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The Astrolabe and Medieval English Life

By BAXTER D. WILSON

> "And men may well preven be experience and sotyle compassment of Wytt, that zif a man fond passages be Schippes, that wolde go to serchen the World, men myghte go be Schippe alle aboute the World, and aboven and benethen. The shiche thing I prove thus, aftre that I have seyn. For I have ben toward the parties of Braban, and beholden the Astrolabre, that the Sterre that is clept the Transmontayne, is 53 Degrees highe. And more forthere in Almayne and Bewne, it hathe 58 Degrees. And more forthe toward the parties septemtrioneles, it is 62 Degrees of heghte, and certeyn Mynutes. For I my self have mesured it by the Astrolabre."
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> (*The Voiage and Travaile of Sir John Maundeville, Kt.* J. O. Halliwell, ed. London: Reeves and Turner (1883).)

SOME ASPECTS OF THE ASTROLABE: ITS HISTORY AND ITS USE IN ENGLAND

I

In the light of modern investigation, Sir John Mandeville has dropped from his former glory. There seems to be a basis in fact for parts of the tales told, but much of it seems to be imagination and second-hand report. One editor, Arthur Layard, believes the tales to be the work of someone trained in a monastery, who may at one time have served as a sort of squire to a knight. One point seems positive; "Other liars have been callous and brazen: Sir John is always modest and conscientious."[1] Like Pooh Bah, he knew the value of "corroborative detail, intended to give artistic verisimilitude to an otherwise bald and unconvincing narrative." If the author of the tales made the observations he writes about, he is to be respected for his earnest endeavor to accurately describe and record things he saw. If the author was perpetrating a gentle hoax, his method is to be admired. But to the student of the history of science it is especially interesting, for it shows the astrolabe to be so well known in the fourteenth century that a writer

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[1] *Voyages and Travels.* Sir John Mandeville. (Arthur Layard, ed.) New York: Appleton (1901). p. x.

could use it to swell the flood of detail in a narrative which helps swing the reader over the spots that may be a shade on the side of the improbable. The astrolabe had come into its own by the XIV century and still had a long, vigorous, and important career ahead.

The purpose of this paper is to give a short survey of the astrolabe in medieval England. The instrument will be described and its astronomical context examined. The uses of the instrument will be touched, as will certain aspects of Chaucer's treatise on the astrolabe. In short, it is an attempt to place the astrolabe in a light that will clarify its place in medieval English life and science.

The term "astrolabe" has been variously used by commentators throughout the history of astronomy. It may be construed to include armillary-type instruments, but throughout this paper, the term will refer only to the "planispheric astrolabe," since that is the customary use of the term by the leading authors today. (The term "planispheric" will be discussed in its proper place in the body of the paper.) Typical of the nonplanispheric type instrument is one pictured by Zinner[2] as a sketch of Ptolemy's astrolabe. This sketch, which shows an instrument that resembles an armillary, throws light on other authors' description of Ptolemy's instrument. (See Note 7.)

Hipparchus gave to western astronomy its first great impetus. He studied and observed at Rhodes from c. 161 to 126 B.C. Some authors attribute to him the invention of trigonometry. He did invent the longitude-latitude system of "fixing" positions for reference, and he discovered the precession of the equinoxes.[3] He was a tireless observer, and catalogued a thousand or more stars. (A commentary on the *Phaenomena* of Aratus and Eudoxus is the only work by him which survives.) However, it was not until Ptolemy began his observations and study that the work of Hipparchus[4] was fully expounded and appreciated.

Ptolemy—Claudius Ptolemaeus[5]—lived and observed at Alexandria in the first half of the second century A.D. He was a versatile scholar and his works include writings on geography, astronomy, and related

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[2] Ernst Zinner. *Geschichte der Sternkunde*. Berlin: Springer (1931). p. 90.

[3] "Precession of the equinoxes" refers to the fact that the year of the seasons is shorter than the year determined by the time at which certain constellations rise and set with the sun. It implies the idea of the equinoxes moving "forward" to meet the sun. This gives a difference of about 20 minutes of time per year. For a discussion of precession, see: H. N. Russell, R. S. Dugan, and J. Q. Stewart. *Astronomy*. New York: Ginn (1945). Vol. I, p. 141 ff.

[4] R. W. T. Gunther, in his *Astrolabes of the World* (Oxford: University Press (1932)), attributes the invention of the planispheric astrolabe to Hipparchus. Gunther writes, "It is said that he was the first man to apply a theory of stereographic projection to the drawing of the celestial sphere upon the plane of the equator. The planispheric astrolabe is impossible without this projection . . ." p. 53. v. I. Gunther indicates that Hipparchus was probably greatly indebted to the Chaldeans for much of his thought and work.

