Introduction to the Astrolabe

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Learn the history, the scientific principles and how to operate this ancient astronomical computer.

Of all astronomical instruments, The Astrolabe was the most widely used throughout the middle ages. It was developed in ancient Greece for measuring the altitude of a heavenly body, but gained popularity all over the world until the sextant replaced it in the 18th century. It provided a means to mark the time of day and the seasons of the year as well as finding the angle of the sun, moon, stars and planets with respect to the horizon or the zenith. It was used for calculating the heights of buildings and mountains and for surveying the land. The Astrolabe was also used as a way of reading one's horoscope and a way for navigators to locate their longitudinal and latitudinal coordinates. Basically, it was a pocket watch, compass, fortune-teller, crude sextant, and theodolite all in a convenient little palm-sized case! [1]

Astrolabe History [2]

The origins of the astrolabe were in classical Greece. Apollonius (ca. 225 BC), the great codifier of conic sections, probably studied the astrolabe projection. The most influential individual on the theory of the astrolabe projection was Hipparchus who was born in Nicaea in Asia Minor (now Iznik in Turkey) about 180 BC but studied and worked on the island of Rhodes. Hipparchus, who also discovered the precession of the equinoxes and was influential in the development of trigonometry, redefined and formalized the projection as a method for solving complex astronomical problems without spherical trigonometry and probably proved its main characteristics. Hipparchus did not invent the astrolabe but he did refine the projection theory.

The first major writer on the projection was the famous Claudius Ptolemy (ca. AD 150) who wrote extensively on it in his work known as the Planisphaerium. There are tantalizing hints in Ptolemy's writing that he may have had an instrument that could justifiably be called an astrolabe. Ptolemy also refined the fundamental geometry of the Earth-Sun system that is used to design astrolabes.

Early Astrolabes

No one knows exactly when the stereographic projection was actually turned into the instrument we know today as the astrolabe. Theon of Alexandria (ca. 390) wrote a treatise on the astrolabe that was the basis for much that was written on the subject in the Middle Ages. Synesius of Cyrene (378-430) apparently had an instrument constructed that was arguably a form of astrolabe. This is plausible since Synesius was a student of Hypatia, Theon's daughter. The earliest descriptions of actual instruments were written by John Philoponos of Alexandria (a.k.a. Joannes Grammaticus) in the sixth century and a century later by Severus Sebokht, Bishop of Kenneserin, Syria, although it is likely that Sebokht's work was derivative of Theon. It is certain that true astrolabes existed by the seventh century.

The Astrolabe in Islam

The astrolabe was introduced to the Islamic world in the eighth and ninth centuries through translations of Greek texts. The astrolabe was fully developed during the early centuries of Islam. Arab treatises on the astrolabe were published in the ninth century and indicate a long familiarity with the instrument (the oldest existing instruments are Arabic from the tenth century, and there are nearly 40 instruments from the 11th and 12th centuries). The astrolabe was inherently valuable in Islam because of its ability to determine the time of day and, therefore, prayer times and as an aid in finding the direction to Mecca. It must also be noted that astrology was a deeply imbedded element of early Islamic culture and that astrology was one of the principle uses of the astrolabe. (See image on page 14).

The Astrolabe in Europe

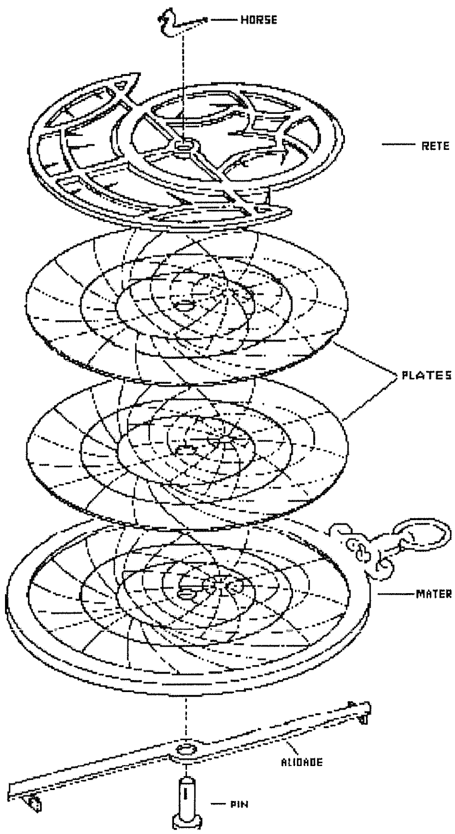
The astrolabe moved with Islam through North Africa into Spain (Andalusia) where it was introduced to European culture through Christian monasteries in northern Spain. It is likely that information about the astrolabe was available in Europe as early as the 11th century, but European usage was not widespread until the 13th and 14th centuries. The earliest astrolabes used in Europe were imported from Moslem Spain with Latin words engraved alongside the original Arabic. It is likely that European use of Arabic star names was influenced by these imported astrolabes. By the end of the 12th century there were at least a half dozen competent astrolabe treatises in Latin, and there were hundreds available only a century later. European makers extended the plate engravings to include astrological information and adapted the various timekeeping variations used in that era. Features related to Islamic ritual prayers were generally discarded in European instruments.

The astrolabe was widely used in Europe in the late Middle Ages and Renaissance, peaking in popularity in the 15th and 16th centuries, and was one of the basic astronomical education tools. A knowledge of astronomy was considered to be fundamental in education and skill in the use of the astrolabe was a sign of proper breeding and education. Their primary use was, however, astrological. Geoffrey Chaucer thought it was important for his son to understand how to use an astrolabe, and his 1391 treatise on the astrolabe demonstrates a high level of astronomical knowledge (See below).

Astrolabe manufacturing was centered in Augsburg and Nuremberg in Germany in the fifteenth century with some production in France. In the sixteenth century, the best instruments came from Louvain in Belgium.

