the author and introduce the scribes and printers whose hands and minds transformed the *Sphere* from a simple textbook prepared by an obscure university professor into a best-seller. Manuscript versions of the *Sphere* varied widely, ranging from gorgeously illuminated presentation copies, made for royalty, to small, plain versions made for impecunious students. Printed versions too differed in the number and kind of illustrations included, the texts they were combined with, dedication letters, and prologues. These variations impacted the experience of reading Sacrobosco's *Sphere* and broadened its readership beyond university students.

Chapters 5, 6, and 7 tell the familiar story of the Scientific Revolution through an unfamiliar set of sources: commentaries on Sacrobosco's *Sphere*. I begin, in chapter 5, with the very earliest commentaries on the *Sphere* from the thirteenth and fourteenth centuries, and show that, far from being a period of intellectual stagnation, these centuries were characterized by lively debate and avid curiosity about the structure of the cosmos. Chapter 6 surveys discussions of Copernicus and heliocentrism in *Sphere* commentaries. Chapter 7 examines the ways that new observations of the heavens, including the stars and nebulae of the Southern Hemisphere, the supernova of 1572, and Galileo's telescopic discoveries, were incorporated into *Sphere* commentaries.

Some of the people who read the *Sphere* had practical motivations. Two important practical applications of astronomy in medieval and early modern Europe were astrology, the subject of chapters 8, 9, and 10; and navigation, the subject of chapters 11, 12, and 13. Astrology was premised on the belief that the celestial bodies influenced life on Earth. This belief was so widespread that no sensible king, queen, emperor, or pope would go to war, get married, or undergo medical treatment without consulting an astrologer. Another measure of the importance of astrology is its prevalence in commentaries on the *Sphere*. Beginning in the late fifteenth century in Spain and Portugal, the *Sphere* was used to train navigators and pilots in the new techniques of celestial navigation.

In turn, the information these men brought back about new lands and peoples was then integrated into the *Sphere*.

The last three chapters examine the importance of the *Sphere* in the religious culture of medieval and early modern Europe. Chapter 14 describes the importance of astronomy in Christian education beginning in the early Middle Ages and its renewed significance in the Reformation, when Catholic and Protestant educators each produced their own *Spheres*. The importance of astronomy and the *Sphere* to European Christians is evidenced by the fact that sixteenth- and seventeenth-century missionaries used the *Sphere* in their efforts to convert the peoples they encountered. Chapter 15 examines the use of the *Sphere* in missionary efforts in New Spain, and chapter 16 examines the use of the *Sphere* in missionary efforts in China.

When he composed the *Sphere* in the early thirteenth century, Sacrobosco probably had no idea that his modest textbook would be read all over Europe for four hundred years, let alone carried to lands and peoples he did not even know existed. Tracing the history of the *Sphere* provides a new window into the massive intellectual and cultural changes that took place in Europe between the thirteenth and seventeenth centuries. The revolutionary works of men like Copernicus, Galileo, and Kepler stand out like stars in a vast dark firmament. Viewing their ideas and discoveries—and those of other lesser luminaries—in the myriad versions of the *Sphere* produced over the course of four centuries brings them back down to Earth. We can observe the old and the new bumping up against each other and jostling for a place in a new world order. Instead of seeing only the few great men whose discoveries and theories transformed understandings of the natural world, we can see the messier and more mundane efforts of a wide variety of authors and readers to come to terms with new knowledge and ideas. In some cases, this meant integrating new findings into older systems of understanding the world, and in other cases it meant jettisoning those older systems in favor of new ones. But they all started in the same place, with Sacrobosco's *Sphere*, the book everyone read.

INDEX

Page numbers in *italics* refer to illustrations.

