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Illuminating Methods, Picturing Instruments: Tycho Brahe's Instrumental Images

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Abstract
This article considers the function of twenty-two hand-colored prints of mathematical instruments in Tycho Brahe's *Astronomiae instauratae mechanica* (Instruments of the renewed astronomy; 1598), a hand-painted presentation treatise dedicated to Emperor Rudolf II and conferred on a network of individuals connected to the imperial court in Prague. Although the accompanying text communicates the instruments' use and composition, the images demand close inspection because they articulate Brahe's observationally driven astronomy. They do so through structured, repeated, and consecutive representations; through expanded viewer access, achieved by adhering to multiple perspectives; through the juxtaposition of colors, which focuses attention on the heads of the instruments (the part that does the measuring); and through the use of gold paint, which emphasizes the head and brings to mind the very metallic nature of the instruments. Much like an astronomer taking multiple measurements of cosmological phenomena, these images allow viewers and readers, as they leaf through the pages of the treatise, to become virtual participants in Brahe's instauration of astronomy.

Keywords: mathematical instrument illustration; instrumentation; illuminated treatises; observational astronomy; embodied viewing; science and art; Tycho Brahe; materiality

A hand-colored wood-block print from Tycho Brahe's *Astronomiae instauratae mechanica* (Instruments of the renewed astronomy; 1598) prominently features an equatorial armillary depicted outdoors against a fading blue sky (see Figure 1).[1] The instrument is composed of two distinct parts. Taking up half the image, the gilded head—the upper, perfectly circular portion, which includes the armillae—has a shiny, metallic surface. The lower half is made up of a colorfully painted base with curling ornamental scrolls and two small figures that stand in dark niches. The decorative base, shown from a different perspective, supports the armillae in space. A thick black line outlines the edges of the picture, framing the instrument, which in turn is surmounted by a Latin inscription —"ARMILLAE AEQUATORIAE"—indicating the instrument's name. Below and above the pictured instrument, a decorative polychrome strip of floral and grotesque decoration provides emphasis, while a patterned decorative frame painted green contains the image on the page. The size of the instrument relative to the page, its careful framing, the clear inscription in majuscule script, the illumination, and the clear labeling of various parts lend an air of importance while also beckoning the viewer to inspect the colored print more closely.

The armillary and its description on the facing page is one of twenty-two prints of mathematical instruments featured in the *Mechanica*, an illuminated presentation treatise that Brahe produced in many copies and conferred upon selected individuals in the hopes of ultimately securing the patronage of Emperor Rudolf II. The treatise introduces the reader to novel instruments designed by the astronomer to observe and record precise cosmological phenomena as part of the instauration, or renewal, of astronomy.[2]

This article functions as a preliminary think-piece about the status and agency of images of instruments in early modern presentation treatises.

[1]Henceforth "the *Mechanica*."

[2]See Daniel Špelda, "The Search for Antediluvian Astronomy: Sixteenth- and Seventeenth-Century Astronomers' Conceptions of the Origins of the Science," *Journal of the History of Astronomy* 44, no. 156 (2013): 337.

Figure 1. *Armillae aequatoriae* (Equatorial armillary). Copperplate engraving on paper, water-soluble paint and gilt. All images are from Tycho Brahe, *Astronomiae instauratae mechanica* (Wandsbek, 1598). The National Library of Denmark and the University Library of the University of Copenhagen. Pictures used with permission from the Royal Library of Copenhagen.

Throughout the text, Brahe highlights his observational methods, which entailed repeated, accurate, and comprehensive planetary observations obtained through the aid of multiple, reliable, and more accurate mathematical instruments—the very same instruments featured in the text. As has been shown by Adam Mosley and others, Brahe's authority in astronomy rested on his instruments, which became central

to his endeavor to renew astronomy.[3] Their unique and prominent presentation in the *Mechanica*, as woodcuts and engravings that are rendered with artistic forms and visual embellishments, demands an inquiry into their effect on Brahe's observationally driven program.[4]

The centrality of Brahe's instruments to his credibility and to his pursuit of a renewal of astronomy has been studied, as has Brahe's ability to expertly and strategically manipulate the patron network by distributing images of his instruments in print (alongside his cosmological findings) while bringing together influential contacts to secure new patronage for his research.[5] Although it has been suggested that Brahe circulated images of his instruments in print to persuade readers of their reliability and, ultimately, to garner support for his cosmological findings, insufficient attention has been given to the images. Analyses often subordinate the visual to the textual. For instance, it has been argued that Brahe's extensive use of labeling helped establish his claims of accuracy and dependability by promoting smooth navigation between image and text, ultimately enhancing trust in Brahe's methods and instruments.[6] Beyond analyzing the images' iconography and their function as aids to understanding Brahe's written descriptions, scholars have not adequately considered *how* the illuminated woodcuts and engravings may have functioned as pictures in their own right.[7] Given the *Mechanica*'s considerable emphasis on illustrations alongside text, and relying on the copy of the *Mechanica* held by the Royal Library of Copenhagen, I propose that the colored images of Brahe's instruments demonstrated, articulated, and allowed the viewer to experience Brahe's observational methods firsthand.[8]

[3]See Adam Mosley, "The Reformation of Astronomy," in *The Impact of the European Reformation: Princes, Clergy, and People*, ed. Bridget Heal and Ole Peter Grell (Aldershot, 2008), 244. For the rise of observations as a means of scientific inquiry, see Giana Pomata, "Observation Rising: Birth of an Epistemic Genre, 1500–1650," in *Histories of Scientific Observation*, ed. Lorraine Daston and Elizabeth Lunbeck (Chicago, 2011), 45–80, and in the same volume, Lorraine Daston, "The Empire of Observation, 1600–1800," 81–113. For an account of how Brahe improved measurement accuracy using his new instruments and methods, see Gudrun Wolfschmidt, "The Observatories and Instruments of Tycho Brahe," in *Tycho Brahe and Prague: Crossroads of European Science*, ed. John Robert Christianson et al., International Symposium on the History of Science in the Rudolphine Period (Frankfurt, 2002), 203–16.

[4]For literature on illustrations of mathematical instruments and their relationship to text, see Suzanna Karr Schmidt and Kimberly Nichols, *Altered and Adorned: Using Renaissance Prints in Daily Life* (Chicago, 2011); Susan Dackerman, ed., *Prints and the Pursuit of Knowledge in Early Modern Europe* (Boston, 2011).

[5]On instrumentation as a means of renewing astronomy, its deployment through the medium of print, and how the images in the *Mechanica* generate embodied viewing that speaks to Brahe's observationally driven astronomy, see the fourth chapter of my dissertation, "Alchemy of the Gift: Things, Material Transformations, and Geopolitics at the Court of Rudolf II" (PhD diss., University of British Columbia, 2015), https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0166243. I thank Bronwen Wilson, Carol Knicely, and Charlotte Townsend-Gault for their invaluable feedback and advice on earlier drafts of this paper. Emma Perkins arrives at similar conclusions in "Instruments of Authority: Tycho Brahe's Technological Illustrations," *History and Technology* 34, nos. 3–4 (2018): 259–72. On the importance of instruments in astronomy and Brahe's emphasis on instrumentation specifically, see Mosley, "The Reformation of Astronomy," 231–50. For a discussion of how Brahe manipulated the patronage network, see John Robert Christianson, *On Tycho's Island: Tycho Brahe and His Assistants* (Cambridge, 2000), 207–36. For Brahe's emphasis on observational astronomy, see Gábor Almási, "Tycho Brahe and the Separation of Astronomy from Astrology: The Making of a New Scientific Discourse," *Science in Context* 26, no. 1 (2013): 3.

[6]Perkins, "Instruments of Authority." However, certain errors in labeling complicate this argument. See the editorial notes in Tycho Brahe, *Instruments of the Renewed Astronomy*, trans. Alena Hadravová, Petr Hadrava, and Jole R. Shackelford (Prague, 1996).