Parts of the Astrolabe

The most common form of the astrolabe was the planispheric astrolabe, which was also the easiest to use. This marvelous invention, often made of brass, was approximately 5 to 10 inches in diameter and included a horse, a rete, climates or plates, the mater, the alidade, vane and pin.[1]



Horse – Inserted into the pin to holds it all together.

Rete / Web - Pointers represent fixed stars. The circle shows the ecliptic

Rule / Vane (not shown) – Another indicator on top of the rete on some astrolabes

Plates / Climates - Engraved with circles of altitude and azimuth for a certain latitude

Mater – Main body

Alidade / Double rule - For measuring the altitude of celestial objects.

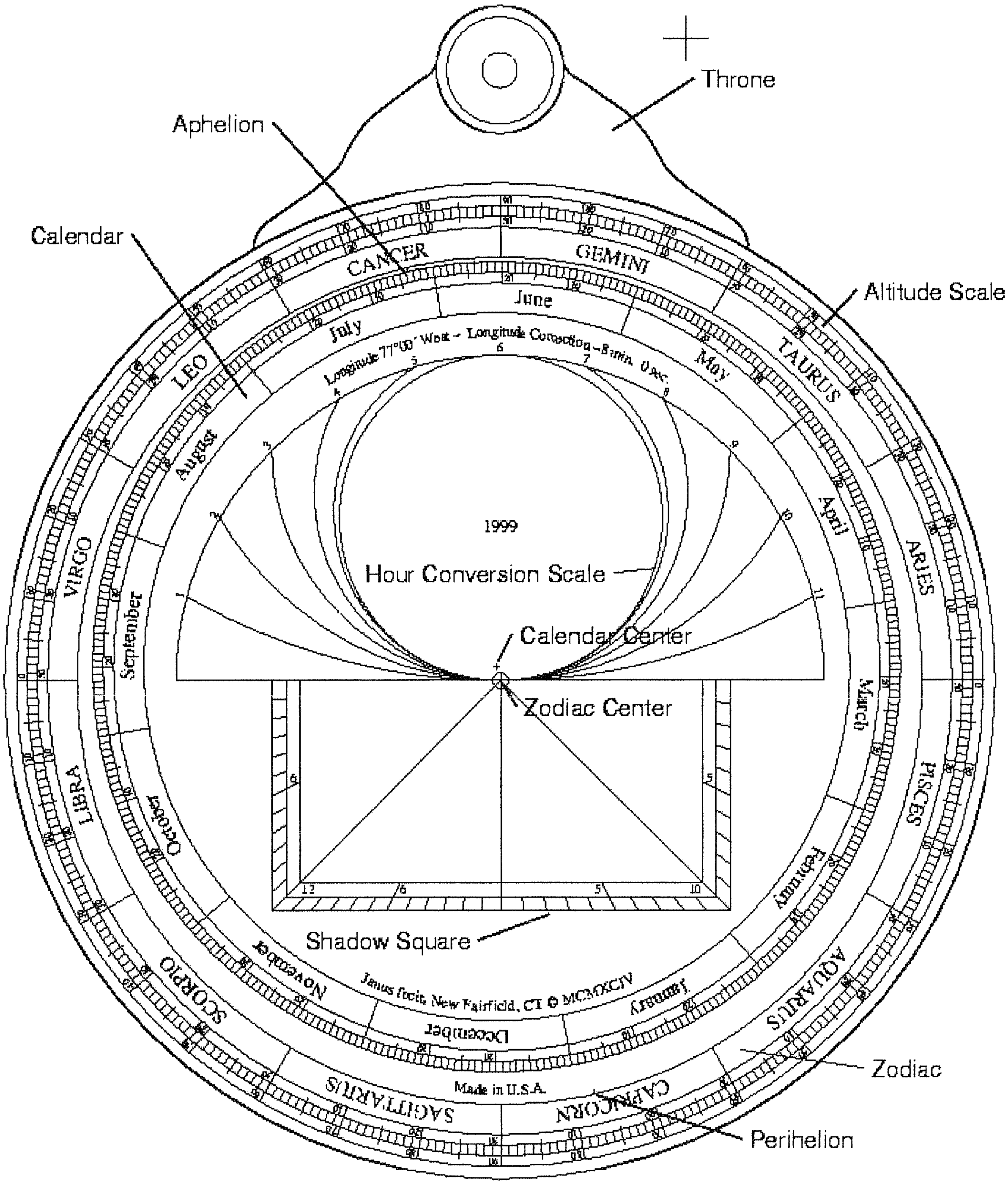
Pin – The pivot point

Astrolabe Back

The back of the instrument was engraved with a wide variety of scales depending on where and when the astrolabe was made. All astrolabes included scales for measuring angles and scales for determining the Sun's longitude for any date. Additional scales were included at the maker's option. Almost all European astrolabes, and many Islamic ones, had a scale for solving simple trigonometry problems called the *shadow square*. A cotangent scale was added to many Islamic astrolabes for determining prayer times. European instruments often had a scale for converting between unequal (planetary) hours and equal hours.

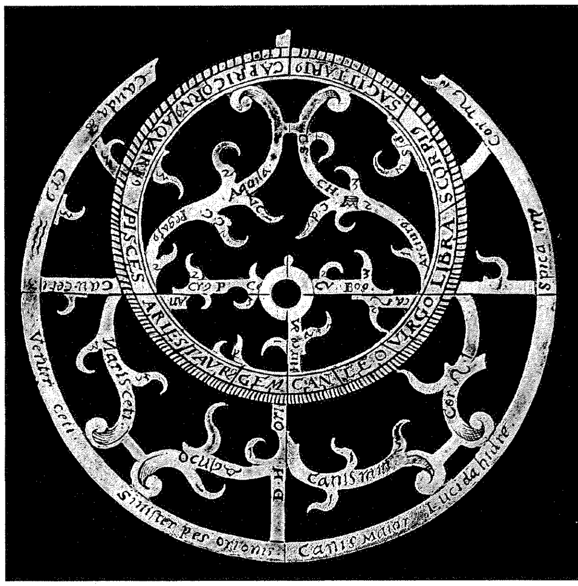
The back of every astrolabe included an *alidade* for measuring the altitude of celestial objects.