- Abenragel, Haly (Abū l-Ḥasan ‘Alī ibn Abī l-Rijāl al-Shaybani), 228–29
 Abū Ma’shar, 151–52
Acerba (Cecco), 187, 188, *plate 15*
 Achillini, Alessandro, 109
 Adelard of Bath, 21
 Aerjanss, Jan, 220
 agriculture, 39
 Ailly, Pierre d’, 106–9, 154, 166, 167, 168, 228, 229, 230, 232
Airs, Waters, Places (Hippocrates), 227
 Albert of Stade, 149
 Albertus Magnus, 227–28, 233
 Alcabitius (‘Abd al-‘Azīz ibn ‘Uṭmān Qabisi), 74, 151, 152, 175
 Alchandreas, 74
Algorismus (Sacrobosco), 8, 53, 54, 61, 71, 72, 73, 75, 149, *plates 3 and 4*
Almagest (Ptolemy), 21, 22, 88, 150–51, 240
 almanacs, 74, 260
 Almansor, Almeon, 102
 Alonso de la Vera Cruz, 258–59
 Alpha Centauri, 130
 Amayon (demon), 186
Annals of Stade (Albert of Stade), 149
 antarctic region, 33–35, 37–38, 46, 98, 130, 132, 186, 224
 Antonio, Nicolás, 260
 Apian, Peter, 82, 84, 89
 apogee, 230
 Aquarius, 157
 Aquinas, Thomas, Saint, 66–67
 Arabic language, 4, 12, 20, 21–22
 Arabic numerals, 8, 71
 arcs, 184
 arctic region, 33–35, 37–38, 46, 133, 186, 224, 235
 Arias, Antonio, 259
 Ariew, Roger, 146
 Aristarchus of Samos, 117–18
 Aristotle, 19, 61, 95, 155; Averroes’s defense of, 105; celestial and terrestrial realms distinguished by, 96–97; climate zones viewed by, 226, 233; comets viewed by, 133–34; Copernicus influenced by, 106; fixed stars viewed by, 121; geocentrism embraced by, 116, 118, 119, 150; Ptolemy’s commentaries on, 88; in translation, 20, 26; unchanging heavens posited by, 144–45, 146; void deemed impossible by, 122–23
 armillary sphere, 45–46, 47, 49, 81, 255, 259, 277, 279, 280
Art of Navigation (Medina), 212, 214, 218–21
 Arzachel, 102
 ascendant, 160
 Asdente (cobbler and prophet), 180
 Asmitus (demon), 184
 astrolabe, 73, 175, 198, 201, 202, 205, 275, *plate 17*
 astrology, 5, 91, 149–63; health and medicine linked to, 74, 164–78, 266–67; magic and witchcraft linked to, 180–83; mathematical precision linked to, 88; Ptolemy’s view of, 151. *See also* horoscopes; zodiac
Astronomica (Manilius), 227
 astronomy: astrology linked to, 5, 88, 150, 162; calendrical uses of, 8; in Christian education, 6, 13; as liberal art, 3, 9, 13, 55; moral and spiritual dimensions of, 14; navigation linked to, 5; in Roman poetry, 18, 23; translations of works in, 12; widespread interest in, 2
Astrophysics for People in a Hurry (Tyson), 296–97
 Augustine of Hippo, Saint, 19

- Avelar, André do, 130, 198
 Averroes (Ibn Rushd), 88, 105, 107, 108, 109
 Avicenna, 230, 233
 Aztecs, 265–66
- Barbarossa (Frederick I, Holy Roman Emperor), 156
 Barents, William, 218–19, 220
 Barker, Peter, 109
 Barozzi, Francesco, 115, 117, 119
 Bartholomew of Parma, 153, 156, 157
 Bartolomaeus Anglicus, 227–28
 Battista, Giovanni, 275
 Beatrice, countess of Burgundy, 149, 152
 Beckwith, Christopher, 12
 Belfortis, Andreas, 76, 77–78
 Benjamin, Walter, 239
 Benvenuto da Imola, 181
 Beta Centauri, 130
 Bible, 95
 bloodletting, 173, 174, 177
 Boccaccio, Giovanni, 180
 Boethius, 25
 Bolingbroke, Roger, 164–65, 179, 181–82
 Bonatti, Guido, 180
 Bonfantini, Accursio, 179
Book for the Calendar of the Chongzhen Era, 291
The Book of the City of Ladies (Christine de Pizan), 238
Books of Chilam Balam, 267–68, 269, 270–72
 Brahe, Tycho, 111, 121, 125, 134, 135, 146;
 geo-heliocentric system of, 137–38, 143, 145, 291–92, 293, 295
 Brecht, Bertolt, 126–27
Brief Compendium of the Sphere and of the Art of Navigation (Cortes), 210, 213, 215, 217, 218, 219, 221
 Buning, Marius, 251, 253–54
 Burgersdijk, Franco, 250–54
 Burnett, Charles, 153
- Cabral, Pedro Álvares, 234
 Cadamosto, Alvise, 128, 195–97
 Caesar, Julius, 100
 calendars, 8, 105, 124, 175, 266; Chinese, 283–85; Gregorian, 283; Julian, 100–102, 283
 Callippus, 106
 Calvinists, 242, 250–53
- Capricorn, 157
 Capuano di Manfredonia, Francesco, 166, 216, 229–32
 Carey, Hilary, 178
 cartography, 91
 Caso Barrera, Laura, 268
 Cassiopeia, 133
 Catholics, Catholicism, 242; books prohibited for, 145, 250; conversions to, 247; editions of Sacrobosco's *Sphere* published by, 5, 249–54. *See also* Jesuits
Cautelae, 71
 Cavellat, Guillaume, 91, 250
 Cecco d'Ascoli (Francesco Stabili), 156–57, 172–73, 179–80, 183–88, 216, *plate 15*
 Cedillo y Rujaque, Pedro Manuel, 221–22
 celestial navigation, 5, 189, 190, 196, 197, 206, 209, 221
 celestial realm, 27, 96
 Champlain, Samuel de, 218
 Charles, duke of Calabria, 179
 Charles V, Holy Roman Emperor, 212, 233
 Chaves, Jerónimo de, 200, 201, 235, 260, 261, 262, 263, 268, *plate 16*
 Chevreul, Jacques du, 115, 116, 117, 124, 144, 145–46, 147
Chilam Balam, Books of, 267–68, 269, 270–72
 China, 275–93
 chiromancy, 184
Christian Psalmody (Sahagún), 260–61, 264, 274
 Christine de Pizan, 238–40, 244
Chronographia o reportorio de los tiempos (Chaves), 260
 Cicero, Quintus Tullius, 14–15, 19, 64
 Ciruelo, Pedro, 104, 109–10, 224–26, 231–33, 234, 241
 Clavius, Christoph, 119, 283; Aristarchus cited by, 117; astronomy promoted by, 246–48; commentary on Sacrobosco's *Sphere* by, 115, 168, 247, 249, 252–53, 275, 280, 281, 287; Galileo's views accepted by, 127, 144; geocentrism defended by, 120–21, 124; mathematical study promoted by, 247; New Star described by, 134, 135–36
 climate zones, 35, 36, 37, 58, 59, 63, 79, 81, 226–31, *plates 6 and 7*