[7]Literature that addresses scientific illustration is significant: William Ashworth, "The Scientific Revolution: The Problem of Visual Authority," in *Conference on Critical Problems and Research Frontiers in History of Science and History of Technology* (Madison, 1991): 326–48; Brian Baigrie ed., *Picturing Knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science* (Toronto, 1996); Sachiko Kusukawa and Ian Maclean, eds., *Transmitting Knowledge: Words, Images, and Instruments in Early Modern Europe* (Oxford, 2006); Adam Mosley, "Objects, Texts and Images in the History of Science," *Studies in History and Philosophy of Science* 38, no. 2 (2007): 289–92. Voker R. Remmert, *Picturing the Scientific Revolution: Title Engravings in Early Modern Scientific Publications*, trans. Ben Kern (Philadelphia, 2011).

[8]The copy in Copenhagen is personally dedicated by Brahe to Petr Vok of Rožmberk (1539–1611), a Czech Protestant magnate of the House of Rosenberg and an enthusiastic collector of books who owned a library of ten thousand volumes at his castle of Český Krumlov. According to Victor E. Thoren, the major portion of his library ended up as Swedish booty during the Thirty Years' War: see *The Lord of Uraniborg: A Biography of Tycho Brahe* (Cambridge, 1990), 467. Rožmberk's copy is one of the finest extant and well-preserved examples. While the argument in this paper extends to other illuminated copies of the *Mechanica*, a detailed analysis of other copies is beyond the present scope.

The *Mechanica* was produced in 1598 to procure patronage after Brahe fell out of favor with Frederick II's successor, Christian IV, who withdrew support of Brahe's astronomical activity on the Island of Hven.[9] In 1597, in search of a new patron, Brahe departed Denmark along with his entire household. Stopping briefly at the castle of Wandsbek, Brahe quickly orchestrated the printing of the *Mechanica* at the hands of the Hamburg printer Philip von Ohrs. Brahe already possessed woodblocks of some instruments that had been used in earlier publications and in some of his correspondence, he thus commissioned four additional engravings.[10] The pages were quickly illuminated and bound, and copies of the *Mechanica* were selectively conferred on a network of colleagues and influential persons (many of whom were variously connected to the Prague court).[11] Before the *Mechanica*, no other astronomer had distributed a presentation copy containing such a complete account of instruments on such a wide scale.[12] By doing so, Brahe broadcasted a detailed account of his observationally derived astronomy based on instrumentation, thus ensuring that his methods and his instruments—the key tools of his science—would become a coveted addition at Rudolf's court, where the pursuit of knowledge was considered of great import.

Rudolf II was a renowned collector and patron of the arts who was fascinated with novelty and innovation.[13] The possibility of adding copies of Brahe's instruments to his extensive collection would have been a welcome prospect for the emperor, who already had numerous instrument makers in his employ.[14] In addition, filling the newly vacant post of imperial mathematician with someone of Brahe's repute and skill—someone who would produce cutting-edge work while under the emperor's protection, and in his name—also appealed to the emperor because it would increase the fame of his

[9]For a discussion of the circumstances that forced Brahe to leave Denmark, see Christianson, *On Tycho's Island*, 195–206, and Thoren, *The Lord of Uraniborg*, 334–425.

[10]For woodcuts that were produced prior to 1597, see Thoren, *The Lord of Uraniborg*, 381–82. As Thoren explains, in an attempt to regain favor with Christian IV, eighteen of these existing woodcuts were used in a pamphlet made in 1596 (p. 382). The engravings made specifically for the *Mechanica* include the *Quadrans minor orichalcicus inauratus*, the *Quadrans muralis sive tichonicus*, and the *Globus magnus orichalcicus*.

[11]For details surrounding the production and dissemination of the *Mechanica*, see Christianson, *On Tycho's Island*, 207–36. For a list of known recipients of the *Mechanica*, see Wilhelm Norlind, *Tycho Brahe: En levnadsteckning med nya bidrag belysande hans liv och verk* (Lund, 1970), 286–93, as cited in Thoren, *The Lord of Uraniborg*, 386.

[12]As Martin Kemp points out, Apianus's *Instrumentum primi mobilis* (1543) and *Astrononicum caaesareum* (1540) "provide only very partial precedents": "Vision and visualisation in the Illustration of Anatomy and Astronomy from Leonardo to Galileo," in *1543 and All That: Studies in History and Philosophy of Science*, ed. G. Freeland and Anthony Corones (Dordrecht, 2000), 37. See also Albert Van Helden, "Telescopes and Authority from Galileo to Cassini," *Osiris* 9 (1994): 10; and Allan Chapman, "Tycho Brahe in China: The Jesuit Mission to Peking and the Iconography of European Instrument-Making Processes," *Annals of Science* 41 (1984): 417–43.

[13]The literature on Rudolf's patronage activities and collecting is vast. See, for example, Thomas DaCosta Kaufmann, "Remarks on the Collection of Rudolf II: The *Kunstkammer* as a Form of *Representatio*," *Art Journal* 38, no. 1 (1981): 22–28; "From Mastery of the World to Mastery of Nature: The Kunstkammer, Politics, and Science," in *The Mastery of Nature: Aspects of Art, Science, and Humanism in the Renaissance* (Princeton, 1993), 174–94; and "From Treasury to Museum: The Collections of the Austrian Habsburgs," in *The Cultures of Collecting*, ed. John Elsner and Roger Cardinal (London, 1994), 137–54. See also Eliška Fučíková, "The Collections of Rudolf II in Prague: Cabinet of Curiosities or Scientific Museum?," in *The Origins of Museums: The Cabinets of Curiosities in Sixteenth- and Seventeenth-Century Europe* (Oxford, 1985), 47–53; Beket Bukovinská, "Die Kunst- und Schatzkammer Rudolfs II: Der Weg vom Rohmaterial zum Sammlungsobjekt als ein Ereknntnisprozess," in *Akten des XXV Internationalen Kongresses fur Kunstgeschichte*, vol. 4, *Der Zugang zum Kunstwerk: Schatzkammer, Salon, Ausstellung,"Museum"* (Vienna, 1986), 59–62; Eliška Fučíková, "Rudolfovy sbírky," in *Umění na dvoře Rudolfa II*, ed. Eliška Fučíková, Beket Bukovinská, and Ivan Muchka (Prague, 1988), 214–48; and ibid., "Zur Konzeptionen der Rudolfinischen Sammlungen," in *Prag um 1600: Beiträge zur Kunst und Kultur am Hofe Rudolfs II*, ed. Eliška Fučíková (Freren, 1988), 59–62.

[14]Such as Jost Bürgi, Erasmus Habermel, Thomas Ruckert, and the Augsburg clockmakers Georg Roll, Mattias Rungel, and Christoph Schissler; see R. J. W. Evans, *Rudolf II and His World: A Study in Intellectual History, 1576–1612* (Oxford, 1973), 187. As Bruce T. Moran explains, the design of machines, automatons, clocks, and instruments used in astronomy became an important preoccupation in Prague, at times involving Rudolf. The emperor apparently designed a self-orienting chart for travelers, controlled by a concealed compass; see "German Prince Practitioners: Aspects in the Development of Courtly Science, Technology, and Procedures in the Renaissance," *Technology and Culture* 22, no. 2 (1981): 255. Rudolf's enthusiasm for technology is also demonstrated by his request to borrow Brahe's odometer to have it copied. Brahe strategically brought it with him to his private audience with the emperor; see Christianson, *On Tycho's Island,* 236.

already renowned court and its artistic and scientific activity, which he patronized with fervor.[15] For someone of Rudolf's standing, patronage of astronomy, as a form of court technology, would garner him more social utility and power.[16] Rudolf likely wondered why the young Danish king had let Brahe slip away.