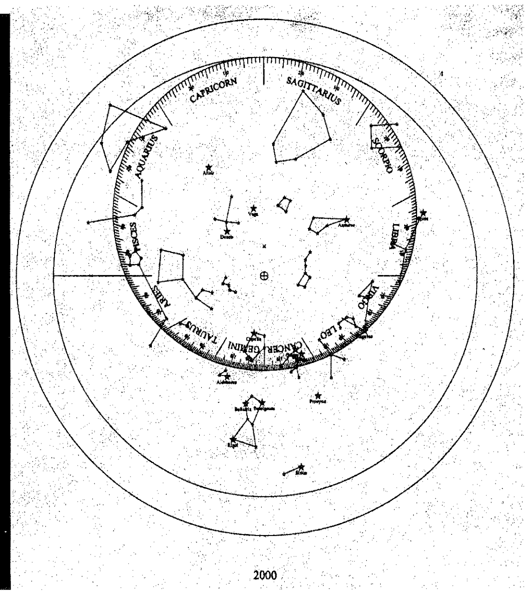
Astrolabe Back



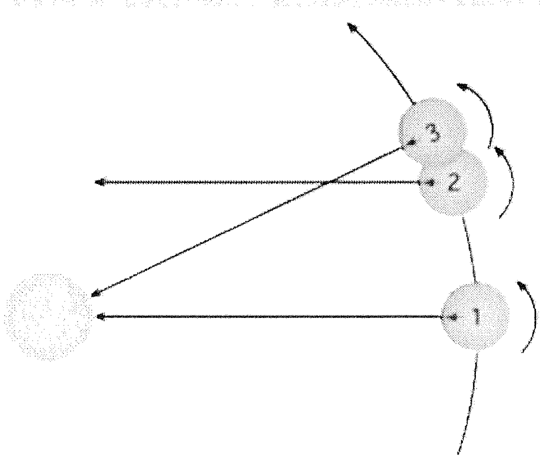
The Rete

Over the plates on the front of the astrolabe is fitted a disk mostly cut away so you could see the plate under it. Pointers represented a number of fixed stars. A circle showing the projection of the Sun's annual path in the sky (the ecliptic) was included on the rete. The ecliptic circle is divided into 30 degree sections representing the signs of the zodiac. The rete is assumed to rotate in one sidereal day to simulate the daily rotation of the stars in the sky.

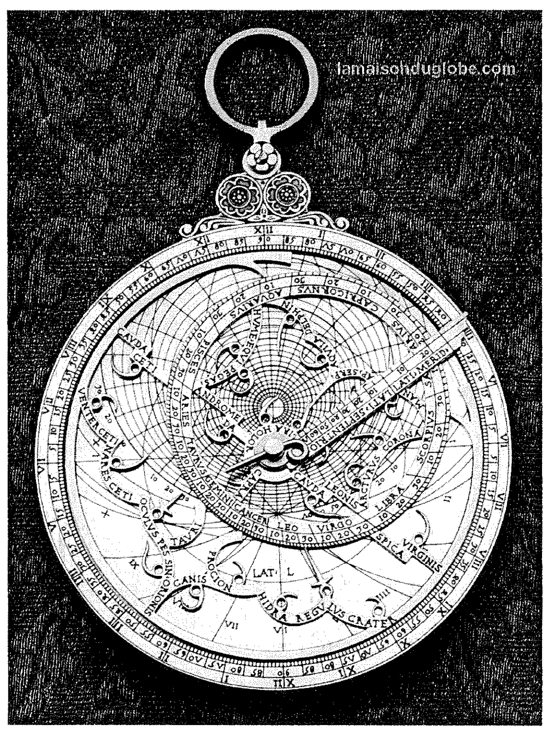




The sidereal day is shorter than the solar day. At time 1, the Sun and a certain distant star are both overhead. At time 2, the planet has rotated 360° and the distant star is overhead again but the Sun is not (1⟶2 = one sidereal day). It is not until a little later, at time 3, that the Sun is overhead again (1⟶3 = one solar day).

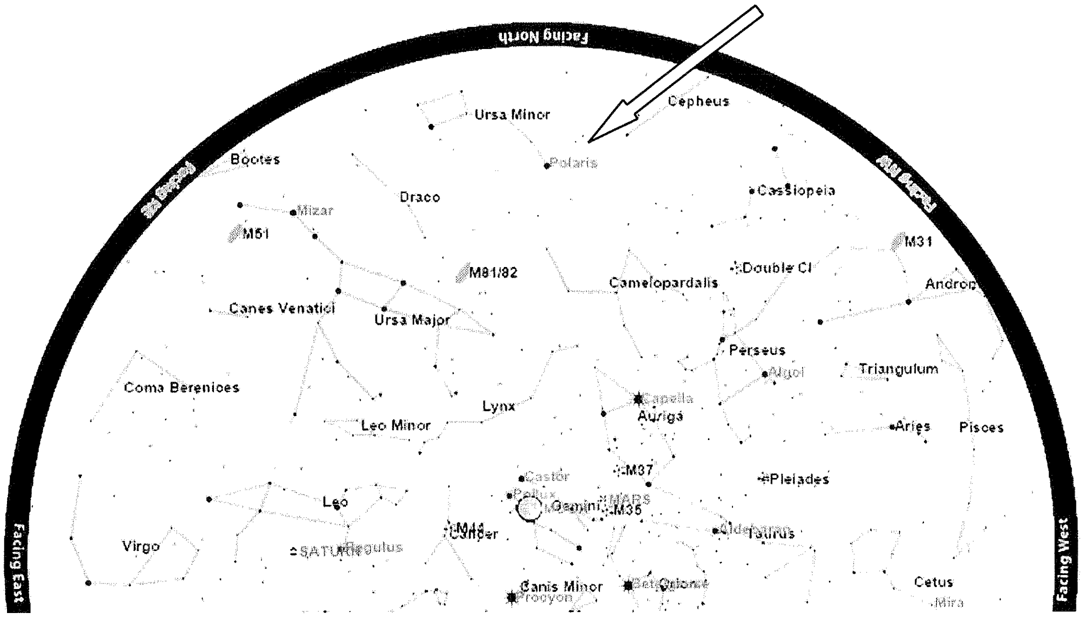


On top of the rete is a clock-type hand called the *rule*. Not all astrolabes had a rule depending on the intended use of the instrument (see page 12 for color images)