[5] Claudius Ptolemaeus was often confused with some one of the kings of the Ptolemaic dynasty of Egypt. For an interesting note on this confusion, see: G. A. Plimpton. *The Education of Chaucer*. New York: (Oxford (1935). pp. 94, 111.)

subjects. Ptolemy was very much indebted to Hipparchus, but his works far exceeded those of his predecessor. The *Almagest*[6] was the result of Ptolemy's many labors and was the authority to which medieval astronomers turned. One of his major contributions to science was the star catalogue included in the seventh and eighth books of the *Almagest*. This catalogue was a remarkable achievement, and one author says:

"It is the first and most ancient document we possess which gives a description of the heavens of sufficient exactness to admit of comparison with modern observations. For many centuries it was held in highest repute, and indeed, until the time of Tycho Brahe it was practically the only source of information of the positions of the stars which the world possessed; for though in the fifteenth century Ulugh Beg prepared a much more accurate catalogue of Ptolemy's stars, it never came into general use."[7]

Ptolemy is most widely known for the system which bears his name. In short, it was a geocentric system, and the orbits of the sun and planets were seen as a series of epicycles. This system of epicycles refers, fundamentally, to a system wherein each planet revolved about a fictional center. In turn, this "center" revolved about the earth in its circular orbit, or "deferent." Venus and Mercury were distinctive in that they revolved about the earth on their deferents once a year and were always between the earth and the sun.[8] In the course of continued study, epicycle was added upon epicycle by Arabian astronomers until the system became very complicated. The system denied the rotation of the earth upon its axis. However, since Ptolemy's hypothesis explained the motion of the planets and enabled the astronomer to predict, it was acceptable. The Ptolemaic system prevailed until Copernicus (1473-1543) published his theory which replaced the older ideas. However, the epicycle system survived, in one form or another, until Kepler (1571-1630) formulated his laws and showed that the planetary orbits are elliptical.

Thus, the importance of Ptolemy's work to the medieval astronomer is readily apparent. Ptolemy was the author of what was perhaps the greatest single scientific work which had appeared. The observations

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[6] No single definitive edition of Ptolemy's *Almagest*—which embodies his geography and astronomy, among other subjects—has ever been published.

[7] C. H. F. Peters and E. B. Knobel. *Ptolemy's Catalogue of Stars, A Revision of the Almagest*. Washington: Gibson (1915). p. 7.

Here, the armillary sphere is said to have been the instrument employed by Ptolemy. It is probably the same type instrument referred to by Zinner. The armillary sphere which we know is quite different from the astrolabe. Briefly, the armillary sphere consisted of a series of metal rings which represented the "celestial spheres." A meridian and a horizon were similarly represented and imposed about the whole series. The rings were movable and could be made to rotate about a polar axis. The system was then, usually, mounted upon some sort of stand or base.

[8] See: *Astronomy*, p. 243 ff. The authors hint that the system—or a similar one—may have been developed by the ancient Egyptians.

which came down from Ptolemy remained unsurpassed until Tycho Brahe began his astronomical studies.* Although many astronomers gained wide repute between the time of Ptolemy and that of Chaucer, none seriously altered or affected astronomical thought. The writings on astronomy in Chaucer's day and later were usually translations — with or without some further elaboration—or re-workings (such were the later editions of Ptolemy's star catalogue) of the material of the *Almagest.*

II

A description of the make-up of the astrolabe is necessary to visualize its place in medieval English life and science. The material which follows is based on Gunther's translation,[9] Skeat's edition, and Robinson's edition.[10] Astrolabes of the fourteenth century varied from instrument to instrument, but the description which Chaucer wrote is applicable to the vast majority of existing instruments.

The body of the astrolabe was called the "mother." (Figure 1). The mother is a heavy disc of metal with a border—a wide ring of metal—affixed to one side. (This ring was riveted in place and the edge filled to make a smooth disc with a large, flat, uniform cavity on one side—the "front half.") The disc is then tooled at one edge to receive the thumb-ring post which holds the thumb-ring. The mother is allowed to hang free and plumb on its ring and the meridional line is made. (It vertically bisects the mother.) This line is crossed at the center of the cavity (at right angles) by the east-west line. The border is then divided into 24 equal parts, each part representing one of the 24 hours, each designated by a letter of the alphabet, in order and clockwise from south. (See Figure 2.) The quadrants are marked in the border, and are further divided into degrees, 0 to 90 in each quadrant. (In Chaucer's sketches, every fifth degree is marked, and every tenth degree is

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*See: Arthur Berry's *A Short History of Astronomy.* New York: Scribner's (1899). pp. 68-73. Berry's discussion of Ptolemy's works, especially the star catalogue, would indicate something quite different from the position suggested by Peters and Knobel (note 7, above). An examination of the catalogue of Ptolemy, says Berry, reveals that it is probably not Ptolemy's own work. "It is therefore probable that the catalogue as a whole does not represent genuine observations made by Ptolemy, but is substantially the catalogue of Hipparchus corrected for precession and only occasionally modified by new observations by Ptolemy or others." (p. 69). Berry also notes that "Throughout the Middle Ages his authority was regarded as almost final on astronomical matters, except where it was outweighed by the even greater authority assigned to Aristotle." On Ptolemy's observations, we find the words, "That his [Ptolemy's] observations, if not actually fictitious, were at any rate in most cases poor." (p. 73.)

[9] R. T. Gunther. *Chaucer and Messahalla on the Astrolabe.* (*Early Science at Oxford,* Vol. V) Oxford: University Press (1930). Gunther's translation is the only existing one of Chaucer's treatise. It includes the original illustrations, a translation of Messahalla's *Compositio et Operatio Astralabie,* and photocopies of the pages of a manuscript of Messahalla's treatise.

