Pseudo-Māshā’allāh
On the Astrolabe

Part VI:
English Translation

by

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[On the Astrolabe: Construction]

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[On the Use of the Astrolabe]

[On the Astrolabe: Construction]

[*Prologue*]

HERE BEGINS THE ASTROLABE [TEXT] OF MESSAHALLA
PROLOGUE TO THE ASTROLABE [TEXT] OF MESSAHALLA

Know that "astrolabe" is a Greek noun whose meaning is "the reception of the stars" because with it the truth is obtained of these things whose knowledge is sought of the positions of the stars. And Ptolemy said that it is like a sphere which has been spread out.[1] And the point of its axis will be visible [there]; and the almucantars,[2] which are on all of its plates, are different from the circles which are [projected vertically from the pole], whose centre is the point of the overhead zenith in the same latitude.[3] And their start is from the circle of the horizon of the same plate[4] in which they (that is, these almucantars) are engraved. We also find the ancients content that there were seven climates for living, this because they found in them the population and the greater part of the housing. And the name "climate" is a Greek name signifying "declination,"[5] For, since the earth is a round shape, those who live on the equator are always in an equality of time;[6] and for those whose overhead zenith is off the said [equatorial] line, the times of the hours become different for them. For this reason the ancients divided the declination[7] into seven sections which they called "climata." And the length of the first part [i.e., the first climate] from the equator was according to the quantity of one equal hour, and the length of the difference of the other parts is a half of one hour; and the difference in the seventh climata reached four equal hours, and the longest day of this place became 16 hours and the shortest 8 [hours].

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1 Many manuscripts have "like a sphere spread out in a plane".

2 Almucantar (Arabic: *al-muqanṭarāt*, المقنطرة; Latin: *almucantharat*): a circle of equal altitude concentric with the zenith of the observer and parallel to the observer's horizon; hence a different plate is needed for each latitude of observation. The Latin word has many variants throughout the treatise. Here it seems to be treated as a feminine plural noun. See Kunitzsch, *Glossar*, no. 31, pp. 535ff.

3 That is, in the same latitude as that for which the plate being used was designed.

4 Astrolabe plates (for various latitudes) were sometimes known as "climates"; this is different from (although related to) the Greek "*climata*" (latitudinal regions) mentioned further on.

It seems that the oldest Arabic-Islamic astrolabes had plates only for the seven climata; in a later development the plates were made for the (geographical) latitudes of specific places. [P.K.]

5 Alternate reading (*entium declinationis*): "...the name of the declination of things".

6 This could refer to the fact that night and day are always the same length at the equator, or to the corollary of this, that the day and night hours are always equal.

7 I.e., the equatorial latitude between the equator and the poles.

[*Construction, Section I*]

FIRST CHAPTER ON THE CONSTRUCTION OF AN ASTROLABE: ON THE PREPARATION OF THE MOTHER

When you wish to make an astrolabe for the latitude of any region, there is one method and it is the same for every latitude. Make a plate for the mother[1] which is wider than the plate for the rete[2] by the amount of the width of the rim (this rim should be a little bit wider than the circle of [the Tropic of] Capricorn), by so much (that is, the amount of space) inside of which the indicator-muri[3] of degrees can be traced out; the indicator-muri is a small tooth projecting from the beginning of Capricorn over the degrees [inscribed] on the aforementioned rim. The depth of this rim should be according to the thickness of the rete, if it be an astrolabe for one latitude; or according to the thickness of the plates and the rete, so that they are level when the pin is inserted and they do not stick out beyond each other.

And you will fasten the rim [together] with rivets in four places or completely, as some people in some places like, as you please. And you will join the rim itself to the mother with tin or silver; and you will make a circle around its edge. After this you will leave space for the inscribing and make again two circles close to one another between which will be the successive degrees of the rete. And you will divide this space which was between these circles into 360 equal divisions and begin to write from the first quarter (between the west and the south) from point A, going to point C, continuing for 360 degrees (God willing[4]).

And you will polish the plate and make it level as best you can. Then draw its diameters which quarter it, intersecting one of them by the other over the centre point E and in such a way that the quadrants are equal; and do the same on the back. And the diameters which intersect on one side of the plate are opposite the diameters which intersect on the other [side], that is, they should be lined up with them.

After this set up in the interior [i.e., central] part [of the mother/plate] the circle

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[1] The "mother" (Latin: *mater*) is the main plate of an astrolabe with a rim within which the rete, and any other plates, can sit.

[2] The "rete" or "net" (also called the "spider") (Latin: *rete/rethe, retis/rethis*) is the open-network plate which displays the positions of the fixed stars and the ecliptic.

[3] The indicator (Arabic: *al-murī*, المري ; Latin: *almuri* or *muri*) is a small pointer, or "hand" on the rete at 270° longitude (the beginning of Capricorn) used to read degrees along the rim. See Kunitzsch, *Glossar*, no. 32a, p. 538. See also Anthony Turner, "Concerning a Pointer on the Astrolabe," *Journal for the History of Astronomy*, 46 (2015), 413-418.

[4] Here and elsewhere, a possible vestige of an Arabic original.

of Aries [i.e., the Equator] and the circle [i.e., the Tropic] of Cancer. Moreover the circle [i.e., the Tropic] of Capricorn is the one which extends to or runs along the outer edge of the plate and this is the largest circle which falls inside the mother.

[FIGURE 1][5]

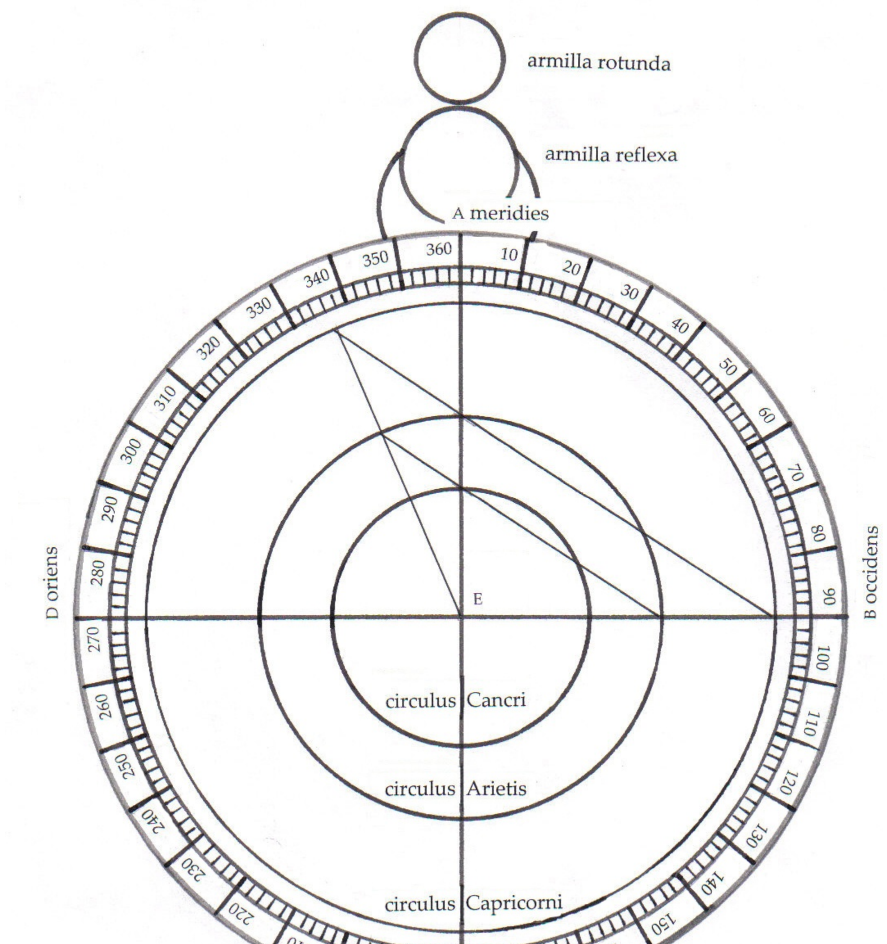

Figure of the interior part of the mother

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[5] The drawing of the equator and the Tropic of Cancer within the Tropic of Capricorn has to be made correctly. No information is given in the text at this point on how to do this; but see Chapter 7.

[CHAPTER 2.] ON THE BACK SIDE OF THE ASTROLABE ; AND FIRST THE CIRCLE OF ALTITUDE

You will make a circle around the edge of the plate and leave a space in which numerals may be written, and you will start to write the numerals from point D, which is at the east, along to point A, which is beneath the armilla,[1] which in an astrolabe indicates the south. And in the same quarter you will complete 90 degrees in this way. You will divide the aforementioned quarter into 18 equal divisions, and you will write 5 in the first division, and 10 in the second, and 15 in the third, and so on increasing up to 90. And with this quarter you will receive [i.e., measure] the altitude of the sun and of the stars. Similarly you will do so in the other quarters.

Now you will begin to write from the eastern point to the southern one, that is, from D to A, as is said above. Then you will begin from point D and make similar [divisions and marks] along to C; after this from B to A; and finally from B to C.

Once these numerals have been marked out, you will next make two circles close together between which will be a small amount of space in which the degrees will be marked; these degrees – as we have mentioned above with the numerals – will be distributed over the 18 divisions in each quarter – 5 in each division – so that in each quarter the 90 divisions[2] of the three signs are found; and there are created all 360 degrees, which are the degrees of the 12 signs. Beneath these you will also leave a space in which you should write the numerals of the degrees, which divide the degrees of every sign into 6 divisions, beginning from the head of the sign so that there are 5 in the first division and 10 in the second and in this way increasing up to 30. And these divisions will be lines coming from the edge of the plate, in order to divide the outer degrees and numerals.

After this you make two circles between which you will leave a space which you will divide into 12 equal parts, in which you will write down the names of the signs, and all of these circles will be based on one point, that is they will have one centre, namely E, which is in the middle of the plate. And you will start from Aries at the beginning of the south-west quarter, which is point B, going towards the south, which is point A; and you will divide each sign into 30 divisions, as above.

After this you will place the ruler on 24°30' of Gemini[3] (however, at this time it

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1 Armilla(e): these are the two suspension rings at the top of the astrolabe. The use of the term here simply indicates means that point A is at the top of the astrolabe.

2 Some mss say "degrees".

3 At issue here is the precession of the solar apsides (about 1.1' per year) and therefore which number to choose. Gemini 24°30' would mean that the aphelion would fall around 9 June (Julian calendar); in AD 2000 it fell on 4 July.

The various numbers here may represent attempts to get a correct position for a current date (as with ms Eυ: Cancer 12° 30' in AD 1443) or error and/or confusion in copying, especially because of the ways 4's and should be placed on 27° and this is because of the motion of the eighth sphere);[4] and will join this to the centre with a fine line. Then you will divide this line from the centre to the circle nearest to it into 32 parts, and you will create an area [i.e., a circle] with the first division from the centre of the circle of signs as its centre;[5] and you will take along this line 30 divisions [as radius], and there will be between both centres one division from these [32] divisions, and between the end of the line [i.e., the radius] [and the circle of signs] another division preventing them from touching each other.[6]

Once more you will make a circle and divide it into 365 divisions according to the number of days in the solar year, if it is a large astrolabe; and if it is a small one, you will draw them two by two. Next inside this you will construct another circle, in which will be the number of the days of the Latin months. After this, you will place the ruler on 15° Sagittarius and join it to the centre of the circle of signs, and you will make a note [where the line crosses] on the circle of months. And this will be the beginning of December, and there will be from here right up to the point C, which is in the north, 15 days and after this gap with the removal of 15 days of December, 350 days will remain, over which you divide the remaining part of the circle, that is, you will multiply 50 seven times, dividing [the space] first by 7, second [each of these 7 parts] by 5, third [each of these] by 2, and once more by 5;[7] and this scheme was devised for the reason

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7's could be written.

Julio Samsó (*On Both Sides of the Straits of Gilbraltar* [Leiden: Brill, 2020], p. 218) notes that the figure of 84°30' for the longitude of the solar apogee is not far off the figure of 85°49' established by Ibn al-Zarqāllah using his observations of 1074-1075; and that the figure of 87° matches a calculation for the solar apogee (coinciding with the apogee of Venus) in his *Almanac* tables for Venus.

[4] A parenthetical note to correct or update the figures given in the previous line by 2°30' or 3°, because of the precession of the solar apsides (here associated with "the motion of the eighth sphere"). The insert is found in both early and late manuscripts, and is missing from both early and late manuscripts.

[5] That is, the centre of the new circle is one division (1/32) away from the centre (E) of the circle of signs.

This solar eccentricity of 1/32 is equivalent to 1;52,30 parts (if the radius of the solar eccentric is 60 parts). Since 1;52,30° is the maximum solar equation (rather than the eccentricity) in Ibn al-Zarqāllah, Samsó speculates that the author of our text made an error here in adopting this figure for the wrong parameter. (Samsó, *On Both Sides*, pp. 418-419.)

[6] That is, if the centre of the new circle is one division (out of 32) away from the centre of the circle of signs, and its radius is 30 divisions (out of 32), the new circle will be inside the circle of the signs (at its nearest point) by one division.

[7] When you divide the remaining arc by 7, you produce 7 units each equivalent to 50 days. When you divide each of these units by 5, you produce 35 units each equivalent to 10 days. And when you divide each of these units by 2, you produce 70 units along the arc, each equivalent to 5 days; and these units are easily divided into single-day units, if necessary.

that multiplication was not appropriate for [the number] 365.[8]

And know that the sun enters the beginning of Aries on 14 March, the beginning of Cancer on 16 June, the beginning of Libra on 17 September, and the beginning of Capricorn on 15 December.[9]

Again, when you divide the year, you will position the ruler on the centre [of the circle] of signs and on the division of the days. And note that the circle of the months can be made concentric with the circle of signs, and it is the same.

[ADDENDUM 2-1][10]

And note that you can always show all the indications (that is, the days and months) of the sun's eccentricity by concentricity, having positioned the ruler on the centre of the eccentric [circle] and on the sign, on which you are directing your attention, up to the end of all the days and months, and this is because of the beauty of the instrument and the convenience and enlargement of the quadrant. Likewise from A towards point B or towards point D you can assume 5 degrees as equivalent to 5 days on the eccentric circle with the ruler positioned on the centre and on 5 degrees. And you will divide the remaining 360 days within the remaining eccentric circle and the degrees.

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[8] I.e., the dividing up of 365 (into 365 equal units).

[9] Compared to the true position of the sun (from the Tables of Toledo), and allowing for rounding to the nearest degree, these dates differ only slightly from those of 1252. (Chabás and Goldstein, p. 85.) [J.C.] Samsó points out that these positions could also approximate those of around 1132 (*On Both Sides*, p. 419).

The difference between these figures and those we are used to, that is, near the 21st of the months in question, is explained mainly by the accumulation of errors in the Julian calendar system.

[10] This material is found in some mss after the third last paragraph, in others after the second last paragraph.

[ADDENDUM 2-2: TABLE]

TABLE: TO KNOW WHERE THE SUN IS AT THE BEGINNING OF ANY MONTH

MONTH[11]	DEGREE	MINUTE	SIGN[12]
March:	16	53	Pisces
April:	17	36	Aries
May:	16	13	Taurus
June:	16	13	Gemini
July:	14	47	Cancer
August:	14	27	Leo
September:	14	35	Virgo
October:	14	12	Libra
November:	15	20	Scorpio
December:	15	51	Sagittarius
January:	17	28	Capricornus
February:	18	53	Aquarius

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[11] Compared to the true position of the sun (from the Tables of Toledo) at the beginning of each month for 1252 (and rounding off the seconds to the nearest minute), most of the values here are between 4 and 6 minutes greater. July is 3 minutes greater and August only 1 minute. (See Chabás and Goldstein, p. 85.)

May is 18 minutes less (but its value is suspicious since the degrees and minutes are the same as for June). It would be more in line with the other months if we were to read Taurus 16º 35' as in some variants.

March is 10 minutes less. There is no obvious explanation for this. [J.C.]

Samsó suggests that these dates also correspond to ca. 1132 (*On Both Sides*, p. 419).

[12] The difference between these positions and those which we would use today (about 6 or 7 days) result from the accumulation of errors in the Julian calendar.

[FIGURE 2]

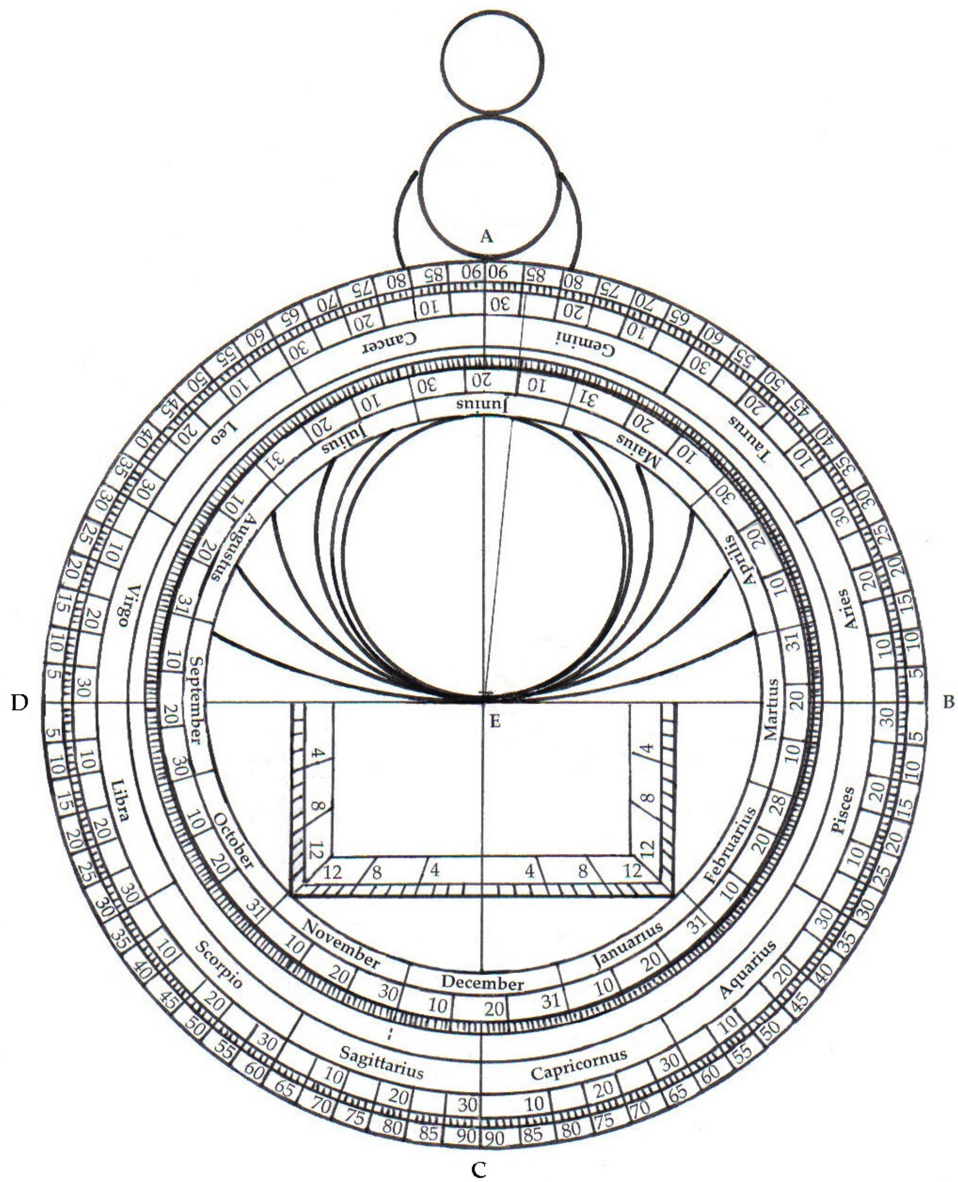

Figure of the back of the astrolabe

[CHAPTER 3.] THE METHOD OF THE ENGRAVING OF THE SHADOW SQUARE

When you wish to include a shadow square[1] [on the back], join the centre of the circle of signs with a faint and hidden line which passes equally through the middle of the north-west quarter, whose end will be the circle of months. Next you will draw from its end two lines to the [radii] of the tabula, and there will be a right-angled quadrilateral. Then, after these two lines, you will make another two near to these, between which will be the points. And likewise make two [other] lines further apart than these between which will be the numerals, and divide the spaces which are between these lines on both sides into 6 divisions for the numerals. However, divide the space which is narrower into 12 according to the number of points, with two points to each numeral; and you will begin to write these [i.e., the numerals] from the diameters. And if you want two [shadow] squares in the astrolabe, you should make [the second] in a similar way in the other north-east quarter, which is next to it.

And within the same two lower squares inside the circle of the months you will be able to construct the hour lines as is done on a quadrant, through which you will also have the natural hours[2] of the day on the back.[3]

And this is the drawing of the back of the astrolabe [Figure 2].

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[1] The shadow square and hour lines are similar to what was found on the *quadrans vetus*.

[2] These are the "unequal" hours which vary according to the length of daylight during the year.

[3] The text suggests that the shadow square(s) be constructed above the horizontal diameter of the astrolabe; or alternatively that they be below that line. Depending on where the unequal hour lines have been engraved, the shadow square could be superimposed on the hour lines. The diagrams of the back vary in this respect (see Figure 2).

[CHAPTER 4.] ON THE FABRICATION OF THE COMMON ALIDADE, WHICH IS ALSO CALLED THE RULE

When you wish to make the alidade,[1] that is, the rule which is placed on the back of the astrolabe, prepare a narrow strip like a ruler whose length should be as the width of the back of the disk and more according to that amount from which two perforated vanes can be cut[2] for taking the altitude [of the sun and the stars]. You will draw a line on it along its middle lengthwise (that is, make a very visible line on it which divides it along the middle), and after you have drawn it, you will cut off from it as much as is needed for making the two aforesaid vanes; and afterwards there should remain [a length] of about the dimension of the disk, either nearly or a little less, that it may not be caught in one's garments. Afterwards divide it very accurately down the middle into two parts and place in the middle of it a mark on which the opening for the axis will be. Then cut away half of the rule on one side (according to what I have indicated to you) and cut it away on the other opposite side.[3] And you will preserve[4] the line which is in the middle of it which passes through the axis while you have done the cutting, because in it will be the fiducial [line].[5] And sharpen the ends of the rule towards the fiducial line, backwards and forwards, so that [each] end of the rule becomes pointed and the degrees can be seen.

After this you will attach the vanes at the same distance from the axis,[6] and ensure that the lines which are on the aforesaid vanes coincide with the ["central"] line of the rule. In addition you will pierce them before attaching them [to the rule] and the holes should be of the same distance from the rule. And these holes should be evenly pierced along the line of the vanes; and in each vane let there be two holes, that is to say, a larger and a smaller, the smaller for receiving the rays of the sun by day and the larger for receiving the [light of the] stars by night. Note that the centre of the two vanes, which are towards the ends of the alidade, and the axis of the alidade ought to

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[1] The alidade (Arabic: *al-ᶜiḍāda*, العضادة; Latin: *allidada*) is a ruler which rotates around the centre of the astrolabe. It has 2 sighting vanes and together with the rule they are used to read the altitude of the sun and of other stars. See Kunitzsch, *Glossar*, no. 19, pp. 527-528.

[2] Or, "as much more as is required to allow the cutting off of two perforated vanes ...."

[3] That is, cut away one side (from the edge to the central line) from one end of the strip to its middle point (of rotation), and cut away the opposite side (from the edge to the central line) from the other end of the strip back to its middle point.

[4] Or "you will not damage ...", "you will not cut into ..."; "you will safeguard ...".

[5] This edge must be very accurate; the measurements "depend" on it.

[6] Literally, "at one length" (i.e., the same distance) but each towards opposite ends.

have the same centre and the line which is on the rule ought to correspond to the centre of the aforesaid vanes, equally when they are placed together on the rule or alidade.

And know that the rings by which an astrolabe is suspended are beveled on their spines [i.e., their inner edges] for as far as one of them runs over the other, as if upon a sword edge, lest [their movement] be impeded and when seated there might perhaps be some leaning towards one side. And if the hole, which is pierced in the mother in which is the ring [i.e., allidadath],[7] which is the armilla reflexa, is not most accurately along the middle line, then because of this there may be some deflection [of the astrolabe] when measuring an altitude. And this you ought to test in this way. Pass a thread through the hole [in the throne] and hang something heavy from it; then hang up the astrolabe by another thread from the same hole. Then if thread lines up[8] on thread and [if there is] no divergence, it is true. But if there is a divergence, then study to adjust it by moving the hole towards that side to which the thread diverges[9] (God willing).

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[7] The base Arabic word is *al-ᶜitāqa* (العلاقة) or "a strap" [or the like, for suspending something]. How this becomes transcribed as *allidadath* (and its variants) is not obvious. Not to be confused with the alidade (*al-ᶜidāda*) or rule (see above Cap. 4, note 1). See Kunitzsch, *Glossar*, no. 20, pp. 528-530.

