THE ELECTRIC ASTROLABE

Janus

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INTRODUCTION TO THE ELECTRIC ASTROLABE

> ***"I know that I am mortal and the creature of a day; but when I search out the massed wheeling circles of the stars, my feet no longer touch the Earth but, side by side with Zeus himself, I take my fill of ambrosia.". Claudius Ptolemy***

Even though the astrolabe is among the world's most ancient scientific instruments, it has never been equaled for providing a clear, concise picture of the heavens. A glance at a properly set astrolabe gives a complete snapshot of the sky at a particular time and place. The astrolabe is also an inherently beautiful device. Its graceful arcs and finely engraved components are both elegant and mysterious. It is a device of wonder to those who do not understand its simple elegance and a source of admiration to those who do. The unique properties of the astrolabe continue to excite interest after more than two millennia.

The astrolabe was the most widely used astronomical instrument for over 1000 years without significant change in its basic form. Despite embellishments to improve its utility in different cultures and epochs, a 10th century astrolabe would be instantly recognized as an astrolabe by a modern user. This spectacular success is due to the uniquely concise, complete and useful view of the heavens that the astrolabe provides. This advantage of the astrolabe is retained when the ancient science of the astrolabe is combined with modern computer graphics and new possibilities emerge that were not possible on classical instruments. The combination of the old and new technologies is synergistic, enhancing both.

The ***Electric Astrolabe*** is a fully functional computer representation of a classical astrolabe. A planetarium program in this form demonstrates the durability of astrolabe principles defined 2000 years ago. Astrolabe technology transfers to computer graphics in a natural and useful way and provides opportunities for enhancements that medieval astrolabists would never have imagined. In addition, recreating an ancient art on modern equipment provides a window to the past and deep appreciation for the intelligence and skill of the original developers.

Perhaps the greatest advantage of the astrolabe display over other planetarium programs is that it shows much of the sky, both visible and invisible, for a given time and place on a single screen. In addition, the ability of the Electric Astrolabe to animate the sky provides a dynamic view of the heavens that dramatically illustrates astronomical ideas. This format provides an extremely compact and efficient method for showing the positions of heavenly bodies. The following information can be determined at a glance from the Electric Astrolabe graphics display once it is set to a location, date and time:

The time of day
The positions of the Sun, moon and planets in the sky
Visibility of the bright stars and significant constellations
The location of all of the Messier objects
The phase of the moon
Sidereal time
The longitude of the Sun, moon and planets
The declination of the Sun
The position of the moon's nodes
Planetary elongations
An estimate of the equation of time

By pressing a few keys you can easily determine:

Time of Sunrise and Sunset
Time of meridian passage for any celestial object
Apparent solar time
Right ascension and declination of a displayed object
Geocentric latitude and longitude of a displayed object
Synodic periods of the planets
Eclipse conditions
Observability of any Messier object
Time and date of conjunctions, oppositions, quadrature and maximum elongation of the planets
The date of Easter

You can also observe:

The effect of latitude on the seasons
Planets as they move from posigrade to retrograde motion and back
Sky conditions at the time of significant historical events (e.g. The position and phase of the Moon the night Columbus first made landfall in the New World.)

The Electric Astrolabe also includes some interesting functions that have nothing to do with astrolabes. For example, you can:

Display an animated orrery of the planets in orbit around the Sun
Display the phase of the Moon, inner planets and Mars
Display and animate the Galilean satellites of Jupiter
Display the rings of Saturn
Shade the sky for daylight, twilight and night time
Watch lunar eclipses

These displays are mainly for education and amusement. The orrery can be used to demonstrate planetary phenomena such as synodic periods, elongation, conjunctions and oppositions.

The Electric Astrolabe also incorporates several text displays giving numerical values of planetary and lunar positions. The text displays, which are implemented as a type of astronomical spreadsheet, are useful for determining the exact time of some event such as the vernal equinox or eclipses.

There are many computer planetarium programs available. Most of them focus on deep sky objects such as stars, nebulae and galaxies. The Electric Astrolabe concentrates on planetary motion and can be used to illustrate the basics of orbital mechanics. An unrelated purpose of the Electric Astrolabe is to sample a bit of the history of astronomy.

Using the Electric Astrolabe should be enjoyable and educational. Watching the dynamics of the heavens is an experience that can illuminate and reinforce many astronomical concepts. It can be used to plan observations or just stay in touch with celestial events. Or it can be used as an extremely elegant astronomical clock.

Note that The Electric Astrolabe deals with astronomical ideas and measurements that range from very basic definitions to extremely sophisticated ideas. A glossary has been included to provide a quick definition of most of the astronomical terms used in this guide. Some of the more advanced topics are covered in the text in the appropriate section. You may need to refer to a good astronomy textbook for complete understanding of some ideas.

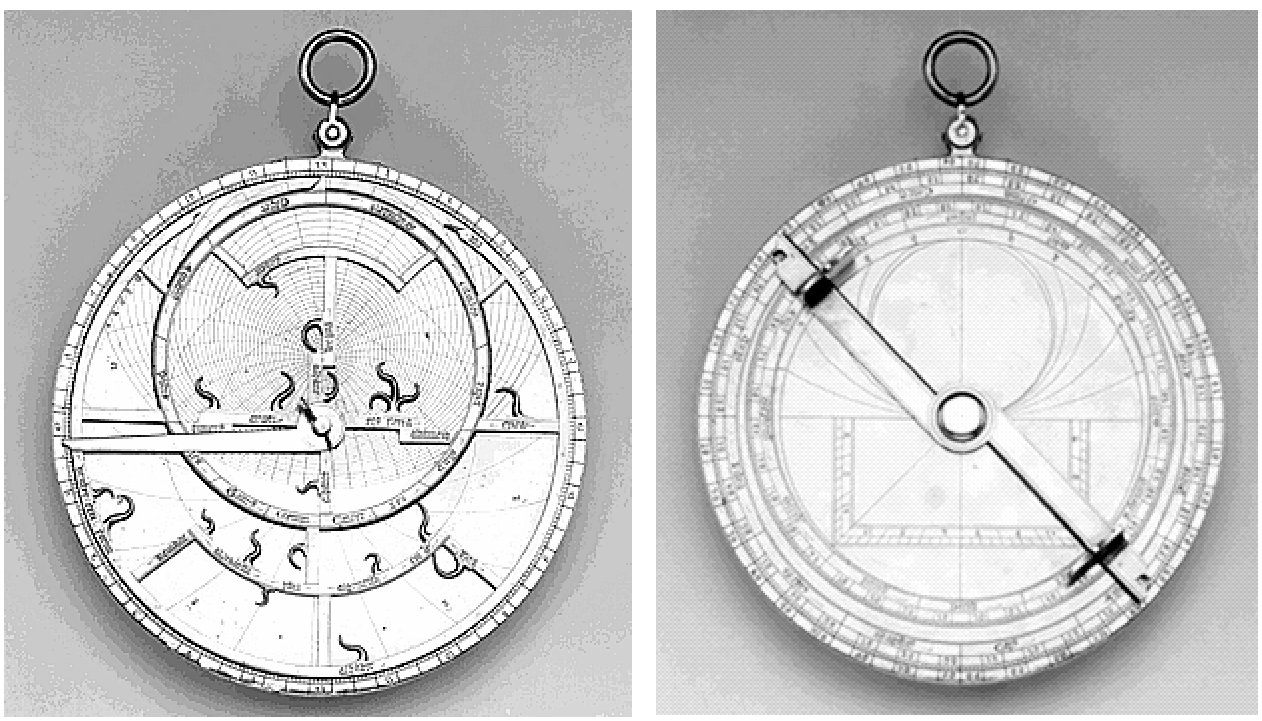
WHAT IS AN ASTROLABE?

It seems appropriate to become familiar with classical astrolabes and their rich history before learning how to operate the Electric Astrolabe program. This section can be skipped without loss of continuity if you are already familiar with astrolabes.

The astrolabe is an astronomical instrument that shows the user the positions of the Sun and stars for a specific time and place. It can be used to solve a great many astronomy problems that would require mathematical calculations if you didn't have such a marvelous device. The name comes from the Greek "aster", meaning star, and "lambanein" (imperf. labein) meaning take, seize, catch, grasp and, derivatively, apprehend, determine, estimate. Combined as the word *astrolabe*, the name means that an astrolabe can be used as either a star finder or a star taker. As a star finder the astrolabe can be used to find stars and other objects in the sky. As a star taker, the astrolabe can be used to find the time by taking a reading of the Sun or a known star's position. The astrolabe is both a map of the heavens and a portable computer for solving astronomical problems. The astrolabe can be considered the world's first personal computer.

The purpose of the astrolabe is to show the user how the sky looks at a specific place at a given local time. This is done by drawing the sky on the face of the astrolabe and marking it so positions in the sky are easy to find. To use an astrolabe, you adjust the moveable components to a specific time and date. Once set, much of the sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems related to time and the position of the Sun and stars to be solved in a very graphical way.

The astrolabe is intended to be used for both observation and computation. For observation, it is fitted with a ring so the instrument can be hung vertically from the thumb while the position of the Sun or a star is measured.



Astrolabe by Jean Fusoris, ca 1400 (courtesy Adler Planetarium and Astronomy Museum)

The Parts of an Astrolabe

An astrolabe instrument has six major components:

The main body of the instrument is usually called the *mater* (Latin for “mother”). The mater is a disk, usually made of brass and six to eight inches in diameter, hollowed out to hold a set of thin brass *plates* (also called *tympans* or *climates* in astrolabe literature). The outer margin of the mater (the *limb)* is engraved with degrees and, on European instruments, the hours.

Astrolabes show the sky as seen from a specific place. That is, it shows the location of celestial objects by their angle above the horizon (altitude) and angle from north (azimuth). Each of the plates is engraved with arcs representing altitudes above the local horizon for a specific latitude. The plates also show the equator and tropics and may include other arcs for telling time.

Fitted above the plate is a pierced sheet that carries pointers indicating the positions of a number of bright stars and the path of the Sun through the year (the ecliptic). The rete is free to rotate over the plate to simulate the daily rotation of the sky. Old astrolabes usually showed the positions of 15-20 stars.

European astrolabes usually included a rotating hand (called the *rule*) that is used to locate the Sun on the ecliptic and show the time on the margin of the mater.

The back of the astrolabe is engraved with scales to find the Sun’s position in the ecliptic (i.e. the Sun’s longitude) for a specific date and with a variety of other scales that varied greatly depending on where and when a specific astrolabe was made.

Astrolabes are also observational instruments. The back was equipped with a rotating hand (the *alidade)* with sights for measuring the altitude of the Sun or a star. The entire instrument could be suspended above eye level by a ring for taking altitude measurements.

In use, a plate was selected for a latitude and the moveable components are set to a specific date and time. Many problems can be solved depending on how the moveable components are set.

Astrolabes were made in many sizes from very small hand held instruments to permanently mounted devices of very large diameter. Most European astrolabes were rather small (six inches or less). Islamic instruments tended to be slightly larger.

The Electric Astrolabe completely reproduces the front of a classical astrolabe but with the addition of the positions of the Moon, planets and deep sky objects. The Electric Astrolabe does not reproduce the back of the astrolabe as the functions on the back were primarily devoted to making observations.

Note that an astrolabe instrument cannot reproduce the motion of the Moon and planets. This is a singular advantage of the Electric Astrolabe over astrolabe instruments. Note also that The Electric Astrolabe can create a plate for any location on Earth. The Electric Astrolabe can be though of as an astrolabe with 10,800 plates.

Why the Astrolabe Works

The following sections of this chapter discuss astrolabe theory, more details on astrolabe instruments and a brief history of astrolabes. These sections can be skipped without loss of continuity and returned to later if you would like to go directly to the next chapter.

The purpose of the astrolabe is to represent the sky on the face of the instrument as it appears at a specific location at a given local time. That is, astrolabes are used to position stars and the Sun by determining their altitude above the horizon and position relative to south. This is done by projecting the sky onto a plane and marking the projected image so celestial positions are easy to find. The principle of the astrolabe is easier to understand if you know a little about the projection technique used.

Much astronomical thought is based on the idea that celestial objects are so far away that they can be considered to be on the surface of a very large sphere known as the celestial sphere, with the Earth at the center. Technically, the astrolabe is a projection of the celestial sphere onto a plane with moveable components to locate celestial objects for any time and date. The celestial sphere is projected onto the plane of the equator on the most common type of astrolabe. This type is known as a planispheric astrolabe and is the type represented by the Electric Astrolabe. Other forms of astrolabe have been constructed but none ever obtained the wide usage of the planispheric type.

The projection used in the astrolabe is the stereographic projection (Figure 1). The sphere in the figure is the celestial sphere of arbitrary but very large diameter with the Earth at the center. The equator and tropics are shown on the celestial sphere as they would be seen from the Earth. In the stereographic projection, which is among the oldest and simplest of all projection techniques, the eye is assumed to be at one of the poles of the sphere being projected (the south pole for astrolabes designed to be used in the northern hemisphere). A ray is projected from the pole to the point on the sphere to be projected. The projected point is where the ray crosses the projection plane. The projection plane for a planispheric astrolabe is the plane of the equator.

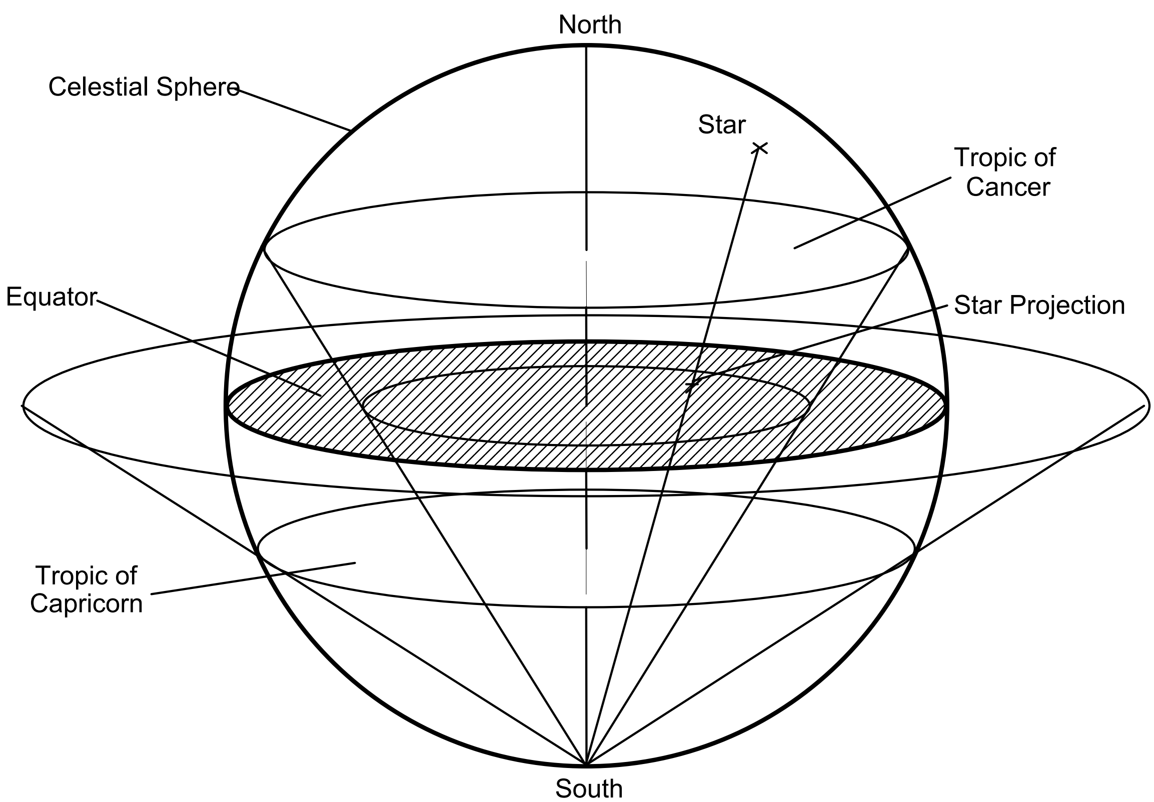


Figure 1. Principle of the Stereographic Projection.

Modern terrestrial maps and stars charts use the stereographic projection with a projection plane tangent to the sphere and centered at the place of interest, usually the zenith for a latitude. The projection principles are identical.

The stereographic projection has two properties that make it ideal for an instrument intended to solve astronomical problems:

- In the stereographic projection, circles on the celestial sphere are projected as circles on the projection plane (the equator for the planispheric astrolabe). This means that the circles such as the equator and ecliptic are projected as circles and that altitude and azimuth arcs are preserved. This property is particularly easy to demonstrate for the tropics which, since they share a common center with the axis of the Earth, are clearly projected as circles.

- Angles between arcs on the sphere are preserved in the projection thus allowing direct measurements to made on the projected plane.

These properties are ideal for astronomical purposes since most celestial positions are measured as angles along circles. Note, however, that this form of projection introduces significant distortions in relative size for objects that are very close to the axis or very far away from it. In theory it is possible to project the entire celestial sphere but astrolabes constructed for use in the northern hemisphere show the celestial sphere only as far south as the Tropic of Capricorn. This range includes almost all of the sky visible from northern temperate latitudes and avoids the severe distortion of scale that would result from including extreme southern declinations.

Using the stereographic projection, it would be possible to project the positions of the stars and planets at any time onto a piece of paper and then take measurements of relative positions. It would, however, be impractical to attempt to project the sky at every instant for every location onto paper. The real genius of the astrolabe is how it makes use of the projection to allow the instrument to be used at any time and to be flexible enough to be used at many locations.

Classical astrolabes were made of brass and were commonly about six or eight inches (15 to 20 cm) in diameter, although much larger and smaller ones were made. No doubt many astrolabes were made of cardboard and paper but few have survived. A typical astrolabe would consist of a brass disk about ¼ inch (6 mm) thick and about six inches (15 cm) in diameter that is hollowed out in the center to hold sets of thin brass plates. The margin of the disk (the limb) was graduated by degrees and, on many European astrolabes, into 24 hours with noon at the top and midnight at the bottom for telling time. Inserted into the hollow section of the disk (the mater) is a plate for the local latitude engraved with lines of altitude and azimuth and circles representing the stereographic projection of the equator and Tropic of Cancer (the outer edge of the plate is the projection of the Tropic of Capricorn). Additional lines for finding the time in seasonal hours or indicating astrological information might be included depending on where and when a specific astrolabe was made. A dashed altitude line below the horizon at -18° was often included to show the end of twilight.

Over the plate is fitted a pierced disk, also made of brass, with pointers representing a number of fixed stars and containing the projection of the ecliptic. The ecliptic circle was always divided into sections of 30° representing the signs of the zodiac. On top of all this is fitted a clock-type hand called the rule. The rule and the star pointers (called the rete) are held in position by a pin through the center of the instrument and are free to rotate over the fixed plate. The instrument could be set to show the orientation of the local sky by rotating the rete until the object of interest is located on the correct altitude arc. All of the stars represented on the rete will be at their correct position when any one star is set to its altitude.

