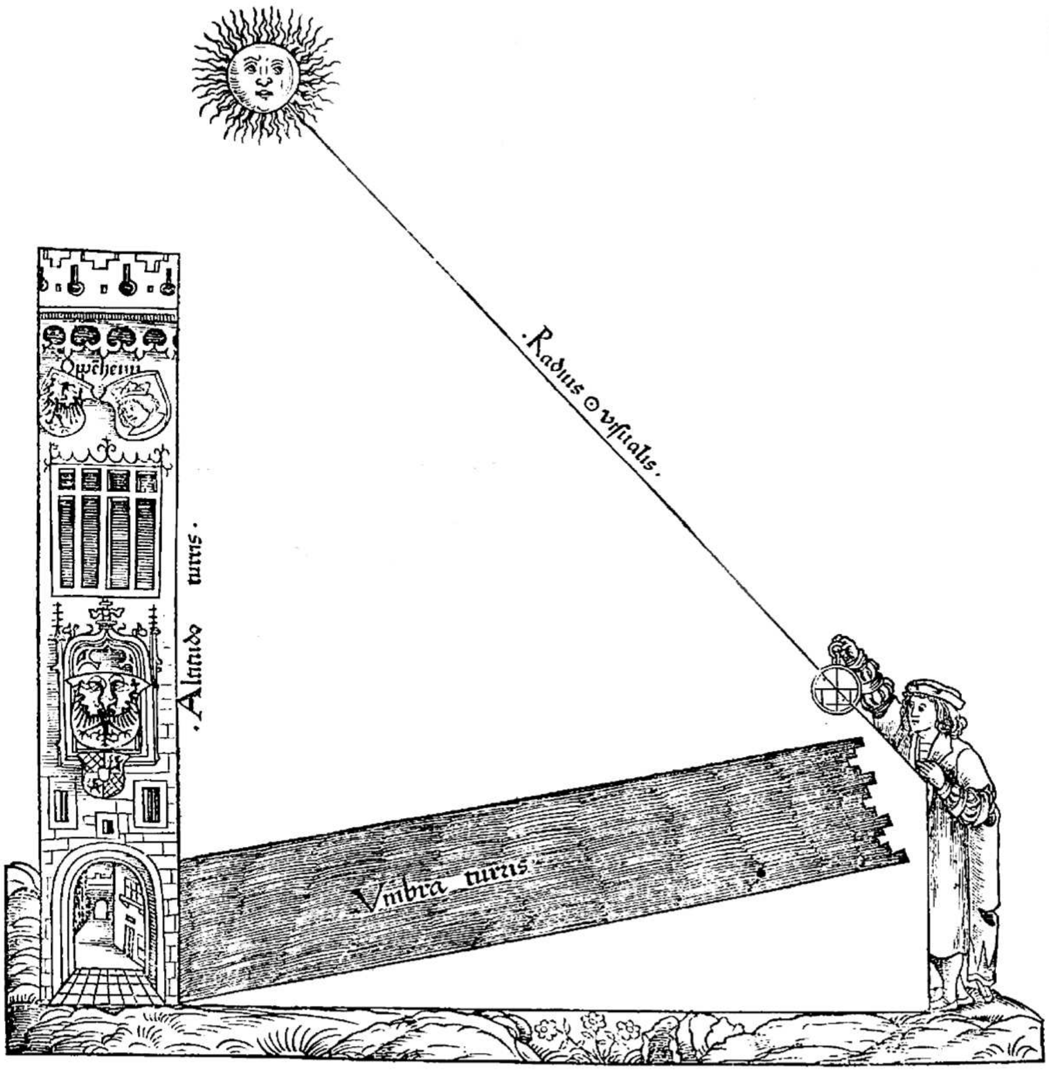
The Astrolabe in Theory and Practice



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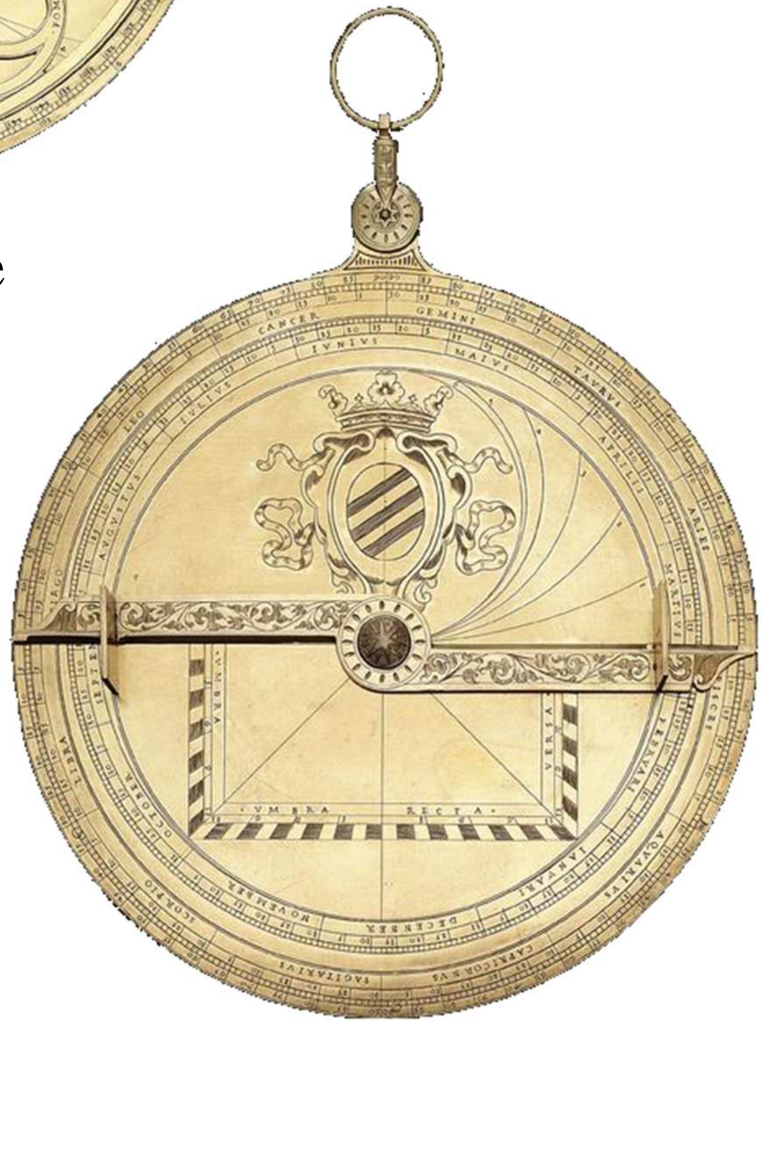
"*LITTLE Lewis my son, I have perceived well by certain evidences thine ability to learn sciences touching numbers and proportions; and as well consider I thy busy prayer in special to learn the treatise of the astrolabe....*".

-- Geoffrey Chaucer, A Treatise on the Astrolabe

The Astrolabe



Acknowledgements

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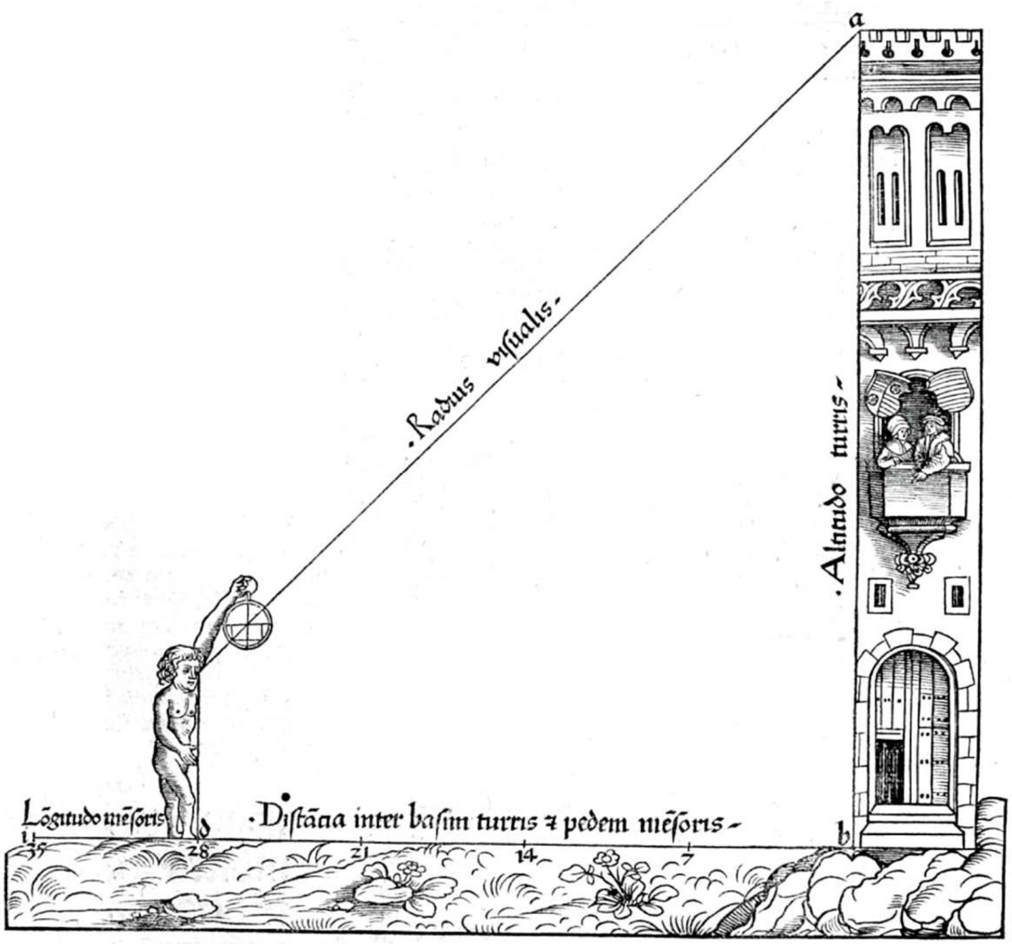
This is a handout for my class "The Astrolabe in Theory and Practice" first given at Pennsic War 39

Copies of this handout and the necessary files to build the astrolabe used as an example are available on my website at www.astrolabeproject.com

Version 7 – May 2019

Part I:

Introduction to the Astrolabe



Astrolabe History in Summary

Greece and Rome

The first primitive astrolabes were developed in Greece and their use quickly spread across the Mediterranean basin.

- "The astrolabe as an instrument is thought to date back at least as far as Ptolemy (2nd cen AD) and may be older" – Neugebauer
- "The earliest surviving descriptions of actual instruments were written by John Philoponos of Alexandria (Johannes Grammaticus) in the sixth century (ca. 530)" – Morrison

Introduction into the Middle East

- "Muslims first encountered the astrolabe in Harran in the mid-8th century. The first Muslim known to actually make an astrolabe was al-Fazari, one of the first Muslim astronomers known to us. The oldest known astrolabe is from the late 8th century." – Morrison
- "Knowledge of astrolabes was widely available by the 9th century. The eminent scholar, Abu al-Abbas Ahmad ibn Muhammad ibn Kathir al-Farghani wrote his Book on the Construction of the Astrolabe and provides complete instructions for design." – Morrison

Re-introduction into Europe

Trade and the crusades re-introduced the much-improved astrolabe to Europe

- "The astrolabe was firmly established in Europe by the end of the 13th century." - Morrison

The astrolabe was in use all over Europe from at least the 13th cen. to beyond the end of our period.

Who would possess/use an astrolabe?

- Alchemists
- Astrologers/Astronomers
- Educated individuals
- Use of the astrolabe was taught in university the way slide rules used to be, and high-end calculators are now.

Materials used to construct astrolabes

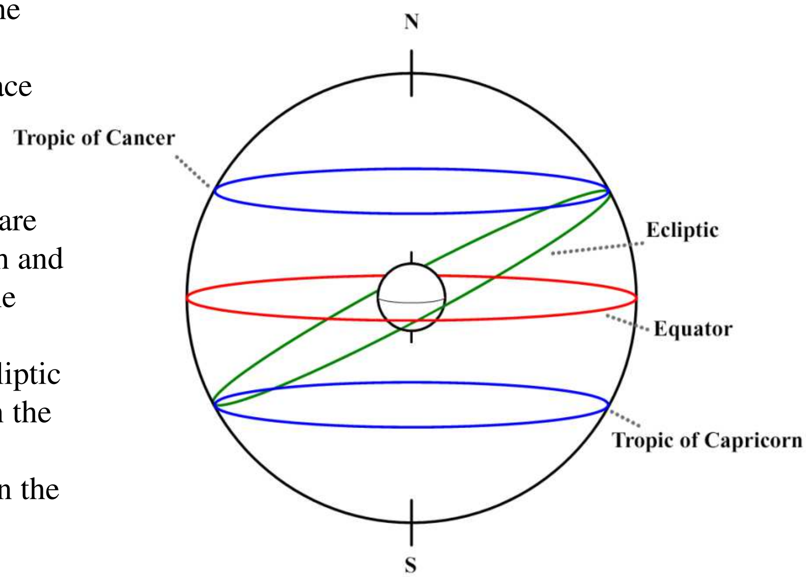
- Paper (few remain, but were probably fairly common as a cheap alternative)
- Wood (both alone and laminated to paper)
- Metal (Most of the remaining examples)

The Theory Behind the Astrolabe: 1

The Celestial Sphere

From the point of view of an observer, the sky and its component elements can be thought of as resting on the interior surface of a vast celestial sphere with the Earth resting in the center.

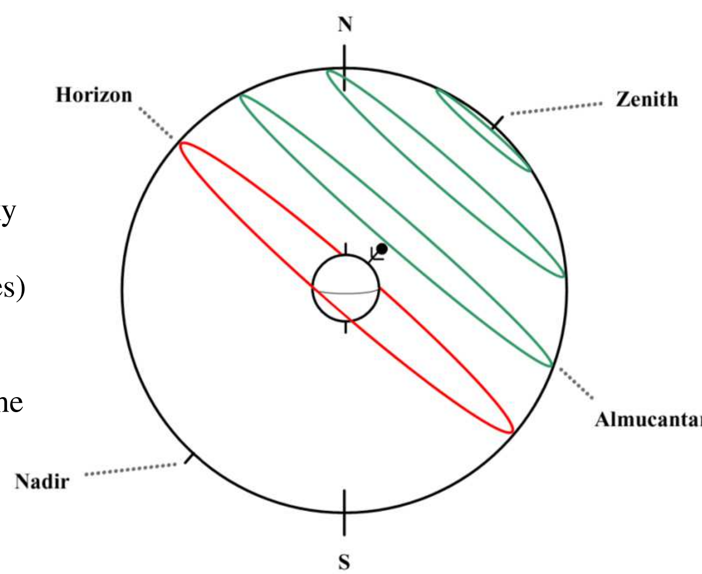
Like the sphere of the Earth itself, there are landmarks to aid navigation… The North and South celestial poles are extensions of the Earth's axis. The celestial equator is a projection of the Earth's equator. The ecliptic marks the annual path of the sun through the sky, and the tropics mark the sun's northernmost and southernmost travels in the sky.



The Local Sky

An observer on the Earth looking up at the sky can see one-half of the celestial sphere. His viewpoint extends from the horizon (0 degrees) to zenith (90 degrees). What part of the celestial sphere can bee seen in the local sky depends on the location of the observer and the time and date.

