Chapter 13

Astrolabes and Medieval Travel

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As Geoffrey Chaucer readied his 10-year-old son for Oxford, he put an astrolabe and instruction manual in his pack, saying:

> Lyte Lowys my sone, I aperceyve wel by certeyne evydences thyn abilite to lerne sciences touching nombres and proporciouns; and as wel considre I thy besy praier in special to lerne the tretys of the Astrelabie ... therfore have I yeven the a suffisant Astrolabie as for oure orizonte, compowned after the latitude of Oxenforde; upon which, by mediacioun of this litel tretys, I purpose to teche the a certein nombre of conclusions aperteynyng to the same instrument.[1]
> [Little Lowys, my son, I have perceived well by certain evidences your ability to learn sciences touching numbers and proportions; and I have also considered your earnest prayer especially to learn the *Treatise of the Astrolabe*. Therefore, I have given you a sufficient astrolabe made for our horizon at the latitude of Oxford, and a little treatise by which I plan to teach you a certain number of conclusions appertaining to the same instrument.]

Chaucer subtitled his treatise "Bred and mylk for childeren," but we should not thereby think that it was a common thing in 1391 for a boy to head out of the house with an astrolabe, any more than Chaucer's career could be deemed common.[2] Setting aside the precocious Lowys, we might well ask whether mature users of the astrolabe would have found the instrument useful for travel, and if so, what evidence exists for their taking them on the road or on the seas.

The queen of medieval instruments

A planispheric astrolabe, like that described by Chaucer, was both an observing instrument that measured angles and a portable analogue computer that could be used to solve astronomical, astrological, and geometric problems.[3] Its design was

1 Geoffrey Chaucer, *A Treatise on the Astrolabe*, in Larry D. Benson (ed.), *The Riverside Chaucer*, 3rd edn. (Boston, 1987), pp. 661–83, quotation on p. 662.

2 Chaucer's *Treatise on the Astrolabe* sometimes carried a Latin title, *Tractatus de conclusionibus astrolabii*, and was based on a popular thirteenth-century Latin text which survives in nearly 200 manuscripts. The text was long, ascribed mistakenly to Māsha'āllāh. See Paul Kunitzsch, "On the Authenticity of the Treatise on the Composition and Use of the Astrolabe Ascribed to Messahalla," *Archives internationales d'histoire des sciences*, 31 (1981): 42–62.

3 Introductory works to the astrolabe include John D. North, "The Astrolabe," *Scientific American*, 230 (1974): 96–106; Sara Schechner Genuth, "Astrolabes: A Cross-Cultural and

based on a model of the universe in which the sun's motion was tracked against the surface of a large celestial sphere centered on the earth. (A glossary of technical terms is found at the end of this essay.)

The typical astrolabe (Figure 13.1) is made of brass and has the following principal parts. On the front, there is the *rete* – a plate so intricately cut and pierced that what remains is a network of circles, arcs, and line segments all lying in the same plane. The circles and arcs on the rete represent the ecliptic, celestial equator, and the tropics of Cancer and Capricorn. The tips of sharp pointers branching off the arcs and lines represent the positions of bright stars. The rete, then, is a flat map of the celestial sphere as it would appear to a spectator at the celestial South Pole, viewing it as projected stereographically onto the plane of the celestial equator.[4] The rete is free to rotate about its center, and this point represents the celestial North Pole and the earth's axis. Behind the net-like rete, and visible through it, there is a flat plate, known as a *tympan*. The tympan is engraved with a stereographic projection of the horizon, meridian, zenith, lines of azimuth, and circles of altitude for a particular latitude. It may also have lines to indicate astrological houses and unequal hours. When the rete rotates on top of the tympan, it simulates the apparent motion of the sun, stars, and planets seen by an observer as they rise and set at his location. A rotating *rule* on top of the rete helps to line up the markings and take readings from them.

Most medieval astrolabes have several tympans whose fronts and backs are engraved for different latitudes. If a user traveled more than 70 miles north or south, he would want to swap one tympan for another, in order to get accurate readings.[5] To keep the alternates near at hand, the astrolabe has a built-in storage compartment. Known as the *womb*, it is the cavity on the front side of the *mater*, the chunky piece of cast brass with a raised rim that forms the shell and back of the astrolabe. The stack of tympans is held fixed inside the mater. The limb on the front of the mater is engraved with markings for equal hours, while the limb on the back is divided into

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Social Perspective," in Roderick Webster and Marjorie Webster, *Western Astrolabes*, vol. 1 of *Historic Scientific Instruments of the Adler Planetarium and Astronomy Museum*, ed. Sara Schechner Genuth and Bruce Chandler (Chicago, 1998), pp. 2–25; A. J. Turner, *Astrolabes, Astrolabe Related Instruments*, part 1of *Time Measuring Instruments*, vol. 1 of *The Time Museum: Catalogue of the Collection*, ed. Bruce Chandler (Rockford, IL, 1985); and David A. King, "The Neglected Astrolabe: A Supplement to the Standard Literature on the Favourite Astronomical Instrument of the Middle Ages," in David A. King, *In Synchrony with the Heavens: Studies in Astronomical Timekeeping and Instrumentation in Medieval Islamic Civilization* (2 vols., Leiden, 2005), vol. 2, pp. 339–402.

4 Imagine a spectator positioned on the surface of the celestial sphere at the South Pole. Every star he sees on the sphere, he will map to the plane of the celestial equator by shifting it up or down along his line of sight. The equator will map to a circle with the North Star at its center. Stars in the northern hemisphere will map to spots within this circle. Stars in the southern hemisphere will map to spots outside of this circle. The stereographic projection is useful because circles on the celestial sphere (e.g., the tropics of Cancer and Capricorn and the ecliptic) are mapped to circles on the plane. The angle between any three stars on the celestial sphere will be the same as the angle between them on the planar map.