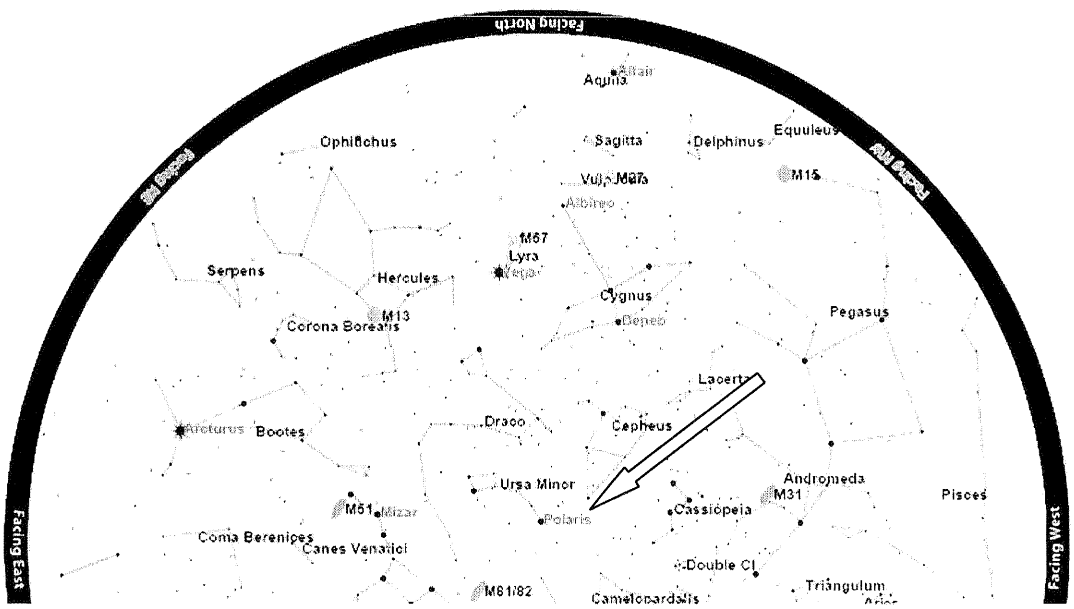


The position of the stars are never changing it is the viewers position on the earth that varies.