- Cobham, Eleanor, duchess of Gloucester, 164, 181
- Coccia, Emanuele, 183
- Codex Mexicanus*, 263, 265, 266, 268
- Collège des Dix-Huits, 12
- Collège Royal (Collège de France), 250
- Columbus, Christopher, 207–10, 224, 225, 232, 234
- colures, 185, 186
- comets, 133–34, 137, 138, 144, 185, 186–87
- commentaries, medieval and early modern, 94–96
- Commentary on the Dream of Scipio* (Macrobius), 14, 16, 17, 19, 57, 64, 227
- compasses, 190
- Compendium of the Art of Navigation* (Cedillo y Rujaque), 221–22
- Complete Book on the Judgment of the Stars* (Abenragel), 229
- Complete Library of the Four Treasuries*, 291
- Computus* (Sacrobosco), 8, 71, 72, 73, 75, 149, 175
- concentricity, 107
- condensation, 107
- Conitiensis, Lucca Walter, 86
- Conrad, duke of Swabia, 149
- Constabulus (Costa ben Luca; Quṣṭā ibn Lūqā al-Baʿlabakkī), 73
- constellations, 27, 29, 31; agricultural tasks linked to, 39
- Copernican system. *See* heliocentrism
- Copernicus, Nicholas, 7, 145, 247, 260, 294, 295; criticisms of, 116, 118–24; Galilean discoveries linked to, 125; heliocentrism introduced by, 3, 96, 112–25, 246; influences on, 106, 113–14, 117–18; size of cosmos calculated by, 121; solar year calculated by, 101. *See also* heliocentrism
- copyright, 117
- Corsali, Andrea, 130
- Cortés, Martín, 210, 212–14, 215, 216–17, 218, 221
- Cosmography* (Apian), 82, 84, 89
- Cosmos* (television series), 297
- Costa ben Luca (Constabulus; Quṣṭā ibn Lūqā al-Baʿlabakkī), 73
- Courson, Robert, 11
- craft skills, 210
- Cronologia y repertorio de la razon de los tiempos* (Zamorano), 250, 268
- Crowe, Michael, 215–16
- Dante Alighieri, 129, 132, 180, 181, 188
- Danti, Piervincenzo, 102
- dead reckoning, 190, 210
- The Decameron* (Boccaccio), 180
- de Campos, Hermão, 190
- deferents, 88, 108
- de la Vera Cruz, Alonso, 263
- de los Ángeles, María, 262
- demons, 185–86
- des Bordes, Guillaume, 91
- A Description of the Northern Peoples* (Olaus Magnus), 235
- Dias, Bartholomeu, 195
- Dias, Manuel, 287–92
- Díaz Álvarez, Ana Guadalupe, 260
- Disputationes contra Cremonensia deliramenta* (Ratdolt), 86
- The Divine Comedy* (Dante), 188
- Doctrina Christiana* (1553), 261
- Dog Star (Sirius), 174
- Drake, Francis, 218
- Duarte, king of Portugal, 191
- Dust of Pearls from the Ocean of Arts*, 291
- eccentricity, of orbs, 42, 44, 82, 86, 105, 109, 110, 151, 256; simple, 108
- eclipses, 47, 88, 151, 177, 215, 273, 281; in Chinese calendar, 284; in Jesuit doctrine, 282; lunar, 43, 45, 57, 60, 61, 72, 81, 82, 84, 175, 255, 256, 260, 262, 270–71, *plates 8 and 9*; new moons linked to, 185; solar, 42, 43, 45, 57, 79, 81, 84, 175, 185, 260, 263, 270, 271, 272, 289
- ecliptic, 73, 101, 160, 161, 185, 186, 205, 272; at center of zodiac, 155, 159; fixed vs. mobile, 102; obliquity of, 102, 103; Sacrobosco's definition of, 31, 222; solstices and, 33
- Edward IV, king of England, 178
- Egim (demon), 186
- Elementa doctrinae de circulis coelestibus et primo motu* (Peucer), 116
- Elements* (Euclid), 21, 25
- Elements of Astronomy* (al-Farghānī), 22, 23
- elephant tusks, 194
- Eliot, T. S., 38
- Elman, Benjamin, 284
- epicycles, 42, 44, 72, 82, 88, 105–10, 121, 151
- Epitome of Questions on the Heavens* (Manuel Dias), 287, 290, 292