[10] W. W. Skeat. *The Astrolabe,* by Geoffrey Chaucer. Early English Text Society, Extra Series, No. XVI. London: Trubner (1872). A detailed study, it has extensive notes, comments, and a series of sketches. F. N. Robinson, *The Poetical Works of Chaucer,* Boston: Houghton Mifflin (1933).

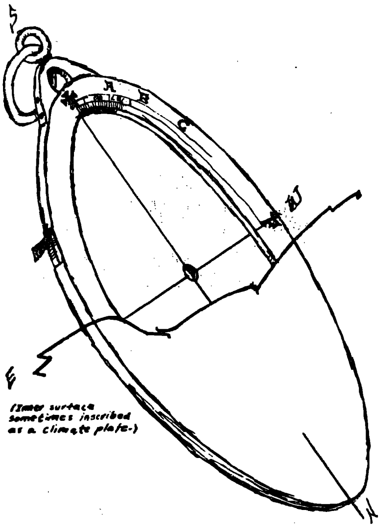

FIGURE 1

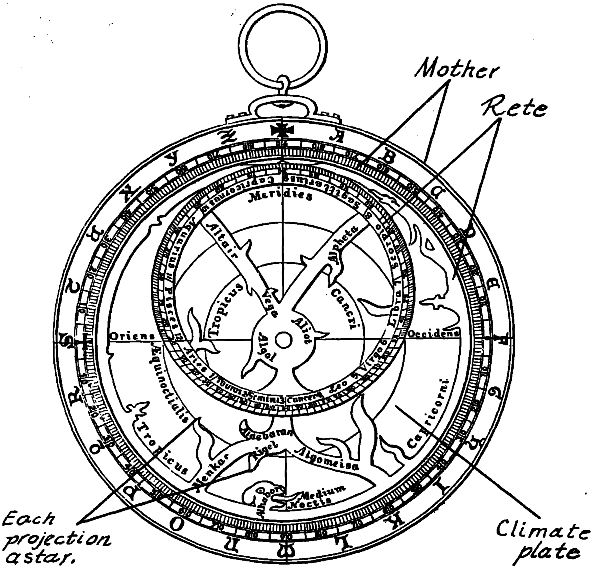

FIGURE 2*

Astrolabe; front half; zodiacal ring represents the zodiacal circle, 30° in width. Center line of zodiacal ring represents the ecliptic. (Copy after Skeat.)

numbered.) Each degree on the border represents four minutes of time. (Five degrees represent a "mile-way," or the average time it takes to walk a mile. Three mile-ways (15 degrees) equal one hour.)

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*Figures 2, 3, and 4 are taken from *The Astrolabe.* Goeffrey Chaucer. Edited by Walter W. Skeat. London: Trübner (1872).

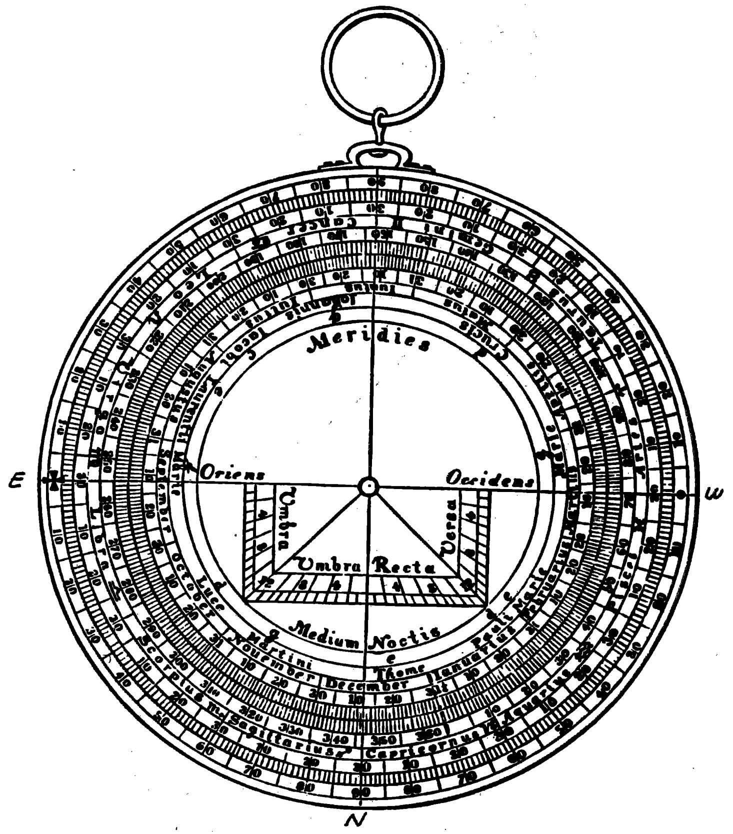

FIGURE 3
Reverse side of Figure 2

The reverse or "back half" of the mother is divided into quadrants coincident with the quadrant divisions on the front half. (See Figure 3.) The back half is scored off with a number of circles, each divided as follows, reading from the outer-most circle toward the center:

(1) Quadrants, divided into five-degree increments, numbered every tenth degree.

(2) Degrees of the circle.

(3) Circle, increments of five degrees, numbered every tenth degree from ten to thirty, for each sign of the zodiac.