The back of the instrument was equipped with a rotating sighting vane (alidade) and engraved with scales of degrees for measuring the altitude of the Sun or stars. The altitude of the Sun or a star was measured by sighting through pinnules on the alidade. Most instruments had a scale for converting the date to the Sun’s position in the zodiac. The date to zodiac conversion scale was usually implemented in the form of two slightly off-center circles. The outer circle, which was concentric with the center of the instrument, was divided into sections of 30° representing the zodiac with the vernal equinox corresponding to the beginning of Aries at the 3 o’clock position. The inner circle was divided by the calendar with its center offset toward aphelion to represent the theoretically sound model of the Sun’s motion on an eccentric with the date of the vernal equinox aligned with the beginning of the sign of Aries on the zodiac circle. It is interesting to note that it is sometimes possible to get an approximate date of manufacture or determine the source of the star positions for an old astrolabe from the date of the vernal equinox used on the calendar conversion scale. Some astrolabes used a calendar scale that is concentric with the center of the instrument and had variable length days. The concentric calendar scale was easier to design but harder to engrave accurately.

Islamic prayer times are astronomically defined and the astrolabe was potentially an ideal aid for satisfying ritual prayer requirements. The back of Islamic instruments often had special purpose scales used for finding the direction to Mecca (qibla) and a scale of cotangents was often included as an aid in determining prayer times. The astrolabe also saw some use in surveying and the backs of many instruments included scales of trigonometric functions such as tangents or cosines. Other scales might be included on the back depending on local customs. For example, there might be a scale for conversion to and from equal (equinoctial) and unequal (seasonal) hours or astrological tables.

The entire instrument was suspended by a cord connected to a ring located at the top of the astrolabe.

The astrolabe was widely used in Europe, Moorish Spain, the Arab world, Persia and India from the 10th through the 17th century. Stylistic differences evolved and the specific functions included on instruments varied depending on tradition and use for the region. The Electric Astrolabe is closest to a European instrument in the style developed by the French scientist and craftsman, Jean Fusoris, in the late 14th century. This style, while not universal, is the only style that can be considered typical for European astrolabes.

Use of the astrolabe was very widespread among well educated people of the Middle Ages, particularly in the Islamic world.

It is not totally clear what astrolabes were used for in everyday life but its uses certainly included telling time, determining the length of the day and, as astrology was a deeply embedded cultural tradition, finding aspects of horoscopes. Planispheric astrolabes were definitely **not** observational or navigation instruments. There was a device called the *Mariner's Astrolabe* that was used to measure celestial altitudes at sea but it was just a ring graduated in degrees with an alidade. The only use for a traditional astrolabe on a ship would have been for timekeeping or astrology in conjunction with planetary tables.

The most common use of the astrolabe was to tell time. Let's assume it is desired to find the time at night. The procedure would be:

1. Suspend the astrolabe by its cord and hold it steady above eye level.

2. Use the alidade to measure the altitude of a known star above the horizon.

3. Find the position of the Sun on the ecliptic (or in the zodiac to be more specific) using the conversion scale on the back of the astrolabe.

4. Set the rete so the pointer for the observed star is at the proper altitude line on the plate.

5. Set the rule so it crosses the ecliptic at the zodiac position determined by the date.

6. The rule now points to the time on the hour scale on the limb.

An experienced user could perform this operation in about 20-30 seconds. It is easy to find the time to within a few minutes this way (the astrolabe is not a very accurate observing instrument).
Telling time during the day is similar using the altitude of the Sun.

Similarly, the time of Sunrise and Sunset and thus the length of the day can be easily found by setting the Sun's position in the zodiac on the east and west horizon and noting the times.

In short, the classic planispheric astrolabe was a portable analog computer for solving astronomical problems.

The plate of a planispheric astrolabe is designed by laying out the tropics and circles of equal altitude and azimuth relative to the local horizon on a sheet of brass and then engraving the arcs and lines. The actual execution requires great care but is not difficult in theory. All methods for astrolabe plate layout rely on the preservation of angles and circles in the stereographic projection to determine the size and orientation of the various circles. That is, a circle is completely determined by finding the location of the center and one point on the circumference or by finding two points on the circumference with a common diameter.

The techniques used for astrolabe design are graphical, where the lines and circles are laid out directly on the plate with a straightedge, compass and protractor, or analytical, where the sizes and locations of the circles are pre-calculated and the measurements are transferred to the plate. There is a Persian technique that uses an auxiliary device based on zenith distance called the dastur that allows a graphical construction without cluttering up the result with numerous layout lines that must be erased from the final result. Available references on how to construct a working astrolabe are not particularly complete and none shows all three methods.

It should be noted that, if you were constructing an astrolabe today, you would use plastic instead of brass with a clear plastic rete and you might divide the ecliptic directly by date.

The Electric Astrolabe updates the astrolabe principles with the use of computer graphics. The original forms and uses have been preserved and no tricks have been played. What you see on the screen is exactly the same form as with a classical astrolabe and derived from identical principles.

A BRIEF HISTORY OF THE ASTROLABE

"History repeats itself; historians repeat each other." Philip Guedella

As with many other histories, references on the history of the astrolabe are not in universal agreement. Even scholars working from the same original sources draw different conclusions on important points and there are instances where eminent scholars working at different times in their careers contradict themselves. Following is a very brief summary of generally accepted highlights in the history of the astrolabe:

The evolution of the astrolabe took place in the following steps:

1. Realization that three dimensional objects can be accurately represented (projected) on a plane (such as a drawing).

2. Discovery of the stereographic projection as a way to represent the celestial sphere.

3. Use of the stereographic projection to make astronomical instruments.

4. Eventual combination of the above elements into the device known today as the astrolabe.

5. Various refinements of scales and design depending on use and local custom.

6. Gradual decline in use as more specialized and accurate instruments became available.

ORIGINS OF ASTROLABE THEORY

The origins of the astrolabe were in classic Greece. Given their interest and sophistication in geometry, various types of projections came as naturally to the Greeks as columns of figures do to us. It is known that Agarthus, an Athenian artist ca. 470 bc, applied the concept of projections onto a plane surface to the theory of perspective. It is easy to accept that a projection as simple as the stereographic projection would have been investigated. Eudoxus of Cnidus (408-355 bc) is credited with a new form of Sundial called “the spider’s web” that some sources say may have been a crude form of astrolabe (but it wasn’t). There is speculation that Apollonius (ca. 225 bc), the great codifier of conic sections, studied the stereographic projection based on some theorems that have direct application to the projection.

The earliest evidence of use of the stereographic projection in a machine is in the writing of the Roman author and architect, Vitruvius, who describes a clock (probably a clepsydra or water clock) made by Ctesibius in Alexandria. Apparently, Ctesibius’ clock had a rotating field of stars behind a wire frame indicating the hours of the day. The wire framework (the spider) was possibly constructed using the stereographic projection with the eye point at the north celestial pole. Similar constructions have been found in Salzburg and north-eastern France so such mechanisms were apparently not all that unusual to the Romans. It is almost certain that the famous Tower of the Winds contained celestial maps using the stereographic projection.

The most influential individual on the theory of the stereographic 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 stereographic projection and probably proved (or least knew about) the preservation of circles in the projection. His main innovation might well have been to move the eye point of the projection to the south celestial pole to improve the utility in the northern hemisphere. Hipparchus was most likely studying the most difficult problem of ancient astronomy: determining the length of the day as a function of latitude (the so-called “rising time” problem). The problem involves finding how many equatorial degrees pass for a given number of ecliptic degrees (see pg. 85). The solution clearly depends on the latitude of the observer and it was a problem of some magnitude to find a solution. Hipparchus did not have spherical trigonometry to solve this type of problem and the stereographic projection worked nicely. Hipparchus did not invent the astrolabe but he did refine the projection theory.

The next major writer on the projection was the famous Claudius Ptolemy 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. If he did have such an instrument it probably covered a larger portion of the sky than later astrolabes. Ptolemy was deeply interested in “the greatest always invisible circle” so any instrument of his would have covered the celestial sphere to the Antarctic circle.

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 does not survive except for the table of contents which was preserved by Ya’qubi in his “History of the World” (ca. 880). This treatise was evidently 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 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 probably introduced to the Islamic world in the eighth and ninth centuries through translations of classical texts that began under the Abbasid dynasty, notably Harun al-Rachid (the caliph of the Tales of the Arabian Nights) and his son, Al-Ma'mun. The astrolabe came into full bloom during the Islamic period. 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 observed that astrology was a deeply imbedded element of Islamic culture and that astrology was one of its principle uses.

Based on some of the instruments preserved in museum collections, it is easy to infer that it must have become something of a status symbol in Baghdad to have a really good astrolabe since some of the instruments appear to be presentation pieces rather than working tools. For example, there is an Islamic astrolabe from 1698 in the Buffalo Museum of Science, Buffalo, NY, that was definitely made for one Mahmud Agha who was chief of the arsenal during the time of Shah Sulayman I (1667-1694) and Shah Husain I (1694-1722) of the Safavid dynasty (see Saliba, George, 'The Buffalo Astrolabe of Muhammad Khalil, Al Abhath, vol. XXVI).

This point of view is somewhat at odds with the journal of Jean Chardin, a French jeweler who lived in Isfahan in the 17th century. According to Chardin, Persian astronomers (astrologers) were also fine craftsmen who made their own instruments and skill in the craft was prerequisite to being accepted as a scholar.

Persian astrolabes became quite complex and some were genuine works of art. There are a number of interesting stylistic differences between astrolabes from eastern Islam (the Mashriq), Northern Africa (the Maghrib), Moorish Spain (Andalusia) and India.

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 on the border between Christian Europe and Islamic 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. By the end of the twelfth century there were at least half a dozen competent treatises in Latin and there were hundreds available only a century later. It is possible that the European adoption of many Arabic star names is a direct result of the engravings on astrolabes imported to England. European makers extended the plate engravings to include the astrological houses and 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 with the peak in popularity in the 15th and 16th centuries. Skill in its use was a sign of proper breeding and education. Their primary use was, however, astrological. Many fine instruments were produced during the guild period including glorious clocks with astrolabe dials where the sidereal rotation rate of the rete was produced with ingenious gear trains. A number of monumental clocks with astrolabe dials were made in the 14th through 16th centuries with the most famous being the astronomical clock at the Strasbourg cathedral. The inclusion of an astrolabe dial on a clock gives one a sense of unity with time and space. It is a shame they are not still used.

Several interesting astrolabe variations to make a single instrument usable in all latitudes were invented in 15th and 16th centuries but due to their high cost and complex operation never gained the popularity of the planispheric type. These instruments projected the celestial sphere on the equinoctial colure (see the glossary) and lacked the intuitive appeal of the planispheric type.

THE ASTROLABE TO MODERN TIMES

The use of the astrolabe declined as more reliable clocks and more accurate scientific devices became available but production, particularly in the Arab world, continued into the 19th century. Much like Sundials, any instruments made today are for curiosity or fun.

It should be noted that astrolabe concepts are still in wide use today. The famous Swiss watch maker Ulysse Nardin sells a very expensive astrolabe wristwatch. There are a number of navigational aids based on the same concepts and the popular star finders are generally just simplified astrolabes. Any astronomical instrument constructed to measure the altitudes of celestial objects can be called an astrolabe. For example, the Astro Compass, Mk. II, used by the U.S. air force until recently and the prismatic astrolabe used to find the precise instant that a star reaches a specified altitude (usually 60°). Such instruments are not astrolabes in the sense used here, but adopt the name as applying to any instrument that is used to determine celestial altitudes.

Considering the age of the astrolabe, it is tempting to justify the Electric Astrolabe program solely on the grounds that it is about time someone computerized it.

THE ELECTRIC ASTROLABE DISPLAY

Learning to read and interpret the Electric Astrolabe display is a little like learning to read a new kind of map, but no more difficult. In order to read a map, you must understand what the symbols mean, how the scale of the map relates to reality, what area the map covers and what features, if any, are distorted by the mapping technique. We will cover each of these topics as we explore the meaning of the Electric Astrolabe display. The figures are based on the program displays. The Electric Astrolabe can be set to any latitude, northern or southern. The following discussion is based on northern latitudes. The Electric Astrolabe display for southern latitudes is discussed at the end of the chapter.

We will first discuss each component of the display individually and then see what information the display contains when they are combined.

THE ALTITUDE / AZIMUTH PLATE

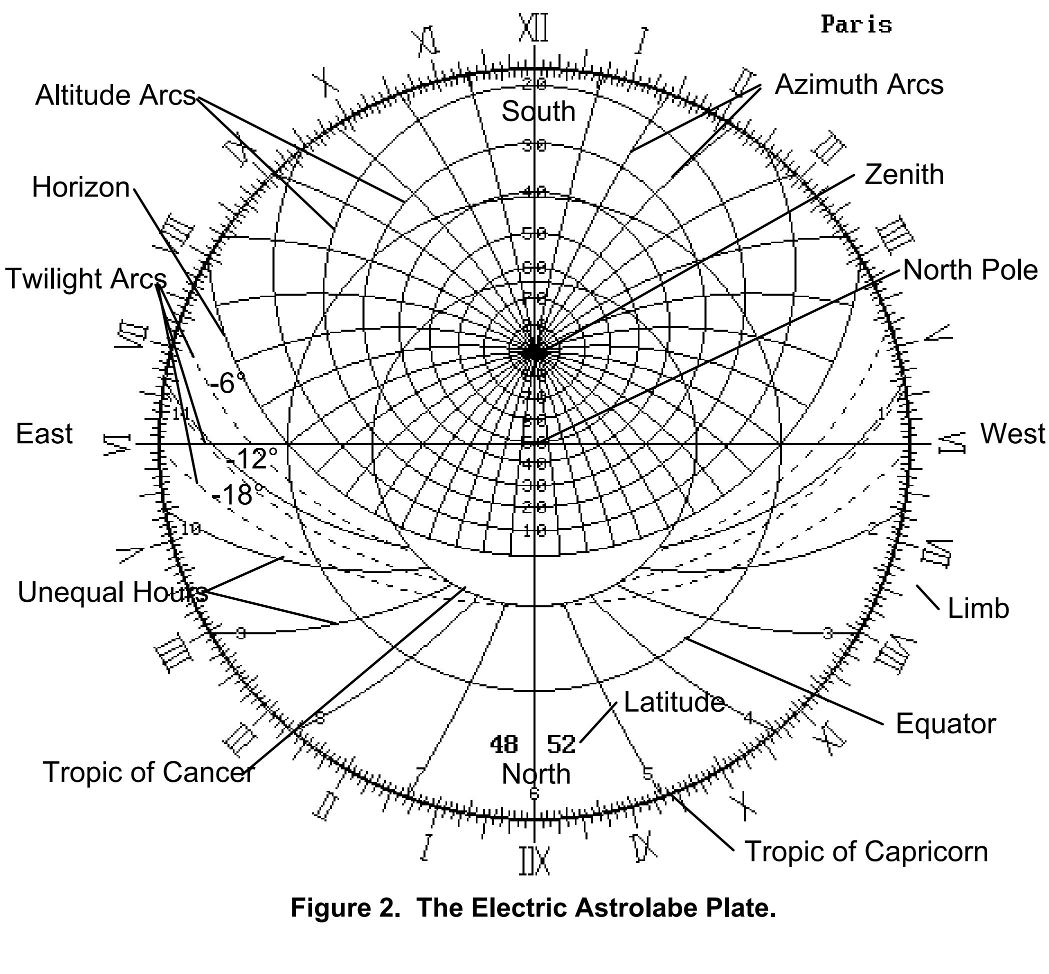


Figure 2. The Electric Astrolabe Plate.

Refer to Figure 2, which is an annotated picture of the Electric Astrolabe plate for the latitude of Paris. The inside of the plate can be thought of as a special kind of graph paper for finding the location of celestial objects in the sky at your location. The main difference between normal graph paper and the graph on the plate is that the lines on graph paper are normally straight while the astrolabe lines are curved.

Find the arc in Figure 2 that represents your horizon; the line where the sky meets the Earth. Any celestial object that is above the horizon line is visible to you (or would be if trees, mountains, buildings and clouds were not in the way). Any object that is below the horizon line is not visible. The circles above the horizon represent lines of equal altitude above the horizon. Objects that fall on the same circle are the same altitude above the horizon. Each circle represents ten degrees in altitude; therefore, any object that is anywhere on, for example, the fifth circle up from the horizon line has an altitude of 50°. The point inside the smallest circle that has a lot of lines radiating from it is your zenith, or the point directly overhead.

The straight lines drawn as diameters of the largest circle show direction. The vertical diameter goes north and south through your location, representing your meridian. The horizontal diameter connects east and west (the projected circle is called the *prime vertical*). South is at the top and east at the left. It is perhaps easiest to visualize the plate as lying flat on a table with the top pointing south.

The lines radiating from the zenith represent lines of equal azimuth. Astronomers usually measure azimuth angles as increasing as you go east from north, so an azimuth angle of 150° is 30° east of south and an azimuth of 270° is due west (but, see the glossary for international definitions). Circles of equal azimuth are shown for every ten degrees. Notice that the azimuth circles for 90° and 270° intersect the horizon at west and east (i.e. the equinoctial colure) respectively. We can locate any object that is visible in the sky from our location with the circles of equal azimuth and altitude .

The dashed altitude circles below the horizon are at 6°, 12° and 18° below the horizon and are called the *crepuscular* (twilight) lines. Because the Earth's atmosphere "bends" the Sun's light rays and because Sunlight is reflected by particles in the air, sunlight can still be seen even when the Sun is below the horizon. Civil Twilight ends when the center of the Sun is 6° below the horizon. At this time artificial illumination must be used to see clearly. Nautical Twilight ends when the Sun is 12° below the horizon and the horizon cannot be seen at sea. Astronomical Twilight ends when the Sun is 18° below the horizon and you are in the full shadow of the Earth; there is no Sunlight at all.

Technically, sunset and sunrise are defined as the time when the upper limb of the Sun is tangent to the horizon. This occurs when the center of the Sun is about 0.833° below the horizon.

Since the particular piece of the sky that you can see varies with your latitude, a different set of altitude and azimuth lines is needed for each latitude. The latitude for each plate is shown by the numbers near the bottom.

The larger circles, centered on the plate, represent the Earth's tropics. The outer circle is a projection of the Tropic of Capricorn, which is the farthest south the Sun ever reaches. The middle circle is the equator and the smaller circle is the Tropic of Cancer. Notice that the equator crosses the horizon in the east and west, as it should. The tropics are the same for all latitudes since the tropics are fixed by definition.

The outside edge of the plate is divided into 24 hours consisting of two twelve-hour sections. This band of numbers is called the limb on astrolabes and is always called the chapter ring on clocks. Each hour is divided into five minute segments. The limb marks the time of day and the sidereal time. Since the Sun crosses our meridian at noon, the XII at the top is noon (1200 hours) and the XII at the bottom is midnight (2400 hours). Sidereal time is counted from zero starting at the top XII and goes to 24 hours. Notice that the numeral for four is shown as IIII instead of IV. This is traditional on clock dials as the mass of the IIII character balances with the VIII and gives the dial better proportions. The inner margin is divided by degrees.