Note that in both views, the position of the North and South celestial poles is the same.



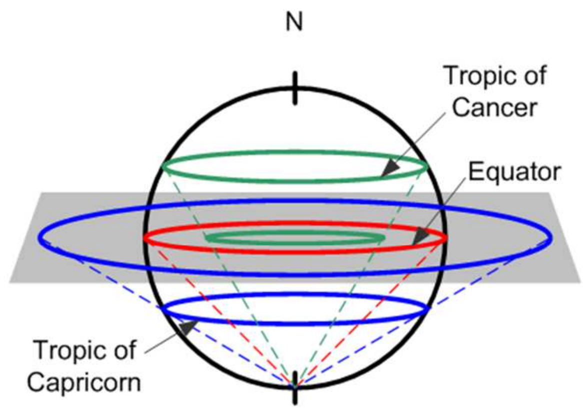
The Theory Behind the Astrolabe: 2

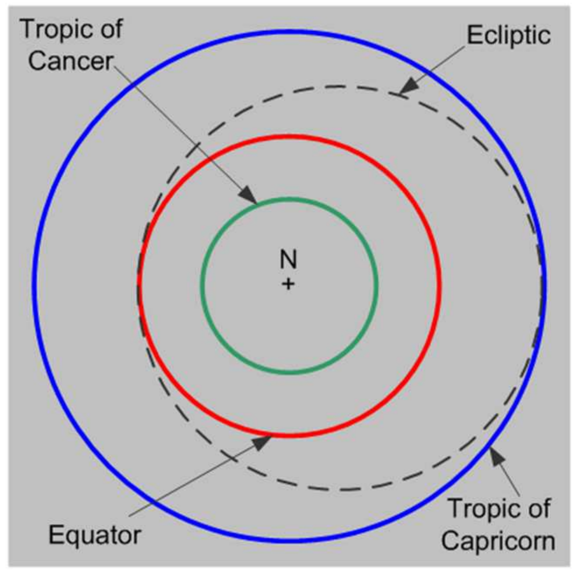
The Planispheric Projection

In a planispheric projection, a sphere is projected onto a plain.

The astrolabe works by overlaying two of these projections:

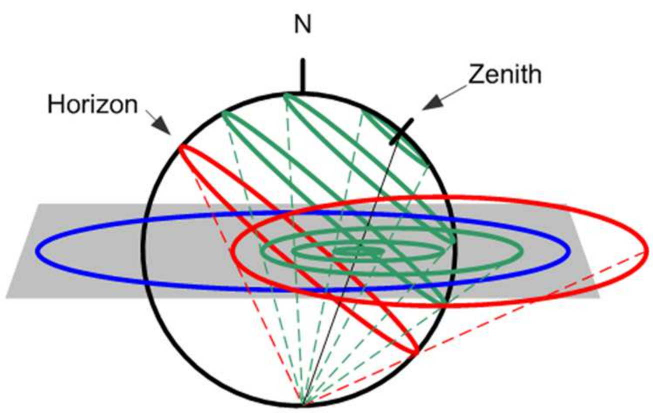
One of the celestial sphere, from the North Pole to the Tropic of Capricorn:

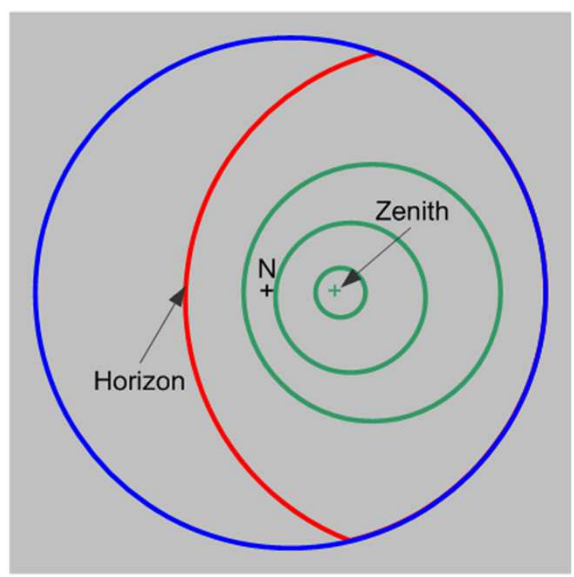




Projecting the celestial sphere

The other of the local sky, from horizon to zenith.



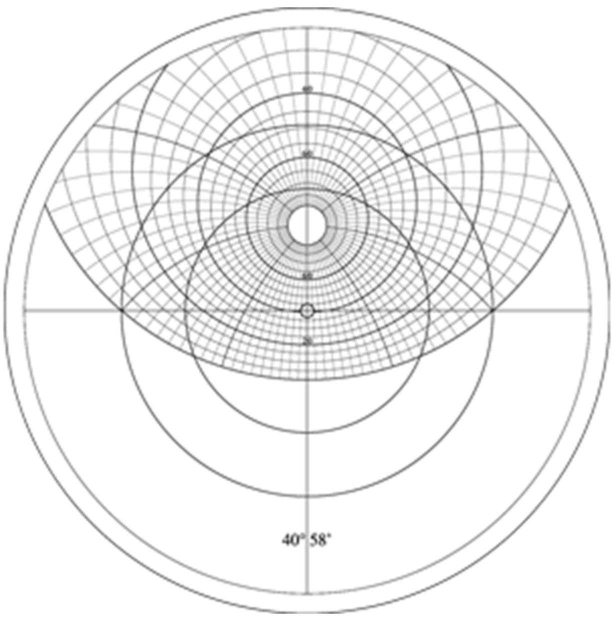


Projecting the local sky

Note that in both projections celestial north is the center point of the projection.

The Theory Behind the Astrolabe: 3

When these two projections are overlaid with their common point, the north celestial pole, as the pivot, the projection of the celestial sphere can be rotated with respect to the projection of the local sky to display a view of the sky for any combination of date or time.

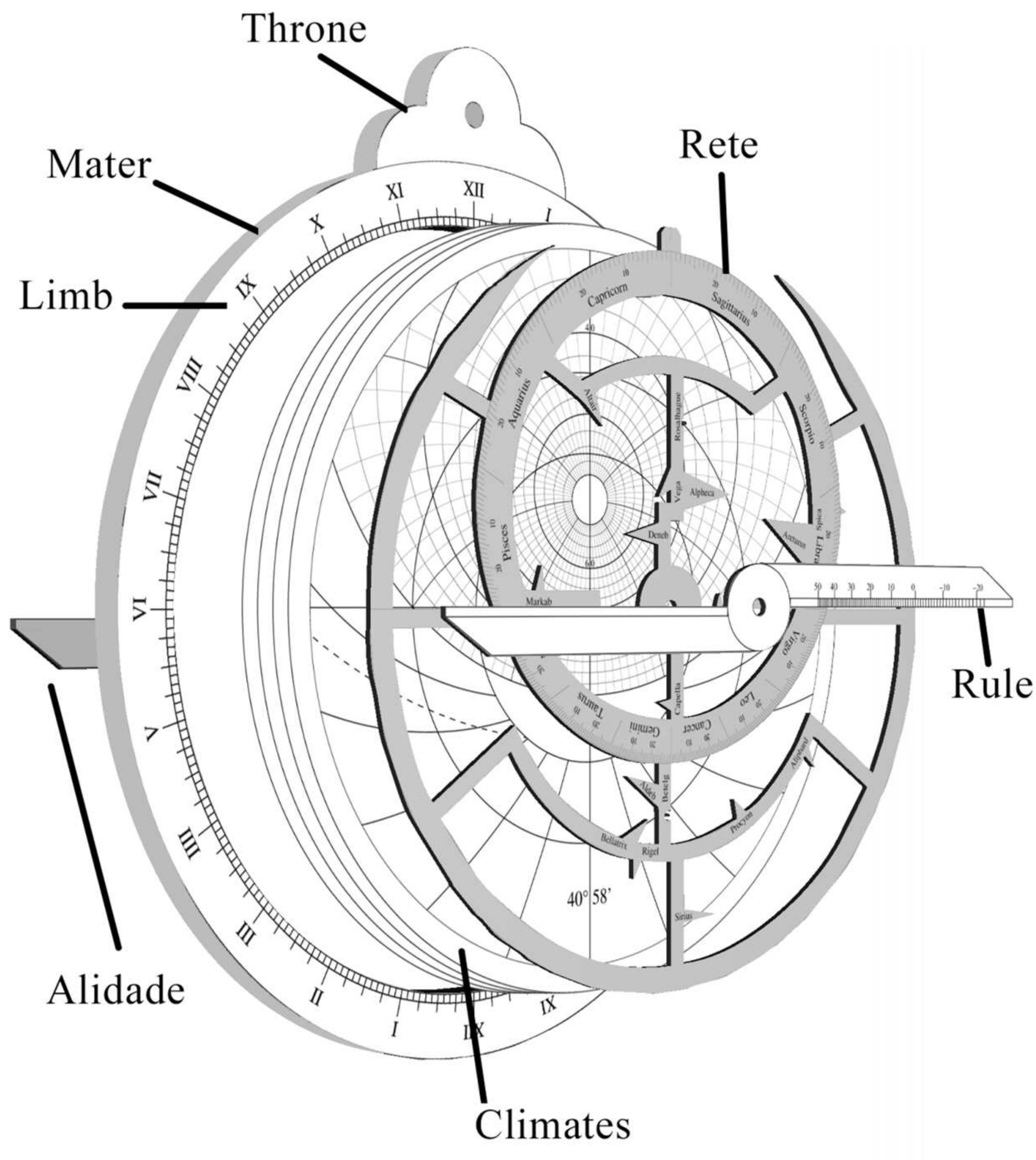


Projection of the local sky

Projection of the celestial sphere

Overlaid

Major Components of the Astrolabe



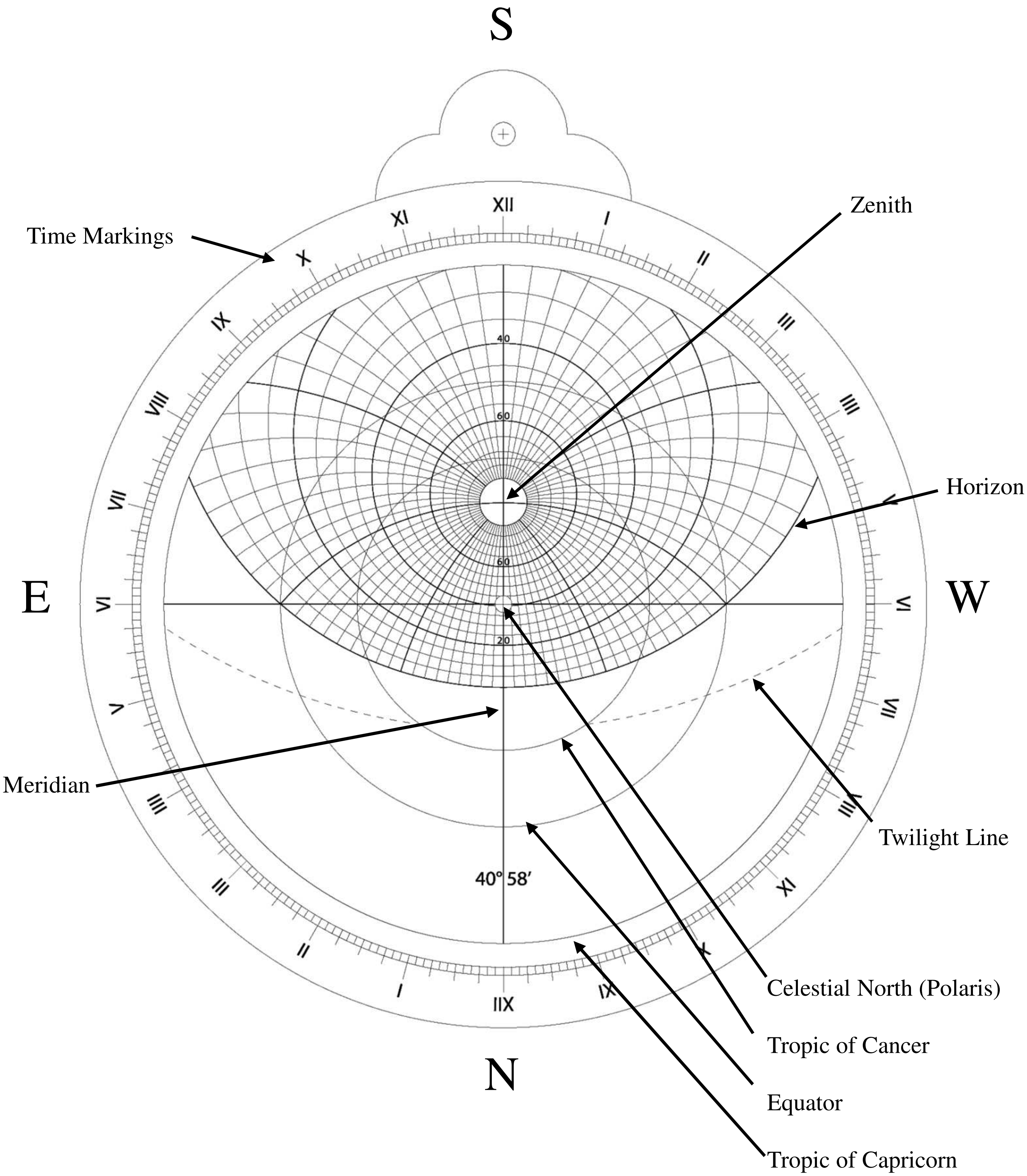
Notes:

-The Alidade Rete and Rule are all designed to rotate freely.