(4) Circle of the signs of the zodiac.

(5) Days of the year in five-day increments, numbered every tenth day.

(6), (7) Days of the year and days of the months.

(8) Circle of months, in five-day increments, numbered every tenth day, last number in each month varying according to the number of days in the particular month.

(9) Circle of the months.
(10) Circle of the Saints' days.
(11) Sunday letters of the Saints' days.

In the lower half of the front half, within the circle of Sunday letters, the shadow scales (Umbra versa and umbra recta,/or "extensa"/) are drawn.[11] A small cross, reference point for many operations, is drawn on the east line.

The "climate" plates are circular metal discs which fit snugly into the cavity of the mother. The term climate here refers to the latitude for which a given plate is inscribed. (See Figure 4.) The plate is divided into four quadrants, and the intersection of the quadrant lines is the center of three circles, the "Circle of Cancer," the "Equinoctial Circle,"

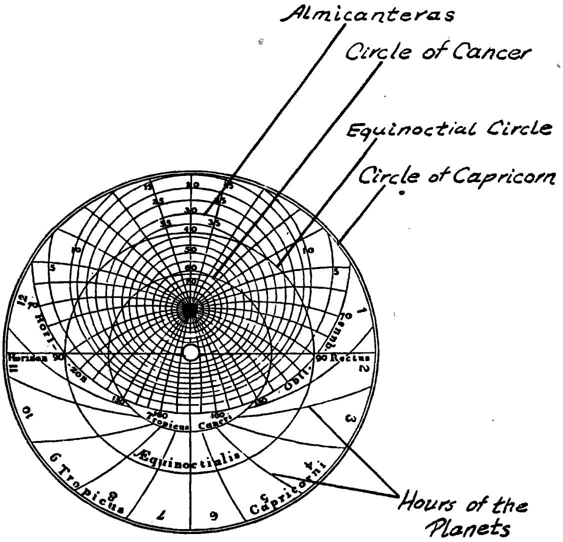

FIGURE 4

Generally, the larger and better the instrument, the greater the number of almicanteras. The center point of the almicanteras, represents the zenith—the point in the sky above the observer's head. Dalton, in describing the Byzantine astrolabe at Brescia, says, "The number of almucantars actually engraved varied widely. The Arabs called an instrument perfect (Tamm), when it was engraved with the full number of ninety almucantars. When every other parallel was engraved, it was a *Nisfi*. If it had thirty, *i.e.*, if no more than every third parallel was marked, it received the name of *Thalthi;* if there was only a line for each five degrees, it was a *Khumsi,* showing eighteen parallels; if one line for every six degrees, it was a *Sudsi* showing fifteen." (*Proceedings of the British Academy, 1926.* London: Oxford University Press.)

Skeat's sketch, copied here, would be a "Khumsi," with a parallel for every five degrees from the horizon ("horizon obliquus") to the zenith. The "Tamm" type instruments were not especially rare; Gunther describes one in *Early Science at Oxford,* II, p. 218.) and many examples in *Astr. of the World.*

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[11] The shadow square was "the most important part of the astrolabe so far as surveying is concerned. To al-Battani (850-929) goes the credit of introducing the shadow square on the astrolabe." E. R. Kiely. *Surveying Instruments.* New York: Bureau of Publications, Teachers' College, Columbia University (1947).

and the "Circle of Capricorn." The almicanteras, the azimuths, and the hours of the planets are also inscribed.

The rete has the strangest appearance of any part of the astrolabe. (The parts of the rete are listed on Figure 2, and the accompanying note.) The rete is made in one piece and rotates around the common center pin of the instrument. Two straight-edges, one on each half of the instrument, were employed. The "rule" was the term applied to the straight-edge on the back. On the rule were the sights used in measuring angles by observation. The label was a simple straight-edge used on the front half.

III

Haskins would date the entry of the astrolabe into Western Europe at about the eleventh century.[12] In the course of the extension of Arabic learning, the instrument found its way into England. That the astrolabe was unknown in England before the eleventh century seems doubtful. In the centuries that elapsed between Augustine's arrival in Kent and the first writings (which survive) on the astrolabe, the instrument must have been known to at least a few of the more scientific scholars. The best arguments for the late arrival of the astrolabe in England lie in the fact that the oldest known astrolabe, the "Anticythera" astrolabe, dates back to c. 250 A.D.,[13] the earliest surviving Arabian instrument is dated c. 950, Moorish, 1029-30, and the earliest of the English instruments is the Sloane[14] which is variously dated c. 1280 to c. 1340. The gap between the Anticythera astrolabe and the first Arabian astrolabe would indicate that the instrument was not so widely known during that period. This does not mean that the instrument was unknown and undeveloped; manuscripts and records of manuscripts indicate some interest in the astrolabe in those early days. Astrolabes came west with the Arabs across north Africa c. 650. This same Arab stock produced the Moors who invaded Spain and ruled there for many centuries. From their position of strength in Spain, the Moors fostered the sciences during this period, and to them the credit for keeping interest alive must be given.