Although Brahe's authority as Europe's preeminent astronomer was contingent on his instruments, which were central to his observationally driven endeavor to renew astronomy, it was the strategically articulated images presented alongside the text that had initially captured the attention of recipients. Indeed, after receiving the *Mechanica*, along with two other manuscripts that contained important cosmological findings obtained through the aid of those same instruments, Rudolf II leafed through its pages late into the night.[17]

Astronomiae Instauratae Mechanica

As its dedicatee, what might have impressed Rudolf II the most about the *Mechanica*? While the copy presented to Rudolf has been lost, we can assume that he received one of the more sumptuous examples. He likely appreciated its luxurious pale silk binding held together by metal clasps. Perhaps he pondered the painted likeness of Tycho Brahe that followed the frontispiece.[18] While it is unlikely that Rudolf read the entire book in one sitting, he likely read the four-page preface dedicated to him before admiring the twenty-two illuminated instruments and the painted engravings of Brahe's observatories.[19] Through the preface, the emperor would have been reminded that by promoting the study of astronomy—which in this context implied patronizing Brahe specifically—he would become the instrument through which God's glory on earth would be increased. His name and honor would be praised in perpetuity.[20]

[15]For Rudolf's interest in scientific instruments, see Antonín Švejda, "Science and Instruments," in *Rudolph II and Prague*, ed. Eliška Fučíková et al. (Prague, 1997), 618–19; Joaneath Spicer, "Referencing Invention and Novelty in Art and Science at the Court of Rudolf II," in *"Novità" Neuheitskonzepte in den Bildkünsten um 1600*, ed. U. Pfisterer and G. Wimböck (Zürich, 2011), 401–24.

[16]Moran, "German Prince Practitioners," 225. For the relevance of astronomy for the early modern court, see Paula Findlen, "The Economy of Scientific Exchange in Early Modern Italy," in *Patronage and Institutions: Science, Technology, and Medicine at the European Court, 1500–1750*, ed. Bruce T. Moran (Woodridge, 1991), 5–24; Darin Hayton, "Expertise *ex stellis*: Comets, Horoscopes, and Politics in Renaissance Hungary," *Osiris* 25, no. 1 (2010): 27–46.

[17]Christianson, *On Tycho's Island*, 236. The two manuscripts include an ephemeris of daily positions of the sun and moon for the year 1599 and a catalog of 1,004 stars, called *Astronomiae instauratae progymnasmata* (Introductory exercise toward a restored astronomy), published posthumously in Prague by Kepler in 1602. Brahe described his reception by Rudolf II in a letter to Holger Rosenkrantz; see Thoren, *Lord of Uraniborg*, 412–13.

[18]According to Christianson, the initial copies of the *Mechanica* were bound in leather, with finer copies bound in vellum, and the most sumptuous ones bound in pale silk with metal clasps (*On Tycho's Island*, 224). The presentation copies of the *Mechanica* that remain in libraries today follow the same content and layout, although some lack the introductory portrait of Brahe, which faces the first page of the dedication. See B. Hasselberg, "Einige Bemerkungen über Tycho Brahes Astronomiae mechanica. Wandesbugi 1598," *Vierteljahrschrift Der Astronomischen Gesellschaft* XXXIX (1904): 186–87. According to Hasselberg, only the finest copies of the *Mechanica*, intended for the most illustrious patrons, contained a painted portrait of Brahe. Some of these are contained in copies at the Strahov Monastery Library in Prague, at the Royal Library of Copenhagen, and at the Cathedral Library in Kolocsa. The other illuminated copies of the *Mechanica* contain a painted engraving of Brahe, produced by Jacques de Gheyn in 1586. See Adam Mosley et al., "Epistolary Culture, Editorial Practices, and the Propriety of Tycho's Astronomical Letters," *Journal of the History of Astronomy* 34 (2003): 421–51.

[19]In addition to the images of instruments, the *Mechanica* contains a dedication to Rudolf II, a scientific autobiography of Brahe's achievements, his future research plans, letters and poems written by his friends and acclaimed colleagues (who praise his achievements and his dedication to astronomy), and pictorial and textual descriptions of his palatial observatories on the island of Hven in Denmark. Rudolf also received two manuscripts.

[20]In the preface, Brahe states, "The more that the honor and Majesty of the best and greatest God, which shines in celestial things more than in other aspects of this great world theater, comes to be known more correctly, the more it is increased and esteemed among the inhabitants of the earth; Moreover, since to preserve, protect, and promote for all posterity these so excellent things, which are almost extraordinary in human affairs, will not diminish Your Imperial Majesty's fame and reputation, may it shine brighter for that and endure as long as the sun and heavenly bodies last, because from these alone, which are perpetual inconstant—of a celestial kind—one may acquire an internal name and undiminished honor." *Instruments of the Renewed Astronomy*, 10.

In the preface, Brahe, lays out his agenda for the *Mechanica* and justifies its focus on instrumentation; he outlines the astronomical practice Rudolf would be supporting. Highlighting the role of instruments in aiding vision, he explains that "in astronomy it is first of all necessary to obtain very many observations, taken over a long period of time by means of instruments that are not liable to error."[21] He explains that using multiple, larger, more accurate, more dependable, and "more excellent" instruments will ensure that observations are "free of error."[22] Brahe also adds that using several instruments requires the presence of six to eight researchers conducting experiments and taking measurements simultaneously.[23] Such an object-driven method would have appealed to Rudolf II, whose own collection of art and curiosities functioned as a research center in its own right.[24]

Leafing through the pages of illuminated woodcuts and engravings, Rudolf would have certainly marveled at the unusual focus on images of instruments and their luxurious presentation, each taking up an entire page, with gilded components that would have sparkled in the candlelight. He may have read parts of the accompanying dense text to gain a better understanding of the function of those instruments that caught his eye. The frequent claims of their exclusivity—in terms of size, variety, accuracy, and dependability—likely engaged his interest, and while pondering their representations he may have hoped to witness a demonstration of their accuracy firsthand.

Rudolf was not the only recipient of the luxuriously presented *Mechanica*. Sources suggest that up to one hundred illuminated copies were distributed among Brahe's network of brokers, friends, and close contacts.[25] Through the carefully tailored dissemination of the illuminated account of his cutting-edge instruments, Brahe's goal was to impress and garner support in his search for patronage.[26] Even though the presentation of luxuriously illuminated treatises to potential patrons was by no means unusual, it was the number of presentation copies produced—which Brahe presented not only to patrons but also to colleagues and friends with connections at the imperial court in Prague—that set this presentation treatise apart.[27] In a culture of collecting, which celebrated material and aesthetic excess, the presentation of such a treatise—attributed to one of Europe's most distinguished astronomers—would have surely intrigued its erudite recipients.

Images of Instruments

Keeping the textual information offered by Brahe in mind, what might the prints of the illuminated instruments have conveyed? In the preface, Brahe explains that using several kinds of instruments to make the same observation improves accuracy, a notion that is emphasized visually through the organized, consistent, and recurrent presentation of his twenty-two instruments—eighteen woodblock prints and four engravings.[28] Each hand-colored print features a single instrument that occupies a simple space with a minimally articulated background. The majority of the images are oriented vertically within an ornamental green frame, which is thicker at bottom.[29] The frames and titles are identical to the *Armillae aequatoriae*, and the denoted function appears in seven prints (see Figure 1). The images

[21]Ibid., 4.

[22]Ibid.

[23]Ibid., 7.

[24]See Kaufmann, "From Mastery of the World to Mastery of Nature," 174–94; Beket Bukovinská, "The Known and Unknown *Kunstkammer* of Rudolf II," in *Collection, Laboratory, Theater: Scenes of Knowledge in the Seventeenth Century*, ed. H. Schramm, L. Schwarte, and J. Lazardzig (Berlin, 2005), 199–227; and Fučíková, "The Collections of Rudolf II in Prague," 47–53.