- equants, 42–43, 44, 72, 82, 88, 151
 equator, 35–36, 185, 199, 229, 230
 equinoctial, 31, 33–34, 46
 equinoxes, 33, 73, 99–105, 186, 231, 256;
 precession of, 100, 101, 102
 Eratosthenes, 208
 ether (quintessence), 88, 133, 140
Etymologies (Isidore of Seville), 227
 Euclid, 21, 25, 57, 81, 247, 254, 280
 Eudoxus of Cnidus, 88, 105, 106
Everything Everywhere All at Once (film),
 184–85
- Faber von Budweiss, Wenzel, 98, 104–5, 109,
 154, 241
 Fabian, Seth, 183
 Faleiro, Francisco, 234–35
 al-Farghānī, Abū al-‘Abbās Aḥmad ibn
 Muḥammad ibn Kathīr, 22, 23
 feast days, 99–100, 257, 265
 Ferdinand V (king of Spain), 207–9,
 224, 234
 Fibonacci, Leonardo, 8
 Ficino, Marsilio, 168
First Collection of Heavenly Studies
 (Li Zhizao), 290
 fixed stars, 27, 67, 68, 112, 121, 272
 Floron (demon), 184
 four elements, 26–27, 68, 96–98, 99, 118, 156,
 169, 186, 266
 Francis I, king of France, 250
 Frederick, duke of Swabia, 150, 160
 Frederick I, Holy Roman Emperor
 (“Barbarossa”), 156
 Frederick II, Holy Roman Emperor, 180
 Frederick III, duke of Saxony, 243
 Frederick V, duke of Swabia, 149–50, 152,
 153, 158–59, 160–61
 Frobisher, Martin, 218
 frontispieces, 81
 Fusco, Domenico, 79, 86
- Galen, 166, 168
 Galileo Galilei, 140, 221, 294; comets viewed
 by, 137, 138; in literature, 126–27;
 telescopic discoveries of, 3, 5, 7, 96, 111,
 125, 139–48, 247, 248, 288, 295
 Gama, Vasco da, 195
 Gante, Pedro de, 258, 261
- Gaurico, Luca, 166
*General Introduction to Calendrical
 Astronomy* (Wang Yingming), 292
 geocentrism, 2, 17, 44, 86, 138, 145, 222; of
 Aristotelian model, 107–8, 116, 118, 119,
 123–24, 150; Clavius’s defense of, 120–21,
 124; Copernican models reconciled with,
 114; decline of, 147; in Greek and Roman
 antiquity, 13–14; in modern use, 206;
 persistence of, 222; solar year and, 100;
 sphericity of the Earth linked to, 29–29;
 Tycho’s rejection of, 137. *See also* Ptolemy,
 Claudius
Geography (Ptolemy), 229
Georgics (Virgil), 38, 39, 41, 227
 Georgius de Monteferrato, 158
 Gerard of Cremona, 21, 22, 72, 78, 103, 109, 175
 Giacomotto-Charra, Violaine, 91
 Gingerich, Owen, 114
 Giunta, Luca Antonio, 166
 Giuntini, Francesco: climate zones viewed
 by, 234; commentary on Sacrobosco’s
 Sphere by, 115, 124, 130, 134, 136, 154; frigid
 zone viewed by, 236; heliocentrism
 viewed by, 117, 119; horoscopes explained
 by, 161–62, 167, 168; humors viewed by, 171
 Global Positioning System (GPS), 206
 Gontier, Guillaume, 86
 Grafton, Anthony, 152, 162
 Graminaeus, Theodor, 157, 158, 159, 170, 172, 173
 Grassi, Orazio, 144–45
 gravity, 119
 Greek language, 19–20
 Gregorian calendar, 283
 Gregory XIII, Pope, 283
 Grendler, Paul, 247
 Griettan, Jean, 86
 Griselle, Pierre, 86
 Grosseteste, Robert, 22–23
 Gryneus, Simon, 244–45
 Gutenberg, Johannes, 76
- heliocentrism, 5, 120, 246; diffusion of, 115;
 Galileo’s discoveries linked to, 127, 143;
 importance of, 112; navigators unfazed by,
 222; skepticism toward, 114, 116, 119,
 123–24, 145–46; traditional elements in,
 113, 117–18; Tycho’s rejection of, 137.
 See also Copernicus, Nicholas