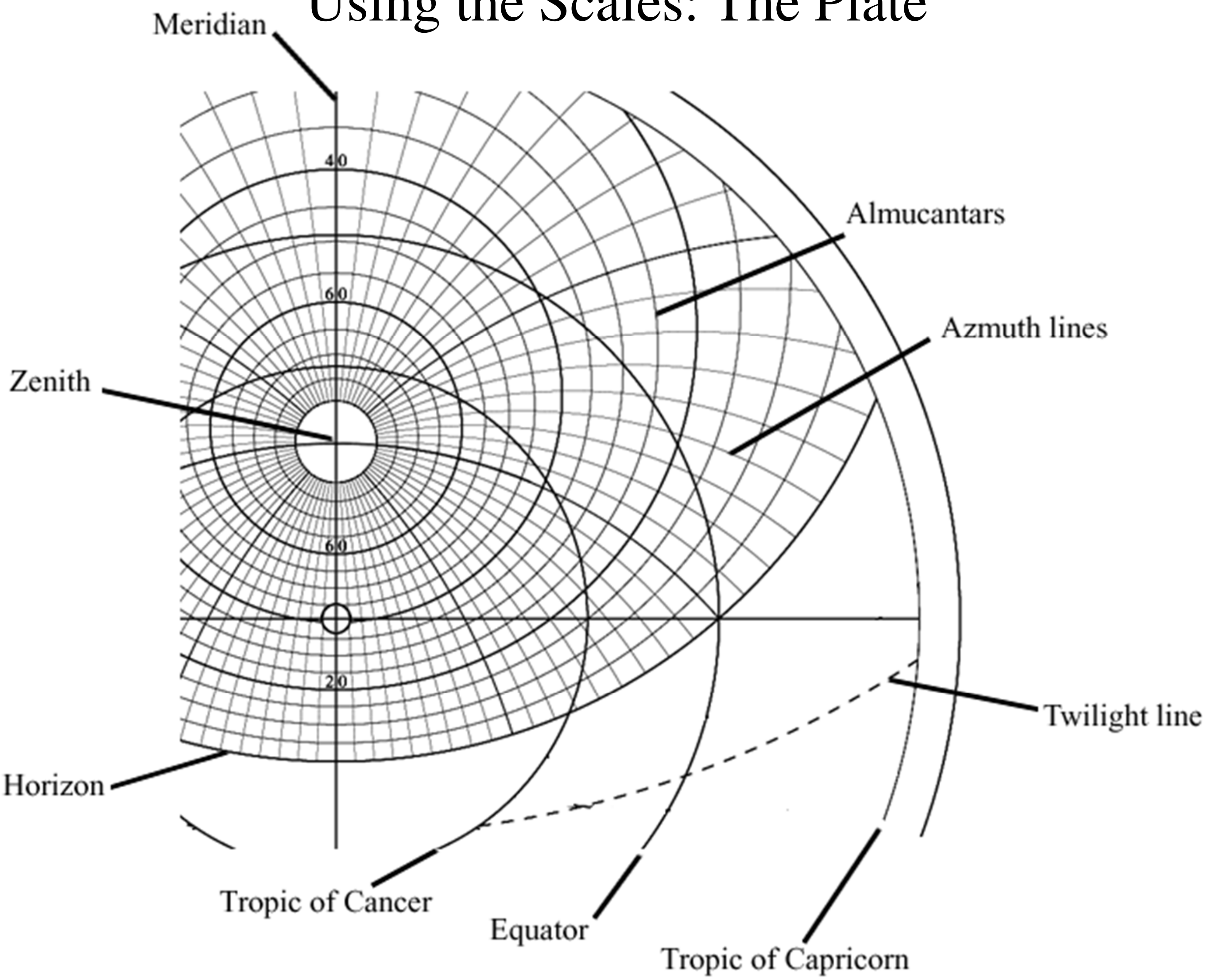
-The Plates (also known as climates) of an astrolabe are specific to a given latitude. Therefore most astrolabes contained a set of climates, that could be swapped out as the user moved to different locations.

-The Astrolabe rule could be either single or double ended.

The Front of the Astrolabe



Using the Scales: The Plate



The plate is marked with almucantars (lines of altitude) and lines of azimuth (direction).

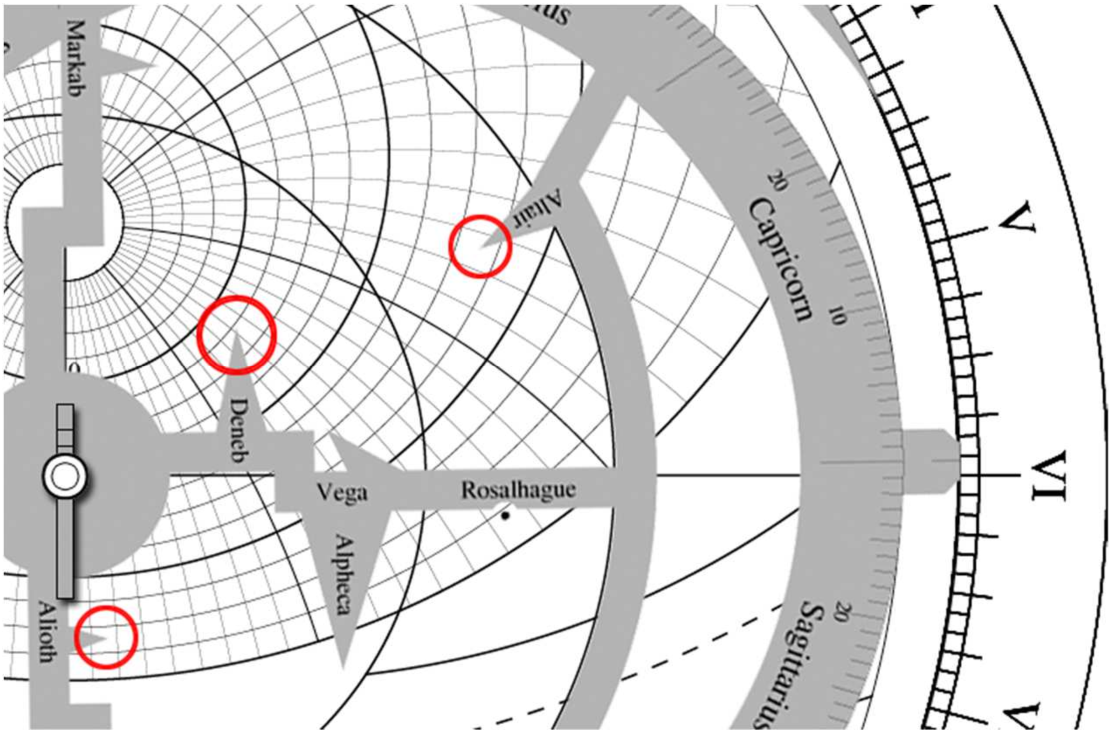
- •The almucantars are 5 degrees apart and 0 (horizon) to 80 deg are marked.
- •Where the lines cross in the center of the 80 deg almucantar marks the zenith (the point directly overhead)
- •The lines of azimuth (direction) are also marked every 5 degrees

The dotted line below the horizon line is the almucantar marking the end of twilight.

The vertical line through the zenith is the Meridian. It marks a line passing overhead that runs North-South. The Sun crossing the meridian marks local noon/midnight.

The time scale on the mater limb is marked in minutes, each mark is 5 minutes, and the hours are marked 1 to 12 twice, once for morning (left side), once for evening (right side), in roman numerals.

Using the Scales: The Plate



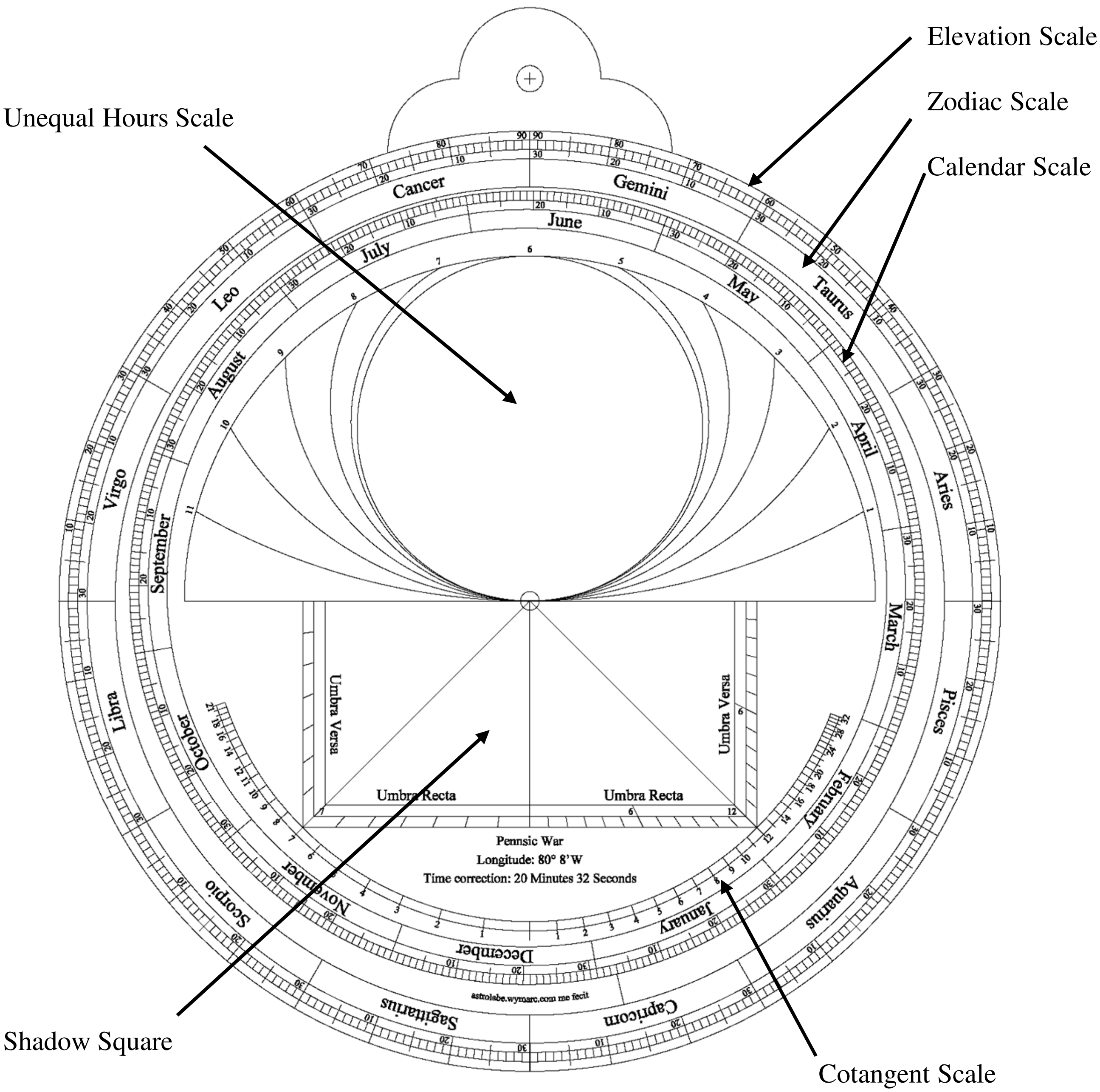
For example, in the illustration above:

•The star Altair (top) is at an altitude of 27 degrees above the horizon and is 13 degrees south of west (or bearing 257 degrees)

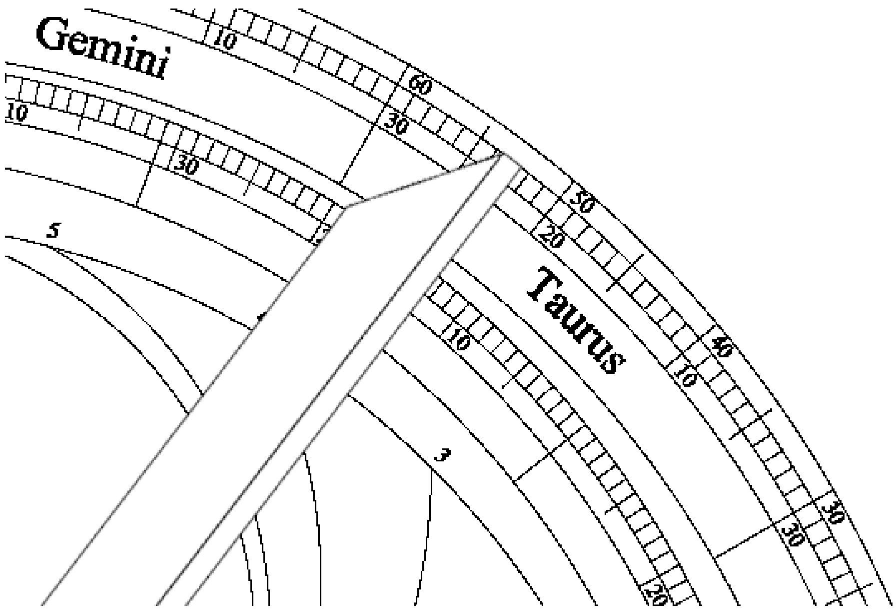
•Deneb (middle) is 54 degrees above the horizon, 25 degrees north of west

•Alioth (bottom) is about 7.5 degrees west of north, and about 8 degrees above the horizon.

The Back of the Astrolabe



Using the Scales: Elevation



Measuring Altitude above the horizon.

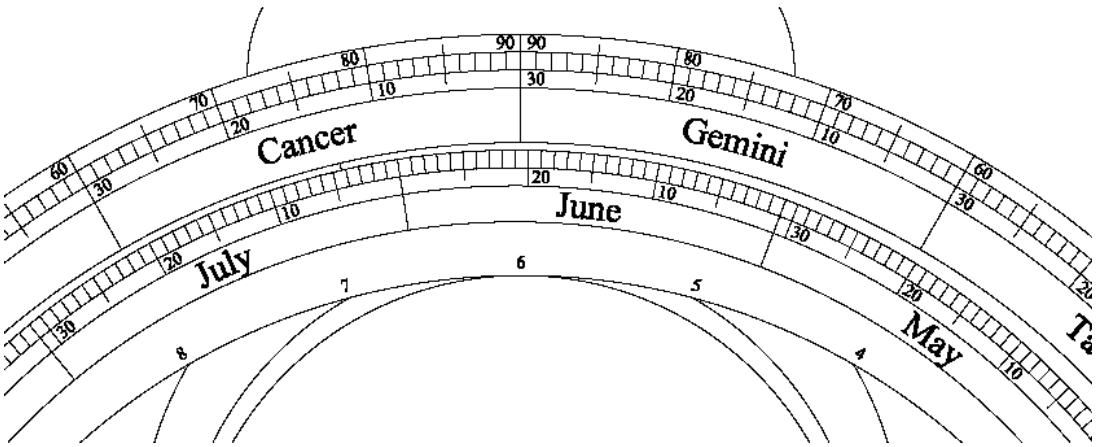
- The outermost scale is marked in degrees above the horizon, 0 - 90 degrees, one degree per tick
- In the example above, the alidade is set to 52.5 degrees.
- This scale is only marked above the horizon, if you wish to read an angle downward, read the scale from the other end of the alidade

A note on taking sights:

On a real astrolabe there are two sights on the alidade to assist in taking an accurate sighting. When sighting on an object, the astrolabe is suspended from a ring through the throne and allowed to hang. The alidade is then rotated until the target can been seen through both sights. The angle can then be read from the elevation scale.

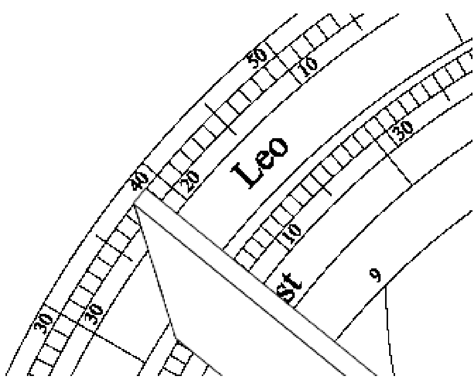
DO NOT sight on the sun this way. Instead, use the shadow of the sights to line up the alidade.