The solid arcs below the horizon that connect the Tropic of Cancer and the Tropic of Capricorn are used to determine the unequal hour of the day. Throughout recorded history, until reliable clocks became widely available in the 15th century, time was described as the fraction of the time from sunrise to sunset that had passed. In most cultures, the time from sunrise to sunset (or sunset to sunrise for hours at night) was divided into twelve equal parts and the time would be described as being, for example, in the 6th hour of the day for the portion of the day just before noon. This method of telling time was quite consistent with the way that people used to think about quantities. Many values were stated as ratios; A is twice as large as B or B is half the size of A. Telling time this way was not all inconvenient even though the length of an hour was different for different times of the year. If you know that the current time is in the third hour of the day you know immediately that the day is about one-forth over. It is a very easy convention to get used to and can still be a more convenient way to tell time if your interest is how long it is until dark. For far northern latitudes, the length of an hour in the winter might be half the length of an hour in the summer but the unequal hours are the same ratio year round. Several methods of counting the unequal hours have been used. The most common use was to count the hours of the day beginning at sunrise and the hours of the night beginning at sunset (Babylonian hours) and this is method used on the Personal Astrolabe. Care must be taken when referring to historical texts because other counting methods were used such as counting the hour as the hours until sunrise or sunset.

The unequal hours are counted from the western horizon starting with 1, the first hour of the day or night, and continuing clockwise through the end of the 11th hour at the eastern horizon. The unequal hour is found by the point where the long rule crosses the Sun's position on the ecliptic during the night and by the ecliptic point opposite the Sun (the *nadir*) during the day. The use of the unequal hour arcs will be described later (see the Ctl+R command). The unequal hour arcs are optional on the astrolabe display.

THE STARS

Everyone knows that the stars appear to move in the sky but, in reality, the stars are fixed and it is the Earth that moves. If the Earth were stationary in its orbit and only rotated the same stars would be in the same position in the sky at the same time every day, but because the Earth is also orbiting the Sun, moving a little in its orbit every day, the field of stars also appears to move a little every day. Because the rotation of the Earth is so constant, we use it as the basis for keeping time. We call the average time between the Sun's appearance on our meridian a day, and we have defined the length of the day as 24 hours. But the length of a mean solar day is not the same as one rotation of the Earth. The Earth must rotate a little extra for the Sun to reach a given meridian since the Earth has also moved in its orbit. The length of one rotation of the Earth is called a Sidereal Day (sidereal means star), and is 23 hours 56 minutes 4.09054 seconds, or about 3 minutes 56 seconds shorter than a mean solar day. It is because of these four minutes or so that we see different stars in the sky at different times of the year.

On the Electric Astrolabe, the coordinate system where we are (the altitude and azimuth circles) does not move because our location does not move, but the stars move in our sky. The entire field of stars rotates in one sidereal day. Figure 3 shows the approximately 150 stars that are included on the Electric Astrolabe (classical astrolabes showed 15-20 stars). When we arrange stars in the sky into figures so they are easier to recognize, the resulting figure is called an *asterism*. Most of the stars on the Electric Astrolabe are arranged into constellation asterisms to make identification easier. The constellation names can be displayed to help you identify the constellations. The bright stars can be displayed separately. All the displayed stars are listed in Appendix A.

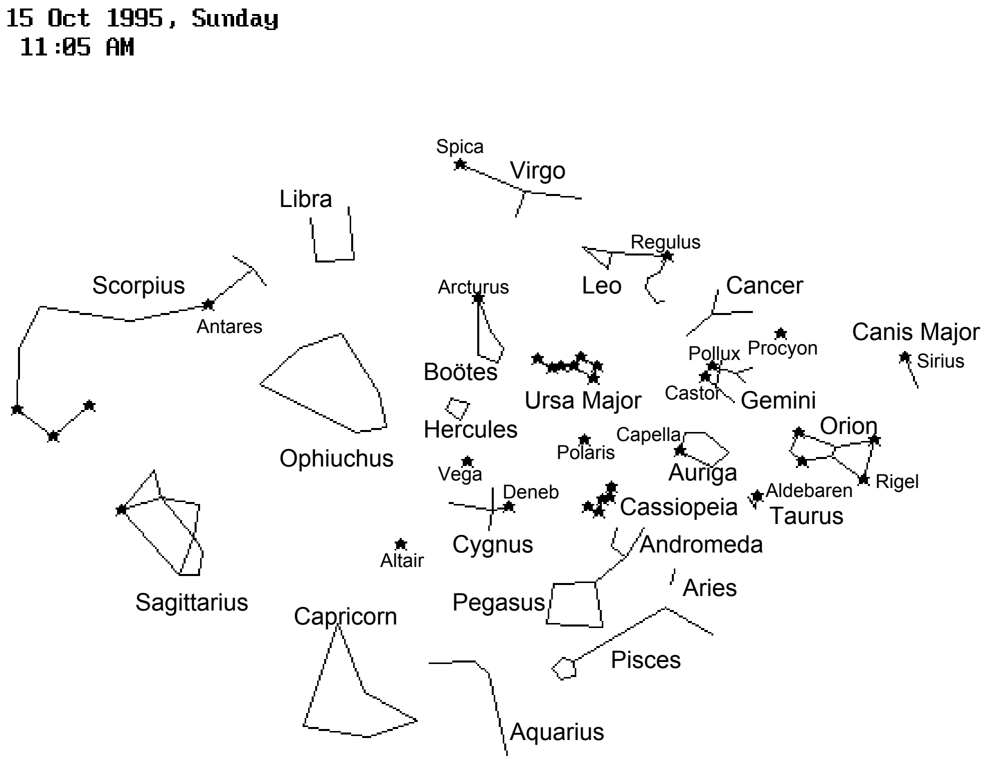


Figure 3. Electric Astrolabe stars.

Notice that the constellation shapes are well preserved by the projection but the sizes near the pole and the Tropic of Capricorn are highly out of proportion to the constellations near the equator. The result of the distortion is similar to the size of Greenland on the popular classroom Mercator projection maps of the world. The coordinates of all displayed stars are in Appendix A. Precession can be applied to star positions.

THE PLANETS

Unlike the stars, the Sun, Moon and planets appear to move in the field of stars from day to day. This movement is, of course, due to the fact that the planets are orbiting the Sun like the Earth, and the Moon is orbiting the Earth itself. The positions of the Sun, Moon and eight of the nine planets in the sky are shown on the Electric Astrolabe display. Pluto is not included.

An example of the planetary images is shown in Figure 4. The planetary images are all different, but it takes a little practice before you can tell at a glance which is which (in the next chapter you will learn how to label the planets until the images are familiar to you). There are a few mnemonic clues to help you. The Sun is pretty obvious since it is always near the rule and is the larger yellow disk. Mercury is always near the Sun and looks small because it is just a small gray disk. Venus is the small white disk (think of the cloud covering). Mars, of course, is reddish. Jupiter is larger and banded and has a small red spot. Saturn is fairly obvious because of the rings. Uranus is bluish (cyan, actually) because all pictures of Uranus show it as blue. Neptune is brown. The Moon's phase is shown.

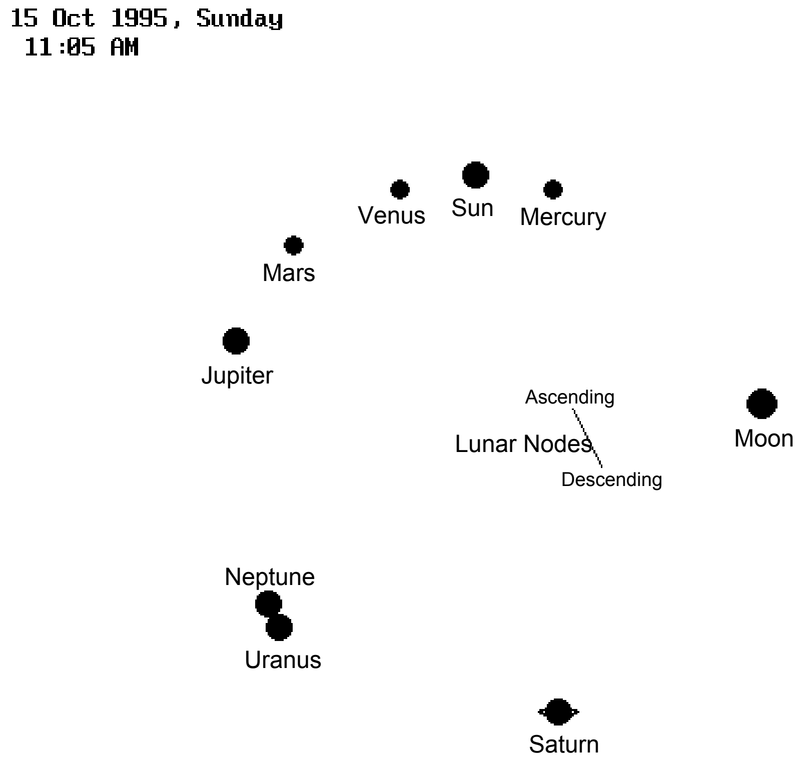


Figure 4. Planets.

The short line in the center of the planet display indicates the Moon's line of apsides, or the line connecting the Moon's nodes (see the glossary). The white end of the line points to the ascending node and the yellow end points to the descending node. Knowledge of the position of the Moon's nodes allows you to do first level eclipse prediction.

Since astrolabe instruments are static devices, it was not possible to include planets. This is a singular advantage of the Electric Astrolabe over the classic type.

THE ECLIPTIC AND RULE

The path of the Sun in the sky over the course of a year is the **Ecliptic.** The tropics of Cancer and Capricorn are defined as the northern and southern limits of the Sun during the year.

It is fairly easy to visualize the extension of the Earth's equator and tropics out to the celestial sphere. The ecliptic plane can also be extended out to the celestial sphere. This is the circle that is projected onto the astrolabe rete. Because the Earth's axis is tilted about 23 ½° to the plane of the ecliptic (this is called the *obliquity* of the ecliptic), the circle on the celestial sphere will be at an angle to the equator and will just touch the Tropic of Cancer in the north and the Tropic of Capricorn in the south. The points where the ecliptic and equator cross are called the equinoxes.

The position of the ecliptic on the celestial sphere never moves, but the motion of the Earth changes the part of the ecliptic that we can see at a given time of day. In the daytime it is easy to find the ecliptic: it is where the Sun is. At night, it not as easy to find the ecliptic unless you can locate a planet. None of the planets is ever more that about 7º from the ecliptic (17° if you count Pluto).

In ancient times (about 550 BC), the ecliptic was divided into twelve sections of 30° each and each section was named for a constellation that was close to that section of the ecliptic. This division of the ecliptic is called the zodiac and, even though the constellations that originally gave the zodiac divisions their names are no longer in the same sections, the traditional names--Aries (♈), Taurus (♉), Gemini (♊), Cancer (♋), Leo (♌), Virgo (♍), Libra (♎), Scorpio (♏), Sagittarius (♐), Capricorn (♑), Aquarius (♒), and Pisces (♓)--have persisted. On classical astrolabes, the ecliptic is traditionally divided by the zodiac. This convention is partially astronomical since the position of the Sun or a planet on the zodiac is, by definition, its (geocentric) longitude but is also due to the fact that astrolabes were widely used by astrologers in the Middle Ages.

People who are new to astronomy often confuse the divisions of the ecliptic with constellations having the same name. The constellations that originally gave the sections of the ecliptic their names have precessed to other parts of the sky. The names are now purely arbitrary and their only use is to define each section of 30° of longitude. It is, perhaps, more useful to forget the names and just think of the ecliptic as being divided into 30° sections of geocentric longitude. The figure shows both divisions.

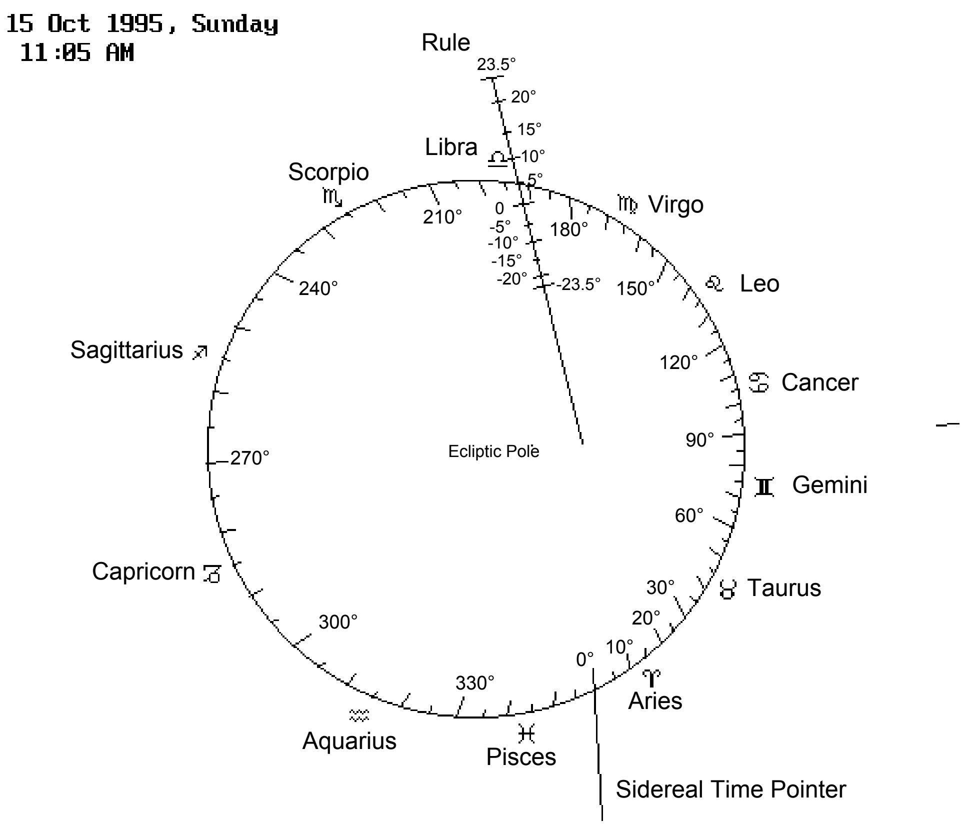


Figure 5. Ecliptic and Rule. (There is an error in this figure. See text)

Refer to figure 5. This figure shows the ecliptic from the Electric Astrolabe divided according to the zodiac. The signs can be identified by the traditional symbols. The line that extends out from the ecliptic circle originates at the First Point of Aries, which is both the Vernal Equinox and the beginning of the sign of Aries and is used to indicate sidereal time. The signs proceed in a counter clockwise direction from that point. Each five degrees is shown. The position of planet on the ecliptic is its geocentric (i.e. Earth centered) longitude. The ecliptic pole is displayed as a dot the same color as the ecliptic.

Two points on the ecliptic require special explanation. Capricorn 0° (the point on the ecliptic that just touches the outer diameter) indicates the right ascension of the point on the equator that is just rising. Similarly, Cancer 0° indicates the right ascension of the point on the equator that is setting and is indicated by a short line that moves along the limb at the Cancer 0° position. These points were used on Islamic astrolabes along with the degree scale to solve problems relating to the length of the day (see, The Rising Time Problem , page 85).

The line across the ecliptic circle is called the rule. The rule rotates at the mean solar rate of once every 24 hours, while the ecliptic and stars rotate once in a sidereal day. The rule points to the current clock time on the limb. The place where the rule crosses the ecliptic changes daily and is the location of the mean Sun in the ecliptic and, therefore, the date.

The rule is divided according to declination with each five degrees shown. Keep in mind that negative declination is on the outside of the equator. **The rule declinations in figure 5 are not labeled correctly. Negative declinations should be on the outside of the equator.** An alternate rule (not shown) is available on the Electric Astrolabe that always goes through the Sun's current position and extends across the entire face of the instrument. The Sun's declination can be estimated by reading the point where the long rule crosses the ecliptic. If the Sun image is in the way just turn the planets off with the "P" key.

MESSIER OBJECTS

In the 18th century Charles Messier, a French astronomer, set out to catalog as many celestial objects as possible that might be mistaken for comets. In a small telescope a comet looks like a dim, fuzzy, gray ball and Messier wanted to create an aid for comet hunters that would list the objects in the sky that might be mistaken for a comet. Messier did not know what the objects were that he was putting in his catalog, but he knew they were not comets. It turns out that Messier made a catalog of all of the non-stellar deep sky objects that can normally be seen in a small telescope. Over time, they were found to be various kinds of star clusters, galaxies and nebulae. Messier's original list has been expanded to 109 objects that are certain to exist. The full Messier list of objects includes numbers up to 110 but some have been dropped for the simple reason that they are not there. Observing Messier objects is one of the great joys of amateur astronomy. See Appendix A for a complete list of the Messier objects.

The positions of all of the Messier objects can be displayed with the Electric Astrolabe. The minimum brightness displayed can be specified to limit the display to those objects that can reasonably be observed with binoculars or a small telescope.

Figure 6 shows the Messier objects of magnitude 8 or less and Figure 7 shows the Messier objects with the stars. The type of Messier object can be seen from the way it is displayed. Spiral galaxies are shown as a small spiral that looks a little like the real thing. Globular clusters are shown as a filled circle. Open clusters are an open circle. Nubulae are a circle filled with vertical stripes. Elliptic galaxies (none shown in figure) are a small ellipse. The numbers of the Messier objects can be displayed as an identification aid.

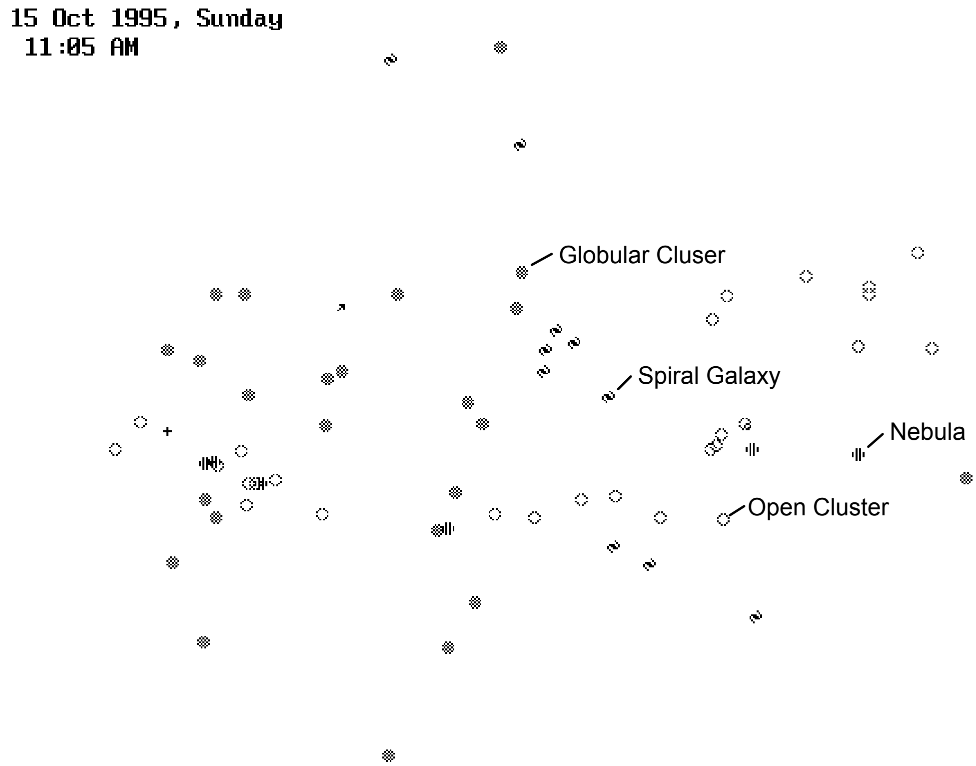


Figure 6. Messier objects (magnitude 8 and below).