[25]See Christianson, *On Tycho's Island*, 224–25, for a discussion of some of the known recipients of the *Mechanica*.

[26]For a discussion of how Brahe succeeded in capturing the attention of Rudolf II, see ibid., 226.

[27]Paula Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley, 1994), 363; and Dackerman, *Prints and the Pursuit of Knowledge*. For presentation treatises that were collected as precious items in the quest for knowledge, see Lisa Jardine, *Worldly Goods: A New History of the Renaissance* (London, 1996), 136–44. See also Pamela O. Long, "Power, Patronage, and the Authorship of Ars: From Mechanica Know-How to Mechanical Knowledge in the Last Scribal Age," *Isis* 88, no. 1 (1997): 20.

[28]Brahe, *Instruments of the Renewed Astronomy*, 4.

[29]The only exceptions are two prints of ruler instruments, which are oriented horizontally; because of the size of these prints, their vertical edges protrude into the frame, such as in Figure 12.

also include labels in the form of letters of the alphabet, to which Brahe refers in the text. In the colored edition, depending on the copy of the *Mechanica* under investigation, the labels are at times obscured by dark illumination.

In terms of their context, the majority of the instruments are portrayed outdoors, set against a sky that changes from very light at the horizon to a dark blue in the upper portion of the picture plane. As a decorative function, the colored sky contextualizes the instruments, reminding the viewer of their use for measuring phenomena in the night sky. In the copy held by the Saxon State and University Library in Dresden, this function is emphasized through the addition of small shimmering stars.[30] In some prints, the outdoor setting is idealized through the addition of a green turf (see Figures 2 and 3, but in most cases the foreground consists of a nonspecific flat platform on which the instrument sits (see Figures 1, 4, 5, and 6).[31] In other instances, the platform takes on architectural elements that bring to mind the placement of these instruments inside crypts at Stjærneborg (see Figures 7, 8, and 9), where they are set simultaneously indoors and outdoors, giving the viewer full access to both.[32]

Embodied Viewing

While engagement with the images is maintained through a variety of minimally articulated settings that encourage the viewer to picture the instruments' use for the observation of cosmological phenomena, viewer participation in the process of observation is achieved through a particular articulation of the instruments that does not always prioritize a naturalistic rendering.

Although the framing devices organize the viewing experience of the printed instruments, in certain prints a peculiar interplay between the heads and bodies of the instruments seems to disrupt their structured presentation. For instance, in the colored print of the *Armillae aequatoriae*, the head of the instrument bears the marks of minutes clearly inscribed on arcs that overlap and suggest volume (see Figure 1). Delineated through a balanced and symmetrical rendering, this brings to mind measurement, precision, and clarity—qualities associated with accurate observations, which are also invoked in the text that accompanies the image. Looking closely at the base, or the body of the armillary, note that the two supporting brackets, which are painted green (labeled "b"), appear to be oriented to the right, with the left-hand bracket partly obscuring the decorative edge of the red portion of the base that contains the two figures, effectively ruining the symmetry of the composition and causing a flattening effect. This is likely a design solution because showing the base perfectly perpendicular to the picture plane would have required strong foreshortening of the green brackets, which would have obscured certain labeled parts of the base from view altogether. Brahe reused certain blocks for the publication of the *Mechanica*, the print of the equatorial armillary being one of them; therefore, one might surmise that in the initial uncolored prints of the armillary, explaining the labeled parts of the instrument through text was favored over a naturalistic representation. In the colored version, that certain labels are nearly impossible to see because of the application of dark paint (such as the two "W"s and the two "X"s near the front of the picture plane) suggests that in the context of the *Mechanica* appealing to the

[30]Referring to the suggested garden settings, Emma Perkins makes a similar observation in "Instruments of Authority," asserting that the "carefully contextualized representations … serve to reinforce their physical reality" (263). A garden setting is indicated behind the *Globus magnus orichalcicus*. The fact that Tycho had this globe placed in his library, rather than under the open sky, suggests that depicting the great globe outdoors under a changing sky was not meant to suggest the reality of its setting.

[31]Ibid. A green turf is also indicated in the *Quadrans minor orichalcicus inauratus* (see Figure 3), and the *Quadrant maximus* from Augsburg appears to occupy a garden setting. As noted by Perkins and Liba Taub, the idealized setting of the small quadrant is similar to how Andreas Vesalius portrayed his dissected humans in a naturalistic landscape. Emma Perkins and Liba Taub, "Perhaps Irrelevant: The Iconography of Tycho Brahe's Small Gilt Brass Quadrant," *Nuncius* 30 (2015): 15–16.

[32]In the latter case, we see instruments mounted on a large vertical tube attached to a circular base encircled by a series of steps. From the top of the circular steps, a wall appears to rise and then partially encapsulate the instrument below. Above the partial roof, a darkened sky is indicated. From Brahe's text we learn that these instruments were located in underground crypts at the observatory Stjærneborg; their purpose was to protect the larger instruments from the elements. The way they are articulated in the *Mechanica* allows the viewer access not only to the interior of the crypt that features the entire instrument but also to its exterior.

Figure 2. *Globus magnus orichalcicus* (Great brass globe). Woodblock engraving on paper, water-soluble paint and gilt.

senses may have been prioritized over fostering a clear understanding of the instruments' construction and function.

A similar effect of disjointedness seems to be at play in the image of the *Quadrans mediocris orichalcicus azimuthalis* (see Figure 10). The clearly delineated quadrant (or head of the instrument), painted with gold, is presented from the side and clearly shows carefully spaced out measurements