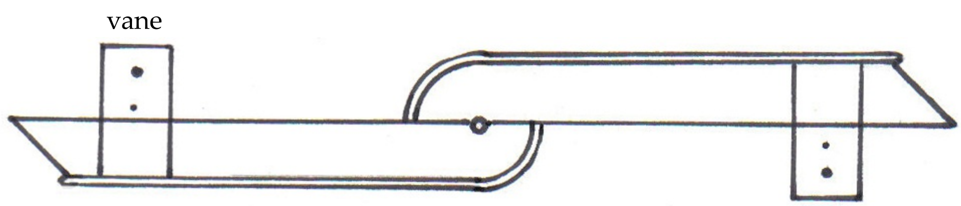
The normal Arabic word for the armilla reflexa is *ᶜurwa* (عروة ; "[ring-like] handle") or sometimes *habs* (حبس ; "holding"). See Cap. 1, figure (variants: armilla reflexa).

[8] Literally, "if thread falls on thread." Michael Masi suggested this translation.

[9] The instructions are too terse at this point. A thread through the hole in the throne is used to suspend the astrolabe, and a second thread with a weight is hung down from the same hole. Due to gravity the threads will always line up with each other, but what surely is really meant is that the thread with the weight hanging down should run along the central vertical line of the astrolabe, that is, along the vertical diameter (usually labeled AC) and across the central hole or axis on which the alidade rotates. If this thread does not line up with the vertical diameter, then the hole in the throne is off centre and needs to be adjusted.

[FIGURE 4]

Alidade – Rule – "Mediclinium"



[CHAPTER 5.] ON THE ARRANGEMENT OF THE HOURS ON THE RULE, WHICH IS ALSO CALLED THE "TIME-TELLING" ALIDADE[1]

When you wish to mark the hours on the rule, divide the length of one of the vanes which are on the rule, in which the holes are, into 12 divisions, and the vane itself will be a position. Then you will divide a diagram of the actual positions on a flat surface or on parchment, or on any surface you like; and divide this (that is, the representation) by points. Next you will place the rule on 15 degrees of altitude [from the vertical] and you will know how much it will have of the reverse shadow. Next you will place a pair of dividers over the distance of the degrees between these points which you have found for that same altitude, and you will transfer this distance onto the rule [beginning] from the base of the vane, which you have divided, as far as it [i.e., the dividers] will reach. And this will be the end of the first hour. Then also place the rule on 30 degrees and you will know how much the reverse shadow will be consistent with it. And you will open a pair of dividers according to the distance of [i.e., between] these points, and transfer this distance onto the rule [beginning] from the base of the above-mentioned vane which you have divided, as far as it will reach. And this same terminus will be the end of the second hour. Likewise place the rule on the shadow of 45 [degrees], next on the shadow of 60, after that on the shadow of 75, which is the end of the 5th hour. And what remains on the rule will be the 6th hour and it does not have an end on the rule. Afterwards the shadow will go back the other way, and the beginning of the 6th hour will be the end of the 7th; the beginning of the 5th will be the end of the 8th; the beginning of the 4th the end of the 9th; the beginning of the 3rd the end of the 10th; the beginning of the 2nd the end of the 11th; and the beginning of the first the end of the 12th.

And if you wish to extract the shadows of these altitudes from a shadow table, that is, from a table of the altitude of a shadow by which the shadow of every altitude is known, do so, since it will be more accurate (God willing).

Similarly, there is also another means of getting the position of the hours onto the rule, easier than the first. They all go back to the same [idea] and work the same. When you wish [to do this], know the length of the line on the rule which falls between both vanes, more precisely only [the length] up to the pin, since it is more fitting that all the shadows should be between the pin [i.e., between one vane and the pin] and add to that length 4 times the height (or the equivalent) of the entire vane from the surface of the rule right up to the top of this vane, and if it [i.e., the length along the rule] is more

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[1] Also known as the "horary alidade."

than 4 equivalents of the whole vane up to its top, that meets with my approval.[2] And if it be not so, it should not be less than these 4 equivalents, since the end of the 4th equivalent is the end of the 5th hour. After this lay out this line on a surface or on parchment or on whatever you wish. Then from the end of the line draw a line at right angles, and take from this, according to the size of the vane, and know [i.e., mark] that point; and draw from this point a line on the right angle as far as you wish.

Then, using this point, which is at [i.e., marks] the end of the vane, as centre, and measuring as much length as you wish [i.e., with any radius] draw a quarter circle. After this you will divide this quarter circle into 6 equal parts. Then join the division points with their centre [i.e., the centre of the quarter circle] and extend the lines until the lines reach the aforesaid line, that is, as far as the rule. And wherever they cut off, these will be the points [i.e., divisions] of the hours; that is, the first, second, third, fourth and fifth; and the beginning of the sixth is the end of fifth since the sixth has no end. And when the shadow is reversed it will show you the rest of the hours.

If, however, the line is as 4 equivalents of the whole vane, it will be the end of the 5th hour near the base of the second vane (or near the pin which is more appropriate). And when the reversed shadow is along the upper edge, this will be the end of the 6th hour and the beginning of the 7th; and when the reversed [shadow] is at the end of the 5th it is the end of the 7th and the beginning of the 8th; and when it reaches the end of the 4th it will be the end of the 8th and the beginning of the 9th; and when it reaches the end of the 3rd it will be the end of the 9th and beginning of the 10th; and when it reaches the end of the 2nd it will be the end of the 10th and the beginning of the 11th; and when it reaches the end of the first, it will be the end of the 11th and the beginning of the 12th.

After this you will transfer the hours with a pair of compasses onto the rule and place the beginning of the rule [i.e., the scale of hours] against the base of the vane, just as you see in this figure.

[ADDENDUM 5-1][3]

Note that here a point is said [to be] a twelfth part of a day, and when the shadow comprises 12 points, it will be equal to the particular day. And when the shadow

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[2] This is an awkward way of warning that the last mark will be along the alidade (from the vane) about 4 times the height of the vane, and therefore the height of the vane when made should be less than one quarter of either the length of the alidade between the vanes, or the length of the alidade from the central axis to the sighting vane, in order for the last engraved line to fit onto the alidade or to fit between the vane and the pin, whichever is more convenient.

[3] This material is found in the margin of some mss and after the second paragraph in others.

contains six points, the mid-point of the line will be [the middle point] of the day and so on regarding the other parts. Understand further that the shadow will consist of more or few points.

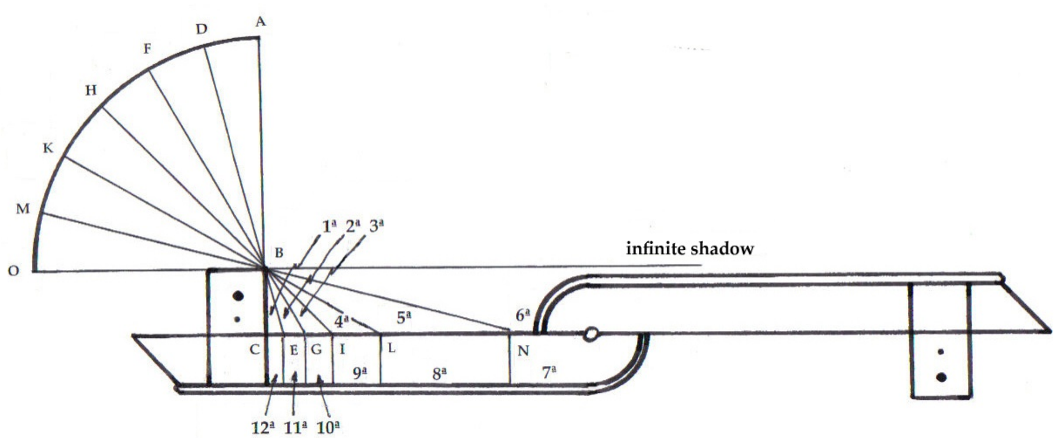
[ADDENDUM 5-2: TABLE]

TABLE OF REVERSE SHADOW[S] BY WHICH YOU WILL POSITION THE HOURS ON THE RULE

Degrees [of the sun]	Points[4] [along the rule]	Minutes
15	3	13
30	6	56
45	12	0
60	20	47
75	44	46
90	infinite	

[FIGURE 5]

The alidade of the hours



[4] Each point is one twelfth the height of the vane.

[Comment on Capitulum 5:

The drawing of the [unequal] "hours" on the rule or alidade essentially turns one vane on the alidade into a gnomon, whose shadow will indicate the time. The text offers three methods of engraving these hours.

The first (lines 2-17) read off distances on the shadow square (for various elevations of the sun) along the *umbra versa* (reverse shadow) or the *umbra recta*[5] (shadow) scale, which are then transferred to the alidade.

The second (lines 18-20) refers to the use of a table of the shadows cast which can then be marked on the alidade. Such a table is found as Addendum 5-2, which are figures also derivable from the shadow square in the first method.

The third method (lines 21-46) is to construct a full-scale diagram of the alidade and vane with a quarter circle (with its centre at the top of the vane) divided every 15 degrees and to then project lines from these points through the centre (at the top of the vane) down to the alidade where the hour lines across the alidade will lie. These lines are then transferred to the actual metal alidade.

For the use of these lines, see *Practica*, Cap. 11.

For a further discussion of this aspect of an astrolabe see Josefina Rodriguez-Arribas, "A Treatise on the Construction of Astrolabes by Jacob ben Abi Abraham Isaac al-Corsuno (Barcelona, 1378): Edition, Translation and Commentary", *Journal for the History of Astronomy*, 49 (2018), 27-82, especially p. 33 and notes 31-34 (pp. 71-72), as well as Appendices 1-3 (pp. 76-79) and the accompanying notes.

Rodriguez-Arribas comments (p. 71 note 32) that very few (extant) Islamic and European astrolabes are actually marked with such hour lines on the alidade, referring to studies by David King.

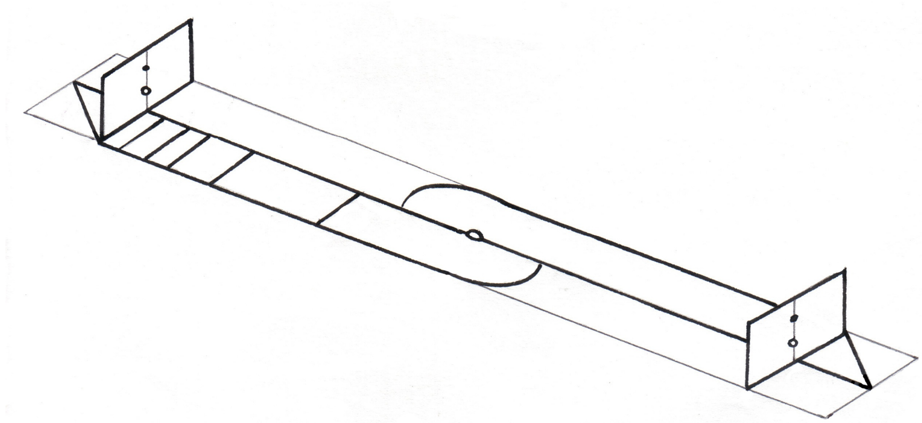


Figure 5A. Perspective view of the Alidade, with hour-lines

Samsó points out that "this kind of alidade, which assumes an increase of 15º in the solar altitude corresponds to the passage of one seasonal hour, is independent of the local latitude. It was known in the Greek and Byzantine world, as well as in early Medieval Europe and in early

[5] *umbra recta*: also known as the *umbra extensa* – see the *Practica* section, Cap. 42.

Islamic astronomy, as described by Ḥabash al-Ḥāsib (fl. 831-860) and by Hermann Contractus (1013-1054)." In his footnote he cites David King (2005), pp. 253-255 and continues, "this kind of device was not unknown in the Andalusi tradition. As remarked by Martí and Viladrich (1983, pp. 69-70) a reference to it appears in Ibn al-Ṣaffār's treatise on the use of the astrolabe: see Millás' Arabic edition (Millás, 1955, pp. 63-64) and his Catalan translation in Millàs, 1931, pp. 39-40."[6]

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[6] Samsó, *On Both Sides*, p. 420 and note. The full references for his sources are:

King, 2005 – David A. King, *In Synchrony with the Heavens.* II, *Instruments of Mass Calculation* (Leiden: Brill, 2005).

Martí and Viladrich, 1983 – Ramon Martí and Mercè Viladrich, "En torno a los fratados de uso del astrolabio hasta el siglo XIII en al-Andalus, la Marca Hispánica y Castilla," in Juan Vernet, ed., *Nuevos Estudios sobre Astronomía Española en el Siglo de Alfonso X* (Barcelona, 1983), pp. 9-74.

Millás, 1955 – José Maria Millás Vallicrosa, "Los primeros tratados de astrolabio en España," *Revista del Instituto Egipcio de Estudios Islámicos*, 3 (1955), pp. 35-49 [Spanish], 47-76 [Arabic].

Millàs, 1931 – Josep M. Millàs Vallicrosa, *Assaig d'història de les idees fisiques i matemàtiques a la Catalunya Medieval* (Barcelona, 1931).

[CHAPTER 5 BIS.] ON THE FABRICATION OF THE "NOVELLA"

You will also make another ruler which is called the "novella,"[1] as is shown here, which has been divided by marks according to the divisions of the meridian line by the almucantars of the plate of the latitude of your region. And this will rotate on top of the face of the rete.

[FIGURE 5 BIS]

Novella

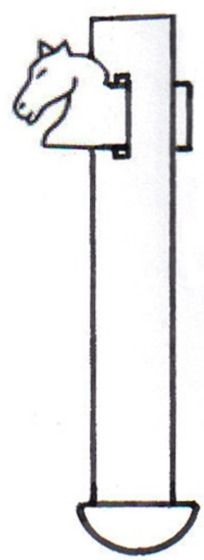
[1] "*Novella*" – something new. Perhaps so named because it seems to be a late addition to astrolabes (it does not seem to be found on Islamic astrolabes).

"*Novella*" is not to be confused with "*volvellum*," which is another name for the rete. See Kunitzsch, *Glossar*, pp. 515-517.

[CHAPTER 6.] ON THE FABRICATION OF THE "QUṬB"[2] AND THE "FARAZ",[3] THAT IS, THE "HORSE"

Once the rule has been finished, you will make a round pin, both well fashioned and pierced, having a well-formed head. This pin should be useful for holding the plates together when they have been pierced. And it [the pin] is called in Arabic "al-quṭb", which we Latins call "the axis." And you will also make in the shape of a horse or wedge or some other animal a small well-made piece which you will insert neatly in the slot in the pin such that it holds the plates together. And this is called "al-faraz" or "the horse" since customarily it is made in the shape of a horse.

Up to this point we have interrupted [our text with material] from various treatises; but now let us return to our book.



[FIGURE 6]

al-faraz
horse
wedge

round bar
nail
axis
al-quṭb
peg

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[2] The pin which holds all the rotating parts of the astrolabe together has various names in Latin: *clavus* (nail), *axis*, *cavilla* (wooden or metal peg), *vectis rotundus* (round bar). The arabic (القطب, *al-quṭb*) gives rise to a wide range of variants. See Kunitzsch, *Glossar*, no. 40, pp. 545-546.

[3] The wedge (Latin: *cuneus*) which secures the pin in its hole is often in the shape of a horse and so is usually referred to as "the horse"(*equus*). In Arabic it is *al-faras* (الفرس), also meaning "the horse". See Kunitzsch, *Glossar*, no. 9, pp. 520-521.

[*Construction, Section II*]

[CHAPTER 7.] PREAMBLE TO THE CONSTRUCTION OF THE RETE AND OF THE LATITUDE PLATES

Take any plate you wish and of whatever size, and on it make a circle whose radius should be similar to the radius of the one which falls on the mother within the limb. And when you have made the circle, cut away from the plate what is superfluous outside the circle itself except for a certain portion which you will leave there in the form of a small tooth in order that it may project into a hole in the limb located for it; and [it should be] well crafted. When the plate sits in the mother, and the small tooth itself is in its hole, so that the aforesaid plate cannot be moved one way or another, and when this has been done, extend the diameters of this same circle in a straight line all the say until they intersect at right angles at centre E, and these will be diameters AC, BD. Then you will make the circle of Capricorn and the circle of Aries and Libra and the circle of Cancer. The circle of Capricorn, however, is circle ABCD.

And when[1] you wish to draw the circle of Aries and Libra, that is the circle through which the beginnings of Aries and Libra travels, and the circle of Cancer, that is through which the beginning of Cancer travels, divide circle ABCD into 360 parts, and each quarter of the circle should consist of 90 parts. Then set arc AZ similar to the number of degrees of the entire [obliquity of the ecliptic][2] which, according to Ptolemy is 23 degrees 51 minutes, and according to Albategni[3] 23 degrees 36 minutes, but even in the days of al-Mā'mūn[4] observers found 23 degrees 33 minutes, and just as we have from the Indians, the [obliquity] approaches 24 degrees. Therefore take this [obliquity] following whom you wish, since there will be there no perceptible disagreement.

When, therefore, you wish to draw the circle of Aries, divide the circle of Capricorn, that that is circle ABCD, into 360 divisions. And take of these, following the abovementioned [obliquity], from point A towards D, and set there some mark. And if

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[1] The first section of this chapter describes how to draw the circle of Aries/Libra and the circle of Cancer, working from the given circle of Capricorn around the outer edge of the plate.

[2] The Latin properly reads "whole [*or* entire, *i.e.*, maximum] declination," that is, the maximum number of degrees of the sun's position measured from the celestial equator. I have substituted "obliquity [of the ecliptic]" for "declination," as a more familiar term to the modern reader. However, this is actually a different concept (the angle of the ecliptic to the celestial equator at the equinoxes) although the value is exactly the same. Those wishing to be more precise in their translation can substitute "declination" for my "obliquity."

[3] Al-Battānī (Abū ᶜAbd Allāh Muḥammad ibn Jabir al-Battānī; Latin: Albategnus), c. AD 858-929.

[4] Al-Mā'mūn (Abū Jaᶜfar Abdullāh al-Mā'mūn ibn Harūn, AD 786-833), Abbasid caliph, AD 813-833. His Latinized name, Almeonis, can be found in Campanus of Novara, *Theorica planetarum*, and in Kepler. Gunther erroneously identified Almeonis as "The son of Albumazar."

you wish, divide this very quarter by 15, and of these take 4 from A towards D and place there a mark;[5] moreover see that the quarters are equal. And if you wish, divide the quarter by 3 and again divide that third, which will have been next to A, by 5, and then from these fifths take 4, which will have been next to point A,[6] and place there a mark. If, however, you wish to divide [it] more precisely, do just as I will say. After you have divided the plate by its diameters and made the quarters equal, and after you have inscribed letters at the ends of the diameters, as one would expect in the upper part of the plate, which is below the armilla/ring and signifies the south A, and in the west B, in the north C, and in the east D, you will divide one of the quarters, that is, from A to D into 90 degrees, and take 23 degrees 51 minutes according to Ptolemy, since he is more authoritative, although modern learned men know for certain it is 23 degrees 33 minutes.

So take the mark for the abovementioned number [for the obliquity], as we have said, and write on it Z, and arc AZ will be the entire [obliquity]. Then join Z with B by line ZB, and it will intersect the line AC at point H; then you place point E on it [i.e., line AC] as the centre and make a circle with radius EH (that is, you will set a compass with one part [i.e., leg] on E and the other on H); and you make the circle, which will be HTKL and this will be the circle along which the beginnings of Aries and Libra travels.

Once more divide this circle into 360 or a quarter of it as above, and place above the number of degrees of the aforementioned [obliquity], as described above, a mark and write on it M, and join M with T by line MT; and line MT will cut line AE at point N, and you will take point E as its centre and you make a circle with radius EN, and you make a circle, which is circle NSOV; and along this circle the beginning of Cancer travels. And this is the diagram.

But[7] if [first] we have determined circle HLKT, which is the circle of Aries and Libra, and we wished to draw from it the circle of Capricorn and the circle of Cancer, we would divide circle HLKT into 360 parts, or we would divide divide the quadrant, as above. Next we would take arc TQ as the entire [obliquity]. Then we would join H with Q and extend the line until it has cut diameter LT at point B. Then we would take point E as centre and we would make a circle with radius EB, which would be circle ABCD, and this would be the circle of the beginning of Capricorn. After this we would also cut off arc HM as the entire [obliquity] and we would join M with T and line MT would cut line HK at point N, and after this we would take point E as centre and make a circle with

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[5] 90 divided by 15 equals 6, and 4 times 6 equals 24, an approximation of the obliquity of the ecliptic.

[6] 90 divided by 3 equals 30, and 30 divided by 5 equals 6; 4 times 6 [i.e., a fifth of 30] equals 24, an approximation of the obliquity of the ecliptic.

[7] This second section describes how to draw the circles of Capricorn and of Cancer having been given the equatorial circle of Aries/Libra.

radius EN, which would be circle NSOV, along which the beginning of Cancer travels.

And[8] if we wished to draw the circle of Aries and Libra and the circle of Capricorn from the circle of Cancer, we would divide circle NSOV into 360 divisions. After this we would take arc SF as the entire [obliquity], and join N with F by line NF, and extend the line directly until it has cut the diameter VS at point T. After this we would take E as the centre and make a circle with radius ET, which would be circle THLK, which is the circle of Aries and Libra. After this we would construct the circle of Capricorn from the circle of Aries and Libra.

[ADDENDUM 7][9]

Or you will divide all the circles thus: after the plate has been positioned in the mother and its diameters drawn, measure along the limbus from A towards D 24 degrees (if you wish), and place the rule at the end of them [i.e., of the 24 degrees] and on point e and make a fine line, which should be labelled EZ, and this with line EA encloses a distance of 24 degrees on every circle inscribed within. And note that by this means we mark on whatever circle inscribed within the limbus, there are as many degrees as we had on the limbus; and this method is better – preserve it.

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8 This third section describes how to draw the circles of Aries/Libra and of Capricorn having first been given the circle of Cancer.

9 This material is found in many mss after the third paragraph; in a few after the fourth paragraph; and in a few more after the fifth paragraph.

[FIGURE 7]

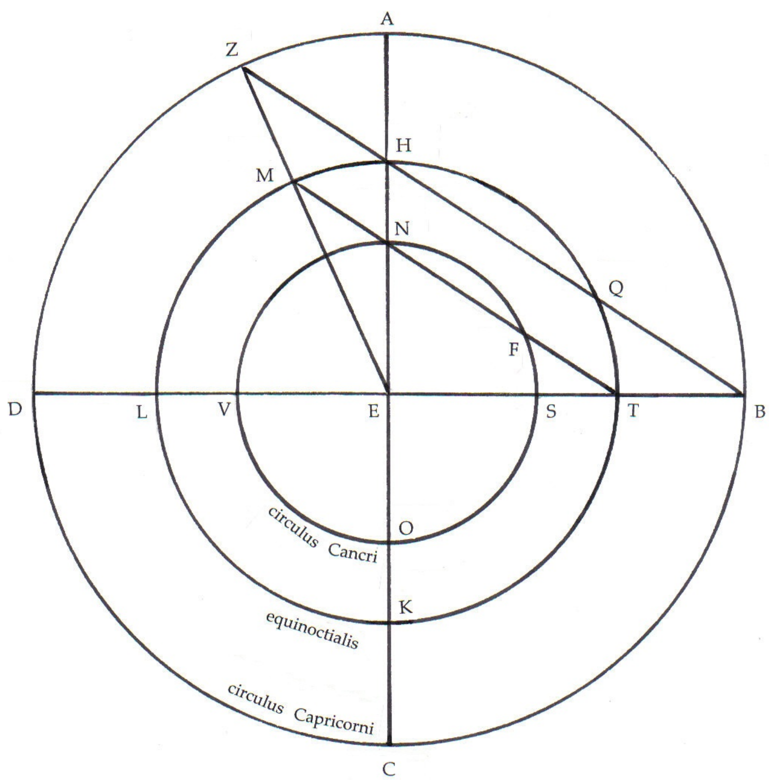

Figure of the inscription of the the three circles using the whole obliquity

[CHAPTER 8.] ON THE ENGRAVING OF THE ZODIAC

After the construction of these three circles, that is, of Capricorn, of Aries and Libra, and of Cancer, make the circle of signs. This is when you divide line AO in half and make a circle on line AO passing through points T and L; if so, you have already done your work. And if it does not pass through these two points you have erred; return then to the work until it is correct. And this circle is the circle of signs [i.e., the ecliptic].[1]

[ADDENDUM 8][2]

And now make a second circle in which degrees can be marked. And again inside this one make another one for writing the figures. Now make a third one inside [the first two] where the signs are written.

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1 While the title of this capitulum makes reference to the zodiac, the text is really about drawing the circle of the ecliptic. The zodiac is technically a band within which the sun moves "up and down" as well as along, the edges of the band marking the maximum deviations on both sides. The ecliptic is the centre line of the zodiac and as a line it is a circle with no breadth.