We may consider the year 1091 as the approximate date of entry of the astrolabe into England. It was in that year that Walcher of Malvern arrived from west-central Europe and settled. Walcher constructed lunar tables, and among his works is a list of data which he recorded during the eclipse of October 18, 1092. (His observations were made with an astrolabe.) By the time of his death, in 1135, he "had

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[12] Pp. 113 ff. From his investigations of several MSS., Haskins states his opinion that "an acquaintance with this instrument had in some unknown way passed into Latin Europe in the course of the eleventh century, thus preceding considerably the arrival of the Arabian astronomy as a whole." (p. 115). Entry may first have been through Byzantium when the Turkish inroads on the Byzantine Empire, and the fall of Byzantium, forced many scholars west.

[13] R. W. T. Gunther. *The Astrolabes of the World.* Oxford: University Press (1932). (2 vols.) pp. 55-58, v. I.

[14] The Great Sloane Astrolabe is described by Gunther, *Ibid.*, pp. 463-5.

acquired a reputation as a mathematician and astronomer." It is interesting to read that Walcher probably learned to use Arabic numerals from one Petrus Anfusi, in England.[15] Adelard of Bath[16] was another of the early students of the sciences. He wrote on such varied subjects as his travels, Euclid, and the astrolabe. Haskins mentions the more scientific treatment in the treatise on the astrolabe (c. 1142), both in style and approach to subject matter over the earlier things Adelard wrote. "Succinct, clear, and sharp, the treatise presents in systematic form the preliminary astronomical facts and the various applications of the astrolabe."[17] Adelard went out and sought knowledge in travel and exploration. He did not consider his studies something to be limited by traditional authority; neither did he grab up new information blindly. "The first, so far as we know, to assimilate Arabic science in the revival of the twelfth century, to him we owe the introduction of the new Euclid and the new astronomy into the West." Among the men who followed the teachings of Adelard was Robert of Chester.[18] Among his writings is a treatise on the astrolabe. (London, 1147.) Robert's greatest contributions were his revisions of astronomical tables and his work in alchemy and algebra, the latter two especially important.

The history of the astrolabe between these early times and the date of Chaucer's treatise (1391) is not well known. It would seem that the works devoted to it, or at least touching upon the instrument, were translations of copies of Arabian works, or re-workings of earlier treatises. However, a notable development in the construction of astrolabes may be traced to eleventh century Spain and should be considered here. Al Zarqoli of Cordova (1029-1087) was the inventor of the "arzachel"—a horizontal projection of the sphere. This invention made the astrolabe a universal instrument, and thereby removed the necessity of having a climate plate for each location where the instrument was used. The instrument which Chaucer described in his treatise was the usual type and employed climate plates. Of the astrolabes of England which Gunther lists—fourteen—which were built before the close of the fourteenth century, only the Sloane appears to have a "universal plate."

With this information as a background we can proceed to a discussion of some of the aspects of Chaucer's treatise—"Bread and milk for little children."

IV

Chaucer, then, inherited a wealth of information on the astrolabe.

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[15] *Studies in the History of Medical Science,* p. 115 ff.

[16] *Ibid.,* pp. 20-42. Haskins refers to Adelard as "the pioneer student of Arabic science and philosophy in the twelfth century, and 'the greatest name in English science before Robert Grossetete and Roger Bacon'." He is known from his writings, some of which were translations (p. 20).

[17] *Ibid.,* p. 41.

[18] *Ibid.,* p. 122.

As we have seen, the astrolabe was concurrent with, if it did not precede, the revival of learning in the eleventh and twelfth centuries. In the thirteenth century, the work of the Englishman Sacrobosco gave further impetus to the active interest in the sciences. And Chaucer contributed his bit a century later, by his own treatise—the first treatise of its kind written in English.

Chaucer's personal interests probably first led him to become familiar with the astrolabe and the literature that existed on it. His seemingly insatiable desire to find out all he could about everything he met with led him into studies that the specialized student of today can hardly imagine. An interest in astrology—it crops up often in his work—required that he learn much that was common to the astronomer as well as the astrologer. It was probably in this connection that he first encountered the astrolabe, but it was probably during his time as Clerk of the King's Works that he grew very familiar with the instrument. The journeys in France, Italy, and Flanders might have necessitated the use of the astrolabe.[19] And it is such points as these that make the astrolabe of special interest to the student. The armillary sphere, and like instruments of the period, could not be easily used in the field. In the astrolabe, we find an accurate instrument for the astronomer, required equipment for the astrologer, a necessity for the engineer, and an aid to the traveller.

The astrologer's problem was easily met by the astrolabe. The usual problem of the astrologer was to determine the position of the stars (zodiacal signs) and planets in the heavens at a given point in time and interpret what he found at the time of the observation. Star and planetary tables would give him this information, but the astrolabe would also give him this information more quickly and with much less effort. With one reading and a simple setting, the astrologer could see the positions of the signs and go to work on his horoscope. If the horoscope had to be cast for a period in the past, then a thorough man would need to spend a few hours with the tables. But, for the reading of a particular moment—say to cast the horoscope of a new-born child—the astrolabe offered the simplest solution. Many of the early writers on astrology insisted on the necessity of knowing and using the astrolabe—and well after Chaucer's day, it was considered a requirement of the intelligent physician.