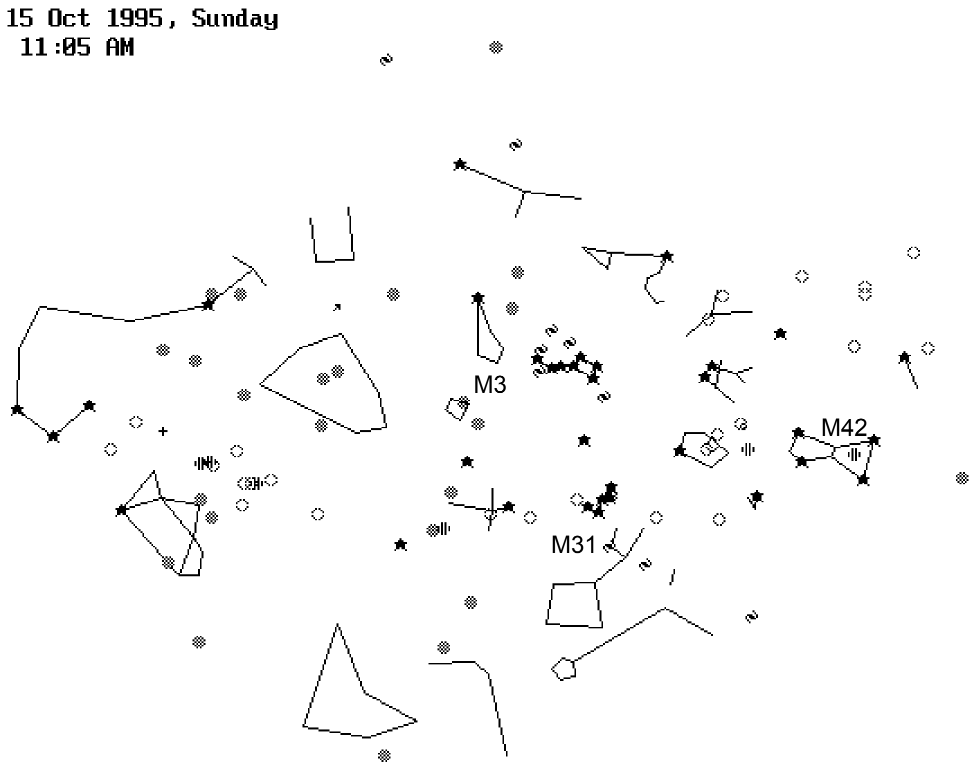


Figure 7. Stars and Messier Objects.

When looking at the constellations on the astrolabe it is important to understand that, unlike paper star charts, the astrolabe represents the sky as seen from outside the celestial sphere which is exactly how you see them when looking at a clear plastic model of the celestial sphere. Most star charts are constructed with a projection where the projection plane is tangent to the celestial sphere and you look at the bottom of the projection. Star charts are intended to be held above the head. You look down on an astrolabe, just like you look down on a compass. The altered orientation is most obvious on the handle of the Big Dipper which arcs in the opposite direction to what you see in the sky. Most of the constellations look enough like the star chart equivalents to be easily recognized.

Complete Astrolabe

Figure 8 shows the complete astrolabe for Paris at 11:05AM on Sunday, 15 October, 1995. A glance at the display gives the following information (the numbers below correspond to the annotation on the figure):

1. The Sun is about 30° above the horizon and a little less than 30° east of south and, with a geocentric longitude of 202°, is near the end of the section of the ecliptic known as Libra and near the star Spica.
2. Mercury is near the meridian at an altitude of 40° above the horizon in the constellation Virgo.
3. The Moon is about half full and is 20° above the horizon nearly due west.
4. Venus is 20° above the horizon about 10° east of the Sun.
5. Mars is 5° above the horizon with a longitude of 236° and is in the constellation Libra.
6. Jupiter, Saturn, Uranus and Neptune are below the horizon. Jupiter is near the constellation Scorpio. Saturn is in Pisces and Uranus and Neptune are between Capricorn and the "teapot" in Sagittarius.
7. Orion is just setting as is the Andromeda Galaxy (M31).
8. The sidereal time is 11:48 which can be confirmed by noticing that the "pointer" stars of the big dipper which have a right ascension of 11h are about one hour past the meridian.
9. The rule shows the time to be 1105.
10. The small arrow just below Mars is the position of Pluto which has been added to the display. The + above Sagittarius is the position of the center of the galaxy.
11. Notice that the Sun is far from the rule. This is because Paris at a longitude of 2° 20′ E is far from the center of the Central European Time zone center at 15° E.

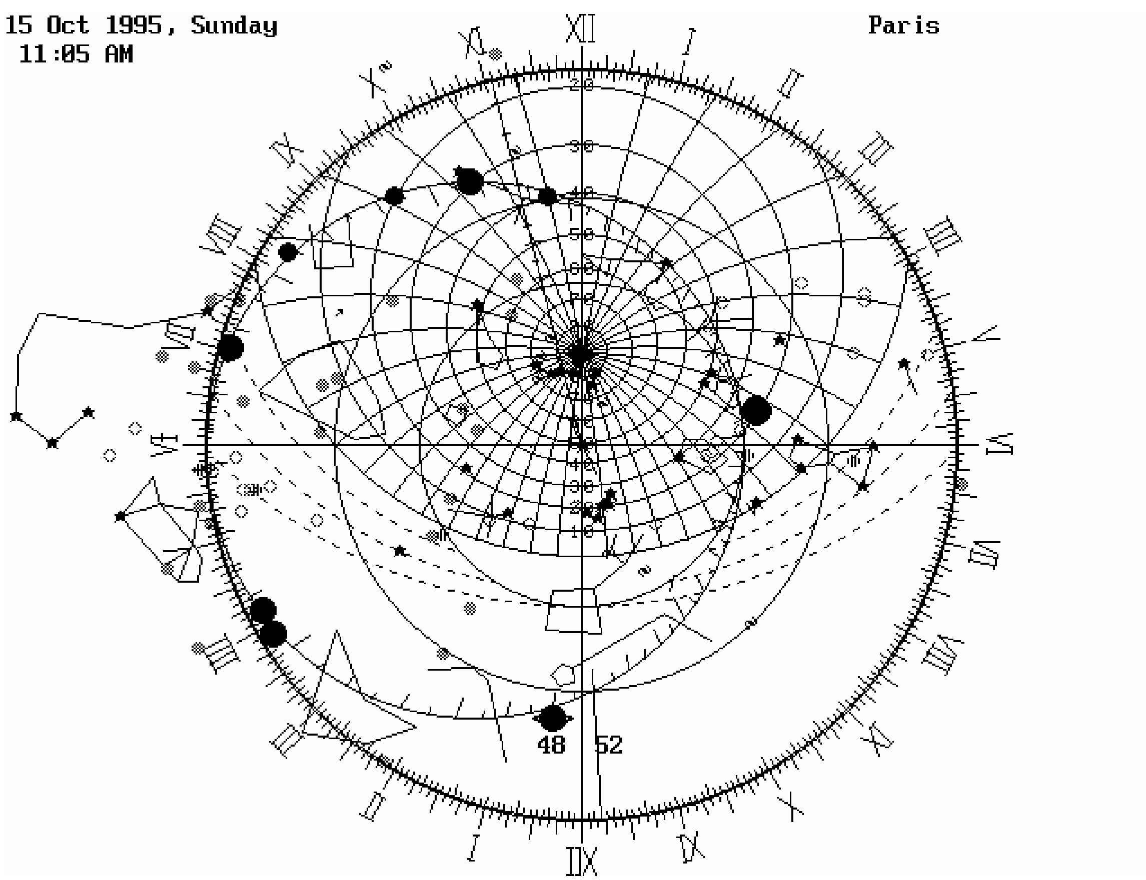


Figure 8. Complete Astrolabe.

SOUTHERN PROJECTION

Several monumental clocks were constructed during the Renaissance with dials based on a variation of the astrolabe where the projection is from the north pole instead of the south pole. Changing the projection origin in this way causes the horizon curve to be convex in the northern hemisphere instead of concave and reverses the sense of positive and negative declination. This projection is known as the *southern projection* because it would create a normal astrolabe for southern latitudes. For northern latitudes the Sun is far from the horizon when its declination is positive, as in the summer, and close to the horizon in the winter when its declination is negative as our experience tells us it should. Clocks with such dials usually contained a special hand with a ball representing the Sun, a projection of the ecliptic and a plate showing the horizon. Other astrolabe features such as stars and altitude lines were generally not included on clock dials

Figure 9 shows the complete astrolabe using the southern projection.

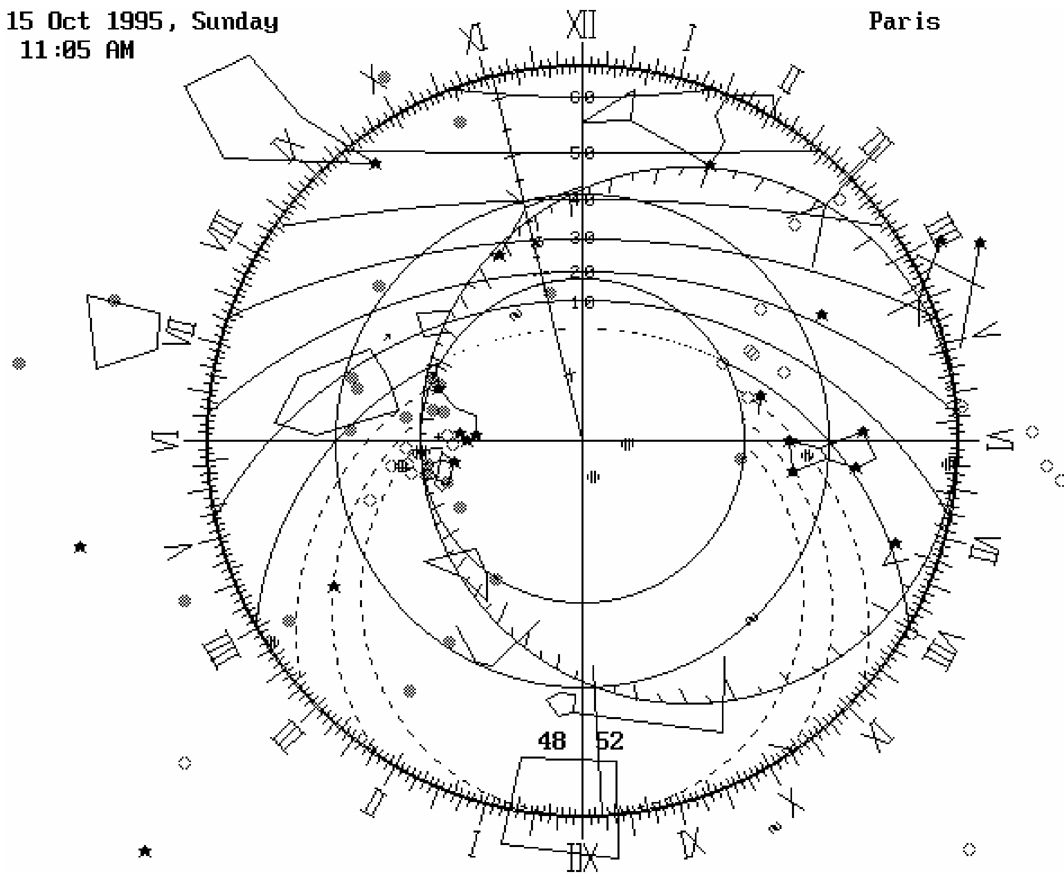


Figure 9. Southern Projection.

You will notice the following changes:

- The horizon and altitude lines curve the opposite way for northern latitudes.
- Azimuth arcs and unequal hours are not shown.
- The zenith may not be visible.
- The constellations are in different places due to the change in the sense of positive and negative declination. The change in projection clearly demonstrates the distortion due to the projection technique.

- The Messier objects are in different places.
- The ecliptic orientation is reversed. Note that the correct sidereal time is still shown.

The constellations shown are those for southern latitudes.

All other Electric Astrolabe functions are the same.

The southern projection is only useful for a clock dial because is shows so little of the sky and few astrolabes were ever made using this technique. It does, however, accomplish exactly what the Renaissance clock makers wanted; a simple astronomical clock dial that shows the position of the Sun in a very intuitive way.

The Electric Astrolabe for Southern Latitudes

The principles of an astrolabe made for southern latitudes are identical to those of an instrument made for the northern hemisphere but there are many detailed changes that must be considered. These changes may seem a little confusing at first but they are very easy to get used to and the intuitive appeal of the astrolabe is not diminished in any way once one has adapted to the orientation. It is interesting to wonder what changes in everyday life we would have had if ancient civilizations had originated in the southern hemisphere instead of the north.

Virtually all astronomical and time keeping conventions originated in middle northern latitudes. This is easy to justify because that is where civilization was centered when these conventions originated. An excellent example is the convention of “clockwise” and “counterclockwise”.

Consider the sundial. The Sun is always to the south when it is observed from any latitude north of the Tropic of Cancer. Therefore, a sundial for middle northern latitudes is oriented so the style (the edge of the plate that casts the shadow) points to the north celestial pole (the style is parallel to the Earth’s axis on most types of sundials). The sundial’s noon line is along your North-South meridian. When you face north, east is to your right. When the Sun rises in the east the shadow on the sundial will fall to the left of the meridian and moves “clockwise” through the day until sunset. There is no question that our tradition of clockwise motion is a direct result of the movement of the shadow on a sundial made for northern latitudes. The Sun reaches its maximum altitude when it is due south in the northern hemisphere.

The situation is reversed in the southern hemisphere. For latitudes that are south of the Tropic of Capricorn (which is just south of Rio de Janeiro and passes a little north of South Africa), the Sun is always to the north. Therefore, the style of the sundial points to the south celestial pole. When the Sun rises in the east which is to your left when you face south, the shadow will be to the right of the meridian and will move counterclockwise through the day. By implication, if sundials had been invented in the southern hemisphere, our sense of clockwise and counterclockwise would reversed and clocks hands would move in the opposite direction to what we consider normal.

This reversal in orientation also applies to the astrolabe since it is based on the movement of the Sun. The following sections describe the differences in an astrolabe designed for northern and southern latitudes.

The Plate

The basic design of the plate is identical for northern and southern latitude instruments except for the orientation and the numerals around the limb. On an astrolabe for southern latitudes the top of the instrument represents north with east to the right. In addition, the numerals around the limb proceed in a counterclockwise direction. Therefore, sunrise is shown by the Sun’s position on the ecliptic rising in the east, which is the right side of the instrument, and the stars will rise and set as the rete rotates counterclockwise. Note that azimuth is measured from the north, increasing to the east in both hemispheres so the azimuth angle is counted from the top of the instrument, increasing in a clockwise direction.

The positions of the tropics are also reversed on a southern astrolabe so the outer limit of the plate is the Tropic of Cancer and the Tropic of Capricorn is the inner circle. The location of the equator does not change.

The Rete

The rete has the most difference between northern and southern astrolabes. First, the rotation of the rete is reversed so it rotates in a counterclockwise direction. The sense of declination is reversed so that positive declinations are now to the outside of the instrument and the entire ecliptic is reversed. Of course, the rete contains different stars for southern latitudes.

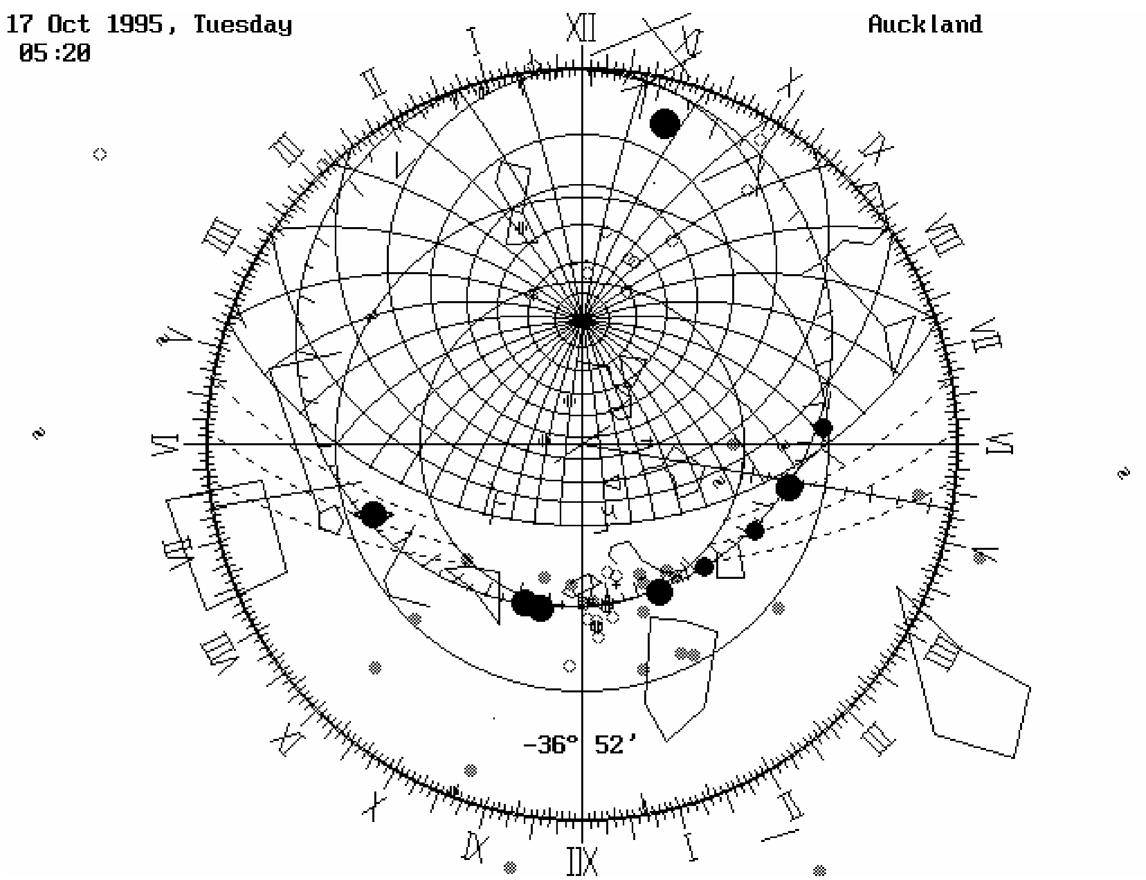
The Rule

The only change to the rule is the sense of declination with positive declinations being toward the outside of the instrument for southern latitudes.

Using a Southern Astrolabe

The principles for using the astrolabe to solve astronomical problems is identical for the two instruments. The only major difference in working problems is the counterclockwise rotation of the rete. In addition, the North American/European rules for daylight savings time do not apply in any country below the equator. You will have turn off automatic daylight savings time setting (the ‘ key) and set DST manually when required.

The figure below shows the Electric Astrolabe display for Auckland, New Zealand. Note the limb numerals and constellations. The Sun is about to rise in the east.



