TWO

DON'T FORGET YOUR APIAN

A DIY Guide to the Cosmos

Peter Apian, a student of prominent astrologers at the University of Vienna, put practical astronomy on the map in a book he published in 1524, the *Cosmographicus Liber*. Before he attained a university position as a mathematician at the University of Ingolstadt in 1527, Apian earned his credentials as a printer of materials intended to chaperone stargazers as a type of field guide.[1] To do this, he translated Ptolemaic cosmography into an observer-based pedagogy that he packaged into printed books. Academic cosmography was delivered via lectures to audiences of armchair astronomers who occasionally used visual aids in their classes. These took the form of metal and paper instruments meant for demonstration purposes and were largely theoretical in nature. By contrast, Apian's update and visualization of the arcane genre into pictorially enhanced editions resurrected cosmography's use for lay stargazers, whom he expected to make their own observations. Apian explained the rather abstract principles of mathematized geography via mechanical pictures, creating diagrams that centered individual viewers at the nexus of a world to be experienced firsthand and observed. Apian's *Cosmographicus Liber*, printed by the cleric Johannes Weyssenburger in Landshut, simplified musty academic astronomy and attracted a broader public with the explanatory clarity of his diagrams.[2] By way of visual and interactive volvelles with moving parts, Apian demonstrated principles of astronomy and mathematized geography to readers in a manner that could help them navigate the world. This chapter provides an art historical treatment of Apian's work by way of his key mechanical images. It argues that

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

Apian converted academic astronomy into prescriptions for viewing practices designed to school the user in making visual judgments. With visual tools that literally pop out of the book, Apian animated both the celestial and the terrestrial spheres. Apian's *Cosmographicus Liber*, a book for learning to look at the heavens, strove to sharpen the eye of the literate stargazer.

This chapter treats observations as practices recommended for early modern night-sky exploration. According to Apian, the vault of the heavens was legible if one understood what one saw there. The author made self-conscious pitches to the reader about how to use vision to confirm the precepts of positional astronomy. This visual knowing, according to Apian, was an analytical category mediated by book illustrations. Objects on the canvas of the sky appear in Apian's texts to be confirmed by observations, using pictures to visually verify phenomena on the horizon. By suggesting prompts for visual reasoning, this chapter argues, Apian instrumentalized observation as the tool for unlocking knowledge of the heavens.

In a dedication to the reader in a French translation of Peter Apian's *Cosmographie* published in Paris in 1553, the editor alludes to the cosmography's usefulness by specifically invoking its ability to present information to the reader's eye:

> My friend, dear reader, Apian . . .
> describes and portrays in this book
> The perfect heavens, earth and planets,
> The movements, powers of nature,
> And he shows to the naked eye,
> In diagrams and figures,
> The regions of the habitable earth:
> To whose end the human creature
> Contemplates in itself what brings profit.[3]

Invoking the "naked eye" as the target of this cosmography's design was not just a publisher's idle pitch; it was a theme that had been developed by Peter Apian in the *princeps* of the *Cosmographicus Liber* and one that would be reprised in Apian's other publications directed to a lay public. In fact, twenty years after the *Cosmographicus Liber*'s first edition, printers still advertised this as the book's most marketable asset. Already from the date of its first printing in 1524 in the Bavarian town of Landshut, Apian appealed to the eye's authority by picturing it frequently in the text. In so doing, Apian acknowledges it as an important agent for whose edification his book strives. The content Apian presented was hardly new; it was cribbed from multiple sources, some of which had been in circulation for centuries.[4] Entirely novel, however, was Apian's presentation of that data as visual templates for discoveries that readers in the field could make for themselves. This update amounted to a popular science for lay observers.

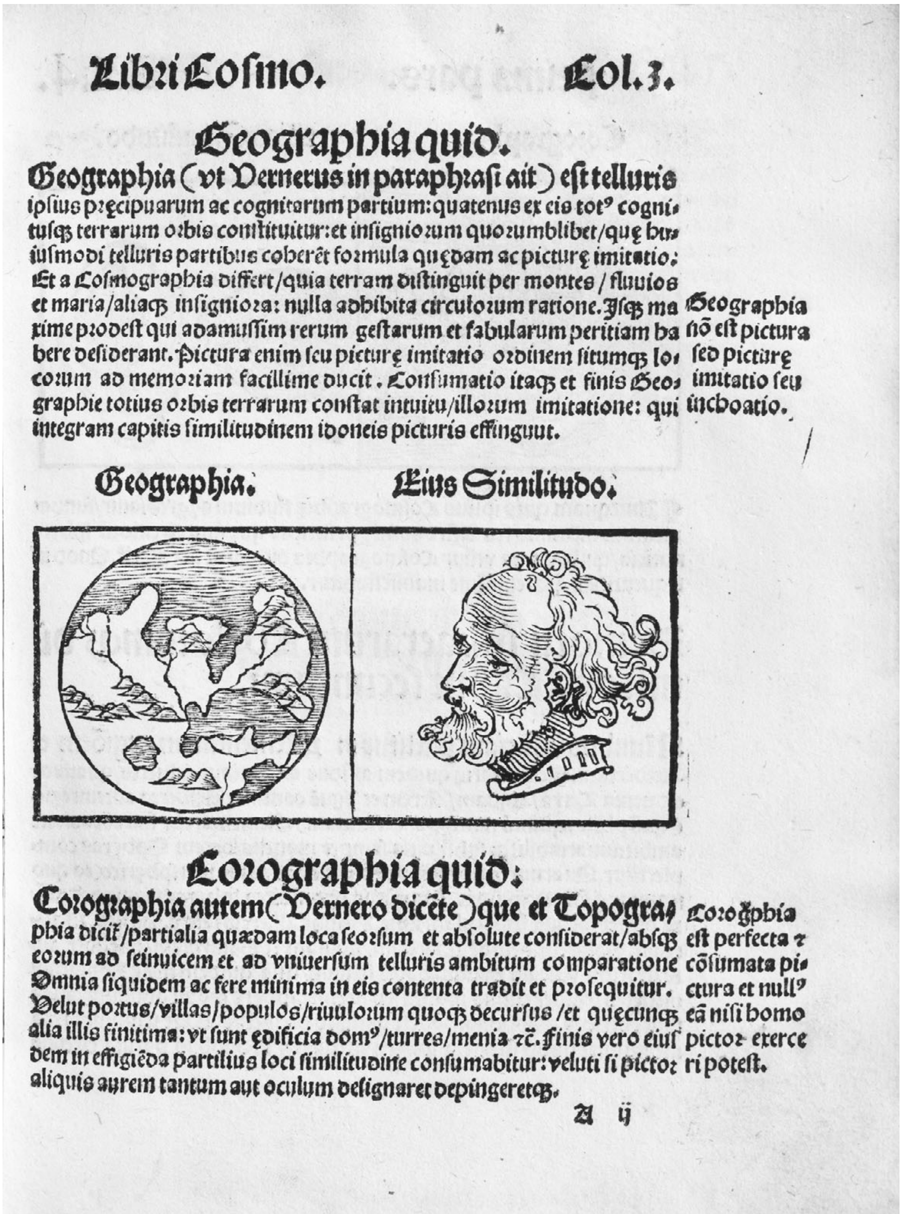
Apian's *Cosmographicus Liber* is a manual of mathematical and astronomical geography that treats the basics of both astronomy and geography, breaking the discipline down into sections.[5] Invoking Ptolemy in the headlining use of the word "cosmography," Apian upheld the tradition of labeling Ptolemy's geographic work as his fifteenth-century Florentine translator Jacopo d'Angelo had also done, recognizing the importance of Ptolemy's work as one that mediated between geographic coordinates and the astronomical data from which those terrestrial coordinates were derived.[6] Sixteenth-century editors of Ptolemaic data such as Apian referred to their efforts as cosmographic ones.[7]

To illustrate the aims of cosmography, Apian included a visual simile that sought to distinguish between geographic and chorographic levels of description active in cosmography by visualizing an analogy that most epitomizers of Ptolemy's *Geographia* had overlooked, and possibly misinterpreted (Figures 2.1 and 2.2).[8] Ptolemy had invoked the juggling act performed by the portraitist to explain this distinction between modes of describing. When rendering an entire head, the portraitist borrows the cognitive framework of the geographer when he contemplates the globe. The production of individual features, on the other hand, is analogous to the task of chorographic, or local, description.

Apian was the first editor of Ptolemy's work to pictorialize this conceit. With this image, Apian announced his book's campaign to visualize the pedagogy of cosmography. In a woodcut consisting of four visual fields, Apian invoked these products of the portraitist: the rendering of the entire head compares favorably to geography's pursuit to capture the macrocosm, whereas topographic description, or chorography, embodies the level of particular features.[9] The illustration demonstrates these two ways to think about the terrestrial sphere, linking a globe to a head and a townscape to an ear and an *eye*. These images enshrined what might otherwise have been a couple of throwaway conclusions. The first point that Apian drove home was that the description of the earth could be translated into inherently visual terms; the second is that distinctions between incipient disciplines could be cultivated by informed observation. Apian was not only the first to recognize the visual potential of Ptolemy's model, but also the first to formalize these principles of visual description as the modus operandi of his campaign to pictorialize cosmography.

The opening images of the eye and the ear in the *Cosmographicus Liber* have been frequently mobilized in the secondary literature; they are usually employed to showcase a dawning self-consciousness in early modern visual practice and the range of description suitable to rendering by a draftsman.[10] But these images, significantly, are also the opening gambit of a text that goes beyond lip service to the eye's role in knowing and describing. Rather than presenting just a handy mnemonic, Apian uses the visual analogy to pitch a claim with larger stakes, one with significant implications for the role of images in early modern scientific pursuits in general. The image provides the rationalization for understanding cosmography through picturing and, thus, underwrites the visual practices active in the book. The *Cosmographicus Liber*'s

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press



Libri Cosmo. Fol. 3.

Geographia quid.

Geographia (vt Vernerus in paraphrasi ait) est telluris ipsius precipuarum ac cognitarum partium: quatenus ex eis tot⁹ cognitusque terrarum orbis constituitur: et insigniorum quorumlibet/que huiusmodi telluris partibus coherēt formula quedam ac picture imitatio: Et a Cosmographia differt/quia terram distinguit per montes / fluuios et maria/aliaque insigniora: nulla adhibita circulorum ratione. Jsque maxime prodest qui adamussim rerum gestarum et fabularum peritiam habere desiderant. Pictura enim seu picture imitatio ordinem situmque locorum ad memoriam facillime ducit. Consumatio itaque et finis Geographie totius orbis terrarum constat intuitu/illorum imitatione: qui integram capitis similitudinem idoneis picturis effingunt.

Geographia nō est pictura sed picture imitatio seu incboatio.

Geographia. Eius Similitudo.

Corographia quid.

Corographia autem (Vernero dicēte) que et Topographia dicit/partialia quedam loca seorsum et absolute considerat/absque eorum ad seinuicem et ad vniuersum telluris ambitum comparatione Omnia siquidem ac fere minima in eis contenta tradit et prosequitur. Velut portus/villas/populos/riuulorum quoque decursus /et quecunque alia illis finitima: vt sunt edificia dom⁹/turres/menia ꝛc. Finis vero eiusdem in effigieda partilius loci similitudine consumabitur: veluti si pictor aliquis aurem tantum aut oculum designaret depingeretque.

Corographia est perfecta ꝛ cōsumata pictura et null⁹ eā nisi homo pictor exercere potest.

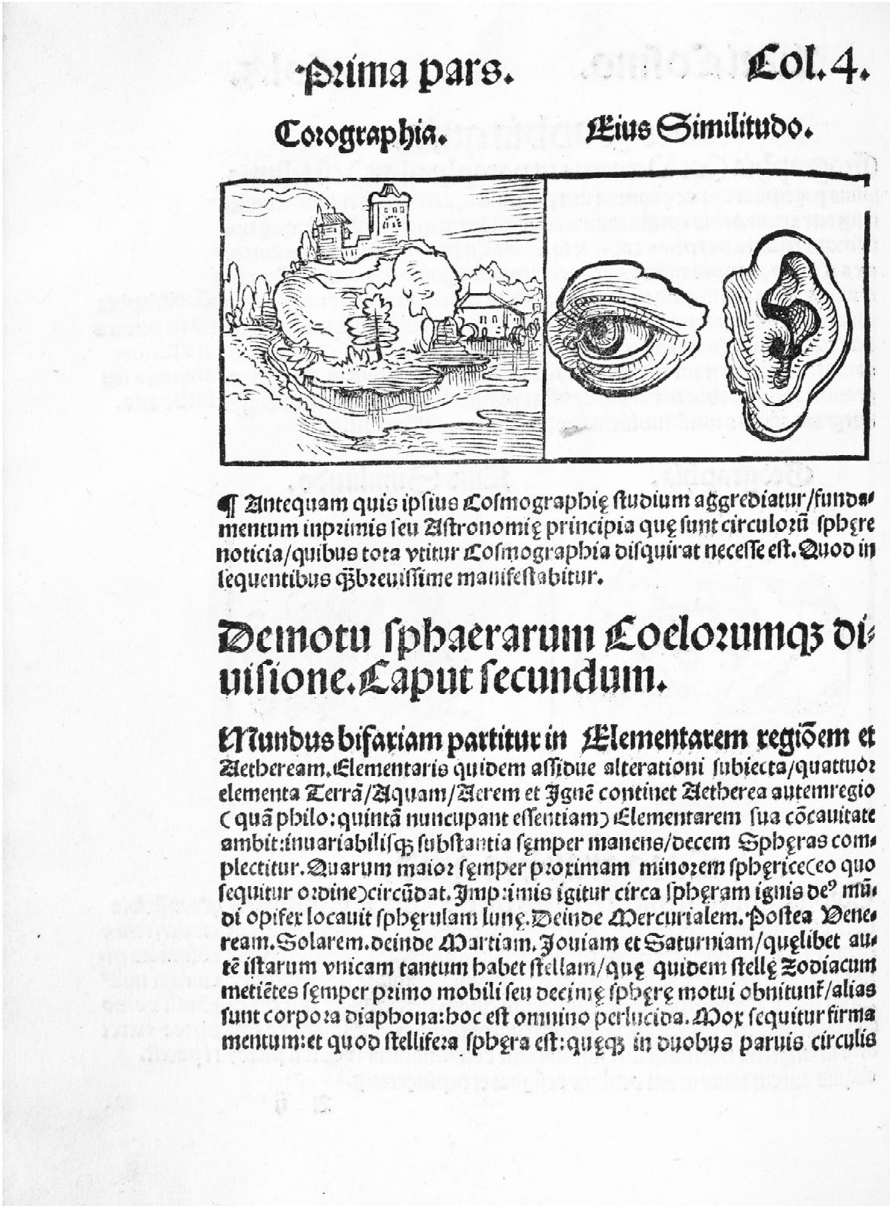
A ij

2.1. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 3. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

strategy for observing the world through visual means potentially revises the matrix in which the relationship between images and the development of popular science has been considered historically. Instead of simply supplementing understanding, images could also activate the observer's eyes.

Apian studied in Leipzig and Vienna. After a brief sojourn in Landshut, he was summoned to Ingolstadt for a university post in mathematics in 1527, and

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press



Prima pars. Fol. 4.

Corographia. Eius Similitudo.

¶ Antequam quis ipsius Cosmographie studium aggrediatur/fundamentum inprimis seu Astronomię principia quę sunt circulorũ sphęre noticia/quibus tota vtitur Cosmographia disquirat necesse est. Quod in sequentibus q̃breuissime manifestabitur.

De motu sphaerarum Coelorumq; diuisione. Caput secundum.

Mundus bifariam partitur in Elementarem regiõem et Aethereã. Elementaris quidem assidue alterationi subiecta/quattuor elementa Terrã/Aquam/Aerem et Ignẽ continet Aetherea autem regio (quã philo: quintã nuncupant essentiam) Elementarem sua cõcauitate ambit: inuariabilisq; substantia sęmper manens/decem Sphęras complectitur. Quarum maior sęmper proximam minorem sphęrice (eo quo sequitur ordine) circũdat. Imprimis igitur circa sphęram ignis deus mũdi opifex locauit sphęrulam lunę. Deinde Mercurialem. Postea Venere am. Solarem. deinde Martiam. Jouiam et Saturniam/quęlibet autẽ istarum vnicam tantum habet stellam/quę quidem stellę Zodiacum metiẽtes sęmper primo mobili seu decimę sphęrę motui obnituntur/alias sunt corpora diaphona: hoc est omnino perlucida. Mox sequitur firmamentum: et quod stellifera sphęra est: quęq; in duobus paruis circulis

2.2. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger,1524), fol. 4. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

it was here that he would establish his own print shop around 1525.[11] As a printer, Apian speculated that privileging visual knowledge was a prerogative that the publishing market was uniquely capable of meeting. He guessed right. The *Cosmographicus Liber* was printed in Latin and in several vernacular tongues from 1524 until the seventeenth century, and the text even withstood Copernicus's reconceptualization of the universe from a geocentric to a

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

heliocentric model. An updated edition was released in Antwerp in 1529 with corrections by the Louvain mathematician and cartographer Rainer Gemma Frisius (1508–55).[12] New additions by Gemma prompted another printing in 1533. Dutch and French vernaculars appeared shortly thereafter (Dutch in 1537; French in 1544). An almost continuous stream of Latin editions accompanied these new vernaculars. Before the end of the sixteenth century, there were at least forty-three editions in four languages.[13] The vernacular editions must have seemed relatively risk-free transpositions of the original Latin to the printers, who surely based the logic of these wider offerings on the strength of Apian's visual apparatus in conveying the book's themes. Indeed, such synthetic astronomical content had never before circulated in vernaculars – as the subjects of astronomy and geography were restricted to university audiences and learned circles. To be sure, many contemporary books repackaged material already in circulation, but the manner in which Apian reconfigured his sources makes this book scarcely resemble any of its direct forebears.[14] It was indebted to material from a number of significant sources of wide-ranging chronology: Ptolemy and Pliny as antique sources; Sacrobosco as medieval; more contemporary practitioners such as Regiomontanus and Martin Waldseemüller; and, later, Gemma Frisius. In fact, as Steven Vanden Broecke argues, it was only with Gemma's enhancements to Apian's *Cosmographicus Liber* that the book's content elevated the status of cosmography in academic settings.[15] Out of this admixture of old and new sources, Apian invented a popular science for lay observers. This chapter shows how Apian reformatted his major sources to configure the eye as the central agent of a pictorial guide to the heavens and the earth's geography.

IMAGES AND VISUAL LITERACY

Apian's illustrations and instruments offer visual evidence that impacts two major scholarly trajectories: first, the development of scientific images; and second, the structuring of visual literacy. The historiography of scientific images has primarily been the province of the history of science, perhaps predictably, but more recently it has generated substantial interest from art history. Apian's diagrams offer a productive reconciliation of these two fields. On the role of scientific images, this chapter proposes Apian's instruments as consequential in shaping empirical practices that would themselves come to define new disciplinary approaches. On the topic of visual literacy, it aims to suggest that Apian's program readied new audiences for the exercise of this skill.

Recent treatments of early modern epistemic, or knowledge-making, images track their role in the scientific revolution, and in a related area, the development of new disciplines of scholarly inquiry. These lines of academic

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

investigation intersect with the history of printmaking at the juncture of the circulation and standardization of pictorial motifs.[16] For both of these concerns, scholars have been particularly attentive to the fields of botany and anatomy.[17] The emphasis on naturalism, along with its ahistorical accomplice "accuracy," in early scholarship on the illustrated natural sciences skewed the attention toward the aesthetic accomplishments of illustrations in a few select fields. This emphasis had the further effect of alienating the treatment of images in the physical sciences whose illustrations were not naturalistically driven. This privileging of mimetic images by select fields, according to Renzo Baldasso, also bankrupted potentially more productive investigations of images' epistemological functions.[18] Mimetic concerns have been tempered in more recent studies, driving considerations toward the rhetorical claims of their media.[19] Examinations of images' conventions and non-unique qualities are also being offered over teleological celebrations of naturalism.[20] More nuanced and historical applications of aesthetics in epistemic images have been tracked in astrological charts and horoscopes.[21] Other efforts have tracked the role of images in guiding scientific practice, especially images considered to be operative in establishing new epistemologies.[22] An important recent intervention has gone some distance to repair this void, considering a heterogeneous range of printed visual media to investigate their role in the formation of disciplinary sciences.[23]

Analyses of the historical reception of images has enabled more nuanced social histories of literacy. The work of images in shaping visual literacy has shifted from considering printed images as mere accompaniments to texts that were otherwise inscrutable to nonreaders to showing how they enlivened popular lay practices, such as devotion.[24] Visual literacy has also been pursued by investigations of images to both reflect and shape a cognitive understanding of collective cultural values, a concept to which an influential study gave the term *period eye*.[25] Studies of the synergy of words and images have emphasized scientific images' efforts to serve as technical support where words failed.[26] Images could also clarify for the reader opaque passages in the text.[27] Some recent inquiries also foreground images' functionality, such as those of technical images;[28] or they have argued for them as a vital component of text technologies.[29] Important work by Suzanne Karr Schmidt that features the reception of prints by early modern publics has given agency to these viewers as *users* – a claim that is backed by a surprising array of genres (including anatomical flap prints, devotional art, and movable dials) that stimulated interactivity.[30] In a concurrent development, the rubric of epistemic images has been invoked to characterize the images' internal pursuit of knowledge itself and explores the degree to which they toggle between representing and showing.[31]

This chapter bridges the themes of epistemic images and visual literacy by arguing that Apian's cosmographic images raised new epistemological concerns for the reading public. The illustrations conspired to shape the visual literacy of a particular stratum of educated readership; Apian's *Cosmographicus Liber* represents a coordinated effort to enhance readers' ability to make visual decisions and sharpen their capacity to observe. Apian relied on popular knowledge as diverse as astrology, amateur navigation, and instructional manuals for scientific instruments, as well as more scholarly sources in astronomy and cosmography. Apian's instruments embedded these forms of lay and learned knowledge into a pictorial program that aimed to facilitate new observational skills. The extent to which these images turned texts into a user's guide can be measured in the next generation of printed books that adopted these images to prompt eyewitness investigations. Epistemic images mediated visual learning, enunciated new fields of inquiry, accompanied technical manuals, and thus helped establish new practices.[32] My inquiry aims to contribute new scholarship on these knowledge-generating images and the investigation of the role of printed images in establishing new competencies in visual practices.[33] Printed media directed the collaborative inquiry that underwrote new scientific disciplines, especially in their capacity to recommend and coordinate visual searches.

UPDATING THE ANCIENTS

In light of the proven strength of Apian's visual program in the course of the long printing history of sixteenth-century cosmographic material, it is highly significant that the first visual analogy in the *editio princeps* already foreshadows the role that visual explanations will play in the illustrations that follow. Apian's first step in transforming Ptolemaic content into empirical principles was to invite the viewer to make visual judgments. Instructed to use the book's illustrations as a template for examining the stars, the viewer is asked by Apian to parse concepts such as cosmography and geography, marking these pursuits as distinct levels of epistemic engagement with the world.

Apian forecasts the guiding principle of his book as one of visual lessons, explicitly announced in the introduction, in which he says, "In these pictures, I will tell you what is meant by cosmography."[34] The isolated eye, as pictured here, is the sense organ with which Apian is most intently engaged, insofar as the eye is directly referenced by many of his diagrams, but, more importantly, by the extent to which the experience of cosmography is presented to a receptive ocular agent. The eye has literal agency for Apian. The book considers cosmography an art to be apprehended sensorily, as Tom Conley has convincingly shown, noting how Apian empowers the limbs of the vernacular reader, presenting body parts as "organs of locative perception."[35] Although he activates the observer's anatomy in the spirit of do-it-yourself investigations, Apian positions the eye as the layperson's antenna to unlocking material previously available only to those initiated in classical astronomical

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

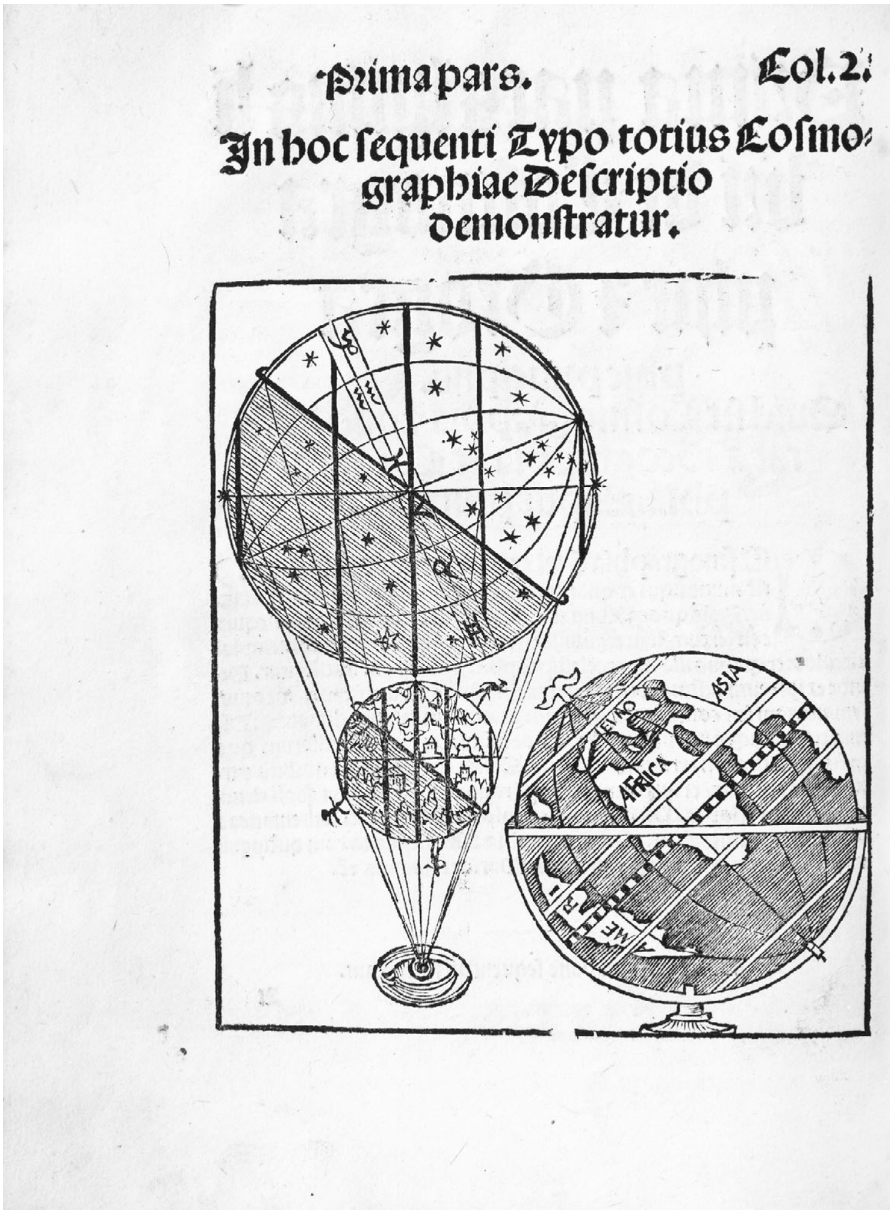
literature via the university. Destined for a broader lay public, which he attracted with the explanatory force of his visual diagrams, Apian's text coached the layperson to access this information with his senses using his eye to measure, to gauge, and to observe. The extent to which Apian overhauls his source material by interactive demonstrations enabled by moving dials makes this text's graphic conception and formatting a milestone in textual illustration and in the history of the book.[36] The *Cosmographicus Liber* positioned illustrations to provide visual tools (both actual and conceptual) as the groundwork for empirical knowledge about the universe. Apian also made special claims for the role of the artist in capturing that empirical knowledge, evoking the artist in his explanation of chorography or topographic description: "Chorography is a complete and useful picture and no one other than a painter is able to do it."[37]

Ptolemy's *Geographia* circulated throughout the manuscript tradition in the form of instructions for making visual projections of the coordinates he treated, but its content throughout its manuscript career was transmitted by text alone. Apian capitalized on this paradox, charging himself with the task of visualizing Ptolemy's principles. A set of images after the title page provides a conceptual introduction to cosmography, using an image of the eye at the base to tie the celestial and terrestrial spheres to each other (Figure 2.3). The adjacent illustration of a globe, a "detail" or fleshing out of the terrestrial sphere (including a continent labeled America), announces the interdisciplinary aims of the book and the ambitious plan to unite mathematical astronomy with geography. The lines that connect this pair of spheres show how information from the celestial sphere provides a basis for data for the terrestrial sphere.[38] Apian sets the conceptual model into dialogue with representations of objects that have analogues in scientific tools, the world globe, and the armillary sphere. Apian's image on the left can be seen as a type of exploded armillary sphere; perhaps more importantly, it is also a projection connected to a hypothetical viewer.