But more interesting are the problems that confronted the engineer which could be solved with the instrument. (Two problems involving the use of the astrolabe will be given elsewhere in this paper.) If he did not trust his estimation by eye, the bridge builder could measure the width of a given river, and then measure the height of the selected trees to see if they would fill his needs. By using his astrolabe he also

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[19] Pocket astrolabes—some less than three inches in diameter—were not unusual. A timepiece that is also useful in geographical orientation is a valuable instrument for any traveller.

determined—if necessary—the time of the next high tide in order that he might utilize his time available to the fullest. Many of the treatises on the astrolabe are more descriptions of the things that can be done in the field than anything else.

The earliest use of the astrolabe in navigation is usually credited to King John II of Portugal, who reigned from 1481 to 1495.[20] In order that he might find some method that his ships might employ to keep to a given course at sea, he employed Roderich, Joseph, and Martin Behaim of Nurenberg to study the problem. Their solution utilized the astrolabe. It is difficult to believe that this was the first instance of using the astrolable in navigation. The instrument had been pretty well exploited by the time of John II, and it does not seem likely that such an excellent use for the instrument would have remained unknown so long.[21]

Of the many operations possible with the astrolabe, we may easily examine two which will serve to indicate the versatility of the instrument and which will also show its simplicity of operation. Two common problems were determining the time and determining the height of a given tower, tree, or the like. Essentially, the operations of the astrolabe involve using the moving parts to set the data of the problem in hand and then determining the result from the information in the borders. Some operations involved interpolation between graduations marked on the borders, but these were not too elaborate for field work.

Assume that it is a fair day and the observer wishes to set the clock he has succeeded in wheedling from a rich friend who has just returned from the continent. Astrolabe in hand, he sets forth. From the position of his shadow, our observer checks to see whether it is before or after mid-day. (He must check on the general time of the day in order that he may be sure to remember which parts of his astrolabe's information he will use. Too, he remembers that he cannot "justly set a clokke" if he uses information obtained between 11 :00 A.M. and 1 :00 P.M.—or the corresponding hours at midnight.)[22] The observer turns his left shoulder to the sun and holds the astrolabe with his right thumb, the back half towards himself. He moves the rule until the light from the sun falls through the sights in the vanes. Then, he reads the number of degrees—the altitude—clockwise from the small cross on the east line. The observer then finds the degree of the sign of the zodiac for the day. (For instance, the degree for the 20th of February is the tenth degree of Pisces.) He turns the instrument over and sets the degree of the sun on the proper (same degree as altitude of the sun) almicantera. He then lays the label on the degree of the sun and

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[20] *Encyclopedia Americana.* New York: The American Corporation (1946). Vol. II, p. 452.

[21] *Astrolabes of the World*, p. 524, v. II. The Spanish philosopher, Raymond Lully (1235?-1315), wrote of the use of the astrolabe in navigation by the Majorcan pilots as early as 1295.

[22] See: *Poet. Works of Chau.*, pp. 647-8, ll. 70-89.

reads the time in the border. If it is before noon, the degree of the sun is set in the east side of the almicanteras; if it is after noon, the setting is in the west half of the almicanteras. If before noon, the time is read in the border of the left half—one to twelve from North clockwise; if after noon the reading is on the right half of the border, reading from South clockwise. (The ascendent is read on the east side of the "horizon obliquus"—the lowest of the almicanteras—and it is that sign of the zodiac then crossing the horizon obliquus.)[23] Since each degree in the border represents four minutes of time, this determination could be quite accurate on a moderately large instrument.[24]

One of the most valuable of the features of the astrolabe was the system of shadow scales. These scales are based on a 45° right triangle. (See Figure 3.) Each scale was divided into twelve equal parts, and the constant relation of the sides made the solution of systems of right triangles—one of which would be represented in the shadow scales—quite simple. Assume that we wish to find the height of a given tower. As did Chaucer, we will assume that we measure a convenient distance—20 feet—from the base of the tower. From this point, we measure the angular height of the tower with the rule. In this case, assume that we read in umbra recta the number "4." We then know that the distance from the observer to the base of the tower represents four-twelfths (one-third) of the height of the tower; in this case the altitude of the tower is found to be 60 feet. If the base of the tower were inaccessible, a procedure employing the umbra versa was used. This involved two readings on the tower and a known distance between the points of reading. In either case, the eye-level height of the observer was added to the computed height.

As we have seen, these are merely two of the operations which were performed with the astrolabe. (An enterprising gunner could have used the instrument as a range-finder in much the same way as would the engineer in determining distances.) Centuries later, instruments of the engineer — and the astronomer — embodied the use of the telescope, but the problem and its solution were much the same.

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[23] The procedure at night is much the same, and involves observations on a fixed star. It may be summarized as follows:

1. Take altitude of a star represented on rete.
2. Note degree of sun for that day.
3. The center (point of projection which represents star) of the star is laid in the almicanteras on the observed altitude. (West almicanteras.)
4. Lay the label over the degree of the sun and read the time in the border.
5. The ascendent may be read from the east horizon.

[24] Existing astrolabes of the XIV century range in size from "pocket models" to instruments large enough to require some method of suspension—or a very strong arm. The Great Sloane Astrolabe is 18.25 inches in diameter, 7/16 inch thick, and weighs 30 pounds. Another instrument (c. 1300-50 is only 3 and 3/8 inches in diameter and 3/16 inch thick. In the history of the astrolabe in all countries and ages, we find examples that range from the astrolabes of India which were sometimes as much as seven feet in diameter to a miniature instrument that formed the crest of an Italian ring. Folding pocket models were quite usual in the centuries following that of Chaucer.