USING THE ELECTRIC ASTROLABE

Astronomy is a complicated subject that takes a lifetime to learn. The Electric Astrolabe deals with astronomical subjects that range from the very simple to extremely advanced topics. You should be able to use the Electric Astrolabe for simple astronomical topics within minutes, but complete mastery of the program and the full range of astronomical subjects it treats will take a considerable amount of time and may require reference to textbooks and other astronomy sources. The effort to master a complex science is repaid many times over in the pleasure derived from personal achievement and the ability to appreciate the wonders in the sky. The Electric Astrolabe will be an able companion in your exploration of astronomy.

INSTALLATION

The Electric Astrolabe distribution disk contains all of the files needed for operation and special installation procedures are not needed. In fact, it can be run directly from the distribution disk. For permanent installation, the files on the distribution disk should be copied to a directory on the hard disk.

To install the Electric Astrolabe, just create a folder for the files and copy all of the files into that folder.

The distribution disk include the Electric Astrolabe program, several files containing color variations (see the section on colors beginning on page 61) and files illustrating SAVE'd displays (see page 60) and the files needed to install the Electric Astrolabe under Windows (ASTRO.PIF and ASTRO.ICO). You will want to customize the installation later (see page 64). Also included is a menu file (MENU.EAM) and a number of .GIF files that make up an introduction to the astrolabe script.

The Electric Astrolabe uses extended memory for certain functions so you need to be sure that an extended memory manager such as HIMEM.EXE is installed . HIMEM.EXE is used by Windows so, if you use Windows, it will be installed already and no further action will be needed. The supplied ASTRO.PIF specifies 4 Mb of XMS memory and 400 KB of regular memory.

STARTING THE *ELECTRIC ASTROLABE*

The command line syntax for The Electric Astrolabe is:

astro [/v] [/m filepath] [/f filepath]

The Electric Astrolabe is a single program file and can be started from any sub-directory. You will generally want the ASTRO directory to be the current directory when running the Electric Astrolabe. For example, if the current sub directory is the root directory (C:\) and the Electric Astrolabe is in sub directory C:\ASTRO, you would start it with:

```
C:\>cd \astro
```

to change to the Electric Astrolabe directory . Then start the Electric Astrolabe by keying:

```
C:\ASTRO>astro
```

If you installed The Electric Astrolabe under Windows or on the Windows 95/98 desktop, just double click the icon.

Note that both NumLock and CapsLock are reset when the Electric Astrolabe is started.

The command line options, which can be keyed when starting The Electric Astrolabe from DOS or included in the Windows 95/98 shortcut properties are:

/v Start The Electric Astrolabe on the text page of summary numerical results. This is a convenience when running under Windows to allow you switch immediately to other functions if your system will not allow you go directly from the astrolabe screen.

/f Start The Electric Astrolabe using a file to initialize default settings. For example, if you have saved a file named 'HERE' with your defaults, you can start the program with:

>astro /f here

to load the defaults. This also allows you to set up as many customized versions of The Electric Astrolabe as you like and start the program with the desired set. See the section on Customization for more details.

/m Start The Electric Astrolabe in menu mode. This option is only used when The Electric Astrolabe is used in a public exhibit.. filepath specifies the path of the menu file. See the section on Menus for more details.

GETTING STARTED

The Electric Astrolabe is a DOS program (see "About the Electric Astrolabe" on page 99 for an explanation of why it is not a Windows program). The Electric Astrolabe is controlled by entering single key commands from the keyboard. The commands are generally mnemonic in that the key used for a command relates to the function to be performed (e.g. "P" turns the planets on and off). The primary display is the sky shown in the form of an astrolabe but other screens are provided for more detail on the positions of objects in the sky and to control the program.

Following is quick tour of some of the Electric Astrolabe functions to give you a feel for how to work the program and introduce you to its operating philosophy.

- Start the Electric Astrolabe. The first screen you see is the graphic display. By referring to the previous section you can get a feel for how to read it but that is not critical at this point.

- When the Electric Astrolabe is first started it shows the sky at the current date and time. That is, the date and time in the computer clock.

- The first display will be for the default latitude and longitude. You will want to change them to your location later.

- Various elements of the astrolabe display can be turned on and off using the keyboard. Press the "P" key (or "p" - either upper or lower case keys can be used for all commands). Notice that the planets are turned off on the display. Press "P" again to turn the planets back on. Turn the stars on and off with the "S". Similarly, the ecliptic display is controlled with the "E", the rule with the "R", the Messier objects with the "O" and the astrolabe plate with the "A".

- Watch the display for a little while. You will see that it is updated every minute.

- Press the PgDn key. The display will change to a screen of values showing the positions of the moon and planets. Notice that the current date and time from the computer clock are displayed on the bottom row. Press the PgUp key to return to the astrolabe display.

- Press the PgDn key several times. The display will cycle through several screens and eventually end up at the screen where you started. You can do the same thing in the opposite direction using the PgUp key.

- Put the astrolabe display on the screen using the PgUp or PgDn key. Press "V". The screen will go directly to the first page of values.

- Press Esc to return to the astrolabe. Each page has a mnemonic key that will take you directly to it. The Esc key takes you to the previous page displayed. This lets you switch back and forth between any two pages quickly.

- Press "V" to go to the first page of calculated values. You will see the date field is highlighted. Type in a new date and press Enter. You will see the values are updated for the new date. Move the cursor to another field with the Tab key and key in a value. You can move the cursor from field to field with the tab or cursor control arrow keys. When you return to the astrolabe display with Esc or PgUp/PgDn you will see it is updated for the changes you typed.

- Go back to the screen of calculated values (Esc or PgDn). Press "T". The highlighted field will go to the Time field. Press "J" to move to the Julian Day field. You can move directly to each field with a mnemonic key.

- Go to the astrolabe display and press "M". You will see the date and time displayed in the upper left hand corner. When the date and time are displayed like this on one of the graphics screens, the display is not updated automatically every minute. This is called "Manual Mode".

- Press the Big + key next to the keypad ([on laptops). The screen will move and the date and time will change. Press the Big - key (laptop]) and the display will go back to the previous value. This is a fast way to add or subtract time intervals for changing the display.

- Press "D" with the astrolabe on the screen. You will see a prompt at the bottom of the screen for a new date. Type a new date in the format MM/DD/YYYY or just press Enter to leave the date the same. You can update the displayed time directly on the graphics screen in this way. The mnemonic keys are the same as on the text pages.

- Press the "F" key. The display will begin to update quickly and you will see the date and time change. Press "F" again to stop it. This animated operation is called "Free Running Mode" which allows you watch the sky change as the time and date changes as fast as the Electric Astrolabe can run. Press the big minus key ( ] on laptops) to slow it down if it is animating too fast.

- Press "M" again to go back to automatic updating.

- Press "N" (for Now) and the display will go to the current date and time.

- Press PgUp. The screen will change to a picture of the four inner planets in their orbits around the Sun. This is the orrery display.

- Press "F". The planets will move around the Sun in their orbit. Press "F" again to stop the animation.

- Press "2". The orbit picture will change to show just the first two planets from the Sun. Press "Shift+1" on the numeric row (i.e. upper case 1). A picture of the phase of Mercury as seen from

Earth will appear in the middle of the screen. Press “F” to watch the phase change over time. Press “F” to turn off free running mode, “N” to set the time to now and “Shift+1” to remove the phase picture.

- Press Esc to return to the astrolabe display. Press F2 to set the time interval to 5 minutes. Press “X” to turn on sky shading. Go to free running mode by pressing “F”. Notice how the sky above the horizon changes color as the Sun passes through twilight and the sky is blue during daytime. Press “X” again to turn off shading, “F” to stop free running mode, F6 to set the time interval to 1 day, “N” for the current time.

- Press “3”. You will see a larger picture of the phase of the moon. Press “3” again to remove it. You can display the phases of the planets including the four bright moons of Jupiter’s first observed by Galileo and Saturn’s rings.

The steps above illustrate some features of the Electric Astrolabe. The next sections have detailed explanations of each command including many other functions.

OPERATION

Once started, the Electric Astrolabe has three modes of operation:

Automatic Mode
Free Running Mode
Manual Mode

In Automatic Mode, the time and positions of the celestial objects are updated automatically every minute. This is the standard operating mode of the Electric Astrolabe. If you leave the Electric Astrolabe in Automatic Mode it gives you a constantly updated view of the heavens that lets you see what is visible in the sky at any time. In Free Running Mode, the time and date of the display are automatically changed as fast as the program can run in increments that you specify. In Manual Mode the time is not updated automatically so you can set the time and place and study the display at leisure.

Larger scale pictures of the phase of the Moon, Mercury, Venus and Mars, the galilean satellites of Jupiter and Saturn's rings are also available at any time.

Since you will often want to concentrate on one particular area, such as planetary or stellar positions, without regard to the other displayed information, you can control the contents of the display. You can specify whether the Ecliptic, Stars, Messier objects, Planets and Moon, Rule or even the Altitude/Azimuth plate itself are displayed. In this way you can eliminate extraneous items that might otherwise clutter up the display and divert your attention from your area of interest. The display can be set for any date and time and any latitude and longitude.

You can calculate the planetary positions with very high accuracy or with lower accuracy to improve the animation speed. Precession can be applied to deep space objects (stars and Messier objects).

The Electric Astrolabe displays the astrolabe itself, the orrery and several text pages. Moving from page to page can be done using the PgUp and PgDn keys or directly as described below. Ctl+PgUp always goes directly to the astrolabe. Ctl+PgDn goes directly to the Orrery.

Calendar conversions between the Gregorian and Julian calendars are done automatically based on assumptions described below or can be controlled manually.

COMMANDS

All Electric Astrolabe functions are controlled by entering commands through the keyboard. Each command is invoked by pressing a single key. The key that is pressed is generally associated with the name of the command so they should be easy to remember. Commands can be entered in either upper or lower case. Some commands result in a prompt for additional information on graphic screens but most execute immediately without further input.

Commands can be entered at any time and in any order. Once a command has started you cannot stop it, but it is easy to recover from errors, usually just by entering the command the way you wanted it in the first place. A few terms are used in the command descriptions that need definition in order to avoid any confusion. "Current Time" means the time represented by the astrolabe display and may not be the same as the current zone time. You can always determine the "Current Time" being used from the numerical display or by pressing "M" (or "m"). In Manual Mode the time is displayed on the graphics screen. "Current Date" has a similar meaning. The current date is the date displayed in manual mode and on the text pages.

Entry of dates, times and angles are not exhaustively range checked but some validity checking is done. If an invalid number is entered the prompt is redisplayed. If you change your mind and do not want to make an entry in response to a prompt just press the Enter key and no changes will be made.

The following command descriptions are intended to complete in all particulars. The astronomical terms used are defined in the glossary. The last page of this document is a command reference.

Additional commands to control the accuracy of planetary calculations and time control are described later in this chapter.

The available commands are (in alphabetical order):

KEY	ACTION
A	Altitudes/Azimuths Display. Press "A" to eliminate display of the Astrolabe plate containing the lines of Altitude and Azimuth. Press "A" again to restore them. If the Electric Astrolabe is started with A=Off then the plate will be drawn the first time A is pressed. Similarly, if you change the latitude while the plate is not displayed, it will be redrawn the next time you press "A".
Alt+A	Display Sun only when planets displayed.
B	Display bright stars. The 33 bright stars with magnitude 2 or brighter and the entire familiar Ursa Major ("Big Dipper") and Cassiopeia constellations can be displayed with or without the constellation display (See S below). Press "B" to display the bright stars and "B" again to turn them off. The list of bright stars is in Appendix A.
Alt+B	Display all stars. Alt+B controls how constellations are displayed. When "On", all stars are displayed as a white dot. When off, only the constellation outlines are displayed. Alt+B is independent of the bright star (B) and star (S) display.
C	Go directly to Program Control page (see Text Pages).
Alt+C	Go directly to page of cities and inserted objects (see Text Pages).
D	Date. Press "D" to enter a new date. Dates are entered as MM/DD/YYYY. For example, 9/21/1949. Note that the entire year must be entered. Entry of years BC are preceded with a minus sign (e.g. -333). Dates giving a negative Julian day are not supported and the results of such a date are unpredictable. N.B. Scholars and astronomers use different date conventions. Scholars count dates backwards from year 1 as 1, 1 BC, 2 BC, 3 BC, … Astronomers count the same years as 1, 0, -1, -2, ... For example, a date shown as 5 BC in a reference will normally be entered as -4. This convention is required for consistent numerical results.
E	Display Ecliptic. The E key controls whether or not the ecliptic is displayed.
Ctl+E	Ctl+E adds labels in the form of the traditional zodiac signs to the ecliptic display. The labels can be turned on and off whenever the ecliptic is displayed. The zodiac symbols can be an aid to reading the position of the Sun or a planet in the ecliptic. Use of these symbols is traditional on astrolabes and is certainly not intended to relay any astrological connotation (they can, however, be used in an astrological sense if you are so inclined).

F Free Running mode. When you press the “F” key the display will be updated continuously, as fast as the program can execute. The time interval for each advance of time is the current setting of the time interval (see the F1-F12 command). The interval can be changed at any time. All commands are active during Free Running mode. If you press “M” for Manual Mode the animation will stop and the date and time are displayed. Press “F” again to return to the mode that was active before starting Free Running mode.

If you have a very fast computer the animation may be too fast for you to follow, particularly on the orrery. You can adjust the speed of the animation in free running mode using the big + and - keys on the keypad and ([,] on laptops). (see Big +/- below).

G Gregorian/Julian Calendar. The “G” key is used to force calendar dates to be calculated according to either the Gregorian or Julian calendars. All dates prior to October 15, 1582 are set to the Julian calendar and cannot be changed. Dates after October 15, 1582 can be represented in either the Julian or Gregorian calendar. When the Julian calendar is in effect a “J” is shown next to displayed dates on all pages. See the Glossary for additional information on the Gregorian and Julian calendars.

H Help. Pressing “H” will cause the help page showing the command keys to be displayed directly. This page also shows the current setting of the time interval and the display control commands.

Ctl+H Star Positions. Display page of star coordinates and current position.

I Display .GIF image file. .GIF (Graphics Interchange Format) image files are in a format defined by CompuServe. The image file name is specified on the Program Control page. To specify an image file for display, go to the Program Control page, type a file name of the file type .GIF in the File: area (e.g. M31.GIF), move the cursor to the Action: field, press Enter until the option IMAGE appears and then press Ctl+Enter. This tells the program the name of the active image file. To display the .GIF file, press “I” on the astrolabe screen. Press any key to return to the astrolabe display (pressing “I” again will show a page of information about the file just displayed; File name, image width and height and display mode and the image’s color map used to display the image). The image will be redisplayed whenever you press “I”. There are literally thousands of astronomy images available in the .GIF format. If you have an image file that not in the .GIF format, most programs that can display graphics are able to export in the .GIF format. **NOTE: Image displays can be invoked only from the astrolabe display.** See Images, page 44.

Alt+I Save a bitmap image of the screen. Alt+I will save a Windows Bitmap (.bmp) file of the current graphics screen content on either the astrolabe or orrery screen. The file name is specified on the Program Control page and must have an extension of either .BMP or .bmp. See Images, page 44.

L Latitude/Longitude. When you press “L” you will be prompted to enter a new latitude and longitude. The plate will be redrawn if the latitude entered is different than the latitude currently displayed . Changing the longitude will affect the sidereal time and the altitude/azimuth of the celestial bodies. The date and time are adjusted for the new location. You can label the plate with a place name if you like.

It is interesting to note that if the longitude being displayed is at the center of a time zone then the Equation of Time can be estimated by the difference in the location of the Rule and the Sun image. Also, if the longitude is set to zero (see “0” below), then the sidereal time is Greenwich Sidereal Time and if you set universal time to midnight (00:00), you

can display the values calculated at 0 UT, in order to compare the calculated values to those tabulated in the Astronomical Almanac and magazines.
One additional note about the effect of changing the longitude: The Electric Astrolabe program keeps track of Universal Time, and calculates current time--the time of the current display--by subtracting the number of hours for the displayed time zone from universal time. By changing the longitude into a new time zone, the time displayed is just an adjustment of Universal Time, which has not changed. This lets you see the position of the sky in different places at the same physical time. If you want to see the sky at a specific local time, change the time displayed using the T (Time) command. (See Home Zone on the Program Control page.)

One must keep in mind that time zone estimates are based strictly on longitude and may not reflect political divisions accurately. If the time zone selected by the Electric Astrolabe is not correct, press the "Z" key to change the zone. Note that the time zone entered is the Standard time zone difference from Greenwich in hours; the amount that is added to local time to get UT (see Z below).

Southern latitudes are entered as negative numbers. Enter 35° 25′ S as -35 25.

There are many sources for latitude and longitude information. City locations can be found in any good atlas. You will want as precise a location as possible for your home location. Good sources are geodetic survey maps and sectional maps used by pilots. Various mapping programs and internet facilities can provide very accurate positions. For example, De Lorme Street Atlas will provide an accurate latitude and longitude for almost any street address in the United States. Given a choice, it somewhat more important to have an accurate longitude since longitude defines local sidereal time.

M Manual Mode. While in Manual Mode the display is not updated automatically each minute. Manual Mode allows you to control the update time interval and to search for the time and date of specific celestial events. When you press "M," the current date and time will appear in the upper left hand corner of the screen. From this point on, as long as you stay in Manual Mode, the display is updated only when you press the + or - keys on the keypad (Big+ and Big-) or you enter a command that changes the display. When the + key is pressed, time is advanced the number of units specified by the current interval values and when you press - , time is moved backwards by the same amount. For example, if you specify an interval unit of 10 days, each time you press + or - the display is updated to a date 10 days before or after the previous display. The current value of the interval is shown on the Help page (see "H" command).

When you leave Manual mode the time is set to the current system clock time.

Manual mode is set automatically when the date or time is changed.

The date and time are displayed in color 7 which is the color of the Messier objects. This is normally a light gray which is readable without being too bright. If you change the background color to a value that makes the date and time hard to read you may want to change color 7 to a color with greater contrast.

Ctl+M Control the Electric Astrolabe from a menu file (see Menu Files, page 69). To specify the name of the menu file, change the File: name on the Program Control page to the name of the menu file and select MENU from the Action: options with Ctl+Enter. The menu file name specified will be used when the menu is activated with Ctl+M. **NOTE: A menu can be activated only from the astrolabe screen!**

N Now. When you press "N", the display is updated to the time and date in the computer clock. The Now command is useful to get you back to a current display if you have been using one of the modes that changes the date and time. The current system clock date and time are displayed on the Help and Values text pages.

Sources for setting your computer clock to an accurate value include the NIST time signal broadcast on WWV at 5, 10, 15, 20 and 25 MHz, the Canadian time signal on 7.033 MHz, the Weather Channel on cable television and hourly time hacks given by some radio stations. The Windows XP function of automatically updating the system clock from reliable sources has made this consideration pretty easy.

Alt+N Reverse projection. Changes projection from north to south or vice versa. See Alt+P for a discussion of how changing the projection affects precessed star positions.

O Display Messier Objects. All Messier objects can be displayed using the "O" key. Five types of Messier objects are displayed:

Spiral galaxies - displayed as a little spiral galaxy that, if you use your imagination, looks a little like the real thing.