The apex of a set of rays resolves on the surface of a pictured eye. This image of an eye has been discussed as the source of omniscient vision belonging to God, a medieval view of God's place as prime mover in a theologically formatted universe.[39] This conceit depends on the framework of linear perspective to impart coherence to the visual model. Arguments for the tenacity of perspective in modeling the infinite, such as Erwin Panofsky's, could logically underwrite readings of Apian's eye as representing God's point of view.[40] Because the eye includes both the earth and the celestial sphere in its purview, as the perspectivist argument would go, it cannot belong to man.

But I would argue that this eye *must* belong to man, by virtue of another model of mathematized space also dependent on perspective: the projection.[41] This type of perspective is not the kind that we detect in Renaissance panel painting, but it did govern certain types of scientific images. That Apian's

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press



2.3. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 2. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

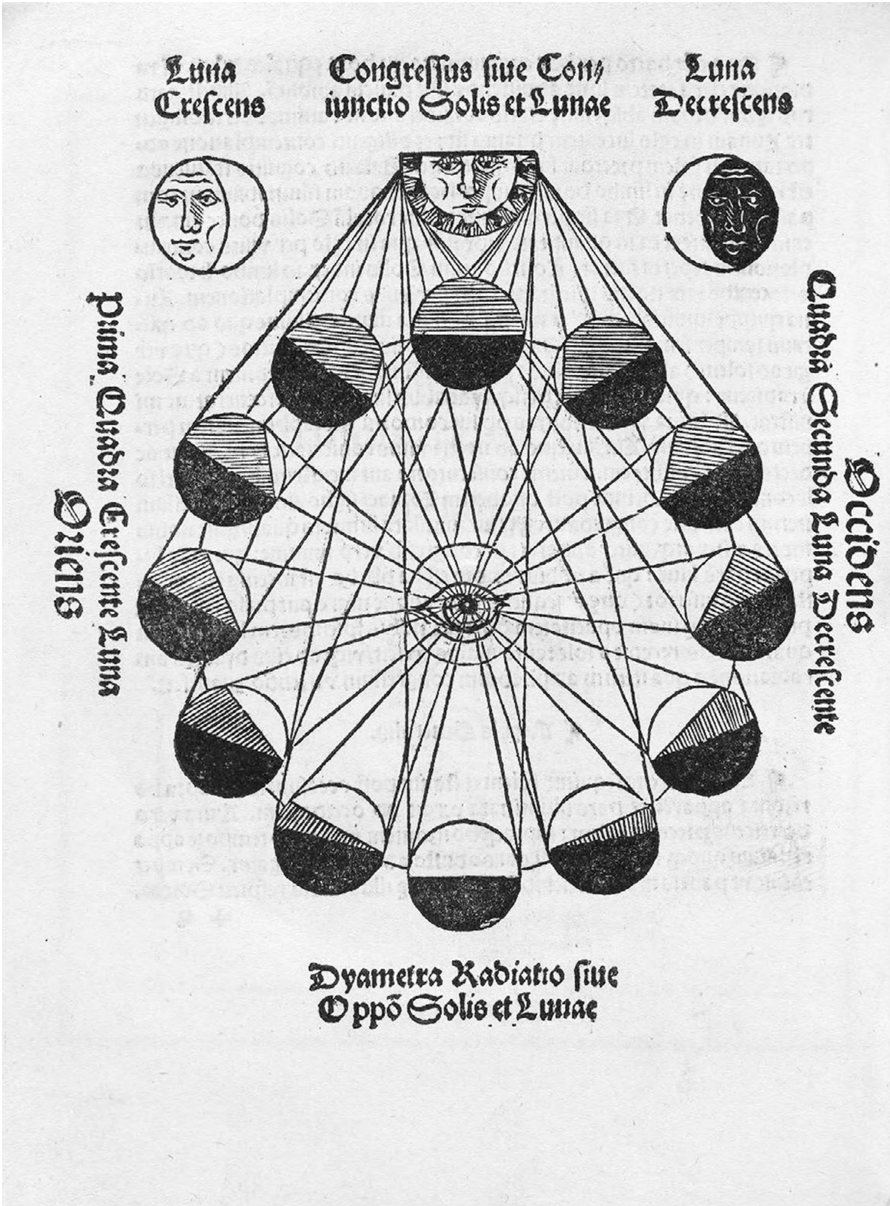
cosmographic model is imagining a planispheric projection (that situates man at the base) makes sense given the reciprocity cartographic projections are assumed to have had with linear perspective.[42] Another visual mode from which Renaissance perspectival models might have taken their cues was architectural projection developed by engineers and theorists, whose designs may have facilitated the visualization of Ptolemy's ideas into cartographic projections.[43]

Most theories of perspective's origins agree on the importance of Ptolemy as a catalyst in the transition to perspectival projections. Ptolemy's projection methods were intended to help readers conceptualize his observations.

Whether these prescriptions originated in cartographic or astronomic materials (which, as this chapter will show, were intimately related), Ptolemy serves as a linchpin for scholarly speculation on the origin of visual projections. Rather than in Ptolemy's geographic works, however, other scholars find this origin in his theorizations of astronomic projections.[44] The construction of a planisphere, according to Ptolemy, requires one to imagine the eye at the south pole; he envisions the equator as the picture plane for the planisphere. Onto this, he projects the tropics of Cancer and Capricorn and the ecliptic.[45] Ptolemy's strategy for planispheric projection, according to Kim Veltman, encompassed all the basic elements for linear perspective (an eye at a fixed point, a picture plane, and an object) and suggests itself as a compelling precedent for the type of abstractions on which linear perspective is built.[46]

Rather than representing the vision of God, it is more likely that Apian means to hail the human eye in this conceptualization of one's visual cone. The resemblance these lines bear to rays depicted in optical models, as Steven Vanden Broecke asserts, also supports a reading of this as a human eye. The eye, for Apian, "centralizes perception as such."[47] Apian's emphasis on the agency of human vision forges a new link in the realm of what was visually possible. Apian's efforts to empower visual knowledge leave no doubt that it is our visual acuity that this book attempts to hone. A similar human eye also anchors the diagram on folio 110r, which shows the various phases of the waxing and waning moon (Figure 2.4). These moons surround the pictured eye like spokes on a wheel that align the sun's light to what the eye takes in; the degrees of shading indicate portions of reflected light. The centralized eye tracks the face of the moon as it waxes and wanes through its cycle. Apian's visualization of these perceptual complexities even extends to what the observer *cannot* see but should understand: the dark side of the moon. In this respect, the human eye can also function as an omniscient eye.

Inserting man's eye as the primary receptor of cosmographic knowledge that connects both the heavenly and the earthly spheres pictured, Apian's text represents an updating and visualizing of the data in Ptolemy's *Geographia*. Apian's aim is to make Ptolemy's principles practical. He sizes Ptolemaic knowledge for the reader's local coordinates. In so doing, Apian engages with his sources in a forthright way; his volume does not disguise his predecessors, but reconfigures their contributions in a way that is useful to the reader.[48] Ptolemy as such had never been considered particularly useful to the academic curriculum; even when Ptolemy did make it into university syllabi, the *Geographia* did not lend itself to the structural commentary that was the modus operandi of university textbooks.[49] The discipline of cosmography in the



2.4. Moon phases, Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 110. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

sixteenth century, therefore, seems to have developed outside the university and through the back door via the popular press and works such as the *Cosmographicus Liber*.[50] More critical seemed to be the practical summaries of Ptolemaic learning in which astronomers trafficked in the medieval period. One of these was Sacrobosco's *De Sphaera* – incidentally, one of the texts for which Apian was also plotting an overhaul.[51]

Although the demand for a synthetic text such as the *Cosmographicus Liber* seems like it should have been secure for a readership of amateur astronomers who recognized the advantage of illustrated and interactive editions, the market for popular astronomy was just getting off the ground.[52] The bulk of information on astronomy proper had been tucked away in the realm of university learning for centuries.[53] As a professional mathematician with a side job printing astrological pamphlets, or *Practica*, Apian must have gauged the spectrum of competencies in and appetites for digesting astronomical literature. This audience likely ranged from stargazers and geographers to monastics in charge of scheduling, or even physicians who were naturally linked to mathematicians through their common interest in astrology.[54] For this diverse reading public, Apian clearly saw a market for crossover works like the *Cosmographicus Liber*, which might have been issued to supplement and clarify existing university texts, but he also updated older, more classical examples of the genre.[55] At the time of the cosmography's printing, Apian was also preoccupied with retooling the substance of one such manual, Sacrobosco's *De Sphaera*. Our evidence for this is twofold: in the first place, the *Cosmographicus Liber* relies heavily on Sacrobosco as source material; and second, Apian would himself publish a new edition of *De Sphaera* in 1526, two years after the first printing of the *Cosmographicus Liber*. It is reasonable to assume that Apian developed the pictorial accompaniments for both his *De Sphaera* and *Cosmographicus Liber* in tandem. It is also therefore not surprising that for his own edition of Sacrobosco, Apian was primarily concerned with updating the visual apparatus of the text, given his sustained translation of astronomical and cosmographic thinking into pictorial formulae in the cosmography.

From the continuous popularity of Sacrobosco's *De Sphaera* from 1220 through the sixteenth century, we can infer that many savvy fifteenth- and sixteenth-century printers saw the rewards of offering popular and vernacular editions.[56] Repackaging information from Ptolemy's *Almagest* and its Arabic commentaries, *De Sphaera* was one of the major sources of Ptolemaic cosmographic knowledge in late medieval and early modern Europe that explained the shape and apparent motion of heavenly bodies.[57] It epitomized the portions of the *Almagest* that referred to earthly coordinates and incorporated the Arabic commentary on Ptolemy.[58] *De Sphaera* was the most popular text on positional astronomy for use in academic instruction throughout the Middle Ages, but its circulation ballooned in the age of print, when it remained a popular manual for teaching astronomy in the university *quadrivium*.[59] Illustrations aided the text's many proofs about the relationship of the terrestrial to the celestial spheres and gave readers a conceptual model of cosmography.[60] Sacrobosco, unlike Ptolemy himself, proved an excellent foundation on which to hang astronomical commentary.[61] The *editio princeps* of *De Sphaera* appeared in either Ferrara or Venice in 1472 or 1473, and the text enjoyed a heavy traffic in reprints until the mid-seventeenth century.[62]

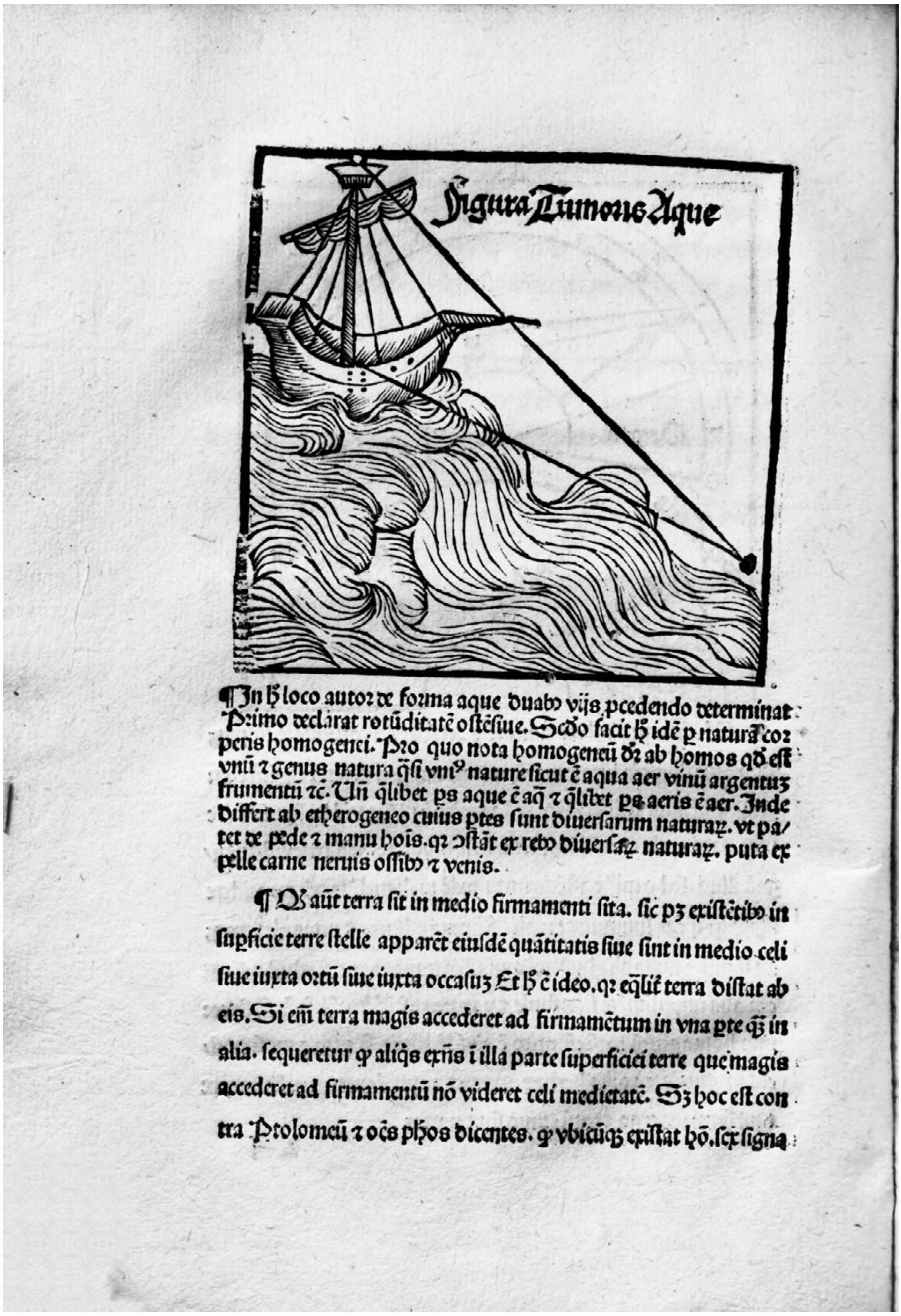
The advent of heliocentrism did little to disturb the useful nature of Sacrobosco's text for practical navigation or instrument learning; it remained a vital source for astronomical knowledge even after Copernicus's revised model of the solar system.[63]

Important developments in the pictorialization of astronomy texts that would influence Apian occurred in Erhard Ratdolt's graphic laboratory. A *Kalendario* in which Regiomontanus's corrected data met novel experiments in design was printed in Venice in 1476 by Ratdolt, followed by a color printing of Sacrobosco in 1482.[64] These moves to streamline the graphic interface and to use color to help the reader discern differences in celestial phenomena show Ratdolt's investment in visualization for the teaching of astronomy.[65] Indeed, these experiments in color inaugurate a new emphasis on visualization in the history of printmaking: Ratdolt's bicolor images of eclipses shown in black and yellow are generally considered to be the first woodcuts printed in color; he expanded such experiments in color printing several years later in Augsburg.[66] Another important chapter in the pictorialization of Sacrobosco was begun by vernacular German editions printed from 1516 onwards, when *De Sphaera* received ample illustrations in recensions by the Nuremberg humanist Conrad Heinfogel.

Apian's *Cosmographicus Liber* follows a tradition of visualization already gaining traction in the printed Sacrobosco editions, capitalizing on a major shift in the relationship between observation and scientific inquiry already being promulgated by these sources. Peter Barker and Kathleen Crowther have explored how this shift was mediated by images in their article "Training the Intelligent Eye," which also provides a useful historiography of the role of images in natural knowledge in general. Even in the tradition of Sacrobosco's tenacious models of spherical astronomy, empirical inquiry had been the prerequisite for the conceptualization of these abstract principles.[67] Observation had always been a necessary component to conceptualization; it was reliance on observables such as the precession of certain planets that held the Ptolemaic model of epicycles and deferents together. Theoretical models were cooked up to explain what stargazers were seeing. Yet with these theories of planetary motion in place, there was little need for most students to leave their warm studies for chilly examinations of the heavens. With Sacrobosco and Peurbach, as the authors argue, the images grapple with explaining old theories.[68] Images are prerequisites for users to form their mental conceptualizations.

While some early sixteenth-century designers of images for Sacrobosco's *De Sphaera* considered the agency of the reader's eye, it was not the focus of visual programs per se. Rather than commandeering the eye's agency to certify a proof, celestial events were presented to the eye in terms of something an observer might have happened to notice. A typical example of the eye's peripheral role can be found in Sacrobosco's explanation of the spherical shape of the earth; the corollary he provides is of the sphericity of water on the earth's surface. According to Sacrobosco, the shape of the earth's surrounding layer of water can be inferred from the spherical shape of dew drops: from the homogenous properties of these drops, we can infer that bodies of water are also round.[69] A supporting proof about the earth's shape confirms this: when at sea, sailors atop a ship's mast can spy a light on land not visible to those on deck. The visual impediment of the deck hands demonstrates the earth's curvature.[70] Some early printed editions tried to convey this parallax with woodcuts showing a square cutaway image of the water and a ship with lines drawn to shore (Figure 2.5).[71] Although the idea of observation is implied by the proof, the accompanying illustration did not necessarily reinforce its demonstration as an empirical act. In Apian's version of the *De Sphaera*, however, he positions observers at the ends of these projected lines, clarifying the proof via an outsized ship sailing on a sphere – literally a round earth that takes account of both ship and shore, picturing observers on the deck and atop the mast (Figure 2.6).[72] Apian's image reprises designs for editions of Sacrobosco printed in Venice in the late fifteenth century that feature the sightlines of the observers in the diagram, marking what they see as "visual rays" (Figure 2.7).[73] The sightings modeled by the pictured observers were critical to the proof at hand – Crowther and Barker explain that such hybrids of diagrammatic and narrative images could be found in manuals designed explicitly for beginners.[74] Deferring to visual strategies like these that attempted to clarify principles, Apian sought to foreground the aspect of the proof that was based on observational practice and pictorialized actual observers. Not far from Apian's illustration appears another optical proof of the heaven's corresponding roundness, and it describes the situation observed as analogous to how rays appear to bend in an atmosphere thicker than air. The illustration provides an example of the magnification of a coin through an aqueous medium (Figure 2.8) – at the receiving end is a disembodied eye that sees through the diffuse light. Eye guides such as this that taught the position of the eye in a diagram about observation have a precedent in sections of astronomical manuscripts devoted to measuring and gauging.[75]

Apian stages his demonstration of the earth's curvature through a visual exercise (Figure 2.9). The image provides the reader with a menu of shapes against which to compare their observations of the moon's surface during a lunar eclipse. By matching the geometry of the shape that appears on the lunar surface with options provided in his diagram, the reader can eliminate erroneous options. The earth's projection of a sphere-shaped shadow confirms to an astute observer that the earth must be a sphere. This proof demonstrates how a finely tuned eye can visually verify evidence. To execute this proof visually, Apian indulged in a lengthy digression of pictorial counterproofs with redundancy built in. Apian's full-page illustration enumerates a variety of other



¶ In h loco autor de forma aque duab viis pcedendo determinat. Primo declarat rotūditatē ostēsiue. Scdo facit h idē p naturā corperis homogenei. Pro quo nota homogeneū dr ab homos qd est vnū z genus natura q̄si vni⁹ nature sicut ē aqua aer vinū argentuz frumentū zc. Vñ q̄libet ps aque ē aq̄ z q̄libet ps aeris ē aer. Inde differt ab etherogeneo cuius ptes sunt diuersarum naturaꝝ. vt patet de pede z manu hoīs. qr ꝯstāt ex reb diuersaꝝ naturaꝝ. puta ex pelle carne neruis ossib z venis.

¶ Qd aūt terra sit in medio firmamenti sita. sic pz existētib in supficie terre stelle apparēt eiusdē quātitatis siue sint in medio celi siue iuxta ortū siue iuxta occasuz Et h ē ideo. qr eq̄lit terra distat ab eis. Si eñ terra magis accederet ad firmamētum in vna pte q̄z in alia. sequeretur q aliq̄s exñs ī illā parte superficiei terre que magis accederet ad firmamentū nō videret celi medietatē. Sz hoc est contra Ptolomeū z oēs phōs dicentes. q vbicūq3 existat hō. sex signa

2.5. Sacrobosco and Wenceslaus Fabri, *Opus sphericum Johannis de sacro busto: figuris et p[er]utili co[m]mento illustratu[m]* (Cologne: Quentell, 1501), 10r. *Source:* Augsburg, Staats- und Stadtbibliothek 4 Math 491. Courtesy of Augsburg, Staats- und Stadtbibliothek.

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

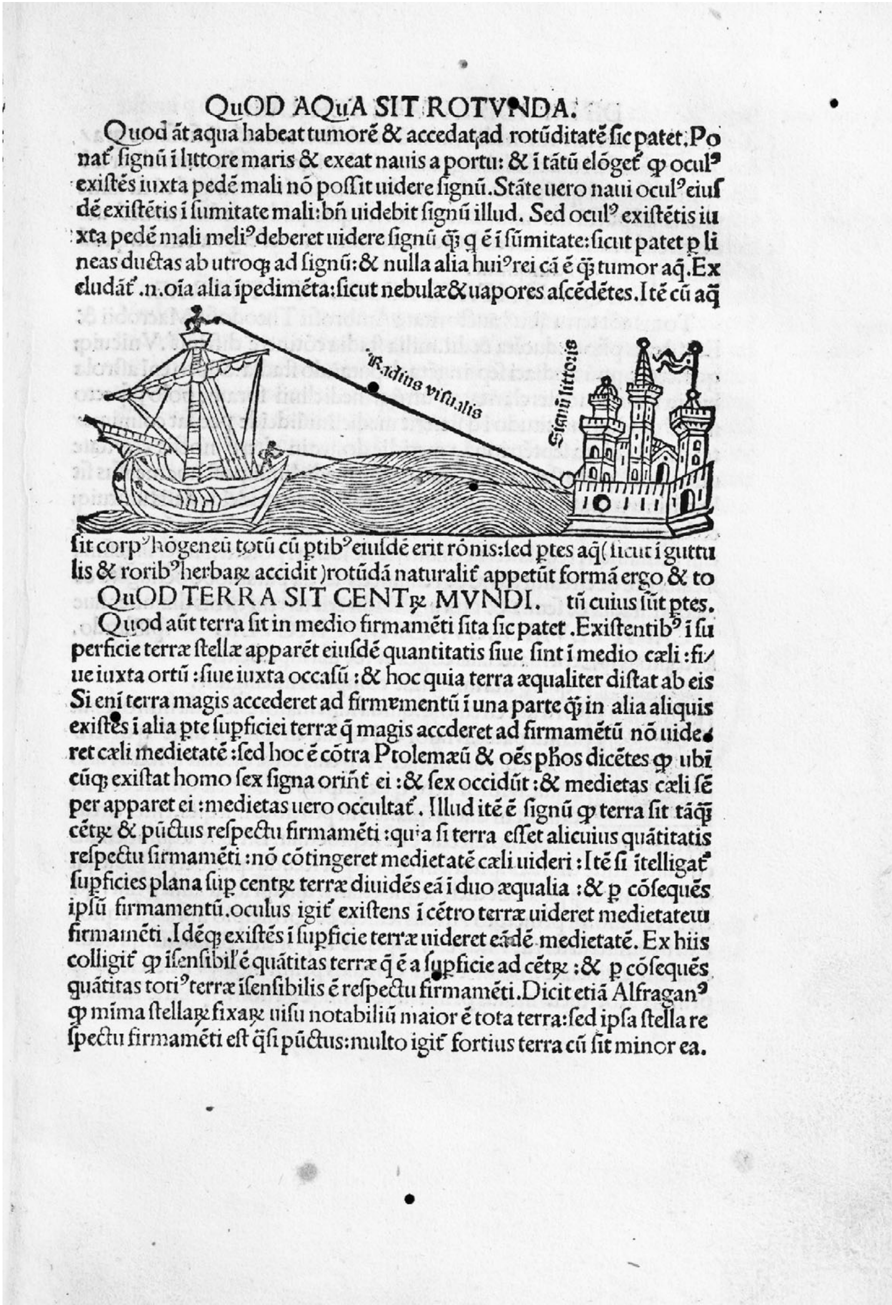
tentrionem . Huius aũt rei causa est tumor terræ. Item
si terra esset plana ab oriente in occidẽtem: tam cito ori=
rentur stellæ occidẽtalibus quàm oriẽtalibus: quod patet
esse falsum. Itẽ si terra esset plana à septẽtrione in austrũ
& ecõtra. Stellæ quæ essẽt alicui sempiternæ apparitiõis:
semp apparerẽt ei quocũq; pcederet: qd' falsum est. Sed
q plana sit præ nimia eius quãtitate hoĩm uisui apparet.

QVOD AQVA SIT ROTVNDA.

Quod aũt aqua habeat tu=
morem & accedat ad ro=
tunditatem sic patet. Po=
natur signũ in littore ma=
ris: et exeat nauis à portu:
& in tantum elongetur q
oculus existẽs iuxta pedem
mali nõ poßit uidere signũ
Stãte uero naui oculus eius=
dem existẽtis in summitate mali bene uidebit signũ illud.
Sed oculus existentis iuxta pedem mali melius deberet ui
dere signũ quàm qui est in summitate: sicut patet per li=
neas ductas ab utroq; ad signũ: & nulla alia huius rei cau
sa est quàm tumor aquæ. Excludantur .n. omnia alia im=
pedimẽta: sicut nebulæ & uapores ascendentes. Item cũ
aqua sit corpus homogeneũ totum cũ partibus eiusdẽ erit
rationis: sed ptes aquæ (sicut in guttulis & roribus herba
rum accidit) rotundam naturaliter appetunt formam:
ergo & totum cuius sunt partes.

Quod

2.6. Sacrobosco, *Sphaera Iani de Sacrobusto* (Ingolstadt: Apian, 1526), 6v. *Source:* BSB Astr.u.151. Courtesy of Bayerische Staatsbibliothek, Munich. CC BY-NC-SA 4.0.



QuOD AQuA SIT ROTVNDA.
Quod ãt aqua habeat tumorẽ & accedat ad rotũditatẽ ſic patet. Ponat̃ ſignũ i littore maris & exeat nauis a portu: & i tãtũ elõget̃ ꝙ ocul⁹ exiſtẽs iuxta pedẽ mali nõ poſſit uidere ſignũ. Stãte uero naui ocul⁹ eiuſdẽ exiſtẽtis i ſumitate mali: bñ uidebit ſignũ illud. Sed ocul⁹ exiſtẽtis iuxta pedẽ mali meli⁹ deberet uidere ſignũ q̃ꝫ q ẽ i ſũmitate: ſicut patet p lineas ductas ab utroqꝫ ad ſignũ: & nulla alia hui⁹ rei cã ẽ q̃ꝫ tumor aq̃. Excludãt̃ .n. oĩa alia ĩpedimẽta: ſicut nebulæ & uapores aſcẽdẽtes. Itẽ cũ aq̃

ſit corp⁹ hõgeneũ totũ cũ ptib⁹ eiuſdẽ erit rõnis: ſed ptes aq̃ (ſicut i guttulis & rorib⁹ herbaꝝ accidit) rotũdã naturalit̃ appetũt formã ergo & totũ cuius ſũt ptes.

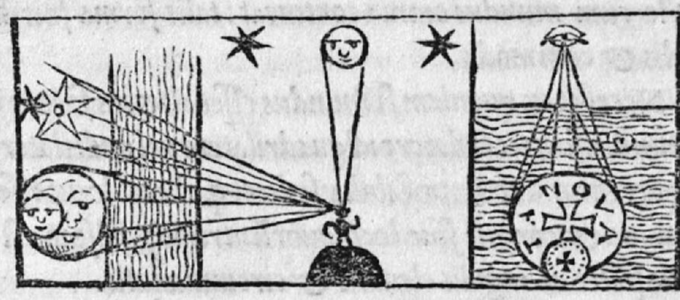
QuOD TERRA SIT CENTꝜ MVNDI.