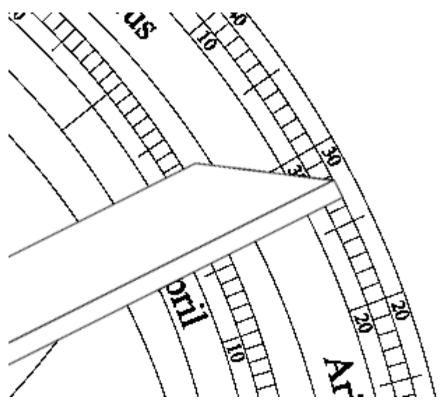
Using the Scales: Zodiac and Calendar



The Zodiac and Calendar Scales

- Used to find the position of the Sun for a given day
- Used to find the day the Sun is in a given Zodiac position



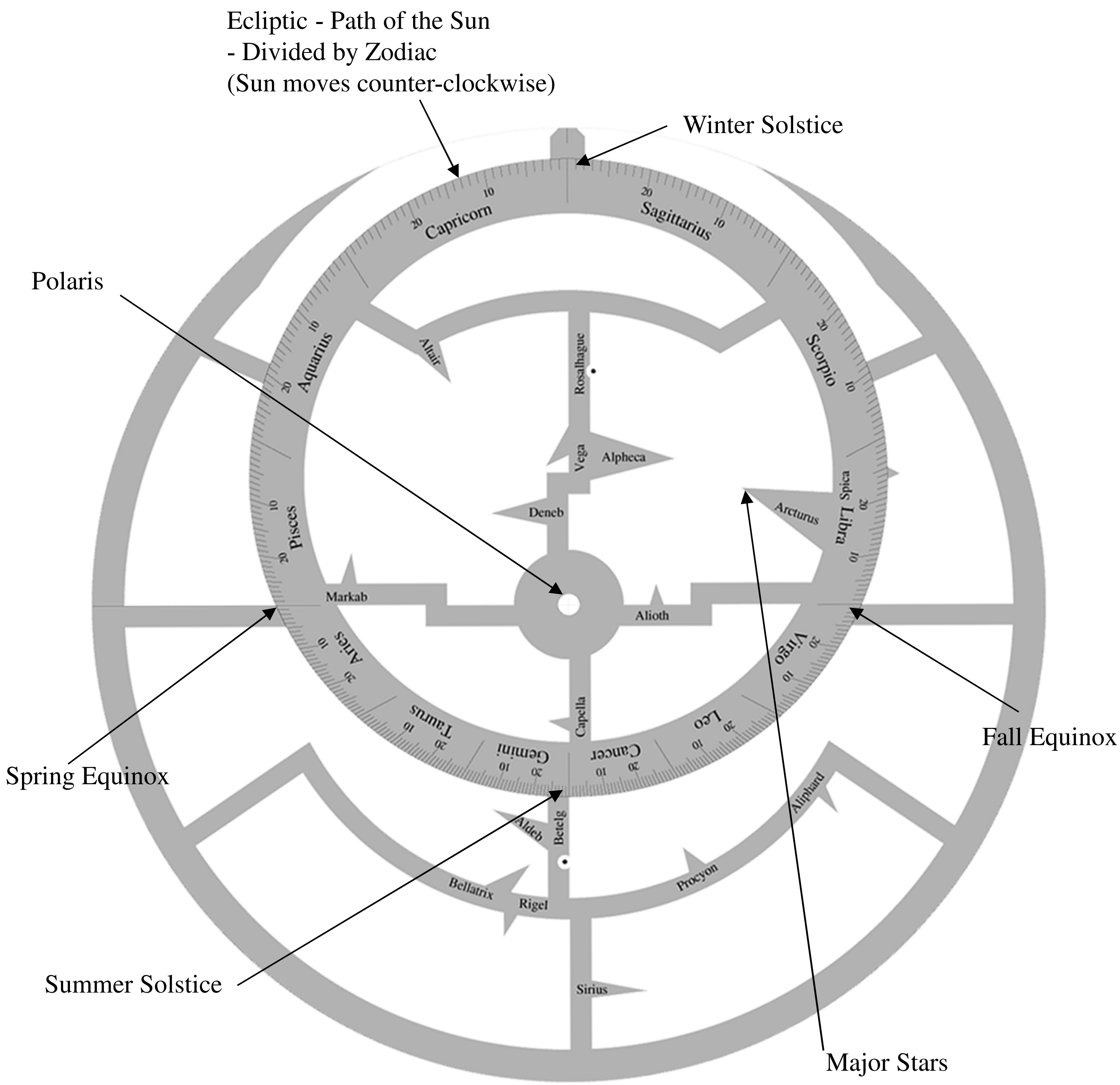


Left: Midnight 13 August / Leo 21.

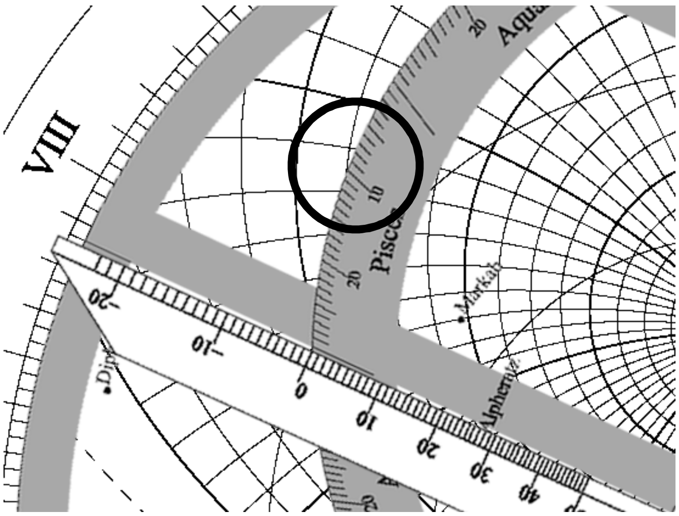
Right: Noon April 16 / Aries 26.5

Note: When reading the scales, the lines mark the end of the day. For example, on the right, the alidade is placed half way between the 15 mark and the 16 mark. (noon on the 16^{th} is half way between midnight on the 15^{th} and midnight on the 16th)

The Rete


Ecliptic - Path of the Sun
- Divided by Zodiac
(Sun moves counter-clockwise)
Winter Solstice
Polaris
Spring Equinox
Summer Solstice
Fall Equinox
Major Stars
Capricorn
Sagittarius
Aquarius
Scorpio
Pisces
Libra
Aries
Virgo
Taurus
Leo
Gemini
Cancer
Altair
Rosalhague
Vega
Alpheca
Deneb
Arcturus
Spica
Markab
Alioth
Capella
Aldeb
Betelg
Aliphard
Bellatrix
Rigel
Procyon
Sirius

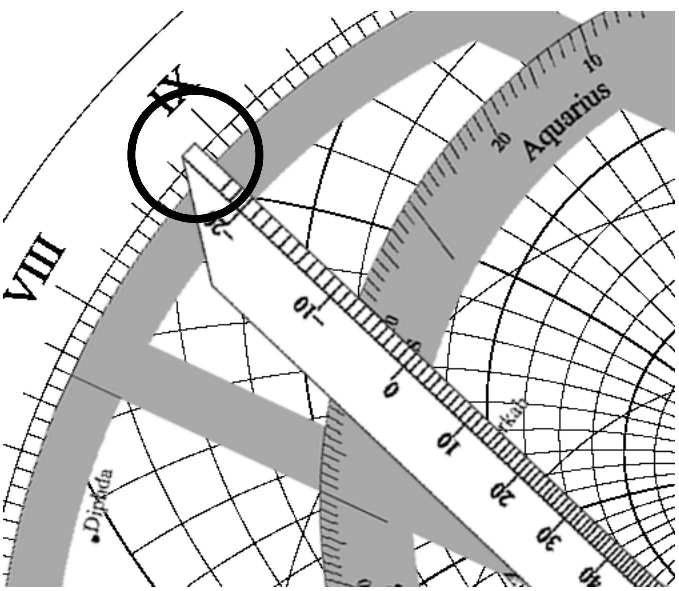
Using the Scales: The Zodiac Scale



The Zodiac Scale on the rete shows the annual path of the sun through the sky

- The scale is marked in degrees, with 30 degrees per sign.

- In the example on the left, the sun is in Pisces 10 and the rete is set to place Pisces 10 at an altitude of 25 degrees above the eastern horizon

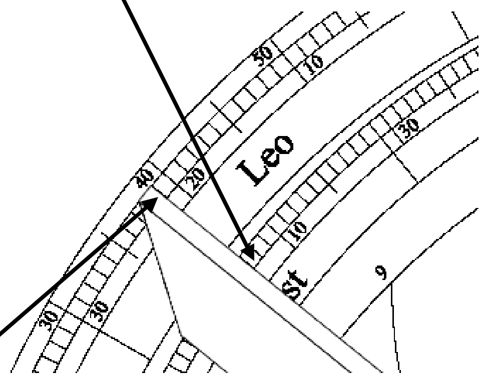


If the rule is then rotated around to Pisces 10, the user can read the local solar time from the limb: 8:54 am.

Example: Find the local time of sunset for 13 August

Step 1: Find the position of the sun on the 13th of August:

-On the back of the astrolabe set the alidade to 13 August

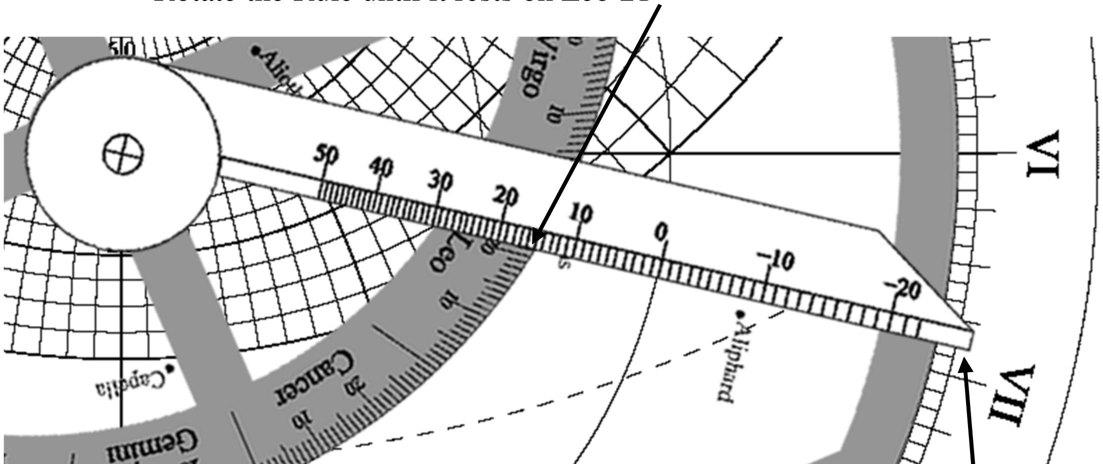


-Read Leo 21 from Zodiac Scale

Step 2: Find the time of Sunset:

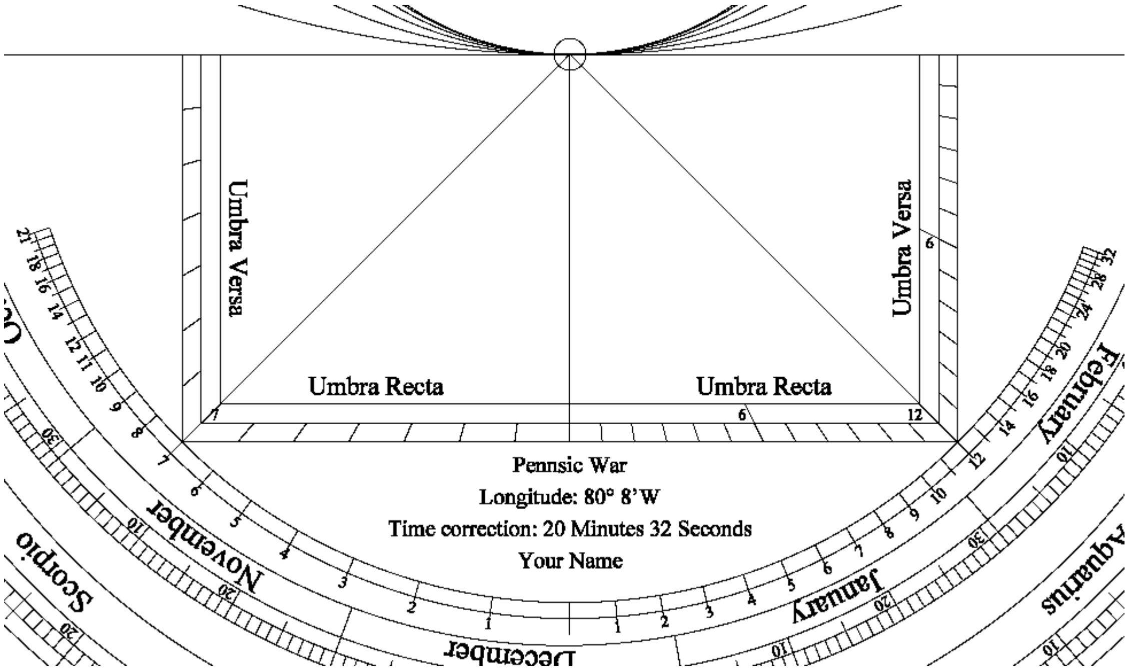
- On the front of the Astrolabe, rotate the Rete until Leo 21 touches the western (right) horizon.

- Rotate the Rule until it rests on Leo 21



- Read the local solar time from the time scale on the limb: 6:52 pm.

Using the Scales: Shadow Scales



There are a large number of available scales devoted to working with shadow length, especially in Moslem countries, where the length of shadows was important to defining the Islamic prayer times. In addition, the various shadow scales can de used to quickly work problems in trigonometry.

For this section we will concern ourselves with the most popular scale: The Shadow Square.

The **Shadow Square** consists of two squares (see above), divided so as to make reading the length of the shadow of an object easy to compute. As many of the calculations for prayer times are based on a 7 foot vertical pole or gnomon, one of the scales is usually divided into 7 sections. The other side of the scale is divided in any number of ways, 10 and 12 being popular.

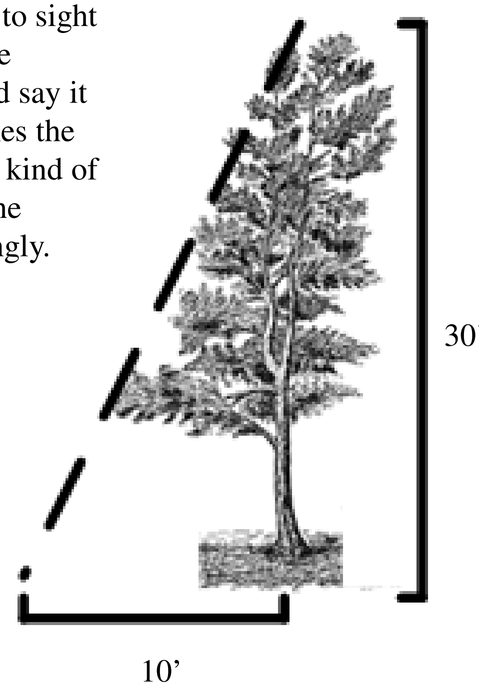
The Umbra Recta (horizontal shadow) scale allows the user to directly measure the length of the horizontal shadow of a vertical gnomon: 0 at noon, 7 (for a 7 foot gnomon) when the sun is at 45 degrees.