Only in the prismatic astrolabe does the name still survive today. The plane-table—"forecast" in the astrolabe—is still considered an effective field expedient in sketching terrain. An interesting device of today which is reminiscent of the astrolabe—insofar as measuring unknown sides of triangles is concerned—is the Critchlow slide rule, one of many types of circular slide rules. (The Critchlow is based on logarithms and is used to solve right triangles.)

Thus, we find the astrolabe doubly important in medieval life. It was an instrument for the scientist who was involved in work of a more theoretical nature and the "man on the ground" who had material problems he wished to solve as quickly as possible. This factor—perhaps as important to Chaucer as Lewis' interest in the instrument —led to his writing a treatise and writing it in English.

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We do not know how many treatises Chaucer knew at the time he began work on his *Astrolabe*. Of the many writings he knew were those of Messahalla, Sacrobosco, and Daniel of Morley. There were probably others which have not yet been identified. The treatise—compared to the poet's other work—has been neglected by students of Chaucer. However, Chaucer's dependence upon Messahalla was early recognized, although it has not yet been thoroughly evaluated.

Little is known of the circumstances of Messahalla's life. Gunther[25] calls him "one of the earliest astronomers of Islam." It is believed that he lived in the late eighth and early ninth centuries, "the renaissance of Arabian science and art." He is remembered for his *Compositio et Operatio Astralabie,* one of his many and varied works. Messahalla was a Jew whose homeland was Egypt. He went east, and was taken into service of Al Naubakht, the Persian. While with Al Naubakht, he made the preliminary survey of the site of Bagdad, which was founded in 762-763. In sharp contrast with this side of Messahalla, we find that there is a text attributed to him on the prices of merchandise—the earliest Arab text on that subject.

That Chaucer should have been interested in Messahalla's treatise over others he knew may be due to any number of considerations. Messahalla's treatise is quite lucid in its description of the actual making of an astrolabe. However, no one has yet taken several manuscripts (of different authors) on the astrolabe and attempted a critical comparison. Such a study could throw much light on Chaucer's choice, and on the literature of scientific instruments of the period. Some work in the investigation of sources has been done with the result of demonstrating some interesting points in Chaucer's method,[26] if not in his selections taken from other authors. Mr. Harvey cites one instance where

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[25] *Chaucer and Messahalla on the Astrolabe.*

[26] S. W. Harvey. "Chaucer's Debt to Sacrobosco," *Journal of English and Germanic Philology.* Vol. XXXIV, January, 1935. Urbana: University of Illinois Press.

gation of Chaucer's *Astrolabe* to attempt to determine whether the poet's approach to this problem was the same as that he employed in his poetry—free and extensive, yet intelligent and creative, use of the works of other writers. But before considering his findings, a word or two on Sacrobosco are necessary.

"Sacrobosco" is the Latinized name of John of Hollywood. Generally, he was known as Johannis de Sacrobusco (or, "Sacrobusto").. Of his life and career, again, we know little. Delambre[27] tells us that he was not an astronomer, but rather a learned man who was interested in a revival of interest in astronomy. His *Sphaera Mundi* is probably the best known of his works, although he wrote on other subjects as well. Interest in astronomy, especially as handed down in the *Almagest,* led to his writing an abridged version of the astronomical material in Ptolemy's great work. This abridgment, *Sphaera Mundi,* was the earliest work on astronomy produced in Europe.[28] Sacrobosco's work gave rise to a series of commentators, the best known being Clavius. Sacrobosco lived and worked in the first half of the thirteenth century, but his work was quite important to the European scholar for centuries.

The close relation of Chaucer's treatise to that of Messahalla was soon discovered and examined. Skeat's edition of 1872 had devoted much space to a discussion of this relation and even included the Latin of the second part—"Operatio"—of the Messahalla treatise. It was also early noted that Chaucer had relied on Sacrobosco to some extent, but the assumption was that the influence of Messahalla far outweighed that of any other writer. This assumption was based on identification of certain specific points from Messahalla, especially in the "conclusions," and assuming that the parts in between these noted points were paraphrases or the like from the *Compositio et Operatio.* Harvey has shown that this is not the case. To illustrate the results of his investigation, Harvey points out that many lines, formerly attributed to Messahalla, were taken directly from another author—more often Sacrobosco than anyone else. For example, Section 17 of Part I of Chaucer's *Astrolabe* was shown by Mr. Harvey to consist of seven lines from Messahalla, thirty-nine lines from Sacrobosco, and nineteen which appear to be original. Mr. Harvey notes that the borrowings from Sacrabosco are more direct—often literal translations. Chaucer's paraphrasing is "extraordinarily close to the original."

Among the borrowings from Messahalla and Sacrobosco are surely selections taken from other authors. Mr. Harvey cites one instance where

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[27] J. L. B. Delambre. *Histoire de L'Astronomie du Moyen Age.* Paris: Courcier (1819). "Sacrobosco et ses Comentateurs," p. 241 f.