2 This material is found in many mss at the end of the chapter.

[FIGURE 8]

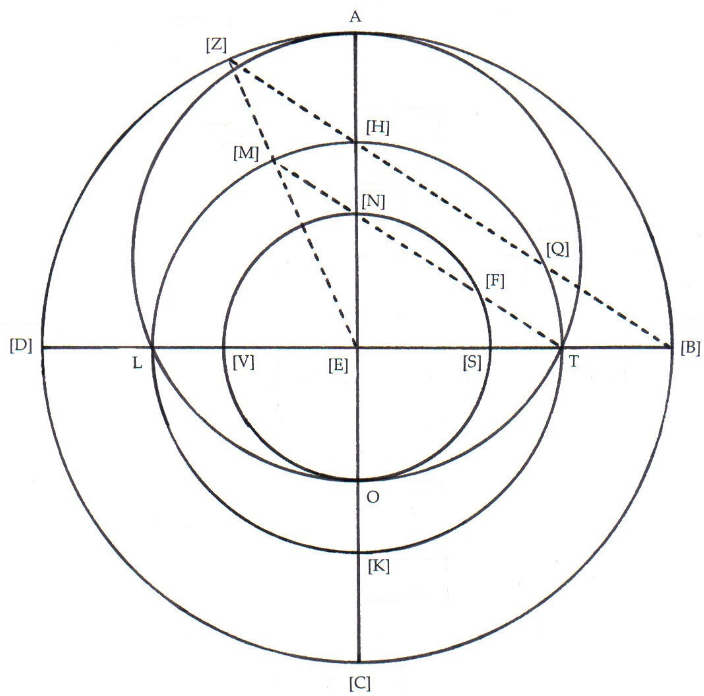

Figure of the inscription of the zodiac

[CHAPTER 9.] ON THE DIVISION OF THE CIRCLE OF SIGNS, OR ZODIAC[1]

When you have made the circle of signs, you should next divide it into signs and degrees of the signs. An example of this is that you should draw the circle of [the beginning of] Aries and Libra, which is circle ABCD and its diameters should intersect at point E and with the circle of signs AZCH.

Then divide circle ABCD into 360 degrees. After this construct arc CT similar to half of the total declination [i.e., obliquity of the ecliptic]. Then join A to T and line AT will cut diameter BD at point K. Next extend diameter BD in a straight line, until it cuts the circle of signs at H. Then point A will be the point of the beginning of Libra, and point H will be the point of the beginning of Capricorn, and point C will be the point of the beginning of Aries, and point Z will be the point of the beginning of Cancer. After this take arc DL and arc BM, namely each one of them, as 30 degrees. Next you will require an arc which is to run through points M, K and L, and will cut the circle of signs at N and S; and HS will be the sign of Sagittarius, and arc ZN the sign of Gemini. After this take each one of the arcs LG and MF [as] 30 degrees. Next seek the arc which runs through points F, K, and G and it will cut the circle of signs at points Q and X, and arc SX will be the sign of Scorpio, and arc NQ the sign of Taurus, and arc XA will remain as the sign of Libra, and arc QC as the sign of Aries. After this construct arc HO equal to arc HS and arc OR equal to arc SX, and arc RC will be the sign of Pisces and arc RO the sign of Aquarius, and arc HO the sign of Capricorn. After this also take arc ZV equal to arc ZN and arc VP equal to arc NQ, and arc AP will be the sign of Virgo, and arc PV the sign of Leo, and arc VZ the sign of Cancer.

Similarly, if you constructed arc DL as 3 degrees and arc BM in the same way, arc HS would be 3 degrees of Sagittarius,[2] and arc ZN 3 degrees of Gemini. In this way you

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[1] The issue of dividing circles projected in the plane which are oblique to the equatorial circle – including the issue of dividing the ecliptic/zodiac into its twelve signs – is discussed in detail in my *Jordanus de Nemore and the Mathematics of Astrolabes: De plana spera,* Studies and Texts 39 (Toronto: Pontifical Institute of Mediaeval Studies, 1978), pp. 62-67; see also the various editions of Proposition 4, and the commentary on pp. 142-143.

The main method in Capitulum 9 is to draw great circles through the pole [K] of a great circle with only half the declination of the ecliptic. These great circles through the pole will cut off equal arcs on both the ecliptic and the equatorial circle, and therefore if they pass through points 30º and 60º along the latter, they will also pass through points 30º and 60º along the former; and similarly for other divisions of both the equatorial circle and the ecliptic. (Thomson, *Jordanus de Nemore*, pp. 65-66; Proposition 4 and commentary, pp. 142-143.)

Samsó argues that this method clearly derives from Maslama's extra chapter to his notes on Ptolemy's *Planisphaerium*. See his lengthy discussion in *On Both Sides*, pp. 421-423.

[2] If one follows the diagram and the lettering used for dividing the zodiac into its signs, almost all the manuscripts insert the wrong signs – Capricorn for Sagittarius, and Cancer for Gemini – in this sentence.

will divide the entire circle of signs into individual degrees, as shown in this figure.

[ADDENDUM 9-1][3]

The zodiac can also be divided in three other ways. First through straight lines using the entire [obliquity],[4] as in the preceding through arcs using half the [obliquity]. Second, by tables of [right] ascensions of the signs in the circle of signs, and we use this method, that is, by drawing a straight line from point E through the zodiac and through the [right] ascension of the sign or degree.[5] The third way is through circles passing through the declinations of any degree of the signs. And if the declination is southern, draw it outside the equatorial [circle, i.e., the celestial equator][6] from A towards D; if it is northern, draw it inside from A towards B, placing the rule on point D and on the declination towards whichever side the drawn declination is, that is, from A towards D or from A towards B.[7]

This may stem from an error in an early ms (Cη, dated AD 1276 – see introduction) where the names in the diagram have been shifted clockwise by one sign.

Note: in the correct version the parts divided off in this example would be the final 3 degrees of the sign.

3 This material is found in many mss at the end of the chapter.

4 Straight lines from the projection of the pole of the ecliptic to points on the equatorial circle (i.e., to 30º, 60º, 90º etc. along the equatorial circle) also cut off equal arcs on both the equatorial circle and the ecliptic. See Thomson, *Jordanus de Nemore*, pp. 66-67; Proposition 4, and commentary, pp. 142-143.

Samsó notes that this method is found in Ptolemy, *Planaesphaerium*, chapter 15 (*On Both Sides*, p. 421).

5 Knowing the right ascension (along the equator) of the beginning of each sign in the zodiac (e.g., as found in the table in Addendum 9-2), then straight lines from these points on the equator through the pole (i.e., great circles through the pole and the points on the equator) will cut off appropriate arcs of the ecliptic. See Thomson, *Jordanus de Nemore*, pp. 62-64; Proposition 4 and commentary, pp. 142-143 and Samsó, *On Both Sides*, pp. 423-424.

A similar but inaccurate method (often known as "false right ascensions") involves drawing straight lines from 30º arcs along the equator to the pole, cutting off arcs on the ecliptic. For the problem with this "method" see Thomson, *Jordanus de Nemore*, p. 64.

6 The circle through the equinoxes is the circle through the beginning of Aries and Libra, that is, the celestial equator. Henceforth this phrase will be translated as "celestial equator".

7 By drawing circles parallel to the equatorial circle at appropriate declinations, these circles will cut the ecliptic at the desired points. However, this method depends on having a table of declinations for the beginning points of the signs along the ecliptic. It is also not very accurate – or at least very difficult to be accurate – because the angle of intersection is always less than the obliquity of the ecliptic making the precise point of intersection very difficult to determine. See Thomson, *Jordanus de Nemore*, p. 66; Proposition 4, and commentary pp. 142-143.

[ADDENDUM 9-2][8]

NOTE: [Right] ascensions of the signs by which the zodiac is divided[9]

Sagittarius, Capricornus, Gemini, Cancer	32 degrees	13 minutes
Aries, Libra, Pisces, Virgo	27 degrees	53 minutes
Taurus, Scorpio, Leo, Aquarius	29 degrees	54 minutes

[8] This material is found in the margin in a few mss.

[9] These are (fairly accurate) right ascensions used in the second method noted above in Addendum 9-1. These right ascensions for the beginnings of the signs are: Aries, 0^o; Taurus, 27^o 53′; Gemini, 57^o 47′; Cancer, 90^o; etc. In modern notation these would be: Aries 0^h; Taurus, 1^h 51^m 32^s; Gemini, 3^h 51^m 8^s; Cancer, 6^h; etc.

The "correctness" of these right ascensions depends of course on the value used for the angle of the ecliptic; and the "usefulness" of the degree of accuracy exhibited here depends on the craftsmanship of the engraver.

[FIGURE 9]

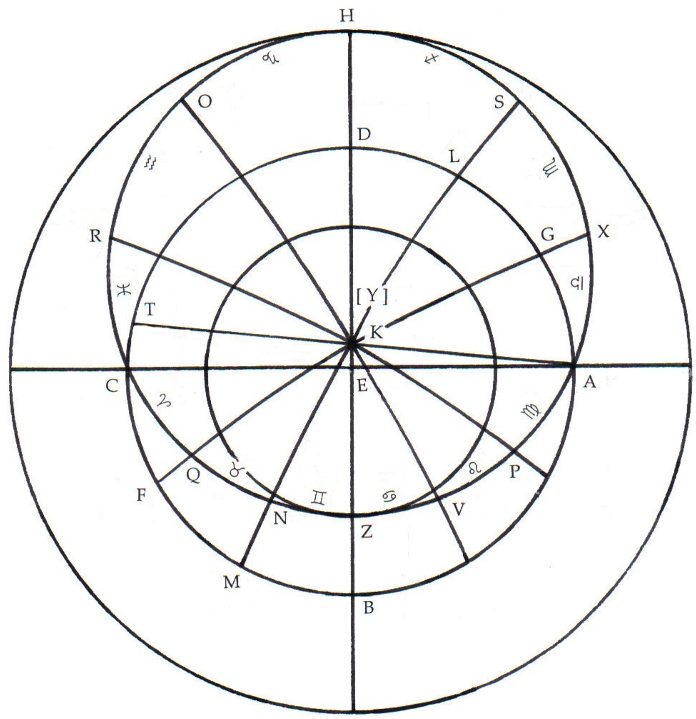

Figure of the division of the zodiac using arcs through the pole of half the declination

[CHAPTER 10.] ON INSCRIBING THE FIXED STARS[10]

When we have divided the circle of signs with very great precision, we should next mark the fixed stars along the circle of signs. To illustrate this, let us suppose a star with its distance[1] from the celestial equator [and] with the degree which reaches the middle of the sky with it.[2] And this is done as follows: We will place the circle of the celestial equator, that is, the circle of Aries and Libra, ABCD and its diameters should intersect at E; and let AZCH be on the circle of signs. And for our example we will take one star from among the stars whose distance from the celestial equator is towards the north and let this star be *Vultur volans*.[3] And from point D toward C we will cut off the degree to which its distance lies from the celestial equator, and it is 7° 25';[4] and this is arc DT. And we will join T with A and cut the diameter [BD] at point K. And we will take point E as the centre, and we will construct a circle with radius EK, and this is circle KM, and it passes through the star. After this we will observe the point on the circle of signs

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[10] This is a fairly standard method for placing the stars in the rete. It is also found in the Maslama's extra chapter (Samsó, *On Both Sides*, p. 424).

[1] I read *longitudo* as "distance". Gunther (along with some of the medieval scribes, particularly later ones) attempted to co-ordinate the use of *longitudo* and *latitudo* (which Gunther sometimes substituted, one for the other, in both the Latin and the English without comment) with either right ascension and declination, or celestial/ecliptic longitude and latitude.

The text, however, actually uses a conflation of these two systems, that is, (modern) declination (from the equatorial circle) for the north/south position, while measuring the east/west position along the ecliptic. For the latter the text then uses the hour circle through the equatorial poles and through the given point along the ecliptic to position the star east/west. This is a "right ascension" positioning, but where the east/west degree given in the text will differ from the true right ascension figure (along the equatorial circle) as a result of the obliquity of the ecliptic. (In the Middle Ages, this measure was known as "mediation".)

[2] That is, with the point on the ecliptic (using the coordinate system of this text) which crosses the meridian at the same time as the star – mediation.

[3] *Vultur volans* (also known as *Altair*) is *α Aql*.

[4] This measure, sometimes (especially in star tables) denoted as "latitude," is actually equivalent to our declination. The modern (2000 CE) declination of *α Aquila* is +08° 52'. Because of the precession of the equinoxes the declination of the star in the Middle Ages would be less than the modern figure. In Kunitzsch's edition of medieval star tables, declinations of 6° (1 table), 6°25' (2), 6°30' (1), and 7° (4) and latitudes of 29°4' (1), 29°10' (7) and 29°30' (1) are found; the difference arises because some of the latter are measured from the ecliptic (Paul Kunitzsch, *Typen von Sternverzeichnissen in astronomischen Handschriften des zehnten bis vierzehnten Jahrhunderts* [Wiesbaden: Otto Harrassowitz, 1966], passim).

In my Lists of Stars (below), Table 1 gives a declination of 7° 0'.

which is in the middle of the sky with it [i.e., the star];[5] this is 16 degrees of Capricorn,[6] which is point L. Then we will join L with E,[7] and line LE will intersect circle KM at M. Thus point M is the position of *Vultur volans*. Similarly you will place all stars whose distance is to the north of the celestial equator.

After this we will take another example of a star whose distance from the [celestial] equator is toward the north, and let it be the star *Cor Tauri*[8] itself. And we will cut off from point D towards C its distance from the celestial equator, since its distance towards the north is 14°,[9] and it is arc DN. And we will join A to N and extend it until it divides [line] HB at point S. Then we will take point E as centre and make a circle with the quantity of the length [i.e., radius] ES, and this is circle SF. Then we will consider the point on the circle of signs with which it is in mid-sky, and this is 26° of Taurus,[10] which

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5 This is "mediatio coeli" or "mediation" which is neither right ascension nor longitude. Instead it is the position of the point on the ecliptic which passes the meridian at the same time as the observed star (in other words, it uses the same hour line as right ascension, but gives the position of that hour-line in reference to the ecliptic). It is often denoted in astrolabe star tables as "longitudo".

6 The right ascension of *α Aquila* (2000 CE) is $19^h\,51^m$ or 27° 45' along the celestial equator from D. This figure would have to be modified to allow for the precession of the equinoxes from the thirteenth century (about 10° less) as well as being translated to the ecliptic (i.e., converted to "mediation"). In Kunitzsch's edition of medieval star tables, mediations/longitudes/right ascensions of 10° (1 table), 10°28' (1), 14° (1), 14°26' (1), 16° (2), 16°30' (1), 17° (2), 17°15' (1), 17°48' (2), 18°30' (1), 20°30' (1), 21° (1), 21°59' (1), and 22°49' (1) are found (Kunitzsch, *Typen von Sternverzeichnissen*, passim).

In my Lists of Stars (below), Table 1 gives a mediation of 16° 0'.

7 In stereographic projection this is equivalent to drawing a great circle through the equatorial poles, that is, drawing an equal-hour line.

8 *Cor Tauri* (also known as *Aldebaran*) is *α Tau*. It is more properly known in Latin as *Oculus Tauri*, because this star actually is the eye and not the heart.

9 The present declination of *α Tauris* (2000 CE) is +16° 30'. Because of the precession of the equinoxes the declination of the star in the Middle Ages would be less than the modern figure. In Kunitzsch's edition of medieval star tables, declinations of 14°12' (1 table), 14°20' (2), 14°30' (3), and 15° (2) and latitudes of –5° (1), –5°10' (8) and –5°12' (1) are found; the difference arises because some of the latter are measured from the ecliptic (Kunitzsch, *Typen von Sternverzeichnissen*, passim).

In my Lists of Stars (below), Table 1 gives a declination of 14° 30'.

10 The right ascension of *alpha Tauri* (2000 CE) is $04^h\,36^m$ or 9° of Taurus along the celestial equator. This figure would have to be modified to allow for the precession of the equinoxes from the thirteenth century (about 10° less) as well as being translated to the ecliptic (i.e., converted to "mediation"). In Kunitzsch's edition of medieval star tables, mediations/longitudes/right ascensions of Taurus 19°18' (1 table), 25°20' (1), 26°47' (1), 27°35' (1), 27°39' (1), 28°47' (1), 28° (3), 28°2' (1), 29° (2), 29°30' (1), 30° (1), and Gemini 1°26' (1), 1°29' (1), and 2° (1) are found (Kunitzsch, *Typen von Sternverzeichnissen*, passim).

In my Lists of Stars (below), Table 1 gives a mediation of 29° 0'.

is point G, and we will join E with G and you will extend it until it cuts circle FS at point F. Therefore point F is the position of *Cor Tauri*. And similarly you will place all the stars whose distance from the celestial equator is towards the south.

If, however, their distance [i.e., of the stars] were to the south of the celestial equator you will take their distance from D towards A, and you will join A with this given distance, and extend the line until it divides line BH, and it will fall outside the [celestial] equator towards the south, and it will be its southern distance.[11] And you will measure out the distance and make a circle which will be through this distance, just as you did for northern stars (God willing).

[ADDENDUM 10][12]

The fixed stars can also be alternatively inscribed by the second table which has been proved near Paris by means of armillas [i.e., armillary spheres], [a table] containing the stars with their distances from the zodiac, and with their distances according to the truth which they have from the great circle running through the poles of the zodiac and through the stars to the ecliptic; this method of inscribing is contained in a certain chapter appended to the end of the composition.[13]

---

[11] The example in the diagram is sometimes labeled as *Alchimech*, i.e. *Azimech*, better known as *Spica*, i.e., *α Virginis*.

[12] This material is found in many mss at the end of the chapter.

[13] See Chap. 22.

[FIGURE 10]

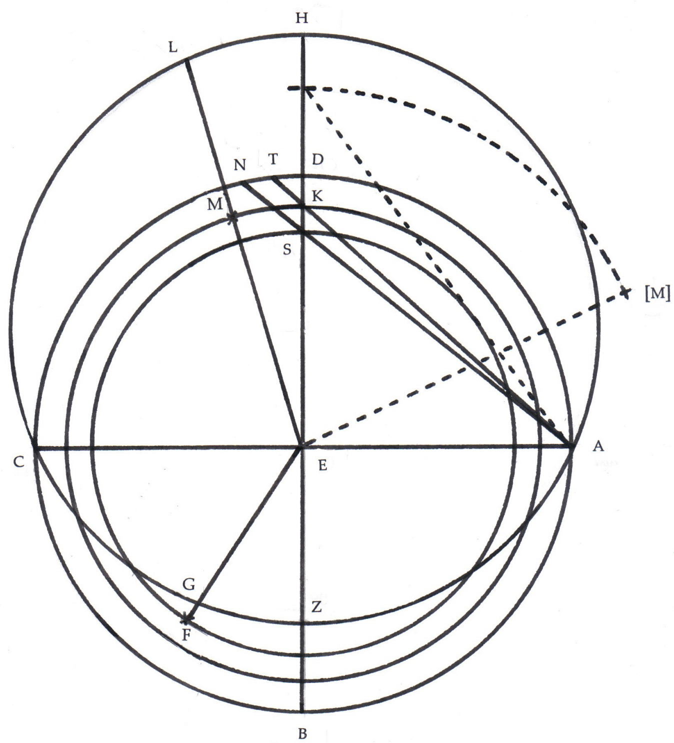


Figure of the inscription of the fixed stars
according to their latitudes from the [celestial] equator

[CHAPTER 11.] THE FITTING OF THE RETE OR SPIDER WEB

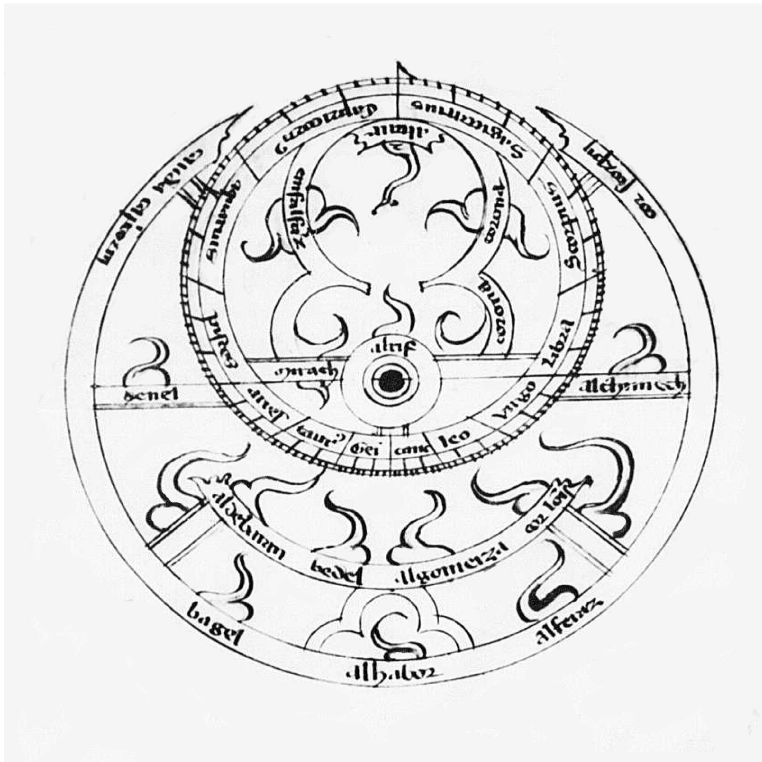
And when you have positioned the fixed stars and divided the circle of signs, you should you take the plate and cut away [its central area] and do not stop except for the circle of signs and the indicators of the fixed stars. When you have united them [i.e., the stars] to the circle of signs, you next incise it and flatten it very thoroughly until it is level with it, and the separation of it from the circle [of Capricorn] [is] such that it neither increases nor decreases. You will do the same with the fixed stars, and flatten it completely. And you will inscribe on each sign its own name, and on every star its name, as is shown in the figure.

And at the beginning of Capricorn let there be the indicator-muri, that is the indicator of degrees, for which some of the Latins, as we have mentioned in a certain book, use the term "calculator". And we have already written above it in the figure "the [indicator-]muri of the degrees". And let the axis of this plate be the centre of the circle of the celestial equator and we have already written on it in this figure "axis". When, moreover, its exposition has been completed, and its description, then it will be complete, and this plate is called "al-hantabuz",[1] whose meaning is "spider-web", and it is [also] called "rete", as here.

---

[1] The Arabic word for rete is *al-^{c}ankabūt* (العنكبوت), meaning "spider"; the Latin transliterations are multiple. In Latin itself, "aranea" is used both for "spider"and for "spider-web". See Kunitzsch, *Glossar*, no. 1, pp. 515-517.

[FIGURE 11][2]



Rete – Volvellum – Walzagora – Spider-web – Al-hantabuz

[2] The image here is just a sample, taken from ms B1.

[CHAPTER 12.] ON THE INSCRIPTION OF THE CIRCLE OF THE HEMISPHERE AT THE LATITUDE OF THE REGION

Afterwards, you will take another plate and this is the one in which will be the circle of the hemisphere [i.e., the horizon] and the circles which follow directly from it, which are called "almucantars", which the Latins call "the progressions of the sun" and "hours of the moon" and "azimuth".[1] And this plate should be larger than the plate of the spider[2] [i.e., rete] by the width of the rim. And what you should first do in this figure, namely you will construct a larger circle, and let it be circle ABCD, and extend its diameters until they intersect at right angles at E, and line EA will be the line of mid sky, and line EB the line of the west, and line ED the line of the east; line EC , however, will be the line of recession.[3]

Next you will set point E as centre, and make a circle whose radius should be as the radius of the circle of Capricorn, which we made in the rete, and it is circle ZHTK. Then you will draw over this circle another one [*or* over this another circle], which should be equal to the circle of the rete, near to it. After this you will divide it into 360 parts and write in it [i.e., in each division] the number, as you see in this figure.[4] In addition draw on it the circle though which passes the head of Aries and Libra, just as you did on the rete which is circle LMNS, and the circle of Cancer which is circle GFQO. And point A will be the place of the "ring" [i.e., allidadath],[5] which is the armilla reflexa.

---

[1] Azimuths (lines of equal azimuth) mark angular distances (east/west) in reference to the observer's zenith point overhead. From the Arabic, *al-sumūt* (السمت). See Kunitzsch, *Glossar*, no. 44, pp. 550-553.

[2] See Chapter 11, note 1.

[3] I have not sure of the meaning of this term used here. Obviously EA would be the midday (= "mid-sky") line, and EC would be the midnight line. In the *Practica*, Chap. 10, line 2, "recessionis" refers to the sun sinking in the sky after midday. Here, after midnight, it may mean that the sun is returning from the other side of the earth towards the east and dawn.

[4] Although instructed to divide the Circle of Capricorn, these divisions are not used in the subsequent capitula; only the equivalent divisions of the equatorial circle are used. However, this may simply be a reflection of the instruction to divide the rim of the plate so that these divisions will appear in the final instrument. See Cap. 1.

There is also the possibility that one could use the divisions of the Circle of Capricorn, rather than the divisions of equatorial circle, in placing the stars in the rete since the divisions would be larger and easier to work with. Apparently this is a suggestion of Ibn al-Samḥ (see Samsó, *On Both Sides*, p. 426 note 465).