5 A one-degree change in latitude is equal to 70 miles traveled north or south.

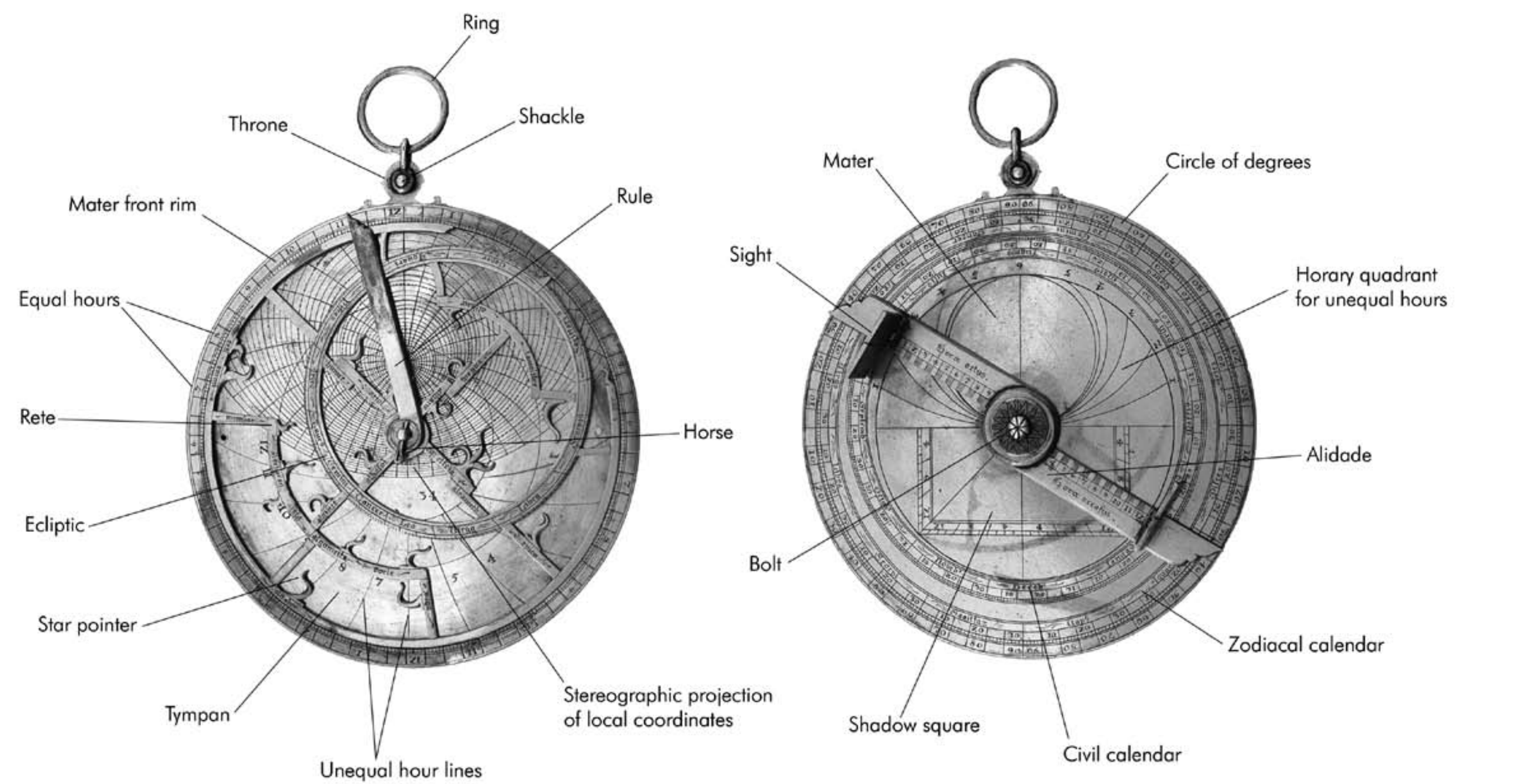

Figure 13.1 Front and back of a planispheric astrolabe made by Jean Fusoris, Paris, c. 1400, Collection of Historical Scientific Instruments, Harvard University, DPW0594.

360 degrees. Within this divided circle are two more circles – one divided into days of the civil calendar and another, eccentric to it, divided into degrees of the zodiac. A rule with sighting vanes, known as the *alidade*, is fastened with a bolt at the center of the mater's back but is free to rotate. The alidade is used to observe the angle of elevation of a celestial body above the horizon. Its edges are also used to correlate a given calendar date with the sun's position in the zodiac. The alidade is also used to observe terrestrial landmarks and measure angles between their parts in conjunction with one or more shadow scales inscribed within the lower quadrants of the mater's back.[6] The most common is shaped like a rectangle divided into two squares, and is known as a *shadow square*. The vertical and horizontal sides of each square are divided into equal parts and use the point where the alidade crosses in order to measure angles in terms of fixed ratios of the sides of the triangle formed (i.e., tangents and cotangents). In the upper left quadrant, eastern Islamic astrolabes typically have a mathematical device to solve trigonometric problems involving sines and cosines. In the upper right quadrant, eastern instruments may have a stereographic projection of the midday sun's declination and zodiacal position, and arcs for unequal hours, the times of prayer, and the azimuth of the *qibla* (the direction facing Mecca). Western Islamic and European astrolabes have horary quadrants for equal or unequal hours in the upper left or right quadrants of the mater. The *bolt* that holds the alidade to the mater also goes through the tympans, rete, and rule. A wedge-shaped pin, called the *horse* (because it frequently takes the shape of a reclining equine) slides through a hole in the bolt to secure all parts of the instrument. The upper part of the mater extends above the outermost divided circles and is called the *throne*. A large ring, suitable for suspending the astrolabe from one's thumb (or from a hook), is attached to the shackle fixed to the throne.

Astrolabes were mathematically complex, difficult to construct, and expensive to buy. Only those with a good grasp on geometry could learn to use them fully and effectively, a point brought home by a late medieval image showing the muse of geometry at work constructing the complex instrument (Figure 13.2).[7]

Astronomers were the primary users of astrolabes. The instrument became a badge of their profession, almost always appearing with astronomers (or their muses) in portraits (Figure 13.3).[8] First and foremost, the astrolabe was a star-finder, able to locate the sun, stars, and planets in the sky and to discover the times of their risings and settings. Since this could be done without ever going outside, the instrument was prized as a teaching tool and astronomical calculator. Outside, astronomers used their astrolabes to observe the altitudes of heavenly bodies and determine their

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6 First mentioned by al-Khwarizmi (d. after 847/8 AD), shadow scales appeared very early on Islamic instruments. King, "The Neglected Astrolabe," p. 368.

7 Gregor Reisch, *Margarita Philosophica* (Strasbourg, 1504), book 6, tract 1, ch. 1.

8 For example, Levi ben Isaac hijo Caro, Barcelona, 1348 (Det Kongelige Bibliotek, Copenhagen, Cod. Hebr. 37, fol. 114r; Hebrew-Spanish manuscript, 1472, Bodleian Library, Oxford, MS Kennicott 1, fol. 90r; Hebrew manuscript from Germany, ca. 1400–1450, British Library, London, MS Or. 10878, fol. 17r; Bohemian manuscript of *Mandeville's Travels*, ca. 1410, British Library, Add. MS 24189, fol. 15r; Hartmann Schedel, *Büch der Cronicken* (Nuremberg, 1493), fol. CCLVr; Joannes de Sacrobosco, *Textus de sphera* (Paris: 1500); Schechner Genuth, "Astrolabes," figs. 1, 2, 3, 8, 9.

azimuths, latitudes, longitudes, declinations and right ascensions. They also used them to find the angular distances between stars, the lengths of comets' tails, and the parallax of the moon, and to determine when an eclipse would occur and how long it would last.[9] Sinical quadrants inscribed on the backs of eastern, Islamic instruments also helped to solve standard problems of spherical astronomy.[10]

Figure13.2 Geometry making an astrolabe, from Gregor Reisch, *Margarita Philosophica* (1504).

9 Schechner Genuth, "Astrolabes," p. 10.

10 King, "The Neglected Astrolabe," pp. 368, 378.

Figure 13.3 Astronomy represented by a muse holding an astrolabe, sculpted from marble by Giovanni Pisano in 1302 on the central supporting column of the pulpit for the Duomo of Pisa.