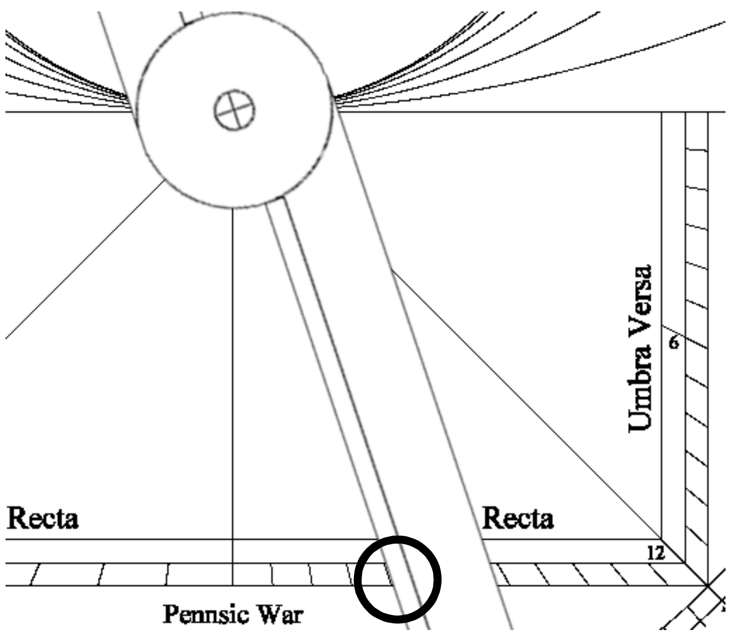
The Umbra Versa (vertical shadow) scale does the same for a horizontal gnomon.

Using the Scales: Shadow Square

Besides measuring directly, you can use proportions to compute lengths and angles with the shadow square.

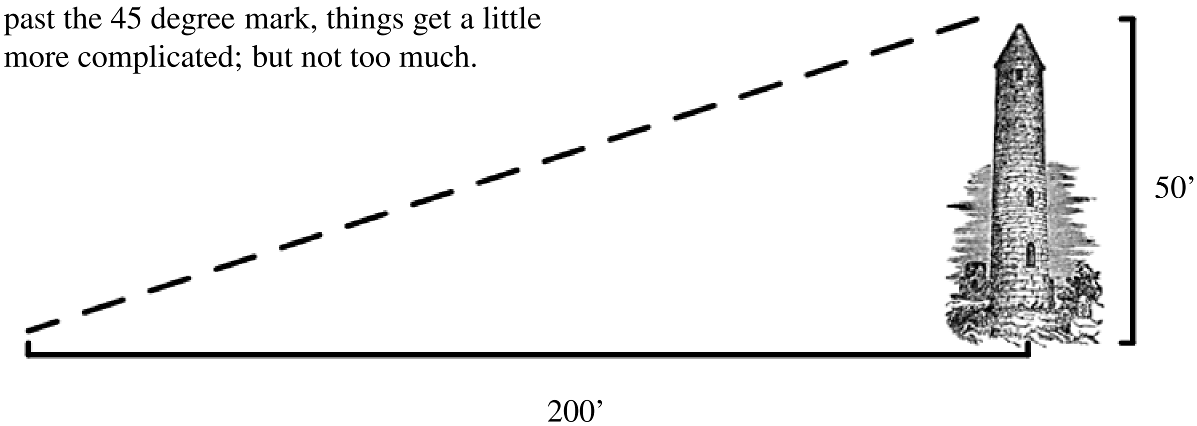
For example: If you wish to compute the height of a tree, you could pace out 10 feet. Then use the astrolabe's alidade to sight on the top of the tree. See where the alidade lands on the shadow square's Umbra Recta (let's use the 12 scale and say it lands on 4). 4/12 is 1/3 so the height of the tree is 3 times the distance you paced out: 30 feet. Note: When doing this kind of work remember you are measuring from the height of the astrolabe, not the ground, and adjust the height accordingly.



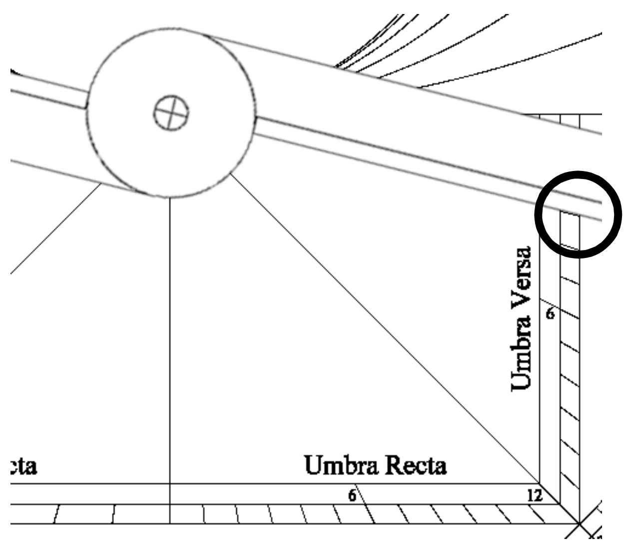


Using the Scales: Shadow Square

2. If the angle you are measuring takes you past the 45 degree mark, things get a little more complicated; but not too much.



Example: You wish to measure the height of a tower. You pace off a distance of 200 feet and use the astrolabe’s alidade to sight on the top of the tower. Reading off the 12-scale shadow square, you get a reading of 3. If this was on the Umbra Recta scale that would mean the tower was 800 feet tall (3 is 1/4 of 12, 4 times 200 is…). But you are on the Umbra Versa scale, so you <u>reverse</u> the proportion: 3 is 1/4 of 12 so the tower height is 1/4 of the distance to the tower, or 50 feet.



Astrolabe Problems

Note: Due to variations in the instruments, and differences in technique, your answers will vary a bit. If you are within 15 minutes you are doing well, within 5 minutes, excellent.

Basic Problems:

1. What is the zodiac position of the sun on July 23?

2. What is the zodiac position of the sun on September 4?

3. On what day does the sun enter Capricorn?

4. What day is the sun in Cancer 23?

5. Where on the zodiac is the sun at its highest noon altitude? What date is that?

6. Where on the zodiac is the sun at its lowest noon altitude? What date is that?

7. Using the astrolabe, what are the dates for the equinoxes and solstices? (Remember. The solstices are the longest/shortest days and the equinoxes occur when day and night are equally long.)

8. Given a 7 foot vertical gnomon: If the sun is at an altitude of 57 degrees, what is the length of its shadow on the ground?

9. Given a 12 foot horizontal gnomon: If the sun is at an altitude of 25 degrees, what is the length of its shadow on the wall?

10. What direction does the sun set at on the 23 of August?

Astrolabe Problems

Medium Problems:

1. It is the 23rd of July. What local time is Sunset? When is the end of evening twilight? When does the star Markab rise?

2. It is the 23rd of August, How long is the day?

3. It is the 12th of December, How long is the day?

4. You need to cut down a tree, You want to be sure there is room for it to fall safely. You pace out 20 feet, you sight the top at an angle of 63 1/2 degrees. Determine the height of the tree.

5. It is the afternoon of the 10th of August. You measure the sun at an angle of 52 degrees. What time is it?

Advanced Problems:

1. It is the dead of winter. Your cook wants to plan a herb garden for behind the kitchen; however, the neighboring house blocks the sun for part of the day. You stand in center of the future garden plot and measure the angle of the neighboring roof (40 Degrees). Estimate the minimum number of hours of sun the garden would get from spring equinox to fall equinox.

2. You are on the top of a 40 foot tower. Engineers are setting up catapults in the distance. You want to know the distance to the catapults. Sighting on them, your astrolabe's Umbra Versa 12 scale shows 2. What is the distance to the catapults?

Answers

Basic Problems:

1. Leo 1

2. Virgo 12.5

3. December 21st

4. July 14/15th

5. Gemini 30/ June 21

6. Sagittarius 30/ December 21

7. Summer solstice: Gemini 30/ June 21 || Fall Equinox: Pisces 30/ March 20 || Winter Solstice: Sagittarius 30/ December 21 || Spring Equinox: Virgo 30/ September 23

8. 4.5 feet.

9. 5.5 Feet

10. 17 degrees North of West / 287 Degrees

Medium Problems:

1. On the 23 of July the sun is at Leo 1.5, Local sunset is at: 7:14 pm solar time, Evening Twilight ends at 9:15 pm solar time, Markab rises at 8:03 pm solar

2. On the 23 of August the sun is at Virgo 0.5, The sun rises at 5:19 am solar, The sun sets at 6:43 pm solar, The day is 13 hours and 22 minutes long

3. On the 12th of December the sun is at Sagittarius 20.5, The sun rises at 7:26 am solar, The sun sets at 4:34 pm solar, The day is 9 hours and 8 minutes long

4. 40 Feet. The 12 shadow square reads 6 at the given angle, so the height of the tree is twice the distance to it (6/12 = 1/2)

5. The sun is in Leo 18, Solar time is 2:14 PM.

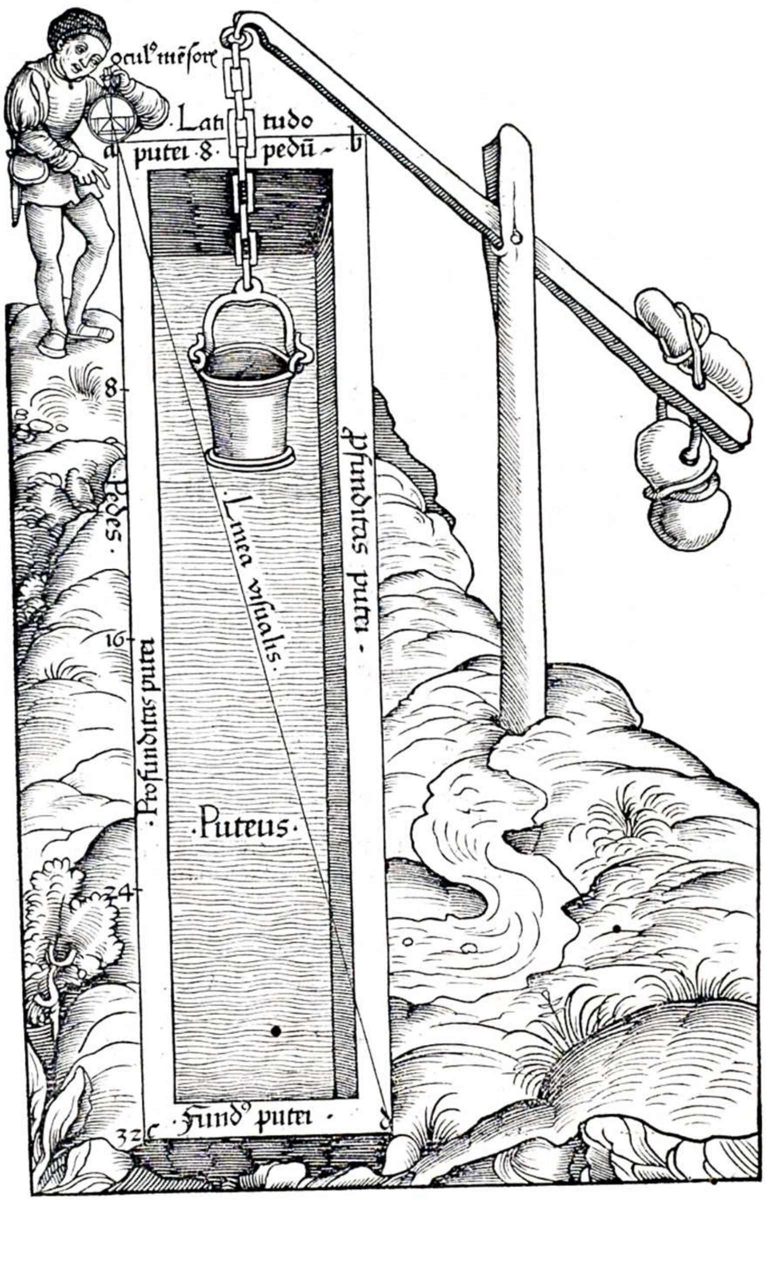
Advanced Problems:

1. The sun will shine on the garden when it is above 40 degrees, Set the Sun's position at the equinox (spring or fall) to 40 degrees above the morning horizon, and note the time (9:54). Then move it to 40 degrees above the evening horizon and note that time (2:03). The time difference is the minimum time the garden will have sun (4 Hours, 9 Minutes).

2. 2/12 = 1/6 and you are on the umbra versa scale so the proportion is reversed: therefore the distance is 6 times that of the height - or 240 feet

Part II

Advanced Astrolabe Functions



Using the Scales: The Moon and Planets

The Ephemeris:

Finding the Sun's position is easy with an astrolabe. Locating the other major objects in the sky is more complicated.

The Sun (by definition) always lies on the ecliptic, all that is needed to locate it in the sky accurately is its location on that line.

The Moon and planets, however often lie up to several degrees north or south of the ecliptic, this makes it harder to locate them precisely. In addition, unlike the Sun, the other bodies in the system do not follow set, repeated paths through the sky, so a simple scale like the one the astrolabe uses to keep track of the sun is not feasible.

To find the positions of the Moon and planets, you will need to make use of a set of tables known as an "Ephemeris" (See the next page)

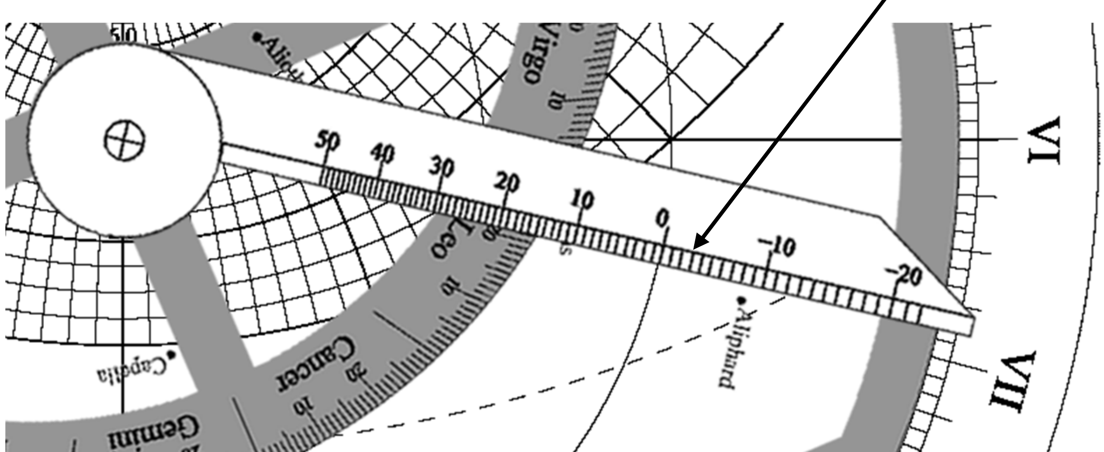
To define the location of a place on the Earth we use a coordinate system of Latitude (N/S) and Longitude (E/W). The Celestial Sphere has a very similar system of location:

- Declination is the angle North or South of the celestial equator
- Right Ascension is the equivalent of longitude. As we are using the zodiac for locating objects East/West, we will ignore right ascension.

The ephemeris gives the location of objects in terms of their zodiac position and declination. This can be a bit confusing at first, remember, declination is the angle above or below the celestial equator, not the ecliptic.

Astrolabes would often have a declination scale on the rule to make working with declination easier.