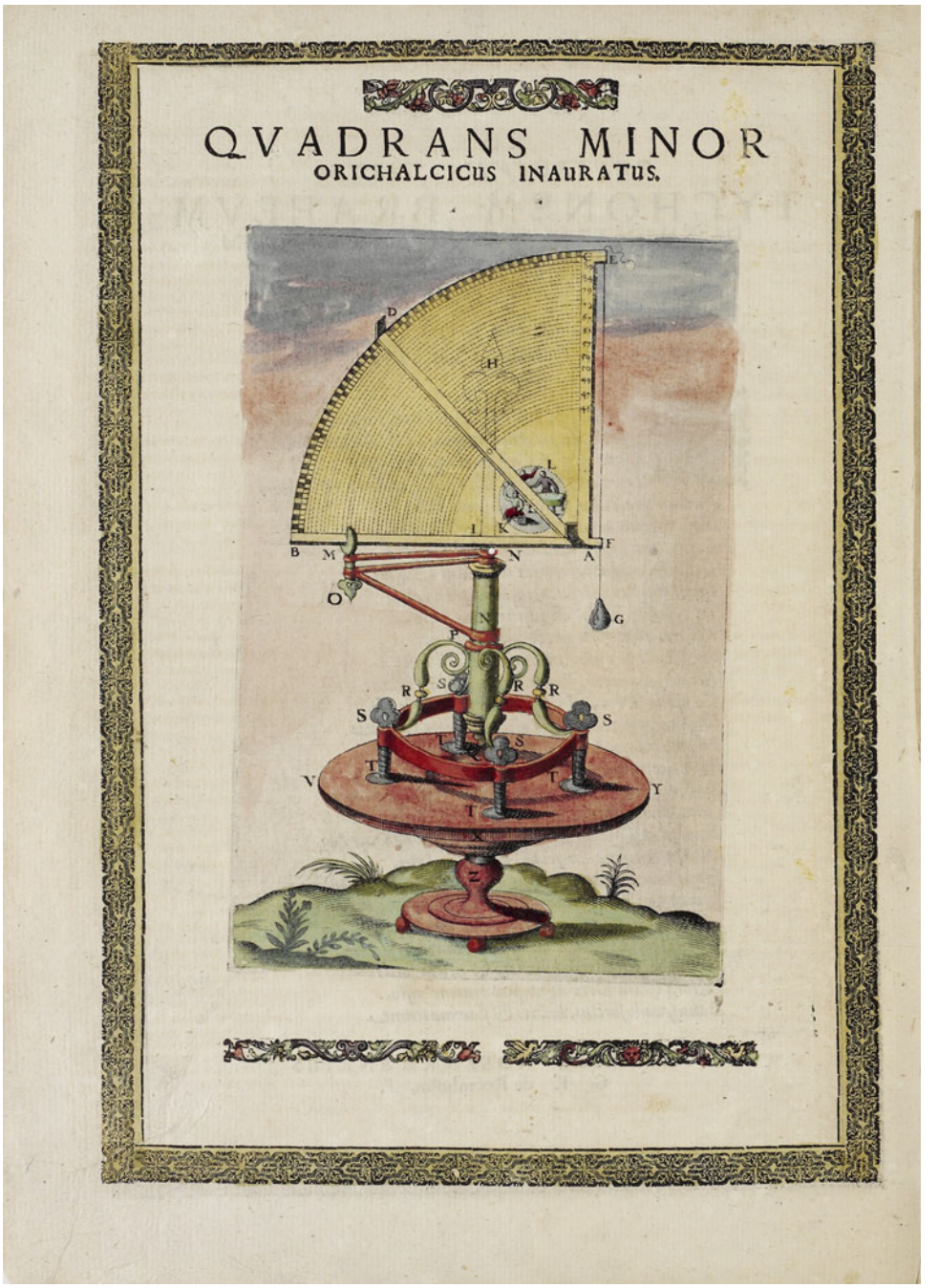

Figure 3. *Quadrans minor orichalcicus inauratus* (Small quadrant of brass). Copperplate engraving on paper, water-soluble paint and gilt.

along the circumference, with the alidade DE positioned to divide the quadrant in half. This again points to notions of order and precision that were so central to the use of the instrument. These notions are emphasized in the head and echoed in the text. Viewer access is again prioritized as our gaze is directed toward the bottom half of the instrument, past the scrolling serpents that facilitate the transfer of weight to the base. We can see the surface of the stool but not the top of the green

Figure 4. *Arcus bipartitus minoribus siderum distantiis inserviens* (Bipartite arc for measuring angular distances). Woodblock engraving on paper, water soluble paint and gilt.

plinths that support the quadrant. If they look closely, observers can see that the two plinths (labeled "Z" and "Y") seem to be simultaneously parallel to and set at an oblique angle to the picture plane. The sharply receding orthogonals of the checkered floor also give the illusion that the instrument is being pushed toward the space of the observer, inviting close inspection. In both the armillary and quadrant

Figure 5. *Sextans astronomicus, prout altitudinibus inservit* (Astronomical sextant for measuring altitudes). Woodblock engraving on paper, water-soluble paint and gilt.

discussed in the preceding text, the instruments encourage the viewer to consider the instruments closely, much as the astronomer would make careful, repetitive observations to obtain reliable measurements of celestial phenomena.

In other prints it is the architectural settings that seem to be awry. For instance, in Figure 11 a sextant for the observation of altitudes appears to be directed toward an arched window, the upper

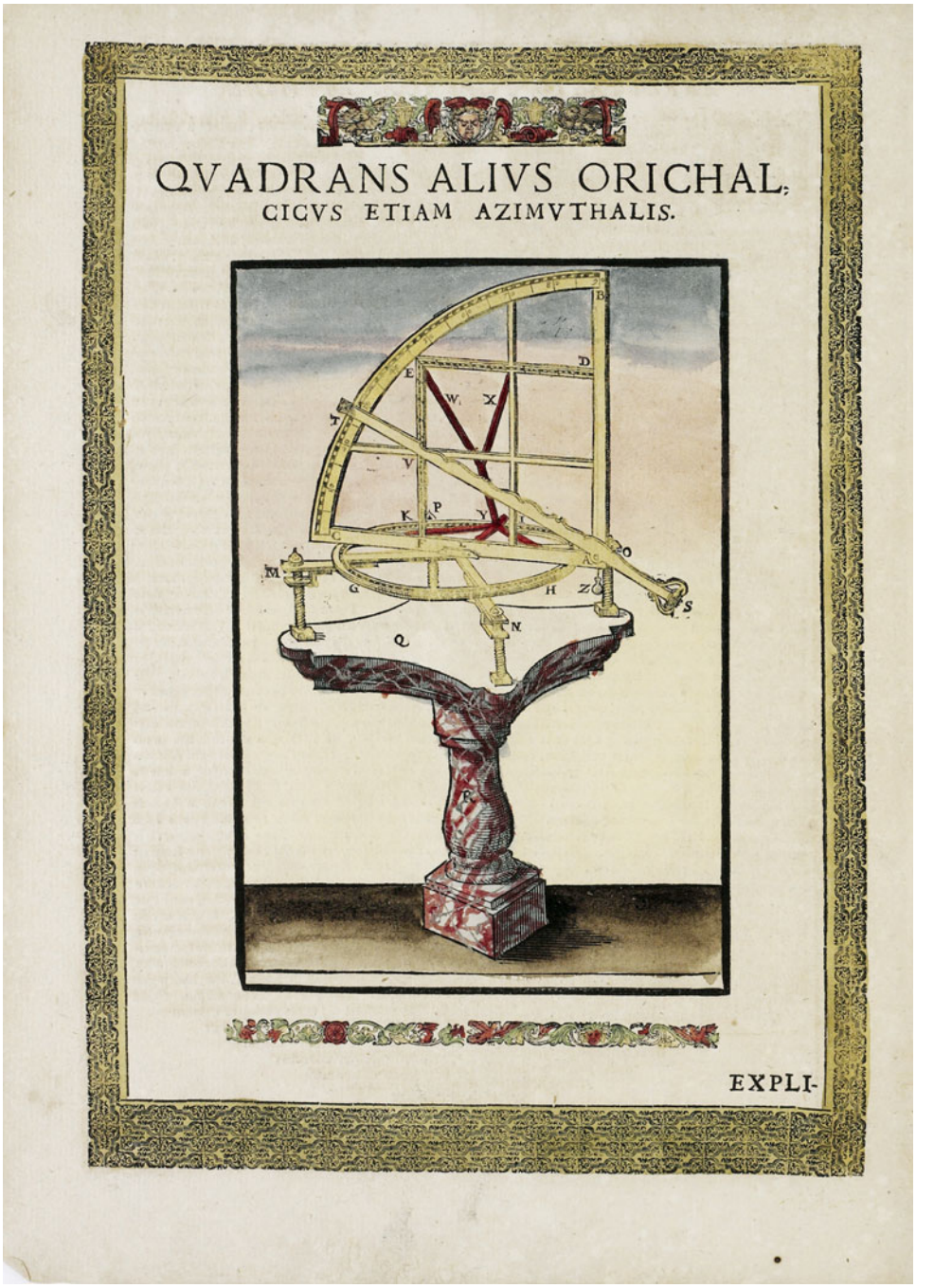

Figure 6. *Quadrans alius orichalcicus etiam azimuthalis* (Another azimuth quadrant of brass). Woodblock engraving on paper, water-soluble paint and gilt.

portion of which seems to be pushed toward the viewer. The instruments represented within a series of encircling steps display similar tendencies: see the *Quadrans magnus chalibeus*, *Quadrans volubilas azimuthalis,* and the *Armilae aequatoriae maximae* (Figures 7, 8, and 9). In all three cases, the circular steps appear to be compressed into the picture plane, suggesting that the instrument is bursting out of its enclosure because of its great size. And, indeed, these instruments, located at the Stjærneborg

Figure 7. *Quadrans magnus chalibeus, in quadrato etiam chalibeo comprehensus, unaquae azimuthalis* (Great steel quadrant, inscribed in a square, also of steel, and revolving in azimuth). Woodblock engraving on paper, water-soluble paint and gilt.

observatory, were very large to give greater resolution of arc in the degree of measurements.[33] In Figure 12, the enclosing wall around the parallitic or ruler-instrument (which has been partially dismantled in the image to provide access to the observer) appears to be leaning toward the viewer at the

[33]Thank you to Jole Shackelford for clarifying this in an earlier draft of this article.