Astrolabes made quick work of finding the time during the day or night using observations of the altitude of the sun or a fixed star. The instrument could also be used to compute the duration of daylight or darkness on a given day, and so could provide a traveler with knowledge of the number of hours available for that day's journey. Moreover, many astrolabes demarcated time in both unequal and equal hours, thereby allowing a conversion between the time-telling systems that were favored by monks and rural workers on the one hand, and by astronomers on the other.[11] With the introduction of the mechanical clock in the fourteenth century, equal hours became preferred by workers in urban areas because they tracked time in a similar fashion to tower clocks. It would be wrong, however, to say that the astrolabe was essential for time finding by travelers moving between the countryside

11 Chaucer, *Treatise on the Astrolabe*, part 2, chs. 3, 6–12.

and cities in medieval Europe.[12] Nor was it essential for finding the time of prayers according to the Benedictine Rule introduced in the sixth century. Indeed, Thomas Aquinas turned up his nose, saying, "The Church does not strive for restriction through clever study of time. One does not need to use an astrolabe to know when it is time to eat."[13] For routine time-finding needs at home or on the road, sundials and direct observations of the stars without instruments did the job much more simply and cheaply.[14]

Those in the Muslim world also employed sundials for common time-finding needs but, in contrast to leaders of the Christian Church, they more strongly embraced the astrolabe for religious uses. From the thirteenth century onward, major mosques and madrasas had an astronomer (a *muwaqqit*) whose job it was to regulate the times of the five daily prayers. The astrolabe was his preferred instrument, and many eastern and north African astrolabes were inscribed with silver arcs for finding the hours of prayer from the altitude of the sun.[15] Moreover, from the thirteenth century onward, eastern Islamic astrolabes had apparatus for finding the direction of Mecca. Arcs representing the azimuth of the *qibla* for key cities were engraved on maters and tympans, and gazetteers inscribed within the mater's cavity listed the direction of and distance to Mecca from numerous cities, along with the terrestrial latitude and longitude of each.[16]

Astrology was yet another motive for users of the astrolabe. The astrological houses were engraved directly on the tympans of European instruments, and unequal hour lines served this purpose on Arabic astrolabes. Tables of lunar mansions and more detailed astrological information were inscribed on the backs of eastern maters.[17] Astrolabes were used to determine a newborn's nativity, to find a propitious time to marry, or to lay a cornerstone, or to predict the outcome of a military campaign or long journey. Astrology, moreover, was a major component of medical care in the

12 Cf. Edgar Laird, "Astrolabes and the Construction of Time in the Late Middle Ages," in *Constructions of Time in the Late Middle Ages*, ed. Carol Poster and Richard Utz (Evanston, IL, 1997), pp. 51–69, esp. pp. 53–4.

13 Thomas Aquinas, *In quattuor libros sententiarum* IV, 15.3, 4C, in Roberto Busa (ed.), *S. Thomae Aquinatis Opera Omnia* (7 vols., Stuttgart, 1980), vol. 1, p. 514; quoted in Gerhard Dohrn-van Rossum, *History of the Hour* (Chicago, 1996), p. 79.

14 On time discipline and sundials, see Sara Schechner, "The Material Culture of Astronomy in Daily Life," *Journal for the History of Astronomy*, 32 (2001): 189–222; Stephen C. McCluskey, *Astronomies and Cultures in Early Medieval Europe* (Cambridge, 1998), pp. 97–113.

15 David A. King, "The Astronomy of the Mamluks," *Isis*, 74 (1983): 531–5, esp. 534–5; King, "The Neglected Astrolabe"; Sharon Gibbs with George Saliba, *Planispheric Astrolabes from the National Museum of American History* (Washington, DC, 1984), pp. 31–3, 54, and cat. nos. 4, 70, 85, 86, 87, 88.

16 King, *In Synchrony with the Heavens* (as in note 3), vol. 2, p. 48; Gibbs and Saliba, *Planispheric Astrolabes*, pp. 26–30, and cat. no. 15.

17 For example, astrological terms, faces, planetary governors, triplicities. Johann Stöffler, *Elucidatio fabricae ususque astrolabii* (Oppenheim, 1513), part 2, props. 53–6; Abu Rayhan al-Biruni, *Book of Instruction in the Elements of the Art of Astrology* [1029/30], trans. Robert R. Wright (London, 1934), p. 195; Gibbs and Saliba, *Planispheric Astrolabes*, pp. 16, 32–8, 54.

Middle Ages, and a royal physician might use an astrolabe to cast a horoscope in order to determine the critical days of an illness or the optimum times for bleeding or got the delivery of medications.[18] A reading taken from an astrolabe not only impressed clients but could also be reassuring. Astrologers offered their patrons a sense of control over future events and an opportunity to profit from inside information.

The astrolabe was also well-adapted for surveying territories filled with landmarks. Medieval treatises on applied geometry usually included instructions for the use of the shadow square for solving problems by means of the geometrical relationships of known and unknown quantities. Such problems included the determination of the height of buildings, depth of wells, or distance between inaccessible places. In *Practica geometriae*, for example, Dominicus de Clavasio (fl. 1346) described how to use an astrolabe to find the distance between the summits of two mountains, the length of a valley, or the distance between the foot of a mountain and its summit.[19] Such skills could be useful to travelers who wanted to discover the distance remaining between themselves and a visible, tall landmark of known height (such as a tower or mountain peak), in order to estimate whether they would reach it by nightfall. They would also be of use to an itinerant surveyor or explorer whose job it was to draw up a map. The simple observation of the altitude of the North Star also gave an explorer his latitude.

We cannot doubt that an astrolabe would offer a traveler many advantages. With the instrument, a traveler could find the time and length of day, the hours of prayer, the direction of Mecca, the distance to be traveled, and his latitude. He could cast a horoscope to predict the most propitious day and hour to set off on his journey in order to secure the best outcome for his trip. If he were a doctor, he could determine when best to give medicine on the road. If he were an astronomer, he had at his disposal a highly portable instrument with which to observe the sky and make mathematical calculations as he moved from one center of learning to another. But all this is said *in theory* and does not speak to how often or widely astrolabes traveled *in practice*. To this we now turn.

Astrolabes on the move

Let us begin by examining the diffusion of knowledge of the instrument. We do not know precisely when all parts of the astrolabe came together to form the standard instrument. The stereographic projection, which lies at the heart of the astrolabe, was known perhaps by Hipparchus (ca. 150 BC) and certainly by Vitruvius (fl. first century

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18 Schechner Genuth, "Astrolabes," pp. 12–14; Lynn White, Jr., "Medical Astrologers and Late Medieval Technology," *Viator*, 6 (1975): 295–308; Nancy G. Siraisi, *Medieval and Early Renaissance Medicine* (Chicago, 1990).

19 See Dominicus de Clavasio, *Practica geomtriae* (c. 1346), book 1, and similar works described in Edward Grant (ed.), *A Source Book in Medieval Science* (Cambridge, MA, 1974), pp. 180–3; Edgar Laird and Robert Fischer, *Pèlerin de Prusse on the Astrolabe: Text and Translation of his* Practique de astralabe [1362], Medieval and Renaissance Texts and Studies, vol. 127 (Binghamton, NY, 1995), part 2, chs. 18–20; Chaucer, *Treatise on the Astrolabe*, part 2, chs. 41–3; Stöffler, *Elucidatio fabricae ususque astrolabii*, part 2, props. 30, 58–65.