Declination Scale



Celestial Equator
(0 degrees Declination)

August 2013

	☉	☽	☿	♀	♂	♃	♄	☊
1	♌ 08-55	♊ 04-07	♋ 19-28	♍ 11-22	♋ 12-21	♋ 07-59	♏ 05-17	♏ 12-56
2	09-53	15-58	20-36	12-33	13-01	08-12	05-19	12-53
3	10-50	27-47	21-49	13-45	13-41	08-24	05-21	12-47
4	11-48	♋ 09-37	23-07	14-57	14-20	08-37	05-24	12-38
5	12-45	21-31	24-31	16-08	15-00	08-49	05-27	12-27
6	13-42	♌ 03-32	25-59	17-20	15-39	09-02	05-29	12-14
7	14-40	15-40	27-32	18-32	16-19	09-14	05-32	12-00
8	15-37	27-57	29-09	19-43	16-58	09-26	05-35	11-47
9	16-35	♍ 10-24	♌ 00-50	20-55	17-38	09-39	05-38	11-35
10	17-33	23-01	02-35	22-06	18-17	09-51	05-41	11-25
11	18-30	♎ 05-49	04-23	23-17	18-56	10-03	05-44	11-19
12	19-28	18-49	06-14	24-29	19-35	10-15	05-47	11-15
13	20-25	♏ 02-03	08-08	25-40	20-15	10-27	05-51	11-14
14	21-23	15-34	10-04	26-51	20-54	10-39	05-54	11-14
15	22-21	29-22	12-02	28-03	21-33	10-51	05-58	11-13
16	23-18	♐ 13-29	14-01	29-14	22-12	11-02	06-01	11-12
17	24-16	27-55	16-01	♎ 00-25	22-51	11-14	06-05	11-09
18	25-14	♑ 12-35	18-02	01-36	23-30	11-26	06-09	11-03
19	26-11	27-26	20-03	02-47	24-09	11-37	06-12	10-55
20	27-09	♒ 12-20	22-05	03-58	24-48	11-49	06-16	10-45
21	28-07	27-06	24-06	05-09	25-26	12-00	06-20	10-34
22	29-05	♓ 11-38	26-07	06-19	26-05	12-11	06-24	10-24
23	♍ 00-02	25-49	28-07	07-30	26-44	12-23	06-28	10-16
24	01-00	♈ 09-33	♍ 00-07	08-41	27-22	12-34	06-33	10-10
25	01-58	22-51	02-06	09-51	28-01	12-45	06-37	10-07
26	02-56	♉ 05-43	04-03	11-02	28-40	12-56	06-41	10-05
27	03-54	18-13	06-00	12-12	29-18	13-07	06-46	10-06
28	04-52	♊ 00-26	07-56	13-23	29-57	13-18	06-50	10-06
29	05-50	12-25	09-51	14-33	♌ 00-35	13-28	06-55	10-06
30	06-48	24-18	11-44	15-43	01-13	13-39	06-59	10-04
31	07-46	♋ 06-08	13-36	16-54	01-52	13-49	07-04	10-00

Declination - August 2013

	☉	☽	☿	♀	♂	♃	♄
1	+ 18-02	19-10	+ 20-31	08-32	+ 23-34	+ 23-02	- 11-03
2	17-46	19-58	20-36	08-03	23-30	23-01	11-04
3	17-31	19-52	20-39	07-34	23-27	23-00	11-05
4	17-15	18-54	20-41	07-05	23-23	23-00	11-06
5	16-59	17-06	20-41	06-35	23-20	22-59	11-07
6	16-42	14-33	20-39	06-05	23-16	22-58	11-08
7	16-26	11-22	20-34	05-35	23-12	22-57	11-09
8	16-09	07-40	20-27	05-05	23-07	22-57	11-10
9	15-52	03-36	20-18	04-35	23-03	22-56	11-12
10	15-34	00-41	20-06	04-04	22-58	22-55	11-13
11	15-17	- 05-00	19-51	03-34	22-53	22-54	11-14
12	14-59	09-09	19-33	03-03	22-48	22-53	11-15
13	14-41	12-56	19-13	02-33	22-43	22-53	11-17
14	14-22	16-08	18-51	02-02	22-38	22-52	11-18
15	14-04	18-28	18-25	01-31	22-32	22-51	11-19
16	13-45	19-44	17-57	01-00	22-27	22-50	11-21
17	13-26	19-45	17-27	00-29	22-21	22-49	11-22
18	13-07	18-26	16-55	00-01	22-15	22-48	11-24
19	12-47	15-52	16-21	00-32	22-09	22-47	11-25
20	12-28	12-16	15-45	- 01-03	22-02	22-46	11-27
21	12-08	07-56	15-07	01-34	21-56	22-45	11-28
22	11-48	03-13	14-27	02-05	21-49	22-45	11-30
23	11-27	+ 01-35	13-47	02-36	21-42	22-44	11-31
24	11-07	06-09	13-05	03-07	21-35	22-43	11-33
25	10-46	10-17	12-22	03-38	21-28	22-42	11-34
26	10-26	13-48	11-38	04-09	21-21	22-41	11-36
27	10-05	16-34	10-53	04-39	21-13	22-40	11-38
28	09-44	18-30	10-08	05-10	21-06	22-39	11-39
29	09-22	19-35	09-22	05-40	20-58	22-38	11-41
30	09-01	19-46	08-36	06-11	20-50	22-37	11-43
31	08-39	19-05	07-50	06-41	20-42	22-36	11-45

☉ **Sun**
☽ **Moon**
☿ **Mercury**
♀ **Venus**
♂ **Mars**
♃ **Jupiter**
♄ **Saturn**
☊ **Rising Lunar Node (Serpent's Head)**

♈ **Aries**
♉ **Taurus**
♊ **Gemini**
♋ **Cancer**
♌ **Leo**
♍ **Virgo**
♎ **Libra**
♏ **Scorpio**
♐ **Sagittarius**
♑ **Capricorn**
♒ **Aquarius**
♓ **Pisces**

Reading the Ephemeris

Object

August 2013

	☉	☽	☿	♀	♂	♃	♄
1	♌ 08-55	♊ 04-07	♋ 19-28	♍ 11-22	♋ 12-21	♋ 07-59	♏ 05-17
2	09-53	15-58	20-36	12-33	13-01	08-12	05-19
3	10-50	27-47	21-49	13-45	13-41	08-24	05-21
4	11-48	♋ 09-37	23-07	14-57	14-20	08-37	05-24
5	12-45	21-31	24-31	16-08	15-00	08-49	05-27
6	13-42	♌ 03-32	25-59	17-20	15-39	09-02	05-29
7	14-40	15-40	27-32	18-32	16-19	09-14	05-32
8	15-37	27-57	29-09	19-43	16-58	09-26	05-35
9	16-35	♍ 10-24	♌ 00-50	20-55	17-38	09-39	05-38
10	17-33	23-01	02-35	22-06	18-17	09-51	05-41
11	18-30	Ω 05-49	04-23	23-17	18-56	10-03	05-44

Day of month

Zodiac sign

Position in sign:
Degrees-Minutes

1. The zodiac symbol is not printed for each entry, scan up the column to read the current sign. Note that angles are divided into Degrees (0 to 360, or 0 to 30 in this case as there are 30 degrees in every zodiac sign), Minutes (60 minutes per degree) and Seconds (60 seconds per minute). In the table above, the first two digits are the number of degrees (0 to 30), the next two are the number of minutes (0 to 60): That is, "14-35" is read as 14 degrees, 35 minutes.

2. Example: On August 10, Venus is in Virgo 22 degrees 6 minutes; and Jupiter is in Cancer 9 degrees 51 minutes. Note: When using an astrolabe you can round to the nearest half degree (i.e. Virgo 22, Cancer 10)

Sources for ephemeris data are listed at the end of the handout

Reading the Ephemeris - Declination

Declination - August 2013

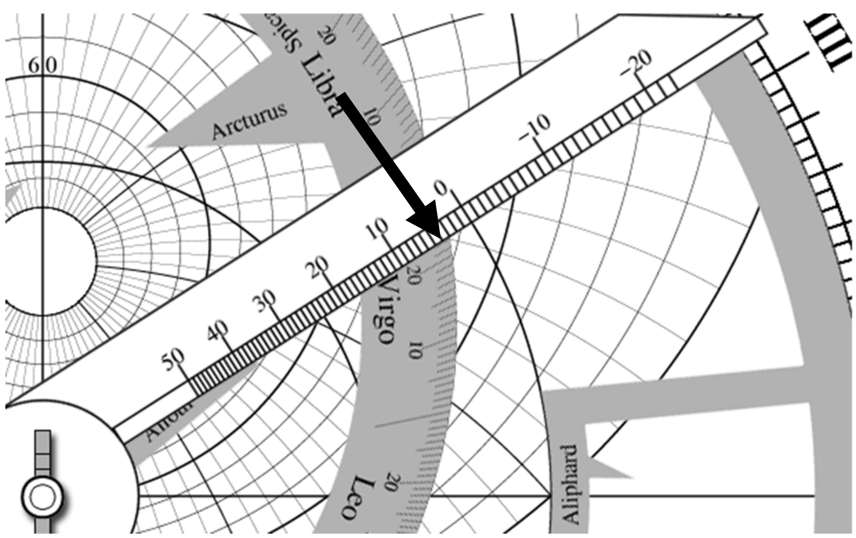
	☉	☽	☿	♀	♂	♃	♄
1	+ 18-02	19-10	+ 20-31	08-32	+ 23-34	+ 23-02	- 11-03
2	17-46	19-58	20-36	08-03	23-30	23-01	11-04
3	17-31	19-52	20-39	07-34	23-27	23-00	11-05
4	17-15	18-54	20-41	07-05	23-23	23-00	11-06
5	16-59	17-06	20-41	06-35	23-20	22-59	11-07
6	16-42	14-33	20-39	06-05	23-16	22-58	11-08
7	16-26	11-22	20-34	05-35	23-12	22-57	11-09
8	16-09	07-40	20-27	05-05	23-07	22-57	11-10
9	15-52	03-36	20-18	04-35	23-03	22-56	11-12
10	15-34	00-41	20-06	04-04	22-58	22-55	11-13

1. The longitude table discussed on the last page gives the object's location on the ecliptic. To find the object's location above or below the ecliptic, you must use the Declination table.

2. As with the zodiac sign and the longitude table, you will need to scan up the column to discover whether the declination is positive (+, above the equator) or negative (-, below the equator).

3. To find the declination of the object on a given date you use the declination table entry for that date.

4. In our previous example we found that Venus was in Virgo 22-6 on August 10th. Checking the declination table you will see that Venus's declination for that date is 4 degrees, 4 minutes above the celestial equator. Again, when working with the astrolabe you can round off to the nearest half degree, so Venus is at a declination of +4.



NOTE: The data shown in these tables is for 0:00am, so the numbers given for August 10th are also midnight August 9th

Example: Find the location of Saturn in the sky at sunset, August 10th 2012.

Step 1: Find the position of the sun on the 10th of August:

- On the back of the astrolabe set the alidade to 10 August
- Read the solar position: Leo 18

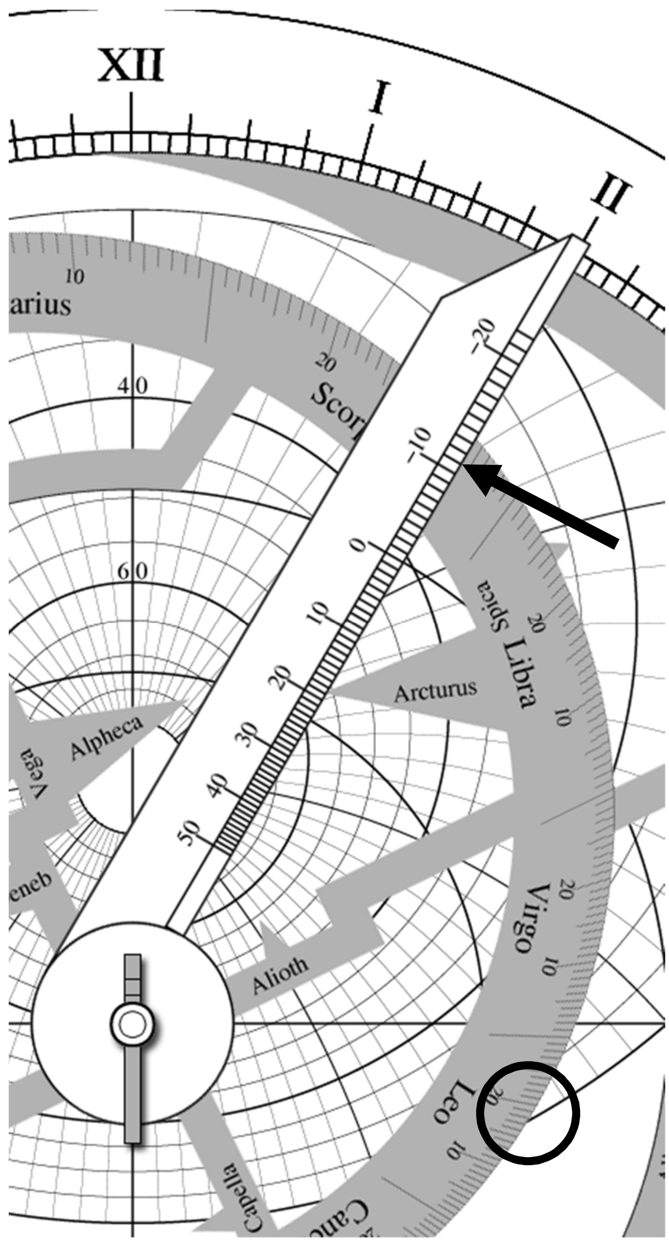
Step 2: Find the location of Saturn for the 10th of August:

- From the ephemeris:
    - Longitude: Scorpio 5-41 (5.5 rounded)
    - Declination: -11-13 (-11 rounded)

Step 3: Set the astrolabe to sunset on 10 August (circled).

Step 4: Rotate the rule to the position of Saturn on the ecliptic (Scorpio 5.5) and read its location on the declination scale (-11) (arrow).

At sunset on the 10th of August, Saturn is located in the Western sky at 34 degrees above the horizon, 35 degrees West of South.



Medieval Timekeeping:
Equal Hours vs. Unequal Hours

In the Middle Ages there were two competing systems of timekeeping:

The Equal Hour system is the one you are familiar with.

The Unequal Hour system is different:

> -The day (sunrise to sunset) and the night (sunset to sunrise) are each divided into 12 hours, regardless of the time of year
> - In Summer an hour of daylight is longer than an hour of darkness, in Winter the reverse is true.
> - The sun rises at the start of the first hour of the day and sets at the end of the 12th hour of the day, which is also the start of the first hour of the night.