[5] See Chapter 4, note 7.

[FIGURE 12]

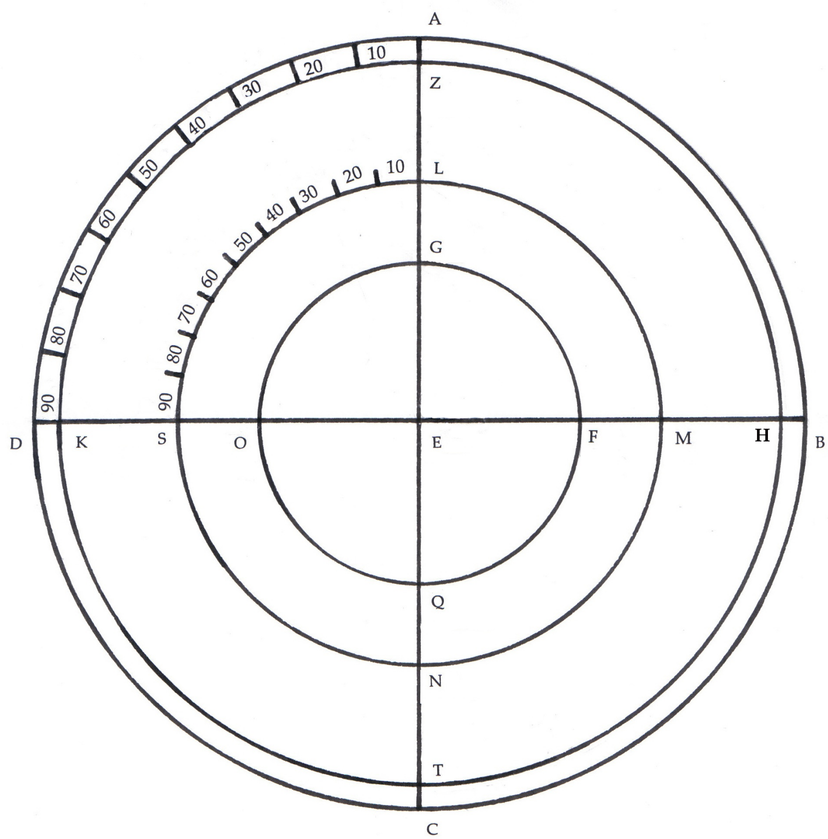


Figure of the inscription of the hemisphere at the latitude of the region

[CHAPTER 13.] ON THE INSCRIBING OF THE ALMUCANTARS

After this, you ought to make the horizon and the circles which follow directly from it which are the almucantars. And you will set out the circle of Capricorn, circle ABCD, and the diameters should intersect on point E. The circle of [the beginnings of] Aries and Libra, on the other hand, will be circle ZHTK, and the position of the ring [i.e., allidadath][6] be point A. Then you will divide circle ZHTK into 360 divisions. Afterwards you will set arc KL in the same way as [i.e., equal to] the latitude of the region, and arc HM similar [i.e., equal] to it, and likewise arc ZG.

Afterwards you will join G with H and it will cut diameter AC at P, and point P will be the point of the zenith overhead. Then you will join H with L and it will intersect diameter AC at S. After this you will join H with M and extend HM until it is joined [with the diameter] at N, and NS will be the diameter of the horizon, which you will divide in half and make part of a circle intersecting the circle of Capricorn on points V and F, and it is this arc, that is VSF; because if this part [i.e., arc] falls on points H, S, K, you have now found [the horizon] and the work is extremely accurate. If, however, it is different, you have erred; therefore, repeat the work again.

After this, you will cut off from point M towards Z an arc of 3 degrees, or 10, or as many as you wish, and this is arc MR and similarly arc LQ. Afterwards you will join H with Q and it will cut the diameter at I; then you will join H with R and extend the line until it cuts the diameter at O. After this you will divide OI in half and make part of a circle cutting the circle of Capricorn at points Y, X, and it is arc YIX. Similarly you will not cease your activity until you reach the point of the zenith overhead, that is P, according to the procedure in this diagram. And you will write the number on the almucantar, as you see in the diagram.

[6] See Chapter 4, note 7.

[FIGURE 13]

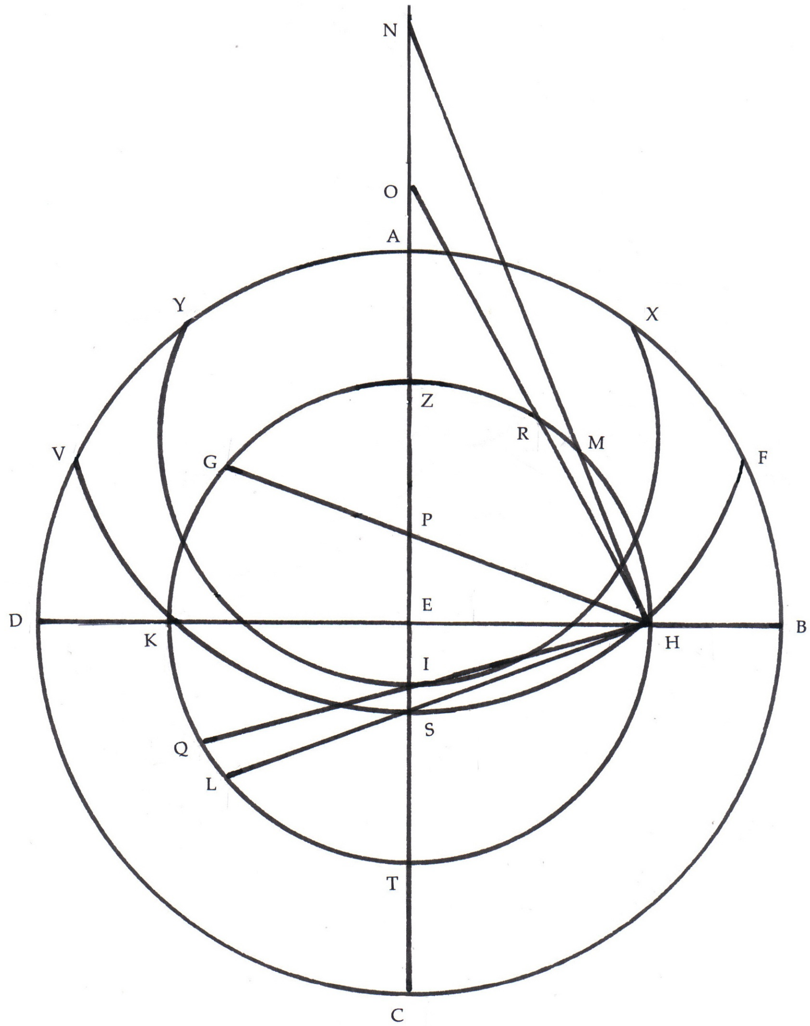


Figure of the inscription of the almucantars at the latitude of the region

[CHAPTER 14.] ON THE DIVISION OF THE HORIZON AND THE AZIMUTHS BY ARCS

And after this it is necessary to make the azimuths;[1] to make these you should attach the plate to some other wooden surface with pitch or with something else, and you draw on it the horizon. Then you divide the horizon as you divided the circle of signs with those three methods;[2] but you use, in place of the whole declination, the whole altitude of Aries and Libra in the same region. Moreover, its altitude in the same region is such that you subtract the latitude of the region from 90, and what will remain this will be the altitude of Aries.[3] And we repeat the instruction about this because it has been shown [to be] better (God willing).

And therefore we take the circle of the horizon ABCD, and circle of [the beginnings] of Aries and Libra EBZD and its diameters intersect on centre H, and we extend diameter ZE straight towards A. Afterwards we take arc DT as the altitude of Aries in the same region. Then we divide it into 2 equal [parts] at K and we join K with B, and we cut diameter AZ at L. Afterwards we take arc EN as 10 degrees, or however much we wish, and arc ZM similar to it. Next sketch out the arc which is through points M, L and N, and this arc cuts the horizon at points S and O. Again do likewise so that you cut the rest [of circle] ABCD. Afterwards you divide quarter AD as quarter AB, and quarter CB just as the division of CD as we made in dividing the circle of signs, and likewise you each horizon circle by 10 and 10 or by 20 and 20 or by degree and degrees, or by minute and minute, or however much you wish, as is shown in this diagram.

[ADDENDUM 14][4]

Actually, the horizon is better divided by straight lines passing through the whole altitude [of the circle] of Aries, that is, through the zenith point and the degree of the equator; and we use this [method].

---

[1] The next step, after the almucantars (Chapter 13), is to draw the azimuths. But to do this one must first divide the horizon into segments equivalent to the spacing of the azimuths. This division is covered in Chapter 14, and the drawing of the azimuths themselves is the subject of Chapter 15.

[2] See Cap. 9. Here in Cap. 14 the last method found in Cap. 9 is not mentioned. Ps.-Māshā'allāh does give the first method in detail, and mentions the second in the addendum, but does not describe the third (using a table of right ascensions). Samsó says that Maslama also gives these three methods (*On Both Sides*, pp. 426-428).

[3] In other words, you use the co-latitude of the observer.

[4] This material is found in many mss at the end of the chapter, but in two mss in the margin, and in one ms in the middle of the first paragraph (after "region").

[FIGURE 14]

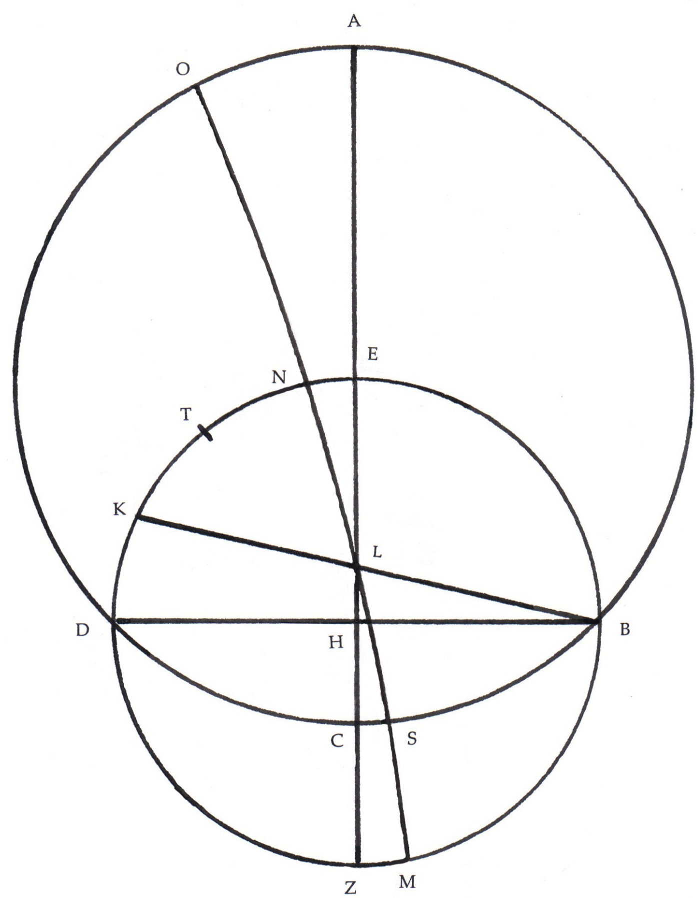


Figure of the division of the horizon using arcs through half the altitude
[of the circle through the beginnings] of Aries and Libra

[CHAPTER 15.] ON THE INSCRIBING OF THE CIRCLES OF AZIMUTH ON THE ZENITH

After you have divided the circle of the hemisphere [i.e., horizon], you will locate the azimuths on it as follows: Make the circle of Capricorn A, B, C, D, the circle of Aries and Libra Z, L, Y, M, and the circle of Cancer H, T, G, S, and the complete circle of the horizon E, L, V, M.

Next we will divide it [the horizon] by any aforementioned method. And let its divisions be EN, NS′, S′M, MH′, HT′, T′V, VR, RC′, C′L, LQ, QO, and OE.[1] And we will draw the overhead zenith point, and it would be point K. Afterwards we will seek the arc of the circle which goes through point N and its nadir,[2] point R, and point K, the overhead zenith point. And let this be arc NKR, and it will divide the path of Aries on point X, and the path of Capricorn on point I, and the path of Cancer at point F′. And we will construct an arc similar to the aforesaid [arc NKR] and it will be the arc which passes through point O, and T′ opposite point O; and this arc will cut the circle of Capricorn at point D′, and the circle of Aries at point F, and the circle of Cancer at point I′.

You will do similarly in arc S′KC′ and QKH′ and MKL. And you will complete the position of these azimuths through this division of 30 and 30 degrees. Similarly you will divide degree by degree, or what you wish. And you write in them [i.e., the divisions] the number in accordance with what is in the figure (God willing).

[ADDENDUM 15][3]

And note that you will find the circle passing through the zenith and the beginnings of Aries and Libra and it will be the first azimuth, and the second [azimuth], because the zenith is depressed or raised. In pursuing this, it is proper to seek the centre of that in various places on the diameter so that the first azimuth always passes through the zenith and the beginnings of Aries and Libra.

---

[1] Because of the large number of letters needed to define these divisions, some of the letters are repeated. Scribes often substituted other letters for the duplications, or added a second letter to the first to distinguish between them. I have added primes in my Latin text, the diagram, and the English translation.

[2] This is not the normal meaning of "nadir", i.e., the point in the celestial sphere vertically opposite the overhead zenith; here the "nadir" of a point or position means the opposite point 180° across (or around) the sphere.

[3] This material is found in many mss at the end of the second paragraph.

[FIGURE 15]

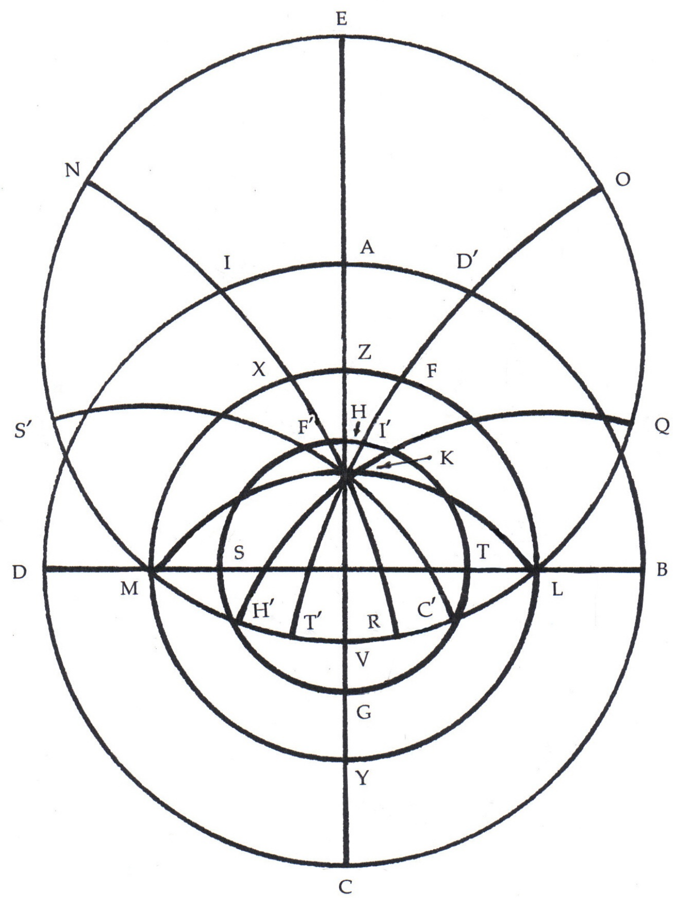


Figure of the inscription of the azimuths through the zenith

[CHAPTER 16.] ON PLACING THE HOURS[1]

And after placing the azimuths, you must situate the hours as follows: You will mark the circle of Capricorn ABC, and the circle of Aries and Libra DEZ, and the circle of Cancer HTQ, and what in it falls from the circle of the hemisphere should have under it A, D, H, L, Q, Z, C; and this very line LTEB passes through the ring [i.e., alidadath][2] and through the point of the plate, that is, the centre, and this is the line of recession.[3] And line LB will be the end of the 6th hour, and the beginning of the 7th. And afterwards you will divide arc HT into 6 equal divisions, and let the divisions be HM, MN, NS, SO, OF, and FT; and you will also divide arc DE into 6 equal divisions, and let the parts be DK, KR, RX, XY, YP, and PE. You will also divide arc AB into 6 equal divisions, and let the divisions be AH^E, H^ED^E, D^ET^E, T^ET^O, T^OH^O and H^OB.

Afterwards you will find the arc which passes through the points H^E, K, M; and you will also seek the arc which passes through points D^E, R, N, and it is arc D^ERN; and you will also seek the arc which passes through points T^E, X, S; and you will search for the arc which passes through points T^O, Y, O; and you will try to find the arc which passes through points H^O, P, F.

And you will complete the first hour, and you will write "first" on it; then "second," "third," "fourth," "fifth," and "sixth," as it is in this diagram. After that you will divide the remaining hours in conformity with the first dividing, and you will write on them "7," "8," "9," "10," "11" and "12," as it is in the place already mentioned. And you should write "west" near the first hour and "east" near the 12th hour. Then you will write on it [i.e., the plate] the latitude of the region in the place described. Afterwards when you have drawn the hours, this face of that plate will be completed; and in this way you will make other latitudes of a different region on another plate (God willing).

---

[1] The hours referred to here are the "natural" hours, also known as the "unequal" hours, i.e., the night and the day each divided into 12 equal parts. Since the length of night and day varies through the year, so do the length of these hours. They are "unequal" in the sense that a daytime hour is different from a night-time hour (except at the equinoxes) and an hour of one day (or night) is not the same as the hour of the next (or previous) day (or night).

[2] See Chapter 4, note 7.

[3] See Chapter 12, note 3.

[FIGURE 16]

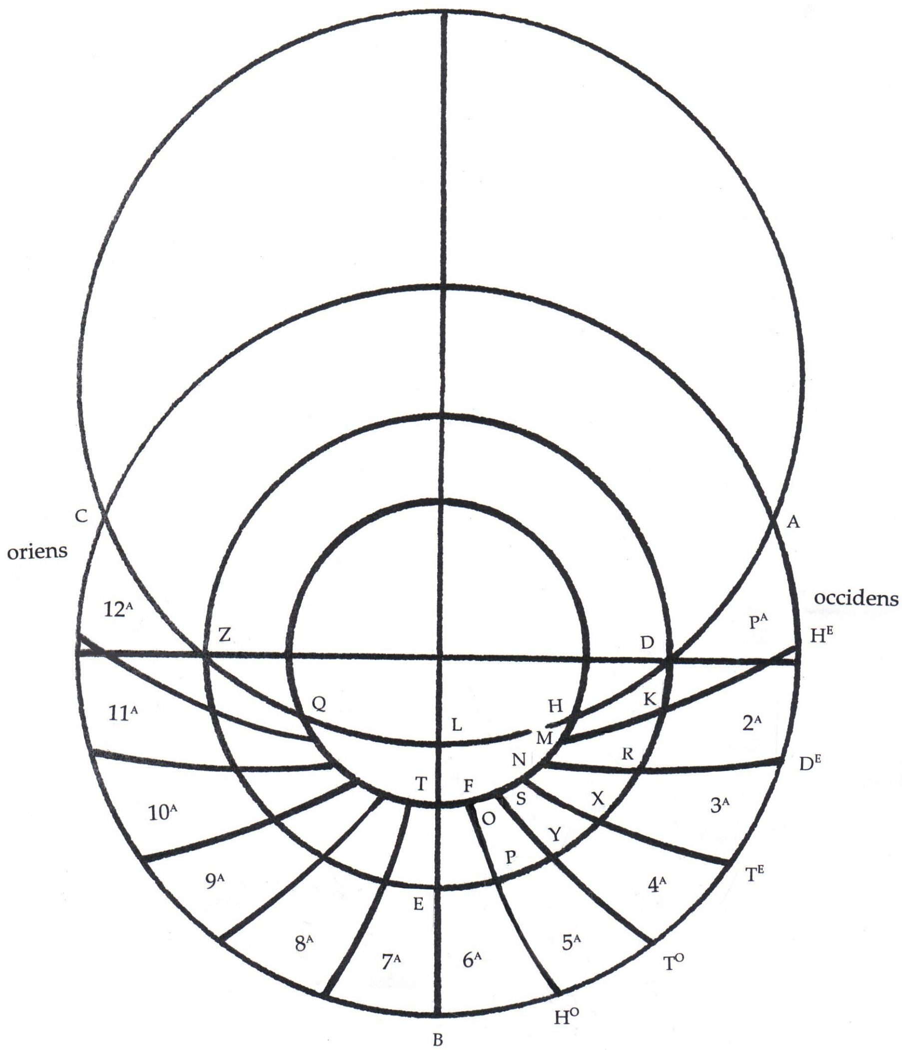


Figure of the inscription of the 12 natural hours

[*Construction, Section III*]

[CHAPTER 17.] THE PROJECTION OF A SPHERE ONTO A PLANE

The flattening or extension, or more correctly the projection by sight,[1] of a sphere onto a plane is effected in this manner. Let the plane be line MBN, the axis of the sphere, line AB, standing perpendicular on the plane MBN so that the north pole touches plane MBN at point B. However, let the other one, that is the southern one, be at the greatest distance from the plane at point A, which is the eye of the observer. Let there be the colure passing through the greatest declinations of the sun;[2] let it be ACBD. Likewise line CD parallel to the plane, is the daily equator, EH the Tropic of Cancer, GF the Tropic of Capricorn and these two are likewise parallel to the plane. Line EF, however, is the ecliptic.

Let two lines extend therefore from point A, the south pole, that is from the eye of the viewer, through the two ends of the equator, that is, C and D, to two points in the plane, P and X, and line PX will be the diameter of the equator. And from the same point [A] two other lines, that is, through E and H the ends of the Tropic of Cancer should meet the plane at points Z and Y and this line ZY will be the diameter of the same Tropic [projected] in the plane. And similarly another two lines through G and F, the ends of the Tropic of Capricorn, meeting the plane at points M et N; they make from this line MN the diameter of [the Tropic of] Capricorn [projected] on the plane. When therefore circles are drawn on the centres of whatever diameters represented in line MBN, they will become the first circles in the plane projected proportionally from the sphere by sight [*or* stereographically].

[1] This specific projection is known as "stereographic projection." See Ron B. Thomson, *Jordanus de Nemore and the Mathematics of Astrolabes: De plana spere* (Toronto: PIMS, 1978).

[2] I.e., the colure or great circle passing through the solstices.

[FIGURE 17]

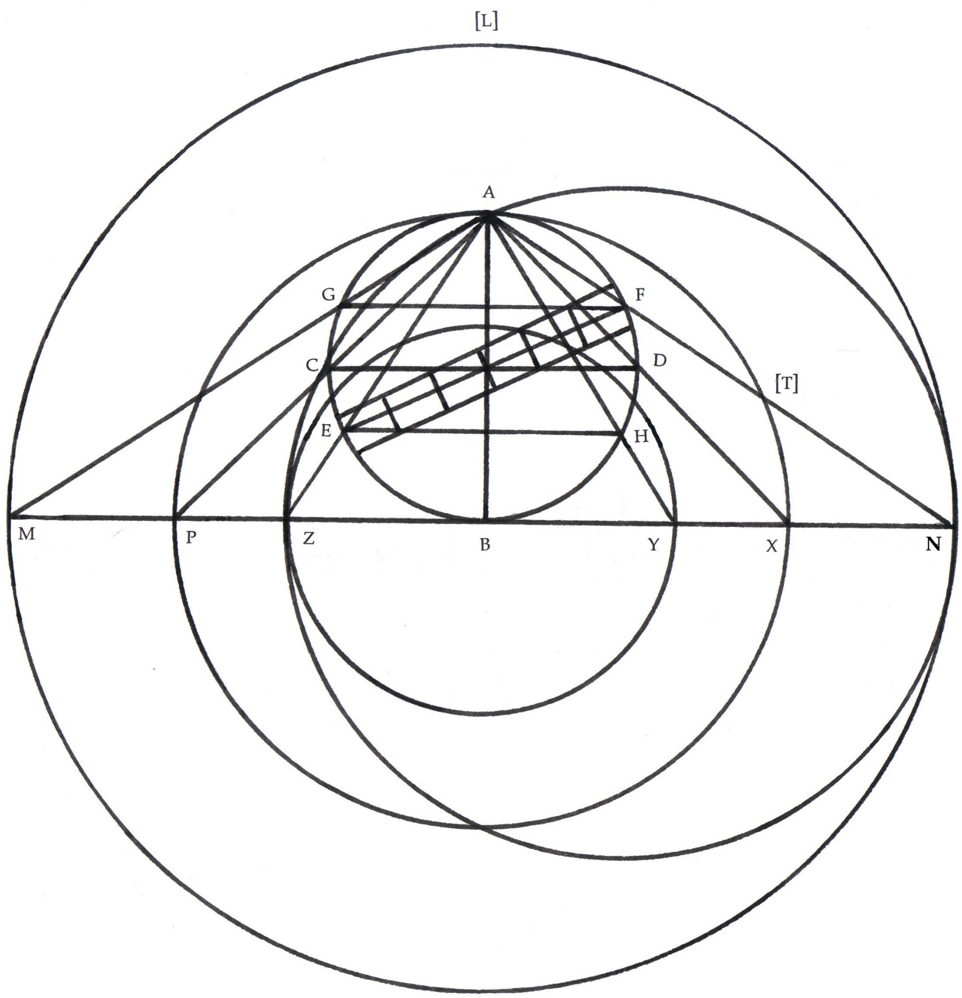


Figure of the projection of a sphere on a plane.[3]

[3] Note: in most diagrams the zodiacal names, Cancer to Sagittarius, read from left to right along the bottom band, and Capricorn to Gemini read from right to left along the top band and are also written upside down. In a few cases Capricorn to Gemini are written from right to left, but right-side up.