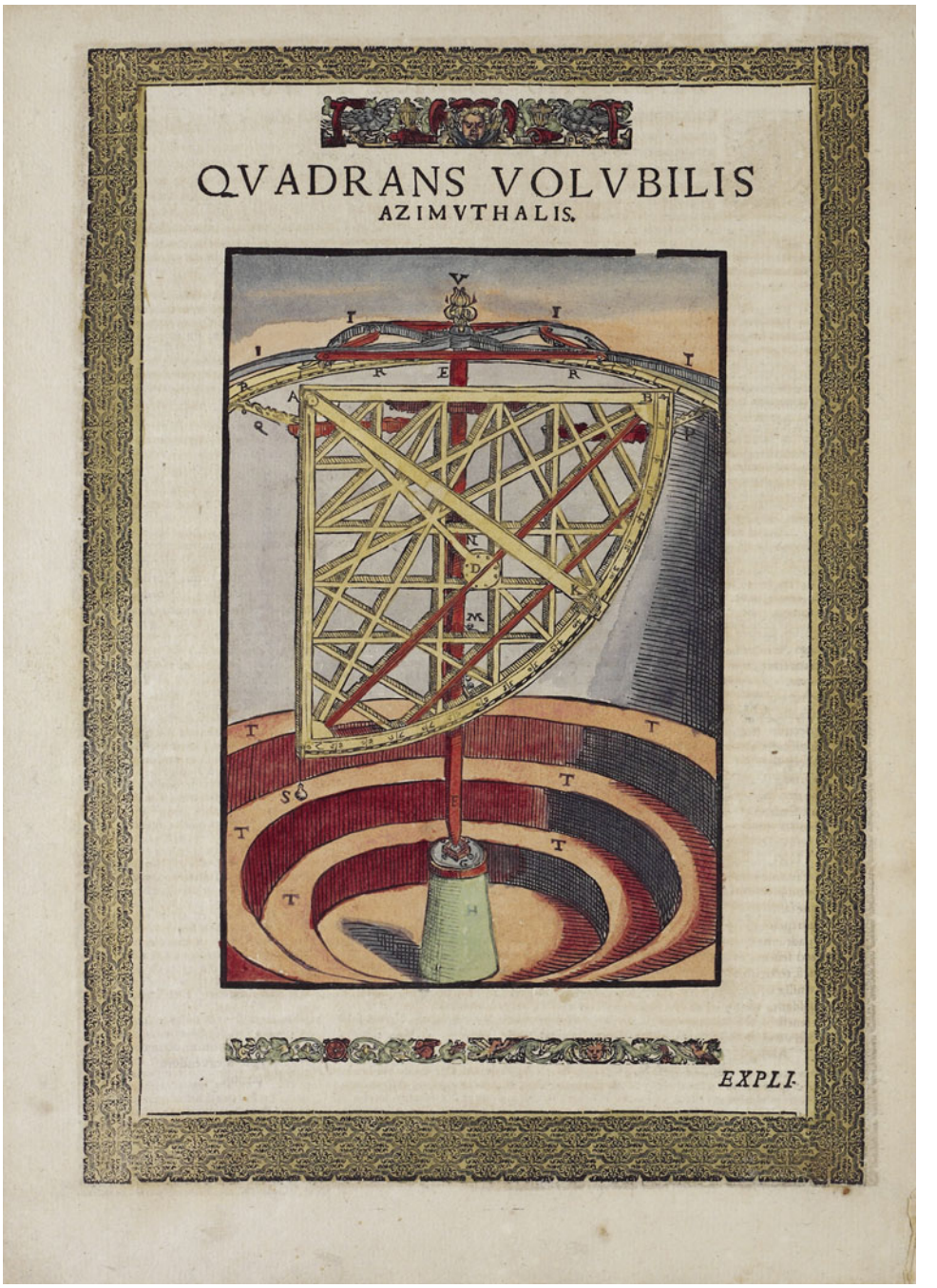

Figure 8. *Quadrans volubilis azimuthalis* (Revolving azimuth quadrant). Woodblock engraving on paper, water-soluble paint and gilt.

point where the bricks are exposed. Even in the print of Brahe's celebrated *Globus magnus orichalcicus* (see Figure 2), which Brahe commissioned for the *Mechanica* as a copper-plate engraving, the horizon (labeled "LMN") appears to be sloping downward. Delineating it more naturalistically likely would have obscured the exact measurements, which are inscribed.

Considering some of these choices, which to a modern viewer may come across as errors on the part of the draftsman responsible for the design of the woodblocks and copperplates, it is plausible that

Figure 9. *Armillae aequatoriae maximae, sesquialtero constantes circulo* (Great equatorial armillary instrument with one complete circle and one semicircle). Woodblock engraving on paper, water-soluble paint and gilt.

certain details were designed with less attention, especially because many of the prints were not initially intended for a presentation treatise. However, as discussed in the preceding text, most of the prints are designed to provide clear visual access to as much of the instrument as possible, especially to the parts of the instruments that contain measurements—components that are emphasized through illumination. Having their attention drawn to the instrument proper, viewers are encouraged to consider the instrument

Figure 10. *Quadrans mediocris orichalcicus azimuthalis* (Medium sized azimuth quadrant of brass). Woodblock engraving on paper, water soluble paint and gilt.

carefully, to focus on the part of the instrument that does the measuring, thus mimicking the action of the observer, who would use these instruments to make observations of the night sky.

Illuminated Instruments

An important feature of these prints is that they are hand-painted using a colorful palate that includes gold. Recent studies on painted prints suggest that the addition of color to the medium of print was not