- heliotrope, 185, 187–88
 Henrique, king of Portugal, 191, 193, 195
 Henry of Sinrenberg, 241
 Henry VI, Holy Roman Emperor, 149
 Henry VI, king of England, 164, 165, 178, 180
Henry VI, Part 2 (Shakespeare), 181
 Henry the Navigator, infante of Portugal, 128–29
 Hephaestio of Thebes, 187
 Hildegard of Bingen, 170
 Hill, Thomas, 115, 116–17, 118, 120, 123, 124, 235
 Hippocrates, 150, 166, 168, 173, 227
A History of Magic and Experimental Science (Thorndike), 183
A History of the Warfare of Science with Theology in Christendom (White), 183
 “The Hollow Men” (Eliot), 38
 Homer, 174
 Hopyl, Wolfgang, 85–86
 horologium, 175
 horoscopes: at birth, 152, 160, 161, 164–65, 181; of Frederick V, 149–50, 152, 153, 158–59, 160–61; “houses” in, 160–61; physicians’ use of, 74. *See also* astrology; zodiac
 horses, 193
 House of Trade, 209, 212, 213, 259
 Hsia, Ronnie Po-Chia, 277
 humors, 156, 166, 168–70
 Humphrey, duke of Gloucester, 164

 Ibn al-Shatir, 113
 Ibn Rushd (Averroes), 88, 105, 107, 108, 109
 Ignatius of Loyola, Saint, 246
Iliad (Homer), 174
 illumination, 54
 illustration, 57–68, 81
Imperially Approved Synthesis of Books and Illustrations Past and Present, 290
 incubae, 186
Inferno (Dante), 180, 181
Initia doctrinae physicae (Melanchthon), 116
 Innocent III, Pope, 11
 Inquisition, 179
 intercalary months, 283
Introduction to Astrology (Alcabitius), 152
 Isabella I, queen of Spain, 207–9
 Isidore of Seville, 227

 Janss, Pieter, 220
 Jean de Meun, 238
 Jesuits, 246–49, 251; in China, 275–93; in New Spain, 255–74
 João I, king of Portugal, 191–92
 Jocius of London, 12
 John of Glogów, 154
 John of Seville, 22
 Jourdemayne, Margery, 181–82
 Julian calendar, 100–102, 283
 Julius II, Pope, 182, 183
 Jupiter, 2, 17, 27, 72, 112, 159; as benevolent planet, 157–58, 167; moons of, 126, 127, 139, 141, 142, 144, 146, 248
 Juste, David, 152
 Juvenal, 77

 Kelly, Kathleen Ann, 232
 Kepler, Johannes, 3, 122, 221, 246, 294
 al-Kindī, Abū Yūsuf Yaʿqūb Ibn Ishāq (Alkindus), 75, 151–52
 Kircher, Athanasius, 285, 286
 Klug, Joseph, 84, 245, 246
 Kochab (star), 200–203
 Konrad von Megenberg, 57, 63
 Köppen, Wladimir Peter, 237
 Krafft, Johannes, 245
 Kreutzer, Veit, 245
 Kusukawa, Sachiko, 243