Globular clusters - displayed as a loosely filled circle.

Open (galactic) clusters - displayed as a sparse circle with nothing inside.

Nebulae - shown as a rough circle made of vertical gray bands. The easiest nebula to find is the one in Orion's sword (M42).

Elliptic galaxies - shown as a small, highly eccentric ellipse.

A complete list of all of the Messier objects and their coordinates is in Appendix A.

Alt+O Messier objects range in brightness from a magnitude of 2 (the Pleides) to 11. The brightness range of the objects displayed can be selected using the Alt+O combination. You will be prompted to enter the magnitude of the dimmest objects you want displayed. For example, if you enter 6 in response to the prompt, all Messier objects of magnitude 6 or less will be displayed. The default value is 8 since all celestial objects with a magnitude of 8 are easily observed with a small telescope. Only integer values of magnitude are supported. The Messier object magnitude can be specified only on graphic pages.

Ctl+O Press Ctl+O to display the Messier object number instead of the symbol. The location of the object is in the center of the units digit. For example, 42 is displayed for the Orion Nebula, M42. The location of the nebula is in the center of the 2. You can switch between object symbols and numbers by pressing Ctl+O repeatedly. Symbols for added objects are not affected by Ctl+O. It is generally easier to see the Messier object numbers if the plate, ecliptic and planets are turned off. Due to the clusters of Messier objects in some areas it can be difficult to read some of the numbers. In some cases this can be alleviated by adjusting the displayed magnitude unless the object is comparatively dim.

P Planet Display. Press P once to remove the planets from the display and press P again to restore them. The planetary images are:

Sun	Yellow disk

Mercury	Small light gray disk
Venus	Small white disk
Mars	Small red disk
Jupiter	Larger banded disk with red spot
Saturn	Peach colored disk with yellow rings
Uranus	Larger cyan disk
Neptune	Larger brown disk
Moon	Larger circle. The phase of the moon is shown.

The planet's position is at the center of the image. The planetary positions shown are calculated whenever the time changes. The values shown are for purely Keplerian orbits, unaffected by perturbations. That is, the gravitational pull on one planet by other planets is not considered in the planetary position calculations. This causes little error in the inner planets, but the outer planets will be affected somewhat more. The accuracy of the calculations is more than adequate for the screen resolution. Significant perturbations in the moon's orbit **are** included in the lunar calculations.

See Planetary Calculations below for information on higher precision calculations.

Alt+P Precession switch. When the precession switch is ON, precession will be applied to stars and Messier objects at each time update. When this switch is OFF, precession is not recalculated and stellar positions are displayed for the initialized positions. When the Electric Astrolabe is started, stars and Messier objects are precessed to the time in the system clock. Similarly, when a set of defaults is LOADed or RESTOREd when precession is set ON, precession is applied to the default date. Note that Here (=) and Now (N) do not do a RESTORE. Therefore, it may be necessary to do a RESTORE to set precessed star positions to their initial values if a default file has been LOADed. Turning the precession switch ON causes precession for the current date and time to be applied. Thus, precession can be calculated at any time by turning the precession switch ON. The use of precession has an observable performance impact. It is generally simpler to FILE and LOAD files with precession set ON, particularly for events far in the past or future. Also, since the star and Messier object positions are initialized to J2000.0 values, precession has no visible affect on displayed star positions for recent dates.

The Electric Astrolabe keeps two sets of star positions for complete flexibility when comparing positions over long periods of time. The set of precessed positions is updated each time the screen is displayed. The other set of positions is calculated only when the Electric Astrolabe is started, on a LOAD or RESTORE with precession set OFF or when changing between the north and south projection. If the two sets of positions seem uncoordinated, set the astrolabe to the desired date and switch between projections with Alt+N.

See the section on added objects (page 54) for a discussion of how added objects are affected by the precession switch.

Precessed star and Messier object positions are rigorously calculated, but proper motion and nutation are not considered by the Electric Astrolabe for star positions.

It is interesting to play with precession by setting the interval to a "sidereal year" of 365.997930 days or a "sidereal century" of 36524.997930 days and watching the stars precess around the ecliptic pole but BEWARE! On July 17, 14960, the eccentricity of Saturn goes to zero and the calculations for Saturn are nonsense from that point on. In any case, you can see Vega become the pole star in about 12,000 years. Note that none of the calculated positions are valid this far in the future. Also recall that large negative Julian days will also cause the program to hang.

Ctl+P Label planets. As an aid to becoming familiar with the planets on the astrolabe display, you can display the planet names by pressing Ctl+P.

Q Quit. Press "Q" to end the program.

Ctl+Q "Quiet" mode. Press Ctl+Q once to eliminate showing the date and time in manual mode and press again to show date and time. "Quiet" mode is useful in menus to avoid showing the time and date when they are not relevant to the menu display.

R Rule Display. Press "R" once to remove the Rule from the display and press "R" again to restore it. The Rule shows you the current zone time. Note that the rule is divided by each five degrees of declination thus allowing a fair estimate of the Sun's declination on any date. The point where the rule crosses the ecliptic is the position of the fictitious mean Sun used to determine zone time and to define the Equation of Time. Remember that positive declination is toward the center of the display.

Ctl+R Display a rule that extends across entire face of astrolabe, centered on the Sun. The long rule points to the current local apparent solar time on the limb. The normal rule points to the current local zone time. The unequal hour arcs are defined by local apparent solar time, therefore a rule that points at the Sun is needed to find the unequal hour. The unequal hour during the day is found by the point where the long rule crosses the ecliptic below the horizon. During the day this will be the point on the ecliptic that is opposite the Sun (the Sun's nadir) and at night is the Sun itself. The long rule is useful anytime it is desired to find apparent solar time. For example, if you set the location to the center of a time zone and the time to noon, you can read the value of the equation of time directly from the long rule. Note also that, since the long rule points to the Sun, you can estimate the Sun's declination from the tic marks on the rule. Also, the moon or a planet is near conjunction or opposition (depending on latitude) when it is on the long rule. You can get close to lunar and planetary conjunctions/oppositions graphically with the long rule.

The long rule can be rotated freely around the astrolabe using Ctl+ the keypad + or - (Ctl+[and Ctl+] for laptops). Pressing Ctl+ the keypad + or - will move the long rule one time interval ahead or behind its current position. The long rule can be positioned quite accurately with the time interval set to 1 minute (F1) or 1 second (F11). The long rule returns to the Sun on leaving Manual Mode. Keep in mind that the long rule will not move if the time interval is set to 1 day.

The long rule can be used to estimate the declination of any object displayed within the astrolabe plate and to find planetary conjunctions and oppositions near the ecliptic or to mark a position in the sky.

S Star Display. Press "S" once to remove the display of the constellation asterisms. Press "S" again to restore them. See Alt+P for precession considerations. See also "B" and "Alt+B".

Alt+S Sidereal Time. Press Alt and S together to set the sidereal time. The astrolabe display will be updated to the time on the current date when the selected sidereal time occurred or will occur. Note that the time displayed may be either earlier or later than the time that was current when the command was entered.

Ctl+S Label stars. You can display the constellation names with Ctl+S as an aid to learning the constellation asterisms used by the Electric Astrolabe, . The constellation names display can get a little congested due to the number of names and their lengths. Just rotate the star field until the name of interest is clear. Also, it is easier to associate the names and asterisms if only the stars are displayed. This function is needed only when first getting familiar with the Electric Astrolabe.

T Time. When you press "T" you will be prompted to enter a new time in 24-hour format (i.e. 4:00 PM is represented by 16:00). The next display refresh will be at the specified time on the current date. The colon is not required but there must be some character between hours and minutes (such as a space).

Alt+T Display time shown in manual mode in 24 hour or AM/PM format. The default is 24 hour format. Press Alt+T to switch between formats.

U Universal Time. When you press "U", you will be prompted to enter the Universal Time. The display will be updated to the UTC entered for the current location. Caution should be observed with the date if the date at Greenwich is different than the date at your location at the UT specified. The updated display will be for UT entered on the current date.

Ctl+U Display unequal hour arcs. Ctl+U toggles the display of the unequal hour arcs. When the unequal hour arcs are on, it is generally useful to use the long rule (see Ctl+R above).

V Display calculated values. Pressing "V" will cause the page of calculated values to be displayed directly. See the section on text displays.

Alt+V Display complete calculated values. Pressing "Alt+V" will cause the page of complete planetary calculations to be displayed. See the section on text displays.

X Shading. When shading is turned ON the sky above the horizon will change color depending on the altitude of the Sun. When the Sun's center is above the horizon the sky is blue. During twilight it is a shade of gray. When the Sun is below nautical twilight the sky is black. Civil sunrise/sunset is defined as when the Sun's upper limb is on the horizon which is when the Sun's center is approximately 0.835° below the horizon. Shading changes from light gray to light blue when the Sun reaches this point as an aid in finding the time of sunrise/set. See the discussion of colors in the section on the program control page.

Z Time Zone. Press "Z" to change the standard time zone for a location. For example, Paris, at longitude 2° 20′ East, would be calculated as being in the same time zone as Greenwich (0°) when in fact Paris is on Continental Time, which is one hour earlier. To set the correct time zone for Paris you would enter -1 in response to the prompt. The time zone convention used by the Electric Astrolabe is, "How many hours do I add to my time to get UT?" which may not be the convention you are used to.

Note: *There are (Iran and Australia) and have been (Hawaii in 1941) places with non-integer time zones. This version of the Electric Astrolabe supports only integer times zones in order to simplify the displays.*

1-6 Display Planet and Moon Phase. When you press one of the digits "1" through "6", a larger picture showing the phase of the Moon or one of the planets is drawn in the color of the planet or moon on the astrolabe display. North is at the top of the picture. The accuracy of the picture, in terms of the position of the illuminated disk, is exact within the limits of the resolution of the display. Pressing the "5" key gives you a picture of the positions of the four galilean moons of Jupiter. The jovian satellites can be identified by the size of the orbit or by color. The default colors are:

Io (I) - Red (color 10)

Europa (II) - White (8)

Ganymede (III) - Yellow (14)

Callisto (IV) - Cyan (12)

Pressing “6” displays Saturn’s rings. The picture appears as Saturn would be seen through binoculars with north at the top. Note that most Saturn drawings in astronomical literature show it as is would appear in a telescope; upside down and with left and right reversed (i.e. with south at the top). The Saturn picture clearly shows the A-ring, Cassini’s division, the brighter B-ring and the dusky C-ring. The relative sizes of the rings and planet are only approximate but are accurate to the display resolution.

Press the same number to remove the phase picture.

All commands are active when the phase picture is displayed. For example, If you press the big plus or minus keys, time will be changed by one time interval and the phase updated. In free running mode the phase picture is updated with the display. It may be necessary to remove parts of the astrolabe display to get a clear picture of the changing phase in free running mode. In fact, the animated display of Jupiter’s moons looks best when it is the only thing displayed. It also works well on the orrery screen but you might want to restrict the planets displayed to only Mercury to avoid having the other planet images flash. The best time interval for animating Jupiter’s moons is 30 min.. depending somewhat on the speed of your computer.

See the Phase= setting on the Program Control page in the next section to see how to change the size of the phase pictures.

7 Lunar eclipses. Press 7 on the astrolabe screen to display the Earth’s shadow at the current distance to the moon and, if it fits in the screen, the full moon. The large gray circle is the Earth’s penumbra. The smaller black circle is the Earth’s umbra. An eclipse is a penumbral eclipse if any part of the moon enters the penumbral shadow. An eclipse is a partial eclipse if any part of the moon enters the Earth’s umbral shadow. In a total eclipse the entire moon is hidden in the umbra. For an example of a total lunar elipse set the Julian day to 2449497.64008.

You can watch a lunar eclipse develop by using the time interval keys and big +/- to step through the eclipse.

It is easy to find lunar eclipses. A lunar eclipse occurs when there is a full moon and the moon is near one of its nodes. The short yellow and white line near the center of the astrolabe points to the moon’s orbital nodes. To find an eclipse, first find a full moon. Then set the time interval to F10, one average lunar synodic period. Turn the long rule on (Ctl+R). Then space using the Big + or - key until the rule is close to the line of nodes. If the rule lies right on the line of nodes there will be a total lunar eclipse. If it is close to the line of nodes there will be a penumbral eclipse or a near miss. When you find a full moon that is near the nodes, press 7 to see what you have. You can adjust the time interval to 30 minutes (F4) or an hour (F5) and move through the eclipse as it develops. It is instantly obvious from the astrolabe display if the eclipse will be visible from your location.

The eclipse display is accurate, but you may not get the exact times published in the Astronomical Almanac because the shadow and moon images cannot be shown with absolute precision and it is not possible to determine the exact instant that an event occurs from the display. You will be able to recreate any lunar eclipse to within a few minutes.

Esc Display previous page. The Escape key will cause the previously displayed page to displayed again. Using Escape you can jump back and forth between two pages directly without going through the intermediate pages. This is an extremely useful function when investigating a particular event.

0 Longitude zero. Pressing “0” adjusts the longitude to 0° without changing the latitude. By setting UT to 00:00 and setting the longitude to 0° you can compare the astrolabe output to the values that are tabulated in the Astronomical Almanac and astronomy magazines with minimum effort. Use “Here” and “Now” to return to your location and time (see “=” and “N”). The “0” command works only on the astrolabe display page.

= Here. Display the Electric Astrolabe for the default latitude and longitude. Pressing “=” followed by “N” gives “Here and Now”. This is a shortcut to get you back to your original location without having to reenter the latitude and longitude each time. The default latitude and longitude are the ones for the first city in the list of cities and are the same values used when the Electric Astrolabe is initially started.

; and ‘ Daylight Savings Time. The “;” key allows you to turn DST on and off. Some locations do not observe DST and there are periods in every year when it may be advantageous not to use DST. Daylight savings time has had an erratic history. It is prudent to check whether daylight savings time was in effect on a specific date in the past. “;” allows you to disable DST entirely. Press “;” again to reactivate DST. The Electric Astrolabe attempts to set DST for the current date. DST is set automatically if the time and date is between 0200 on the first Sunday in March and 0200 on the last Sunday in November. Some areas do not observe daylight savings time or use a different schedule. The ‘ (single quote) can be used to disable automatic DST setting. When disabled with the quote key, DST must be set manually.

BIG +/ ([,]) Change time by one time interval amount. The Big+/- keys are the keypad + and -. You can advance or retard time by one time interval (see F1-F12 below) at any time. Big+ adds the time interval to the current UT and Big- subtracts it. See M for manual mode considerations. Most computers have a way to change the keyboard repetition rate or you can set the rate with the Windows Control Panel keyboard function. Most laptop computers do not have the keypad. The [and] keys perform the same function for use on laptops

In free running mode the big + and - keys are used to speed up and slow down the rate of animation. Press Big- several times to slow down the display. Big+ will speed it up again. This function is useful if you have a very fast computer and the animation is so fast that the screen is updated faster than the display refresh rate causing part of the display to blank out or if you want to slow down the animation in order to watch some event more easily. Each keypress changes the time between screen updates by 20 msec.

See Ctl+R for moving the long rule using Ctl+ Big +/-.

F1-F12 Interval Specification. The Electric Astrolabe sets the intervals to be used for manual and free running display updates using the functions keys. One of these function keys can be pressed at any time to make a new interval update value effective. The intervals set by the function keys are:

F1 = 1 minute (0.000694 days)
F2 = 5 minutes (0.003472 days)

F3 = 10 minutes (0.006944 days)
F4 = 30 minutes (0.020833 days)
F5 = 1 hour (0.041667 days)
F6 = 1 day
F7 = 5 days
F8 = 10 days
F9 = .997269568 day (one sidereal day)
F10= 29.53059 days (one lunation, tropical month or synodic period)
F11= 0.000011574 day (1 second)
F12 = 365.242191 days (one tropical year)

The Alt+Fn key is the negative of the values above. For example, Alt+F2 sets the interval to -5 minutes. A negative value reverses the sense of the big +/- keys and causes time to decrement in free running mode which lets you go backwards in time.

The current interval setting is shown on the Help screen. If you change the interval shown on the Help (Command Summary) page by keying in a new value, this value replaces the F10 value and negative of the same value replaces the Alt+F10 value.

The primary value of the interval setting is to look for some specific condition. For example, if you want to find the time of Sunrise you might initially press F5 to set the interval to 1 hour and then position the Sun near the eastern horizon using the Big+ key. Then set the interval to some smaller increment such as 1 minute to position the Sun more precisely.

F6-F8 are useful for finding events on a longer time scale. For example, if you would like to find the synodic period of Venus, for example, you might set Venus at conjunction using a one day interval and then set the interval to 5 days, go to free running mode and stop the update when Venus is close to the next conjunction and fine tune the display with shorter intervals as needed.

Judicious use of the interval setting, the display contents and free running mode gives opportunities to watch some interesting astronomical phenomena. For example, if you put the Sun on the meridian, set the interval to one or five days and let the display run free you can watch the Sun trace out the analemma for your latitude and longitude. This analemma is the basis for the definition of the Equation of Time. You can also watch the outer planets go from posigrade to retrograde motion and back. This is most easily seen by restricting the display to the planets and stars. When a planet is in retrograde motion it will move clockwise relative to the stars.

The values set by F9-F12 can be used in interesting ways. Setting the interval to a sidereal day keeps the stars in the same place on the screen each time increment and lets you see the planets move in the star field. This is an easy way to observe planetary phenomena such as posigrade and retrograde motion. The Draconitic period and period of a lunation allows an easy way to look for eclipses (see glossary). As stated above, you can set the value for F10 by changing the interval displayed on the Command Summary (H) page.

N.B. Not all computers use F11 and F12 in the same way. If you have trouble it may be more convenient to set these values on the Command Summary text page.

Ctl+F1-F12 Fast city change. Pressing Ctl + one of the function keys is a fast way to change between cities that are of frequent interest. The city is selected from your list of cities (see Alt+C) in the order of the function key number. That is, F2 selects the second city in the list, F3 the third city and so on up to the twelfth city. Note that Ctl+F1 serves the same function as =.

PLANETARY CALCULATIONS

The Electric Astrolabe will calculate the positions of the planets in two ways:

- Using classical formulas derived from Kepler's theory of planetary motion. In this method, the orbital parameters (eccentricity, inclination, etc.) are derived from polynomials based on the Julian date. The planet's position in its orbit is then calculated from the basic orbital parameters and converted to geocentric measurements (right ascension and declination). The results are the pure Keplerian orbits, unaffected by perturbations. The instant for the calculation is the Julian date. The calculations are very fast but of low accuracy, particularly for the outer planets. The Moon's position is calculated with significant perturbations included but is still of low accuracy by astronomical standards. This calculation technique is useful for graphical display and animation on a slower computer.

- Higher precision positions can be calculated using the full VSOP87 method as described in *Astronomical Algorithms* by Jean Meeus (Willman-Bell, 1991). The results are corrected for nutation, light time and aberration and are generally within an arc second of the values in *The Astronomical Almanac*. UT can be corrected for dynamical time as a user option (see Dynamical Time below). The computational overhead is about 100 times that of the lower precision calculation and the speed of animation is greatly reduced. The higher precision calculations are selected with Ctl+X. The calculated values are valid for several thousand years in the past or future.