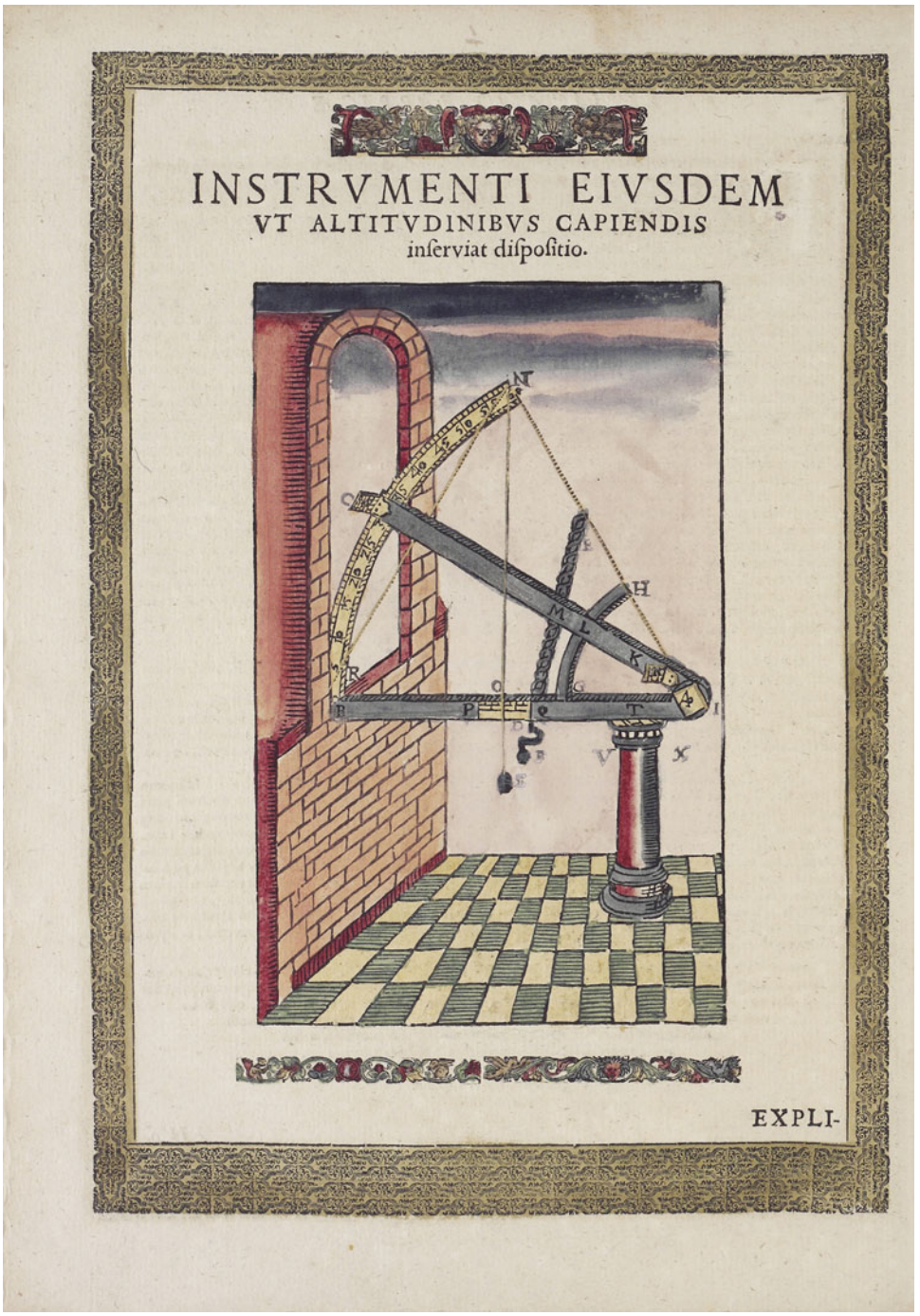

Figure 11. *Instrumenti eiusdem ut altitudinibus capiendis inserviat dispositio* (Mounting of the same instrument for observations of altitudes). Woodblock engraving on paper, water-soluble paint and gilt.

simply a question of aesthetics.[34] In addition to creating a more luxurious effect, the colorful palate in the case of the *Mechanica* also creates contrast, which allows the viewer to more clearly visualize the

[34]See Susan Dackerman, *Painted Prints: The Revelation of Color in Northern Renaissance and Baroque Engravings, Etchings, and Woodcuts* (University Park, 2002); Schmidt and Nichols, *Altered and Adorned*; and Dániel Margócsy, Mark Somos, and

Figure 12. *Parallaticum aliud, sive regulae tam altitudines quam azimutha expedientes* (Another parallatic or ruler-instrument that shows the altitudes as well as azimuths). Woodblock engraving on paper, water-soluble paint and gilt.

different parts of the instruments. Gilding emphasizes the part of the instrument containing measurements while simultaneously bringing to mind the very materiality of the instrument in question,

Stephen N. Joffe, *The Fabrica of Andreas Vesalius: A Worldwide Descriptive Consensus, Ownership, and Annotations of the 1543 and 1555 Editions* (Leiden, 2018), 13–24.

which, as Brahe explains, was often brass fitted. In many of the pictures, contrasting colors are used to differentiate between the head of the instrument and its base, such as in the print of the *Sextans astronomicus, prout altitudinibus inservit*, in which the sextant is painted red (with some parts in gold) and the base is painted green (see Figure 5). In *Quadrans minor orichalcicus inauratus*, the same colors are used not only to distinguish between the base of the instrument (green) and the plinth on which it rests (red) but also to bring out the instrument from the ground—a green mound (see Figure 3). In *Quadrans alius orichalcicus etiam azimuthalis*, red paint is added to the plinth in a manner that suggests marble veining (see Figure 6). In *Armillae aliae aequatoriae*, the use of color helps to bring out the base of the instrument (green), which would otherwise be less visible against the checkered ground (see Figure 13).

Color is also used to differentiate the finer details of the instruments, such as the armillary rings of the *Armillae zodiacales*, where one ring is painted red and the other gilt, while the meridian is grayish-blue (see Figure 14). Here, small rectangular shapes along the meridian are also painted a bright red, such as at points "C" and "D" (similar to what may be seen at points "F," "S," "R," and "E" on the meridian of the *Armillae aequatoriae,* Figure 1).[35] In the copy held at the British Museum in London, illumination makes certain details more discernable, such as the small circular image labeled "K" and "L" in the *Quadrans minor orichalcicus inauratus*; however, this is not followed consistently because the same detail is not illuminated in the copy held at the Royal Library in Copenhagen.[36] In some cases the use of color in the background and foreground serves to situate the instruments indoors or outdoors, connecting them to the ground with a horizon. For instance, the *Armillae aequatoriae* and the *Arcus bipartitus minoribus siderum distantiis inserviens* stand on a darkly colored ground, painted brown (see Figures 1 and 4).[37] Color is also used to draw attention to certain decorative details and iconographic elements that would be hard to see otherwise and that are not discernible without Brahe's explanatory text.[38]

However, the illumination among the copies of the *Mechanica* is not uniform in terms of the colors used or in the attention paid to their application. For instance, the decorative borders around the prints vary: the copy held at Ludwig Maximilians-Universität in Munich and the London copy have green frames, while the Copenhagen copy is yellow.[39] There are also notable differences in the sky. For instance, in the London copy, the *Globus magnus orichalcicus* boasts a sky that is mostly blue, but swirls indicate clouds that turn light gray at the horizon, suggesting a stormy sky. In the Dresden copy, the blue of the sky is mixed with pink; it becomes lighter at the horizon, like a sky at dawn. In the Munich copy, the dark blue and pink above the instrument gradually turn to a light yellow that brightens at the horizon, like a sky at dawn on a summer's day. In the Copenhagen copy, the sky at the top of the image is the darkest of the four, with a suggestion of pink clouds that turn a pale yellow at the horizon (see Figure 2). Although this association of the color of the painted sky with the times of the day is subjective, the use of color nonetheless contributes to the overall experience of the images in a significant way. It reminds viewers of the instruments' function as tools used for the observation of the heavens while making the pictures more interesting and visually pleasing.

Depending on the copy, there is significant range in the use of illumination. For example, in the *Globus magnus orichalcicus*, the illumination in the London copy includes yellow to emphasize a small plant that grows on a mound, whereas in the Dresden copy the plant is subsumed by the green of the foreground. Similarly, the signs of the zodiac on the globe are not differentiated in the latter as they are in the Copenhagen copy, the London copy, or the Munich copy. As pointed out earlier, the absolute legibility of the labels was not of key import: some labels are barely visible because of the application of dark illumination—another inconsistent detail among the copies of the *Mechanica*.

[35]Brahe explains that they are metal clips, some of which represent points of the axis, but they are not specifically discussed in the text. Therefore, for the uninitiated viewer, their purpose is unclear.

[36]For a discussion of its significance and the wider use of iconographic elements on Brahe's instruments, as discussed textually in the *Mechanica*, see Perkins and Taub, "Perhaps Irrelevant," 9–36.

[37]The same is true of the *Semicirculus magnus azimuthalis* and the *Arcus bipartitus minoribus siderum distantiis inserviens* (see Figure 4).

[38]For instance, the figures standing in niches in the colorful base of the *Armillae aequatoriae* (see Figure 1).

[39]The copy at Dresden has a mix of noncolored, red, and green frames.

Figure 13. *Armillae aliae aequatoriae* (Another equatorial armillary instrument). Woodblock engraving on paper, water-soluble paint and gilt.

In addition, the same instrument is often painted in different colors or shades. All these variations contribute to making each copy of the treatise unique.[40]

[40]Because the copies of the *Mechanica* had to be produced and illuminated quickly, it is perhaps not surprising that certain details suggest a hurried process. Perhaps these were then gifted to less illustrious individuals on the part of Brahe. Whether the

Figure 14. *Armillae zodiacales* (Zodiacal armillary). Woodblock engraving on paper, water soluble-paint and gilt.