[28] *Ibid.,* p. 241. "Le plus ancien ouvrage d'Astronomie que l'Europe ait produit, ou qui nous soit parvenu, est la Sphere de Sacrobosco . . ." Delambre also lists the name "Jean Halifax," another of the names by which the scholar was known.

a bit from Daniel of Morley[29] is inserted between two passages taken from Sacrobosco. Such evidence indicates that Chaucer carried the borrowing method of his poetry over into his *Astrolabe*. This reliance on older authorities is to be expected and further work in identification of these authorities should be as enlightening as similar investigations of his poetic works have been.

From these points, we may draw certain conclusions about Chaucer and his *Astrolabe*. We know that the astrolabe was an ancient instrument and many scholars had written on it long before our poet decided to take up the problem. We find that Chaucer chose Messahalla's treatise as a basis and borrowed freely from other sources. (Mr. Harvey sees Chaucer using Messahalla's work for a frame on which he hangs passages from Sacrobosco, and perhaps others.) We still do not know how deeply Chaucer had gone in astronomy, but he had more than a casual interest. He knew the works of Sacrobosco and Daniel of Morley, both of whom probably knew trigonometry. Chaucer had served in capacities requiring a knowledge of, or at least familiarity with, the problems of civil engineering. He had travelled in Italy, France, and Flanders, and may have been acquainted with some of his continental contemporaries who were working in astronomy and the related sciences. The poet may have known some of the men then engaged in work in astronomy and the instruments they used at Oxford. For example, the "Merton astrolabe" is one of the few surviving and most interesting of the English instruments of the fourteenth century. It is unique in its construction.[30] It was primarily a planetary astrolabe —one used in working out problems involving the planets. Chaucer may have known this instrument; Lewis Chaucer was at Oxford and the poet's treatise describes an instrument made for the latitude of Oxford.

Chaucer outlined a monumental task for himself when he described in his preface the proposed extent of his treatise. It was no more than many had done before him, but it was an elaborate plan and one which would have taken quite some time to complete. Of the five proposed parts, only two were completed, and there are many questions unanswered about the portions .which we know. At best, only two of the parts are in a final stage. The first part is a description of the instru-

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[29] Daniel of Morley was a student at Paris and, later, at Toledo. He was much interested in the sciences as they were taught in Toledo and felt the work going on there to be superior to that in Paris. His *Liber de naturis inferiorum et superiorum* quoted by Mr. Harvey was written on his return to England "to explain the teaching of Toledo to Bishop John of Norwich (1175-1200) . . ." See: *Stud. in the Hist. of Med. Sci.*, pp. 126 f.

[30] *Astr. of the World*, pp. 472-4. The Merton has two projections ("ears"), fitted with vanes perforated to be used as sights, which are close to and equidistant from the thumb-ring post. At the base of the left ear on the front half is a rivet and eyelet to which was attached a plumb line for working with a quadrant scale on the instrument. A small projection at the bottom of the instrument —an extension of the north line—was perforated to take a loop holding weights to steady the instrument when it was being used. The instrument does not have the usual raised border, but this feature is shared by other instruments.

ment, and the second is a series of problems, or "conclusions." This much was completed. The third part—a series of tables, the fourth—"to declare the moevyng of the celestiall bodies with the causes" and more tables, and the fifth—"the general rewles of theorik in astrologie" with more tables, were never written. The parts that were finished offer the student a convenient and simple introduction to the instrument. This is apparently what the author intended. But, the proposed treatise would surely have been a healthy bit for Lewis at his "tendir age of ten yeer." In considering the treatise we must remember that it was designed to accompany an instrument which the author had in mind. The MSS. were illustrated with sketches of the parts which were described. We must remember that it is only two-fifths of the original plan, and must be judged as a fragment.

The introduction to the treatise has been of great interest to the student of Chaucer, although the rest of the work seems pretty largely ignored. The identification of the "Lewis" of the introduction has been a problem much bandied about, and only reluctantly do the historians seem to grant that Chaucer could have had a son named Lewis. The literary merits of the introduction are numbered by Robinson: "It is a short specimen, but it indicates that if Chaucer had written any considerable amount of freely composed prose it would have been superior in form to the *Boece* and the *Melibee*."[31]

To the student of Chaucer, a study of the *Astrolabe* is doubly stimulating. Such a study points out new and interesting phases of fourteenth century life which he may never have suspected. More important, perhaps, such a study gives a greater insight into the mind of the man who wrote the *Boece* and the *Troilus*. The work indicates the poet's varied and honest interest in the world around him, and the greatness of his mind. He was not a scientist and did not profess to be one. Chaucer writes in his introduction: "I n'am but a lewd compilatour of the labour of olde astrologiens, and have it translated in myn Englissh oonly for thy doctrine." But in this 'compilation' he has left a great heritage for the student of the history of English science and Chaucerian lore.

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The Paradox of the Foucault Pendulum

By **PAUL E. WYLIE**

The motion of the Foucault pendulum affords an irrefragable proof of the rotation of the Earth. In many places, such pendulums are in operation, so that one may actually see the Earth's rotation. This proof is not overlooked in astronomical texts. The demonstrations of the theory of the pendulum in most texts are, however, incomplete; indeed, statements are often made which lead to a paradox which remains un-

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[31] *The Poetry of Chaucer*, p. 461.