Quod aũt terra ſit in medio firmamẽti ſita ſic patet. Exiſtentib⁹ i ſuperficie terræ ſtellæ apparẽt eiuſdẽ quantitatis ſiue ſint i medio cæli: ſiue iuxta ortũ: ſiue iuxta occaſũ: & hoc quia terra æqualiter diſtat ab eis Si enĩ terra magis accederet ad firmamentũ i una parte q̃ꝫ in alia aliquis exiſtẽs i alia pte ſupficiei terræ q̃ magis accderet ad firmamẽtũ nõ uideret cæli medietatẽ: ſed hoc ẽ cõtra Ptolemæũ & oẽs phõs dicẽtes ꝙ ubicũqꝫ exiſtat homo ſex ſigna oriũt̃ ei: & ſex occidũt: & medietas cæli ſẽper apparet ei: medietas uero occultat̃. Illud itẽ ẽ ſignũ ꝙ terra ſit tãq̃ꝫ cẽtꝜ & pũctus reſpectu firmamẽti: quia ſi terra eſſet alicuius quãtitatis reſpectu firmamẽti: nõ cõtingeret medietatẽ cæli uideri: Itẽ ſi ĩtelligat̃ ſupficies plana ſup centꝜ terræ diuidẽs eã i duo æqualia: & p cõſequẽs ipſũ firmamentũ. oculus igit̃ exiſtens i cẽtro terræ uideret medietatem firmamẽti. Idẽqꝫ exiſtẽs i ſupficie terræ uideret eãdẽ medietatẽ. Ex hiis colligit̃ ꝙ iſenſibil' ẽ quãtitas terræ q̃ ẽ a ſupficie ad cẽtꝜ: & p cõſequẽs quãtitas toti⁹ terræ iſenſibilis ẽ reſpectu firmamẽti. Dicit etiã Alfragan⁹ ꝙ mĩma ſtellaꝜ fixaꝜ uiſu notabiliũ maior ẽ tota terra: ſed ipſa ſtella reſpectu firmamẽti eſt q̃ſi pũctus: multo igit̃ fortius terra cũ ſit minor ea.

2.7. Sacrobosco, *Sphaerae Mvndi Compendium Foeliciter Inchoat. … Iohannis de sacro busto sphæricum opusculum* (Venice: Sanctis & Santritter, 1488), fol. 77. *Source:* Zentralbibliothek Zürich, Ink. K 294. Courtesy of ETH-Bibliothek Zürich.

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

Item ſicut dicit Alphraganus ſi cœlum eſſet planũ: aliqua
pars cœli eſſet nobis ꝓpinquior alia: illa ſcilicet quæ eſſet
ſupra caput noſtrum: igitur ſtella ibi exiſtens eſſet nobis
ꝓpinquior quàm exiſtẽs in ortu uel occaſu. Sed quæ nobis
ꝓpinquiora ſunt maiora uidentur. Ergo Sol uel alia ſtella
exiſtẽs in medio cœli maior uideri deberet quàm exiſtens
in ortu uel occaſu: cuius cõtrarium uidemus contingere.
Maior enim apparet Sol uel alia ſtella exiſtens in oriente

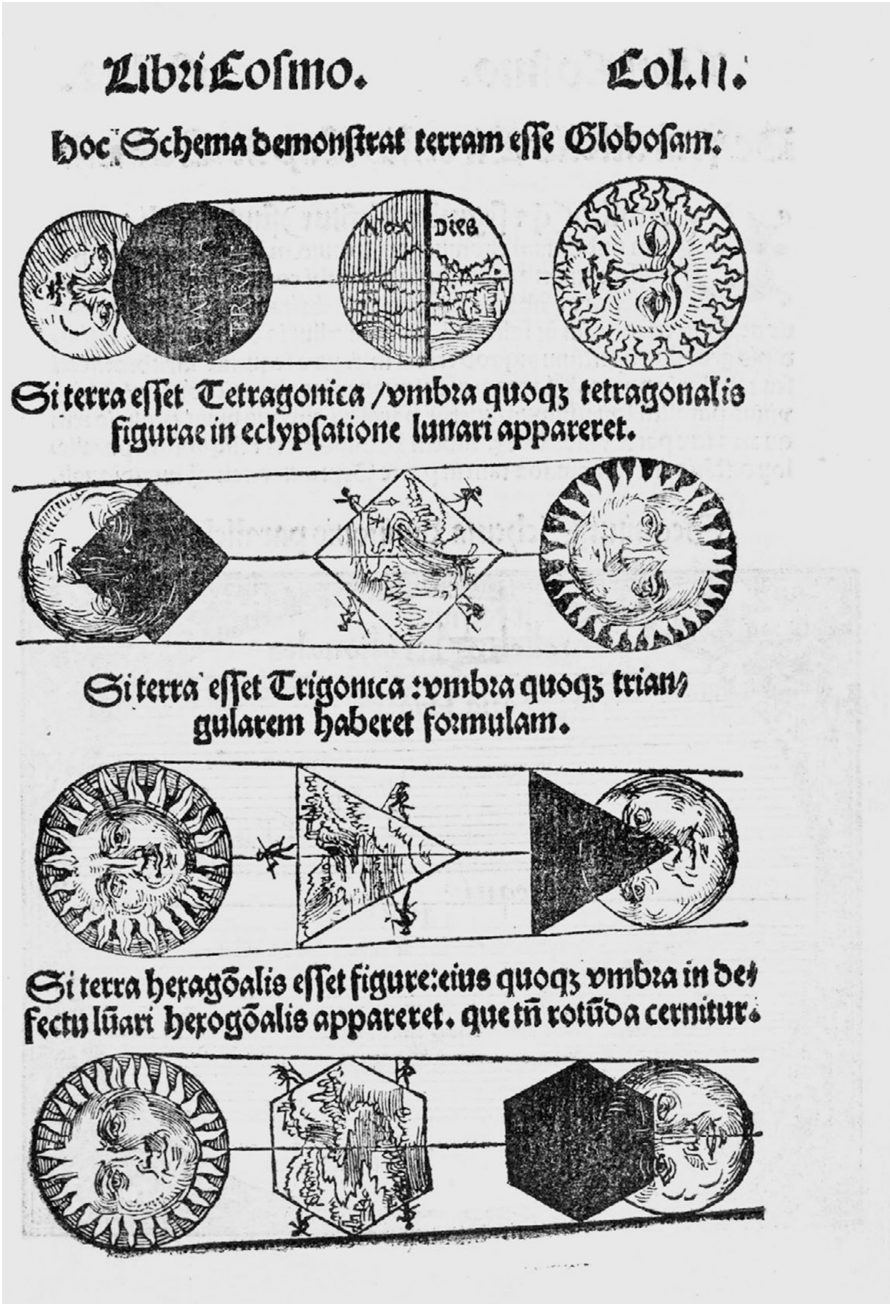


uel occidente quàm in medio cœli: ſed cũ rei ueritas ita nõ
ſit, Huius apparentiæ cauſa eſt: ꝙ in tp̃e hyemali uel plu=
uiali quidam uapores aſcendũt inter aſpectum noſtrũ &
Solem uel aliã ſtellam & cum illi uapores ſint corpus di=
aphonum diſgregãt radios noſtros uiſuales: ita ꝙ non cõ=
prehendunt rem in ſua naturali & uera quãtitate: ſicut
patet de denario proiecto in fundo aquæ limpidæ qui ꝑ
ſimilẽ diſgregatõem radiorũ apparet maioris q̃ ſuæ ueræ
qnãtitatis.

QVOD TERRA SIT ROTVNDA.

Quod etiam terra ſit rotunda ſic patet. Signa & ſtellæ
nõ æqualiter oriũtur et occidũt omnibus hominibus ubiq;
exiſtentibus: ſed prius oriũtur & occidunt illis qui ſunt
uel

2.8. Sacrobosco, *Sphaera Iani de Sacrobusto* (Ingolstadt: Apian, 1526), 5v. *Source:* BSB Astr.u.151. Courtesy of Bayerische Staatsbibliothek, Munich. CC BY-NC-SA 4.0.



2.9. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 11. *Source:* Smithsonian. Image in the public domain.

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

shapes that the earth's shadow might assume when projected onto the lunar surface; these include a triangle, a square, and a hexagon.[76] Apian used these differently shaped earths to caution his reader to rule out conditions that were not empirically verifiable. This explanation assumes good evidence to be observations that can or cannot be confirmed by the naked eye during eclipses, explicitly coaching the making of visual judgments. The sphericality of the earth enjoys incontrovertible proof when based on the empirical experience of an actual observer.[77] This image records eyewitness observations, accompanied by caveats to rule out options that cannot be empirically supported.

Apian's experiments with explanatory diagrams and such visual reiterations suggest that he developed the cosmography for readers for whom such proofs based on empirical experience seemed persuasive. Instead of the recursive bundles of resemblances and conveniences that characterized Michel Foucault's explanations of causality in the premodern episteme, Apian's empirically activated reader was empowered by books to settle for nothing less than visually verifiable truths.[78] Illustrated guides to the heavens were proving increasingly useful to a broader stratum of the lay population in search of manuals to accompany their firsthand searches.

MECHANICAL PICTURES FOR OBSERVER-CENTERED PEDAGOGY

University lectures presented the basics of positional astronomy and frequently relied on various tools for their pedagogy. Apian trained in mathematical astrology in Leipzig and Vienna under Georg Tannstetter, whose own pedigree included Regiomontanus, Peurbach, and Andreas Stiborius – all of whose tenures were financed by imperial projects. The wall calendars and almanacs that resulted from these efforts expressed abstract designs and theories primarily intended for a group of university and court professionals. While many of his teachers' efforts were in the service of explaining universals and updating tables, Apian instead envisioned a market that could unpack these trade secrets for the layperson.[79] As a major strategy for popularizing basic astronomy for lay audiences, Apian converted narrative academic proofs into mechanical pictures, or volvelles, that centered observers by positing them as users. The earliest volvelles in printed literature appeared in the 1474 Nuremberg edition of Regiomontanus's *Calendarium* and Erhard Ratdolt's editions printed in Venice in 1476; these were also tools for gauging the movement of heavenly bodies.[80] Printed volvelles embodied the premise of spherical astronomy and likely were intended to recall tools like armillary spheres that were a cornerstone of classroom instruction. Engagement with moving tools such as these spawned printed volvelles in works including Johannes Schöner's *Aequatorium Astronomicum* (printed in Bamberg in 1521 and in Nuremberg in 1534), a work with which Apian was certainly in dialogue, and one that Suzanne Karr

Schmidt cites as a precedent for Apian's later horoscopic opus, the *Astronomicum Caesareum* (published in Ingolstadt in 1540).[81] Apian likewise implemented complex moving paper dials and tools assembled from a variety of printed parts that translated the theoretical teachings of Sacrobosco into more practical information.[82] With these, Apian could simplify his explanation of cosmographic principles. Placing man himself literally within the picture, Apian redirected astronomy away from principles and toward observer-centered pedagogy. For the spherical astronomy that Sacrobosco's text served, little math was actually required – so it was the perfect text into which to insert observer-centered focus.[83] Apian tweaks Sacrobosco to privilege the visual study of the viewer's surroundings by articulating the observer as a recipient of sensory stimulus.

The relationship between the horizon and the zenith formed a major pillar of lay astronomy: the intersection of these lines centered the human observer. The zenith–horizon volvelle (Figure 2.10) anchored celestial circles to an earth-bound perspective. It encouraged the reader to envision the zenith as the extension of their head into space. Apian's diagram teaches that the zenith is the pole of *any* observer's horizon; the observer's zenith is expressed in terms of the point it describes on the celestial meridian. The dial also aimed to show the relationship of the observer's position to both their horizon and to their pole; and how the angular relationship between any observer's zenith and their respective horizon is always preserved.[84] Apian's horizon volvelle incorporates the salient points of Sacrobosco's textual proof, cuing the landmarks of spherical astronomy (such as the poles and the celestial circles) to adjustable earthly positions.[85]

The imaginary lines of the horizon and the zenith were important values for the amateur student of astronomy because they explained cosmographic truths in terms that could be confirmed visually. Circumscribed by the practitioner's empirical experience, the horizon describes the portion of the globe that one can see. Apian's dial consequently blocks from view the portion of the sphere that sinks beneath the horizon. The dial spins by way of a pointer fashioned as an earth-bound observer. By setting the figural index at the observer's latitude, the dial reveals the horizon formed by that terrestrial circle. Thus, no matter what the latitude, the observer's head remains at the center of a hemisphere articulated by what he is able to observe. The observer can also infer from this tool that their latitude is also equal to the altitude of the celestial pole. The fact that the hemisphere beneath the horizon remains hidden beneath the decorated space reinforces the idea of it as "that [line] which limits [one's] vision."[86]

The horizon also served as an important pedagogical benchmark for deriving latitude. Apian's interactive dial converts Sacrobosco's similes into coordinates of latitude that can help the user find geographic bearings in the world picture, providing an explanation that is easier to grasp than Sacrobosco's original proposition.[87] Apian's reader is taught to convert the abstract lines of

Libri Cosmo. Col. 17.

lat/et videris tot esse gradus eiusdem meridiani ab equinoctiali circulo vsq3 ad zenith depicti hominis/quotquot arc:: s eiusdem meridiani inter polum mundi et horizontem cōprehendit.

Corollarium.

¶ Zenith Capitis semper equaliter ex omni parte ab horizōte: id est. 90 gradibus seu quadrante distat/eo dicit Polus horizōtis. et vbiq3 existētibus (exclusis omnibus alijs impedimentis) semper medietas cœli siue hemisphęrii apparet In quantū igit aliquis ab equinoctiali pcedit versus septentrionē vel austrum in tantum etiā deprimit horizon sub polo ex parte vna \ ex altera vero eleuatur super polum oppositum.

2.10. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 17. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

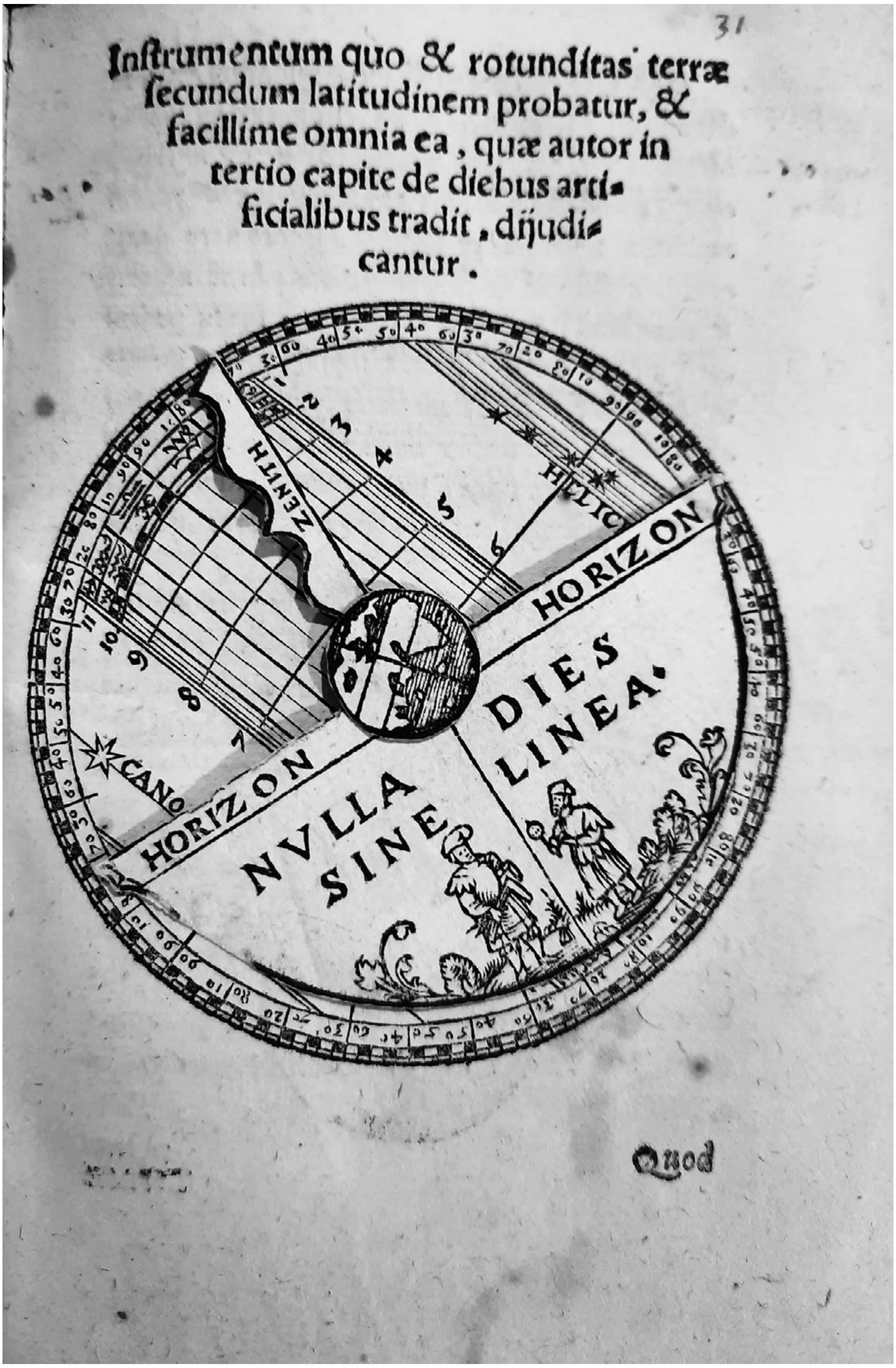
https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

zenith and horizon into the practical value of latitude. The volvelle's index, a figure of a man indicating his zenith, provides a stand-in for the user, to show how an observer's latitude can be measured against the horizon and zenith. Apian's dial extrapolates from Sacrobosco's text practical knowledge useful to an amateur stargazer. Apian's staging of this point through a demonstrative model follows what Steven Vanden Broecke claims marks an important shift to non-verbal visual thinking in the explanation of astronomy.[88] The eye, whose intelligence Kathleen Crowther and Peter Barker argue was conditioned by the visual programs of astronomic texts that helped steer readers' corporeal vision into inner mental visions of the cosmos's order, becomes truly animated in Apian.[89] The illustrations of the *Cosmographicus Liber* prioritized what the viewer could observe and assisted the mental visualizations necessary to grasp celestial motions within an observer-centered universe.

APIAN'S UPDATE OF SACROBOSCO'S *DE SPHAERA*

Sacrobosco's text had weathered the generations fairly intact until its collision with Apian's emphasis on pictorial learning. Recognizing the significance of his recent visual re-evaluations of Sacrobosco within the cosmography, Apian printed his own edition of *De Sphaera* in 1526, two years after the *Cosmographicus Liber*'s first printing.[90] Apian, also the father of the portable "in octavo" editions of *De Sphaera*, significantly improved on the visual didactics found in most printed editions of Sacrobosco up to that date.[91] As we have already seen in the example of the ship and the light on land (see Figure 2.6), for instance, Apian amplifies the triangular diagrams found in earlier editions of Sacrobosco to feature the more salient point that the water's bulge must show the round earth that lay beneath it. Whereas Sacrobosco tells the entire story of astronomy through Euclidean geometry of spheres and intersecting lines, Apian's repackaging imagines what these laws and propositions would look like to a roving agent.[92] As with his *Cosmographicus Liber*, Apian's update of Sacrobosco expanded on the existing cosmographic literature, hoping to clarify it through visual, and frequently interactive, demonstrations.

Apian's volvelles and diagrams were popularized in his own *Cosmographicus Liber* as well as in editions of Sacrobosco that he printed for academic communities. Sacrobosco continued to be printed throughout the century, with many publications issuing from university towns such as Wittenberg. Aware of their didactic advantages, printers pirated Apian's volvelles for their own mid-sixteenth-century editions of Sacrobosco's *De Sphaera*.[93] New volvelles were adapted from Apian's *Cosmographicus Liber*, such as the one found in a *Sphaera* printed in 1538 in Wittenberg by Joseph Clug (Figure 2.11).[94] Later editions, such as one printed in 1540, combined the teachings of volvelles that appeared separately in the source material.[95] Integrating Apian's zenith–horizon dial and



2.11. Sacrobosco and Melanchthon, *Ioannis De Sacrobusto Libellus, De Sphaera* . . . (Wittenberg: Joseph Clug, 1538), fol. 31. *Source:* HAB N62.8 Helmst. Courtesy of Herzog August Bibliothek Wolfenbüttel.

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

the *Organum Ptolomei*, the user of Clug's volvelle could set the horizon hemisphere to their latitude on top of a disc marked with lines of the sun's declinations. The caption on the dial reads: "With this instrument, the roundness of the earth can be tested, followed by latitude. And it will be easier to judge all things which the author teaches about the artificial day in the third chapter."[96] Such declarations prompted the readers' interaction with the dials.

New objectives could be mapped onto these paper instruments, endorsing practices by printers eager to lend them an imprimatur of usefulness that served their own brand. "*Nulla Dies Sine Linea*," or "No day without its line," pleads the inscription on a volvelle in an edition of Sacrobosco printed in Wittenberg. With this motto, the printer advertised the celestial decoding that users could perform with the tool.[97] This adage about daily routines popularized by Erasmus originated in Pliny's commentary about the artist Apelles's practice of daily drawing. It is mobilized here by the printer Joseph Clug to incite his readers to observe the daily linear path of the sun.[98] The word *linea* frequently appears in Apian's volvelles as demarcations of regions – on the *Organum Ptolomei* dial, for example – and perhaps that term also carried references to the threads themselves that accompanied dials as indicators throughout Apian's oeuvre. Clug surely reprises the adage here not just to refer to the notional lines of the celestial sphere or planetary paths, but as an exhortation to readers to engage in artisanal operations – in other words, a note to the self about self-help. Clug's semantic shift from the idea of "lines" from daily observances or routines to the "lines" of the sun's path was received in a context where a concomitant change was occurring in the meaning of the word *observation* itself. Katherine Park and Gianna Pomata have pointed out how *observationes* transitioned in early modernity from connotations of regimens followed into a term explicitly signaling empirical practice.[99] It seems that observation in both senses of the word converge in Clug's volvelle: the dial's motto inspires the user to make celestial observations a regular routine.[100] The recycling of this hybrid volvelle throughout the century seems to confirm the growing popularity of the firsthand tracking of the sun's path as a daily pastime for do-it-yourself observers.[101]

The transformation of academic astronomy into the subject of amateur investigation for "vernacular" viewers was achieved through the visualization of its principles. I would argue that the resurgence that the *De Sphaera* enjoyed in the sixteenth century came in large part from the potential that Apian saw in the visualization of spherical astronomy. We can say that Apian boosted future printings of Sacrobosco's text on the strength of the popularity of their visual devices, which were borrowed from his cosmography. Vernacular editions of Sacrobosco's material both laicized and energized observational practice. The vernacular *Sphera Materialis* edited and translated by Conrad Heinfogel in Nuremberg in 1516, already emphasized visual pedagogy.[102] A reader's

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

annotations in the 1533 German edition of Sacrobosco's *Sphera Materialis: Eyn Anfang und Fundament der Astronomi* suggest that this emphasis made an impact. That reader's own drawings, which follow the foregoing Sacrobosco edition bound with other volumes at the Herzog August Bibliothek in Wolfenbüttel, include a featured eye.[103] The illustrations on added manuscript pages indicate that the author tried to supplement textual content derived from Sacrobosco with images that expand the principles of spherical astronomy by mapping them onto the plates of a torquetum, an astronomical instrument that simulates the celestial sphere by featuring different coordinate systems on several movable plates. This reader's pictorial supplement materializes the "material sphere" of Sacrobosco: an attempt to familiarize abstract principles by applying them to an actual instrument. While instruments such as the torquetum were designed to help the user envision the abstractions of spherical astronomy, this particular user seems to have been trying to facilitate comprehension of Sacrobosco's principles by thinking them through with an instrument.

The vernacular *Sphera Materialis* edited and printed by Johannes Dryander in 1539 derived illustrations from Apian.[104] While Dryander's edition was an important contribution to the vernacularization of spherical and theoretical astronomy, such as in Waldseemüller's *Der Welt Kugel* (printed by Grüninger in Strasbourg in 1509) and the Sacrobosco *Sphaerae* edited by Conrad Heinfogel, his was not prolifically illustrated. It was likely destined for a university audience, probably at Marburg, where Dryander occupied the chair in mathematics.[105] But illustrations were becoming a priority for the popular editions of Sacrobosco, especially after Apian's publication; Isabelle Pantin, for instance, notes the impact of Apian's visual program on astronomy's waxing pedagogical clarity.[106] Whereas the marketing of Conrad Heinfogel's German *Sphaera Mundi* in 1516 rested in part on the new vernacular translation from Latin, the title pages of the 1533 and 1539 editions explicitly advertised their contents as easier to understand because of the accompanying illustrations.[107] These many recensions owe a debt to *De Sphaera*'s open design, a format that Matteo Valleriani claims was critical to Sacrobosco's reception in the sixteenth century as a commentary useful for presenting practical mathematics for a number of fields.[108]

Perhaps this new enthusiasm for vernacular editions of *De Sphaera* can be attributed to astrology's popularity in Wittenberg, where academic reforms by Lutherans were also afoot.[109] Sacrobosco's circulation within the local faculty was probably fed by intense interest in astrology and spurred by the reformer Philip Melanchthon's own advocacy for popular astronomy.[110] Just a few years after Apian's edition, Melancthon penned an introduction for an edition of the *De Sphaera* (1531). Here, he articulated a reciprocal relationship between the observer's eye and the practice of scanning the heavens for stars, suggesting that vision was particularly well suited to, if not explicitly designed for, astronomy.[111] If the relevance of this thirteenth-century text was waning, sentiments like these reinvigorated Sacrobosco's work and publishers attempted to boost sales with such hyperbole that linked the function of vision itself to the pursuit of amateur stargazing.[112] Melanchthon's suturing of the eyes to the stars was no doubt intended to elevate the importance of astronomy, but perhaps his comments were also prompted by the new publics of lay observers educated by the *Cosmographicus Liber*. Volvelles and diagrams derived from Apian's cosmography came increasingly to define the profile and format of Ptolemaic recensions (such as Sacrobosco) produced in the wake of it.[113] Diagrams derived from Apian also became a hallmark for many subsequent printings from the 1530s onward.[114] Owen Gingerich notes that the moving dials became features adopted in most printing sites (including Paris, Antwerp, Cologne, and Venice) and the *sine qua non* of printed Sacroboscos from the 1540s onwards.[115] Thus, the sixteenth-century reception of Ptolemy was greatly indebted to Apian's visual apparatus for the *Cosmographicus Liber*.

Apian's mechanical pictures as filtered through vernacular editions of *De Sphaera* ultimately made Sacrobosco a new locus for popular knowledge about the heavens. It is precisely in these updates to Sacrobosco that Matteo Valleriani locates a general trend of unifying diverse strains of study into early modern books that would become the sites of codified practical knowledge.[116] That Sacrobosco would continue to be a mainstay in astronomic literature is clear from the many later publications, as well as the fact that significant debates about geocentrism would revolve around this publication as an authoritative source, including the 1611 commentary by the Jesuit Christopher Clavius, who would spearhead the Catholic Church's resistance to Galileo.[117] Printed beginning in 1570, the eight versions of the Clavius edition of Sacrobosco were no longer useful as practical guides to the heavens, as they were weighty and printed in larger formats. In place of Apian's market-ready volvelles, they instead made room for propagandistic commentary in service of Jesuit science.[118]

Almost exactly contemporary with the vernacularization of Sacrobosco's *De Sphaera* and its retrofitting with visual tools was the appearance of Apian's *Cosmographicus Liber* in a number of vernacular editions, particularly Dutch and French volumes produced in Antwerp and Paris.[119] It is perplexing, in light of these other versions, that Peter Apian seems never to have offered a German translation of the *Cosmographicus Liber*. Explanations for this could include the inability of Middle High German to handle scientific vocabulary, but many vernacular neologisms for spherical astronomy had been introduced by Conrad Heinfogel's vernacular *Sphera Materialis* in 1516.[120] Apian's own trade in printed vernacular editions of instrument manuals for a wide readership may have also diverted the need for a German-language *Cosmographicus Liber*.[121] I suspect that Apian never sensed a specialized market for a German vernacular edition of the

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

Cosmographicus Liber in regions where the Latin version was already circulating – so confident was he that the pictures could carry his argument. He might have judged that amateur stargazers in academic and humanist circles were equally well served by the Latin, or any of the number of vernaculars circulating post-1537. Perhaps Apian's preoccupation with other projects that likewise promoted the role of tools in the visualization of complex astronomic principles kept him too busy. Or he might have considered that a new vernacular *Cosmographicus Liber* would be a duplication of visualization efforts already underway in *De Sphaera* (1526) or the *Cosmographiae Introductio* (1529), and especially in his anticipated *Instrument-Buch*.