Much could be said about the illumination, its process, and what it can tell us about the recipient of each copy. There is no doubt that illumination added to the *Mechanica*'s overall aesthetic effect, making it more attractive to royal and noble collectors by giving the impression that each copy was

choice of color and the quality of application tells us anything about the potential recipients of each copy is beyond the scope of this study.

Figure 15. *Quadrans muralis sive tichonicus* (The mural, or tychonian quadrant). Copperplate engraving on paper, water-soluble paint and gilt.

luxurious and one of a kind.[41] But what is important here is that the hand-coloring had other, possibly unintended, consequences. The illumination creates contrast that clarifies parts of the instruments, allowing the viewer to more easily differentiate between components. The illuminated grounds,

[41]For a discussion of illumination of images in the context of medical illustration, see Margócsy et al., *The Fabrica of Andreas Vesalius*, 24; and Dackerman, *Painted Prints*.

which augment the utopian character of the images, may also serve to remind viewers of the instruments' ultimate function: to measure natural phenomena. The use of gilt on key parts alludes to and emphasizes the materiality of the prints' referents, and more so than the suggested outdoor or indoor context of the instrument, it also augments the reality effect of the images, bringing to mind the metallic surface of the brass-plated instruments.

Picturing Methods: The Mural Quadrant

The majority of the illustrations direct viewers' attention to the part of the instrument that does the measuring while also encouraging them to study the illustrated instruments attentively and repeatedly, like an astronomer who would observe the night sky. However, the engraving of the *Quadrans muralis sive tichonicus* (see Figure 15) offers something else: a visually narrated account of Brahe's observational method. It is the only print in the *Mechanica* to do so.

As Brahe describes in the text, the engraving depicts the instrument as it once stood, fastened to a wall at the Uraniborg observatory on which was painted a mural that featured the astronomer himself.[42] In the print, the quadrant acts as a threshold that separates the foreground from the middle and background. In the foreground, three figures use the quadrant to obtain the longitude of stars as they pass the meridian: the observer on the right calls out the moment this happens, the timekeeper calls out the exact time, and the person at the desk writes it down.[43] Depicted from a higher vantage point, the picture behind the quadrant creates the illusion of extending the room, which culminates in tiered architectural views, a distant landscape, and an inscription.[44] Although Brahe notes in the accompanying text that the mural is "not quite relevant," he goes to some lengths to describe it; clearly, it was an important component of the whole, and its representation in the *Mechanica* should be considered.[45]

For Christianson, the mural demonstrates "that Tycho Brahe had created a research institute to probe the secrets of heaven and earth, and that the institute itself comprised a microcosm in harmony with the cosmos."[46] Indeed, moving past the foreground, the viewer meets the the imposing likeness of Brahe. Attired in courtly dress, with partially gilded sleeves and buttons, and seated at a desk, his looming figure presiding over the space. The wall behind Brahe supports two shelves stacked with books, framed on either side by an oval portrait medallion. Beneath is a shallow niche containing a globe. Brahe tells us that the two medallions contain the portraits of King Fredrick II of Denmark and Queen Sophie and that the globe in the niche was a gift Brahe gave to their son and successor, Christian IV, when they visited Hven years ago.[47] The dog at his feet is, as Brahe mentions in the accompanying text, his most loyal dog.[48] Moving to the background, to the upper architectural level, which portrays an outdoor patio with a stone railing, we can see some of Brahe's instruments in the process of being used by observers. In the middle tier, we can see an indoor space separated by his great globe that includes a table on either side and Brahe's assistants working in collaboration. In the lowest tier is an underground laboratory that includes flasks, furnaces, and a single figure; it serves as a visual reminder of another of Brahe's interests: alchemy.[49] Much

[42]According to Christianson, it was painted in 1587 by Hans van Steenwinckle, Hans Knieper, and Tobias Gemperlin (*On Tycho's Island*, 118).

[43]This instrument was used by Brahe to note the longitude of one thousand stars. Thank you to Jole Shackelford for clarifying the use of this instrument.

[44]The inscription reads: "Figure of Tycho Brahe, Otto's son, the builder of this building and of astronomical instruments. In the year 1587, at the age of forty years." Brahe, *Instruments of the Renewed Astronomy*, 34n64.

[45]Ibid., 32.

[46]Christianson, *On Tycho's Island*, 118.

[47]Brahe adds that the king in return had given him a golden chain, "a magnificent work of art, of the kind which he was at the time wont to wear, beautifully worked and adorned with his own portrait." Brahe, *Instruments of the Renewed Astronomy*, 33.

[48]For a discussion about the iconographic significance of the dog in the *Quadrant muralis*, see Karsten Gaulke, "Perfect in Every Sense: Scientific Iconography on an Equation Clock by Jorst Burgi and the Self Understanding of the Astronomers at the Kassel Court in the Late 1580s," *Nuncius* 30, no. 1 (2018): 63–65.

[49]For Brahe and alchemy, see Jole Shackelford, "Tycho Brahe, Laboratory Design, and the Aim of Science: Reading Plans in Context," *Isis* 84, no. 2 (1993): 211–30; and Owen Hannaway, "Laboratory Design and the Aim of Science: Andreas Libavius versus Tycho Brahe," *Isis* 77, no. 4 (1986): 584–610.

could be said about this image and its iconography in relation to the patron-client relationship, but what matters here is that Brahe hoped to convey that loyalty and patronage were key requisites for—and thus important components of—the instauration of astronomy.

But what of the action suggested by Brahe? Looking closely at the open book beneath Brahe's left hand we can see a gilt triangle and sphere, which represent the importance of mathematics. Beside the book lie two small gilded instruments, a compass and a ruler—typical instruments associated with astronomy. Brahe's gesture thus underlines the necessity of knowledge as presented in books by mathematicians and philosophers of the past. However, Brahe's simultaneous action of looking and pointing upward with his right index finger, toward the opening in the wall where measurements of the celestial bodies are being taken by the figures in the foreground, both parallels and supersedes the action of his left hand, suggesting that it is through the doing of it that astronomy will be made anew. Overall, the print articulates that under the direction of Tycho Brahe, and under royal patronage, an instauration of astronomy will be brought about through active observational work by multiple observers working together in collaboration—and using Brahe's many accurate instruments.

Conclusion

Intended as a presentation book for an elite clientele, the *Mechanica* set a new precedent for the publication of independent treatises devoted to a comprehensive description and illustration of mathematical instruments.[50] The textual component of the treatise offered a direct account of the instruments of Brahe's renewed and observationally grounded astronomy (based on the use of multiple accurate instruments and repeated observation and collaboration), while the printed and painted images of instruments embodied some of these very ideas.

For Brahe, repeated observation was the key requisite of astronomy, and the recipients of the *Mechanica* were asked to participate in the act of observation as they beheld its twenty-two woodblocks and engravings. Although one engraving, the *Quadrans muralis*, offered a didactic demonstration of Brahe's methods, the majority involve the viewer by asking them to observe the instruments carefully. By offering expanded access to the instruments and by juxtaposing colors and using gold to highlight the metallic nature of the most salient parts, the images draw the viewer to the main component of the instrument: the part that generates measurements. The illuminated prints of Brahe's instruments do not declare their purpose but instead ask the viewer to observe, to inspect closely and repeatedly, much like an astronomer noting measurements of the heavenly bodies.

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[50]As Jim Bennett notes, the *Mechanica* "established an influential precedent for ambitious observatory astronomers," such as Johannes Hevelius, John Flamseed, and Ole Roemer; "Early Modern Mathematical Instruments," *Isis* 102, no. 4 (2011): 700. See also Bennett, "Instruments and Illustrations in Eighteenth-Century Astronomy," in *Science and the Visual Image in the Enlightenment*, ed. William R. Shea (Canton, 2000), 137–54.

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