Following are some considerations for selecting the calculation method.

- You will usually want to use the higher precision planetary positions on the graphical displays even though the display resolution is not sufficient to reflect the very slight differences in position resulting from using the higher precision calculations except for the outermost planets. The calculated differences are usually a few tenths of a degree for the outer planets and less for the inner planets.

- Animation speed is reduced by a factor of about three when using the higher precision calculations and the slight position differences cannot be seen during animation. This can actually be an advantage on a very fast computer because the high precision calculations might slow the animation rate to an acceptable speed.

- If one of the purposes of using the Electric Astrolabe is education about how orbits are calculated then you will want to use the Keplerian orbits. The VSOP87 method calculates the ecliptic latitude, ecliptic longitude and distance from the Sun from which the apparent positions are derived. The true and eccentric anomalies are derived from the ecliptic coordinates and are not exactly the same as those derived from first principles.

In general, the higher precision calculations are needed when you are looking for some specific event such as the exact time of an eclipse or a conjunction. For fun, look at February 27, -1952 at about 07:00 UT and enjoy the fantastic conjunction of all the planets out to Saturn.

It is strongly suggested that you have a copy of the Astronomical Almanac handy when you are using the higher precision calculations in order to have access to the precise definitions for the values displayed. For example, if you want to confirm the length of the tropical year, high precision calculations must be OFF because the tropical year is defined by mean values, not apparent values. Also, eclipse conditions are presented with the Julian date as an instant in UT, not dynamical time, so you will have turn dynamical time OFF to recreate the positions. Such subtle differences in measurements can be very confusing if you do not have access to the proper reference material and may be confusing even if you do.

Following are keys used to control higher precision planet calculations:

Alt+X Change planet images to a small "+" ("X" for the Moon). Displaying the planetary positions with the "+" lets you see exactly where the center of the planet is (to the resolution of the display). This lets you test certain conditions, such as conjunctions, with greater confidence. The Electric Astrolabe is not accurate enough for occultation work but you can get a better feel for exactly where a planet is when its position is shown in cross hairs. The "+" is the same color as the planet except for Jupiter which is mixed blue and white. Use Ctl+P to label the positions if you are not sure which planet is which. Press Alt+X again to return to the planet images.

Ctl-X Use higher precision planetary position calculations. When Ctl+X is selected, the pages of calculated values reflect the higher precision calculations. In addition, a page of calculated positions is inserted in the sequence of text pages and can be accessed directly with Ctl+V. The planetary positions can be changed to a small "+" with Alt-X. The position of the Moon is calculated to very high precision. A small block is displayed on the bottom line of the pages of numerical values when higher precision calculations are being used. Star positions are not corrected for nutation and the annual aberration when higher precision planet calculations are in effect. To return to the lower precision calculation press Ctl+X again**.**

Ctl+V Display the page of higher precision planetary calculations. No action is taken if higher precision calculations are not in effect (Ctl+X). Planetary positions on this page are shown in degrees (or hours), minutes and seconds to match the format used in The Astronomical Almanac. Longitude and latitude are ecliptic longitude and latitude. Geocentric positions are apparent right ascension and apparent declination (i.e. corrected for nutation and aberration).

DYNAMICAL TIME

Time measurement is perhaps the most complicated part of positional astronomy. Astronomers want time to flow in an constant stream, unaffected by physical uncertainties, in order to compare observations. They adopt more precise time measurement technology as it becomes available in order to approach this goal. In the process, they create new levels of confusion for astronomical calculations. The concept of dynamical time, which is based on atomic clocks, was adopted in 1984 and comes close to the astronomical ideal for time. However, the use of dynamical time causes astronomical time to be out of step with civil time which is based on the slightly irregular rotation of the Earth. The difference in dynamical time and civil time (UT) is based on the equation $\Delta T = TDT - UTC$ where TDT is Terrestrial Dynamical Time and UTC is Universal Time. ΔT is usually expressed in seconds.

The magnitude of ΔT varies with the year and is unpredictable for the future. Values for ΔT have been determined as far back as 1620, which is the earliest that reliable observations existed on which to confirm the values. These values are listed in *The Astronomical Almanac*. For 2008, ΔT was 65.46 seconds. The exact value for 2009 will not be known until precise observations are processed but 65.7 sec. is estimated.

Astronomical calculations are performed for an instant in dynamical time. This instant can either be specified directly by stating a specific Julian date or the Julian date can be derived from the year and UT. The Electric Astrolabe supports dynamical time. ΔT is determined by various methods depending on the year. For years between 1620 and 2013 the value is looked up in the table as printed in *The Astronomical Almanac*. The exact value for a date is interpolated linearly within a year. For values after 2013, ΔT is estimated as increasing at the rate of 1 second per year. For dates before 1620, DT is estimated using formulas due to F. R. Stephenson and M. A. Houlden. The value of ΔT is quite large for times in the distant past; more than 15 hours for year -2000. The date of a calculation can get confusing when the date in dynamical time is different from the date in UT. The date shown is always derived from UT. To determine the date in dynamical time, turn off dynamical time and enter the desired Julian date. The exact value used is shown on the Help screen in seconds. The rounded value is shown on the value screens.

There are situations where you might find it more convenient to ignore dynamical time. You can turn the use of dynamical time on and off with Ctl+T. When dynamical time is in effect the symbol "Δt" is displayed next to UT on the text pages. The value of DT in use for a specific date is showed on the page of higher precision values (Ctl+V). This value is set to 0 if dynamical time is off. You will normally want dynamical time ON. The UT for computed values is the value of UT shown when dynamical time is ON.

CTL+T Use dynamical time adjustment. Default is ON. Press CTL+T to turn off the correction for dynamical time. The Julian date is always calculated from the date and UT. The Julian date will change when DT is turned on and off and the UT will stay the same.

The Julian day shown is the one used in calculations. If you are comparing the calculated results to a source that uses JDE (ephemeris time), turn dynamical time off and enter the exact JDE. For results based on UTC, turn dyanamical time on.

In a later chapter we will discuss how to use the Electric Astrolabe to solve astronomical problems.

For what it is worth, a major failing of many popular astronomy programs is lack of consideration for dynamical time. This oversight leads to meaningful differences in calculated positions.

IMAGES

The Electric Astrolabe will display images in the CompuServe .GIF format (Graphics Interchange Format). There are many thousands .GIF files in circulation and many can be downloaded for bulletin boards and on line services. The .GIF format is widely available and very efficient for scanned images.

The content of the graphics screens can also be saved as a Windows Bitmap file.

.GIF FILES

.GIF files conform to a standard defined by CompuServe. .GIF files are compressed so they take as little disk space or transmission time as possible. .GIF files normally contain 256 color images but it is possible to store monochrome and 16 color images in this format. .GIF files do not require a specific display mode. The Electric Astrolabe chooses the display mode depending on the image dimensions and number of colors as follows:

Rows	Columns	Colors	Mode
<320	<200	N/A	320x200,256
320	200	N/A	320x200,256
>320	<=400	256	640x400,256
>320	>400	256	640x480,256
Any	Any	16	640x480,16

The 320x200,256 color and 640x480,16 color modes are available on any VGA equipped computer. The 640 column, 256 color modes require an SVGA graphics controller card and a VESA interface program. Interlaced images are supported.

The Electric Astrolabe attempts to use the VESA Video BIOS Extension to display images. If your computer does not natively support VESA, it probably came with a DOS program to provide the correct interface. Lack of an installed VESA extension is the most common reason for image display problems. .GIF images can be displayed in two ways: one at a time from the astrolabe screen or in groups using a menu file. If you want to display a single .GIF image, follow the steps below:

1. Go to the Program Control page (C) and enter the file name in the FILE field.
2. Then go to the ACTION field and select IMAGE and press Ctl+Enter.
3. Return the astrolabe screen and press I to display the image.

In a menu file, an image will be displayed when an I command followed by the file name is encountered (see Menus, page 69).

.BMP FILES

A copy of the graphics screen contents can be saved to a Windows Bitmap file (.bmp). The bitmap file can then be converted, if needed, to a .gif or other graphics format for inclusion in a document or presentation using any of the large number of graphics file conversion programs available.

The file name must be specified before creating the screen copy. Enter the file name in the File: field on the Program Control page. The file extension must be either .bmp or .BMP. Simply enter the file name and press Enter to store it. To save the bitmap image, go to one of the graphics screens and press Alt+I. The saved file will be 151 Kb (153,718 bytes). A .gif file created from the .bmp file will be about 20 Kb. An error message will be posted on the Program Control page if the file extension is not correct.

To get a round astrolabe or correct orbits on the orrery page, the Aspect Ratio on the Program Control page must be set to 1.000 before saving the screen. You may find that you will want to change the screen colors before saving the screen if you will be using the image in a document. In particular, a light gray background looks better on the page and the colors of other elements may need to be changed to provide adequate contrast. Note that color 7 is used for the Manual Mode text, which may need to be darkened for the image.

SAVE/RESTORE and LOAD/FILE

SAVE/RESTORE and LOAD/FILE are described in detail in the next chapter (page 60). This section is a brief introduction to the concepts.

SAVE and RESTORE is the process of temporarily saving the current state of The Electric Astrolabe. SAVE copies all of the program settings to an internal storage area. RESTORE copies the most recent set of settings that have been SAVE'd. The initial settings are SAVE'd when The Electric Astrolabe is started so there is always one set of SAVE'd values. You might want to RESTORE the initial values if you have been experimenting with colors or screen contents and want a fast way to return to the initial settings. SAVE is also a good way to temporarily store a screen configuration that you want to recall.

SAVE and RESTORE have a special use when working with dates far in the past or future. Some astronomical values such as the obliquity of the ecliptic or the longitude of perihelion change very slowly and are not recalculated each time the display is updated. The entire Electric Astrolabe is recalculated when the state is RESTORE'd. RESTORE can be used to make sure these values are calculated for the time of the display. For example, if the Electric Astrolabe date is set to year -2800, the planets will not be on the drawn orbits on the orrery because the orbital values have changes so much over nearly 5000 years. Simply do a SAVE followed by a RESTORE to recalculate the orbits.

The altitude labels on the plate are not shown when a RESTORE is performed and shading is set OFF. This allows a clean printout without the areas above the horizon being obscured by the shading color.

All SAVE'd values are lost when The Electric Astrolabe is stopped.

FILE allows you to save Electric Astrolabe settings permanently. To save a particularly interesting celestial configuration, specify the name of the file you want to save into in the FILE: field of the program control page and select FILE in ACTION: field. A small file will be written that contains the necessary information to recreate the event. LOAD loads settings that have been FILE'd.

If the FILE: field is set to ASTRO.EXE (the default), the settings will be added to program execution file. All values in effect when performing a FILE to ASTRO.EXE will become the program defaults each time the Electric Astrolabe is started. Note that a FILE to ASTRO.EXE will also save the list of cities and added objects (see Customizing on page 64).

TEXT DISPLAYS

"The purpose of computing is insight, not numbers", Richard Hamming, Bell Labs

The astrolabe is a geometrical model of celestial motion while the more familiar astronomical tables are an arithmetic model. The answer to just about any problem that can be addressed with an astrolabe can be read directly from the graphic astrolabe display. But, in this increasingly digital world, there seems to be added comfort in seeing the actual values rather than interpreting an analog display. The arithmetic model has replaced the geometric model in modern culture.

The Electric Astrolabe acknowledges this fact by providing text displays of calculated values. Examples of the text displays are shown in Figures 10 through 15. Definitions of all terms used are in the glossary. The first page is a summary of calculated planet and lunar data. The lunar detail is for eclipse prediction and definition of the moon's phase. The second page contains the complete calculations of the planetary positions and is useful for reconstructing specific planetary events such as conjunctions and description of the planetary orbits. The third page is a help screen showing all of the keyboard command and the status of the display switches. The help screen applies specifically to the astrolabe display but, in general, also applies to the text and orrery functions with the exceptions noted on the specific page descriptions. The Program Control page contains values that are used when the astrolabe is initialized. On this page you can set your latitude and longitude and any switches or colors that you want to have in effect when the Electric Astrolabe is started. The Program Control page also allows you to change the displayed colors, save defaults to be used when the Electric Astrolabe is started or to save specific astronomical events. A page of cities and added objects is provided to make it easy to change the displayed location and to add elements to the display.

The text pages are displayed using the PgUp and PgDn keys or directly with a mnemonic key. When the Electric Astrolabe is started the astrolabe is displayed. If you would like to see the numerical values of the planetary and lunar positions that are displayed you can press PgDn for the first text page and PgUp to return to the graphic display. The display pages are displayed in sequence and when the end of the sequence is reached it starts again at the top. If you press either PgUp or PgDn repeatedly you will see each page in turn and eventually end up where you started. The mnemonic keys used to access the text pages directly are:

V	Value - page of calculated values.
Alt+V	Full Values - page of complete orbital calculations.
Ctl+V	High precision calculations (available only when high precision calculations are on)
H	Help. Command Summary page.
Ctl+H	Star coordinates and positions.
Alt+C	Cities and Inserted Objects.
C	Program Control. Page of customization variables.

You can change time and location values directly on the text screens. Just type over the displayed value and the new value will be reflected in the displayed numbers when you press the Enter key. You can change more than one value before pressing Enter. All of the values are stored in the program when you press Enter.

The text pages can be thought of as a sort of astronomical spreadsheet in the sense that a change of one variable is immediately reflected as a change in all related values. Variables that can be changed are above the double line. Calculated results are below the double line. Use of the text pages to change values obviates the need for some of the commands described earlier since rather than, for example, pressing D to change the date you can just type in the desired date on the display.

In the interest of consistency, you can use the same command keys on the text pages that are used on the graphics pages. The difference is that a prompt is not displayed. Rather, the cursor jumps to the appropriate field for modification. For example, if you press "T" to change the time, the cursor will jump to the time field on the displayed page so you can enter a new time. The "J" key takes you directly to the Julian Day field but note carefully that only positive Julian days are fully supported. Entry of negative Julian days can cause erratic and sometimes fatal results (to the program) .

An interesting feature of the Electric Astrolabe is the ability to position the cursor under a number on the text page and increment or decrement that value with the big +/- keys. This feature is fully described below.

A WORD ABOUT ACCURACY

"Measure with a micrometer, mark with chalk, cut with an ax." Engineering tradition

Accuracy of astronomical values must be considered in the context of the use of the results. The Electric Astrolabe is a graphics program that represents the sky in an analog model. Precision of the calculations for the Electric Astrolabe is greater than the screen resolution and are more than adequate for the astrolabe model, but are not to professional standards. The basic calculations for the planetary orbits are for the purely Keplerian orbits without consideration of perturbations. Lunar calculations do include significant perturbations. None of the values can be considered accurate to the precision shown on the text pages. Star and Messier object positions are precise for J2000.0 and can be precessed to other epochs. Calculated results are shown with several decimal places in order to allow comparison to tabulated results available from other sources. An easily available reference for comparison of the computed values is the Planetary Data section of the "Celestial Calendar" in *Sky and Telescope* magazine each month. Note that the data tabulated in *Sky and Telescope* is for 0 hr. UT for the dates shown. Be sure to confirm that you have the date and time set correctly before making comparisons. This can get a little tricky and you may find it easiest to set the UT to 00:00 first and then set the date. You will find excellent agreement for the inner planets and some difference in the outer planets.

The Electric Astrolabe will calculate very accurate planetary positions. For additional information see Planetary Calculations in the previous chapter.

Sky and Telescope publishes a graphical table of the positions of Jupiter's moons every month when Jupiter is observable at night. Note that if you compare the *Sky and Telescope* graph of Jupiter's moons to the display that the sense of east and west is reversed. The magazine shows the satellites as they would appear in a telescope and the Electric Astrolabe shows them as they really are or would appear in binoculars. *Sky and Telescope* also publishes more detailed information on Jupiter's moons when viewing conditions are advantageous. You will find excellent agreement between the Electric Astrolabe display and the published events.

If you are looking at events that are far in the future or past, you can improve the accuracy of the graphical displays slightly by doing a SAVE followed by a RESTORE. The restore causes all values to be reinitialized and will result in more accurate representation of values that change over time such as the obliquity of the ecliptic and the location of perihelion shown on the Orrery. Numerical values on the text pages are recalculated for every time change and the accuracy will not be affected by RESTORE.

KEYBOARD USAGE

Following are the keyboard conventions used for the text pages:

ARROWS
The right and left arrows move the cursor one position to the right or left. At the end of a field the cursor goes to the next field. The up and down arrows move to the nearest field on the line above or below. Pressing the up arrow on the top line moves the cursor to the nearest field on the bottom line and vice versa. Nearest field is defined as the field in the next line that ends at a cursor position that is farther to the right than current field. For this reason the cursor may not return to the same field on an up/down or down/up sequence.

HOME
Moves cursor to beginning of the field. **Ctl+Home** moves the cursor to the first position of the first modifiable field on the page.

END
Moves the cursor the last position in a field. **Ctl+End** moves the cursor to the first position of the last modifiable field on the page.

PgUp
Displays the previous page in the list of pages. **Ctl+PgUp** goes directly to the first page (the astrolabe).

PgDn
Displays the next page in the list of pages. **Ctl+PgDn** goes directly to the last page in the list (the orrery).

TAB
Moves the cursor to the next field. Shift+Tab moves the cursor to the previous field.

DELETE
Deletes the character at the cursor and moves the remainder of the field one position left.

INSERT
Puts the keyboard in insert mode so each entered character pushes the rest of the field one position to the right. The cursor changes to a large cursor.

BACKSPACE
The conventional rubout function.

CTL+BACKSPACE
Erases the contents of the field.

SHIFT+BACKSPACE
Erases the field from the cursor position to the end of the field.

Only numbers and the appropriate punctuation can be entered into fields. The NumLock key has the normal function; changing the context of the keypad from cursor and page control to numbers. Either Enter or / key can be used. The keypad and gray keys have exactly the same usage. Use whichever set is most comfortable for you.

The big + and - keys on the keypad have a slightly different usage on the text pages. Position the cursor under a number and press **SHIFT** + **Big+** or -. The number in that position is incremented or decremented by one. Notice that the new values carry into related fields. For example, if you are using the **Big+** to increment minutes in the time field, the date is incremented when you pass midnight. The date components overflow similarly. The time intervals specified with F1-F12 operate the same as on the graphics screens.