BC) and Ptolemy (c. AD 160), but there is no conclusive evidence of the existence of the astrolabe as we know it until about AD 375, when Theon of Alexandria wrote a tract on it. This was followed by treatises in Greek by Ammonius (c. AD 390) and John Philoponus (AD 530), in Syriac by Severus Sebokht, Bishop of Nisibis (pre-660), and in Arabic by al-Fazari (late 700s).[20]

Early manufacture was centered on Harran, a Sabian city (now in southeast Turkey) which was a hub for the translation of Greek and Syriac works into Arabic. From there, knowledge spread eastward from the Syro-Egyptian region to Iraq and Persia prior to the tenth century. About a dozen Islamic astrolabes survive from this period; the earliest dated example is by Bastulus (AD 927/8). Continuing eastward, the travels of Persian scholars such as al-Biruni may have brought the astrolabe to India as early as the eleventh century, although the earliest-known Sanskrit text on the astrolabe dates from 1370. Moving westward along the southern Mediterranean, knowledge of the astrolabe reached North Africa and Muslim Spain by the tenth century. Arabic texts and instruments were introduced into the Latin West when Christian and Jewish scholars traveled to Spain and returned with translations in Latin and Hebrew. Most famous among these early "importers" was Gerbert of Aurillac (ca. 945–1003), who demonstrated the astrolabe to his students at Rheims on his return from Catalonia. Knowledge of the astrolabe may also have come directly to Europe from the Byzantine Empire and Greek sources. One Byzantine example dated 1026 survives and was clearly patterned after Islamic instruments.[21]

Although itinerant scholars and treatises in Greek, Syriac, Arabic, Hebrew, Latin, and Sanskrit spread knowledge of the instrument widely, there were few Latin instruments and original texts in Europe before the twelfth century. Indeed, the earliest European astrolabes seem to have been imported Islamic instruments on which Latin names were later engraved alongside the Arabic.[22] By the mid-thirteenth century, however, many Latin manuscripts on the astrolabe were available to scholars, who were introduced to the instrument in their studies of astronomy at the universities.[23] Images of the instrument also began to appear in miniatures and in cathedral sculptures, such as the depiction of a muse with an astrolabe on the central supporting column of the pulpit Giovanni Pisano created in 1302 for the Duomo

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20 Otto Neugebauer, "The Early History of the Astrolabe," *Isis*, 40 (1949): 240–56; Otto Neugebauer, *A History of Ancient Mathematical Astronomy* (3 vols., New York, 1975), vol. 2, pp. 868–79; Turner, *Astrolabes*, pp. 10–13.

21 Schechner Genuth, "Astrolabes," 3–6; Paul Kunitzsch, "Observations on the Arabic Reception of the Astrolabe," *Archives internationales d'histoire des sciences*, 31 (1981): 243–52; David A. King, "The Origin of the Astrolabe According to Medieval Islamic Sources," *Journal for the History of Arabic Sciences*, 5 (1981): 43–83; Turner, *Astrolabes*, pp. 14–29.

22 Turner, *Astrolabes*, p. 29.

23 For example, the census of scientific manuscripts used in the Jagellonian University in Krakow in the fourteenth to sixteenth centuries includes 44 texts on the astrolabe. Grażyna Rosińska, *Scientific Writings and Astronomical Tables in Cracow: A Census of Manuscript Sources (XIVth–XVIth Centuries)*, Studia Copernicana, vol. 22 (Wrocław, 1984); Lynn Thorndike, *University Records and Life in the Middle Ages* (New York, 1944), pp. 281, 403; Charles Homer Haskins, *Studies in the History of Medieval Science*, 2nd edn. (Cambridge, MA, 1927).

of Pisa (see Figure 13.3).[24] Further recognition was encouraged in the second half of the fourteenth century with the production of treatises in the vernacular – most notably in French by Pèlerin de Prusse in 1362 and in English by Geoffrey Chaucer in 1391–92. Around the turn of the fifteenth century, Jean Furoris of Paris established one of the earliest commercial workshops to produce astrolabes and astronomical instruments. His clients included John I, the king of Aragon; Louis I de Valois, the duke of Orléans; Charles III, the king of Navarre; Richard Courtenay, the bishop of Norwich; Henry V, the king of England; and John XXIII, the antipope.[25]

The location of instruments and their imagery suggests that, in addition to university circles, the astrolabe was familiar to those in the church and royal courts, where university-educated men sought preferment. In the later Middle Ages, magnates and princes became patrons of astronomy and were pleased to have Latin or vernacular texts on the astrolabe dedicated to them.[26] Patronage enhanced their prestige and offered evidence of erudition, but more importantly secured them the service of an astrologer, for whom the astrolabe was very handy. Michael Scot consulted his astrolabe in the service of Frederick II, the Holy Roman Emperor (c. 1214–34); and so did Pèlerin de Prusse, in the service of Charles V while he was dauphin (c. 1362). Abraham Zacuto used his astrolabe for the good of John II and Manuel I, kings of Portugal (1481–1521), and Bonet de Lattes in the service of Popes Alexander VI and Leo X (1498–1514).[27] The astrolabe was not only seen as a necessary tool for good government –permitting the astrologer to advise the king on the outcome of military campaigns, forecasts of weather and crops, or the propitious time to marry – but was also viewed as a rare jewel fit for a monarch's treasury. Charles V had no fewer than a dozen astrolabes, including one of gold and two of silver – more than one for each of the eight astronomer–astrologers at his court.[28] His brother, Jean, Duc de Berry (1340–1416), owned exquisite books fastened in gold and silver and encrusted with gems and gilt astrolabes.[29]

Clearly, astrolabes and related texts traveled widely across Europe, the Middle East, and North Africa as knowledge of the instrument was diffused. But once they

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24 Emmanuel Poulle, "L'astrolabe médiévale d'après les manuscrits de la Bibliothèque Nationale," *Bibliothèque de l'École de Chartes*, 112 (1954): 81–103, esp. 89.

25 Emmanuel Poulle, *Un constructeur d'instruments astronomiques au XV^e siècle, Jean Fusoris* (Paris, 1963).

26 Adelard of Bath wrote *De opere astrolapsus* for Henry Plantagenet (later Henry II of England) in 1142–46; Pèlerin de Prusse's *Practique de astralabe*, 1362, was dedicated to Charles V of France; Jean Fusoris's *Composition et usage de l'astrolabe*, written 1407–12, was dedicated to Peter of Navarre, Count of Mortrain. See Laird, "Astrolabes and the Construction of Time," pp. 52, 56; Haskins, *Studies in the History of Medieval Science*, pp. 28–9.

27 Lynn Thorndike, *Michael Scot* (London, 1965), p. 32; Laird and Fischer, *Pèlerin de Prusse on the Astrolabe*, pp. 5–8; Thérèse Metzger and Mendel Metzger, *Jewish Life in the Middle Ages* (New York, 1982), p. 157; *Encyclopaedia Judaica*, s.v. "Lattes, Bonet"; Schechner Genuth, "Astrolabes," pp. 6–7.

28 Jules Labarte, *Inventaire du mobilier de Charles V, roi de France* (Paris, 1879), listings 1990, 2072, 2216, 2270 (2 astrolabes), 2427 (3 astrolabes), 2714, 2817, 3119, 3121.

29 On astrolabes as mathematical jewels, see Schechner Genuth, "Astrolabes," p. 8.

were established, questions remain as to whether owners commonly took their instruments with them when they traveled, and whether the common traveler's needs were best met by use of an astrolabe on the road.