[CHAPTER 18.] THE INSCRIBING ON A PLANE OF A [CIRCLE][1] ON A SPHERE PARALLEL TO THE ZODIAC

However, if we wished to project on a plane [the image][2] of any point [i.e., circle] in the sphere parallel to the ecliptic[3] it will be done thus. Let circle AB pass through the poles of the globe, which are A and B, B, however, touching the plane; and line MBN is the common section of [the plane of] circle AB and the plane [of projection]. CD is the diameter of the equator, EF the diameter of the zodiac,[4] GH the diameter of one [of the circles] parallel to the zodiac of those which are towards the region of the north, KL the diameter of another parallel to the zodiac which is towards the region of the south. Hence each of the two arcs CE and DF is the declination of the zodiac from the equator; moreover the two arcs CG and DH are the two extreme[5] declinations from the equator of the circle whose diameter [is] GH. Similarly the two arcs CK et DL are the two extreme declinations from the equator of the circle whose diameter [is] KL. Therefore, let the lines AKOM, ACP, AEZQ, AGIR, AHZ′Y,[6] ADX, AFTV, ALSN cross.

And PX will be the diameter of the equator which will pass through A; for since [the angle] is equal at it [i.e., P] and A, PB will also be equal to BA. Again ZV will be the diameter of the zodiac which will also pass through A since this very one [i.e., the zodiac] divides the equator in half. And IZ′ will be the diameter in the plane of the circle whose diameter is GH in the sphere. Whereas on the other hand MN will be the diameter in the plane of the circle whose diameter is KL in the sphere; and in addition arc PQ will be similar to arc CE, for each is subtended by angle PAQ standing on the circumference of each circle; and PR is similar to arc CG for the same reason, and PO is similar to CK.

---

[1] The mss read *puncti*, where they should read *circuli*.

[2] There must be some understood noun here in order to explain the genitive construction in the Latin. None is obviously suggested but "image" or "projection" might suffice.

[3] This is also treated in Ptolemy's *Planisphaerium*; see *Opera Omnia*, 2: *Opera astronomia minora*, ed. J. L. Heiberg (Leipzig: Teubner, 1907), pp. 252-258. [J.S.]

[4] More correctly (here and throughout), the ecliptic. In these last chapters (17 to 22) the author is less exact in his terminology.

[5] In this case, and in line 9, *maxime* cannot mean "greatest" since one of the arcs in each case (DH here, and CK in line 9) is actually the minimum declination of the parallel circle. Hence I have read *maxime* as the "extremes" or the points of the greatest and the least declinations.

[6] Two points are labelled "Z" in this chapter. To distinguish between them some manuscripts use two forms of the letter, i.e., the regular "Z" and an earlier form which looks like "Ç". I have chosen to simply label the second one as "Z′", i.e., Z-prime.

And in the same way, and for the same reason,[7] arc XS will be similar to DL, and XY similar to DH.

When therefore you wish to plot on a plane any circle parallel to the zodiac, if it be south of the zodiac, assume on the equator from point X towards A a single arc equal to an arc composed of the declination of the zodiac from the equator, and [the declination][8] of that circle to be drawn from the zodiac, as here it is arc XS which is composed of arc XT, which is the declination of the zodiac from the equator, and of arc TS which is the declination of that [circle] from the zodiac. Then, on the other side, subtract the declination of the zodiac from the equator from the declination of this [circle] from the zodiac, if you can, as here arc PQ from arc OQ and assume the remainder which is PO from point P towards A. But if you cannot subtract the declination of the zodiac from the equator from the declination of this [circle] from the zodiac, do the opposite, that is, subtract the declination of this [circle] from the zodiac from the declination of the zodiac from the equator, and assume the remainder from point P, not toward A but toward the opposite direction; and so extend AS and AO until they cut diameter MBN at points M and N, and MN will be the diameter of the circle which is sought.

If however this were to be north from the circle of signs, assume the combined declination below P on the opposite side, and the difference of the two declinations below X if the declination of the zodiac from the equator is less, or above if it is greater, and draw lines from A through [the ends of] the diameter to MBN, and they will cut off the diameter IZ′ of the circle which is sought, as is clear in this diagram.

---

[7] It is possible, but I think not probable, that "in the same way" and even "for the same reason" could be part of the previous sentence.

[8] When speaking of circles parallel to the zodiac/ecliptic and of their distance from the ecliptic, one should really use the term "latitude" to distinguish it from the modern concept of declination (that is, vis-à-vis the celestial equator). However, I have kept the term "declination" in this chapter, to reflect the Latin.

[FIGURE 18]

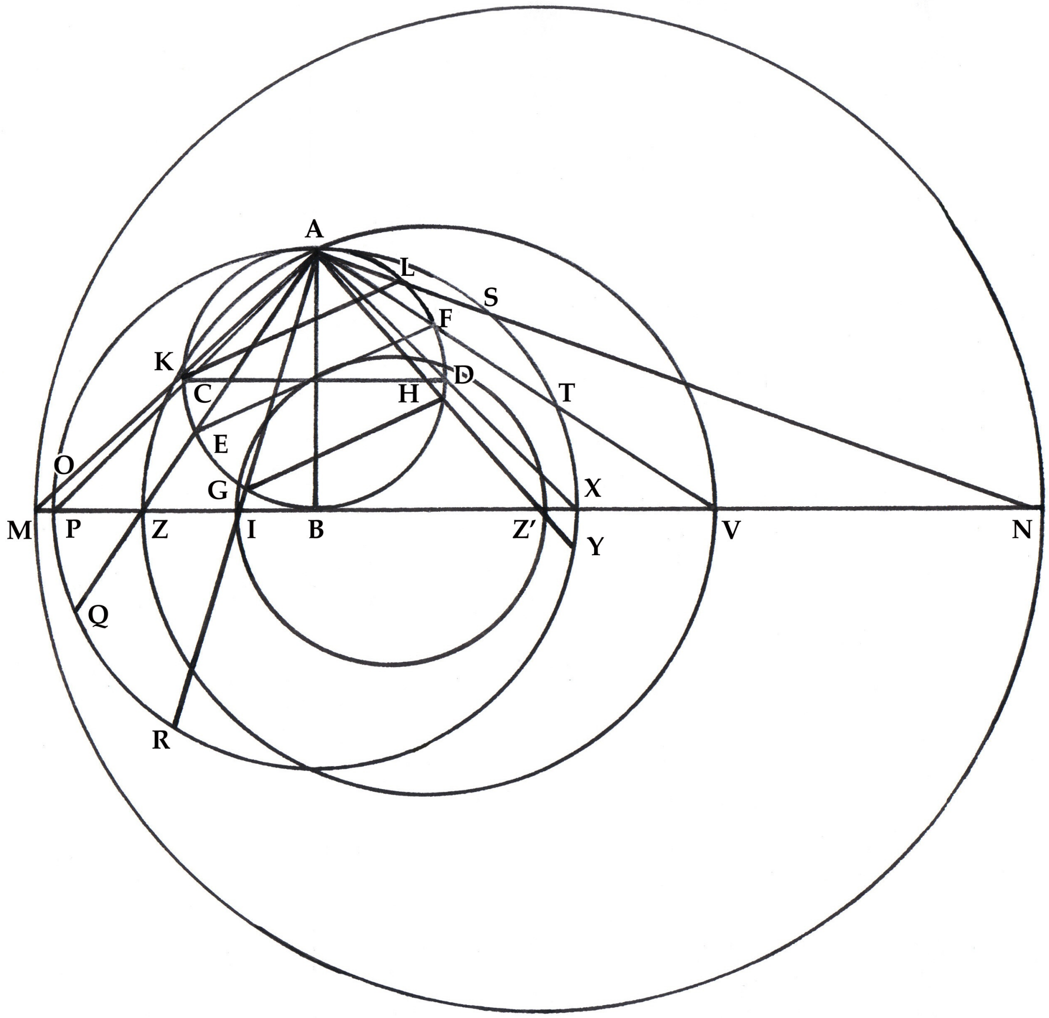


Figure of the inscribing in a plane of a circle[9] on the sphere parallel to the zodiac

[9] As noted above, while the text reads *puncti*, it should read *circuli*.

[CHAPTER 19.] ANOTHER WAY OF MAKING AZIMUTHS[1]

And again, azimuths can be made in this way. Let there be 3 circles, as before: ABCD ,the [Tropic or circle] of Capricorn; FGHI [the circle through the beginning] of Aries; LMNP [the Tropic or circle] of Cancer. Therefore take from point H, in the quarter HG, 48 degrees of latitude[2] where K is; and in the same way from F in the opposite quarter FI where let it be Q, and where the line extended from G to K meets diameter AC, let it be R; indeed, where the line extended from G to Q meets diameter AC, let it be S, which is the zenith. Then on the diameter RS divided in half at point X draw the first azimuth, and that part of it which falls on the circle of the horizon should be visible; the rest, however, as if hidden (because afterwards will be deleted) which necessarily will cross beyond points G, I, just as the horizon. And when you have divided the semicircles SGR, RIS in half at points Z, O, extend line ZO in length in each direction, necessarily passing through centre X. For in that [line] you will find the centres of the remaining azimuths in this sequence. You will divide, that is the portion of the first azimuth which is RI,[3] into 9 equal parts; though it [RI] is greater than a quarter, nevertheless it carries the weight [or value] of a quarter of a circle. Similarly you will

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[1] This method (among others) of drawing azimuths has been studied by J. L. Berggren in "Medieval Islamic Methods for Drawing Azimuth Circles on the Astrolabe," *Centaurus*, 34 (1991), 309-344. It is what he has called "An Anonymous Method" (pp. 330-333) found in our text and in the writings of al-Sijzī and al-Bīrūnī.

This method is also given by Abū ᶜAlī al-Ḥasan al-Marrākushī (p. 332) who introduces some errors, one of which (dividing individual "quadrants"[SG, GR, RI and IS] into equal parts rather than dividing the whole circle, or the two semicircles, into equal parts) is copied here at lines 12 and 13.

See also Samsó, *On Both Sides*, pp. 429-430. Samsó notes (p. 430) that "these two chapters [i.e., 19 and 20] pose the problem of the source used: neither al-Sijzī nor al-Bīrūnī seem to have been known in the Islamic West, and al-Marrākushī's *Mabādi'*, a work written in Egypt which shares a common error with the *De compositione*, was never accessible in a Latin or Hebrew translation. The method probably derives from an unknown source or was actually used by astrolabe-makers. Whatever the case, it is also in the treatise by Rudolf of Bruges." [Notes refer to Julio Samsó, "al-Bīrūnī in al-Andalus,"in Josep Casulleras and Julio Samsó, eds., *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet* (Barcelona: Instituto "Millàs Vallicrosa", 1996) 2: 583-612, reprinted in Samsó, *Astronomy and Astrology in al-Andalus and the Maghrib* (Aldershot: Ashgate-Variorum, 2007), VI; and Richard Lorch, "The treatise on the astrolabe of Rudolf of Bruges," in Lodi Nauta and Arjo Vanderjagt, *Between demonstration and imagination. Essays in the history of science presented to John D. North* (Leiden: Brill, 1999), p. 90.]

[2] Latitude 48°N passes through Orléans, Munich/München and Vienna/Wien.

[3] This is erroneous; the entire semicircle SIR (or the entire circle) should be divided into equal parts, rather than just the individual "quadrants" (SG, GR, RI and IS). The same error is repeated in the next line. The text is following the lead of al-Marrākushī who appears to have introduced the error. See Berggren, "Medieval Islamic Methods, " p. 332.

also divide the portion IS into 9 equal parts; though it is less than a quarter as drawn, nevertheless a quarter is assigned, and the first ninth from R should be RT, the second TY, the third YZ′, the fourth Z′X′ so that the centres of the other azimuths will be set where lines from point S, which is the zenith, drawn only to nine parts [i.e., points][4] (that is to the second, fourth, sixth, eighth, and so on) will have touched [i.e., intersected] the diameter of the first azimuth in the omitted parts [i.e., the area of plate below the horizon]; and all [the azimuths] will circle through S, the zenith, such that parts of them extending beyond the horizon or the circle of Capricorn are minimally drawn. And so you will find to the right of centre X eight centres according to the number of the same; and in like manner you will create to the left of X an equal distance from them.[5] And note, when you divide the quarters by 9 where any ninth contains 10 degrees, that though they are unequal to any of the nine[6] they will extend 10 degrees, and azimuths containing 5 degrees will then be produced; and if the division of the quarters into 20 [degree segments]were made, azimuths of 10 degrees would be produced, in a half proportion.[7]

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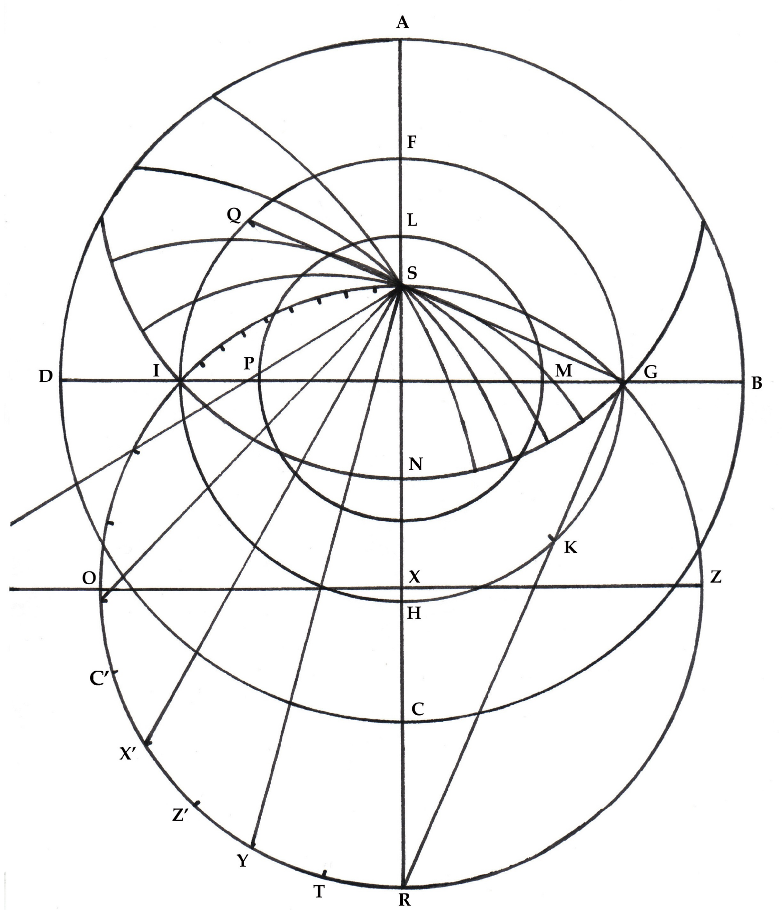
[4] That is to 9 of the 18 points of division along the semicircle RS. This produces azimuths spaced 10° apart.

[5] This sentence contains problems of strict translation and interpretation. However, the sense is that one constructs on the right of X a mirror image of what is on the left of X, that is, a set of centres on which you would construct the rest of the azimuths.

[6] Since the text contains a mathematical error, the divisions of the semi-circle are not equal; those in one "quarter"segment will be larger than those in the other "quarter" segment. While they represent divisions of 10 degrees on the sphere, in fact they are drawn larger or smaller than 10 as a result of being projected on the plane.

[7] The text is re-iterating the fact that the spacing of the azimuths are half of the degrees in the divisions of the first azimuth. Thus dividing the first azimuth into "10-degree" segments will produce azimuths representing 5 degree spacing; and dividing the first azimuth into "20-degree" segments will produce azimuths representing 10 degree spacing.

[Figure 19]



A second method of inscribing azimuths[8]

[8] Since the text incorporates the error of dividing each of the two "quadrants" (SI and IR) into 9 parts, rather than the whole semicircle SIR into 9 (or 18) parts, the drawing of all the azimuth lines becomes virtually impossible (the radii of the circles become extreme as one approaches S along the semicircle SIR). Therefore I have followed the medieval scribes in drawing only a few of the lines from S and a few of the azimuths. Note: the diagram reflects the text and not the correct means of drawing azimuths.

[CHAPTER 20.] ANOTHER WAY OF MAKING AZIMUTHS

Another way of making azimuths,[1] easier [to execute[and clearer than the one mentioned above: make the circle of Capricorn, ABCD, and the equator, EFGH, on centre I, and we will make part of the horizon circle, BFHD, and we will draw the diameters EG, HF perpendicularly intersecting at I, and let point K be the zenith overhead. Again we will make – the centre positioned in diameter AG extended uninterrupted and straight – a circle on point O passing through points H, K, F which is to be [circle] KFLMNH. And we will draw diameter NL parallel to HF in both directions as much as it ought to be; and we will divide semicircle MLK by 3 at a time and 3 at a time or 5 at a time and 5 degrees at a time or 10 at a time and 10 at a time to the extent that you wish to make azimuths. And we will connect point M which is the point opposite to the high point overhead with each of those divisions right up to line LN, and let the extended lines be MP, MR, MS, MT, MY, MZ, MF′. Next, after positioning the centre on points P, R et cetera, draw circles passing through point K, which is the overhead zenith, and if they were completed [properly] they would pass through point M which is opposite the overhead zenith; therefore when they pass through opposite [points] on the sphere, they will all be from the greater circles;[2] however, of these circles you will construct only the parts appearing above the circle of the horizon as far as the circle of Capricorn, and there will be between whichever two of these circles as many degrees as were cut off between the divisions of semicircle KFLM. However, when you have done this, take from line LN clearly 11 equal parts OF, OZ and so on. And on those points taken as centres draw circles passing through K, and these will be the azimuths. In the other two quarters made similarly just as the previous ones they will separate off just as many degrees between them as the previous ones. and this is the figure.

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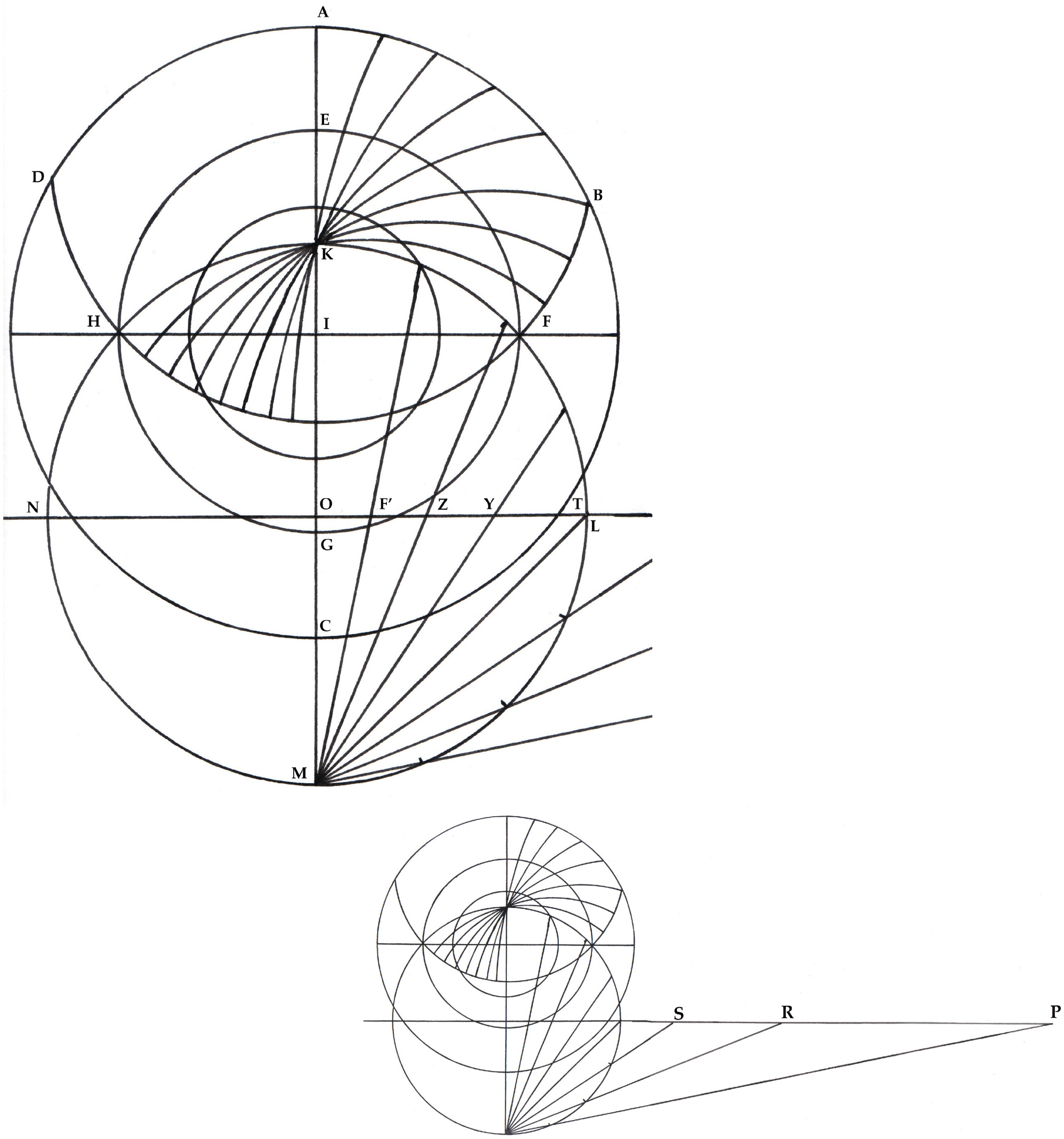
[1] This method is the same as in Capitulum 19, only here the first azimuth is correctly divided into equal segments. As well the lines which are drawn to the division points (and which intersect with the diameter of the first azimuth circle) start not from the zenith point but from the projection of the point on the sphere diametrically opposite the zenith point.

For Samsó's comments on possible sources for this capitulum, see Cap. 19 note 1.

[2] I.e., "great circles" – circles on a sphere which pass through opposite points, usually, but not necessarily, the poles.

[FIGURE 20]



A third method of inscribing azimuths

[CHAPTER 21.] ON THE PLACING OF THE LINE OF TWILIGHT[1] AND DAYBREAK

When you wish to make the twilight and daybreak line, draw a parallel[2] to the horizon below it to the side of the point opposite the overhead zenith, whose latitude from the horizon should be 18 degrees; for with the appearance of the sun below the horizon at so many degrees, the light of the sun is visible. You will describe this, however, in this way: make the circle of Capricorn, ABCD, and of Aries and Libra, EFGH, on centre I, which you will make square by having the two diameters cut each other perpendicularly on I, as AC, DB; and you will assume the latitude of the region along the equator from F towards E, which should be KF; similarly from H towards G, which should be HL, and let lines FK and FL be drawn, which are to meet with diameter AC extended as much as is useful uninterrupted and straight at point O and Q; and after dividing line OQ part of circle THQFS should be drawn on the mid-point, which will be the horizon circle. After this let arcs of 18 degrees be assumed from K towards F and from L towards G, which are KM, and LN. And after you draw lines FM and FN, they will meet with line AC on points P and R; we will therefore divide line PR in half, and having positioned the centre in the mid-point, we will describe a part of the circle VRX, which will be the circle parallel to the horizon, whose latitude from the horizon will be 18 degrees, and this is the line of twilight and daybreak, of which this is the diagram.

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[1] *Crespusculum* usually means evening twilight, but it can refer to both morning (*crespusculum matutinum*) and evening (*crespusculum vespertinum*}. Here, in its singular form and differentiated from *aurora* ("break of day") it would be evening twilight.

The captions of many of the diagrams (q.v.) use *linea crepusculorum*, which would cover both times of day. The twilight line functions for both – when the sun is approaching the horizon at daybreak and night fades, and when the sun recedes below the horizon at sunset.

[2] Obviously the twilight/daybreak line or circle is parallel to the horizon in the sphere, not parallel (or concentric) when projected on a plane.