15° 00' N, 0° 00' W Dec. 25, 2007, 01:00 am

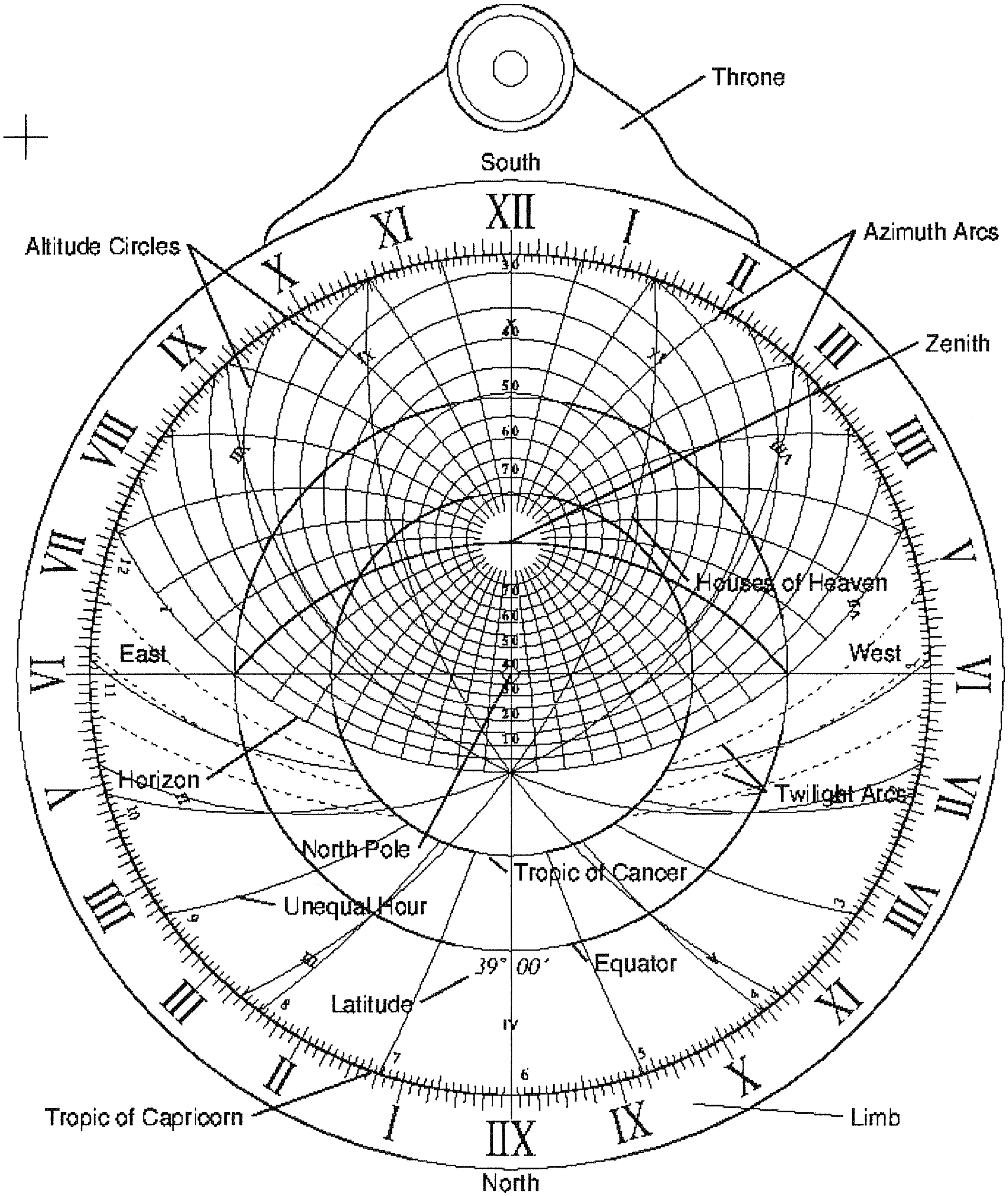


85° 00' N, 0° 00' W Dec. 25, 2007, 01:00 am



So it falls to the last component, the plates, to account for the viewer's perspective.

The Plates



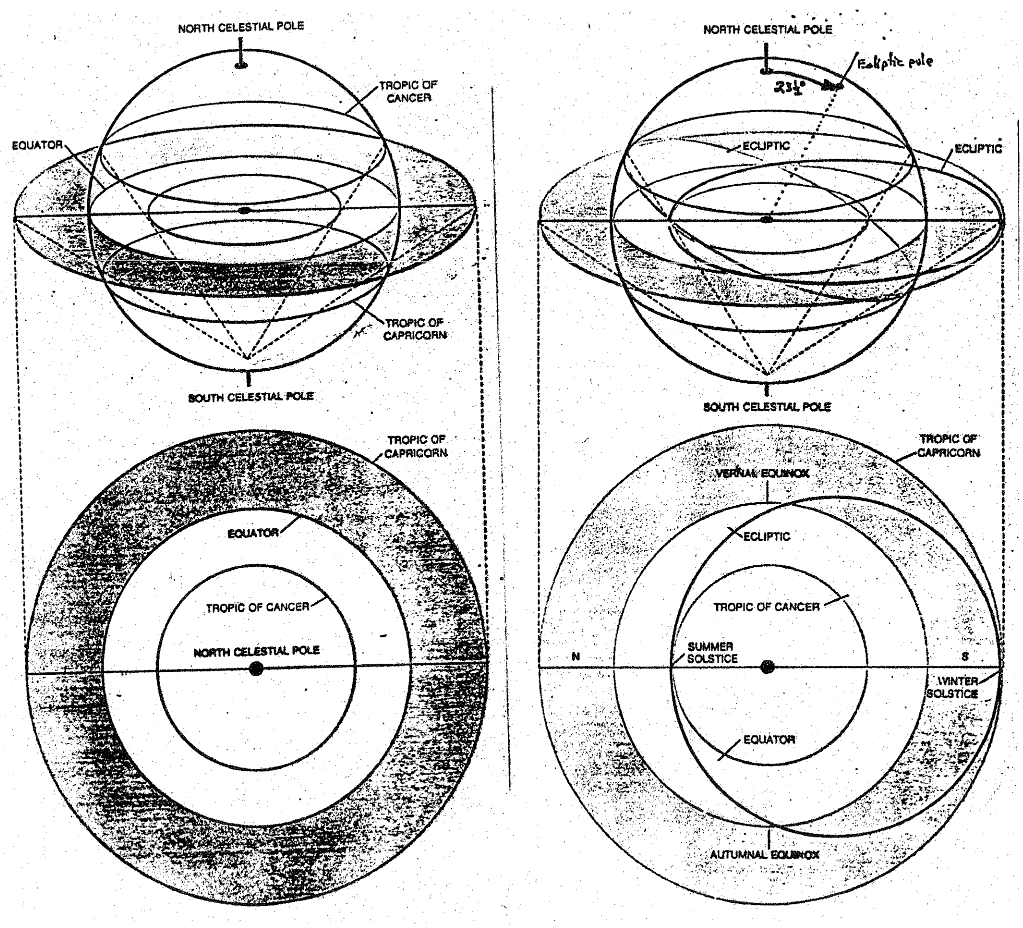
Throne
South
Altitude Circles
Azimuth Arcs
Zenith
Houses of Heaven
East
West
Horizon
Twilight Arcs
North Pole
Tropic of Cancer
Unequal Hour
39° 00'
Equator
Latitude
Tropic of Capricorn
Limb
North

There are many different ways of rendering three-dimensional objects into two dimensions. Different kinds of projections are able to represent realistically things like size, areas, distances, and perspective. One particular kind of projection used for representing spheres and circles on spheres in two dimensions (i.e. on the climates of an astrolabe, or on some maps of the earth or celestial sphere) is stereographic projection. Stereographic projection has two important characteristics that differentiate it from other kinds of projections:

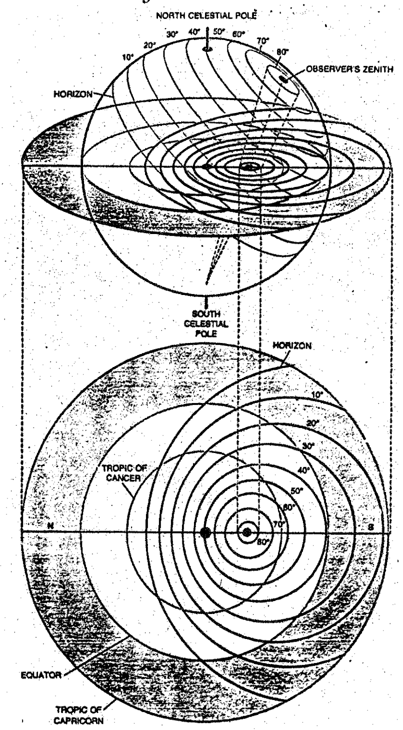
Stereographic Projection preserves circles
Stereographic Projection preserves angles

This means that circles on a sphere (i.e. latitudes on the Earth) are represented as circles on a plane and the angles between lines are retained when the lines are projected. This is how the climates of the astrolabe are created. The lines of latitude, azimuth, and hour angles are represented stereographically onto a plane (usually taken is the equatorial plane) and the climates are merely a scaled-down representation of this.