Astrolabes in the hands of travelers

There are two principal approaches to answering these questions. The first is to examine the material culture that survives; the second is to analyze textual and visual sources. The material culture consists of astrolabes surviving from the Middle Ages, whose inscriptions, components, and wear and tear might offer evidence of their owners using them on journeys. Twenty-eight European examples are listed in Table 13.1. Although a few instruments are engraved for a single latitude, the others, on average, have four to five tympans and are engraved with projections for six different latitudes. In many cases, the latitudes are spaced two or three degrees apart and cover a wide swathe of Europe from southern Spain to England. This may imply an owner who had cause to travel far. Other astrolabes are inscribed for localities that are closely clustered. For instance, one late fourteenth-century English astrolabe has a single tympan inscribed for latitudes 51° and 51° 34', and another has three tympans for use at 51°, 52°, 53°, 54°, 55°, and 56°, which correlate with major English cities. This would suggest that their users planned to stay close to home or to travel within a small compass. Some tympans are indicative of a special geographical interest of their owners. A Christian on a crusade to Jerusalem would find the 1326 English astrolabe to his advantage; a European doing business in Arabia would want one of the thirteenth- or-fourteenth century Hispano-Moorish instruments with tympans inscribed for latitudes of 22° to 24°, appropriate for Mecca and Medina. Arabic astrolabes of the medieval period are similar to European examples insofar as some are designed for many, widely spaced latitudes, while others are centered on a smaller geographical area. The inclusion of *qibla* devices for orienting devout Muslims towards Mecca reinforces the evidence that the instruments were designed for travel.

Table 13.1 Medieval European astrolabes constructed before 1500

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
French	Unsigned	13th century	IMSS, 1107	2 plates (others missing): 41° and 42° 43° and 44° [Castille and Provence]
Hispano-Moorish	Unsigned	c. 1260	MHS, 37878	7 plates: 38° and “Parisius” 41° [Saragoza] and 42° 45° and 45° 47° and 48° 49° and 50° 55° and “Parisius” 57° and 58°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
Hispano-Moorish	Unsigned	c. 1260	MHS, 43504	5 plates (one unfinished): 12° 24° and 30° 36° and 41° 45° and 48°
Hispano-Moorish	Unsigned	c. 1260	MHS, 49033	4 plates: 30° and 35° 40° and 45° 48° and 52° 55° and 60°
Sicily (Hispano-Moorish)	Unsigned	14th century	MHS, 50769	2 plates: 36° and 41° 45° and 49°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
Spanish	Unsigned	14th century?	BM, MLA 1961,12-1.1	On mater, 15° 3 plates: 23° and 30° 36° and 41° 45° and 48°
Hispano-Moorish	Unsigned	c. 1300	MHS, 45307	7 plates: 22° and 31° 35° and 38° 39° and 43° 40° and 41° 44° and 48° 50° 51°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
English	Unsigned	c. 1300	BM, MLA SL54	On mater, 42° [Rome] 3 plates: 48° 30' “Ma” and 51° 52° [London] and 55° 53° and 54°
English	Unsigned	1326	BM, MLA 1909, 6-17.1	5 plates: 32° 0' [Jerusalem] and 35° 30' “Babilonie” 41° 50' [Rome] and 44° 40' [Montpellier] 48° 32' [Paris] and 51° 50' [Oxford] 66° 0' “Tab[u]la sub polo zodiaci” and “Tabula sub Equinoctiali”
English	Blakene	1342	BM, MLA 1853, 11-4.1	2 plates (partly unfinished): 52°
English	Unsigned	c. 1350	MHS, 47901	1 plate: 51°

Origin	Maker	Date	Collection, accession number[1]	Plates and latitudes of projections[2]
Spanish	Unsigned	mid 14th century?	BM, MLA 1893, 6-16.3	In Hebrew and in Arabic transliterated into Hebrew script. 5 plates: 33° and 43° 35° and 42° 36°and 40° 37° and 41° 38° and 39°
English	Unsigned	c. 1370	MHS, 47615	4 plates (one with horizons only): 33° and 36° 38° and 45° 42°

Origin	Maker	Date	Collection, accession number[1]	Plates and latitudes of projections[2]
English	Unsigned	c. 1370	MHS, 47869	3 plates: 40° [Toledo] and 42° [Rome] 49° [Cologne] and 49° [Paris] 52° [London] and 57° [Berwick]
English	Unsigned	late 14th century	BM, MLA 1914, 2-19.1	3 plates: 51° [Dover] and 52° [Oxford] 53° [Nottingham] and 54° [York] 55° [Newcastle] and 56° [Berwick]
English	Unsigned	late 14th century	MHS, 49359	1 plate: 51° and 51° 34'
unknown	Unsigned	late 14th century?	MHS, 36338	2 plates (1 unmarked): 47°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
French	Unsigned	c. 1400	MHS, 54330	4 plates: 38° and 40° 42° and 44° 47° and 49° [Paris] 51° 40' [London] and 60°
unknown	Unsigned	c. 1400	MHS, 52869	On mater, a saphaea universal projection 2 plates: 42° and 45° 48° and 51°
French	Unsigned	c. 1400	MHS, 41468	4 plates: 41° and 48° 45° 50° and 51° 52° and 53°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
Paris	Workshop of Jean Fusoris	c. 1400	MHS, 39540	5 plates: 40° and 43° 45° 47° and 51° 53° and 56° “Parisi”
Paris	Workshop of Jean Fusoris	c. 1400	MHS, 53801	4 plates (versos blank): 42° 45° “Parisi” 52°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
French	Workshop of Jean Fusoris	c. 1400	MHS, 49636	6 plates (one blank): 42° 45° and 54° 30' 52° 55° 30' and [Paris] 56° and 51°[?]
French	Workshop of Jean Fusoris	c. 1450	Boerhaave, 3102	2 plates: 44° and 46° 49° and 52°
French	Unsigned	c. 1450	MHS, 47674	On mater, 50° (no plate)
Italian	Unsigned	late 15th century	MHS, 40829	On mater, 38° (no plate)
Italian	Unsigned	late 15th century?	BM, MLA 1867, 7-5.22	On mater, 16° 1 plate (2 likely missing): 45° and 48°

Origin	**Maker**	**Date**	**Collection, accession number**[1]	**Plates and latitudes of projections**[2]
French	Unsigned	late 15th century?	BM, MLA 1857, 5-23.1	On mater, 42° 2 plates (several likely missing): 45° and 47° 49° and 51°

Notes

1 Source of sample: *Epact: Scientific Instruments of Medieval and Renaissance Europe*, www.mhs.ox.ac.uk/epact.

BM	British Museum, London
Boerhaave	Museum Boerhaave, Leiden
IMSS	Istituto e Museo di Storia della Scienza, Firenze
MHS	Museum of the History of Science, Oxford

2 Place names in brackets are marked on the plate in Latin or in abbreviated form. Those in quotation marks are as inscribed.