 Latin language, 12, 18, 19–20, 21–22
 latitude, 198–99, 205
 Lattis, James, 124, 248
 leap days, leap years, 283
 le Breton, Guillaume, 11
 Lefèvre d’Étaples, Jacques, 85, 229, 232
 Leitão, Henrique, 287
 Leon, Juan de, 260
Liber Abacus (Fibonacci), 8
Life of Galileo (Brecht), 126–27
 Limbach, Saskia, 245
 Lipperhey, Hans, 139
 literacy, 89
 Little Dipper (Ursa Minor), 198, 200–201
 Li Zhizao, 281, 285, 290
 Lucan, 18, 37, 38–41, 191
 Lucero, Gonzalo, 255, 257, 276, 282
 Lucretius Carus, Titus, 137

- lunar eclipse, 43, 45, 57, 60, 61, 72, 81, 82, 84, 175, 255, 256, 260, 262, 270–71, *plates 8 and 9*
- Luther, Martin, 242–43
- Lutherans, 242–46, 250
- Macrobius, Ambrosius Aurelius Theodosius, 14, 15, 16, 17, 19, 26, 57, 227
- madrassa, 12
- Magellanic Clouds, 130, 131, 132
- Magone, Rui, 290
- al-Ma'mun, Caliph, 22
- Manilius, Marcus, 227
- Marnef, Denise de, 91
- Marnef, Jérôme de, 91–92
- The Marriage of Philology and Mercury* (Martianus Capella), 16–18, 19, 149
- Mars, 2, 17, 27, 112, 146, 147
- Marschall, Roger, 74–75, 177–78
- Martial, 77
- Martianus Capella, 16–18, 19, 143, 149
- Martins, Roberto de Andrade, 94–95
- Māshā'allāh (Messahala), 73, 151–52
- Ma'shar, Abu, 21
- Mathematical Principles of Natural Philosophy* (Newton), 7, 296
- Mathematical Syntaxis*, 21
- Matthew of Szamotuł, 98, 110
- Maya, 267–74
- Medici, Cosimo de', 126, 139
- Medici, Giuliano de', 130
- Medici, Lorenzo di Pierfrancesco de', 129
- Medina, Pedro de, 210–21
- Melanchthon, Philip, 116, 243–46, 248, 250
- Mercator, Gerhard, 235–36
- Mercury, 2, 17, 27, 112, 121, 145, 146, 188
- meridian, 160–61
- Merlin (magician), 186
- Messahala (Māshā'allāh), 73, 151–52
- Mesue (Yuhanna ibn Masawaih), 166
- Metamorphoses* (Ovid), 18
- Meteorology* (Aristotle), 226
- Metham, John, 232
- Milex (comet), 186–87
- Milky Way, 144, 248
- moon, 2, 27, 112, 139–41, 163, 170–71, 248; eclipses of, 43, 45, 57, 60, 61, 72, 81, 82, 84, 175, 255, 256, 260, 262, 270–71, *plates 8 and 9*; as symbol, 270
- Morisanus, Bernardus, 115, 124
- Moss, Ann, 175
- Moulin, Isabelle, 94
- Müller von Königsberg (Johannes Regiomontanus), 86, 89, 109, 175
- Mundus Novus* (Vespucci), 130
- Munich Guide*, 190–91, 203, 207, 210–11, 221
- Muslims, 192–93
- Mysterium Cosmographicum* (Kepler), 122
- Nahuas, 260–67, 274
- Natural History* (Pliny the Elder), 20
- navigation, 91, 128; celestial, 5, 189, 190, 196, 197, 206, 209, 221
- nebulae, 130
- necromancy, 184
- New Star (1572), 134–36, 144
- New Theorica* (Peurbach), 86, 88, 90, 109, 112, 175
- Newton, Isaac, 7, 119, 138, 221, 294
- Ninety-five Theses* (Luther), 242
- non-naturals, 169
- North, John, 178
- north pole, 36–37, 199
- North Star (Polaris), 190–91, 205; Regiment of, 197–204, 217
- Notre-Dame Cathedral, 10, 24
- Nye, Bill, 297
- Olaus Magnus, 238
- On Generation* (Aristotle), 155
- On the Angular Motions of the Five Planets* (Wang Hsi-shan), 292–93
- On the Changing of Times* (al-Kindi), 75
- On the Motion of the Eighth Sphere*, 72–73, 103–4
- On the Republic* (Cicero), 14–15
- On the Revolutions of the Heavenly Spheres* (Copernicus), 7, 96, 101, 112–14, 116, 124, 145, 246, 260, 296
- On the Sphere* (Grosseteste), 22–23
- On the Sphere* (Pecham), 22–23
- Oosterhoff, Richard, 85
- Oresme, Nicole, 239
- Oriens (demon), 186
- original sin, 19
- Orion's Belt, 139
- Ortelius, Abraham, 277
- Osiander, Andreas, 246
- Ovid, 18, 37, 38, 55, 233, 234