In any event, it is significant that Apian's *Instrument-Buch* of 1533 delivered a synopsis of cosmographic principles formatted as a very visual how-to book.[122] Apian explicitly designed this book with vernacular audiences in mind. The *Instrument-Buch*'s pictorial demonstrations would have served amateur astronomers and surveyors in an even more practical way than the *Cosmographicus Liber* itself.[123] That Apian was cited in vernacular contexts provides evidence that his content was available among the burgeoning audience hungry for ways to develop their empirical experience of the world. Evidence of Apian's role as a popularizer of astronomy can be seen in the contemporary manuals that introduced instruments such as the cross-staff and celestial globe and that invoked his name as an authority.[124] Authors of printed practical mathematics still referred back to Apian's *Cosmographicus Liber* for instructions on how to calibrate the eye in the night sky.

This last section has examined the dialogue between the *Cosmographicus Liber* and vernacular circulating astronomical texts in order to show how the theoretical content of spherical astronomy ceded its authority in the printed press to a growing visualized practice. Historians of science agree that not until the sixteenth century did Sacrobosco editions attempt to activate the hands and eyes of the astronomer; I would argue that much of this impetus to shape Sacrobosco into a useful text in the mid-1530s came from Apian's visual engagement with those principles in the *Cosmographicus Liber*.[125] While Apian was thoroughly steeped in updating Sacrobosco's teachings for the 1526 Latin reprint he designed for university audiences, he simultaneously imagined the ways in which he could reshape the content for a learned but lay readership. Mechanical pictures not only helped locate a new audience for fusty academic knowledge, but these audiences also prompted a novel demand for spherical astronomy to be explained via interactive how-to volumes.

EXERCISING OBSERVATIONS

In tracking the premium placed by epistemic genres on the direct interface of observers with their environment, a milestone is marked by their

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

self-conscious use of the term *observation* to characterize their searches. Such a turning point has been located in the appearance of the term (or some variation of the Latin verb *observare* or *observatio*) in the mid-sixteenth-century publication of astronomic material in Nuremberg. The rubric of *Nachlass Observationes* (1544) was invoked in the title of a volume that included a variety of visual samplings: the collected notes and coordinates of the astronomer George Peurbach, Regiomontanus's treatise on astronomical instruments, and the weather observations of Bernard Walther and Johannes Werner. Historians of scientific observation hail Johannes Schöner's use of *Observationes* in the title of his *Scripta Clarissimi Mathematici M. Ionnis Regiomontani ... Observationes XXX annorum a I. Regiomontano et B. Walthero Norimbergae habitae*, a book that included treatises on astronomical instruments such as the astrolabe, torquetum, Ptolemaic regulum, and the cross-staff by Regiomontanus and George Peurbach.[126] With the term *observationes*, Schöner, functioning as an editor here, indicated the idea of collective observing practices.[127] While this term had previously signaled individual case studies, we might say that the shift in its use around the mid-sixteenth century to promote "collective empiricism" might have been the result of individual agency in practicing observations as pictorially developed by Apian's *Cosmographicus Liber*.[128] In fact, Apian was already using the term *observatio* in a pamphlet announcing the comet of 1532 as well as in the related *Practica* for that year.[129] The degree to which both Schöner and Apian attended to the publication of their works with interactive diagrams and volvelles, and the fact that both of them resorted to self-publishing in order to more precisely supervise a printing process increasingly reliant on visual props, suggests a dialogue between them that went beyond the formal similarities of some of their astronomical publications.[130] Their labors cultivated audiences for empirical experiences customized by the practice of observation.

At least one of the practical applications of systematic celestial observations arose at the point at which academic astronomy and astrology came together. Apian's list of publications reflects the interpenetration of the two pursuits in early modernity and illuminates how their concerns were brought together within the publishing industry. In the age of print, it was inevitable that academic astronomy would meet the visual platform that was active in genres that *did* present useful information derived from celestial knowledge: astrology.

Celestial knowledge was the basis of astrology, a lay genre related to astronomy that traced the sun's path through the zodiac in order to cue those movements to quotidian labor, health, hygiene, and aspirations for matrimonial bliss.[131] Published data on the movements of celestial bodies circulated on a popular level in the form of almanacs, prognostications, and short pamphlets, typically of eight to ten leaves, called *Practica*.[132] In addition to other topics, these books suggested propitious times for daily activities based on knowledge of the heavens. Many seasonal practices such as bathing, cupping, and venesection were scheduled by astrological observations; the published recommendations for these routines were generated by mathematicians.[133] Apian's publishing activity spanned lay genres such as astrology and more academic astronomy, and thus promoted cross-fertilization between the pictorialized cosmographic publications and the vernacular literature on prophecies and prognostications.

Apian's own roots in practical mathematics served his busy program of printing vernacular astrological pamphlets. The annual lunar calendars and predictions that Apian printed beginning in 1523 as *Practica* financed his more scholarly ventures.[134] Seasonal almanacs that predicted weather, *Practica* also speculated on the outcomes of wars, public health hazards, and the success of harvests. Eclipse schedules in Apian's *Practica* followed the design of those found in contemporary calendars.[135] Perhaps it was Apian's attention to the needs of local astrologers, physicians, and weather watchers that fed his conviction that Ptolemy need not be the first and last word in astronomical texts. Instead, Apian emphasized in these publications how observations obtained with modern instrumentation could serve useful ends.[136] Such pragmatic needs were also serviced by the wide array of *Practica* (including almanacs and "weather books") marketed to a growing audience of practitioners. In both their address to readers and their title page illustrations featuring farmers and peasants, these books were among the first that hailed a broad cross-section of social classes as reading publics of lay learners.[137]

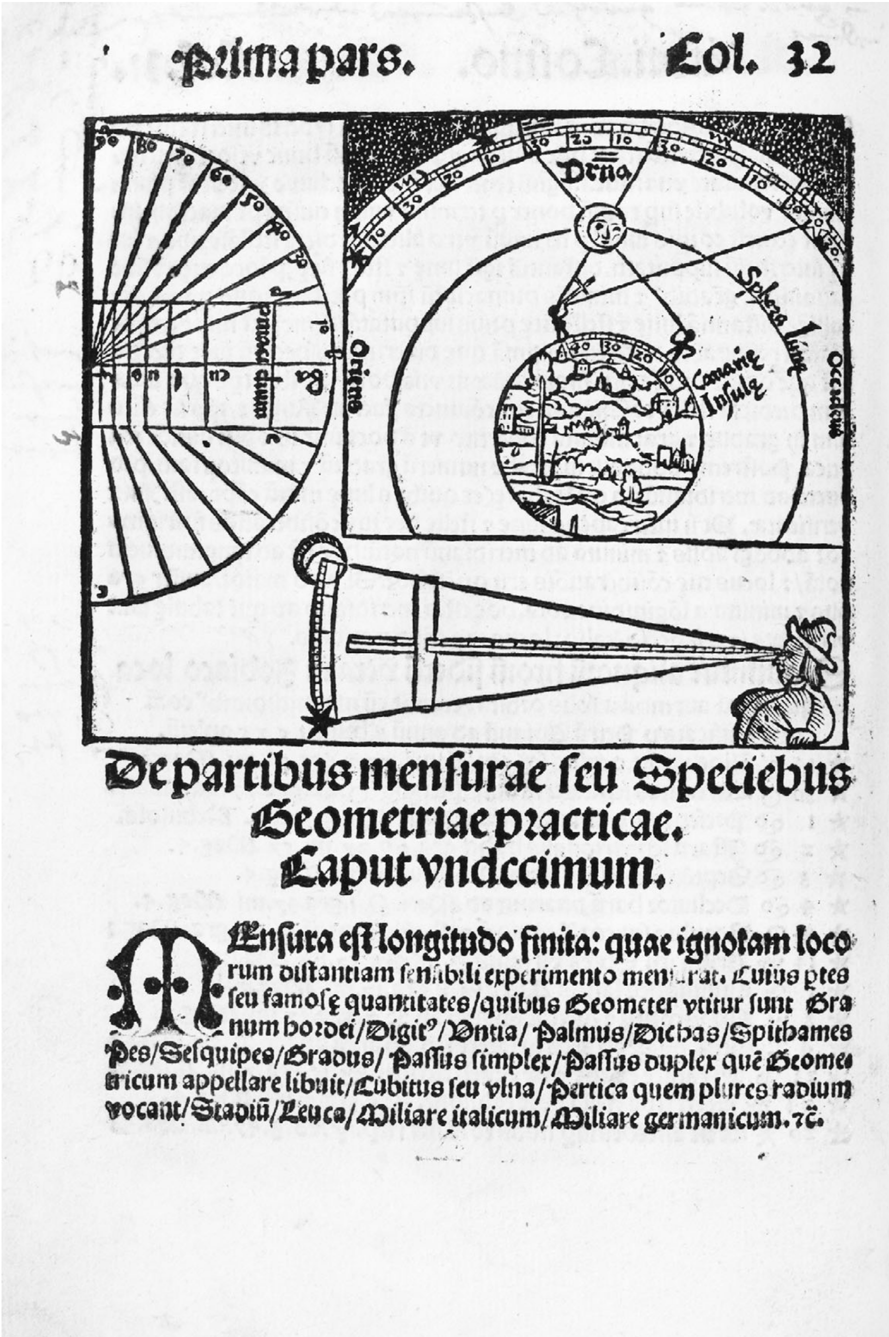
Ambitions to serve markets for both academic and popular literature in Apian's press probably guided his fashioning of the *Cosmographicus Liber* into a perfect text to reach crossover audiences – it borrowed images from academic astronomy texts, but it was also clearly indebted to the practical demands of astrological publications.[138] Schedules of lunar phases and eclipses inspired by Regiomontanus's *Calendaria* also appeared in the *Cosmographicus Liber*. Apian's version of such a calendar showed an approximately fifty-year schedule of eclipses relating to specific coordinates on the globe (in this case, the coordinates of Apian's hometown of Leisnig in Saxony). Such data mimicked that found in local astrological publications. While academic texts on spherical astronomy did publish images of lunar phases, how, one might ask, was such data pertaining to local coordinates such as Leisnig actually useful to readers of theoretical astronomy? The cosmography's lunar calendar took a middle ground: this schedule was a theoretical model with practical applications. In the context of the *Cosmographicus Liber*, it was one of two methods Apian presented to help determine one's location. The eclipse times shown for Leisnig provided the prospective observer with a reference meridian and time. If observers could time the eclipse at their local coordinates, they could then calculate the time difference between Leisnig and their own locations. Converting this to an angular measure would produce a longitude reading.

A more practical way of deriving longitude involved tracking the motion of the moon relative to a fixed star, a technique employed by mariners in celestial navigation. This strategy elaborated on the lunar distance method publicized by the Nuremberg mathematician and astronomer Johannes Werner in an edition of the *Geography* printed in 1514. Apian's text coupled instructions on how to obtain these values through the use of a simple instrument, a section introduced on folio 30 as the *Use of the Cross-Staff* (Figure 2.12), and followed by an illustration that explained how to make and deploy such an instrument. With it, one could determine the elevation of an object above the horizon, or measure the angles between two celestial features.[139]

Apian's cross-staff illustration can be seen as a hybrid model with both narrative and diagrammatic components. This tripartite woodcut shows principles that governed the cross-staff's production, including the angular scale by which it should be calibrated, a depiction of an actual observer using it to measure the angle between the moon and a star, and, lastly, a demonstration of its application on earth by a user.[140] The pedagogical value of Apian's three images together clearly outstrips the narrative explanation offered by the text itself.[141]

One of the challenges facing the non-specialist researching the secondary literature of early modern scientific instruments is that their use, calibration, and purpose are never presented in a predictable or pedagogically clear order. Furthermore, explanations are typically vague about which quantities are already known or required in order to use them. This stands in stark contrast to some relatively complete early modern explanations. Apian's illustration aims to clearly deliver instructions for the proper calibration and use of the cross-staff as related aspects. For this reason, his illustrations are vastly more informative than many later ones. They pictorialize the purpose and use of instruments and often show methods and results of observations made using them.

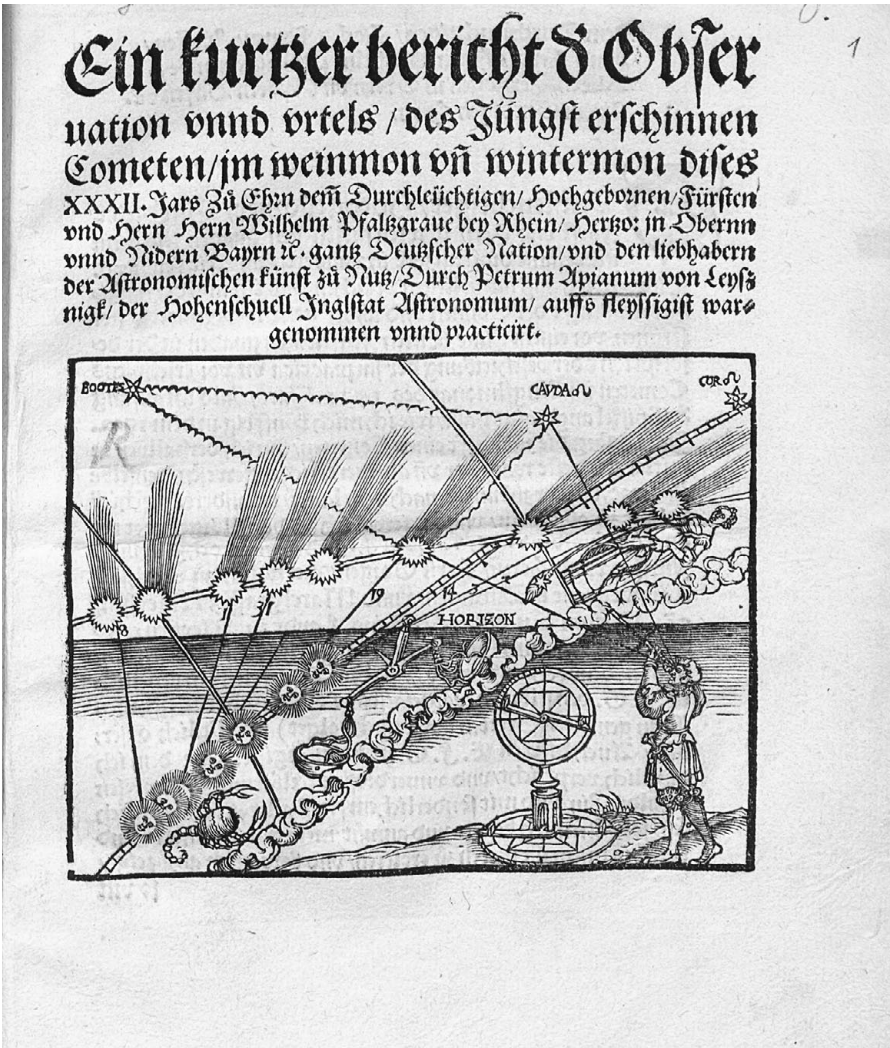
As the illustration at the base of the image shows, the staff was supported just under the eye to sight both the moon and a nearby star. The user then slid a movable cross-piece until it spanned the distance between two points; the reading taken from the staff would show the angle of separation. The device should be calibrated via a scale shown in the left-hand woodcut.[142] Instead of showing how to hold the staff itself, the illustration in Apian's *princeps* simply floats the staff before a pictured eye.[143] Lack of instructions was perceived as a shortcoming that was rectified in Apian's later editions, as he increasingly came to see the job of images to be to assist the user in the field. Apian retooled his images around the needs of a prospective user: in many practical publications that would follow the *Cosmographicus Liber*, he would feature practitioners in the field using the instruments he recommended in the text. Apian would continue to publish pamphlets for amateur observers of the heavens, sometimes in the context of *Practica*, and sometimes in pamphlets devoted to a particular celestial event. In *Ein kurtzer bericht der Observation unnd urtels des*


Prima pars. Fol. 32

De partibus mensurae seu Speciebus
Geometriae practicae.
Caput vndecimum.

Mensura est longitudo finita: quae ignotam locorum distantiam sensibili experimento mensurat. Cuius ptes seu famose quantitates/quibus Geometer vtitur sunt Granum hordei/Digit⁹/Vntia/ Palmus/Dichas/Spithames Pes/Sesquipes/Gradus/ Passus simplex/Passus duplex quē Geometricum appellare libuit/Cubitus seu vlna/Pertica quem plures radium vocant/Stadiū/Leuca/Miliare italicum/Miliare germanicum.7c.

2.12. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 32. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.


Ein kurtzer bericht d Obser uation vnnd vrtels / des Jüngst erschinnen Cometen/jm weinmon vñ wintermon dises XXXII. Jars Zů Ehrn dem Durchleüchtigen/Hochgebornen/Fürsten vnd Hern Hern Wilhelm Pfaltzgraue bey Rhein/Hertzo: jn Obernn vnnd Nidern Bayrn 2c. gantz Deutzscher Nation/vnd den liebhabern der Astronomischen künst zů Nutz/Durch Petrum Apianum von Leysz nigk/ der Hohenschuell Inglstat Astronomum/ auffs fleyssigist war genommen vnnd practicirt.

2.13. Peter Apian, *Ein kurtzer bericht der Observation unnd urtels des jüngst erschinnen Cometen jm Weinmon vnd Wintermon dises XXXII. Jars* (Ingolstadt: Apian, 1532). *Source:* BSB Res/4 Astr. p. 511.30. Courtesy of Bayerische Staatsbibliothek, Munich.

jüngst erschinnen Cometen… dises XXXII. Jars (printed in 1532), a title page image shows a comet blazing across the sky viewed by a pictured observer who tracks its position against reference stars with a cross-staff (Figure 2.13).[144] Illustrations of the path of the sun against a backdrop of the zodiac band, as well as dates of his observations, appear in both this publication and an almanac Apian printed that same year, *Practica auff das 1532. Jar.* In these two publications, we see echoes of both the methodology and the pictorial apparatus of the *Cosmographicus Liber* constructing the foundation for Apian's future visual programs for his vernacular spinoffs. Significantly, we also see the term *observation* creeping into these titles and providing the justification for the publication.

In both of these works on the comet, Apian clamors repeatedly for observational acuity that underwrites the rigorous training of the astronomer. Even in the more astrologically oriented text of the *Practica auff das 1532. Jar*, Apian announces himself as an astronomer whose assiduous observations ensure the precision of his predictions. Such visual explanations of instruments for amateur stargazers would reach an apogee in a publication designed around the use of instruments, *Instrument-Buch* (1533). These works conspired to turn the products of university astronomers into more practical field guides.

Period advancements in determining longitude through both the eclipse and the lunar distance method have not been properly credited to Apian's relatively clear diagrams, according to Uta Lindgren, who also believes that these illustrations' alleged purposes are masked by captions that dilute their true contributions.[145] The chapter of the *Cosmographicus Liber* preceding the diagram announces the *Usus Baculi* or the "use of the cross-staff" (fol. 30). According to Lindgren, this title does not go far enough to highlight the device's more significant contribution as a means of calculating longitude – a purpose that is unequivocally announced in the text that follows the subject heading. The image of observers placed at some distance from one another serves as an explanation of longitude; the difference between their respective angles of vision is equivalent to their difference in longitude.[146] The word *differentia* found in later printings of the woodcut, according to Lindgren, indicates the difference in degree between the moon and the fixed star at the observer's locations. Apian's pedagogy not only coached readers to make their own observations, but it also taught the principle that observations were relative to their observers.

This lesson was adopted by later publications that extrapolated from these principles. The Louvain mathematician Gemma Frisius has often been considered a student of Apian's because of his long engagement with Apian's texts as his editor. Gemma spurred the printing of the *Cosmographicus Liber* in the Antwerp press, frequently padding those editions with his own notes and amendments. One popular addition were charts that would enable longitude to be found via the lunar distance method. This entailed providing data of the relative positions of moon and stars. To find longitude via the lunar distance method, data points obtained must be read against a table of relative positions of the moon to the stars, such as those enumerated in Regiomontanus's *Ephemeridies*.[147] Later editions of the *Cosmographicus Liber* also include a chart inserted by Gemma that details the positions of fourteen stars near the ecliptic that can be used to calculate the moon's position. Such data had already been presented in novel visualized formats in contemporary print productions. Johannes Stabius's wall chart *Astrolabium imperatorium* (1515) offered an aesthetic presentation of the diurnal location of the sun and also the position of ten bright stars.[148] A compelling graphic presentation of the stellar positions, according to Richard Kremer, was Stabius's most important contribution to mathematical astronomy.[149] Kremer argues that the coordinates rendered by this device, a geometrical tool without moving parts, were explicitly conceived so that the viewer could simply consult the device as a visual model, rather than as a conceptual one. It cleverly displayed, rather than proved, and thus encouraged new types of cognition. Apian embedded demonstrations of celestial data collecting in short sections labeled with explanatory chapter titles and images that illustrated how to perform these tasks, balancing practical application with more theoretical objectives.

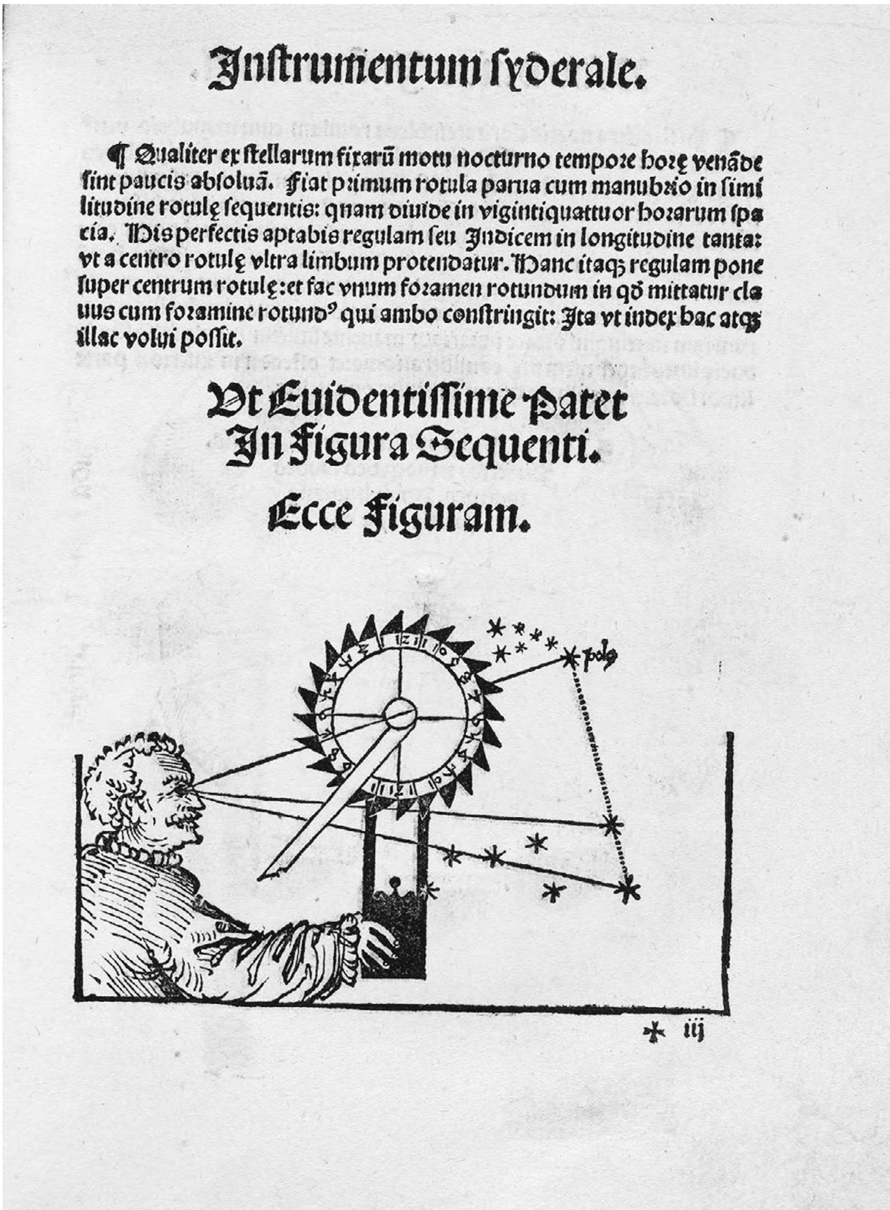
Although the first textual mention of the cross-staff surfaced *c.* 1342 in the context of surveying and astronomy, its use in the sixteenth century by mariners and navigators was surely expedited by Apian's clear explanations. Apian geared his tools toward the amateur who could now attempt personal celestial observations. Graphically embedding visual demonstrations within the explanatory text, Apian designed the *Cosmographicus Liber* to instruct amateur astronomers to gather observations. With this objective, Apian's work inspired a generation of practical publications, primarily spearheaded by Gemma Frisius. With this practical agenda, Frisius's works differed from those of his French counterpart Oronce Fine, whose emphasis was on theoretical practical mathematics.[150] Gemma Frisius's corrections and additions to editions after 1529 made Apian's cosmography even more versatile for a class of professional observers such as surveyors. Sections on surveying added by Gemma came with diagrams and appeared as an appendix entitled *Libellus de Locorum describendorum ratione* in the editions printed in Antwerp beginning in 1533, with a reprint by Arnold Birckman and Johannes Graepheus.[151] In later Antwerp editions, these sections are accompanied by woodcuts of surveyors armed with the cross-staff measuring angles they could see but not reach. That readers were developing a new useful position vis-à-vis the text can be seen in a copy preserved at the Museum Plantin-Moretus into which the owner directed the book binder to insert periodic gatherings of blank pages. Clearly, this patron added extra pages to enable commentary on the text. The comments by the owner here include marginal synopses of the text's discussion, principles of geography distilled into a list of twenty-two points, observations about eclipses, and a drawing of a hand whose fingers form a didactic model of the climate zones.[152] Gemma's amendments to Apian would go on to serve a community of non-academics such as surveyors, architects, and builders who needed to make use of such angular measurements for their calculations.[153] Vernacular editions from 1561 feature Gemma's tools, such as the sea-compass, in their titles.[154] Practical knowledge about how a compass might have been used for navigation would certainly have been of interest for the reader/viewers Apian developed: a community of mathematical amateurs.[155]

ENABLING EMPIRICISM

Another form of data collection Apian popularized was finding the time at night. That Apian's cosmography was being sought for these practical aspects is suggested by a brief table of contents in the 1561 Dutch edition that lists finding the "hour of the night via the stars" to be the third most noteworthy feature of the book. The nocturnal dial needed for this was used principally by mariners whose time readings enabled them to stay on course in their latitudes and to predict the tides.[156] Other segments of the populace who could profit from readings of nocturnal time were astrologers producing horoscopes, or monastic communities in charge of scheduling prayers, chants, and other rituals.[157] A nocturnal dial determines the time at night, just as sundials mark the hour during the day. The last few pages of Apian's 1524 edition were devoted to the explanation of the nocturnal (Figure 2.14), explaining the principles, theory, and use of the dial. One page even provided a model of the instrument itself.[158]

Apian both illustrates the theoretical model of the nocturnal dial and provides one that could be used to find the time by sighting Polaris through the center and then aligning the arm to the reference stars (Figure 2.15). Over successive pages, he illustrates a user employing the tool to find the angle between the pole star and the reference star; lastly, he includes a page that contains a model of the dial and a pointer arm, presumably to be cut out and attached to firm backing and a stick. Most of these seem to have been printed on or glued to sturdier parchment and tipped into the manual.[159] Once the instrument was detached from the book, it either could have been used in the field in a rudimentary way or could be manipulated alongside the book for better comprehension of the actual tool's workings.[160] These explanations showed how to make use of local coordinates for telling the time and to help stargazers orient themselves. Tools like these would form the focus of Apian's guides to a variety of instruments (such as ones on quadrants and dials) published in the 1530s, including the *Instrument-Buch* that established the foundation for the observations of Tycho Brahe, for instance, whose attention to description and use of instrumentation were key in formulating a working model of the universe.[161]

A lunar instrument, the *Instrumentum Noctis* (Figure 2.16), was more of a theoretical volvelle than the nocturnal dial, but one whose elegance was predicated on stunning design. It appears in the appendix to the *Cosmographicus Liber* along with Apian's disclaimer that it was designed at the behest of his brother Georg. Using two moving plates, to each of which a pointer is attached, one should be able to derive the time at night. A lower plate carries a design made from an algorithmic projection that simulates the moon's changing phases through an opening in the circular plate. Apian's text



Instrumentum syderale.