But we should not be hasty in presuming that hardware for multiple latitudes is a certain indicator that the instrument actually did accompany a traveler to those places. The astrolabe inscribed for Jerusalem also has tympans for the Arctic Circle and equator. It is highly unlikely that its owner would have ventured so far. In fact, there are many western and eastern astrolabes with projections for all the seven inhabitable climates identified by Ptolemy, suggesting that these instruments were intended more as a comprehensive astronomical model, which could be used for calculations pertinent to past, present, or future star positions over many geographical zones by scholars who never removed themselves from home. Not all instruments designed to travel ever did. Many portable astrolabes stayed in university libraries or in the treasuries of princes.[30] Indeed, a person's fascination with a place does not require him to go there. An astrolabe might have appealed to a rich, armchair traveler.

Stronger evidence of travel is found in unusual replacement parts or markings. Astrolabes from the Paris workshop of Jean Fusoris, c. 1400, typically contain four or five brass tympans with projections for four to eight European latitudes within the range of 40° to 56°. An example at Harvard, however, has a single, silver tympan inscribed for 34°, the latitude of Fez and Rabat (Morocco), Sultanabad (Iran), Herat (Afghanistan), and within half a degree of Damascus and Baghdad.[31] This European instrument may have been customized for an owner traveling to or living in the Islamic world. Likewise, an astrolabe preserved in Copenhagen has inlaid arcs marking the azimuth of the *qibla* on only two out of four tympan sides (32°, 34°, 36°, 40°), and these are labeled for Herat (34°) and Samarqand (40°). The instrument was made in 1426/27 especially for Ulugh Beg, the astronomer-prince who established an observatory in Samarqand where he was provincial governor, but traveled back and forth to Herat, the Timurid capital.[32]

Medieval documents on rare occasions refer to an astrolabe with a traveler – as in the case of a priest who took his astrolabe to Norway from the "northern islands" in 1364[33]– but most travel references are theoretical. For instance, university-based readers of the *Sphere* of John of Sacrobosco (fl. 1230–55) learned that the astrolabe could be used by a geographer to find latitude from observations of the Pole Star. Sacrobosco also pointed out that if a person observed the Pole Star from two locations that were separated by one degree along a meridian, he could determine the circumference of the earth.[34] A great idea, but how often did anyone try this? The

30 Turner, *Astrolabes*, 30.

31 Astrolabe, Jean Fusoris workshop, Paris, c. 1400, Collection of Historical Scientific Instruments, Harvard University, inv. DPW0594.

32 Astrolabe, Museum of Decorative Art in Copenhagen, inv. 6/1972, now in Davids Samling, inv. D25/1986; discussed in King, *In Synchrony with the Heavens* (as in note 3), vol. 2, pp. 46, 745–65.

33 R. A. Skelton, Thomas E. Marston, and George D. Painter, *The Vinland Map and the Tartar Relation* (New Haven, 1965), p. 180; cited in Francis Maddison, *Medieval Scientific Instruments and the Development of Navigational Instruments in the Xvth and XVIth Centuries* (Coimbra, Portugal, 1969), p. 12 n. 35.

34 Lynn Thorndike (ed.), *The Sphere of Sacrobosco and Its Commentators* (Chicago, 1949), pp. 85, 122–3.

narrator of *Mandeville's Travels* (written about 1357) reported that he had observed with his astrolabe how the altitudes of the Pole Star and "star Antarctic" varied as he had gone north or south, and suggested how this variation could be used to prove the earth's roundness. Although the narrator wrote as if he were an eyewitness – "I myself have measured it by the astrolabe" – the text is clearly a compilation of other people's data, and not a good one at that, since the numbers are rather dodgy. Illustrations in a Bohemian copy of the manuscript in the British Library do not show the fictitious Sir John Mandeville with his astrolabe in Belgium, Libya, or any of the other places where he claimed to have used it, even though one illumination does depict two philosophers observing the sky with astrolabes in the pure, dry air atop Mount Athos.[35]

Lastly, let us consider the appearance of astrolabes in medieval romances and literature. A recent work of literary criticism has claimed that Chaucer smuggled the astrolabe into his *Canterbury Tales* and had many of the pilgrims silently using it.[36] The claim is far-fetched, but worth considering here, for Chaucer's pilgrims represent a cross-section of society and offer us a vehicle by which to analyze how common knowledge of the astrolabe would have been among travelers.

In the *Canterbury Tales*, the Knight and his son, the Squire, have the highest social standing of all the pilgrims and both have traveled widely on military campaigns. From the Baltic to the Mediterranean, North Africa to Anatolia, the Knight has crusaded against Moslems, Russian Orthodox, and pagans, and has fought as a mercenary in Arabic armies. Chaucer implies that the Knight has served both Peter I of Cyprus and the Sultan Yakoub, Lord of Palatye (in Turkey), and he suggests that the Squire has gone on a crusade with the bishop of Norwich, Henry Despencer, in Flanders, Artois, and Picardy.[37] In the service of these magnates, the Knight and Squire might have seen a court astrologer consulting an astrolabe to predict a military outcome. Even so, an astrolabe was not standard equipment for a knight and it would be highly unlikely for his entourage to have had one in their saddle bags.

Given that Abelard and Heloise named their son Astrolabe,[38] and many treatises on the instrument were copied in monasteries, we might expect Chaucer's Prioress and Monk to have some modest knowledge of the astrolabe.[39] The Prioress is refined and well schooled, but speaks a coarser version of French than the Parisian style used at the royal court. The Monk, however, is clearly no scholar, preferring his horses, hunting, rich food, and fine clothes to poring over a book in a cloister cell. He is unlearned in astronomy, and an astrolabe would bore him. He is the administrator

35 M. C. Seymour (ed.), *Mandeville's Travels* (London, 1968), chs. 3, 20; Picture book of Sir John Mandeville's Travels (Bohemia, c. 1410), British Library, MS Add. 24189, fol. 15.

36 Marijane Osborn, *Time and the Astrolabe in The Canterbury Tales* (Norman, OK, 2002).

37 Benson, *Riverside Chaucer* (as in note 1), pp. 800–2.

38 Schechner Genuth, "Astrolabes," 7.

39 The oldest extant Latin treatise on the astrolabe was produced in the late tenth century at the Benedictine monastery of Santa Maria de Ripoll in Catalonia. Treatises were copied in monastic houses in Fleury, Liège, Reichenau, Malvern, and elsewhere. See Turner, *Astrolabes*, pp. 16–18; Laird, "Astrolabes and the Construction of Time," pp. 53–4.

of a small monastic cell, but rejects the Rule of St. Benedict as too old-fashioned. The Prioress, on the other hand, is the governess of a Benedictine nunnery. Although she violates many of the rules of her order, she is praised for her chanting of the divine office.[40] Nevertheless, she would not need an astrolabe to find the time of her prayers. When the character of the monk in the Shipman's Tale requires the time, he consults his "chilyndre," which was a type of portable sundial.[41]

The Doctor of Physic holds an advanced degree and has become "grounded in astronomye" at university. He can determine the rising signs and ruling planets and uses this information when deciding the optimum time to bleed his patient, administer medicine, or prepare curative, talismanic "images."[42] Although very late medieval texts boasted that the astrolabe was "not only very practical and even necessary for astrologers, doctors, geographers, and others cultivating the arts and sciences,"[43] few physicians would have used the instrument unless, like Jean Fusoris, they served a person of high nobility. For astrological information, someone like the Doctor of Physic would typically have consulted an almanac such as the *Kalendarium* of Nicholas of Lynn or a medical *vade mecum*.[44] Moreover, the astrolabe was not symbolic of the medieval physician, as it was of the astronomer. The badge of the physician was a flask of urine, for this was his most important instrument. Indeed, the Host, Harry Bailey, refers to it in praise after the Physician's Tale, and the Ellesmere Manuscript of the *Tales* depicts the Physician on horseback with his diagnostic flask.[45]