- Padilla, Luis de, 259–60
 Palm, Erwin Walter, 256
 palmistry, 184
 Pantin, Isabelle, 250
The Path of Long Study (Christine de Pizan), 238–40
 Paul, the Apostle, Saint, 241
 Paymon (demon), 186
 Pecham, John, 22–23
 Pedersen, Olaf, 8, 71
 Pedro, infante of Portugal, 191
 Pérez de Mesa, Diego, 115, 117–18
 perigee, 230
 Perkins, Peter, 222–23
 Petrarch, Francesco, 182–83
 Petreius, Johannes, 246
 Pettegree, Andrew, 77
 Peucer, Caspar, 116
 Peurbach, Georg, 86, 89, 90, 109, 110, 112, 175, 260
 Peutinger, Conrad, 191
Pharsalia (Lucan), 39–40, 41
 Pherkad (star), 200–203
 Philip II, king of Spain, 212
 Philolaus the Pythagorean, 117–18
 Pietro d'Abano, 166
 Pifféri, Francesco, 115, 124, 130, 132, 173–74
 piracy, in book trade, 78
 Piron, Sylvain, 183
 planetary motion, 41–42, 86
 Plato, 240
 Pliny the Elder, 20, 37, 187
 Plutarch, 77
 Polaris (North Star), 190–91, 205; Regiment of, 197–204, 217
 polar regions. *See* antarctic region; arctic region
 precession of the equinoxes, 100, 101, 102
Principles of the Planetary Motions, 291–92
 printing, 75, 76–92
 Prosdócimo de' Beldomandi, 98, 166
 Protestant Reformation, 6, 242, 296
 Pseudo-Dionysius, the Areopagite, 26
 Ptolemy, Claudius, 19; armillary sphere described by, 45; astronomy and divinity linked by, 14, 240; comets viewed by, 187; Copernicus influenced by, 113; cosmos measured by, 121; geocentric model of, 58; nebulae viewed by, 130; precession of the equinoxes viewed by, 101; predictive models designed by, 88, 150–51; in translation, 20, 21, 26, 229; world map of, 235; zodiacal declination calculated by, 102. *See also* geocentrism
 pulse rate, 175
Il Purgatorio (Dante), 129, 132
 Pythagoras, 117, 233

 al-Qabīsī, 'Abd al-'Azīz ibn 'Uṭmān (Alcabitius), 74, 151–52, 175
Quadrans, 71, 200
 quadrant, 175, 198, 202, 275, *plate* 16
Questions on the Sphere (D'Ailly), 154
 quintessence (ether), 88, 133, 140
 Qu Rukui, 280, 293
 Qusṭā ibn Lūqā al-Ba'labakki (Costa ben Luca; Constabulus), 73

 rarefaction, 106–7
 Ratdolt, Erhard, 79, 81–82, 86
 “Reconquest,” of Christian lands, 192–93
 Reformation, 6, 242, 296
 Regiment of the North Star, 197–204, 217
 Regiment of the Sun, 204–6, 216
 Regiomontanus, Johannes, 86, 89, 109, 175
 Renner, Franz, 79, 81, 86
 retrograde motion, 41–42
 Rheticus, Georg Joachim, 246
 Rho, Giacomo, 291
 Ricci, Matteo, 275–85, 287, 292, 293
 Rideau-Kikuchi, Catherine, 82, 89
 Robertus Anglicus, 9, 73, 106, 172, 216, 228, 230, 241
 Rocamora, Ginés, 260
Romance of the Rose (Jean de Meun), 238
 Roman numerals, 8
Romeo and Juliet (Shakespeare), 4
 Rottweil, Adam von, 79, 86
 rubrication, 51, 54
 Ruggieri, Michele, 276–77
 Rutkin, Darrel, 160

 Sabra, A. I., 22
 Saenz Santayana y Spinosa, Rodrigo de, 115, 117, 119
 Sagan, Carl, 297
 Sahagún, Bernard de, 260–61, 264, 274