"I will meet you a 10 tonight" vs. "I will meet you at the third hour of the night"

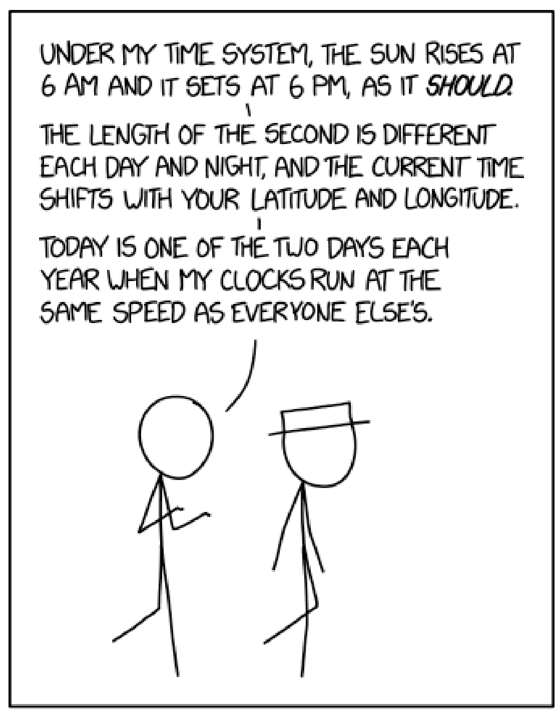
The unequal hour system was used for Christian prayer times among other uses

Equal Hours

1. 24 hours in a day
2. An hour is 60 minutes long
3. Daytime hours and nighttime hours the same length
4. Night time and day time different lengths

Unequal Hours

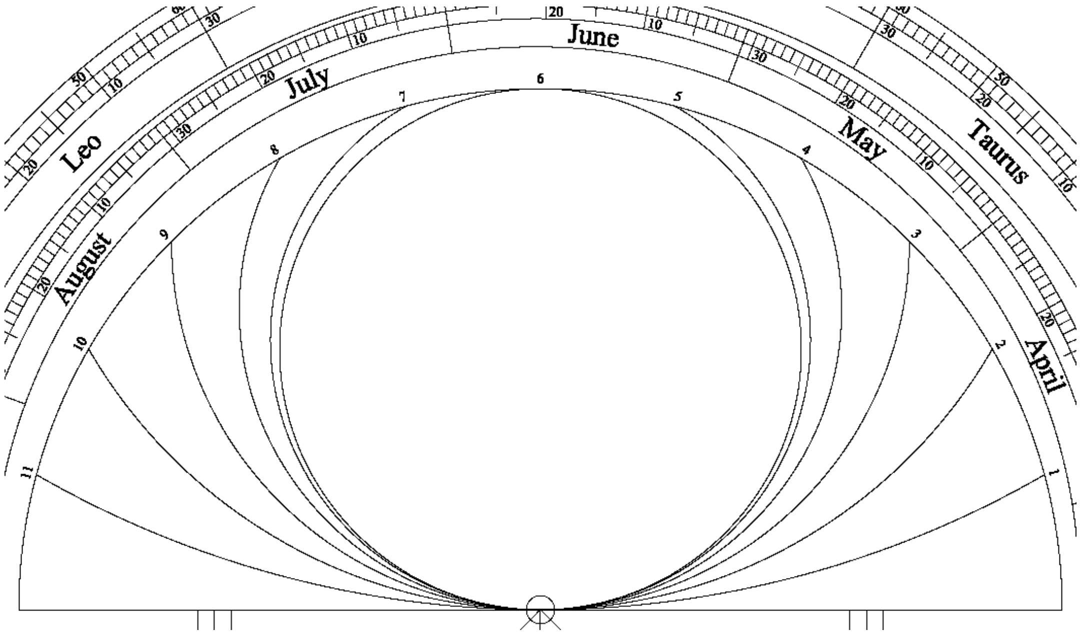
1. 24 hours in a day
2. The length of an hour varies over the course of a year
3. Daytime hours and nighttime hours different lengths most of the year
4. Night time and day time each 12 hours long



TIME STANDARDS ARE SO UNFIXABLY MESSY AND COMPLICATED THAT AT THIS POINT MY IMPULSE IS JUST TO TRY TO MAKE THEM WORSE.

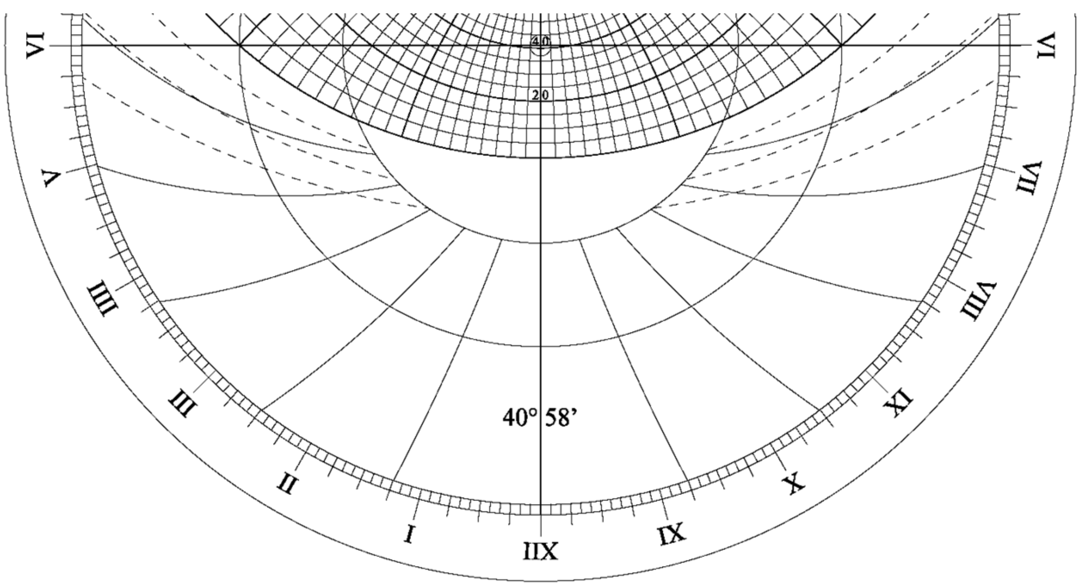
For example: During Pennsic war week a daytime unequal hour is about 70 minutes and a nighttime unequal hour is 50 minutes.

Using the Scales: Unequal Hours



Converting to Unequal Hours
- One common use of the astrolabe was converting solar time (equal hours) to unequal hours

The Unequal hour scales can be found it two possible places: On the back (above), and sometimes on the front, below the horizon line (below). As the unequal hour scale is symmetrical, sometimes only half of it us shown (See the example in the front of the handout).

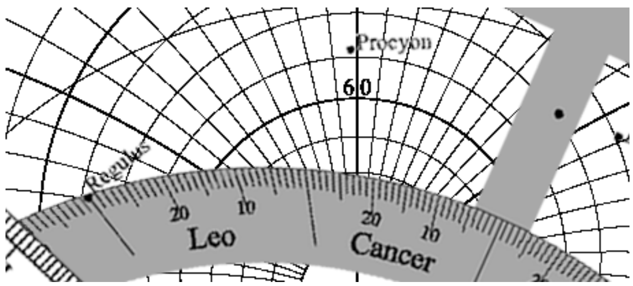


Using the Scales: Unequal Hours

Example: Find the Unequal Hour for 4:45 PM on July 14th

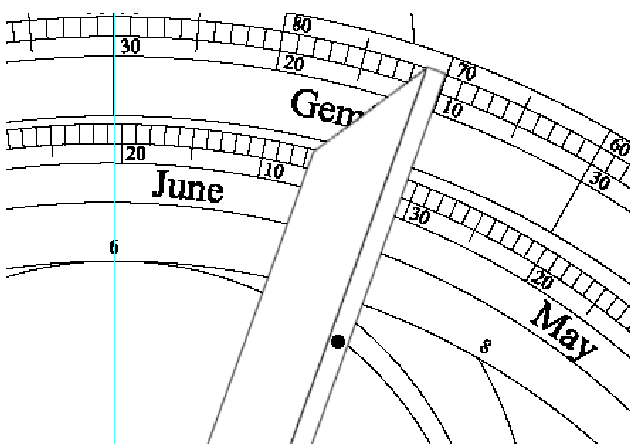
Step 1: Find altitude of the sun at noon on the 14th of July.

- The sun is at Cancer 22.5 (From the zodiac scale).
- rotate the rete until Cancer 22.5 is on the noon meridian.



-Read 70 degrees from plate: The sun's noon altitude is 70 degrees.

Step 2: Rotate the alidade to 70 degrees:

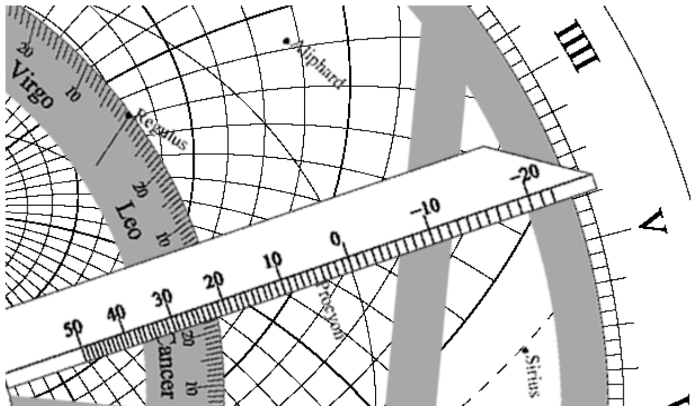


- Mark the location of the noon (6) unequal hour on the alidade.

Using the Scales: Unequal Hours

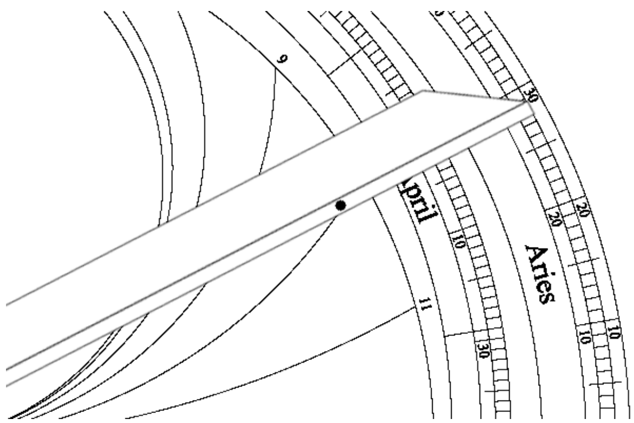
Step 3: Find altitude of the sun at 4:45 on the 14th of July.

- Rotate the rule to Cancer 22.5.
- Rotate the rete and rule together until the rule points to 4:45 on the time scale.



-Read 27.5 degrees altitude from plate

Step 4: Rotate the alidade to 27.5 degrees:



- Read the unequal hour from the mark: The tenth hour, or the beginning of the 11th Hour of the day.

Medieval Timekeeping:
Prayer Times

Both the Christian and Islamic traditions prescribe set daily prayer times. The astrolabe is useful for determining the times for both. (Note: In both cases times may vary by location and century).

Christian prayer times - based largely on the unequal hours of the day

1. Matins - Start of the day, ninth hour of the night
2. Lauds - Beginning of morning twilight (Sun 18 degrees below horizon)
3. Prime - Sunrise (12th hour of the night / beginning of the first hour of the day)
4. Terce - Third hour of the day
5. Sext - Sixth hour of the day (Noon)
6. None - Ninth hour of the day
7. Vespers - Sunset (12th hour of the day / beginning of the first hour of the night)
8. Compline - From bedtime to the third hour of the night

Islamic prayer times

The Times for the five required daily prayers are:

1. Fajr - Morning/Dawn prayer. Starts at beginning of morning twilight (Sun 18 degrees below horizon), and ends at dawn.

2. Zuhr - Midday prayer. Begins when the shadow of a vertical gnomon (usually 7 feet) is equal to its length at noon plus 1/4 the length of the gnomon, and ends at the start of Asr.

3. Asr - Mid-afternoon prayer. Begins when the shadow of a vertical gnomon (traditionally 7 feet) is equal to its noontime length plus the length of the gnomon. Ends when the shadow is the noontime length plus twice the length of the gnomon.

4. Maghrib - Sunset prayer. Starts at sunset, Ends at end of evening twilight (Sun 18 degrees below horizon).

5. Isha - Evening prayer. Starts at the end of evening twilight. Ends at start of morning twilight.

(Note: There are various schools of thought, and regional and cultural variations. The above is not definitive and is based on several sources; with definitions chosen to highlight the use of the shadow squares).

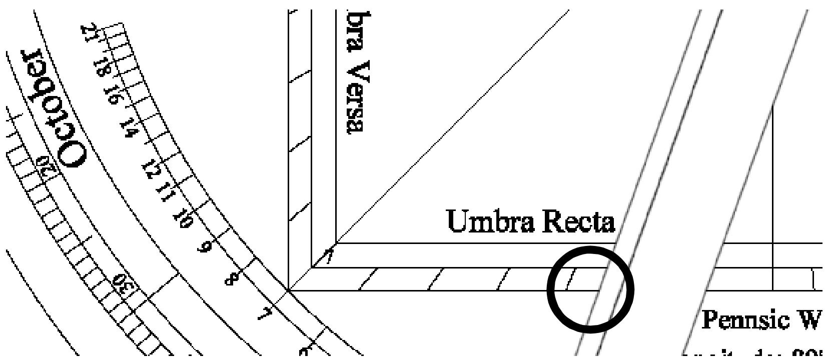
Using the Scales: Shadow Square

Example: In Islam, the midday prayer, Zuhr, is defined as beginning when the shadow of a vertical gnomon (usually 7 feet) is equal to its length at noon plus 1/4 the length of the gnomon. Find the Local Solar time for Zuhr on July 14th.

Step 1: Find length of the shadow at noon on the 14th of July.

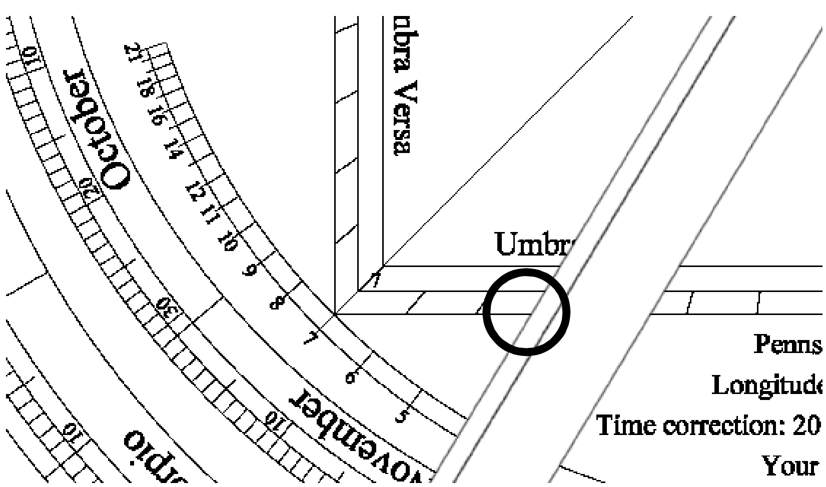
- The sun is at Cancer 22.5 (From the zodiac scale)
- Rotate the rete until Cancer 22.5 is on the noon meridian
- Read 70 degrees from the plate

Step 2: Rotate the alidade to 70 degrees:



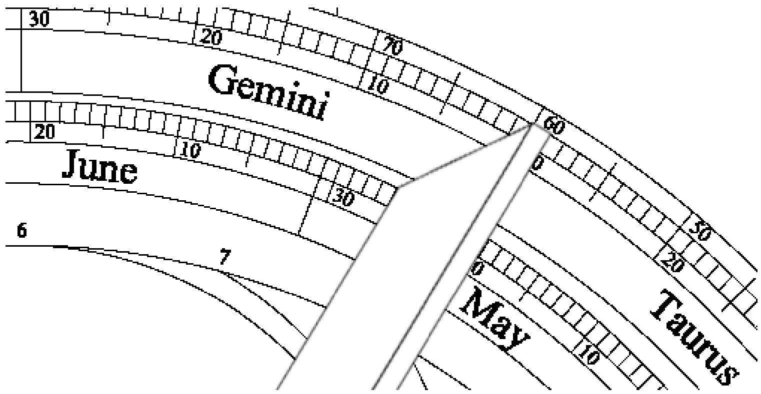
- Note where the alidade crosses the 7 unit scale Umbra Recta (2.5)
The shadow of a 7 foot vertical gnomon would 2.5 feet