The most likely pilgrim to know how to use an astrolabe is the Clerk from Oxford and, in the Miller's Tale, the crafty Oxford student, Nicholas, keeps an astrolabe beside his bed "for to lerne astrologye." But the Clerk is too poor to own an astrolabe, having spent his limited resources on books, and so would be Nicholas, the "poure scoler," if Chaucer had been more realistic in his depiction. In fact, although the vulgar Miller is the only pilgrim to refer directly to an "astrelabie," it is implausible that someone of so low a station would have knowledge of the instrument (or of "augrym stones," the "Almageste," or horary questions).[46] This is Chaucer's conceit to put such big words in the Miller's mouth; it is perhaps a joke. It also defies reason to argue that Harry Bailey, the innkeeper, would be using an astrolabe to find the time on the road to Canterbury. A sundial would suffice to know the time of day or the number of hours left until nightfall.

Lastly, there is the Shipman. Chaucer describes him as a ship's master and mariner coming from the west, perhaps Dartmouth, and curiously arrayed in foreign

40 Benson, *Riverside Chaucer* (as in note 1), pp. 803–7.

41 *Canterbury Tales*, Shipman's Tale, p. 206.

42 *Canterbury Tales*, General Prologue, pp. 411–18.

43 Jacob Köbel, *Astrolabii declaratio, eiusdemque usus mire jucundus, non modo astrologis, medicis, geographis, caeterisque literarum cultoribus multum utilis ac necessarius* (Mainz, 1535).

44 Lynn White, Jr., *Medieval Religion and Technology* (Berkeley, 1978), pp. 299, 308–9.

45 *Canterbury Tales*, Introduction to the Pardoner's Tale, p. 305. On uroscopy, see Carole Rawcliffe, *Medicine and Society in Later Medieval England* (Stroud, England, 1995).

46 *Canterbury Tales*, General Prologue, pp. 285–308, Miller's Tale, pp. 3190–220.

clothing and carrying a dagger. Like the Knight, he has traveled from the Baltic to the Mediterranean, but he is more of a rascal. He admits to having embezzled Bordeaux wine from merchants' cargo and is not too concerned with the law.[47] But the Shipman knows his navigational skills:

> ... his craft to rekene wel his tydes,
> His stremes, and his daungers hym bisides,
> His herberwe, and his moone, his lodemenage.[48]
> [... how to determine well his tides,
> his currents, and the dangers near at hand,
> his harbors, and his moon's (position and phases), his pilotage.]

Here Chaucer offers an excellent description of medieval navigation, and we might expect to read of the astrolabe, because it was an excellent tool for explorers and geographers. But we would be wrong. The Shipman exclaims, "Ther is but litel Latyn in my mawe!" and such a complex instrument would have been beyond his ken.[49] The astrolabe was a latecomer to navigation and would not make its mark at sea until the end of the Middle Ages.

We must conclude, then, that none of Chaucer's pilgrims would have had both the means to own and the knowledge and cause to use a precious astrolabe. Setting aside the rare cases of an astronomer on a journey or a royal astrologer in the entourage of a prince, we find little conclusive evidence among material culture, written reports, stories, travel literature, or illustrations of medieval travelers taking an astrolabe on the road or to sea until the late fifteenth century.

Astrolabes go to sea

In the Middle Ages, ships traveled within the Mediterranean, skirted around Europe, and across the Indian Ocean using both the techniques of coastal navigation and those for sailing in open waters. In coastal areas, the earliest instruments were the sounding pole or sounding lead and line, which were used to measure the depth of water and sample the seabed. Knowledge of the tides, the establishment of port, and the age of the moon were also essential and usually held in memory before the introduction of tide tables. Local pilots steered the vessel in shallow water on behalf of the ship's master who would be unfamiliar with some foreign coastlines.[50]

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47 *Canterbury Tales*, General Prologue, pp. 388–410, Epilogue to Shipman's Tale, pp. 437; William Sayers, "Chaucer's Shipman and the Law Marine," *The Chaucer Review*, 37 (2002): 145–58.

48 *Canterbury Tales*, General Prologue, pp. 401–3.

49 *Canterbury Tales*, Epilogue to the Man of Law's Tale, p. 1190.

50 E. G. R. Taylor, "The Early Navigator," *The Geographical Journal*, 113 (1949): 58–61; E. G. R. Taylor, *The Haven-Finding Art* (New York, 1957), pp. 35–64; Charles O. Frake, "Cognitive Maps of Time and Tide Among Medieval Seafarers," *Man*, n.s. 20 (1985): 254–70.

Away from shore, the master guided his ship by winds and stars. The Pole Star in the tail of Ursa Minor (the Lesser Bear, or Little Dipper) gave direction, as did the winds, and the Guard Stars, which rotated around it, served like a hand on a clock to tell time at night. By the thirteenth century, common sailors memorized the position of the Guards at midnight for every month in order to be able to find the time on any night during the year. The changing altitude of the Pole Star, estimated by eye or measured by hand-breadths (and much later by a quadrant or kamal[51]), gave the navigator a sense of his progress toward his desired port as he sailed north or south. The magnetic compass was introduced in the twelfth century and by the late 1200s, ships' inventories listed one or more mariner's compasses, lodestones, sand-glasses, rules and dividers, charts, and sailing instructions. The charts were marked with wind roses and bearings. The sailing directions spelled out the courses to set, the distances between places, the height of the Pole Star at different localities, the shoals and dangers, the landmarks and anchorages, and places to get fresh water. The sand-glasses were used to measure one's time on a given bearing in order to estimate the distance gone; the rule and dividers were used to mark one's position on the chart.[52]

The earliest European mention of a maritime observation of the Pole Star with an astronomical instrument was in 1456/57. The instrument was not an astrolabe but a quadrant. It may have been used because the ship was transporting the sister of King Alfonso from Lisbon to Pisa, and this was a rare occasion when astronomers were on board.[53] In 1483, when describing a pilgrimage to the Holy Land, a German monk noted that on his ship, which also carried very important people, there were "besides the pilot, ... other learned men, astrologers and watchers of omens, who considered the signs of the stars and sky, judged the winds, and gave directions to the pilot himself. ... At night they knew the time by an inspection of the stars." After describing the mariner's compasses, the monk added that the crew had "other instruments with which to judge the course of the stars, the direction of the wind, and the path of the sea."[54] Neither quadrant nor astrolabe was mentioned.

Some authors have claimed that Ramon Lull, writing between 1286 and 1295, implied that Majorcan pilots were using the astrolabe for navigation at that time.[55] This seems to be a misunderstanding of Lull's ambiguous word, *instrumentum*, which was not an astrolabe but a form of navigating table that resolved how to determine the course made good when tacking against the wind.[56] Astrolabes were too costly for the purse of a medieval navigator and too complex for his needs.

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51 An Arabic instrument for measuring angles, consisting of a rectangle of wood held at a fixed distance from the eye by means of a knotted cord.