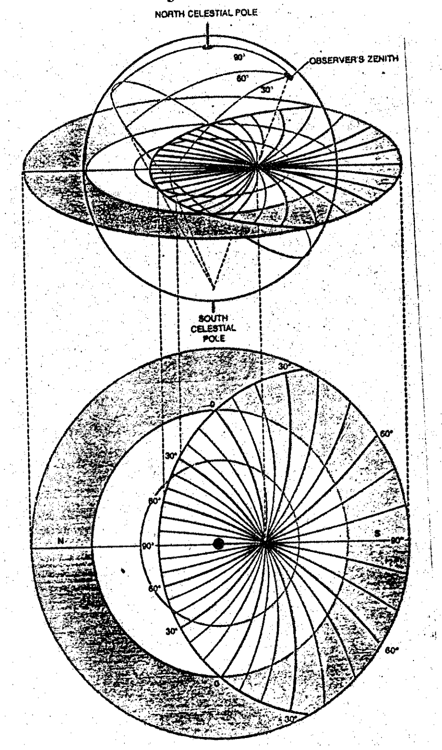
(For the math of it all, see reference 1)



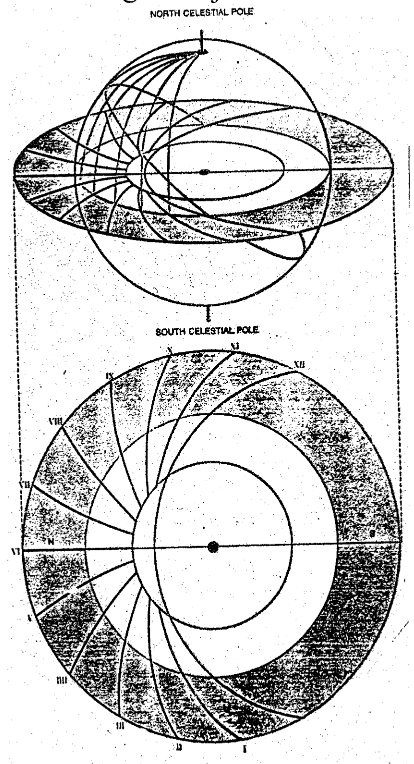
Altitude Projections

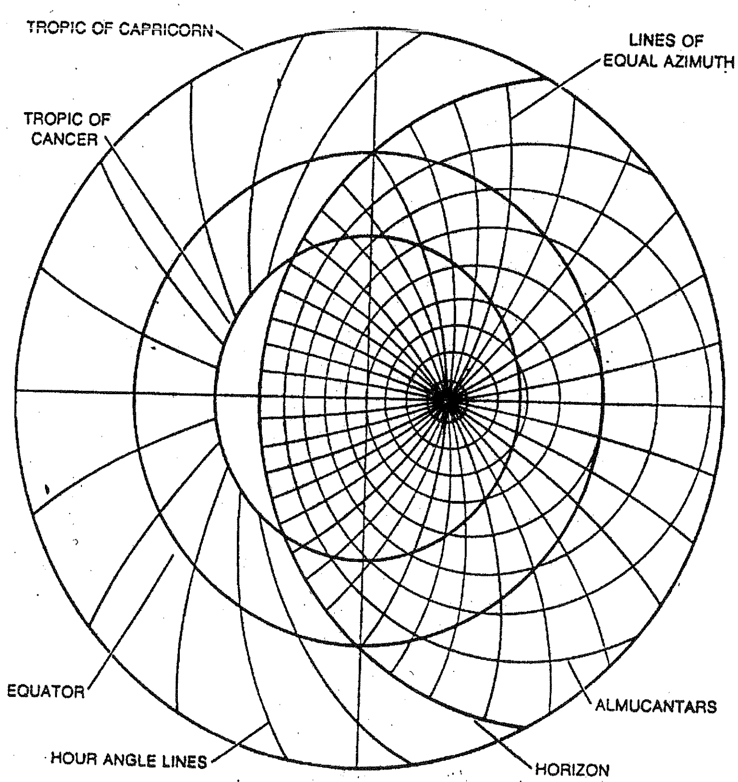


Azimuth Projections

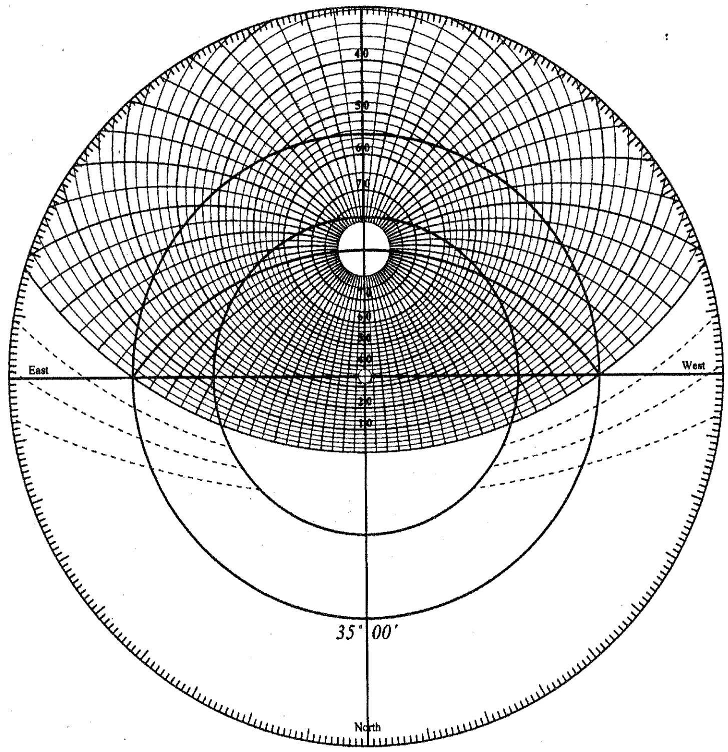


Hour Angle Projections

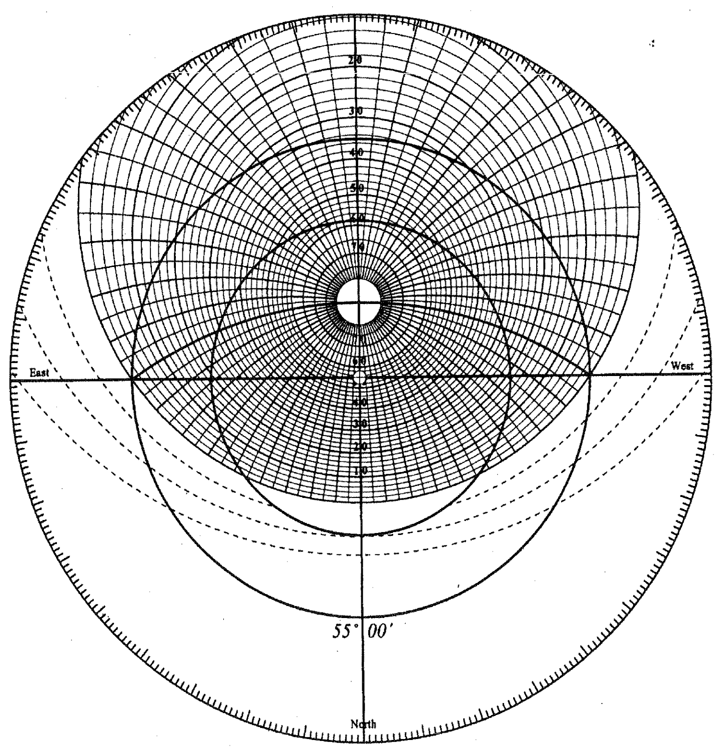




Complete Climate



Climate for 35 degrees



Climate for 55 degrees

So how do we actually use an astrolabe? [2]

Finding the time of day

The time of day is found in the following steps:

1. The altitude of the Sun or a bright star is determined using the back of the instrument. The astrolabe is held above eye level from the suspension. The astrolabe is oriented so the Sun or star is lined up with the back of the astrolabe. The alidade is rotated until the Sun's shadow or the star itself is visible through the sights on the alidade. The altitude is noted from the altitude scale on the back of the instrument.
2. The Sun's position on the ecliptic is found by setting the alidade on the date and reading the Sun's longitude on the zodiac scale.
3. On the front of the astrolabe, the rule is rotated until is crosses the ecliptic at the Sun's current longitude. The point where the rule crosses the ecliptic is the Sun's current position.
4. The rete and rule are rotated together until the Sun or star pointer is at the measured altitude.
5. The rule points to the apparent solar time on the limb. Apparent solar time is the time as shown on a sundial and is different for each longitude. In modern use, apparent solar time must be corrected to zone time by compensating for the equation of time and the difference in longitude from the center of the time zone.

Finding the time of a celestial event.

The time of a celestial event such as sunrise, sunset or the culmination of a star is found by setting the astrolabe to the circumstances of the event and reading the time:

1. Determine the Sun's position on the ecliptic (longitude).
2. Set the rule to that position on the ecliptic on the front of the astrolabe.
3. Rotate the rete and rule together until the desired event is in position. For example, to find the time of sunrise, rotate the rete and rule until their intersection is right on the eastern horizon.
4. Read the time from the rule's position on the limb.

The length of the day can be found by finding the time of sunrise and sunset and calculating the difference. Similarly, the time until sunrise and sunset can be found as the difference with the current time.