[FIGURE 21]

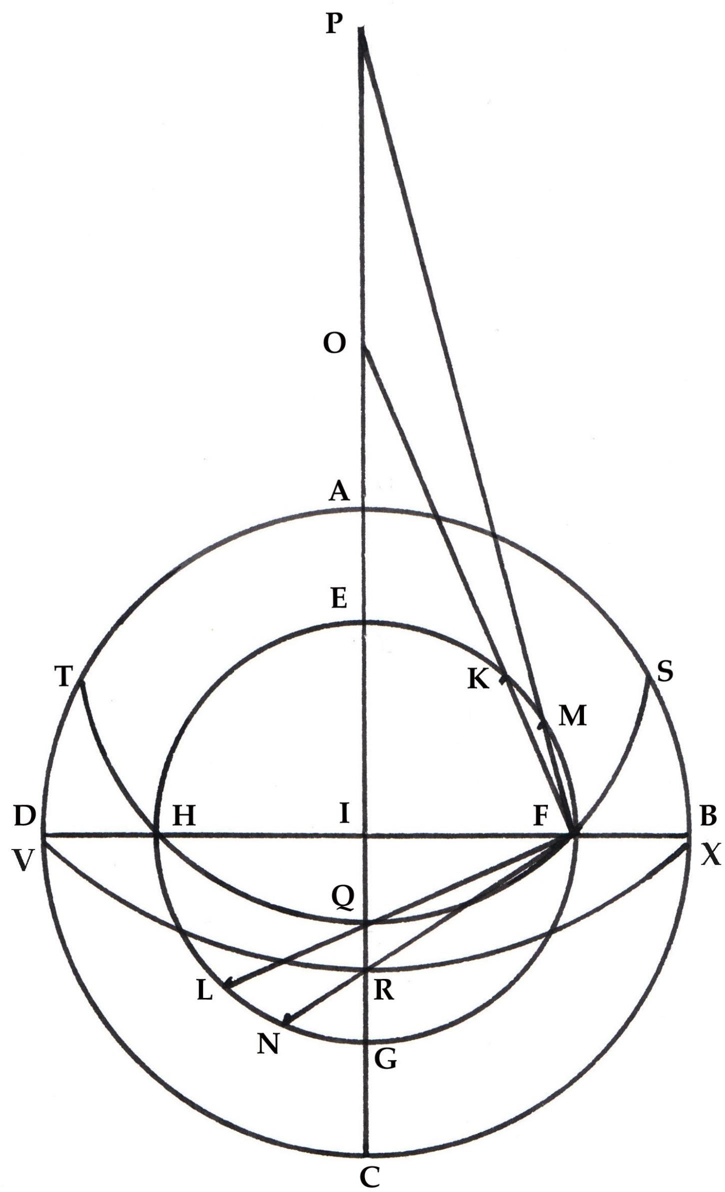

Figure of the inscription of the twilight and daybreak line

[CHAPTER 22.] THE PLACING OF THE FIXED STARS IN THE RETE BY THEIR DISTANCE FROM THE ECLIPTIC[1]

When you have divided the circle of signs most accurately, you next ought to describe the fixed stars in the circle of signs in this way: We will take the circle of the celestial equator, that is [through the beginnings] of Aries and Libra ABCD and let the diameters intersect on E, and there should be on the circle of signs [the letters] AZCH. Then you will count off along the circle [through the beginnings] of Aries and Libra from point D towards C the declination of the sun, that is 24 degrees, and you will place there T; and similarly in the opposite part from B towards A, and you will place there X. Then place a ruler on T and X, that is on each end of the number of 24 degrees, and you will draw a faint line from T to X. Next in the table of fixed stars you will take note of the star the star which you wish to place in the circle of signs, in which of the signs it would be, and its longitude and latitude, and whether it is to the north or to the south.

Now if it be to the north, you will count off along the circle [through the beginnings] of Aries and Libra from point T towards D as many degrees as is the latitude of that star, and you will place there V; and similarly on the opposite side that is from X towards A and you will place there Y. Next put one end of a ruler on point C, which is the beginning of Aries, and the other end on the end[-point] of the latitude of the star, that is on V, and you will note the contact of the ruler and diameter HB, and there you will put R. Afterwards, similarly you will place one end of a ruler on point C and [the other end] on Y, and where the ruler cuts diameter HB, you will place the letter S. Afterwards make a circle passing through the letters R and S, and in this circle ought to be the elevation of that star. Then in the table of fixed stars take note of the longitude of the said star, in which degree of which sign it be, and through the total number of its degrees and through the total number of its nadir, namely outside the circle of the zodiac,[2] and through the pole of the zodiac, that is through point K, see that one arm[3] of

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[1] This capitulum uses the system of defining star positions vis-à-vis the ecliptic, known in modern astronomy as "celestial latitude" and "celestial longitude". The latitude is that of a circle parallel to the ecliptic and through the star, and measured from the ecliptic up to the pole of the ecliptic. The longitude is a great circle through the star and passing through the poles of the ecliptic, meeting the ecliptic at right angles and measured along the ecliptic from the beginning of Aries. Although this system is mentioned in Capitulum 10, it is different from the system described there in detail which uses right ascension and mediation to locate the star. See the notes to Capitulum 10. Samsó notes that this method is more or less standard, and is also described in Maslama's extra-chapter (*On Both Sides*, p. 431).

For a further discussion of this problem, see Thomson, *Jordanus de Nemore*, Proposition 5, and commentary pp. 144-145.

[2] That is (here and throughout), the ecliptic.

[3] A difference between Latin (a "foot" of a compass) and English (an "arm" of a compass) idioms.

a compass passes uniformly and where the compass cuts circle RS, there will be the elevation of that star. And if with the degree of that longitude and latitude there are minutes, take from the following degree one sixth part if there are 10 minutes; if 15, a quarter part [of a degree]; if 20, a third, and so on for the others, and also do this as above for northern stars.

If, on the other hand, it is a southern [star], again you will count along the circle [through the beginnings] of Aries and Libra from the mark of the sun's declination, that is from T towards C as many degrees as is its latitude [and place there a mark]; and similarly in the opposite part from X towards B, and make a mark there. And set the ruler on one of those marks and on the beginning of Aries, that is on C, and where it cuts diameter HB, make a mark on the diameter. And similarly place the ruler on the other mark and on C, and where it cuts diameter HB, make a mark. Afterwards make a circle according to the longitude of those two marks on the diameter; and in this circle will be the elevation of that star. Then in the table of fixed stars take note in which degree of which sign it be. And make sure that one arm[4] of a compass passes uniformly through the end of the number of its degree and through the end of its nadir, that is on the outside of the circle of the zodiac, and through the pole of the zodiac, that is through point K. And where the compass cuts the circle at two marks on the diameter, there will be the elevation of that star. And similarly place all the southern stars.

Moreover, you will find the pole of the zodiac thus: count from point A along the circle [through the beginning] of Aries towards D 12 degrees,[5] and place there a mark;[6] and place a ruler on that mark and on C and where it cuts diameter DB, make the mark K; that mark will be the pole of the zodiac, as is clear in this figure.

The *Construction of an Astrolabe* ends.

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[4] See the previous note (note 3) above.

[5] When projected on the plane, the pole of the ecliptic is found by using half of its declination (from the celestial pole), i.e., 12 degrees rather than 24. Many scribes, however, did not understand this and accepted the substitution of 24 for the correct number, 12. The diagram (Fig. 22A) generally shows the correct use of 12 degrees, and is reflected in the caption. See also Chapter 9.

[6] In some diagrams (Fig. 22A), this point is labelled "F".

[FIGURE 22]

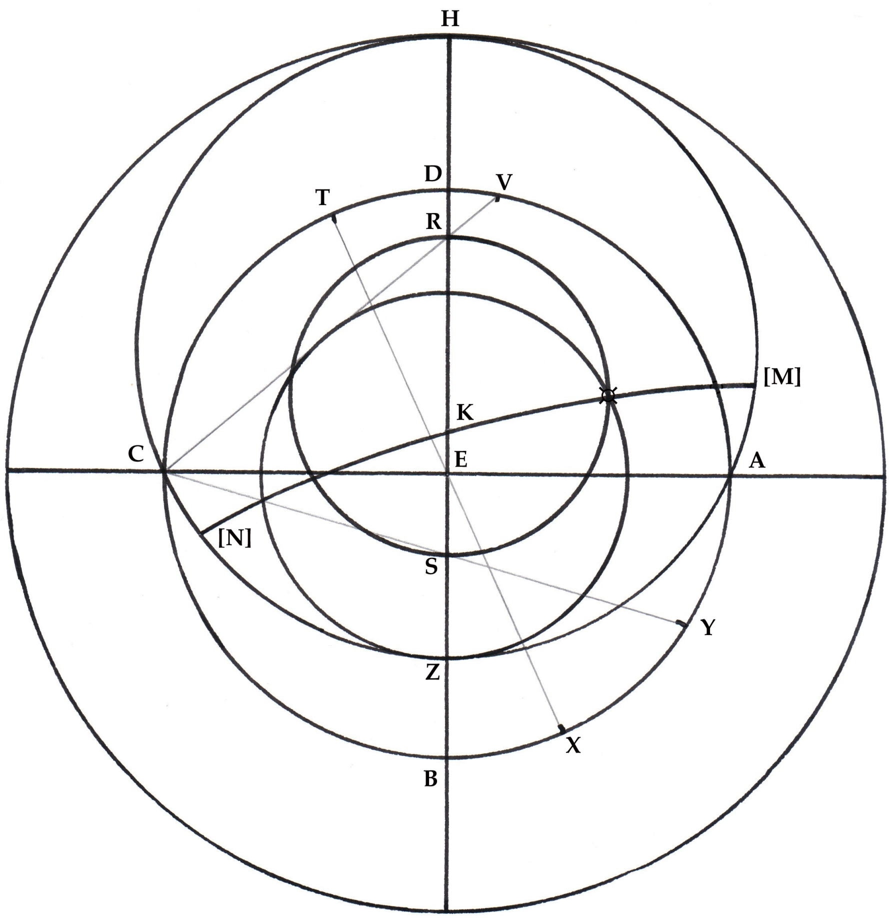

Figure of the inscription of the fixed stars in the rete by their distance from the ecliptic[7]

[7] This figure shows the positioning of a northern star only.

[FIGURE 22A]

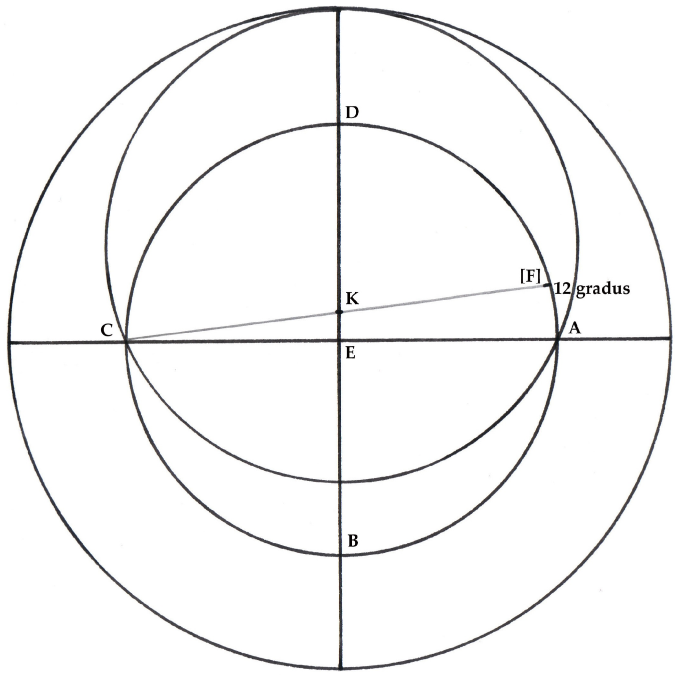

Figure of the inscription of the pole of the zodiac on half of its declination

[Lists of Fixed Stars][1]

[1] Detailed information about the various stars are found in Appendix 1 to the critical edition of the Lists of Stars.

[*LIST OF STARS 1*][1]

TABLE OF FIXED STARS WHICH ARE PLACED IN AN ASTROLABE, WITH DEGREES WHICH MEDIATES THE SKY, AND WITH THEIR DISTANCES FROM THE [CELESTIAL] EQUATORIAL CIRCLE.

Signs	Names of the stars	Images	Longitude[2] ° / ′	Latitude[3] ° / ′	Part of the latitude[4]
ARIES					
[β And]	Mirach		7° 0′	32° 30′	N
[ζ Cet]	Baten Kaitos[5]		18° 30′	13° 30′	S
[ζ Cet]	Pantakaitoz	belly of the Whale	20° 0′	14° 0′	S
[α Ari]	Enif[6]		22° 0′	23° 30′	N
[θ Eri]	"End of the flowing"[7]		25° 0′	4° 30′	S
TAURUS					
[α Cet]	Menkar	nose of the Whale	6° 0′	1° 0′	N
[α Per]	Algenib[8]	forehead of Algonis[9]	10° 0′	49° 0′	N
[τ^2 Eri]	Angetenar		22° 0′	16° 0′	S
[α Tau]	Aldebaran	eye or heart of Taurus	29° 0′	14° 30′	N

[1] Contains 49 stars. Paul Kunitzsch, *Typen von Sternverzeichnissen in astronomischen Handschriften des zehnten bis vierzehnten Jahrhunderts* (Wiesbaden: Otto Harrassowitz, 1966), Typ VIII, mss a-I; pp. 51-58.

[2] Mediation.

[3] Declination

[4] This column indicates whether a star is north (*septentrionalis*) or south (*meridionalis*) of the celestial equator. In modern notation this is usually indicated by a plus or minus sign.

[5] Batenkaytoz/Baten Kaitos and Pantakaitoz are long-standing duplicates.

[6] Usually known as "Hamal".

[7] Known as "Acamar". The sense of the name is "the end of the river Eridanus."

[8] Now "Mirfak".

[9] Perseus?

GEMINI

[α Aur]	Capella	he-goat[10] or shoulder of the charioteer[11]	6° 0′	45° 0′	N
[β Ori]	Rigel	the foot of Orion	11° 0′	10° 0′	S
[α Ori]	Betelgeuse	the right shoulder of Orion	15° 0′	8° 0′	N

CANCER

[α CMa]	Sirius	in the mouth of the southern dog[12]	3° 0′	15° 0′	S
[α Gem]	Castor	a head of the twins	9° 0′	33° 0′	N
[α CMi]	Algomeiza[13]	in the neck of the northern dog[14]	13° 0′	7° 0′	N
[ϱ Pup]	Markep		21° 0′	22° 30′	S
[μ UMa]	Egregez[15]		24° 0′	45° 0′	N

LEO

[ ][16]	Aldiran	in the forehead of the lion	6° 0′	6° 0′	S
[α Hya]	Alfard	horse[17] or solitary one	13° 0′	18° 30′	S
[α Leo]	Cabalezed[18]	heart of the lion	20° 0′	15° 0′	N
[θ UMa]	Alrucaba	the [knee of the] bear	20° 0′	35° 0′	N

VIRGO

[ ][19]	Corvus		1° 0′	11° 30′	S

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10 But traditionally it is "she-goat," hence its common name, "Capella".

11 Or simply "driver."

12 The "southern dog" would be the constellation Canis Maior.

13 Also known as "Procyon".

14 Canis Minor.

15 Now known as "Tania Australis",

16 Kunitzsch suggests that this is a duplication of α Gem: Razalgeuze. See *Typen*, p. 57 (VIII-18 note).

17 From the confusion between the Arabic for "solitary one" (*al-fard*) and for "horse" (*al-fars*).

18 Better known as "Regulus".

19 Kunitzsch suggests that this is a duplication of γ Crv: Algorab. See *Typen*, p. 57 (VIII-22 note).

[α UMa]	Dubhe	that is, the bear	2º 0′	67º 0′	N
[β Leo]	Denebola	the tail of the lion	15º 0′	19º 30′	N
[γ Crv]	Algorab[20]	in the centaur	22º 0′	13º 30′	S

LIBRA

[α Vir]	Azimech[21]	the unarmed [*Simāk*]	10º 0′	7º 0′	S
[ηUMa]	Benetnash[22]	daughters of the bier, along the shaft[23]	9º 0′	53º 0′	N
[α Boo]	Arcturus	the spear-man/lancer	27º 0′	24º 0	N

SCORPIO

[α CrB]	Alphecca	in the crown of Ariadne[24]	16º 0′	29º 0′	N
[β Sco]	Alachil[25]		17º 0′	14º 0′	N
[δ Oph]	Yed [Prior]		26º 0′	3º 0′	S
[α Sco]	Calbalacrab[26]	the heart of the scorpion	27º 0′	23º 0′	S

SAGGITTARIUS

[α Oph]	Rasalhague[27]	the head of the dragon	13º 0′	15º 0′	N
[γ Dra]	Rastaben[28]	the head of the serpent	25º 0′	51º 0′	N

20 “Algorab” is now the official name of δ Crv.

21 More commonly known as “Spica.”

22 Also now known as “Alkaid”.

23 Of the seven stars forming the asterism known as “The Plough” or “The Big Dipper” or “The Great Wain”, four form the plough itself, or the bowl of the dipper, or the wagon. The other 3 stars are along the shaft(s) of the plough or wagon, or the handle of the dipper. Benetnash is the last star along the shaft or pole (or handle), furthest from plough/wagon. In this Arabic image three maidens lined up along the shaft are pulling a bier through the heavens.

24 I.e., the crown given by the god Dionysus to the Cretan princess Ariadne, daughter of King Minos, and set by Dionysus in the heavens.

25 Also known as “Graffias.”

26 Better known as “Antares.”

27 I.e., Ra’s al-hague, “head of the serpent collector.”

28 The name “Rastaben” has now been transferred to β Dra. γ Dra is now known as “Eltanin”.

CAPRICORN

[α Lyr]	Vega	the falling vulture	3º 0′	38º 0′	N
[α Aql]	Altair	the flying vulture	16º 0′	7º 0′	N
[ε Del]	[Deneb] Dulfim		29º 30′	12º 39′	N
[α Cyg]	Alridf[29]	in the swan	29º 0′	42º 0′	N
[α Cyg]	Addigege[30]	the tail of the hen	30º 0′	43º 0′	N

AQUARIUS

[δ Cap]	Libedeneb[31]	the tail of the [he-]goat	6º 0′	22º 0′	S
[? Del][32]	Delfin	more clouded[33] and more easterly	10º 0′	6º 0′	N
[α Cep]	Alderamin[34]		10º 0′	59º 0	N
[ε Peg]	Enif	the muzzle of the horse Pegasus	13º 0′	7º 0′	N
[δ Cap]	Deneb Algedi[35]	the tail of the he-goat/ Capricorn	14º 0′	19º 39′	S
[δ Aqr]	Scheat[36]	the shin[37]	30º 0′	19º 0′	S

PISCES

[β Peg]	Alferaz	in Pegasus	6º 0′	24º 0′	N

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29 Now known as "Deneb."

30 A duplication of Alrif (an expansion of the the name).

31 While Libedeneb is found many times in rete diagrams and also on actual astrolabes, it is a corruption in Latin of Denebalgedi (or Deneb Algedi). Sometimes Denebalgedi and Libedeneb are treated as two different stars, as in Kunitzsch, *Typen*, p. 46: VIII-40 (based on III-18) and VIII-44 (based on VI-35). The compiler of list VIII (i.e., this list) worked from at least two different sources and did not realize that he was dealing with the same star.

32 Kunitzsch (*Typen*, p. 58) suggests that this is a duplicate of ε Del, with quite different co-ordinates.

33 Or "dimmer/fainter".

34 The Latin, "Aldiran", copies the name of the star found in Leo, above.

35 See Libedeneb, above.

36 A name later associated with β Peg (q.v.). "Scheat" has now officially become "Skat".

37 The shin of the horse, i.e., Pegasus?

[β Peg]	Markab[38]	the shoulder of the winged horse[39]	18º 0′	25º 0′	N
[ι Cet]	Deneb Kaitos	the tail of the whale	22º 0′	10º 0′	S
[α Cas]	Schedar		18º 0′	53º 0′	N

38 A duplicate of Alferaz.

39 I.e., Pegasus.

[*LIST OF STARS 2*][1]

TABLE OF FIXED STARS VERIFIED BY ARMILLAS AT PARIS.

And their longitude is the degree along the circle of signs to a circle passing through the poles of the zodiac and the stars. Their latitude, however, is the arc of the same circle falling between the stars and their degree of longitude.

Names of the signs	Names of the stars	Images	Longitude[2] ° / '	Latitude[3] ° / '	Part of the latitude[4]
ARIES					
[α Cet]	Pantakaytoz	belly of the Whale	10° 0′	20° 0′	S
TAURUS					
[α Tau]	Aldebaran	eye or heart of Taurus	20° 0′	5° 0′	S
[α Per]	Algenib	right side of Perseus	20° 0′	30° 0′	N
[α Cet]	Menkar	nose of the Whale	2° 0′	12° 0′	S
GEMINI					
[β Ori]	Rigel, of Orion[5]	the foot of Orion	5° 0′	30° 0′	S
[α Aur]	Capella	he-goat[6]	10° 0′	22° 40′	N
[α Ori]	Betelgeuse	the right Shoulder [of Orion]	15° 0′	15° 30′	S

[1] Contains 31 stars. Kunitzsch, *Typen*, Typ VII, pp. 47-50.

[2] Celestial longitude.

[3] Celestial latitude.

[4] This column indicates whether a star is is north (*septentrionis*) or south (*meridianalis*) of the celestial equator. In modern notation this is usually indicated by a plus or minus sign.

[5] "Algeuze" is from "al-Jauzā'," i.e., Orion; Rigil is "the foot [of Orion]".

[6] Traditionally "she-goat" and hence its common name, "Capella."

CANCER

[α CMa]	Sirius	in the mouth of small dog[7]	3º 0′	39º 10′	S
[α CMi]	Algomeiza[8]	in the neck of "Canis Minoris"	14º 0′	15º 30′	S
[α Gem]	Castor	a head of the twins	8º 0′	10º 0′	N

LEO

[α UMa]	Dubhe	the bear	4º 0′	40º 0′	N
[α Leo]	Cabalezed[9]	the heart of the lion	18º 0′	0º 10′	S
[α Hya]	Alfard	horse[10] or the solitary one / girdle[11]	15º 0′	22º 30′	S

VIRGO

[β Leo]	Denebola	tail of the lion	9º 0′	12º 0′	N
[γ Crv]	Algorab	raven	29º 0′	15º 0′	S
[η UMa]	Benetnash	daughters of the bier[12]	16º 0′	53º 30′	N

LIBRA

[α Boo]	Arcturus	the spear thrower	13º 30′	31º 30′	N
[α Vir]	Azimech[13]	the unarmed [*Simāk*]	11º 30′	2º 30′	N

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7 Usually used with Canis Minor, but here it must be Canis Maior.

8 Also known as "Procyon."

9 Better known as "Regulus."

10 From the confusion between the Arabic for "solitary one" (*al-fard*) and for "horse" (*al-fars*).

11 It is possible that the insertion of "cingulus" ("belt"/"girdle") is the result of a misreading, at some point, of "singularis." Of course Hydra is a narrow stretched-out constellation, often represented in maps of the heavens by a snake, and "belt"/"girdle" may reflect this.

12 Of the seven stars forming the asterism known as "The Plough" or "The Big Dipper" or "The Great Wain", four form the plough itself, or the bowl of the dipper, or the wagon. The other three stars are along the shaft(s) of the plough or wagon, or the handle of the dipper. Benetnash is the last star along the shaft or pole (or handle), furthest from plough/wagon. In this Arabic image three maidens lined up along the shaft are pulling a bier through the heavens.

13 More commonly known as "Spica."

SCORPIO

[α CrB]	Alphecca	in the crown	1° 30′	44° 30′	N
[α Sco]	Calbalacrab[14]	the heart of the scorpion	28° 0′	4° 20′	N

SAGITTARIUS

[γ Dra]	Rastaben[15]	the head of the dragon	12° 0′	47° 30′	S
[α Oph]	Rasalhague[16]	the head of the serpent	10° 0′	36° 0′	N

CAPRICORN

[α Lyr]	Vega	the falling vulture	3° 0′	62° 0′	N
[α Aql]	Altair	the flying vulture	20° 0′	29° 30′	N
[α Cyg]	Addigege	the tail of the hen	21° 0′	60° 30′	N

AQUARIUS

[δ Cap]	Deneb Algedi	the tail of the goat	13° 0′	2° 30′	S
[? Del]	Delfin	more clouded,[17] and more easterly	6° 0′	32° 30′	N
[ε Peg]	Enif	the muzzle of the horse, Pegasus	21° 0′	23° 0′	N
[δ Aqr]	Scheat	the shin [of Pegasus]	27° 0′	7° 40′	S

PISCES

[β Peg]	Alferaz Markab	the shoulder of the horse [Pegasus]	20° 0′	31° 0′	N
[β Cet]	Deneb Kaitos	the tail of the Whale	21° 0′	20° 0′	S

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14 Better known as "Antares."