52 Taylor, *Haven-Finding Art*, pp. 89–148; Alfred Clark, "Medieval Arab Navigation on the Indian Ocean: Latitude Determination," *Journal of the American Oriental Society*, 113 (1993): 360–73.

53 Taylor, *Haven-Finding Art*, p. 159.

54 Ibid., pp. 143–5.

55 Gunther, *The Astrolabes of the World* (2 vols., Oxford, 1932), vol. 2, p. 524; Peter Ifland, *Taking the Stars: Celestial Navigation from Argonauts to Astronauts* (Newport News, VA, 1998), p. 6.

56 Taylor, *Haven-Finding Art*, pp. 117–8.

This changed in the mid to late fifteenth century, when Prince Henry the Navigator and successive Portuguese monarchs sought to establish new trade routes and settlements further west into the Atlantic and south down the coast of Africa. At this time, sailors were taught to sail north or south until the *altura* (height) of the Pole Star was the same as that for their destination, and then to go east or west at that *altura* until they reached landfall. After the equator was crossed in 1474, the Pole Star could no longer be seen and the *altura* method was converted into one based on latitude, which could be found by the altitude not only of the Pole Star but also of the midday sun corrected for solar declination. For this purpose, King John II of Portugal in 1484 convened a group of scholars who produced a manual, *Regimento do Astrolabio e do Quadrante*, which provided rules on the use of astronomical instruments for navigation. At first, the quadrant was tried but, being hand-held, proved difficult to keep vertically aligned on a rocking ship. Next to be tried was the planispheric astrolabe, which swiveled from a suspension ring and so could stay vertical in spite of the rolling waves. Nevertheless, it still had a tendency to sway in rough, windy weather. This problem was mitigated in the late fifteenth century, when the astrolabe was stripped of all its non-essential and most costly parts, leaving only a heavily weighted brass plate with a graduated limb and an alidade whose sighting vanes were closer together. The new sea astrolabe was used as early as 1481 by Diogo d'Azambuja on a voyage down the west coast of Africa, and by Bartolomeu Dias on his trip to the Cape of Good Hope in 1487–88. Christopher Columbus employed a sea astrolabe in 1492, and Vasco da Gama had a large wooden one at St. Helena Bay, South Africa in 1497. When Ferdinand Magellan began his circumnavigation of the globe in 1519, he took six metal astrolabes and one wooden one.[57]

Although the first form was a solid plate of brass, in 1517 an Italian spy reported that the Portuguese had begun to use an open, cast-wheel form to their advantage.[58] The new design allowed the wind to pass right through the instrument (Figure 13.4). In this form, the astrolabe came of age as a nautical tool and was readily adopted by European mariners. Only then do we have conclusive proof of the astrolabe, in this specialized form, becoming an essential tool for sea travel.

***

In 1025, Radolf of Liège wrote to Ragimbold of Cologne, inviting him to visit during the festival of St. Lambert in order to see his astrolabe. "You will not be sorry for it," he said.[59] In the eleventh century, an astrolabe was a rare attraction that school masters such as Radolf and Ragimbold traveled to see. Beautiful to

57 Ibid., pp. 162–3; R. G. W. Anderson, *The Mariner's Astrolabe* (Edinburgh, 1972), pp. 3–4; Alan Stimson, *The Mariner's Astrolabe: A Survey of Known, Surviving Sea Astrolabes* (Utrecht, 1988), pp. 13–16.

58 Stimson, pp. 16–18.

59 Marty Catherine Welborn, "Lotharingia as a Center of Arabic and Scientific Influence in the Eleventh Century," *Isis*, 16 (1931): 188–99, esp. 191; McCluskey, *Astronomies and Cultures*, pp. 177–8.

behold and mathematically sophisticated, astrolabes were prized for their utility. They could be used to find time, direction, and latitude, to observe stars and planets, to know risings and settings, to cast horoscopes and teach astronomy, to perform mathematical calculations, and to conduct surveys. Within 300 years of Radolf's letter, astrolabes were more widely diffused throughout Europe, North Africa, and the Middle East, but they remained too costly and complicated to be commonly carried on the roads or seas, despite their apparent usefulness. When they traveled, they were the precious baggage of an astronomer or noble collector. It was not until the late fifteenth century, when Portuguese monarchs had strong economic and political incentives to equip their ships with astrolabes and mathematically trained navigators that astrolabes traveled widely and often.

Figure 13.4 Man using a mariner's astrolabe to measure the altitude of the sun, from Pedro de Medina, *Regimiento de navegacion* (1552).

Glossary

ALTITUDE: The angle of elevation of a celestial object above the horizon.

ASTROLOGICAL HOUSES: A division of the ecliptic into six parts above and six parts below the horizon.

AZIMUTH: An angle measured along the horizon, typically clockwise from north, and used to indicate direction in terms of compass bearing.

CELESTIAL EQUATOR: The projection of the earth's equator onto the celestial sphere.

CELESTIAL POLES: The projection of the earth's north and south poles onto the celestial sphere.

CELESTIAL SPHERE: An immense sphere centered on the earth and to which the stars were thought to be fixed.

DECLINATION: The angular distance north or south of the celestial equator on the celestial sphere.

ECLIPTIC: The circular path of the sun's apparent motion each year against the celestial sphere.

EQUAL HOURS: A time-telling system in which the diurnal period is divided uniformly into 24 hours.

HORIZON: An imaginary circle centered on the observer that marks the farthest extent of the visible surface of the earth and defines the horizontal plane.

LATITUDE, CELESTIAL: The angular distance north or south of the ecliptic on a celestial sphere.

LATITUDE, TERRESTRIAL: The angular distance north or south of the equator on the earth.

LONGITUDE, CELESTIAL: The angular distance east or west of the vernal equinox, measured in the plane of the ecliptic.

LONGITUDE, TERRESTRIAL: The angular distance east or west of the prime meridian, measured in the plane of the terrestrial equator.

LUNAR MANSIONS: The 28 stations of the moon.

MERIDIAN: A great circle on the earth or celestial sphere passing through the North and South Poles and the observer's zenith.

RIGHT ASCENSION: The angular distance east or west of the prime meridian, measured in the plane of the celestial equator (generally expressed in terms of 0 to 24 hours).

TROPIC OF CANCER: The circle on the terrestrial globe (or projected onto the celestial sphere) marking the latitude farthest north reached by the sun, which it achieves at the summer solstice.

TROPIC OF CAPRICORN: The circle on the terrestrial globe (or projected onto the celestial sphere) marking the latitude farthest south reached by the sun, which it achieves at the winter solstice.

STEREOGRAPHIC PROJECTION: A map in which features on a sphere are projected onto a plane tangent to the sphere (or another parallel to this one) from the point diametrically opposite to the tangent. In an astrolabe, features on the celestial or terrestrial spheres are projected onto the plane of the equator from the South Pole.

UNEQUAL HOURS: A time-telling system in which the periods of daylight and darkness are divided into twelve hours each, no matter what the season. Consequently, an hour will grow or shrink in length as the seasons change. Also known as seasonal hours.

ZENITH: The point on the celestial sphere directly above the observer.

ZODIAC: The circular band on the celestial sphere, centered on the ecliptic, against which the sun, moon, and planets appear to move. It is divided into twelve 30° segments, each corresponding with a constellation.

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