- saints' days, 102, 265
 Sánchez de Aguilar, Pedro, 255–56, 257, 270, 276, 282
 Sanderson, Marie, 236
 Sandler, Lucy Freeman, 52
 Sanzio, Raphael, 182–83
 São Tomé, 203–4
 Saturn, 2, 17, 27, 72, 112, 144, 158; as “evil” planet, 156–57, 167; rings of, 143, 146, 248, 290
 Schall von Bell, Adam, 291
The Schoole of Skil (Hill), 116–17
School of Athens (Sanzio), 182
 Schotte, Margaret, 221
 Schreckenfuchs, Erasmus Oswald, 115, 124, 153–54, 161–62, 233, 234, 236
 Scientific Revolution, 5, 296
 Scipio Aemilianus Africanus, 15
 Scot, Michael, 97, 153, 155–58, 166, 180–81, 228, 230
The Seaman's Tutor (Perkins), 222–23
 Seitz, Peter, 245
 Seneca, Lucius Annaeus, 77, 137
 Sessa, Melchior, 245
 Shakespeare, William, 4, 181, 189
Sidereus nuncius (Galileo), 139, 140, 141, 142
 Sirius (Dog Star), 174
 Sivin, Nathan, 292
 slave trade, 194, 204, 235, 236
 solar eclipse, 42, 43, 45, 57, 79, 81, 84, 175, 185, 260, 263, 270, 271, 272, 289
 solar year, 100–101, 124, 264
 solstices, 33, 99–105, 186, 256
 Southern Cross, 129–33, 197, 204
 Southwell, Thomas, 164–65, 178, 181–82
Sphaerics (Theodosius of Bithynia), 21, 25–26
 sphere, defined, 25, 57–58, *plate 10*
The Sphere of Sacrobosco (Thorndike), 183
 spice trade, 195
 Stapulensis, Jacob Faber, 166
Starry Messenger (Galileo), 7, 248
 stellar parallax, 120, 121, 125
 Stoics, 137–38
 succubae, 186
 sun, 2, 18, 90, 112, 155; darkening of, at Passion, 185–88; declination of, 84, 124, 184, 191, 205, 216; eclipses of, 42, 43, 45, 57, 79, 81, 84, 175, 185, 260, 263, 270, 271, 272, 289, 290; Regiment of, 197–204, 217
 sunspots, 143, 144, 146, 248
 supernovae, 133
 tables, for data, 84–85
 telescopy, 3, 5, 7, 96, 111, 125, 139–48, 247, 248, 288, 295
 terrestrial realm, 27–28, 96–97
Tetrabiblos (Ptolemy), 151
 Thābit ibn Qurrah (Thebit), 73, 103
 Thales, 233
 Theodosius of Bithynia, 21, 25–26, 57–58, 81
Theorica (attrib. Gerard of Cremona), 72, 73, 78, 86, 109, 175, 260
 Thorndike, Lynn, 8–9, 183
 tides, 163, 190
 title pages, 81
 Tockler, Conrad, 104–5
 translation, 12, 20, 26, 89, 91
 trepidation, 73, 102, 104–5
Triumph of Fame (Petrarch), 183
 Tropic of Cancer, 33–35, 41, 46, 186, 224, 230, 233
 Tropic of Capricorn, 33–35, 46, 186, 224
 al-Tūsī, Naṣīr al-Dīn, 114
 Tūsī couple, 114
 Tyson, Neil deGrasse, 38, 296–97
 University of Paris, 4, 8–12
 University of Wittenberg, 242–44, 246, 250
 urine, 175, 177
 Ursa Minor (Little Dipper), 198, 200–201
 Veer, Gerrit de, 219
 Venus, 2, 17, 27, 112, 188; phases of, 142, 145, 146, 248
 Vernaghi, Ana, 260
 Vespucci, Amerigo, 128, 129, 130, 132, 234
 Vespucci, Bartholomew, 166
 Vinet, Élie, 250
 Virgil, 18, 37–39, 41, 55, 189, 191, 227, 233, 234
 volvelles, 82, 84
 “wandering stars,” 27
 Wang Hsi-shan, 292–93

- Wang Yingming, 292, 293
weather forecasting, 75
Weill-Parot, Nicolas, 183
Welcome to the Universe (Tyson), 38
Werner, Sarah, 78–79
White, Andrew Dickson, 183
woodcuts, 79, 82, 91
Woods, Marjorie Curry, 39
Wootton, David, 31

Xu Guangqi, 180, 283, 285

Yuhanna ibn Masawaih (Mesue), 166
Yunes Vincke, Estefanía, 262

Zamorano, Rodrigo, 260, 268
zenith, 205, 231
zodiac, 34, 46, 58–59, 155–60, 266–67;
 declination of, 102, 103; human anatomy
 linked to, 176, 177; signs of, 31. *See also*
 astrology; horoscopes
Zoest, Hermann, 175
Zoroaster, 182, 186