15 The name "Rastaben" has now been transferred to β Dra.

16 I.e., Ra's al-hague, "head of the serpent collector."

17 Or "dimmer/fainter."

[On the Use of the Astrolabe]

THE USE OF THE ASTROLABE BEGINS

The names of the "instruments" [i.e., parts of the astrolabe] are these. First is the suspending ring[1] for measuring an altititude, and it is called "the halqa"[2] in Arabic. Second is the habs,[3] that is, the ring which is joined to it.[4] Next the mother,[5] that is a small disk, containing in itself all the plates and the rete, to which is joined a marginal lip thus divided into 360 degrees.[6] The plates morover contained by this are inscribed with three circles of which the smaller is the circle of Cancer, and the middle one the equatorial circle [i.e., the celestial equator], and the greatest the circle of Capricorn.[7] Next the almucantars, which are circles drawn in the upper middle of which some are complete, others appear incomplete;[8] the first of them is the horizon,[9] and it divides the two hemispheres.[10] The centre, moreover, of the lowest almucantar is called the overhead zenith.[11] Next are the azimuths which are parts of the circles intersecting the almucantars.[12] After these are the hours, marked in the lower middle area.[13] Within the hours are indeed the two twilight lines.[14] Afterwards the line of the middle of the sky[15] which is the line descending from the ring through the centre to the opposite part of the astrolabe, of which the half from the centre to the ring is called "the midday line" and

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1 See *Comp*., Fig. 1; Chap. 2, note 1.

2 The Arabic word for "ring" is *al-ḥalqa* (الحلقة); in Latin, *armilla suspensoria* or *ansa*. See Kunitzsch, *Glossar*, no. 11, pp. 522-523.

3 *alhabor*: a variant on the Arabic word for "holding or keeping back" (*al-ḥabs*; الحبس), an alternative for "handle"; in Latin: *armilla reflexa* or *ansa*. See Kunitzsch, *Glossar*, p. 559.

4 *Comp*., Chap. 2, note 3.

5 *Comp*., Chap. 1.

6 *Comp*., Chap. 1.

7 *Comp*., Chap. 7.

8 *Comp*., Chap. 13.

9 *Comp*., Chap. 13.

10 I.e., above the horizon and below the horizon.

11 *Comp*., Chap. 13.

12 *Comp*., Chap. 15.

13 *Comp*., Chap. 16.

14 *Comp*., Chap. 21.

15 *Comp*., Chap. 12.

the other is called the angle of the earth"[16] and "midnight [line]." After this there also follows the hantabuz,[17] that is the spider [i.e., the rete] in which the signs are set in order with the zodiac, likewise the fixed stars, in which the path of the sun is said to be.[18] And whatever from the zodiac[19] would be within [the circle] of the beginning of Aries and of Libra is said to be to the north; what, however, [would be] outside is called southern. There follows the muri,[20] which is called "the indicator" in Latin, that is a small tooth, outside the circle of Capricorn, extending from the hantabuz.[21] Next [is] the mehaur,[22] that is, a hole which is in the middle of the rete, in which is the axis [i.e., pin] holding the plates of the climates [i.e., the various latitudes], into which the faraz,[23] that is, the "horse," like a wedge, enters fastening the rete with the plates.[24] And on the other side of the mother [i.e., the back of the astrolabe] are two circles for the equation of the sun,[25] one of which contains the number of the 365 days of the year, and the names of the months will be written below it.[26] The other circle [contains] the degrees of the signs, and within it are written the names of the signs.[27] Then [there is] a quarter for

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[16] In the sphere, the angle (along the midday colure through the poles) below the horizon to the opposite (the south) pole is equivalent to the latitude ("angle of the earth") of the observer, that is, the latitude of the astrolabe plate.

[17] For *alhantabut* (or *alhanthabuth*), العنكبوت (al-[c]ankabūt) – spider-web, i.e., rete – see *Comp*., Chap. 11, note 1, and Kunitzsch, *Glossar*, no. 1, pp. 515-517.

[18] *Comp*., Chap. 10 and 11.

[19] Again, we should really be referring to the ecliptic (a circle) rather than the zodiac (a band).

[20] *Comp*., Chap. 1 and 11. For *almuri* see note to *Comp*., Chap. 1, note 3.

[21] The rete (see above, note to line 15). See *Comp*., Chap. 11.

[22] The centre of the rete and plates: *al-miḥwar* / المحور. See Kunitzsch, *Glossar*, no. 28 (pp. 533-534/79-80).

[23] *al-faras* [the wedge]: see *Comp*., Chap. 6, note 2.

[24] See *Comp*., Chap. 6.

[25] "Equation of the sun" (also known as the "equation of time"): the relating of the position of the sun along the ecliptic to the day of the year. This not the meaning of the phrase in more technical astronomy where "the equation of the sun" means converting the sun's mean motion to true motion. See Franicis S. Benjamin, jr. and G. J. Toomer, eds., *Campanus of Novara and Medieval Planetary Theory. Theorica planetarum* (Madison: University of Wisconsin Press, 1971), pp. 41-42.

[26] *Comp*., Chap. 2.

[27] *Comp*., Chap. 2.

measuring an altitude.[28] Then a square, whose sides are divided into 12 points.[29] The rule is next, which rotates on the back of the astrolabe on which are perforated vanes for taking the altitude of the sun in daytime and of the stars at night.[30]

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[28] *Comp*., Chap. 2.

[29] *Comp*., Chap. 3.

[30] *Comp*., Chap. 5.

[CHAPTER 1]. CHAPTER ON FINDING THE DEGREE OF THE SUN

When you wish to know the degree of the sun [along the ecliptic], set the rule [or alidade] on the day of the current month, and the degree touched by its tip will be the degree of the sun – you will see which sign this is – and note it on the zodiac [i.e., the ecliptic] on the rete on the other side [of the astrolabe]. And you will note its nadir, which is a similar degree of the 7th sign.[1] And you also find the day of the month from the degree of the sun, for the rule, when placed against the degree of the sun, will show the day you have sought.

[Comment:

The calendar and zodiac circles around the rim on the back of the astrolabe enable the true motion of the sun along the ecliptic to be linked to the day of the year, and vice versa. This can then be used to set the rete on the front.]

[1] This is not the normal meaning of "nadir", i.e., the point in the celestial sphere vertically opposite the overhead zenith. Here the "nadir" of a point or position means the opposite point 180° across (or around) the sphere. In this capitulum it means the same degree as the sun but in the opposite sign. Beginning with (and including) the sign in which the sun was found and counting around the zodiac, the opposite sign will be the seventh sign.

[CHAPTER 2]. ON FINDING THE ELEVATION OF THE SUN AND THE STARS.

When you wish to know the elevation of the sun, suspend the astrolabe from your right hand using its ring, and with your left side away from[1] the sun, raise or lower the rule [alidade] until a ray of the sun passes through the pin-holes of both the vanes; having done this, see how many degrees the rule is raised above the eastern line, and that is the altitude of the sun. You will do the same thing at night using the fixed stars.

[Comment:

Suspend the astrolabe from its ring so that it is vertical, then adjust the rule with its sighting vanes toward the sun or star so that the sun's rays pass through the two (smaller) holes in the vanes or so that the star can be seen when looking through the two (larger) holes in the vanes. The degree of elevation can then be noted, as the point at which the rule intersects with the graduated rim of the astrolabe.]

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[1] For "*oppositus*" Gunther writes "towards the sun." However, it makes no difference if the observer's left or right side is toward the sun or away from the sun. One angles the alidade so that the sun's rays pass through both pin holes, and one can read the altitude of the sun along the edge, whether the alidade is angled from the upper left to the lower right (the observer's left side toward the sun), or from the upper right to the lower left (the observer's right side toward the sun).

[CHAPTER 3.] ON FINDING AN UNEQUAL HOUR AND THE SIGN WHICH IS RISING[1]

However, if you wish to ascertain with certain knowledge the hour and the [sign] which is rising [at that time], set the degree of the sun [i.e., its position along the ecliptic on the rete] on the almucantar of the altitude on the side of the east, if the altitude be before noon, or on the side of the west, if you have taken the altitude after midday; and upon whichever hour the nadir of the degree of the sun falls that is the present hour; and the sign which would be on the east side of the horizon [i.e., toward the eastern horizon] is rising, that is, ascending; moreover, that one toward the west is setting. And what indeed falls on the line of the middle of the sky is in the middle of the sky and its nadir, the "angle of the earth."

And if it has fallen between two almucantars, observe the difference of the number between the preceding almucantar and the altitude of the sun, and compare this difference with the longitudinal number[1] of the almucantar, which is six if the almucantar comprises 6 degrees and 6 degrees; but if the almucantars comprise 3 degrees and 3, compare the part of them with three, and so for the others. Then observe the movement of the indicator-muri from the beginning of the first almucantar as far as the beginning of the second [almucantar] along the degrees on the margin, and place on the part of them compared with them,[2] according to the proportion of the said difference, from 6 or from 3 degrees; and then you will have the exact degree between the two almucantars; and then consider these hours, etc., as was said above.

If[3] you were to wish to know the same thing at night, take the altitude of any star marked on the hantabuz [i.e., rete] which crosses from the east or the west, and place the cacumen [i.e., tip of the star-pointer] of this star on the almucantar of its altitude, and the degree of the sun will indicate to you the hours [or hour] of the night, just as its nadir [showed] the hours [or hour] of the day; for all others do as was said above.

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[1] The use of *ascensio* and *ascendere* in the *Practica* refers to the point on the horizon where the sun, or a star or planet, or the beginning (or end) of a sign (or another point on the ecliptic) crosses or rises above the horizon in the east. Similarly *occasus* and *occidere* refer to the setting of such objects or points on the horizon in the west. I have avoided the use of "ascendent" and "descendent" in English, preferring "rising" and "setting".

[1] I.e., the number of longitudinal degrees between each pair of almucantars.

[2] If the sun's altitude falls between two almucantars, place the sun's position for that day on each of those two almucantars and note the positions of the indicator-muri along the rim. Divide that arc along the rim according the the proportion of the sun's altitude to (or between) the two almucantars, place the muri on that point of division, and then the sun will be in the correct position for reading off the time.

[3] A minority of mss treat this as the beginning of a new chapter; hence there are added titles in some.

[Comment:

Having observed the altitude of the sun (Cap. 2) move that day's position of the sun (along the ecliptic on the rete) (Cap. 1) to the almucantar for that altitude, on the east if in the morning and on the west if in the afternoon. Lay the ruler on this point and examine the point on the ecliptic opposite to it, that is, the nadir of the sun. The time will be where the nadir lies between the unequal hour lines in the bottom segment of the astrolabe.

If the altitude lies between two almucantars, work proportionately.

The same can be done at night using the altitude of a star (if it is engraved on the rete). In this case, the position of the sun along the ecliptic (and not its nadir) will indicate the unequal hour of the night.

Note: obviously, if the sun's altitude is measured in the morning, the sign (in which the sun is that day) will be rising or ascending; and if measured in the afternoon, the sign will be setting.]

[CHAPTER 4.] ON THE EVENING AND MORNING TWILIGHT

When you wish to know the end of evening twilight and the beginning of early morning [twilight], observe when the degree of the sun comes to the line of the western twilight; then this is its end; and when [it comes] to [the line] of the eastern [twilight], it is the beginning of [morning] twilight.

Or thus:[1] see [when] the nadir of the sun shall have come to the 18-degree almucantar in the east; this will be the end of the evening dusk; and when it shall have come to the 18-degree almucantar in the west, it will be the beginning of the dawn twilight, which is easier [to perform].

[Comment:

When the place of the sun on the ecliptic for that day reaches the twilight line (or the twilight almucantar) in the west, the evening twilight is over and full night begins; when it arrives at the twilight line in the east, night ends and dawn begins.

Since working with the sun's position below the horizon might be difficult, the second method is to work with the opposite position (its nadir) above the horizon. Thus twilight ends at night when the nadir of the sun's position crosses the 18º almucantar in the east; and dawn begins when the nadir of the sun's position crosses the 18º almucantar in the west.]

[1] A minority of mss treat this as the beginning of a new chapter; hence there are added titles in some

[CHAPTER 5.] ON FINDING THE ARC OF THE DAY AND OF THE NIGHT.

If you want to know the arc of the day and of the night, set the place of the sun, that is, the degree in which it is, on the first almucantar in the east; and mark the place of the indicator-muri among the degrees of the rim. After this move the degree of the sun until it comes to [first almucantar in] the west, and also note its place among these degrees; and its motion from one mark to another is the arc of the day. On the other hand, the remaining part of the circle is the arc of the night, since these two will contain 360 degrees, which is the quantity of the day and the night. And you will do similarly for the fixed stars, if you wish to know their duration above the earth.

[Comment:

Place the sun's position on the ecliptic on the first almucantar (i.e., the horizon) to the east, and then to the west. Use the indicator-muri to find the two corresponding degrees along the rim and the number of degrees between them is the "arc of the day". The remainder of the circle will be the "arc of the night."]

[CHAPTER 6.] ON THE QUANTITY [I. E., LENGTH] OF THE UNEQUAL HOURS OF THE DAY

If you wish to know the quantity/length of the unequal hours of the day, divide the arc of the day by 12, and you will have the number of the degrees of a daytime hour; if you subtract this [number] from thirty, the number of degrees of the nighttime hour will remain, since an unequal nighttime hour with an unequal daytime hour amounts to 30 degrees in the whole /every day, which are two equal hours.

If[1] you wis As indicated by the added titling (or sometimes by an enlarged initial capital) many mss treat this as a separate capitulum. h to find out /know about the equal hours of the day, divide the arc of the day by 15 and you will have the number of equal hours; similarly in the night.

[Comment:

If you know the arc of the day, it can be divided by 12 to give the length of an unequal daylight hour.

Substracting the length of a daylight unequal hour from 30 will give the length of a night-time unequal hour.

Dividing the arc of the day by 15 will give the number of equal hours in the day and similarly for the number of equal hours in the night.]

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[1] As indicated by added titles (or sometimes by an enlarged initial capital) many mss treat this as a separate capitulum.

[CHAPTER 7.] ON FINDING THE PART OF AN HOUR WHICH HAS PASSED USING THE MURI

When a part of an hour has passed and you want to know what part of an hour it is, ascertain the number of degrees on the rim from the beginning of this hour to the indicator-muri, and in the way that number has to the number [of degrees] of the whole hour, so the part of the hour which has passed will have to the whole hour.

[Comment:

Compare the current position of the indicator-muri along the rim of the astrolabe to the whole distance the indicator-muri would move in an hour, and that proportion will be equivalent to the portion of the hour which has elapsed.]

[CHAPTER 8.] ON THE NUMBER OF EQUAL HOURS OF A DAY WHICH HAVE PASSED

If you wish to know how many equal hours have passed in a day, take the degree of the sun and set it on the almucantar of the altitude and mark the place of the indicator-muri on the degrees. Then turn the degree of the sun back as far as the first degree almucantar [i.e., the horizon] in the east; and then mark the place of the same muri. After this divide the degrees which are between the two marks by 15 and you will have the equal hours.

You will proceed similarly at night, for after you have found the equal hour using the degree of the sun and the altitude of some star, and the place of the indicator-muri has been noted, you will bring back the degree of the sun to the western horizon, and you will mark again the place of the muri. And you will divide the space [i.e., the degrees] between these two places as before, [that is], by 15, and you will find [the answer]. In the same way you will know how many equal hours are between midday or any other point and any moment you please.

[Comment:

Find the current position of the sun and (using the indicator-muri to find the degrees) divide the degrees from there back to the sunrise by 15 and this will give the number of equal hours which have passed since dawn. At night divide (by 15) the difference in degrees of the current position of a star back to the time of sunset and this will give the number of equal hours which have passed at night.

And you can do this for elapsed time from any (starting) point to the current point in time.]

[CHAPTER 9.] ON THE CONVERSION OF UNEQUAL HOURS INTO EQUAL HOURS

If you wish to restore unequal hours into equal hours, ascertain the degrees of the unequal hours how many there are, and divide them by 15, and you will have the equal hours. You will do the same with equal hours.

[COMMENT:

Take the length in degrees of a day or some part thereof in unequal hours and divide this by 15, and this will give the number of equal hours in that period.]

[CAPITULUM 10.] ON HAVING KNOWLEDGE OF THE ALTITUDE OF THE SUN AT MIDDAY

If you wish to know the altitude of the sun at midday, which is the beginning of its decline [i.e., the beginning of its afternoon descent to the horizon], set the degree of the sun on the line of the mid-sky, then the number of the almucantar degrees from the place of the sun on the horizon is the altitude of the same at midday. You will perform the same action with the fixed stars.

[Comment:

If you want to know the altitude of the sun at midday, place the point of the sun on the ecliptic (for that day) over the line through the middle of the sky (that is, the vertical diameter), and the number of the almucantar where it lies will be the altitude of the sun.]

[CHAPTER 11.] FINDING THE HOUR OF THE DAY BY THE ALIDADE

If you wish to know the natural [i.e., unequal] hour of the day using the hour-alidade [or "time-telling" alidade], place the alidade on the back of the suspended astrolabe on the altitude [of the sun] at the middle of that day; and turn the back to the sun until the shadow of each edge of the upper vane falls on the alidade, anywhere in line with its side. And where it falls in the divisions will be the desired hour.

[Comment:

This chapter depends on the marking of the unequal hour-lines as outlined in the *Constructio*, Cap. 5. (Because, as noted there in the comment, few western astrolabes had these markings, Capitula 11 and 12 of the *Practica* are often omitted.)

Placing the time-telling alidade or rule (specifically the end along which the time-telling hours have been marked) on the maximum altitude of the sun for that day (noon, solar time) sets the two variables which determine the length of the natural day and of the 12 unequal hours for that day – the latitude of the observer and the day of the year (or the position of the sun along its annual orbit). Then, suspending the astrolabe, turn it so that the edges of the upper vane toward the sun will cast a shadow down the alidade, the edges of the shadow lining up along the rule. The unequal hour can then be read where the end of the shadow falls, according to the lines engraved across the alidade.

Note: since the alidade will be pointing more or less upwards toward the place in the sky where the noon-day sun would be, the early morning hour shadow or the late day hour shadow will cross the alidade close to the vane; and the nearer the hour is to noon, the more "vertical" will be the shadow and hence cross the alidade further from the vane. This is why the hour lines on the alidade are numbered from the vane outward toward the centre (1 to 6) and then back from near the centre to the vane (7 to 12).

Note: in modern practice, one must adjust the calculation by using the "solar noon" when the sun is indeed vertically overhead in the sky for the observer, rather than "civil noon" based on the modern time zones. Solar noon can easily be calculated by dividing the length of time between sunrise and sunset by two, and adding this to the time of sunrise.

Thus if the sun rises at 6:34 a.m. and sets at 8:04 p.m. (or 20:04), the difference is 13:30 hours, half of which is 6:45 hours. Noon would then be at 6:34 plus 6:45 or 13:19 (i.e., 1:19 p.m.) Which would be the end of the 6th unequal hour and the beginning of the 7th. (It does not matter whether this is standard time or daylight saving/summer time as long as the calculations and the final reading all use the same time system.)]

[CHAPTER 12.] ON FINDING THE SAME THROUGH THE [HOUR-]LINES

Also by the alidade on the back and the hour lines between the sides of the gnomon[1] as if they were placed on a quadrant, thus. Place the alidade on the midday altitude of the sun on that day and note where the midday [unequal hour] circle, that is, the line of the end of the 6th hour, cuts the trusted line[2] of this alidade, and place there a red mark;[3] and this mark takes the place of the bead[4] in a quadrant. Then take the altitude of the sun at whatever hour you want and that mark between the hours will give the natural hour, as in a quadrant.

[Comment:

To find the unequal hour for any point of time in the day, first note the altitude of the sun at midday for the day in question by rotating the ecliptic circle on the rete so that the position of the sun in the ecliptic on that day is on the vertical midday line, and then by reading the altitude using the almucantars.

On the back of the astrolabe set the alidade to that midday altitude, and mark (temporarily) on the alidade (along its "centre line" edge) the point where it cuts the sixth unequal hour-line arc (found above or below the shadow square). Next rotate the alidade to the altitude of the present time; the temporary mark will now sit on or between other unequal hour-line arcs, and from this you can read (or estimate) the present time in unequal hours.

One would follow similar steps if one were ascertaining the present time using a quadrant.]

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[1] The use of *gnomon* here is not clear. Perhaps because gnomons cast shadows, it is an oblique reference to the shadow square on the back of the astrolabe, and hence to the unequal hour-lines which are usually drawn next to it.

See also Cap. 42, 43 and 44.

[2] *The trusted line*: the line down the "centre" edge of the alidade must be accurate and trustworthy since measurements depend on it. See *Comp*. Cap. 4 line 13.

[3] The term *incausto* usually denotes the use of red wax. *Encausto* would be ink or dye. Here one needs to make a temporary mark on the alidade, and a dot of wax would be one (temporary) way of doing this. Note that one ms suggests "blacking" (*atramentum*).

[4] Although the actual meaning of *margarita* is an oyster's "pearl", it is also the name commonly given to the sliding bead on the plumbline of a *quadrans vetus*.

[CHAPTER 13.] PRELIMINARY CHAPTER TO CERTAIN THINGS WHICH FOLLOW

Further know that the circle of signs is divided into two semicircles, of which one is from the beginning of Capricorn to the beginning of Cancer, and the other from the beginning of Cancer to the beginning of Capricorn; and the beginning of Capricorn is the winter solstice, the beginning of Cancer the summer [solstice]. Know as well that every two degrees equidistant from any of these solstices are of one declination [*or* have the same declination] toward the north or the south; and their days and nights are equal, and the shadows and altitudes at midday are always equal.

[COMMENT:

Astronomical information useful for the following chapters:

The ecliptic can be divided into two semicircles at the solstices, with the winter solstice at the beginning of Capricorn and the summer solstice at the beginning of Cancer.

And pairs of points on the ecliptic equidistant from the either solstice will have the same declination (north or south of the celestial equator), and equal days and nights; and at midday the sun will have the same altitude and cast equal shadows.]

[CHAPTER 14.] ON FINDING THE UNKNOWN DEGREE OF THE SUN BY THE RETE

[i.e., finding the position of the sun along the ecliptic, using the rete]

If you wish to learn the unknown degree of the sun, place a mark on its midday altitude which you have previously taken with the rule on the back of the astrolabe. Then turn the rete and two degrees will fall on the said mark, one of which you will know to be the degree of the sun by the sign of the month of which it will have been the day.

[Comment:

To ascertain the position of the sun along the ecliptic, measure the altitude of the sun at midday. Then rotate the rete until the ecliptic is over the intersection of the almucantar of that altitude and the midday line, i.e., the vertical diameter.

There will be two possibilities depending on how far you turn the rete, for instance, a degree in Gemini and a degree in Leo. Common sense will tell you which to choose, i.e., Gemini if it is springtime or Leo if it is autumn.]

[CHAPTER 15.] WHAT DAY IS EQUAL TO WHICH DAY

If you wish to know which day is equal to which day, you will know this by the degrees equidistant from the solstices, since the days of those [degrees] are equal, as was said above.

[Comment:

If you want to know to know which day is equal to which other day, look at the degree of the sun in the ecliptic for the day, and days which are equidistant from the solstices by the same amount are equal, as was said above (Cap. 13).]

[CHAPTER 16.] ON FINDING THE DEGREE OF A STAR WITH WHICH IT DIVIDES [I.E., COMES TO THE MIDDLE OF] THE SKY

If you wish to know with which degree any star comes to the meridian, or rises, set the star on the midday line, since the degree which falls on the same line is the degree sought; do the same for the east line and the west [i.e., for the rising and setting of the star on the horizon].

Moreover you will have as a discovered fact the degree [or the discovery of the degree] of longitude through a string placed on the pole of the zodiac across the whole declination.

[Comment:

To find the degree of the ecliptic which crosses the meridian at the same time as a particular star (i.e., mediation), turn the rete so that the star is on the meridian line and then observe what degree of the ecliptic is also on the meridian line.

This can also be found by running a string from the pole of the zodiac to the star and on to the ecliptic.]

[CHAPTER 17.] ON FINDING THE CENITH [I.E., AZIMUTH][1] OF THE SUN BY THE ALTITUDE

If you wish to know the cenith of the altitude of the sun [i.e., its azimuth], take its altitude for which hour you wish to know this, and set the degree of the sun on the almucantar of the altitude on the side [i.e., to the east or west, whether it is morning or afternoon] which it was just as you do for finding the hours. After this take what coincides with the degree of the sun in the azimuths that this quarter be the north-eastern, or the south-eastern, or the north-western, or the south-western. And similarly you will do this for the fixed stars through their altitudes.

[Comment:

To find the azimuth of the sun at any time, take its altitude at that time. Then rotate the rete so that the position of the sun on the ecliptic for that day sits on the appropriate almucantar of the altitude. This intersection will also indicate the azimuth on which the sun lies at that time. (It will be to the east if the hour is in the morning and to the west if it is in the afternoon.)]

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[1] The word "zenith" here (for "azimuth") is not used in the usual modern sense of the word, but is well attested in medieval Latin. Both "zenith" and "azimuth" are derived from the same Arabic word meaning "direction". Our use of "zenith" as the point overhead is actually derived from the more restrictive medieval term *cenith capitis* which is found elsewhere in this text, especially in the *Compositio*. See J.D. North, *Chaucer's Universe* (Oxford: Clarendon Press, 1988), p. 60 note 18.