¶ Qualiter ex stellarum fixarū motu nocturno tempore horę venãde sint paucis absoluã. Fiat primum rotula parua cum manubrio in similitudine rotulę sequentis: quam diuide in vigintiquattuor horarum spacia. His perfectis aptabis regulam seu Indicem in longitudine tanta: vt a centro rotulę vltra limbum protendatur. Hanc itaqꝫ regulam pone super centrum rotulę: et fac vnum foramen rotundum in qd mittatur clauus cum foramine rotundoꝰ qui ambo constringit: Ita vt index hac atqꝫ illac volui possit.

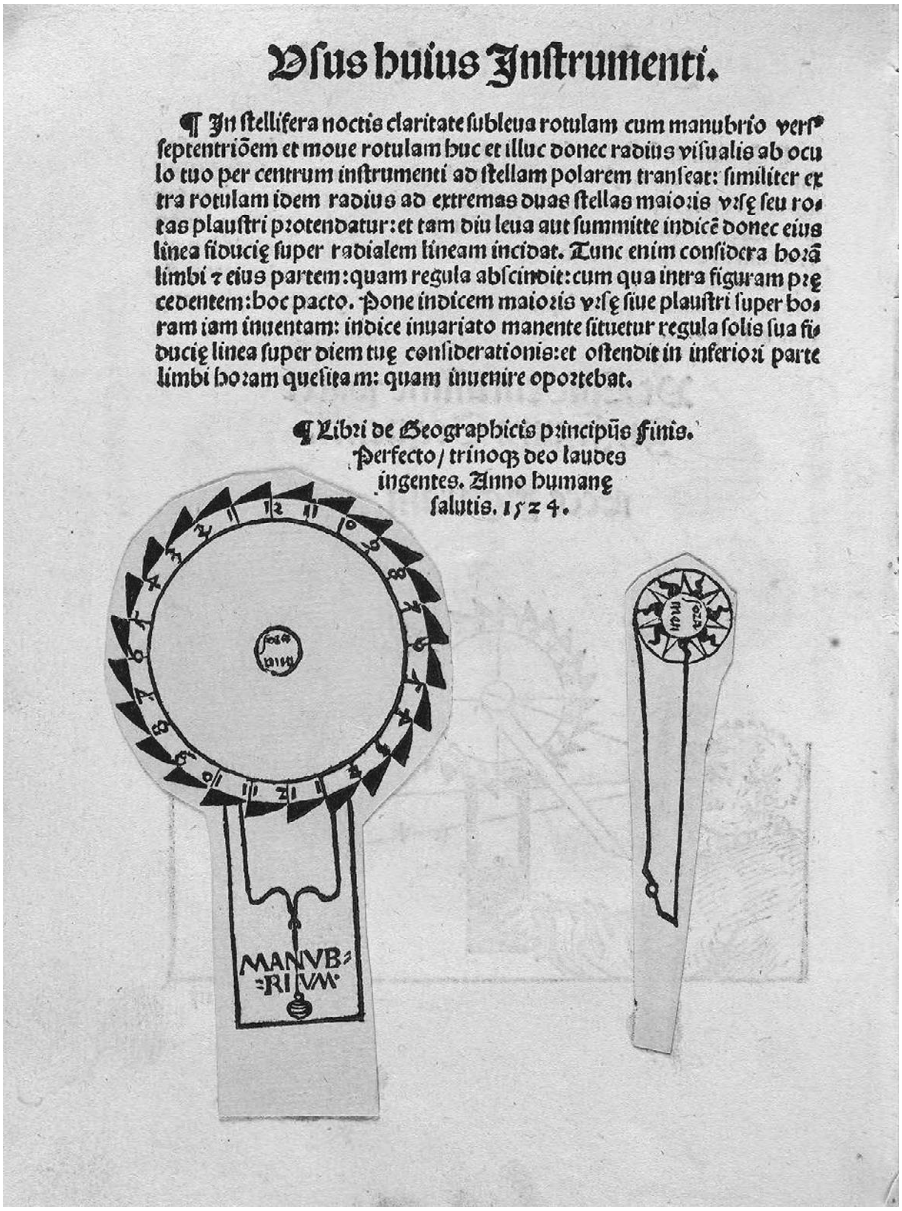
Vt Euidentissime Patet
In Figura Sequenti.

Ecce Figuram.

iij

2.14. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), appendix, fol. 109. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

explains that the pointer of one dial is set to the altitude of the moon; the other dial, with the circular window, should be squared to the moon's phase. Together, these two dials point to a number that renders the time at night. The dial derives useful data from the observation of the moon's phase: the reflected light seen on the lunar surface is a measurement of the relative angle between the moon and the sun. Coupling this with a measurement of the



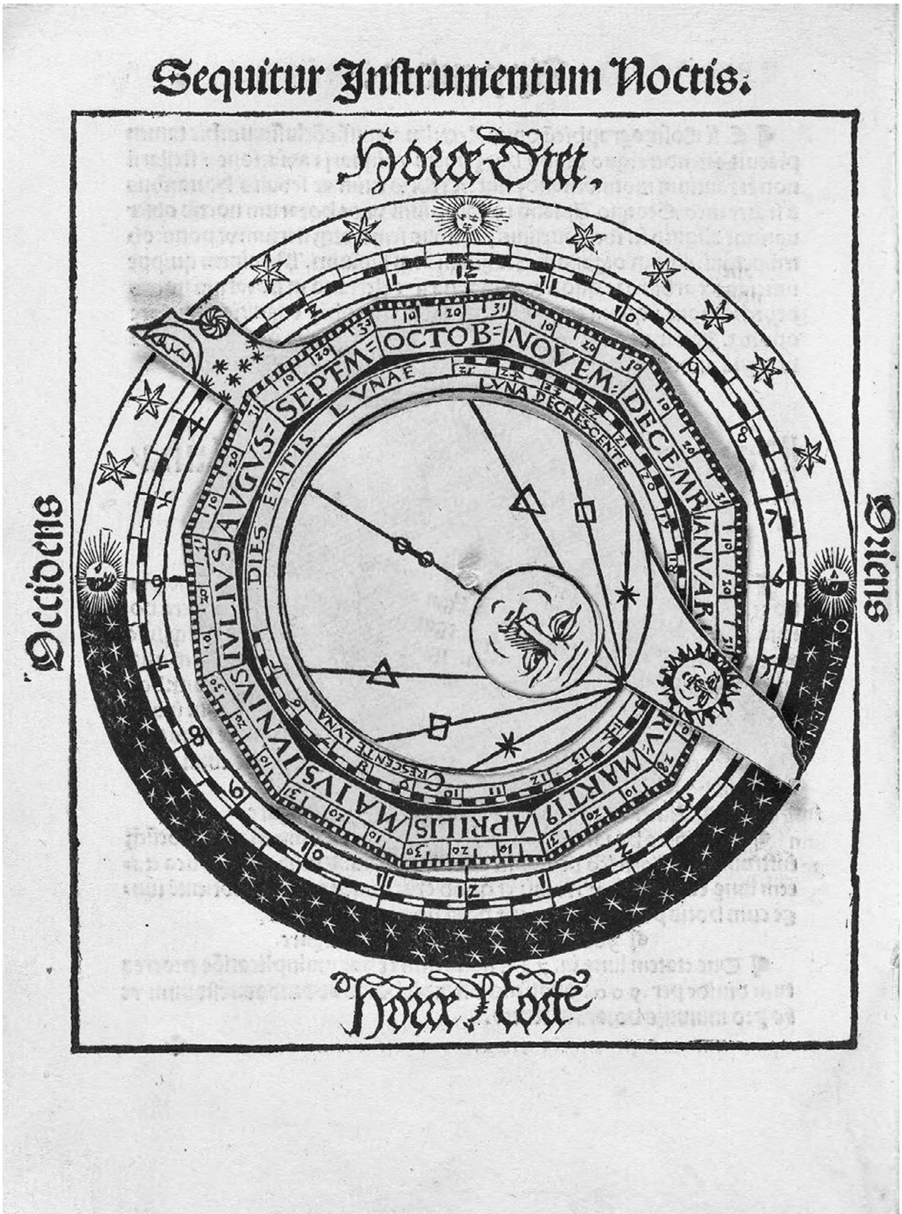
Usus huius Instrumenti.

¶ In stellifera noctis claritate subleua rotulam cum manubrio vers⁹
septentrio͂em et moue rotulam huc et illuc donec radius visualis ab ocu
lo tuo per centrum instrumenti ad stellam polarem transeat: similiter ex
tra rotulam idem radius ad extremas duas stellas maioris vrsę seu ro
tas plaustri protendatur: et tam diu leua aut summitte indicē donec eius
linea fiducię super radialem lineam incidat. Tunc enim considera horā
limbi ⁊ eius partem: quam regula abscindit: cum qua intra figuram prę
cedentem: hoc pacto. Pone indicem maioris vrsę siue plaustri super ho
ram iam inuentam: indice inuariato manente situetur regula solis sua fi
ducię linea super diem tuę considerationis: et ostendit in inferiori parte
limbi horam quesitam: quam inuenire oportebat.

¶ Libri de Geographicis principiis finis.
Perfecto / trinoqz deo laudes
ingentes. Anno humanę
salutis. 1524.

2.15. Peter Apian, nocturnal parts in *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), appendix, fol. 110. *Source:* Burndy Library. Image in the public domain.

moon's altitude provides the location of the sun. The time at night can thus be inferred by triangulating the position of the sun beneath the horizon.[162] This data point renders a value more useful to the viewer: the time at night. This value could be used for scheduling events, predicting eclipses, making horoscopes, or simply estimating the number of daylight hours. Apian's stargazers would also have found the lunar volvelle admirable for its elegance in design

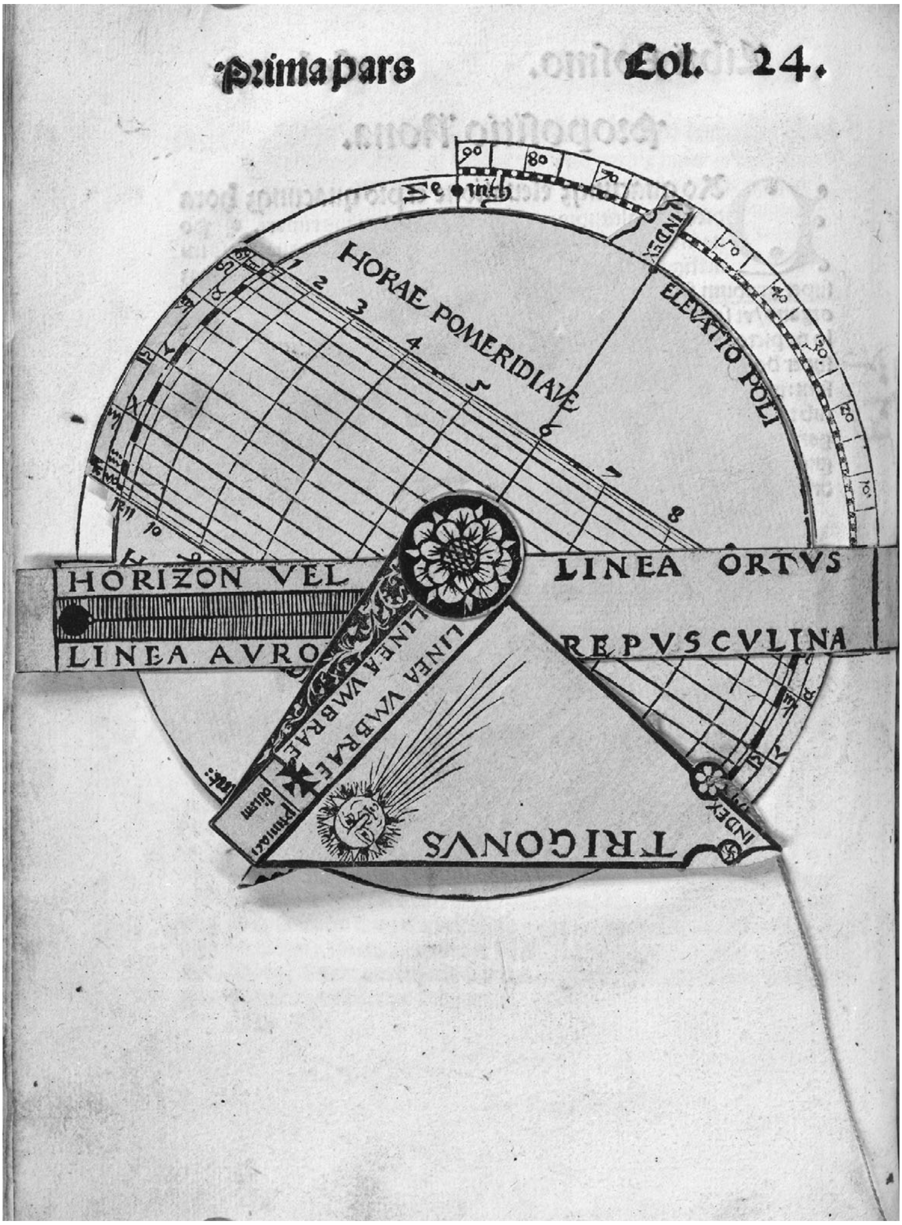


2.16. Peter Apian, nocturnal instrument in *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), appendix, fol. 106. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

and the way it synthesized the clockwork of the heavens with just a few moving parts.

Paper instruments could also pictorially synthesize theoretical astronomic propositions. With another moving paper volvelle, readers could derive practical values from complex Ptolemaic concepts. This dial found on folio

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press



2.17. Peter Apian, *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 24. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

24 revives the *Organum Ptolemei* (Figure 2.17), a disc with a projection of the sun's declination and the hours. It was a tool that astronomers over the centuries had tried to reconstruct from Ptolemy's prescriptions.[163] While reports about the *Organum Ptolemei* proliferate in manuscript sources, Apian's might actually be an early attempt to create one in paper.[164]

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

Apian's version of the Ptolemaic instrument is comprised of three movable parts mounted atop a disc with latitude markings. The components include a rectangle representing the horizon; a rotating triangle called *Trigonus* marked with the line of shadow that would be cast by the sun; and a rotating disc with a grid of morning and afternoon hours bordered by the zodiac band. The cylindrical grid printed on this disc is an orthographic projection of the equinoctial (colure); it offers a schema that reconciled the parallels of the celestial sphere to the plane of the equator.[165]

The instrument's functionality was loosely explained by the ten propositions that precede it in the text. With the instrument, it is possible to calculate one's latitude and the position of the sun in the house of the zodiac, derive the height of the celestial pole from the altitude of the sun (via the triangle activated as a shadow vane), and also determine the height of the pole star. Furthermore, one could derive the time of day in the same way as one might employ a sundial; establish the time of sunrise and sunset; measure the length of unequal hours of days and nights; and lastly, determine the height of the sun on cloudy days.

Users are instructed by Apian how to set the dials. The user would align the horizon bar to the appropriate latitude and set the index pointer of the large disc in the marked quadrant to the height of the pole star. While the dials are meant primarily to demonstrate principles, at least two of the propositions suggest that the parts could work in concert to enable empirical investigations. Once the user's latitude was entered in the *Organum Ptolemei*, "the intersection of the triangle with the grid of parallel and hour lines on the rotating disc works like an equatorial sundial, while the intersection of the horizon line with this grid can easily be related to the set-up of a horizontal sundial."[166] While the tool mimics the principles of the sundial in this way, Apian expanded the dial's practical operations. He layered both practical ends and theoretical didactics onto the dial.[167]

A sundial was a purely practical tool designed to measure time from readings of the sun's altitude at specific locations, and it was tied to those specific locations. By contrast, Apian's instrument can be used for determining the length of daylight hours for a given latitude, enabling the user to calculate the length of the day or night at any location and at any time of year. From these values, the user could generate new data, such as measuring fluctuations in daylight hours over the seasons. While information about local daylight hours could also be found in almanacs and calendar pamphlets, this tool could help derive data that was handy for cuing regimens to the length of the day at specific times of the year.[168] From practical *calendaria*, the reader could schedule precise dates for activities such as planting, harvesting, healing, and distilling. But Apian's tool is in fact *more* useful than these purely practical aids, argues Vanden Broecke, because it clarifies the operation of a sundial by mapping astronomic data onto terrestrial coordinates that could be visualized.[169] By demonstrating principles of the empirical processes by which that data was derived, the *Organum Ptolemei* enabled the reader to translate theoretical knowledge into more practical applications.

By synthesizing data from observations gathered over time, this tool could demonstrate variance in the length of daylight hours over seasons. These were data points that amateur observers had little chance of grasping in the absence of regular and sustained investigations. In this way, we can think of the *Organum Ptolemei* as a calculator of real values for a series of variables, such as how to divide the day up into hours of daylight. It is thus a tool that replicated a phenomenon that could be observed, and it gave the reader a purchase on the observable world. It taught the reader how to turn observations into practical knowledge.

The tool could illuminate other astronomical phenomena that could be inferred from observations. On the movable triangle marked *Trigonus*, there is a boundary line marked *Linea Umbrae*; this refers to the line of shadow that would supposedly be cast by the instrument. But another function can be inferred from it beyond its function as a pop-up shadow vane: the *Terminus* could also have potentially suggested to the viewer the boundary between light and darkness. This line might also represent the threshold of light and darkness, that boundary, or terminator, that we witness in air travel today, but one that could only be inferred in Apian's day.[170] Apian's tool aims to help conceptualize a phenomenon that, at least in principle, should be observable. Imagined here as a visual exercise, this terminator between night and day was surely a theoretical notion in this period, but one derived from the data of collective observations.

While the experts still disagree about the precise practical applications of the complex *Organum Ptolemei*, most would concur that this volvelle had an enormously influential afterlife. The volvelle's capacity to direct do-it-yourself activity can be seen in subsequent printings of other astronomic material. Versions of the volvelle surface regularly in later editions of Sacrobosco's *De Sphaera*, in which, we will remember, it became a critical feature of the afterlife of that text in the sixteenth-century printed editions.[171] It should also be noted that, at this point, Apian's volvelles find their way back home into more academic contexts – indeed, Gingerich calls these Sacrobosco editions the first true ancestors of modern astronomy textbooks. Steven Vanden Broecke argues convincingly for how Apian's illustrations rewire the practice of cosmography by prioritizing visual learning; he argues that these tools "technologized" cosmography, making it mechanical and useful.[172] This knowledge also helped to make celestial events foreseeable. On the road to shaping a more predictable universe, Apian's instruments required users' input, incentivized empirical engagement with the world, helped sharpen their observational acuity, and created expectations of visual verifiability.

The goal of informed peerings into the heavens under the rubric of cosmography was to bring astronomy down to earth. Apian's cosmography ripened in the age of geographic discovery and paralleled empirical developments in that field. In addition to astronomy, the other discipline to which sixteenth-century cosmography was indebted was geography, a field whose practice was simultaneously being overhauled by empirical experience in cartography. New knowledge was made possible by firsthand reports of data confirmed by navigational techniques and data recording enabled by instrumentation. This synergy displaced old coordinates and plotted new ones. Apian established cosmography as a genre that bridged the disciplinary divides between astronomy and geography. To be sure, the second-century AD Alexandrian Ptolemy himself had envisioned cosmography in this way. Ptolemy's intention was to furnish the *Geography* with maps, but these were never transmitted along with the projection methods and the data. Despite Ptolemy's original vision, astronomy and geography had essentially remained discrete pursuits in the scribal tradition.

Travel accounts printed in Latin and in vernacular languages were profuse enough by the 1480s to be collected by publishers in anthology format in the early 1500s. Their rapid furnishing with visual accompaniment brought new credibility to the eyewitness when those claims were backed by empirical experience suggested by images. One of the first important syntheses of empirically derived data sourced from travelers occurred in a cartographic think-tank located in St. Dié in present-day Alsace. Chief among those amendments made to geography was the incorporation of the Americas into existing models of the globe. These developments in the visualization of these "discoveries" (as Europeans understood them) took place against the backdrop of the Ptolemaic world picture and were specifically registered in the St. Dié workshop as revisions made on empirical grounds. Ptolemaic cartography was challenged by new facts whose novelty was accompanied by a self-conscious embrace of instruments and technology. The geographical revisions made at St. Dié reached their widest audiences via the circulation of newly drawn maps – it can be argued that the strikingly visual impact of these revisions underwrote the success of their conclusions. Therefore, it is not surprising that Apian, whose graphic projects were already heavily invested in the display and use of instrumentation, purposefully cribbed the cartographic novelties from St. Dié as a foundation for the second half of the *Cosmographicus Liber*. This appropriation can be interpreted as Apian's kindred pursuit of evidence derived from instrumentation and empirical inquiry.

Apian's geographic pictures and Gemma Frisius's maps that would later accompany editions of *Cosmographicus Liber* are among those that helped broadcast the cartographic knowledge developed in the St. Dié workshop. As Apian illustrates at the beginning of the *Cosmographicus Liber*, geography and

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

astronomy supported the intellectual weight of cosmography in equal measure. The text's entire second half aimed to incorporate geography's new developments, following the dictates of a slim volume from St. Dié that was also engaged with contemporary advancements in instrumentation and data collecting. Incidentally, this volume also bore the word "cosmography" in its title. Edited by Matthias Ringmann and including maps made by cartographer Martin Waldseemüller, the *Cosmographiae Introductio* (1507) was a pamphlet dedicated to the Emperor Maximilian that included Amerigo Vespucci's reports of travels to the Americas and was intended to provide commentary to an accompanying map.[173] In addition to this world map, the workshop also printed gores for a terrestrial globe that could be constructed by the reader.[174] Cartography was intimately tied to other cosmographic disciplines such as astronomy, navigation, and especially instrument making during the sixteenth century. Many advances in cartographic precision would emerge from the instrumentation produced in the workshop of Gemma, whom we have already met as the editor of Apian's *Cosmographicus Liber*.[175] This cross-pollination between cartography and instrument making, with their byproducts visible in cosmography, was also highlighted by Apian and Frisius.[176] Like astronomy, revisions to cartographic knowledge would keep pace with the production and use of tools. Printmakers involved in these innovations frequently found it expedient to construct their own presses for their customized publications: such was the case with Waldseemüller and Mercator, in addition to Apian, who established a press in Ingolstadt in 1525.

Waldseemüller and Ringmann's collaborative publications were among the earliest humanist productions to plot coordinates derived from recent travel accounts of merchants against the world picture established by Ptolemy.[177] Vespucci, after all, had also referred back to Ptolemy when accounting for his geographic findings.[178] Among the adjustments that Ringmann and Waldseemüller made to the world map was the clearing of space in the Atlantic for a new continent they had the temerity to name after the Florentine merchant who claimed it to be both recently discovered territory and the fourth part of the world.[179] Waldseemüller's map projection can be thought of as a major intervention in the visualization of early modern data, and it reflected a series of visual choices so powerful that it not only rearranged the world picture but also gave birth to one of the largest early modern maps. The size of the printed woodcuts (set together, they measure 4.5 × 8 feet or 1.37 × 2.44 meters), in addition to the effort extended to produce and assemble them, suggests that St. Dié mapmakers were prescient in finding a graphic format to match the size of the epistemic break that using the new name of America would forge. The Waldseemüller map, a document whose touting as the "birth certificate of America" aimed to justify the $10 million price tag that accompanied its sale to the US Library of Congress in 2003, also made a sizable splash at the time of its printing.[180]

The St. Dié workshop published their new work in productions that privileged pictorial formats and visual "tools" such as globes and maps, but texts still provided the explanatory mortar for the featured visual accompaniments. Ringmann and Waldseemüller's *Cosmographia Introductio*, a roughly fifty-page manual, was intended as a primer for this large map. The publication introduced the new territories presented on the map, but the text itself is disappointingly peremptory, disorganized, and visually bereft, especially considering the unambiguous visual impact of the map. It was without clear chapter markings, and the occasional diagrams of the globe with degree and axis markings brought the total number of included images to four. Short shrift is given to spherical astronomy, with a brief sketch of circles encountered on the globe, yet the book is flush with glosses that point to ancient commentators on the world picture, such as Virgil, Ovid, Ptolemy, and Caesar. Three diagrams of spheres try to model celestial astronomy for the reader, and one larger celestial map folds out of the quarto-sized volume. Rudimentary discussions of climate zones are given, followed by lists of placenames. Perhaps the most flamboyant novelty, Vespucci's discovery of America, is embedded in a discussion of zones and climates, winds, and sections of the world unknown to Ptolemy.

Like the lines dividing the earth into terrestrial circles, "places unknown to Ptolemy," or *extra Ptholomeum*, was a time-honored way of demarcating boundaries in early modern geography as a black and white divide, with little gray area. Early sixteenth-century cosmographers were quick to invoke the zonal episteme of *extra Ptholomeum* for the stark contrast it provided between ancient facts and novelties still struggling for reconciliation. It was a handy scrim on which new data could easily be projected, and a well-functioning model of the order of things. Taking the name *Cosmographia* from Ptolemy, Apian's own *Cosmographiae Introductio* of 1529 still opened summarily with the analogy from Ptolemy that laid out the principles for the notional divisions between geography, which, perhaps most importantly, provided the rhetorical justification for the practice of picturing to convey information.[181] Using a woodcut showing the observer's eye as a vertex for the terrestrial and celestial sphere, Apian borrows for his front matter of this text an image similar to the opening visual gambit of his *Cosmographicus Liber* in 1524. Despite deference paid to Ptolemy on the first page, Apian invokes Ptolemy later in the text for the purpose of correcting him. If Apian neglects to mention Waldseemüller as a source in the text, he alludes to him in the book's title and spirit; they shared a kinship in their projects to revise Ptolemy.

Apian's *Cosmographiae Introductio* initiated a dialogue with the printed products of the St. Dié workshop. His streamlining of Waldseemüller's content around graphic design was critical to its production, a characteristic of Apian's publications post-1524. Apian designed the *Cosmographiae Introductio* to be a more useful guidebook to the cosmos than was Waldseemüller's original publication.[182] It was divided into clear chapters inspired by Waldseemüller, but then expanded and organized around diagrams that served to explain their principles. Following twelve years on the heels of Waldseemüller's text, Apian filtered Waldseemüller's content through the thoroughly visual programs of recent cosmographic publications of his own. He used Ptolemy strategically, placing emphasis on his data – i.e., coordinates – and reinforced his advocacy of visual aids.[183] In a text of approximately eighty pages in length, Apian's choice to include twenty-five images made the visual component substantial. Like his reissue of Sacrobosco's *De Sphaera* in octavo format in 1526, Apian's updating of Waldseemüller was crafted into a handy and portable edition. That it also appeared in Latin perhaps also testified to Apian's desired crossover appeal to both lay and academic audiences. Printed first in Ingolstadt in 1529, Apian's *Cosmographiae Introductio* then went into sixteen later editions in Paris, Cologne, and Venice, including some vernacular printings.[184]

Apian was forthright about the aspect of Waldseemüller's *Cosmographiae Introductio* that he found most important. He privileged the map that expressed the relationship between the astronomical and terrestrial coordinates in a systematic and technological manner. Waldseemüller's map cast the new data in light of the instrumentation used to obtain it: here, instruments pose as attributes of the protagonists at the map's top, where Ptolemy holds a quadrant and Vespucci holds dividers, a tool used by mariners and mapmakers. Waldseemüller's unequivocal emphasis on the visual material contrasts with evidence buried in the text's ramblings and disorganized quotations from ancient sources.