Other uses.
The rule on many astrolabes was divided by declination. The declination of a celestial object could be found by placing the rule over the object and reading the declination directly. This function is particularly useful for the Sun.

Right ascensions are found by rotating the rete until the celestial object is on the meridian and reading the sidereal time from the position of the First Point of Aries on the rete.

Surveying (Using the Shadow Square)

The rectangle below the center is called the "Shadow Square" and was almost universal on all astrolabes from all sources. It is called the Shadow Square because it is used to solve simple problems in trigonometry that are most easily described by the shadows cast by a vertical or horizontal stick. The scale is simply a graphical way to find the tangent or cotangent of an angle and solve simple problems involving triangles.

The sides of the scale are divided into equal parts of whatever units of length were in common use where the astrolabe was used. The vertical scale is used to solve problems involving the shadow cast by a vertical gnomon. For example, if you want to find the height of a tree, pace off a know distance and use the alidade to find the angle to the top of the tree. The alidade will cross the vertical scale on the Shadow Square at the proportion that the height of the tree is to the distance of the tree. For example, if you pace off 100 feet and read the top of the tree at 26o, the alidade crosses the scale at 5 so you know that the tree is 5/10 (one half) as high as you are away from it; the tree is 50 ft tall.

Old astrolabe treatises contained detailed instructions on how to use the shadow scale to solve many problems such as finding the depth of a well or to estimate distances. A variety of problems can be solved by using the astrolabe as a theodolite; i.e. holding the astrolabe flat and reading angles between objects.

Chaucer [3]

In 1391, Chaucer wrote a work entitled "A treatise on the Astrolabe". The introduction of the work would imply that it was written for his son, however it may have been written instead for the son of a friend, Lewis Clifford. Whoever it was written for, the boy most likely died in 1391, which is why Chaucer's work was never finished. "A treatise on the Astrolabe", according to the F.N. Robinson edition, is the oldest known "technical manual" in the English Language and it was compiled from different foreign sources.