[CHAPTER 18.] ON FINDING THE [POINT][1] OF THE RISING OF THE SUN, AND OF THE OTHER PLANETS

And if you wish to know the [point, i.e., direction] of the rising of the sun, or of any fixed star, take [i.e., observe or locate] the degree of the sun or the star on the eastern horizon, and observe which azimuth falls near it, on which it rose; and this is the [point] of the rising. And on its corresponding [degree] will be the setting in its corresponding quarter – it will be either north or south.

[Comment:

Relate the day of the year with the position of the sun in the zodiac, as before.

To find the degree of the eastern horizon where the sun (or a star) rises, rotate the rete until that point on the zodiac is on the eastern horizon. The degree of sunrise will be shown by the azimuth of that point.

The degree of sunset will be the same azimuth but along the western horizon.]

[1] Again "cenith" is being used in the general sense of "direction" (i.e., point).

[CHAPTER 19.] ON THE FOUR DIRECTIONS [CARDINAL COMPASS POINTS][1] OF THE WORLD

To find the four [cardinal] compass points of the world with exactitude, take the altitude of the sun as before and see in which quarter it is. Then see in which altitude is this degree of the sun among the azimuth lines in/from the beginning of the eastern quarter, which starts from the northern colure or the midnight line, from which you begin to count. And whichever the number is, take as much on the back of the astrolabe from the same colure towards the ring, proceeding to the east, if it is before midday or towards the west if it be after midday; and where the same number ends, place the rule there. Then holding the astrolabe in both hands, with its back surface turned upwards, carefully turn yourself toward the sun until a ray of the sun passes through both pin-holes. Then carefully place it on the ground [or place it horizontally] so that it [the rule or alidade] is not moved to either side; and you will have the four lines meeting in the centre of the astrolabe indicating the four [cardinal] compass points of the world directly opposite [each other], namely east, west, etc. Similarly you will work at night through a fixed star.

Or[2] having already set the rule on the back of the astrolabe with its face turned upward, parallel to [or level with] the the horizon as was said in the previous section, make the shadow of the two sides of the vane fall along the two sides of the rule, that is the right shadow along the right side and the left shadow along the left side; and automatically you will have the four lines and the four [cardinal] compass points of the world, as mentioned above.

[Comment:

To find the 4 cardinal points of the compass at one's current location, take the altitude of the sun (at any given time) using the alidade, and then place the degree of the sun (along the ecliptic for that day) on the almucantar of that altitude. This point will then intersect with an azimuth line. Note how far this azimuth is east or west of the meridian (i.e., the vertical diameter).

Returning to the back of the astrolabe, set the alidade on that degree along the rim. Now set the astrolabe on a horizontal surface with its back facing up and, not letting the alidade move, rotate the whole astrolabe so that the sun's rays pass through the holes in the vanes (or fall along the alidade's centre line), that is, the alidade is pointing directly at the sun. The vertical and horizontal diameters on the back of the astrolabe will then point east/west and north/south.

Instead of letting the rays of the sun pass through the hole(s) in the vane(s), you can also

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[1] Although the Latin *plaga* means an area as in an open expanse of land or sea, a territory or region, or a climatic region or zone, in this capitulum it must mean a direction or compass point.

[2] Many mss treat this as a new capitulum, with or without a title.

turn the astrolabe so that the edges of the shadow of the vane toward the sun fall along the sides of the alidade, in order to line up the alidade (and astrolabe) with the sun.]

[CHAPTER 20.] ON FINDING THE DECLINATION OF ANY DEGREE [ALONG THE ECLIPTIC]

If you wish to know the declination of any degree of the ecliptic, set it on the line of the middle of the sky or of the day, and know its altitude above the horizon [using the almucantars]; afterwards know the altitude of the beginning of Aries and Libra on the same line. Then consider each altitude and the difference of their altitudes is its declination of the degree from the celestial equator. If however the degree of the sign were to the north, its declination is northern; if to the south, southern. And know that the degrees of the northern signs are higher than the [celestial equator] which is through through the beginning of Aries and its opposite [point]; and of the southern signs, lower, according to their declination from it. Moreover the greatest declination is at the beginning of Cancer and of Capricorn. By the same method you find the declination of the fixed stars.

[Comment:

To know the declination of some degree or point on the ecliptic, place that point over the meridian line and read its altitude (using the almucantars). Then place the beginning of Aries (or Libra) on the same meridian and read its altitude. The difference in altitudes will be the declination of the point from the equator.

The northern signs (Aries to Virgo) have northern declinations, and are above the equator; the southern signs (Libra to Pisces) have southern declinations, and are below the equator. The greatest declinations are at the beginning of Cancer (northern) and the beginning of Capricorn (southern).

Declinations of the fixed stars can be similarly found.]

[CHAPTER 21.] ON THE ALTITUDE OF THE POLE OR THE LATITUDE OF A REGION

Know that the latitude of a region is the latitude of its overhead zenith from the celestial equator toward the north or the south, which is similar to the altitude of the northern pole (and its opposite depression) from the horizon, which two are always equal.

Therefore when you wish to know the latitude of any region, consider the altitude of the sun at midday which you will subtract from 90 if the sun is in [the circle through] the beginning of Aries and Libra, and what is the remainder will be the latitude of the region, for then the motion of the sun will be on the celestial equator. If, however, the sun is in some other degree, settle on the declination of the same degree through a table of solar declinations, or through the instructions given above [in Cap. 20]; this you will deduct from the altitude of the sun at midday if it is northern; if, on the other hand, it is southern, add it. And you will [then] have the altitude of [the sun at] the beginning of Aries in this region, which you will subtract, as said before, from 90, and what remains is the distance of region from the celestial equator.

[Comment:

The latitude of a location is the angle between the equatorial circle and the zenith of the location, and is also equal to the angle between the horizon and the north (or south) pole.

When the sun is at an equinox, that is, on the equatorial circle, the latitude of a location will be the complement of the midday altitude of the sun, or 90º minus the altitude of the sun at midday.

If the sun is at some other point along the ecliptic, determine the declination of the sun for that day (as outlined in Cap. 20, or from tables), and if the sun is north of the equator (between the spring and autumn equinoxes) subtract this declination from the midday altitude; if it is south of the equator (between the autumn and spring equinoxes), add this declination to the midday altitude. This addition or subtraction adjusts the current observed midday altitude of the sun to the midday altitude of the sun at the equinoxes, which then can be subtracted from 90º, as before, which will then be the latitude of the location.]

[CHAPTER 22.] CHAPTER ON THE SAME, BUT DIFFERENT

Or if you wish to take the higher altitude of any star, examine its elongation from the celestial equator, and do with it as was said above. And seek out the higher and lower altitude of any star which does not set in the same region [i.e., never dips below the horizon] and take the mean of both collected at the same time, and this is the altitude of the pole in the same region.

[Comment:

Or you can take the highest altitude of a star, calculating its distance from the equatorial circle as noted before. Measure its highest and lowest declinations on the same day twelve hours apart, and the average of the two will be the altitude of the pole above the horizon at that location (and therefore the latitude of the region, as indicated in Cap. 21).]

[CHAPTER 23.] ON THE LABELING OF A PLATE WITH ALMUCANTARS

If you wish to know for which region or latitude a plate with almucantars has been made, see how many almucantars there are from the celestial equator to the zenith along the meridian line, or from the axis to the horizon in the north; and the plate is made for such a latitude. Indeed the altitude [of the beginning] of Aries is as many degrees as are from the same circle to the horizon, or from the zenith to the axis.

[Comment:

To find which latitude a plate has been engraved, examine the number of almucantars counting along the meridian line from the zenith southwards (i.e., towards the top of the astrolabe) to the equatorial circle. ("Counting" means the number of engraved almucantars multiplied by the number of degrees between them.)

Similarly, the latitude would be the distance of the axis of the astrolabe north to the horizon; in other words, the almucantar on which the axis is set.

The "altitude of the beginning of Aries" is the altitude (to an observer at the latitude of the plate) of the intersection of the ecliptic and the equatorial circle which on an astrolabe is the complement of the latitude, and therefore the distance of the horizon to the equatorial circle or the zenith to the axis.]

[CHAPTER 24.] ON FINDING THE TIME BY THE LATITUDE PLATES

When you wish to find the time by an astrolabe in any region whose latitude was not inscribed on the plates of the astrolabe, take note of the difference between the latitude of this region and of the lesser latitude [of a plate which is] engraved there closer to it. Then commit to memory the proportion of that difference to the difference which is between the lesser latitude [of the plate] engraved there and and the greater, between which is clearly the latitude of this region. Afterwards having taken the altitude of the sun in that region, ascertain the hours [i.e., the time] by the lesser latitude, and similarly at the latitude of the greater, and of the difference between these diverse hours [or times] take a [proportional] part according to the proportion of the difference [in latitude]; taken above which part you will add to the hours of the lesser latitude, if they are fewer than the hours of the greater latitude, or you will subtract from the same, if they are more; and what then remains will be the hours of this region. Similarly you will do this for the hours of the night and in other calculations.

[Comment:

If you do not have a plate for your astrolabe which matches your latitude and you still wish to know the time, take the plate for the next greater latitude and the plate for the next lesser latitude. Note the proportional differences between the latitudes of these two plates and your own latitude.

Next measure the altitude of the sun and calculate the time using both (the greater and lesser latitudes) plates. Then divide the difference between these times according to the proportions calculated for the latitudes, and this will be the time at your latitude.]

[CHAPTER 25.] TO ASCERTAIN THE UNKNOWN DEGREE OF THE SUN [ALONG THE ECLIPTIC]

When you wish to find the degree of the sun on whatever day by the hantabuz [i.e., rete], consider its altitude in the middle of the day, which you will mark on the almucantar at the midday line; then turn the quarter of the circle of signs in which the sun was; and the degree which will touch the mark of the altitude in the middle line is the degree of the sun.

[Comment:

To ascertain where along the ecliptic the sun is on a particular day, measure the height of the sun at noon. Note that position on the meridian line (from the zenith to the south, that is, towards the top of the astrolabe) using the almucantars. Then rotate the rete so that the circle of the ecliptic intersects with the meridian and the noted almucantar and this will give the degree of the sun along the ecliptic, or in the zodiac.

Note that for any noon-day altitude there are two possible positions along the ecliptic, equidistant from the solstices, so one chooses the obvious sign given the season of the year, e.g. Pisces in the late winter or Libra in the autumn.]

[CHAPTER 26.] ON FINDING THE DISTANCE [IN LONGITUDE] BETWEEN TWO REGIONS BY AN ECLIPSE

The longitude of a region from any other is the distance of the meridian circle of one from the meridian circle of the other. And when you wish to know the distance between two regions, consider the beginning of a lunar eclipse, by how many equal hours it is distant from noon of the previous day in both regions. Then substract the hours of one region from the hours of the other, and what remains are the hours of longitude between both. Therefore multiply them by 15, you will ascertain the number of degrees of their distance from each other.

The longitudes, however, of specific regions, that is, the distances of their meridian circles from the meridian circle of the farthest region habitable region in the west, and their latitudes, that is, distances from the celestial equator we will note in a certain table.

ADDENDA 26

(1)	degrees	minutes
Latitude of Hiolen[3]	40	8
Latitude of Montis Pesidani[4]	44	4
Latitude of Paris	48	8
Longitude Hiolen from the very west	28	30
Difference from the habitable west	11	0

(2)

Name of the region	longitude		latitude	
	degrees	minutes	degrees	minutes
Alexandria	51	20	31	0
Jerusalem	56	0	32	0
Cremona	48	30	44	22
Paris	40	47	49	6
Toledo	28	30	40^{39}	0^{51}
Marseille				
Florence				

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[3] Hiolen: not identified. (The ms could read "Hiden", but unlikely.)

[4] Mons Pesidanus/Mons Pesidani: not identified.

[Comment:

Finding the difference in longitude between two regions involves working from some same event visible in each place; here a lunar eclipse is suggested.

Knowing the time (in equal hours) that has elapsed in each location between the beginning of the eclipse and the previous local noon allows the user to calculate the time it has taken for the sun to move from one region to the other. Multiplying these (equal) hours by 15 gives the difference in longitude in degrees.

The text notes that there is a table which gives the comparative longitudes of various places including the most westerly known habitable region (usually taken to be the Canary Islands), but such a table is found in very few mss.]

[CHAPTER 27.] ON THE SAME IN *MILIARIA* [ROMAN MILES][1]

If you seek to know how many *miliaria* are between two regions distant one from the other consider the longitude and the latitude between the two. Then add the longitude taken [i.e., multiplied] by itself to the latitude multiplied by itself. And take the square root from the combined sum, and for each degree and a half of this root give 100 *miliara*; and by so many *miliaria* is one region distant from the other.

If, however their latitude is the same, treat a degree of longitude just as a degree of the root ought to be treated. If, however, the longitude is the same, treat it as with the latitude and you will find what you seek.

[Comment:

To calculate the distance in Roman miles between two points, ascertain the latitude and longitude of each, and the difference in degrees between them. Then, (following Pythagoras's theorem), multiply the difference in longitude by itself and add to it the difference in latitude multiplied by itself; take the square root of the sum. Then multiply each degree and a half by 100 and this will be the distance in Roman miles.

If the two places have the same latitude, simply multiply each degree and a half of longitude by 100; if they have the same longitude, multiply each degree and half of latitude by 100.

Note: This is not really accurate since a degree of longitude varies when measured at the equator (maximum, where it equals a degree of latitude, ignoring the slightly non-spherical shape of the earth) and when measured at the poles (minimum, i.e., 0). And even when the length of the degree is standard (along the equator, along a meridian, or along a great circle), this calculation gives an earth circumference of about 35,500 km when in reality it is just over 40,000 km.]

[1] *Miliarium*: "1000 [of something]". In terms of distance, it is 1000 paces, each consisting of 5 Roman feet, hence a distance of 5000 Roman feet. The Roman foot is generally taken to be about 296 millimetres, and a Roman mile would be 1,480 metres, i.e., 1.48 km.

[CHAPTER 28.] ON THE RISINGS OF THE SIGNS IN THE DIRECT CIRCLE [I.E. VIS-A-VIS THE EQUATORIAL CIRCLE]

However, if you wish to known the risings of the signs in the direct circle, place the beginning of any sign on the meridian line, and note the place of the indicator-muri on the rim. Afterwards turn the rete until the end of the sign falls on the meridian line, and the degrees by which the indicator-muri will be moved will be the rising of the same sign; and you will do this similarly for any portion of the circle of signs.

[Comment:

Essentially this is about measuring the projection of a section of the ecliptic against the equatorial circle, or, for instance, how far has the sun moved vis-à-vis the equator when it has moved through a full sign along the ecliptic. In modern terms it would be the difference in right ascension between the beginning and end of that section/sign.

One places the beginning of the section/sign on the meridian circle, and notes the position along the rim where the indicator-muri at the beginning of Capricorn rests; then one rotates the rete until the end of the section/sign is over the meridian line. The amount that the indicator-muri moves along the rim will be the amount of ascension.]

[CHAPTER 29.] ON THE RISINGS OF THE SIGNS IN THE OBLIQUE CIRCLE [I.E., VIS-A-VIS THE HORIZON]

However, you will be able to find the rising of the signs for any region thus: move the rete from the beginning of the sign to the end of the same and the degrees by which the indicator-muri is moved along the rim will be the risings of the sign in the same region; for you will move the sign in the eastern part of the horizon, so that you know its rising. However, in order for you to know its delay in {time of} setting, you will move it to the western part of the horizon; also it will be done thus in whatever part of the circle.

As well if the degrees of the risings are divided by 15, and the residue reckoned as fractions of an hour, you will have the equal hours; or if they [the degrees of the rising] are divided by the number of degrees of an unequal hour, it will show by how many natural or unequal hours with fractions, a given sign or planet or whatever portion [of the sky] rises or sets in whatever region.

[Comment:

To measure the rising (or setting) of a sign (or planet or any part of the sky) vis-à-vis the "oblique circle" (i.e., the horizon), set the beginning of the sign on the horizon (in the east) and note its position along the outer rim using the indicator-muri on the rete (at the beginning of Capricorn). Then move the rete so that the end of the sign, etc., crosses the horizon and then see how far the indicator-muri has moved along the rim. Do the same along the western horizon for the descent or setting of a sign.

To find the length of time for the rising or setting, divide the degrees of the point of rising by 15 to give the number of equal hours (and fraction thereof). Or divide the degree of the point of rising by the number of degrees in an unequal hour (for that day) to give the number of unequal hours (and fraction thereof).]

[CHAPTER 30.] ON KNOWLEDGE OF UNKNOWN STARS POSITIONED IN AN ASTROLABE

In order that you have knowledge of unknown stars which are positioned on an astrolabe, first take the altitude of any known star, and place it among the almucantars on [one of] a similar altitude. After this examine the star which you wish to know, on which altitude among the almucantars it lies and in what part it is, that is, in the east or in the west; having seen this place the rule/alidade on the back of the astrolabe on the same altitude, and turn this astrolabe to the same area of the sky in which you have observed the star; and the larger star which you see through the pin-holes of the rule is the very one you seek.

[Comment:

If you find a star engraved on the rete of an astrolabe which you do not recognize, observe in the sky the altitude a star you do know. Plot this star on the rete (it may already be there) along the almucantar of the appropriate altitude. Then compare the unknown star with this, as to its altitude and whether it is east or west of the known star.

Setting the alidade on the back of the astrolabe to the altitude of the unknown star, look through the pin-holes at the part of the sky that it should be in (i.e., east or west of your known star), and the largest star you then see through the pin-holes (at that altitude and in that region) will be the unidentified star in the rete. (By examining the constellation in the sky in which the unidentified star is found, you should be able to figure out which star it is.)]

[CHAPTER 31.] ON KNOWLEDGE OF UNKNOWN STARS NOT POSITIONED IN AN ASTROLABE

When wishing to know the degree of an unknown star or planet not positioned in an astrolabe, wait until this planet or star is on the meridian. Then observe some star whose position you know for certain and has been marked on the astrolabe, set in the rete according to its altitude, placing the star among the almucantars on a similar altitude; and in line with the degree of the signs which will be in the line of the middle of the sky will be the star about which you have doubts, and its longitude is marked; its latitude is obvious, the almucantars having been counted from the mark of this altitude unto the celestial equator. As well you can set on the rete by the setting of the sun, if you know no star. And so you will know all the stars.

[Comment:

If you find a star which you do not recognize and is not engraved on the rete of an astrolabe, observe its altitude in the sky when it is on the meridian line. Then having observed at that same time some star which you do know (and is engraved on the astrolabe) set the rete so that this known star is on its appropriate almucantar. Then the unknown star will be on the centre-line of the astrolabe, and you can read its "longitude"[1] along the ecliptic where the ecliptic crosses the centre line. Its latitude is found by counting the almucantars from the equatorial circle up to the altitude observed.

If there is no star visible that you know, you can set the rete according using the the point where the sun sets that day.]

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[1] This actually mediation, the point on the ecliptic which crosses the meridian at the same time as the star.

[CHAPTER 32.] TO KNOW IN WHICH DEGREE OF A SIGN THE MOON IS

When you wish to know in which degree of a sign the moon is, determine the altitude of the moon; and mark it in the almucantars in the part in which it is [i.e. east or west]; then place some star in the rete located on its altitude measured in the same hour as the altitude of the moon [was measured], in the part which it is; and the degree of the circle of the zodiac which falls between the almucantars on the mark of the altitude of the moon will be the degree of the moon. If however it appears in the daytime, you will do the same with its altitude and the altitude of the sun. Therefore consider of which sign is the degree. Likewise you will also be able to discover in the same way the location of the planets, if you will be able to measure their altitude at night.

[Comment:

In order to determine in which degree in which sign the moon (or a planet) is, measure the altitude of the moon and at the same time the altitude of a nearby star (a star which is engraved or marked on the rete of the astrolabe). Then set the rete by positioning the star on the appropriate almucantar (either to the east or the west according to the observation), and then read on the ecliptic the sign and degree where the ecliptic crosses the almucantar of the moon. Again choose the sign according to whether the moon is to the east or to the west. This will be the position of the moon vis-à-vis the ecliptic.]

[CHAPTER 33.] ON FINDING THE LOCATION OF THE MOON

When you wish to find in which degree of a sign the moon is, consider how many days of the lunar month it has [i.e., has passed] [up to] the day in question, after doubling this, divide up what has been calculated by giving 5 [units] to each sign. And you should begin from the sign in which the sun was [at the beginning of the lunar month], and where the number finishes in the same sign is the moon. And if one from the 5 [units] remains, the moon has already travelled 6 degrees [in the sign]; and if 2 [units remain then] 12 [degrees]; and so on up to 5. Always take 6 degrees for every single [unit] remaining.

[Comment:

The moon moves 360 degrees along the ecliptic in a lunar month, or 30 degrees (one sign) in 2.5 days, or 12 degrees in one day. Since dividing 30 (days) by 12 (signs) is complicated, the suggestion is to double the days that have passed and divide this by 5 to produce 5 "units" for each sign.

To find the position of the moon on any day, take the number days that have passed since the beginning of the lunar month (the "new" moon), double this and divide by 5. Starting with the position of the sun (along the ecliptic) at the time of the new moon (when the sun and the moon are at the same point along the ecliptic), count off these groups of 5 units along the ecliptic, each one being a sign.

When all the units have been distributed along the ecliptic, the last unit will be the position of the moon in whatever sign you have ended in. There will probably be some remainder of units (between 1 and 4), and in each one of these the moon will have travelled 6 degrees, so you can then calculate how far the moon has moved in the last sign.

As an example, if it is 16 July and the lunar month began on 25 June, the lunar month is 21 days old; you double the 21 and divide by 5 to produce 8 with a remainder of 2. If on 25 June the sun was in 4° of Cancer, then counting from this point you will be arrive at 4° of Pisces. Since there is a remainder of 2, the moon will have moved another 12 degrees and its position will therefore be 16° of Pisces.

Note: the fact that you begin the calculation from position of the sun at the beginning of that lunar month means that issues of co-ordinating the solar and lunar calendars do not arise; the starting point is always a new "observation" of the two together. Again the fact that the lunar month is only (approximately) 29.25 days long also becomes irrelevant (or at least undetectable).]

[CHAPTER 34.] ON FINDING THE LOCATIONS OF THE PLANETS

You will be able to discover the locations of the planets in another, more accurate way. Take the altitude of the planet when it is near the line of the middle of the sky, and keep [*or* make note of] it. Likewise at the same hour take the rising by any one of the fixed stars, and keep [*or* make note of] this also with the time. After this observe when this planet begins to descend from the mid-sky line, and take observe its altitude when it is equal to the altitude when observed earlier before [it reached] the mid-sky line, and again at the same hour observe the rising and the hour by some fixed star. Next assume the mean between the first rising and the second using the indicator-muri on the rim; and the degree which then falls on the mid-sky line, there is the planet.

[Comment:

This "more accurate" way of finding the positions of planets involves observing the planet in question at some altitude just before it reaches the mid-sky meridian, and again at the same altitude after it has passed the meridian and begun its descent. At the same time as these observations are made one also observes the rising of a star. One next takes the mean position between these two risings, and sets that degree of the ecliptic on the horizon; the point on the ecliptic which is then on the meridian will be the "longitude" of the planet.

Note: this is not completely accurate since the point of rising does not change its degree uniformly over time, and therefore the point sought is not necessarily the mean between the two. The error is minimal if the two observations are made when the planet is near the meridian, but this is not an ideal time to make the observations of altitude, since the closer the planet is to the meridian, the less its altitude changes over time and therefore the more difficult it is to know when the planet is at exactly the same altitude for the two observations.[1]]

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[1] See J.D. North, *Chaucer's Universe* (Oxford: Clarendon Press 1988), pp. 68-69 and note 26.

[CHAPTER 35.] ON FINDING THE LATITUDE OF PLANETS FROM THE PATH OF THE SUN

If you wish to know whether a planet is south or north of the path of the sun, consider whether the altitude which you observed when it [i.e., the sun] was near the line of the middle of the sky is equal to the altitude of the degree in which the planet is, or greater or less. For if it is equal, then it is directly in the path of the sun and has no latitude [vis-a-vis the sun]. However, if the altitude of the planet is greater than the degree in which the [sun][1] is, then the planet is north of the path of the sun; if less then it is southern; and it is so much distant from the path of the sun as much as that altitude is greater or lesser.

[Comment:

This is fairly straightforward. Measure the altitude of the planet vis-à-vis the ecliptic and of the sun when each passes the middle of the sky, and compare the two. If the two altitudes are equal, the planet is on the ecliptic. If the altitude of the planet is greater, it is to the north; if it is less, it is to the south. And the difference in altitudes will be the distance of the planet from the ecliptic.]

[1] Nearly all the manuscripts read "planeta", but to make sense of the sentence, the altitude of the planet (the subject of the sentence) must be compared with that of the sun; hence my amendment.