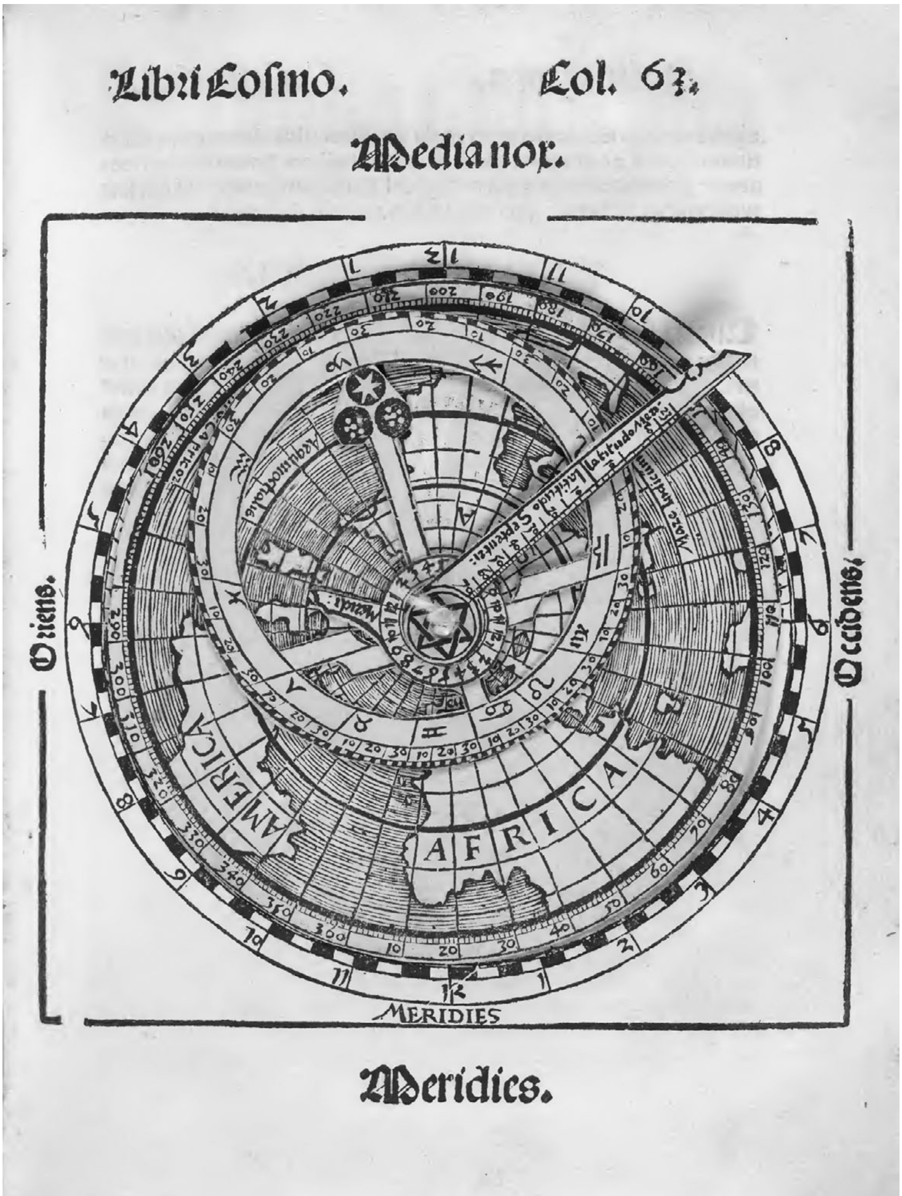
Apian's visualization zeroed in on the cartographic advances made in the think-tank of St. Dié in the early 1520s; it was probably exactly these geographic entanglements that partly inspired the production of the book at this chapter's center, the *Cosmographicus Liber*. Apian's terrestrial globe in the graphic description of cosmography on folio 2 was positioned to feature America. But Apian cribbed from Waldseemüller most assiduously in the projection of the terrestrial globe in the *Speculum Cosmographicae*, a unique instrument in the cosmography to be discussed below.

Several of Apian's publications prior to the *Cosmographicus Liber* also took the new world map as their subject, albeit in a slightly altered format. Apian repurposed Waldseemüller's data in a scaled-down woodblock version of a world map (Figure 2.18), considerably reducing the size of the 1507 original.[185] A cordiform projection derived from Waldseemüller, it even borrowed the design of the northern wind head Septentrio, from whose mouth not only gusts but also longitude lines seem to emerge. Designed by Apian for Camertius's commentary on Solinus, *Solini Polyistoria Enarrationes*, published in Vienna in 1520, the map appears as a single-sheet foldout tipped into the text near the beginning.[186] The map can also be found in some editions of

2.18. Peter Apian, world map in *Joannis Camertis ... in C Julii Solini Polyistora enarrationes. Additus eiusdem Camertis Index* (Vienna: Sigrenius and Alantse, 1520), 28.5 cm × 42 cm. *Source:* Courtesy of John Carter Brown Library. CC by 4.0; cf. https://jcblibrary.org/permissions.

Pomponius Mela's *De Situ Orbis*, such as the one that appeared in Basel in 1522. Another publication of Apian's, the 1521 *Isagoge*, a short pamphlet of cosmographic propositions, discussed strategies for picturing the earth's surface, included an explanation of Waldseemüller's map, and forecasted the author's plans for a cosmography.[187] The announced cosmography is widely believed to have become Apian's *Cosmographicus Liber* of 1524. In 1522, Apian provided the text for a pamphlet, *Declaratio et Usus Typi Cosmographici* (published by Paul Khol in Regensburg), with illustrations by Michael Ostendorfer, including a title page with a south-oriented oval-shaped map that shows a tiny, though assertive, America marked with the initials AM.[188] Lastly, twelve globe gores were printed *c.* 1520 and also are likely from Apian's press – these certainly appear to be designed to function on the level of a tool, a purpose that the later *Speculum Cosmographicae* would also serve.[189] Apian published the results of Waldseemüller's findings in these various repackagings, so we should not be surprised that the initial credit for Waldseemüller's original wall map was in fact usurped by him in the early secondary scholarship. Before the wall map's rediscovery in the Waldburg-Wolfegg collection in Swabia in 1901, most scholars assumed Apian to have been the first printer to place America's name on the globe, so avid a promoter was he of Waldseemüller's findings.[190]

While it is unclear whether Apian's cosmography announced in his 1521 *Isagoge* eventually became the *Cosmographicus Liber*, it is certainly true that the



2.19. Peter Apian, *Speculum Cosmographiae* in *Cosmographicus Liber* (Landshut: Weyssenburger, 1524), fol. 63. *Source:* Zentralbibliothek Zürich, NR 870. Courtesy of ETH-Bibliothek Zürich.

cosmography was his synthesis of geographic advancements made in St. Dié. Privileging usable information, Apian presented these adjustments to the world map in the unique form of a coordinate dial in the *Cosmographicus Liber*, an instrument he dubbed the *Speculum Cosmographicae* (Figure 2.19). This was a geographically oriented astrolabe, in which Waldseemüller's projection of the earth forms the backdrop of the device. While the astrolabe proper schematized the heavens in order to show what the sky looks like at a given latitude

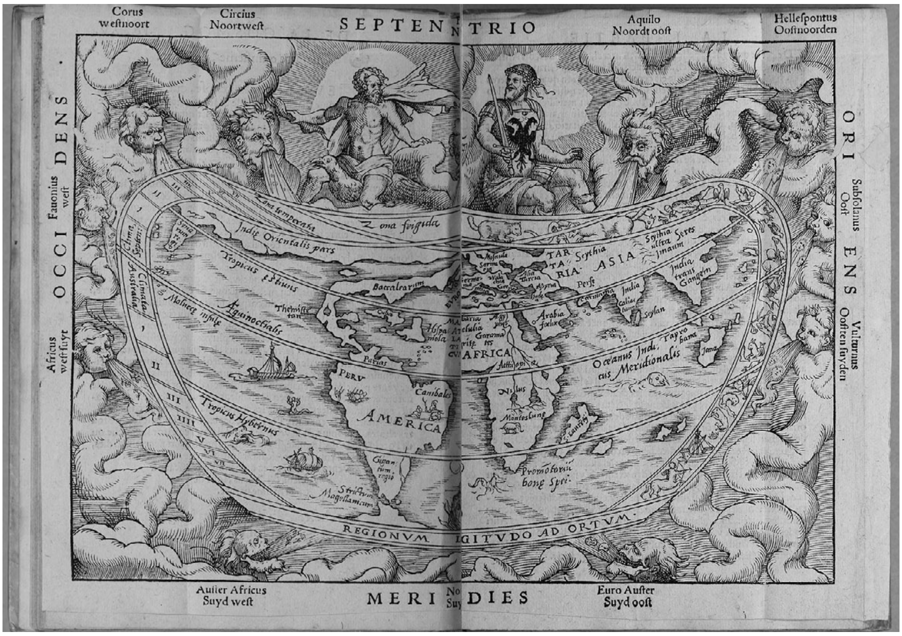
https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

and how celestial bodies move in relation to each other, Apian's *Speculum* provided instead information about terrestrial coordinates. On a traditional astrolabe, the bottom-most plate, or *mater*, shows the stereometric projection of the celestial sphere that maps stars onto the interior of the vault of the heavens. But the *mater* of Apian's device carries a projection of the earth seen from the north pole; the dial attempts to set the celestial coordinates into dialogue with their terrestrial analogues.[191] Placed at the conclusion of the astronomical part of the *Cosmographicus Liber* on folio 63, the tool introduces the book's second half on geography.

To construct the *Speculum*'s series of rotating parts, Apian borrowed the design and nomenclature from astrolabes.[192] Apian preserves the equator, tropics, and the ecliptic but projects these on top of a terrestrial map, instead of a celestial one. A movable disc carried the ecliptic and zodiac markers. Insofar as it represented a projection of the celestial circle, it mimicked the traditional astrolabe's star map, or *rete*, a circle that typically carries the zenith–horizon coordinate system for a particular latitude. Atop this moved the *rule* that serves as an index or pointer for the front; it is usually marked with a scale of declinations.

Physical astrolabes were outfitted with a number of removable discs that could be set to the local latitude; then, with the aid of a sighting device, or *alidade*, with which most were equipped on their rear surfaces, sightings could be taken to determine the altitude of sun or stars to find the time in order to appropriately position the discs.[193] Modern scholars agree that most astrolabes, until the weighty mariner's astrolabe that could be stabilized on board a ship became common, were primarily didactic tools for showing the stars and circles in relation to each other. Contemporary readers might have been familiar with publications such as Johann Copp's *Erklärung unnd gründtliche Underweysung alles nutzes, so in dem edlen Instrument, Astrolabium genannt . . .*, which appeared in 1525. This included a ready-to-assemble instrument, along with many images that set store by measurements made by the eye and observers in action.[194]

The astrolabe permitted investigation of the major terrestrial and celestial lines and attempted to provide knowledge of the celestial system as a whole. But Apian's instrument rehabilitated cosmography's intention to combine positional astronomy with *geography* – by using it to visualize earth-bound observations. Apian's text preceding the placement of this disc was a summation of five propositions that explained the purpose of this "mirror of cosmography," among which was to help the user understand the earth in the way one encounters one's face in the mirror: in other words, to develop visual intimacy with the earth as one knows oneself.[195] Again, Apian invokes the epistemic bite of portraiture: just as peering into a mirror would reveal self-knowledge, to observe one's coordinates was to understand one's place in the universe.



2.20. Peter Apian and Gemma Frisius, world map in *La Cosmographie de Pierre Apian,… nouuelleme[n]t traduict de latin en francois* (Antwerp: de Bonte, 1544). *Source:* Courtesy of John Carter Brown Library. CC by 4.0; cf. https://jcblibrary.org/permissions.

The dial was intended to help visualize abstract principles – showing readers the processes by which geographic coordinates operate and how to visualize their relationship to the cosmos. Retooling the projections of the traditional astrolabe, the celestial circles have been replaced by a projection of the continents from the north pole. This was a clear sign of Apian's intention to bring cosmography quite literally down to the study of the earth. After all, this was cosmography's guiding philosophy. This tool cast the net of celestial lines over a geographic representation of the earth befitting the book's section on geography. The *Speculum* volvelle precedes this narrative section and combines astronomical and geographic knowledge, placing it in the text at the threshold between astronomy and geography. The following narrative about continents and a list of coordinates for the world's cities presents the map as a system that links the celestial and terrestrial realms. The *Speculum* activates the Ptolemaic system by adding a user interface. The tool helps conceptualize geographic coordinates by having users capture the data themselves in the manner of professional cartographers.

Like the *Speculum*'s globus, a world map is also a tool. Editions of the cosmography printed after 1544 included a map of the world not present in Apian's *editio princeps* (Figure 2.20).[196] This was another addition made by Gemma, the instrument designer best known for his contributions to surveying and mapmaking and in whose workshop the future cartographer

Gerard Mercator worked.[197] Gemma's position on the faculty of medicine at the university in Louvain hardly alludes to his range of teaching or to the subject areas for which he was responsible, which included mathematics, astronomy, and geography. This map anchored Gemma's most heavily edited section of the *Cosmographicus Liber*. The map placed the new discoveries within the discursive context of geopolitical cartography which the image at the top announced: the Holy Roman Emperor Charles V in a Roman cuirass sits with Eolus, the wind, astride a dove.[198] The framing figures of this map echoed a trend in the updating of geography by agents already active in Waldseemüller's map of 1507, the document on which this map is based. Framing revisions to the world picture with portraits of the two empiricists who generated them, Waldseemüller had placed Ptolemy with a quadrant at the top, alongside the navigator Amerigo Vespucci, styled here as Ptolemy's early modern updater. Both earned their spots in the cartographic firmament on the strength of their reputations as observers, wielding tools of firsthand inquiry and presciently aware of the novelty of their data. By positioning the modern observer Vespucci at the top of his map, Waldseemüller tacitly argued for the agency of instrument users to reshape the world picture. This reference was surely not lost on Apian, who promised that the secrets of geography and spherical astronomy could be unlocked by his own printed tools.

The allegorical trappings of empire would dominate the shape of later cosmography, where portraits of sovereigns would edge out the representations of tool-laden empiricists. New discoveries in astronomy and geography would soon be mobilized in the service of geopolitical aims. The empirical basis for cosmography would later surrender to a genre that would feature narrative accounts of the world's spaces, providing the history of peoples and their conflicts, and a parceling out of what belonged to whom. In this period, we can already detect the slow creep of these empirical projects into the territory of imperial imaginings. Waldseemüller's edition was dedicated to the Emperor Maximilian, after all, and Apian's later projects reflect the involvement of Charles V, who commissioned a horoscope from him in the shape of a book with movable dials, the *Astronomicum Caesareum*.[199] Cosmography fell increasingly into the hands of operatives eager to win dominion over geographic territories.[200] Later cosmographies (such as those by Sebastian Münster and André Thevet) changed course and "wrote themselves back into medieval, encyclopedic tradition, bestiary, universal history, adding to these recent geographic encroachments."[201] But cosmography as Apian conceived it was still the appropriate genre for both mathematical geography and tools.

Thus, Apian's *Speculum Cosmographicae* visualized the main geographic contributions of Waldseemüller's publications and also raised the profile of empirical study of both the heavens and the world. The *Speculum* might be the first model to set the jewel of a geographically mapped earth into the setting of the starry vault, an instrument with which stargazers could orient themselves in the broader context of the universe. In short, this model reprises the principles of Apian's first linear diagram that connected the celestial and terrestrial spheres to the eye (see Figure 2.3). With the *Speculum*, Apian assembles into one interactive tool all the components of his opening diagram that explains cosmography: this volvelle completes the ambition to graphically depict the world system as a dialogue between astronomical and geographic spheres. At this juncture of the book, users themselves usurp the authority of the prime mover: observers activate the tools with their own hands, producing individually relevant data points.[202]

TOOLS AND THE "VERNACULAR" VIEWER

The *Cosmographicus Liber* fully endorsed the use of tools as a means for vernacular observers to discover things in their own environment and made explicit that the book's content was derived largely from firsthand study. Empirical observations not only helped fill in the mortar between the ancient bricks; in some cases, they repaired some of the crumbling patches as well. Karl Röttel has judged the complex visual lessons learned from Apian's mechanical pictures as a critical intermediary stage for the development, and especially the popularization, of instruments.[203] Apian's translation of mathematized astronomy into visual terms laid the groundwork for a spate of vernacular publications devoted to the use of instruments: sundials, quadrants, astrolabes, and nocturnal dials.[204] Apian popularized tools and brought knowledge of them to a much broader swath of the general public. The collection of tools in the *Cosmographicus Liber*, per the argument of Margaret Gaida, fashioned Apian's text into a toolkit.[205] This amounted to no less than the birth of a new reading public: mathematical autodidacts ready to brave a cosmos that could be unlocked by do-it-yourself tools.

In fact, Apian's *Cosmographicus Liber* identified so much as a book about tools that Gemma Frisius commandeered the 1539 edition as a vehicle to publicize his new scientific instrument: the astronomical rings, later called Gemma's rings. Gemma's first edits to Apian's text appeared in Antwerp in 1529; these emboldened him to use Apian's text as a malleable palimpsest for his own cosmographic musings. Soon after the first edition, in which his corrections appeared in an appendix, Gemma relocated some of Apian's volvelles into a separate section, likely sensing this as a space that he could later amplify with copy written around his own tools.[206] The Antwerp edition printed by Arnold Birkman in 1539 bundled a number of spinoff publications with Apian's text.[207] Birkman's printing attached Gemma's appendix on surveying and trigonometry, the *Libellus de Locorum describendorum ratione, & de eorum distantijs inueniendis, numquam antehac visus, per Gemmam Frisium*, to the cosmography. This text was followed by a thirteen-page discourse on Gemma's astronomical rings, the *Usus Annuli Astronomici, Gemma Frisio Mathematico Auctore*, a text that Gemma had printed as an independent short pamphlet in 1534 under the title *L'usage de l'anneau astronomique*. This practical text featured a number of pictured observers making trigonometric calculations of the altitudes of fortresses and steeples through ringed instruments that Gemma had designed.[208] Gemma's how-to treatise on the rings essentially hijacked Apian's text in order to publicize his instruments in the appendices. Gemma rewired the cosmography into a manual that would provide the foundation for the use – and, importantly, the sale – of his instruments. This marketing initiative broadened the scope of empirical knowledge that could be processed with the book.

Gemma Frisius became an ardent proponent of the practice of observation. Gemma's son Cornelius reported in 1561 that his father kept two journals of his own observations. Apparently expecting that perusal of his printed texts would mobilize similar types of data recording, Gemma chastised stargazers for simply following Ptolemy and not using their own observations to update the Alfonsine Tables. The empirical approach that united the interdisciplinary activity of Gemma and Cornelius in the collection of astronomic, weather, and medical data, according to Gianna Pomata, reveals a new method afoot in empirical explorations of the period.[209] This type of visual investigation of the world was spearheaded by Apian, but it was endorsed and perfected by Gemma. The move away from doctrine – even when the older sources were still invoked in the contemporary literature – is what united the multiple categories of empirical inquiry that coalesced into a *modus operandi* for exploring the world. Both Apian and Gemma knew that this user-based interface could best be achieved by images that would chaperone these visual searches in the world picture. These images and tools centered the agency of a literate eye schooled by books.

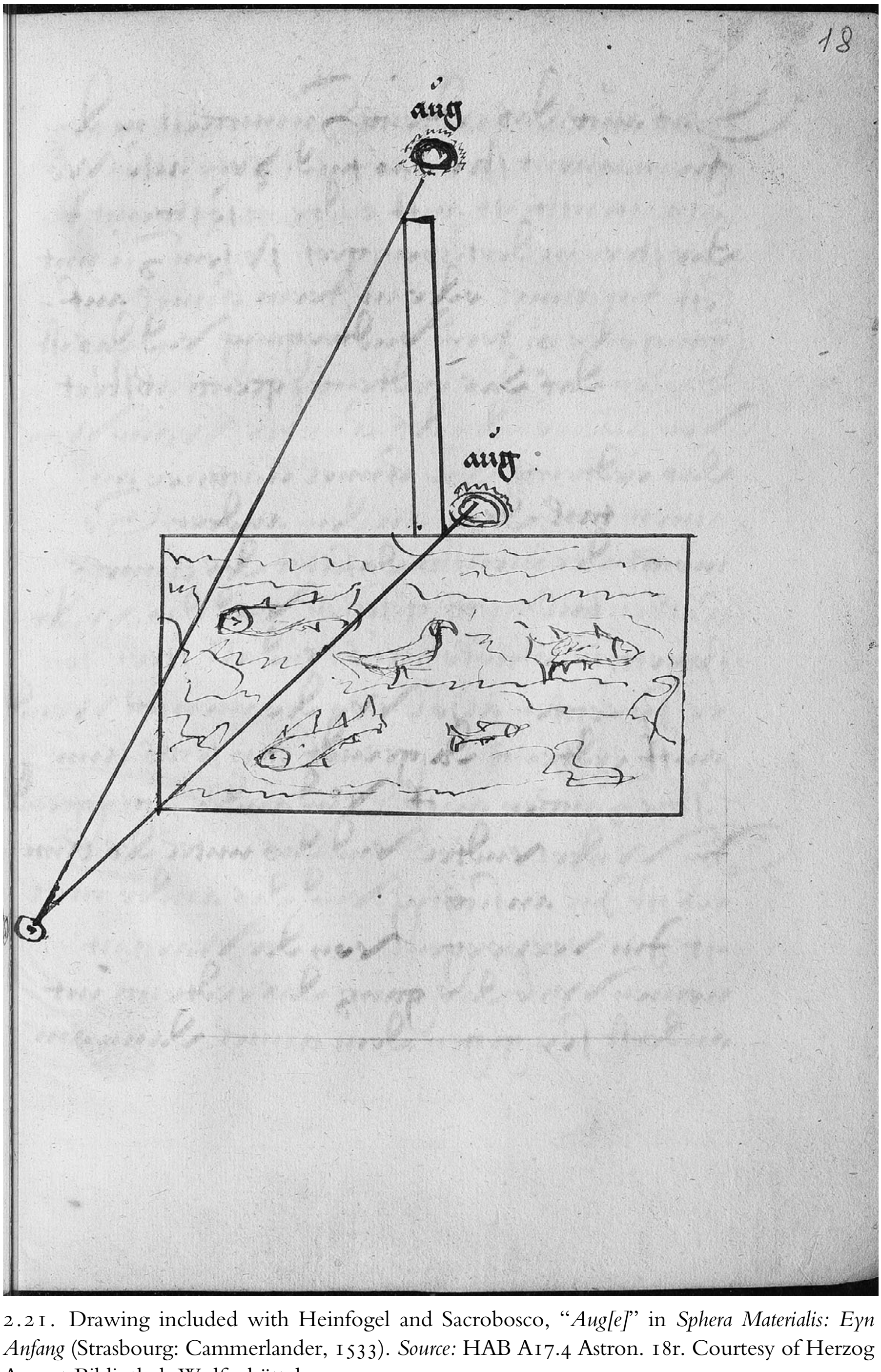
Images in astronomical texts, mechanical and otherwise, brought lofty principles to earth and sometimes functioned together with words in new pedagogical combinations: images and even verse appear in these books to facilitate understanding for the reader and to encourage personal observation in these pursuits.[210] Apian himself capitalized on the content of texts such as Conrad Heinfogel's vernacular translation of Sacrobosco's *De Sphaera* that provided helpful hints about the progression of lunar phases in language that only a layman could love. In the 1516 edition, verses accompany two diagrams that set the sun and moon in relation to each other to explain reflected light from the sun. In the 1533 edition, an unrelated diagram of a lunar eclipse accompanies versions of the original verses:

Note what I diligently teach you:
The way the moon ignites
when the sun bathes it,
you should understand it to be half-lit

Although the moon is at all times
rather more than half-illuminated
One never sees its full shine
only sometimes large, then small again.[211]

This was a far cry from their lofty cosmographic precedents; sixteenth-century pointers about astronomy were rendered in doggerel for the practical purpose of serving the reader's memory. Heinfogel's use of a jaunty imperative mood was intended to stimulate memory, not unlike lessons learned today by amateur stargazers who need to distinguish between waning and waxing moons with mnemonics such as "when the light is on the right, the moon is getting bright." Delivery of such wisdom by speaking images was another tactic to engrave those precepts in the mind. The subtitle of this volume – "the path of the heavens together with all of the stars, much easier to learn with the accompanying pictures" – foregrounds its attempt to cultivate a new public of amateur astronomers by way of helpful images.[212]

A clue to the efficacy of popular astronomy's visual pedagogy is embedded in one reader's response to the material. A hand-drawn sheet of astronomic principles that appears in a codex gathering of a book preserved in the Herzog August Bibliothek in Wolfenbüttel cribs from a variety of sources.[213] This sheet collates diagrams from Sacrobosco's *Sphera Materialis: Eyn Anfang* (the 1533 edition from Cammerlander) and other works of popular cosmography, probably including Apian's *Cosmographicus Liber*. A rare example of likely contemporary reception of this material, here we see a reader working out principles of observation derived from the images. One drawing rehearses Sacrobosco's familiar proof of the ocean's sphericality demonstrated by the contrasting views of two shipboard observers, one on deck and one at the mast. To clarify the proof, this scribe added another image in which he replaced the actual observers with two eyes, each labeled "*Aug[e]*," in order to situate the eye at the receiving end of the observation (Figure 2.21).[214] With this, he substantiated the agent also at the heart of Apian's concerns: the eye of the user. Apian frequently animated eyes, ears, hands, and feet in his illustrations. Small, black, thickened stick figures dot his schematic models to provide human receptors for the observations his demonstrations taught. Human actors served as surrogate reference points for the users' own observations. When the reader of the Wolfenbüttel Sacrobosco saw an unanchored eye in a cosmographic text, it was clear that they did not mistake it for the eye of God; rather, they saw it as their own. With the aid of Apian's tools, this earth-bound eye peered through the earth into the heavens for the purpose of drawing up a practical data set. This perspective was increasingly



2.21. Drawing included with Heinfogel and Sacrobosco, "*Aug[e]*" in *Sphera Materialis: Eyn Anfang* (Strasbourg: Cammerlander, 1533). *Source:* HAB A17.4 Astron. 18r. Courtesy of Herzog August Bibliothek Wolfenbüttel.

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

conditioned by the visual acuity taught by these manuals and reiterated their promotion of visual knowledge.

Apian himself called on such visual vigilance in his practical publications. He argued vociferously for his own expertise as an observer, a claim that was designed to activate the intended reader to follow in his footsteps. This confidence rested on the premise of the expanse of the heavens over Ingolstadt as a visual horizon he shared with an imagined community of fellow observers whom he hoped to goad into becoming a group of collective empirics: "We see the sky everywhere before our eyes because it spins day and night around the earth, and we would like to easily observe and describe it."[215] In the prologue of his *Practica auff das 1532. Jar*, Apian distinguishes the empirical knowability of the heavens from that of the earth. Because the earth stretches beyond the visual field of the observer, it presents a greater challenge to description because it cannot be encompassed without costly travel. On the strength of his visual acuity, Apian intones, the reader should summon the services of an astronomer who has been observing and recording the effects of the stars on weather and storms (the topic of this almanac), because he has trained his eye to track these conditions.

Peter Apian led the era of publishing cosmographic texts framed as methods to train the visual aptitude of amateur observers. Packaged for new readerships, this foray into new territory and its fallout can be tracked in new vernacular manuals that capitalized on the gathering of empirical knowledge. The age of Apian's publications was firmly dedicated to serving up usable manuals to new devotees of astronomy. Apian situates his reader locally (important to cosmographical accuracy) and provides demonstrations of things that can be observed on earth. Never asked to take phenomena on faith alone, Apian's readers were provided with a theoretical armature to accompany their search for events in a visually constituted field. We need only remember Apian's pictorial demonstration of how the shape of the earth can be visually verified during observations of lunar eclipses: we see the roundness of the earth projected onto the eclipsed moon. Apian reminds his readers that if the earth took the shape of a square or triangular or hexagon, they would instead see these shapes reflected on the lunar surface. As a direct and easy appeal to the eye, the point is shored up by a rhetorical directive to the viewer: compare and contrast. What the naked eye sees can unpack larger principles. How-to tools that helped activate and contextualize both astronomical and geographical observations centered them no longer around a theoretical "eye," but around an actual earth-bound "*Aug[e]*."

NOTES

1 For Apian's activities as a printer and mathematician in Ingolstadt, see Peter Meurer, "Cartography in the German Lands, 1450–1650," in David Woodward, ed., *The History*

of Cartography. Volume 3: Cartography in the European Renaissance (Chicago and London: University of Chicago Press, 2007), 1198–201.