- Add 1.75 (7/4) and move the alidade to that position (4.25)



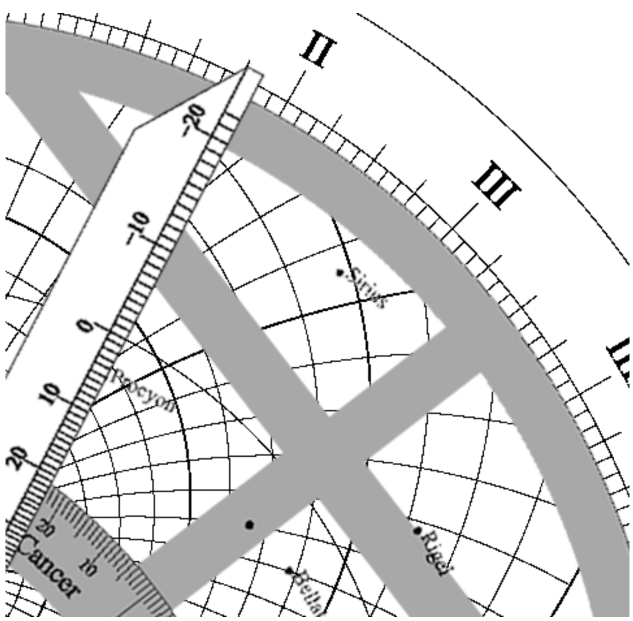
Using the Scales: Shadow Square

Step 3: You can now read the altitude of the sun at the start of Zuhr from the altitude scale (59 degrees)



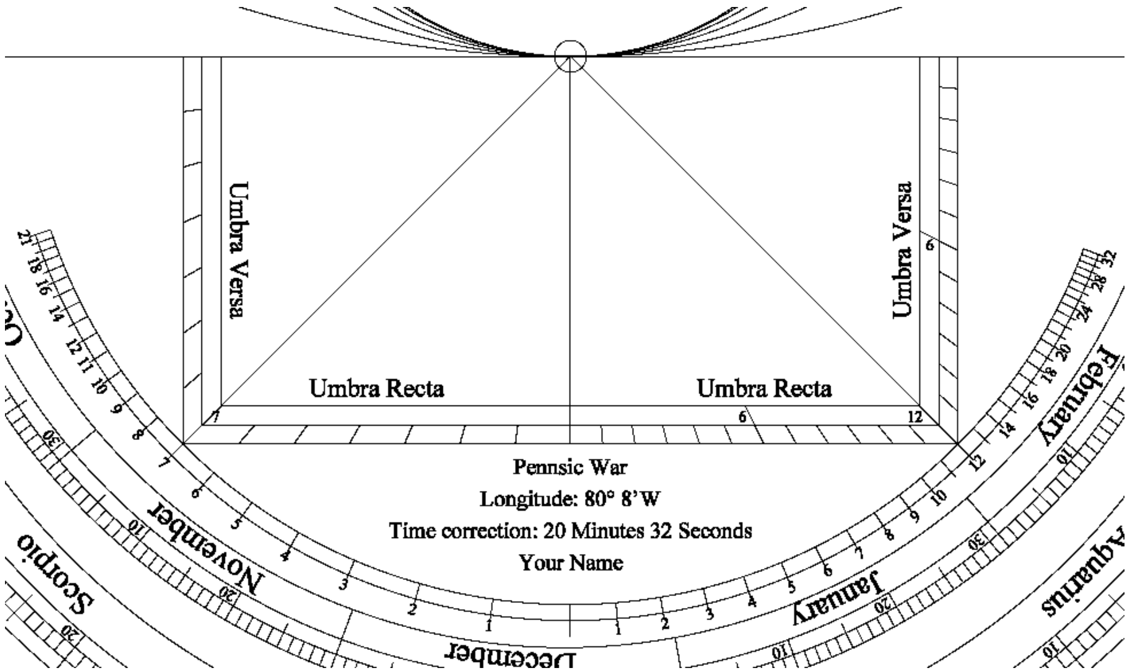
Step 4: Find the Time

- Set Cancer 22.5 to 59 degrees above the west horizon



- Rotate the rule to Cancer 22.5 and read the time: 1:50pm

Using the Scales: The Cotangent Scale



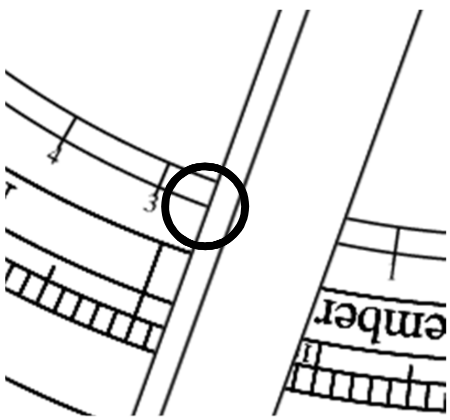
In addition to the shadow square, some astrolabes include additional scales for working with shadow lengths. The **Cotangent Scale** (the curved scale below the shadow square) is one of these.

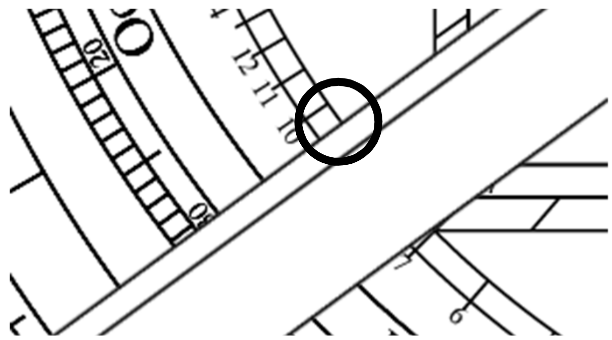
Like the shadow square, it can be computed for a variety of gnomon lengths, unlike the square, it allows angles past 45 degrees to be read directly.

Using the Scales: Cotangent Scale

Example: In Islam, the start of the afternoon prayer, Asr, begins when the shadow of a vertical gnomon is equal to its noontime length plus the length of the gnomon. Find the Local Solar time for the start of Asr on July 14th.

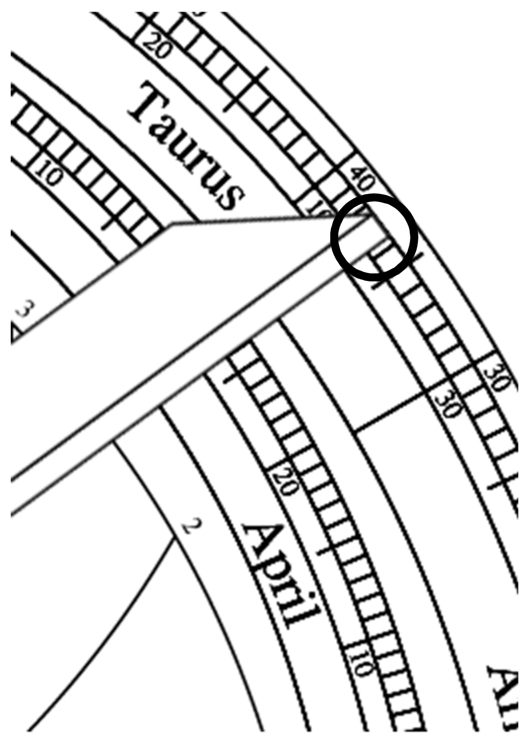
Step 1: From the previous example (see page 40) we know the Sun's noontime altitude is 70 degrees. Set the alidade to that, and note where the opposite arm crosses the cotangent scale (2.5). Add 7 to that (the length of our notional gnomon) to get a shadow length of 9.5.





Step 2: Rotate the alidade to 9.5 on the cotangent scale and read the angle of the sun from the other end of the alidade (36.5 degrees).

Step 3: Find the time that the sun is at an angle of 36.5 degrees in the afternoon sky, using the front of the astrolabe (left to the student).



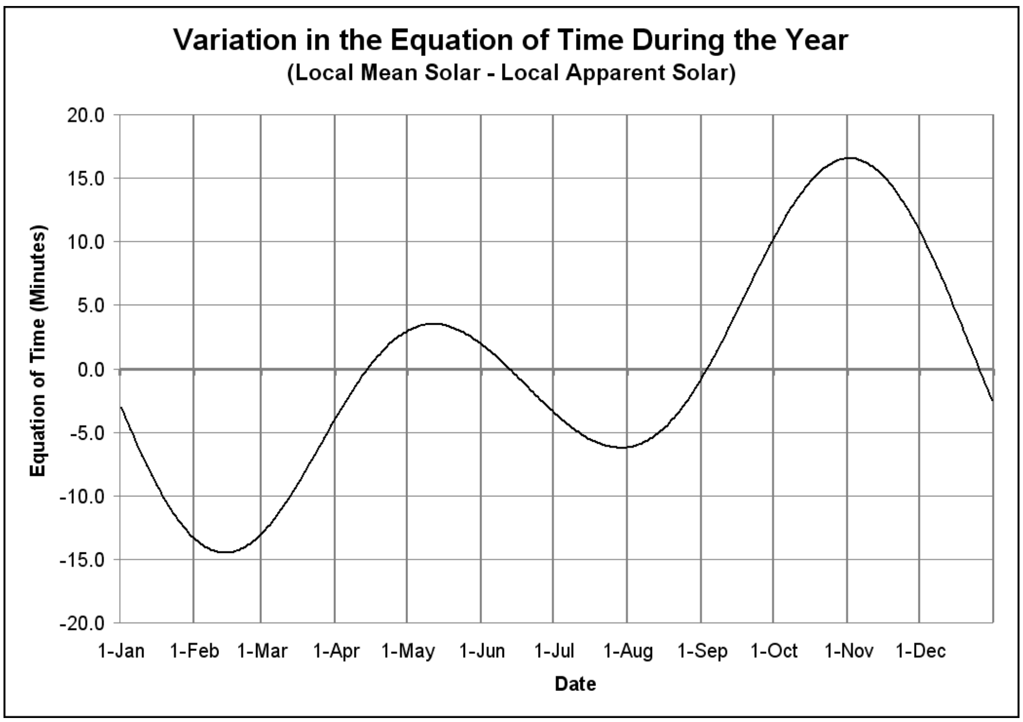
Dealing with the Modern World: Adjusting Local Solar Time to Local Standard Time

When you read/set the time on an astrolabe, you are working in solar time. To convert to local standard time you will need to make the following adjustments:

1. **Daylight Savings Time correction** -- if DST is in effect, you will need to add an hour to the time on the astrolabe.

2. **Time zone correction** -- as standard time uses the same time over the width of a time zone, you will need to add or subtract up to 30 minutes depending on where you are in the time zone. The time zone correction for Pennsic is +20 minutes.

3. **Equation of Time correction** -- depending on the time of year, solar time varies from clock time due to the eccentricity of Earth's orbit. The graph below gives the correction. To convert from solar time to clock time, subtract the number. To convert from clock time to solar time add the number.



Example: Find sunset time for 13 August in EST:

- on 13 August, the sun sets at 8:17 pm EST
- according to the astrolabe the sun sets at 6:52 pm solar time
- add 1 hour for DST – giving 7:52 pm
- add 20 minutes time zone correction for Pennsic – giving 8:12 pm
- subtract -5 minutes EoT correction from graph above – giving 8:17 pm.

Astrolabe Problems

Note: Due to variations in the instruments, and differences in technique, your answers will vary a bit. If you are within 15 minutes you are doing well, within 5 minutes, excellent.

-Times are in local solar time unless otherwise specified

Medium Problems:

1. It is 3:00 in the afternoon by the sun, on September 4th. What is the unequal hour?

2. It is the start of the fifth hour of the day on May 12th. What is the equal hour time by the sun?

3. It is the afternoon of the 10th of August. You measure the sun at an angle of 52 degrees. What time is it? (Local Solar time and Eastern Standard Time)

Advanced Problems:

1. What time does Jupiter rise on 24 August?

2. When is the full moon in August? The new moon?

3. Determine the local solar times for the Christian prayers for the 4th of August. (Lauds, Prime, Terce, Sext, None, Vespers)

4. Do the same for the Islamic prayer times. (Fajr, Zuhr, Asr, Maghrib, Isha)

5. You are planning tactics for the field battle. It is scheduled for 10 AM EST on the 13th of August. You have been asked to calculate the direction and angle of the sun so that glare can be taken into account. Remember that you need to convert from EST to local solar time. Find the local solar time and the direction and altitude of the sun.

Answers

Medium Problems:

1. On the 4th of September the sun is at Virgo 11.5. The noon altitude of the sun is 56 degrees. Therefore the time is 3/4 of the way through the 9th hour of the day

2. On the 12th of May the sun is at Taurus 21.5. The noon altitude of the sun is 66 degrees. Therefore the start of the fifth hour of the day is 9:45 am.

3. The sun is in Leo 18, Solar time is 2:14 PM, EST is 3:39 PM

Advanced Problems:

1. On 24 August Jupiter is in 12.5 Cancer at a declination of +22.5. The Sun is in 1 Virgo. Place Jupiter on the Eastern (left) horizon and read the time as 1:17AM.

2. I'm being tricky. The Moon is full when it is directly opposite the sun in the sky (opposite side of the ecliptic); and is new when it is at its closest to the sun in the sky (same side of the ecliptic) The moon will be full on 7 August and new on 21 August.

3.

Lauds	- 3:00 AM
Prime	- 4:55 AM
Terce	- 8:31 AM
Sext	- 12:00 AM (Noon)
None	- 3:23 PM
Vespers	- 7:01 PM

4.

Fajr	-3:00 AM – 4:55 AM
Zuhr	-1:52 PM – 3:55 PM
Asr	-3:55 PM – 5:02 PM
Maghrib	-7:01 PM – 8:54 PM
Isha	- 8:54 PM - Dawn

5. On the 13th of August 10 AM EST converts to 8:35 AM solar time. On the morning of 13 August the Sun will be in 20.5 Leo. Setting that to 8:35 AM the Sun will be 38 degrees above the horizon at 16 degrees South of East.

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Zachary, Michael, The Astrolabe Part 2: Constructing the Astrolabe, The Compleat Anachronist number 148, 2010

Astrolabe Resources

Websites:

http://astrolabeproject.com – My website - home of the Astrolabe Generator
http://www.astro.com/swisseph/swepha_e.htm - ephemeris source. PDF files
http://www.autodidacts.f2s.com/astro/index.html - Keith's Astrolabe
http://www.ted.com/talks/tom_wujec_demos_the_13th_century_astrolabe.html
http://www.mhs.ox.ac.uk/astrolabe/ - an online collection of astrolabes

Software:

The Astrolabe Generator – free and open-source. Generates custom PostScript (EPS) files allowing you to print out and build your own astrolabes - http://astrolabeproject.com

Stellarium – A free and open-source planetarium program. Good for working astrolabe problems and checking results. http://www.stellarium.org/

Shadows Pro – Sundial software that incorporates an astrolabe simulator – 50 Euros – I have not used this personally – http://pagesperso-orange.fr/blateyron/sundials/shadowspro/gb/index.html

Illustrating Shadows – Spreadsheets for calculating sundials and astrolabe plates http://www.illustratingshadows.com/

Printing EPS files: **PrintFile** – Windows - http://www.lerup.com/printfile/

Viewing EPS files: **GhostScript** and **GSView** - http://pages.cs.wisc.edu/~ghost/