Lyte Lowys my sone, I aperceyve wel by certeyne evydences thyn abilite to lerne sciences touching nombres and proporciouns; and as wel considre I thy besy praier in special to lerne the tretys of the Astrelabie. Than for as mochel as a philosofre saith, "he wrappith him in his frend, that condescendith to the rightfulle praiers of his frend," therfore have I latitude of Oxenforde; upon which, by mediacioun of this litel tretys, I purpose to teche the a certein nombre of conclusions aperteynyng to the same instrument. I seie a certein of conclusions, for thre causes. The first cause is this: truste wel that alle the conclusions that han be founde, or ellys possibly might be founde in so noble an instrument as is an Astrelabie ben unknowe parfitly to eny mortal man in this regioun, as I suppose. An-other cause is this, that sothly in any tretis of the Astrelabie that I have seyn there be somme conclusions that wol not in alle thinges parformen her bihestes; and somme of hem ben to harde to thy tendir age of ten yeer to conceyve.

References

[1] Stereographic Projection, Chaucer and the Astrolabe
http://www.math.ubc.ca/~cass/courses/m309-01a/montero/math309project.html

[2] *Janus* - The Astrolabe
http://www.astrolabes.org

[3] A Treatise on the Astrolabe (1391-1392) by Geoffrey Chaucer
http://www.astrolabe.vidmo.net/index.html

Starry Messenger
http://www.hps.cam.ac.uk/starry/starrymessenger.html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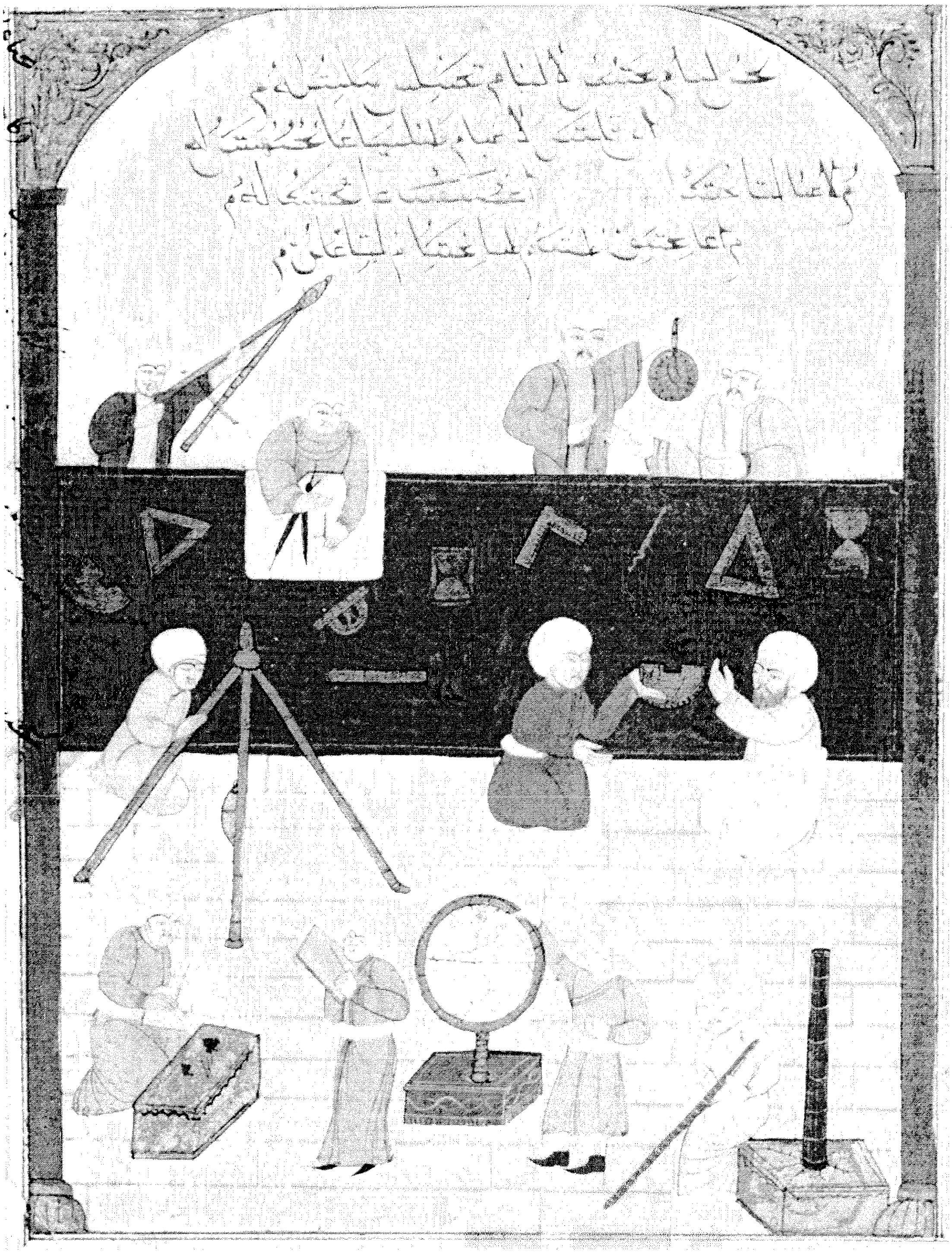
GEORGIVS HARTMAN
NOREMBERGE FACIEBAT
ANNO MDXXXI
VMBRA RECTA VMBRA RECTA



The Istanbul Observatory
The painting shows workers at the observatory of Taqi al-Din at Istanbul in 1577 (AH 985). Two observers are working with an astrolabe. A universal astrolabe of the saphea form is on the table in front of the man with the dividers and paper.
The painting is from Shahinshah-nama (History of the King of Kings), an epic poem by 'Ala ad-Din Mansur-Shirazi, written in honor of Sultan Murad III (reigned 1574-95 [AH 982-1003]). [2]