2 The colophon announces that Apian had the work printed at his expense but using the infrastructure of the Weyssenburger press: "*Excusum Landshutae Typis ac formulis D. Joannis Weyssenburgers: impensis Petri Apiani* [Printed in Landshut with the typographic material of Joannes Weyssenburger, at the expense of Petrus Apianus]." Many thanks to Joost Depuydt and Paul Gehl for help with the translation of printing terms. For Apian's printer, Johannes Weyssenburger, see K. Steiff, "Weyssenburger, Johannes," *Allgemeine Deutsche Biographie* 42 (1897), 290–1; see also Karl Schottenloher, *Die Landshuter Buchdrucker des 16. Jahrhunderts* (Nieuwkoop: B. de Graaf, 1967), 39f., no. 117.

3 Peter Apian, *La Cosmographie de Pierre Apian Docteur et Mathematicien Tres Excellent: Traictant de Toutes les Regions Pais Villes & Citez du Monde* (Paris: Gualtherot, 1553), fol. 1r. I use Tom Conley's translation in Tom Conley, *An Errant Eye: Poetry and Topography in Early Modern France* (Minneapolis: University of Minnesota Press, 2011), 58.

4 The content includes Ptolemy's *Geographia*, a medieval astronomy textbook of Sacrobosco's *De Sphaera*, as well as a much more contemporary source, Martin Waldseemüller's *Cosmographia Introductio*.

5 For a complete list of Apian's publications, along with their current locations, see Karl Röttel, *Peter Apian: Astronomie, Kosmographie und Mathematik am Beginn der Neuzeit: Mit Ausstellungskatalog* (Buxheim: Polygon-Verlag, 1995), 259–76.

6 For the reception of Ptolemy in the early modern period, see Zur Shalev and Charles Burnett, eds., *Ptolemy's Geography in the Renaissance*, Warburg Institute Colloquia (London: Warburg Institute, 2011), 8ff.

7 Later editions of Ptolemy's work would restore the title of *Geographia*. For the translation history of the vocabulary *geographia* and *cosmographia*, see especially Dario Tessicini, "Definitions of 'Cosmography' and 'Geography' in the Wake of 15th and 16th Century Translations and Editions of Ptolemy's *Geography*," in Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance,* 31–49; see also Adam Mosley, "The Cosmographer's Role in the Sixteenth Century: A Preliminary Study," *Archives Internationales d'Histoire des Sciences* 59 (2009), 424–39.

8 Denis E. Cosgrove, ed., *Mappings* (London: Reaktion Books, 1999); see also Lucia Nuti, "Mapping Places: Chorography and Vision in the Renaissance," in Cosgrove, ed., *Mappings*, 90–108. According to Nuti, Apian misread Jacopo d'Angelo in his transcription.

9 Contrasting the mathematical modeling of geography (or world cartography) with the descriptive aims of chorography (regional cartography), Ptolemy says: "World cartography is an imitation through drawing of the entire known part of the world. Regional cartography sets out individual localities . . . the goal of regional cartography is an impression of a part, as when one makes an image of just an ear or an eye; but [the goal] of world cartography is a general view, analogous to making a portrait of the whole head." Claudius Ptolemaeus, *Ptolemy's Geography: An Annotated Translation of the Theoretical Chapters*, ed. John L. Berggren and Alexander Jones (Princeton, NJ: Princeton University Press, 2000). Here, I have used the editors' translation (at 57).

10 Jessica Maier, *Rome Measured and Imagined: Early Modern Maps of the Eternal City* (Chicago: University of Chicago Press, 2015), 5; Bronwen Wilson, *The World in Venice: Print, the City and Early Modern Identity* (Toronto: University of Toronto Press, 2005), 191ff.; Svetlana Alpers, *The Art of Describing: Dutch Art in the Seventeenth Century* (Chicago: University of Chicago Press, 1983), 119ff.

11 For Apian's press in Ingolstadt, see Christoph Schöner, *Mathematik und Astronomie an der Universität Ingolstadt im 15. und 16. Jahrhundert* (Berlin: Duncker & Humblot, 1994), 361–3.

12 For Gemma, see Samuel Gessner, "The Use of Printed Images for Instrument-Making at the Arsenius Workshop," in Nicolas Jardine and Isla Fay, eds., *Observing the World through Images: Diagrams and Figures in the Early-Modern Arts and Sciences* (Leiden and Boston, MA: Brill, 2014), 129ff.; see also Gessner, "The Perspective of the Instrument Maker: The

Planispheric Projection with Gemma Frisius and the Arsenius Workshop at Louvain," in Sven Dupré, ed., *Perspective as Practice: Renaissance Cultures of Optics* (Turnhout: Brepols, 2019).

13 Fernand van Ortroy, *Bibliographie de l'oeuvre de Pierre Apian* (Amsterdam: Meridian, 1963); Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 94.

14 As much as Apian relied on earlier sources for his content, his own content was also repackaged in later publications roughly bearing the title *Cosmographia* in fifty-eight editions in four languages between 1524 and 1609.

15 Mosley, "The Cosmographer's Role," 424–39, especially 435; Steven Vanden Broecke, *The Limits of Influence: Pico, Louvain and the Crisis of Renaissance Astrology* (Leiden and Boston, MA: Brill, 2003), 113–36.

16 William Mills Ivins, *Prints and Visual Communication* (New York: Da Capo Press, 1969); Elizabeth L. Eisenstein, *The Printing Press as an Agent of Change: Communications and Cultural Transformations in Early-Modern Europe* (New York: Cambridge University Press, 1979).

17 George Sarton, *The Appreciation of Ancient and Medieval Science during the Renaissance (1450–1600)* (Philadelphia: University of Pennsylvania Press, 1955); John W. Shirley and F. David Hoeniger, eds., *Science and the Arts in the Renaissance* (Washington, DC and London: Folger Shakespeare Library and Associated University Presses, 1985).

18 This edged out considerations of images' roles in astronomy, mathematics, and physics, for example. See Renzo Baldasso, "The Role of Visual Representation in the Scientific Revolution: A Historiographic Inquiry," *Centaurus* 48 (2006), 69–88, especially 84.

19 See Martin Kemp, "Temples of the Body and Temples of the Cosmos: Vision and Visualization in the Vesalian and Copernican Revolutions," in Brian Scott Baigrie, ed., *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science* (Toronto: University of Toronto Press, 1996); Sachiko Kusukawa, *Picturing the Book of Nature: Image, Text, and Argument in Sixteenth-Century Human Anatomy and Medical Botany* (Chicago: University of Chicago Press, 2011); Sachiko Kusukawa and Ian Maclean, *Transmitting Knowledge: Words, Images, and Instruments in Early Modern Europe* (Oxford and New York: Oxford University Press, 2006).

20 Stephanie Leitch, "Visual Acuity and the Physiognomer's Art of Observation," *Oxford Art Journal* 38, no. 2 (2015), 187–206; Lisa Voigt and Elio Brancaforte, "The Traveling Illustrations of Sixteenth-Century Travel Narratives," *PMLA* 129, no. 3 (2014), 365–98.

21 Alexander Marr, "Ingenuity in Nuremberg: Dürer and Stabius's Instrument Prints," *Art Bulletin* 100, no. 3 (2018), 48–79.

22 Jardine and Fay, eds., *Observing the World through Images*.

23 Susan Dackerman, *Prints and the Pursuit of Knowledge in Early Modern Europe* (Cambridge, MA and New Haven, CT: Harvard Art Museums, 2011).

24 Jörn Münkner, *Eingreifen und Begreifen: Handhabungen und Visualisierungen in Flugblättern der Frühen Neuzeit* (Berlin: Erich Schmidt, 2008); Lisa Pon, *A Printed Icon: Forlì's Madonna of the Fire* (New York: Cambridge University Press, 2015); David S. Areford, *The Viewer and the Printed Image in Late Medieval Europe* (Farnham and Burlington, VT: Ashgate, 2010).

25 Michael Baxandall, *Painting and Experience in Fifteenth Century Italy: A Primer in the Social History of Pictorial Style*, 2nd edition (New York: Oxford University Press, 1988).

26 Baldasso, "The Role of Visual Representation," 78; see also Marie Boas, *The Scientific Renaissance 1450–1630* (New York: Harper and Row, 1962), 53–4.

27 Richard J. Oosterhoff, "A Book, a Pen, and the *Sphere*: Reading Sacrobosco in the Renaissance," *History of Universities* 28, no. 2 (2015), 1–54.

28 Renzo Baldasso, "Illustrating the Book of Nature in the Renaissance: Drawing, Painting, and Printing Geometric Diagrams and Scientific Figures," PhD dissertation, Columbia University, 2007; Horst Bredekamp and Pablo Schneider, *Visuelle Argumentationen: Die Mysterien der Reprasentation und die Berechenbarkeit der Welt* (Munich: Wilhelm Fink, 2006); Horst Bredekamp, Vera Dünkel, and Birgit Schneider, *The Technical Image: A History of Styles in Scientific Imagery* (Chicago: University of Chicago Press, 2015).

29 Stephanie Leitch, *Mapping Ethnography in Early Modern Germany: New Worlds in Print Culture* (Basingstoke: Palgrave Macmillan, 2010).

30 Suzanne Karr Schmidt, *Interactive and Sculptural Printmaking in the Renaissance* (Leiden and Boston, MA: Brill, 2018); see also Suzanne Kathleen Karr Schmidt, "Art – A User's Guide: Interactive and Sculptural Printmaking in the Renaissance," PhD dissertation, Yale University, 2006; Suzanne Karr Schmidt and Kimberly Nichols, *Altered and Adorned: Using Renaissance Prints in Daily Life* (Chicago and New Haven, CT: Art Institute of Chicago, distributed by Yale University Press, 2011); see also Suzanne Karr Schmidt and Edward Wouk, *Prints in Translation, 1450–1750: Image, Materiality, Space* (Abingdon: Routledge, 2017).

31 See Lorraine Daston, "Epistemic Images," in Alina Alexandra Payne, ed., *Vision and Its Instruments: Art, Science, and Technology in Early Modern Europe* (University Park: Pennsylvania State University Press, 2015), 13–35.

32 Alexander Marr, "Knowing Images: A Review Essay," *Renaissance Quarterly* 69, no. 3 (2016), 1000–13; Bredekamp, Dünkel, and Schneider, *The Technical Image*.

33 Lorraine Daston and Elizabeth Lunbeck, *Histories of Scientific Observation* (Chicago: University of Chicago Press, 2011), 81–113.

34 Peter Apian and Gemma Frisius, *Cosmographie, oft Beschrijinghe der geheelder werelt* (Antwerp: Gregorius de Bonte, 1553), fol. 3r.

35 Conley, *An Errant Eye*, 69. Conley suggests that the disembodied body parts that appear in the text might be related to the tradition of bodily blazons; to this I add that the isolated features might also be in dialogue with the focus on the same body parts in contemporary physiognomies.

36 For Apian's engagement with the Ptolemaic curriculum in general, see Benjamin Weiss, "The Geography in Print: 1475–1530," in Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 93–6.

37 "*Corographia est perfecta (et) consumata pictura et nulla eam nisi homo pictor exerce ripotest*." Many thanks to Barbara Tramelli for help with the translation.

38 Michael J. Sauter, *The Spatial Reformation: Euclid between Man, Cosmos, and God* (Philadelphia: University of Pennsylvania Press, 2019); for globe pairing, see 55ff. Johannes Schöner was the first to produce a paired set of terrestrial and celestial globes in 1515. See also Karr Schmidt, *Interactive and Sculptural Printmaking*, 265.

39 Tom Conley, "A Topographer's Eye: From Gilles Corrozet to Pieter Apian," in Walter S. Melion and Lee Palmer Wandel, eds., *Early Modern Eyes* (Leiden: Brill, 2010), 70. Tom Conley shows the agency active in man's eye.

40 Erwin Panofsky, *Perspective as Symbolic Form*, trans. Christopher S. Wood (New York: Zone Books, 1991).

41 Sauter, *The Spatial Reformation*. Sauter would also claim this eye for man's eye. Excluding God from this space, Sauter argues, Apian's image credits humanity with this mode of projection (pp. 56–7).

42 Samuel Y. Edgerton, *The Renaissance Discovery of Linear Perspective* (NY: Basic Books, 1975), 91ff. Edgerton argues that Ptolemaic projection contributed to geometric abstraction that preceded the embrace of linear perspective by Florentine artists and theorists in the fifteenth century.

43 See Angelo Catteneo, "Map Projections and Perspective in the Renaissance," in Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 54.

44 Kim H. Veltman, "Ptolemy and the Origins of Linear Perspective," *Atti del Convegno Internazionale di Studi Tenutosi al Castello Sforzesco, Civiche Raccolte d'Arte di Milano, dall'11 al 15 Ottobre del 1977* (Florence: Centro Di, 1980), 403.

45 The astrolabe incorporates a few more projections: latitudes (in the form of almucanthars) and longitudes (or azimuths) relative to a viewer's position. Veltman, "Ptolemy and the Origins of Linear Perspective,"403.

46 Veltman, "Ptolemy and the Origins of Linear Perspective," 404.

47 Steven Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography: The Cosmography of Peter Apian and Gemma Frisius," *Paedagogica Historica* 36, no. 1 (2000), 130–52, here 137.
48 Anthony Grafton, *Commerce with the Classics: Ancient Books and Renaissance Readers* (Ann Arbor: University of Michigan Press, 1997), 220–1.
49 Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 116. The holograph Ptolemy texts themselves do not appear in the university curricula until the mid-sixteenth century.
50 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 142.
51 Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 107.
52 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 133.
53 Darin Hayton, *The Crown and the Cosmos. Astrology and the Politics of Maximilian I* (Pittsburgh: University of Pittsburgh, 2015); for the academic context for astrology, see 68–97.
54 On the relationship between mathematicians and physicians, see Robert S. Westman, "The Astronomer's Role in the Sixteenth Century: A Preliminary Study," *History of Science* 18 (1980), 118. Apian's teacher George Tannstetter was also primarily employed as a physician; see Hayton, *The Crown and the Cosmos*, 96–7.
55 Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 94.
56 Johannes Sacroboscо, an astronomer likely originally from England, taught at the University of Paris in the thirteenth century, where the first copies of the *De Sphaera* appeared around 1220. See Lynn Thorndike, ed., *The* Sphere *of Sacrobosco and Its Commentators. Corpus of Mediaeval Scientific Texts: Volume 2* (Chicago: University of Chicago Press, 1949). Thorndike's English translation of Sacrobosco is available online at www.esotericarchives.com/solomon/sphere.htm. Another useful online resource is the collection of astronomical images in the University of Cambridge Digital Library.
57 Jürgen Hamel, *Studien zur "Sphaera" des Johannes de Sacrobosco* (Leipzig: Akademische Verlagsanstalt, 2014). Michael Scot's commentary on it appeared in 1230–5.
58 Charles Coulston Gillispie, *Dictionary of Scientific Biography. Volume 12* (New York: Scribner, 1975).
59 For the use of Sacrobosco in university settings, see "Sacrobosco, Johannes De (or John of Holywood)," in *Complete Dictionary of Scientific Biography* (Detroit: Charles Scribner's Sons, 2008); available online at www.encyclopedia.com/doc/1G2-2830903812.html.
60 The bulk of Sacrobosco's medieval commentators, according to Richard Oosterhoff, foregrounded the theoretical underpinnings of the cosmos rather than providing a practical guide to it. See Oosterhoff, "A Book, a Pen, and the *Sphere*," 6–7. Commentary by these readers were still surrounded by the matrix of older notions of resemblances and conveniences based on received knowledge rather than observed practice. For the extent to which patterns of resemblance characterized the Renaissance episteme, see Michel Foucault, *The Order of Things: An Archaeology of the Human Sciences* (New York: Vintage Books, 1994), especially 17–25.
61 For the early modern commentaries, see Matteo Valleriani, ed., *De Sphaera of Johannes de Sacrobosco in the Early Modern Period: The Authors of the Commentaries* (Berlin: Springer, 2020).
62 Owen Gingerich, "Sacrobosco as a Textbook," *Journal for the History of Astronomy* 19, no. 4 (1988), 272–3. See also Kathleen M. Crowther and Peter Barker, "Training the Intelligent Eye: Understanding Illustrations in Early Modern Astronomy Texts," *Isis* 104, no. 3 (2013), 429–70, here 430–1.
63 The Jesuit Christopher Clavius provided commentaries for a new edition of Sacrobosco in 1611, despite its strictly geocentric emphasis. See James M. Lattis, "Christopher Clavius and the 'Sphere' of Sacrobosco: The Roots of Jesuit Astronomy on the Eve of the Copernican Revolution," PhD dissertation, University of Wisconsin-Madison, 1989. For various editions of Sacrobosco online, consult astronomical images in the Cambridge Digital Library. See also Matteo Valleriani, ed., *The Structures of Practical Knowledge* (Cham:

Springer, 2017), 438; Volker Remmert, "Catholic Biblical Exegesis and the Origins of the Galileo Affair: The Engraved Title Page of Clavius's *Opera Mathematica* (1612)," in Volker R. Remmert, *Picturing the Scientific Revolution* (Philadelphia: Saint Joseph's University Press, 2011), especially 31–6.

64 Baldasso, "Illustrating the Book of Nature in the Renaissance," 207, 209ff., 221–3. Printers of Sacrobosco's text also inherited the idea of a visual apparatus from a tradition of printing technical astronomic diagrams active in Nuremberg *c.* 1473–5, where Regiomontanus was the first to update ancient astronomic data by purposefully transmitting it into print.

65 Melanie Grimm, Claudia Kleine-Tebbe, and Ad Stijnman, *Lichtspiel und Farbenpracht: Entwicklungen des Farbdrucks 1500–1800: Aus den Beständen der Herzog-August-Bibliothek* (Wiesbaden: Harrassowitz, 2011), 70. The hand-coloring of the eclipse diagrams in the early Ratdolt edition from 1482 attempts to distinguish among various spheres. The moons are executed in brown wash, while the earth and suns are rendered in yellow. By 1490, the Venetian printer Scotus prints the moons in orange and the suns in gold. The 1490 Venice imprint is one of the first to be illustrated in detail and also included demonstrations. See also Ad Stijnman and Elizabeth Savage, *Printing Colour 1400–1700: History, Techniques, Functions and Receptions* (Boston, MA: Brill, 2015).

66 Stijnman and Savage, *Printing Colour 1400–1700*, 29ff.

67 Crowther and Barker, "Training the Intelligent Eye," 429–70.

68 Crowther and Barker caution contemporary readers about our own post-Copernican biases to see orbits in the two-dimensional cross-sections of Peurbach's planetary models. Instead, these nesting circles were meant to represent conceptualizations of epicycles.

69 See Sacrobosco on the spherical nature of drops of water: "Also, since water is a homogeneous body, the whole will act the same as its parts. But parts of water, as happens in the case of little drops and dew on herbs, naturally seek a round shape. Therefore, the whole, of which they are parts, will do so." Thorndike, ed., *The* Sphere *of Sacrobosco and Its commentators*.

70 "Let a signal be set up on the seacoast and a ship leave port and sail away so far that the eye of a person standing at the foot of the mast can no longer discern the signal. Yet if the ship is stopped, the eye of the same person, if he has climbed to the top of the mast, will see the signal clearly. Yet the eye of a person at the bottom of the mast ought to see the signal better than he who is at the top, as is shown by drawing straight lines from both to the signal. And there is no other explanation of this thing than the bulge of the water. For all other impediments are excluded, such as clouds and rising vapors" (Sacrobosco, book I).

71 Johannes and Wenceslaus Fabri, *Opus sphericum Johannis de sacro busto: figuris et p[er]utili co [m]mento illustratu[m]* (Agrippine: Per Henricum Quentell, 1501).

72 Johannes de Sacrobosco and Peter Apian, *Sphaera Iani de Sacrobusto astronomiae ac cosmographiae candidatis scitu apprime necessaria* (Ingolstadt: Peter and Georg Apian, 1526).

73 Sacrobosco, Johannes Regiomontanus, and Georg von Peuerbach, *Spaerae Mvndi Co[m]pendiu[m] Foeliciter Inchoat.: Daran: Regiomontanus, Johannes: Disputationes contra Cremonensia in planetarum theoricas deliramenta. Mit Widmungsvorrede des Autors an die Gelehrten. – Peuerbach, Georg: Theoricae novae planetarum. Mit Gedicht auf die Drucker'Uranie quantum quantum* . . . (Venice: Johannes Lucilius Santritter and Hieronymus de Sanctis, 1488).

74 Crowther and Barker, "Training the Intelligent Eye," 453.

75 See, for example, the astronomical miscellany Garrett MS. 99 in Princeton University Special Collections: Anon., *Tractatus Astronomici*, *c.* 1275–1325, Parisian. Gift of Garrett, Robert, acquired through Wilfred Michael Voynich.

76 "This schema demonstrates that the earth is a sphere. If the earth were square, during a lunar eclipse, its shadow would appear to be a square; if a triangle, the shadow would appear as a triangle; if a hexagon, a hexagon."

77 Cf. the 1553 Antwerp edition, in which layout and images make knowledge comprehensible to audiences.

78 Foucault, *The Order of Things*.

79 Hayton, *The Crown and the Cosmos*, 68–97.

80 Karr Schmidt, *Interactive and Sculptural Printmaking in the Renaissance*, 241; Johannes Regiomontanus, *Calendarium … Dvctv Ioannis De Monteregio* (Nuremberg: Johannes Regiomontanus, 1474), www.loc.gov/resource/rbc0001.2013rosen0051/?sp=2&st=gallery. Regiomontanus's models for his volvelles and instructions for constructing the diagrams in this work are found in the *Ars generalis and Ars brevis* of the fourteenth-century Catalan philosopher Ramón Lull. Regiomontanus owned manuscript copies of these works. See www.prphbooks.com/blog/2019/9/3/volvelles-what-a-passion.

81 For an extensive discussion of the *Astronomicum Caesareum*, see Karr Schmidt, *Interactive and Sculptural Printmaking*, 3ff., chapters 8 and 10; for Schöner, see 261, 244, sections 10.1, 10.3–10.5; for Apian's involvement with Schöner's work and principles, see 295ff.

82 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 132. Vanden Broecke's article provides the most ambitious English-language overview of the working of the instrumentation in Apian's *Cosmographicus Liber*.

83 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 133.

84 Sacrobosco's text renders it thus, in terms of a three-dimensional image of the world: "the sphere is divided into the sphere right and the sphere oblique. For those are said to have the sphere right who dwell at the equator, if anyone can live there. And it is called 'right' because neither pole is elevated more for them than the other, or because their horizon intersects the equinoctial circle and is intersected by it at spherical right angles. Those are said to have the sphere oblique who live this side of the equator or beyond it. For to them one pole is always raised above the horizon, and the other is always depressed below it. Or it is because their artificial horizon intersects the equinoctial at oblique and unequal angles." See Thorndike, ed., *The* Sphere *of Sacrobosco and Its commentators*, chapter 1.

85 "The zenith of the head is always equidistant from the horizon on every side (that is, by 90 degrees or a quadrant); and therefore it is called the pole of the horizon, and (in the absence of other impediments) it always appears to people in any location as the middle point of the sky or hemisphere. Therefore, to the extent that someone proceeds from the equator to the north or south, to the same extent the horizon is pushed down under the pole on one side, but raised above the opposite pole on the other side. This can be seen more plainly from the instrument."

86 "*Unde appellatur horizon.i. terminator visius*."

87 The proof in *De Sphaera*, book II, demonstrates this concept via similar triangles. Sacrobosco explains that the angle between the elevation of the pole and the horizon is equal to the angle between the zenith and the celestial equator. Apian's proof, by contrast, demonstrates this relationship to his reader in terms of latitude (the measurement of the height of the pole star, or Polaris, above the horizon renders terrestrial latitude). When the user spins the dial, one obtains the numeric value of Sacrobosco's angles as a latitude reading. Apian shows the relationship between terrestrial latitude and the celestial pole, expressed by Apian as the "height of the world."

88 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 140.

89 Such as editions of Sacrobosco and Georg von Peuerbach's *Theorica Planetarum*; see Crowther and Barker, "Training the Intelligent Eye," 438.

90 Sacrobosco and Apian, *Sphaera Iani de Sacrobusto astronomiae ac cosmographiae candidatis scitu apprime necessaria* (Ingolstadt: Peter and Georg Apian, 1526).

91 Apian followed on the heels of pedagogical illustrations presented in a vernacular text edited by Heinfogel in Nuremberg in 1516. On the practical aspects of Apian's *Sphaera*, as well as its resonance for the next generation of printed editions of *Sphaera*, see Isabelle Pantin, "Borrowers and Innovators in the History of Printing Sacrobosco: The Case of the In-Octavo Tradition," in Valleriani, ed., *De Sphaera of Johannes de Sacrobosco in the Early Modern Period*, 273–282.

92 Baigrie, ed., *Picturing Knowledge*. We might say that this style contributes to what Martin Kemp calls "rhetoric of irrefutable precision" (p. 444).

93 Apian's 1526 update of Sacrobosco's *De Sphaera* did not include volvelles.

94 Johannes de Sacrobosco, *Ioannis De Sacrobusto Libellus, De Sphaera: Eiusdem Autoris Libellus, Cuius Titulus Est Computus, Erruditißimam Anni & Mensium Descriptionem Continens*, ed. Philipp Melanchthon (Wittenberg: Jospeh Clug, 1538). The digital copy in Staatsbibliothek Berlin (HAB HN62.8Helmst) is missing the top dial.

95 Sacrobosco, *Ioannis de Sacrobusto Libellus, De Sphaera* (Wittenberg: Clug, 1540), 38. The copy at the Bayerische Staatsbibliothek shows a volvelle with the *Organum Ptolomei* at the base, but without the (likely) top hemisphere dial.

96 *Instrumentum quo & rotunditas terrae secundam latitudinem probatur, & facillime Omnia ea, quae autor in tertio capite de diebus artificialibus tradit, dijudicantur*. An image of the dial appears in Gingerich, "Sacrobosco as a Textbook," 271.

97 These appeared in later editions printed in Wittenberg and Paris as well.

98 Gingerich, "Sacrobosco as a Textbook," 271. Erasmus's *Adage* about the importance of observing daily regimens is reinterpreted here to refer to the daily path of the sun.

99 Katherine Park treats the continuity and distinctions between *experimentia* and *observatio* in "Observation in the Margins, 500–1500," while Gianna Pomata's essay "Observation Rising: Birth of an Epistemic Genre" tracks the high incidence of *observationes* between 1530 and the 1570s in astronomy and medical texts specifically. Both essays appear in Daston and Lunbeck, *Histories of Scientific Observation*, 21ff., 49ff.

100 I thank DeWayne Carter for his insight into this and other astronomical problems.

101 Owen Gingerich, "Astronomical Paper Instruments with Moving Parts," in R. G. W. Anderson, J. A. Bennett, and W. F. Ryan, eds., *Making Instruments Count: Essays on Historical Scientific Instruments Presented to Gerard L'Estrange Turner* (Aldershot: Variorum, 1993), 63–6.

102 Sacrobosco and Conrad Heinfogel, *Sphera Materialis* (Nuremberg: Gutknecht, 1516); see http://dx.doi.org/10.3931/e-rara-2230, ETH-Bibliothek Zürich, Rar 4468; VD16 J739. The preface of this volume claims for Germans' proprietary interest in this art, a point reinforced in the colophon that mentions its translation for German audiences.

103 Johannes de Sacrobosco, *Sphera Materialis: Eyn Anfang und Fundanment der Astronomi*, ed. Jakob Cammerlander and Conrad Heinfogel (Strasbourg: Cammerlander, 1533), HAB A17.4 Astron. For instance, see the eyes drawn in manuscript hand on 18r. The author of this manuscript is clearly consulting images derived from related sources. The German-language text of the accompanying 1533 Sacrobosco emphasizes the word "eye" where the observer is concerned and this emphasis is also taken up by the illustrator. Some of these images likely come from Apian's edition of the *Sphera* of 1526. Among these are the eyes in the diagram of the eye seeing the coin underwater on fol. 4v; cf. Ms. 29v with the cutaways in Apian 1526, fol. 9r; Ms. fol. 68r with Apain's diagrams on fol. 24r.

104 Johann Dryander, *SPHERA MATERIALIS| Siue globi coelestis. <Das ist>|| Des Hymels lauff gründtliche außle=||gung/ so vil zur anleytung der Astro||nomie dienet/ mit vilen nützlichen regeln verfast/|| durch IOHAN DRYANDERN/ genent || Eychman/ ordinarien Medicum, der löblichen Vni=||uersiteten Marpurg/ von newem ver=||deütscht vnnd ann tag bracht.||* (Marburg: Johannis Dryander and Christian Egenolff d.Ä., 1539). Dryander was a mathematician and a high-ranking official in the administration at the University of Marburg. As he was the sub-rector of the University of Marburg at the time of the 1539 printing, Dryander very likely introduced material from Sacrobosco into the classroom.

105 Westman, "The Astronomer's Role in the Sixteenth Century," 119.

106 Valleriani, ed., *De Sphaera of Johannes de Sacrobosco in the Early Modern Period*, especially 273.

107 Johannes de Sacrobosco, *Sphaera Mundi: Eyn Anfang und Fundament der Astronomi/ Aus den Alten Astronomis dur Johannem de Sacro Busto ins Latin Zusamen Gesetzt und Nachmals Durch M. Cunrad Heynfogel von Nuremberg Verteutscht/ Unnd in Vier Teyl Getylt/ Deß Himmels Lauff Sampt Allem Gestirn/ Leichtlicher auß den bei Gesatzten Figuren Zuerlernen*, ed. Conrad Heinfogel (Strasbourg: Cammerlander, 1539), http://digital.onb.ac.at/OnbViewer/viewer.faces?doc=ABO_%2BZ178846106.

108 Valleriani, ed., *The Structures of Practical Knowledge*, 427–38. Valleriani maintains that authors who were involved in the production of knowledge around *De Sphaera* likely numbered over 150; most of these were natural philosophers and mathematicians, including humanists, experts in mechanics, and those preparing for military careers. Among the knowledge traditions to which the book contributed were navigation, nautical astronomy, geography, cartography, and meteorology.

109 For Melanchthon, see Jennifer Nelson, *Disharmony of the Spheres. The Europe of Holbein's Ambassadors* (University Park: Pennsylvania State University Press, 2019), especially 23–49; Sachiko Kusukawa, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon* (Cambridge and New York: Cambridge University Press, 1995); Wolf Dieter Müller-Jahncke, "Melanchton und die Astrologie: Theoretisches und Mantisches," in Frank Günter and Stefan Rhein, eds., *Melanchthon und die Naturwissenschaften Seiner Zeit* (Sigmaringen: Jan Thorbecke, 1998), 105–36.

110 For astrology and astronomy in Wittenberg, see Claudia Brosseder, *Im Bann der Sterne: Caspar Peucer, Philipp Melanchthon und andere Wittenberger Astrologen* (Berlin: Akademie Verlag, 2004); Claudia Brosseder, "The Writing in the Wittenberg Sky: Astrology in Sixteenth-Century Germany," *Journal of the History of Ideas* 66 (2005), 557–76.

111 Gingerich, "Sacrobosco as a Textbook," 269. "Plato has very admirably written that eyes were given to men for the sake of astronomy . . . for he wished to point out that nothing is more beautiful in all of nature than those celestial lights and that nature compels mankind to this enjoyment of beauty; and to me the eyes themselves would seem to bear a very important affinity with the stars."

112 Crowther and Barker, "Training the Intelligent Eye"; on the early modern distinctions between corporeal and spiritual vision, see 441–2.

113 Dryander's 1539 vernacular volume is sparsely illustrated, but the frontispiece aims to show the functioning (and labeled) parts of an armillary sphere, with meridian line and ecliptic band shown ready for assembly. Dryander says of the sphere (a demonstration sphere), "on certain globes you find a band for the zodiac, day and month." The accompanying image on fol. 12r appears to be derived from the *Cosmographicus Liber*, complete with graphic representation of a thread marked "filum."

114 See, for example, the 1537 edition of Sacrobosco from Venice that borrows the globe and cosmos diagram from Apian, as does the 1538 Wittenberg edition; see also https://cudl.lib.cam.ac.uk/collections/astronomicalimages/1.

115 Gingerich, "Sacrobosco as a Textbook," 270.

116 Valleriani, ed., *The Structures of Practical Knowledge*, 4, chapter 16.

117 Remmert, *Picturing the Scientific Revolution*; Lattis, "Christopher Clavius and the 'Sphere' of Sacrobosco."

118 I often wonder why Apian's *Cosmographicus Liber* did not overhaul the demand for new Sacrobosco textbooks. Although Apian's contributions to lay astronomy were substantial, perhaps the *Cosmographicus Liber* was simply too summarily synopsized, empirically driven, and therefore too popular for the more established market of university professors and students. As university audiences had provided a secure readership for Sacrobosco for centuries, Peter and Georg Apian may have been wise to cover all potential markets by re-releasing an edition of Sacrobosco's *De Sphaera* in 1526.

119 For a list of editions, see the virtual exhibition "Cosmographia: A Close Encounter," hosted at the Museum of the History of Science at Oxford, at www.mhs.ox.ac.uk/students/98to99/.

120 Kathleen Crowther et al., "The Book Everybody Read: Vernacular Translations of Sacrobosco's Sphaera in the Sixteenth Century," *Journal for the History of Astronomy* 46, no. 1 (2015), 8.

121 Karr Schmidt, *Interactive and Sculptural Printmaking in the Renaissance*, 301.

122 Peter Apian, *Instrument-Buch Durch Petrum Apianum erst von new beschriben. Zum Ersten ist darinne begriffen ein newer Quadrant, dardurch Tag vnd Nacht, bey der Sonnen, Mon vnnd andern*

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

Planeten, auch durch ettliche Gestirn die Stunden vnd ander nutzung Gefunden werden. Zum Andern, wie man die höch der Thuern vnd anderer gebew . . . messen soll. Zum Dritten wie man das wasser absehen oder abwegen soll . . . vnd wie man die Bruenne suchen soll. . . . (Ingolstadt: Apian, 1533). For a cogent description of the *Instrument-Buch*'s merits, see Alexandra Challenger, "Printing the Cosmos: Images, Readers, and Mathematics in Peter Apian's Instrumental Texts," PhD dissertation, Florida State University, 2022, 52–76.

123 Karr Schmidt, *Interactive and Sculptural Printmaking*, 240.

124 As we see in Johannes Dryander's German vernacular edition of *Sphaera materialis sive globi coelestis, Das ist des hymels lauff gründtliche außlegung . . .* (1539?), 8r, www.e-rara.ch/zut/content/zoom/12598857. The text's author referred his readers back to Apian to clear up any confusion about how to gauge the elevation of the pole star: "note here what Peter Apian has to say: look for the back wheels of the *Heer-Wagon* [Ursa Major, which contains the Big Dipper], find a line directly over your face, and the closest star that you will find in this line will be the pole star; then measure its height from the earth with a quadrant" (10r).

125 Oosterhoff, "A Book, a Pen, and the *Sphere*," 6–7. Oosterhoff maintains that these textbook editions teach "students how to manipulate the tools of the astronomer."

126 Johannes Regiomontanus and Johannes Schöner, *Scripta clarissimi mathematici M. Ioannis Regiomontani, de torqueto, astrolabio armillari, regula magna ptolemaica, baculo[que] astronomico, & observationibus cometarum, aucta necessariis, Ioannis Schoneri . . . additionibus. Item observationes motuum solis, ac stellarum tam fixarum [qua . . .] erraticarum. Item libellus M. Georgii Purbachii de quadrato geometrico* (Nuremberg: Joannis Montanus and Ulricus Neuber, 1544), www.e-rara.ch/doi/10.3931/e-rara-18965.

127 Daston and Lunbeck, *Histories of Scientific Observation*. See Pomata, "Observation Rising," 45–80, especially 49; see also Vanden Broecke, *The Limits of Influence*, 204–5.

128 Daston and Lunbeck, *Histories of Scientific Observation*, 50.

129 Peter Apian, *Practica Auff Das 1532 Jar . . . auch wird nachvolgenden von dem naeschst erschinen Cometen/ wie unnd in was Gestalt in gemelter Apianus Observiert hat und welhe biß her dero vil sindt in irem Schreiben irrig gefunden bewerlich angezaygt* (Landshut: Georg Apian, 1532); Peter Apian, *Ein kurtzer bericht der Observation und urtels des jüngst erschienenen Cometen jm Weinmon vnd Wintermon dises XXXII. Jars* (Ingolstadt: Apian, 1532).

130 Karr Schmidt, *Interactive and Sculptural Printmaking*, 295.

131 A horoscope is the measure of the sun's entry into a particular zodiac sign as determined by the position of the moon at night when directly overhead.

132 The term "to practice," or *practicieren*, emerged in German printshops *c.* 1470; the term *Practica* evolved into the name of printed practical literature. On *Practica* and their printers, see Richard L. Kremer, "Incunable Almanacs and *Practica* as Practical Knowledge Produced in Trading Zones," in Valleriani, ed., *The Structures of Practical Knowledge*, 333–69, especially 345ff.

133 The earliest appearance of the term in a title accompanied a work by Johannes Engel, a mathematics and astronomy professor at Ingolstadt, for a work printed in Nuremberg in 1488: *Die dewtsch practick . . .* See Valleriani, ed., *The Structures of Practical Knowledge*, 339.

134 Apian says he printed such publications to pay the bills and ceased this activity later. Röttel, *Peter Apian*, 135–7.

135 These included the *Kalendarium* (Nuremberg: Regiomontanus, 1474); see Baldasso, "Illustrating the Book of Nature in the Renaissance," 202–3. Such visual motifs can also be seen in the 1496 *Shepherd's Calendar*; see Max Engammare, *Calendrier des bergers* (Paris: Presses Universitaires de France, 2008).

136 Grafton, *Commerce with the Classics*, 185. While Apian and Copernicus had not forged a break with Ptolemy, Kepler broke with traditional cosmology here in his first major cosmographical work, the *Mysterium cosmographicum* (1596). Basing his work on Tycho Brahe's data gathered using measuring instruments in the Uraniborg, Kepler rejected the notion that Ptolemy necessarily provided a single point of origin for astronomical study.

137 Sky Michael Johnston, "Printing the Weather: Knowledge, Nature, and Popular Culture in Two Sixteenth-Century German Weather Books," *Renaissance Quarterly* 73, no. 2 (2020), 395.

138 Apian later imported some of the information from the *Cosmographicus Liber* into his more popular vernacular publications. Apian builds a bridge from the autodidactic cosmographic texts to small pamphlets that were eminently more readable, condensed, and directed toward an audience of laypeople to whom he broadcast lunar and solar eclipses for what they could tell their readers about the weather. Apian's practical pamphlet *Practica auff das MDXXXXI Jar/ durch Petrum Apianum von Leyßnick auß dem lauff der gestirn/ Zu Ingolstat Practicirt/ und in vier Capiteln auffs kürzest begriffen* (1541) imports lunar and solar diagrams from his more cosmographical texts. Here, Apian shows both lunar and solar eclipses for the coming year in diagrams that show the trajectories of each in their path through the constellations. The frontispiece provides the dates of the coming celestial conjunctions: 12 March and 21 August (for the local area). In the text, Apian discusses these happenings as ones that are clearly visible and take place before the backdrop of the night sky, indicating where in the constellation they can be seen and also when they disappear. This is a practical prediction that can serve as a guide to the night sky during lunar conjunctions that were likewise important for cosmography.

139 Bruce Stephenson, Marvin Bolt, and Anna Felicity Friedman, *The Universe Unveiled: Instruments and Images through History* (New York: Cambridge University Press, 2000), 40.

140 An explanation of this scale is also included in the 1514 publication of Johannes Werner's translation of Ptolemy, *In hoc opera haec continentur Noua translation primi libri geographiae Cl. Ptolemaei*.

141 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 139.

142 Röttel, *Peter Apian*, 160.

143 The scale necessary to clarify this point would have required an extraordinarily long arm to move the cross-piece.

144 Apian, *Ein kurtzer bericht der Observation und urtels des jüngst erschienenen Cometen jm Weinmon vnd Wintermon dises XXXII. Jars* (Ingolstadt: Apian, 1532).

145 Röttel, *Peter Apian*, 158–60.

146 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 139.

147 Röttel, *Peter Apian*, 159–60.

148 For the value of aesthetics in scientific instrument prints, see Marr, "Ingenuity in Nuremberg."

149 Richard L. Kremer, "Playing with Geometrical Tools: Johannes Stabius's Astrolabium Imperatorium (1515) and Its Successors," *CNT Centaurus* 58, no. 1–2 (2016), 116.

150 Adam Mosley positions Fine's spherical astronomy, such as his *Sphaera Mundi*, between a theoretical model of the universe and natural philosophy's search for causation. Fine's geometry set an agenda for publications that used scientific instruments to unpack a theoretical image of the cosmos. See Adam Mosley, "Early Modern Cosmography: Fine's *Sphaera Mundi* in Content and Context," in Alexander Marr, ed., *The Worlds of Oronce Fine: Mathematics, Instruments, and Print in Renaissance France* (Donington: Shaun Tyas, 2009), 122–3.

151 See http://kvk.bibliothek.kit.edu/view-title/index.php?katalog=ARCHIVE_ORG&url=http%3A%2F%2Farchive.org%2Fdetails%2Fcosmographicusli00apia&signature=AKO8P0JkE0UuL8sbEecPUrBlNbaHEiW-yG7rMVlFJ2w&showCoverImg=1. An edition at the John Carter Brown Library includes at the rear manuscript tables that treat degrees and distances.

152 Apian and Frisius, *Cosmographia Petri Apiani, per Gemmam Frisium …* (Antwerp: Plantin, 1574). See the blank pages and handwritten notes and diagrams throughout: MPM A27 at https://anet.be/digital/opacmpm/mpm/dg:mpm:474/N.

153 Woodward, ed., *The History of Cartography. Volume 3*, 477–508; see Uta Lindgren, "Land Surveys, Instruments, and Practitioners in the Renaissance," in Woodward, ed., *The*

History of Cartography. Lindgren argues for Gemma's instantiation of a practical treatment of triangulation, following in the tradition of Alberti and Regiomontanus. See also Conley, "A Topographer's Eye," 63ff.

154 Apian and Frisius, *Cosmographie, oft beschrievinghe der gheheelder werelt van Petrus Apianus/ . . . metten Zeecompasse ende anderen boecxkens byden selve Gemma daer toegdedaen* (Antwerp: Jan Verwithaghen (I), 1561), ETH-Bibliothek Zürich, MPM A 2049.

155 Margaret Gaida, "Reading Cosmographia: Peter Apian's Book-Instrument Hybrid and the Rise of the Mathematical Amateur in the Sixteenth Century," *Early Science and Medicine* 21, no. 4 (2016), 277–302.

156 I am indebted to discussions with Alexandra Challenger on this topic.

157 Michael Hoskin, ed., *The Cambridge Concise History of Astronomy* (Cambridge: Cambridge University Press, 1999), 79–81.

158 Stephenson, Bolt, and Friedman, *The Universe Unveiled*, 62–3. The nocturnal dial needed to be calibrated for the particular day by setting a tooth on the inner disk marked with hours to the date indicated on the outer disk. The other tooth is set for the reference star. The user orients it as he would a clock dial, holding its face parallel to him and sighting Polaris through the center hole. The movable arm is rotated to align with the reference star (generally the pointer stars in the Big Dipper, sometimes marked on the arm itself as alpha and beta). Once aligned to the reference star, the large arm should intersect with the hour of the night marked on the notched inner dial. In the darkness, one can count the number of notches from the longest tooth (midnight) and thus the user can find the time.

159 For volumes with the instruments tipped in, see the copy at the Morgan Library (PML 127688).

160 This is precisely the function of an app based on Apian's nocturnal developed by the Mathematisch-Physikalischer Salon at the Staatliche Kunstsammlungen Dresden. The free tablet/smartphone app "Behind the Stars" (in English or German versions, for iOS or Android) can be found at BehindTheStars@skd.museum.

161 Baigrie, ed., *Picturing Knowledge*, 71. On Tycho's repeated observations, see also Daston, "Empire of Observation," in Daston and Lunbeck, *Histories of Scientific Observation*, 93–5. Among these instrument books were the *Horoscope* (1531) and *Quadrant* (1532), which preceded his *Instrument-Buch* (1533).

162 I am grateful to the kind assistance of DeWayne Carver, Kevin Huffenberger, Chase van Tilburg, and Alexandra Challenger for making this complex tool come to life. Editions at the Museum Plantin-Moretus and the Morgan Library and Museum both have a missing top dial that allows us to see the algorithmic projection of the moon – inscribed with circles made by the compass used to figure it out. The traces of the compass markings print because they *de facto* engrave the wood. For this, see the Newberry Library's copy.

163 On sources for the *Organum Ptolomei*, as well as conventions for distinguishing between instruments and diagrams in manuscripts, see Catherine Eagleton, "Medieval Sundials and Manuscript Sources: The Transmission of Information about the *Navicula* and the *Organum Ptolomei* in Fifteenth-Century Europe," in Kusukawa and Maclean, eds., *Transmitting Knowledge*, 41–71, especially 67–9. Eagleton shows that most instruments known as the *organum* were ones that primarily shared a similar geometric method of construction. Ernst Zinner, *Deutsche und niederländische astronomische Instrumente des 11.–18. Jahrhunderts*, 2nd ed. (Munich: Beck, 1967), 131–4. According to Zinner, Apian creates an *Organum vel rota mobilis*, an invention of either Georg von Peuerbach or Regiomontanus, which is a device more useful than a sundial.

164 The incipit "*organum ptolomei ita sit*" describes dials in a variety of fifteenth- and sixteenth-century manuscripts linked to Vienna. Eagleton posits that these dials are of a *navicula* type that are medieval English in origin. See Catherine Eagleton, "Oronce Fine's Sundials: The Sources and Influences of *De solaribus horologiis*," in Marr, ed., *The Worlds of Oronce Fine*, 83–100.

165 James E. Morrison, *The Astrolabe* (Rehoboth Beach, DE: Janus, 2007), 37; see also note 3, p. 37. Here we see the "plane that passes through the solstices . . . pulled back the center of

https://doi.org/10.1017/9781009444491.003 Published online by Cambridge University Press

the projection to an infinitely distant point on the line passing through the equinoxes. It is thus properly described as an orthographic projection, and it is easily recognized, as the parallels of the celestial sphere become straight lines parallel to the equator." The Rojas astrolabe (*c.* 1550), introduced by Gemma's pupil, the Spanish astronomer Juan de Rojas, added an orthographic projection.

166 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 141.

167 Gingerich is likewise skeptical of its use as an actual sundial, citing the potential difficulties involved in stabilizing it. Gingerich, "Astronomical Paper Instruments with Moving Parts," 64.

168 Does the Nulla Dies dial in the Wittenberg Sacrobosco infer this?

169 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 140.

170 I acknowledge a debt to my brother Erik Leitch for helping to interpret both the workings and the novelty of this instrument.

171 Gingerich, "Astronomical Paper Instruments with Moving Parts," 64–6.

172 Vanden Broecke, "The Use of Visual Media in Renaissance Cosmography," 138ff.

173 Albert Ronsin, Pierre Monat, and Amerigo Vespucci, *La fortune d'un nom: America: le baptême du Nouveau Monde à Saint-Dié-des-Vosges* (Grenoble: J. Millon, 1991), 111–12. The Vespucci letter is omitted from the edition preserved in Wolfenbüttel (HAB HN94.4 Helmst. 6).

174 Anthony John Turner, *Early Scientific Instruments: Europe 1400–1800* (London: Sotheby's Publications, 1987), 47.

175 The cartographer Gerard Mercator also worked in Frisius's workshop.

176 See the website developed by the Museum of the History of Science in Oxford: www.mhs.ox.ac.uk/students/98to99/.

177 See also Waldseemüller, *Der Weltkugel* (1509). This might be the earliest Ptolemaic cosmographic text in vernacular.

178 Shalev and Burnett, eds., *Ptolemy's Geography in the Renaissance*, 11.

179 Christine R. Johnson, *The German Discovery of the World: Renaissance Encounters with the Strange and Marvelous* (Charlottesville: University of Virginia Press, 2008), 81.

180 *Universalis cosmographia secunda Ptholemei traditionem et Americi Vespucci aliorum que lustrationes* (A drawing of the whole earth following the tradition of Ptolemy and the travels of Amerigo Vespucci and others). See http://purl.oclc.org/coordinates/b4.htm.

181 Petrus Apian, *Cosmographiae Introductio: Cum Quibusdam Geo-Metriae ac Astronomiae Prin=||cipijs ad eam Rem Necessarijs.||* (Ingolstadt: Peter and Georg Apian, 1529).

182 Denis Cosgrove argues that Apian's work was fuller than Waldseemüller's because its instructions in spatial surveying were designed to clarify the world map; see Cosgrove, "Images of Renaissance Cosmography," in Woodward, ed., *The History of Cartography. Volume 3*, 67.

183 Apian, *Cosmographiae Introductio* (1529/1533). See chapter 14, which mentions "the whole world known to Ptolemy"; chapter 18 explains how to use the *Tabularum Ptolemei*.

184 Apian, *Cosmographiae Introductio*. For a digital edition, see http://daten.digitale-sammlungen.de/~db/0003/bsb00039825/images/. For the sixteen editions of this text, see Röttel, *Peter Apian*, 267–8.

185 Röttel, *Peter Apian*, 169–71. Map size 28.5 cm × 42 cm.

186 Caius Julius Solinus, Joannes Camers, and Johann Singriener, *Joannis Camertis . . . in C Julii Solini Polyistora Enarrationes. Additus Eiusdem Camertis Index* (Vienna: Alantse, 1520).

187 Röttel, *Peter Apian*, 171.

188 Röttel, *Peter Apian*, 173. For the map, see the entry for Michael Ostendorfer in F. W. H. Hollstein et al., *Hollstein's German Engravings, Etchings and Woodcuts 1400–1700*, vol. 30 (Amsterdam: M. Hertzberger, 1991), no. 56. The pamphlet today is preserved in the Staats- und Stadtbibliothek Augsburg.

189 Röttel, *Peter Apian*, 173.

190 Röttel, *Peter Apian*; Rodney W. Shirley, *The Mapping of the World: Early Printed World Maps, 1472–1700* (Riverside: Early World Press, 2001), 45.

191 See John P. Snyder, "Map Projections in the Renaissance," in Woodward, ed., *The History of Cartography*, 367. Snyder classifies this as the polar stereographic projection.
192 Apian's *Speculum Cosmographiae* mimicked the moving components of an astrolabe and included many indicators related to astrolabes, including rotating parts for which Apian cribbed astrolabe nomenclature, calling these parts a limb, a rete, and an alidade. Conley, *An Errant Eye*, 73ff.
193 Turner, *Early Scientific Instruments*, 12. A traditional astrolabe features a number of rotating discs held together in a circular case called the *mater*. The first solid plate shows a projection of the world sphere on the two-dimensional plane of the equator, consisting of the circles of the equator, the tropics, the path that the sun describes on the celestial sphere (the ecliptic), and the fixed stars. A cutaway and movable circle, called a *rete*, revolves on top of this bottom plate; the *rete* usually carries the zenith–horizon coordinate system for a particular latitude (the ecliptic marked with the signs of the zodiac and certain prominent stars). Then there is the *rule* that serves as an index or pointer for the front; it is usually marked with a scale of declinations. The astrolabe permitted investigation of the major terrestrial and celestial lines and attempted to provide knowledge of the celestial system in toto. Actual astrolabes were outfitted with a number of removable discs with which actual latitude could be accounted for; then, with the aid of a sighting device with which most were equipped on their rear surfaces, sightings could be taken to determine the altitude of sun or stars to find the time in order to appropriately position the discs.
194 Johann Copp, *Erklärung unnd gründtliche Underweysung alles nutzes, so in dem edlen Instrument, Astrolabium genannt, begriffen, und erfunden würt/ denen so der lateinischen Sprach unverstendig/ doch liebhaber der Kunst/ erkannt trewlich verteütscht/ unnd durch den Truck außgegangen* (Augsburg: Otmar, 1525).
195 "Just as we look in a mirror . . . we can think about the entire world this way . . . Hereafter follows the ways you can use the Speculum of Cosmography." Apian, *Cosmographicus Liber*, chapter 19.
196 The world map's first appearance was in the French edition of 1544 printed in Antwerp: Peter Apian and Gemma Frisius, *La Cosmographie de Pierre Apian* (Antwerp: de Bonte, 1544).
197 The 1533 edition of Peter Apian's *Cosmographicus Liber* (Antwerp: Birckman, 1533) included Gemma's *Libellus de Locorum describendorum*, a tract that supplied the first image of triangulated surveying.
198 Röttel, *Peter Apian*, 181.
199 For Apian's plans for the book, see Schöner, *Mathematik und Astronomie*, 407. For the printing context of Apian's Astronomicum Caesareum (Ingolstadt: Apian, 1540), see Challenger, "Printing the Cosmos," 78–110.
200 In fact, it was in the context of courts that professional cosmographers came into being. Mosley, "The Cosmographer's Role," 430–5.
201 Denis E. Cosgrove, *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore: Johns Hopkins University Press, 2001), 96–9. By the mid-sixteenth century, the cosmographer's job became that of a data collector, processing incoming information from a variety of sources. Court cosmographers were responsible for processing the data that came into the realm and cosmography necessarily became a collective enterprise of explorers, navigators, writers, and engravers, a "center of calculation."
202 For the tension between the data that pertained to universals versus data relevant to individuals, see Nelson's discussion of the locative. Nelson, *Disharmony of the Spheres*, 51–88.
203 Röttel, *Peter Apian*, 160.
204 Schöner, *Mathematik und Astronomie an der Universität Ingolstadt*.
205 Gaida, "Reading Cosmographia," especially 279.
206 To be sure, Apian had already begun to print books devoted to the explanation of instruments, including vernacular treatises on the quadrant (1532) and the sundial/

horologium horoscope (1533), perhaps spurred on by these developments in the vernacular instrument books being published in Antwerp.

207 Petrus Apian, *Cosmographia, Additis de Eadem Re Libellis, ut Sequens Pagina Docet*, ed. Rainer Gemma Frisius (Antwerp: Birckman, 1539).

208 The *Usus Annuli* was nearly always included in Gemma's editions of Apian's cosmography printed after 1539.

209 See Pomata, "Observation Rising," 55, 61. Gemma kept two notebooks: one recorded data about the disposition of the stars, while a second recorded his experience as a physician.

210 One reader's customized response to Apian can be found in an Antwerp edition of *Cosmographia* printed by the Plantin press (Antwerp: Plantin and Verwithaghen, 1574); see MPM A27 at https://anet.be/digital/opacmpm/mpm/dg:mpm:474/N. This edition was bound with blank pages in periodic gatherings throughout to accept marginal notes. Some annotations enhance the text, such as in the sections on the principles of geography, and notes on eclipses.

211 The verses originate in the 1516 edition, where the diagrams show lunar phases: www.digitale-sammlungen.de/en/view/bsb00002755?page=56. In an annotated edition from 1533, an unrelated eclipse diagram accompanies those verses: cf. https://digital.slub-dresden.de/werkansicht/dlf/15207/65. Thanks to Britta-Juliane Kruse and Peter Hess for improving my translation.

Merck ich lerne dich fleissiglich
Wiewol der Mond entzundet sich
Allzeyt wie ihn die Son sicht an
Ist er halb liecht soltu verstan.

Wie wol der Mond zu aller frist
Vilmer dann halb erleuchtet ist
Doch siht man steets nit gantzen scheyn
Nur yetzund groß dann wider kleyn.

212 Sacrobosco, *Sphera Materialis*; "*deß himels lauff sampt allem gstirn/ leichtlicher auß den bei gesatzten figuren zuerlernen*."

213 This *Sammelband* is preserved in the Herzog August Bibliothek in Wolfenbüttel (HAB A17.4 Astron.). The manuscript gathering begins with "*Thier hebt sich an Spera materialis* …"; in Heinfogel and Sacrobosco, *Sphera Materialis: Eyn Anfang* (Strasbourg: Cammerlander, 1533).

214 See HAB A17.A #2, fol. 18r. The manuscript hand borrows the idea of the "*Aug[e]*" from Sacrobosco's text that explains the shape of the water from the perspective of an eye.

215 Peter Apian, *Practica Auff Das 1532 Jar*, prologue, p. 3: "*wir sehen vor augen den hymel allenthalben/ die weyler tag und nacht gerings umb die Erde geet/ und mögen in auch leichtlich observieren unnd beschreiben. Die Erde aber mag so leicht nit beschreiben/ un(d) die natur on allen orten oder flecke(n) in achtgehalten werden/ die weyl der mensch dieselbigen on gro(ss)e unkost un(d) langes rayßen nicht shen oder umbziehen mag/ vil weniger die natur recht beschreyben*." On collective empiricism, see Pomata, "Observation Rising," 50.