The Text Screens

```
      Date=10/15/ 1995   Julian Date=2450005.91943  UT=10:05  t Zone= -1

   Latitude= 48 52 Longitude=  -2 20 Time= 11:05     Sidereal Time=  11:48:13.3
--------------------------------------------------------------------------------
                Mercury  Venus    Sun    Mars   Jupiter Saturn  Uranus  Neptune

 Right Ascension  12:20   14:17   13:20   15:35   16:46   23:24   19:55   19:38
 Declination      -1 05  -13 09   -8 25  -19 52  -21 57   -6 26  -21 23  -21 01
 True Longitude  71.749 236.858 201.580 258.595 261.310 352.374 299.446 294.689
 Altitude        39.577  19.828  29.295   4.852  -6.764 -47.256 -36.581 -33.600
 Azimuth        169.566 141.322 153.820 128.010 115.887   8.948  80.823  83.900

   Equation of Time     Longitude Correction     Solar Time     Sun on Meridian
     14 Min   7 Sec       -50 Min  40 Sec       10 : 28 : 27      12 : 36 : 32

                                                           MOON

        Right Ascension:  06:33      Altitude:  20.829    Longitude:  97.766
        Declination    :  18 13      Azimuth : 274.168    Latitude :  -5.009

       Ascending Node  : 206.545           Fraction Illuminated   :   0.620
       Semi-diameter   : 14' 51.1"         Position of Bright Limb:  94.474
       Distance        : 404533.8 km       Phase Angle            : -76.090

   11/ 2/95                                _                          14:34:20
```

Figure 10. Page of Calculated Values.

```
Date=10/15/ 1995   Julian Date=2450005.91943 Δt =   61 UT=10:05  T=-0.042137729
--------------------------------------------------------------------------------
  Obliquity =  23°26'15.4"  Nutation: Obliquity = -7.933"  Longitude =   6.838"
                                                              Right
           Longitude     Latitude     Radius    Ascension   Declination  Distance

Mercury   71°35'34.7"   2°47' 1.9"  0.308941  12:20:19.4   -1° 4'31.5"  0.833302

Venus    236°53'25.5"   1° 8'54.2"  0.724600  14:16:46.5  -13° 9'22.4"  1.642657

Sun      201°34'47.1"  -0° 0' 0.8"  0.997186  13:19:46.8   -8°24'44.1"  0.997187

Mars     258°34'57.4"  -0°53'53.6"  1.480211  15:34:35.9  -19°52'19.8"  2.189150

Jupiter  261°18'52.5"   0°25'38.5"  5.295933  16:45:54.6  -21°57'23.4"  5.861670

Saturn   352°21' 0.9"  -2° 7'31.7"  9.600087  23:23:49.7   -6°26' 8.8"  8.743621

Uranus   299°26'37.9"  -0°33' 1.1" 19.734814  19:54:47.3  -21°23' 3.0" 19.621310

Neptune  294°41'48.9"   0°30'10.3" 30.167181  19:38: 7.5  -21° 0'47.0" 30.126415
```

Figure 11. High Precision Calculations.

Date=10/15/ 1995   Julian Date=2450005.91943 UT=10:05 t T=-0.042137729

	Mercury	Venus	Sun	Mars	Jupiter	Saturn	Uranus	Neptune
Eccentricity	0.20563	0.00677	0.01671	0.09340	0.04849	0.05552	0.04630	0.00899
Inclination	7.005	3.395	0.000	1.850	1.304	2.489	0.773	1.770
Perihelion Arg.	29.110	54.863	282.865	286.457	-86.158	-20.655	98.959	-83.674
Ascending Node	48.281	76.642	0.000	49.526	100.421	113.629	73.984	131.738
Mean Longitude	73.753	236.113	203.476	268.846	266.409	358.521	295.942	295.083
Mean Anomaly	356.362	104.608	280.611	292.863	252.145	265.547	122.999	247.020
Ecc. Anomaly	355.420	104.979	279.660	287.790	249.630	262.545	124.341	247.099
True Anomaly	354.359	105.354	278.715	282.613	247.047	259.400	126.504	246.626
True Longitude	71.749	236.858	201.580	258.595	261.310	352.374	299.446	294.689
Radius Vector	0.309	0.725	0.997	1.480	5.296	9.600	19.735	30.167
Ecliptic Long.	71.593	236.890	201.580	258.583	261.315	352.350	299.444	294.697
Ecliptic Lat.	2.784	1.148	-0.000	-0.898	0.427	-2.125	-0.550	0.503
Geocentric Long.	185.090	216.345	201.580	236.120	252.864	349.162	296.561	292.805
Geocentric Lat.	1.031	0.506	-0.000	-0.607	0.386	-2.334	-0.554	0.504
Dist. to Earth	0.833	1.643	0.997	2.189	5.862	8.744	19.621	30.126
Elongation	16.521	14.774	0.000	34.545	51.285	147.507	94.981	91.225
Right Ascension	12:20	14:17	13:20	15:35	16:46	23:24	19:55	19:38
Declination	-1 05	-13 09	-8 25	-19 52	-21 57	-6 26	-21 23	-21 01
Altitude	39.577	19.828	29.295	4.852	-6.764	-47.256	-36.581	-33.600
Azimuth	169.566	141.322	153.820	128.010	115.887	8.948	80.823	83.900

11/ 5/95 _ 22:56:04

Figure 12. Complete Orbital Calculations.

NOTES ON TABULATED VALUES

SIDEREAL TIME
Mean sidereal time is normally displayed. Apparent sidereal time is displayed when high precision calculations are in effect. Dynamical time should be OFF to compare the displayed sidereal time to values tabulated in the *Astronomical Almanac* in order for UT to be 0:00 at the tabulated Julian dates.

EQUATION OF TIME is calculated as the Sun's mean longitude - Sun's right ascension. This is a valid method of calculating the equation of time over a wide range of times.

LONGITUDE CORRECTION is the time difference from the center of a time zone to the current location. The displayed value changes whenever the longitude is changed.

SOLAR TIME is the apparent solar time for the civil time shown in the Time= field. This value is useful when working with any problems that use solar time such as those found in historical texts or when working with sundials or astrolabe instruments.

SUN ON MERIDIAN is the combination of the Equation of Time and Longitude correction for conversion from apparent solar time to zone time and is the time the sun will be exactly due south at your location. These three values are useful for determining true south and working with apparent solar time or sundials. This value is most accurate when the zone time is close to apparent noon, particularly when the sun's declination is changing rapidly such as near the equinoxes.

The following values are tabulated for the Moon:

ASCENDING NODE is the longitude of the Moon's ascending node. The longitude of the descending node is 180° from this value. You need to know the position of the Moon's nodes to predict eclipses.

SEMI-DIAMETER is the Moon's semi-diameter in minutes and seconds of arc. The value shown is the topocentric semidiameter (i.e. the value as seen from the surface of the Earth). This value is shown only when high precision calculations are on.

DISTANCE is the geocentric distance of the Moon in kilometers. This value is shown only when high precision calculations are on.

FRACTION ILLUMINATED is the fraction of the Moon's disk that is illuminated and is approximately 1.000 for a full moon, 0.000 for a new moon, 0.250 for first quarter, etc.

POSITION OF BRIGHT LIMB. The precise term is Position Angle of the Bright Limb and is the angle from north of a line connecting the cusps of the illuminated part of the lunar disk. The orientation of the Earth's shadow on the Moon changes depending on the Moon's latitude. This figure measures the effect.

PHASE ANGLE is the angle from the Earth to the Sun as seen from the Moon. It will be approximately zero at a new Moon and 180° at a full Moon. The moment of a new or full Moon can be determined by comparing the Moon's longitude to the Sun's longitude. At full Moon, the longitudes will differ by 180° and they will be same at new Moon.

T shown on the page of full calculated variables (Alt+V) is the number of Julian centuries of 35625 days from epoch J.2000 (1/1/2000 0:00 DT) and is the coefficient for the polynomials used to calculate planetary positions. The ΔT next to UT shows that dynamical time is being used. The ■ at the bottom of the screens indicates that high precision calculations are on. The value of ΔT in seconds is shown on the Ctl+V page and to three decimal places on the Help screen.

The current system clock date and time are updated each second on the V, Alt+V, Ctl+V and Help pages.

Help

```
---------------------- COMMAND SUMMARY ---------------------------------------
Command       Value                    Description
   A           On          Display Altitude Azimuth Plate.   Shading (X) = On
   D       10/15/ 1995     Specify Date  G=Gregorian/Julian Calendar
   E           On          Display Ecliptic
   F           Off         Free Running Mode
 F1-F12         1.000000   Interval for Manual and Free Running Modes (Days)
   H                       Help (This Screen)
   J      2450006.21110    Specify Julian Date
   L     41 52     87 36   Latitude and Longitude (= for Here)
   M           On          Manual Mode
   N    11/ 8/94  10:48:03  Now. Current Date and Time. Projection (Alt+N) = N
   O           On          Display Messier Objects.    Magnitude (Alt+O) =  8
   P           On          Display Planets and Moon.    Sun only (Alt+A) = Off
   Q                       Quit.  Terminate Program.  Quiet mode (Ctl+Q) = Off
   R           On          Display Rule.              Long Rule (Ctl+R) = Off
   S           On          Display Stars             Precession (Alt+P) = Off
 Alt+S       12:50         Specify Sidereal Time
   T         11:05         Specify Time. ";" = DST.        AM/PM display = On
   U         17:05         Specify Universal Time. Unequal Hours (Ctl+U) = On
   V                       Display Numerical Values
 Alt+V                     Display Complete Numerical Values
   Z            6          Specify Standard Time Zone
   1-6                     Display Planet/Moon Phase
   Esc                     Display previous page
```

Figure 13. Help screen.

The help screen shows a summary of the commands and the status of each of the switches. As on the other text pages, you can enter new time and location values by typing over the value displayed. You can change the interval time for the F10 key by typing a new interval as the fraction of a day for each step. The settings for switches are shown when you change the switch by pressing the key corresponding to the switch. Two status values are not shown on the help screen; dynamical time is shown as a ΔT next to UT on the calculated values pages and high precision calculations are shown by a ■ in the center of the bottom line of the same pages.

CITIES

```
----------------------------------- CITIES -----------------------------------
      City           Lat    Long    Zone       City          Lat   Long    Zone
New Fairfield      41 28    73 30     5  London            51 30    0 10     0
New York           40 43    74 01     5  Paris             48 52   -2 20    -1
Washington,DC      38 53    77 02     5  Brussels          50 50   -4 20    -1
Toronto            43 39    79 23     5  Copenhagen        54 41   -5 32    -1
Miami              25 46    80 11     5  Stockholm         59 20  -18 03    -1
Chicago            41 51    87 39     6  Cairo             30 02  -31 15    -2
Tulsa              36 09    95 59     6  Madrid            40 24    3 41    -1
Dallas             32 49    96 47     6  Rome              41 58  -12 40    -1
Denver             39 44   104 59     7  Athens            37 58  -23 43    -2
Vancouver          49 16   123 19     8  Cairo             30 02  -31 15    -2
San Francisco      32 59   109 22     8  Moscow            55 45  -37 35    -2
Los Angeles        34 03   118 14     8  Tel Aviv          32 05  -34 48    -3
Honolulu           21 19   157 47    10  New Delhi         28 36  -77 12    -5
                    0 00     0 00     0  Singapore          1 22 -103 48    -8
                    0 00     0 00     0  Hong Kong         22 15 -114 11    -8
                    0 00     0 00     0  Tokyo             35 45 -139 30    -9
------------------------------- ADDED OBJECTS --------------------------------
     RA     Decl Mag Type    Name             RA     Decl Mag Type    Name
1. 15:44  -5 09   0  9   Pluto         6. 00:00   0 00   0
2. 17:44 -28 59   0  8   Galactic Ctr. 7. 00:00   0 00   0
3. 00:00   0 00   0                    8. 00:00   0 00   0
4. 00:00   0 00   0                    9. 00:00   0 00   0
5. 00:00   0 00   0                    0. 00:00   0 00   0
```

Figure 14. Cities and Added Objects.

A page of city locations is provided in order to make it easier to switch between locations. City names, latitude, longitude and time zones can be changed by just typing in new values and pressing **Enter**. A new city is selected by moving the highlighted cursor to the city name and pressing **Ctl+Enter**. The astrolabe for the new city is displayed automatically at the current date and time. When a new city is selected with Ctl+Enter the city name is displayed in the Description field of the Program Control page. **The first city in the list is used as the default location when the Electric Astrolabe is started.** The page of city names is selected with Alt+C.

Updated city names are NOT saved with a FILE unless the destination file is ASTRO.EXE. If you want to revise the list of locations, make the updates on the city page and then save a new default file to ASTRO.EXE.

To add a new city permanently, follow these steps:

1. Enter the new city name, latitude, longitude and time zone and press **Enter.**

2. Go to the Program Control Page (C).

3. Go to the File: field. It is fastest to get to the file name field with Ctl+End.

4. Make sure the file name is ASTRO.EXE.
5. Go to the Action: field. Press **Enter** until **File** appears in the field.

6. Press **Ctl+Enter.**

The city will now be in the list every time you start the Electric Astrolabe. Note once again that the first city in the list is your home location whenever the Electric Astrolabe is started. See Customization below for how to set a new city as the default location when The Electric Astrolabe is started.

UNDER WINDOWS 95, SAVING A NEW CITY LIST MUST BE DONE UNDER NATIVE DOS.

The locations of major world cities provided with the Electric Astrolabe were taken from *The New International Atlas* (Rand McNally, 1991). There are many sources for the latitudes and longitudes of locations. Particularly accurate sources include geodetic survey maps and sectional maps used by pilots and Google Earth. A good source for time zone information is the International Airline Guide.

Using the Electric Astrolabe to hop between cities has been useful for determining the hours of daylight for trip planning, duplicating conditions for a specific location such as an observatory and following history in the making by noting the astronomical conditions during historic events.

ADDITIONAL OBJECTS

You can define up to ten additional celestial objects to be displayed with the Messier objects by entering the right ascension, declination, magnitude and display symbol on this page. A name or very brief description can also be entered. The object is “created” when the type is entered. This is an important point. If you add an object and then go back and change the coordinates or magnitude, you must move the cursor to the Type field and press Enter for the new values to take effect. The name or description can be changed at any time.

The added objects are displayed when the “O” switch is ON (depending on the magnitude). Specifying a magnitude of zero or one allows you to set the object display magnitude so only the added objects are displayed.

If the precession switch (Alt+P) is ON when the added object is created, its displayed position will be precessed to the current date and time. If the precession switch is OFF, the added object will be inserted at the coordinates specified without precession. This allows you to go to a distant date, enter the J2000.0 coordinates of an added object and then display the position of the object at that date.

The symbol displayed for an added object is specified with a code letter indicating the object type. The object types are:

G Spiral galaxy

C Globular cluster

O Open cluster

N Nebula

E Elliptic galaxy

I The number of the object is displayed as a small number equal to its index in the list.

1 Small filled square (■)

2 Small square outline (□)

3 Small filled diamond (♦)

4 Small diamond outline (◊)

5 Small filled circle (●)

6 Small circle outline (○)

7 ×

8 +

9 Small arrow pointing to object location (↗)

0 Do not display. Changing the object type to 0 allows you to temporarily prevent the object from being displayed without losing the coordinates.

Added objects are saved with the program defaults thus allowing different lists to be constructed for special purposes. You might find it useful to FILE lists of your favorite objects that can be loaded at will.

Inserted objects might be a star, deep space object not included in the Messier list, a comet for which you know the right ascension and declination, Pluto’s position or anything else that appears in the sky (you don’t have to enter Pluto’s position often since it changes VERY slowly - once a year may be enough). Added objects can also be used to mark a coordinate of interest such as the J2000.0 position of a star to compare precessed and unprecessed positions or merely to mark a specific a point in the sky.

Star Positions

```
Date=  3/21/ 2004  UT=03:27 Time=22:27     AT=22:19:20 Sidereal Time=10:26: 6.8
-------------------------------------------------------------------------------
Star         RA 2000    Decl 2000      RA          Decl       Alt       Az
Aldebaren   4:35:55.2  16°30'33.0"  4:36: 9.7   16°31' 3.3"  12.155   281.543
Alkaid     13:47:32.3  49°18'48.0" 13:47:42.3   49°17'32.5"  52.980    56.575
Altair     19:50:46.9   8°52' 6.0" 19:50:59.1    8°52'45.3" -30.303    45.790
Antares    16:29:24.4 -26°25'55.0" 16:29:39.9  -26°26'27.5" -16.812   110.730
Arcturus   14:15:39.6  19°10'57.0" 14:15:51.4   19° 9'46.8"  37.015    94.432
Bellatrix   5:25: 8.0   6°20'59.0"  5:25:21.6    6°21'11.7"  15.514   265.685
Betelgeuse  5:55:10.3   7°24'25.0"  5:55:24.0    7°24'26.7"  21.996   261.636
Canopus     6:23:57.2 -52°41'44.0"  6:24: 2.8  -52°41'52.8" -15.342   213.164
Capella     5:16:41.3  45°59'53.0"  5:17: 0.0   46° 0' 8.8"  34.692   304.505
Castor      7:34:35.9  31°53'18.0"  7:34:52.0   31°52'44.0"  54.723   272.250
Deneb      20:41:25.8  45°16'49.0" 20:41:34.4   45°17'43.8"  -2.779    18.073
Merak      11: 1:50.4  56°22'56.0" 11: 2: 5.5   56°21'34.1"  71.363    15.724
Pollux      7:45:18.9  28° 1'34.0"  7:45:34.5   28° 0'56.4"  55.128   264.437
Procyon     7:39:18.1   5°13'30.0"  7:39:31.5    5°12'54.4"  39.613   239.211
Regulus    10: 8:22.2  11°58' 2.0" 10: 8:35.7   11°56'47.2"  62.964   189.460
Rigel       5:14:32.2  -8°12' 6.0"  5:14:44.3   -8°11'49.3"   4.216   255.981
Sirius      6:45: 8.9 -16°42'58.0"  6:45:20.2  -16°43'14.5"  14.285   234.239
Spica      13:25:11.5 -11° 9'41.0" 13:25:24.8  -11°10'59.8"  24.945   130.296
Vega       18:36:56.2  38°47' 1.0" 18:37: 4.7   38°47'14.6"   3.593    41.066
3/21/04                            ¦                              22:26:49
```

Figure 15. Page of Star Positions

The page of star positions shows the J2000.0 and current coordinates of 19 bright stars. This page allows you to find or set a star's position very accurately.

It is not always easy to set the position of a star precisely on the astrolabe display. The computer's monitor is made up of many individual dots. The curves and points drawn on the computer monitor are calculated very accurately, but what actually appears on the screen is necessarily rounded to the nearest screen dot (called a pixel or pel – picture element). For example, say you want to set the astrolabe to the exact instant when Altair is at an altitude of 40°. You can set it fairly closely by just positioning the dot representing Altair on the 40° almucantars. The problem is that the dot may be on or right next to the 40° almucantars for several minutes of time and you can't tell from the graphic display which is the exact time. Also, the arcs themselves are subject to rounding when they are drawn and some points that are actually on the theoretical circle fall between pixels and may not be able to tell exactly where the almucantars is on the screen.

This page allows you to find the instant when one of the listed stars is at a specific altitude or azimuth. Simply narrow in on the desired position using various values of time intervals until you have it at the correct value. The rete is now positioned accurately and you can read the time, apparent solar time or sidereal time at this instant.

This page is also useful for finding the precessed coordinates of the listed stars. The precessed values are updated as determined by the Precession switch (Alt+P). All displayed stars are precessed to the computer time when The Electric Astrolabe is started. The precessed coordinates are updated on each time change if the Precession switch is ON. They are left at the values calculated when the program was started if the Precession switch is OFF.

Thus, this page is a convenient reference for the coordinates of the listed bright stars and a tool for setting the astrolabe to a specific event of interest.

PROGRAM CONTROL VARIABLES

The astrolabe that is initially displayed when the Electric Astrolabe is started is defined by values that are stored in the program. These values include the latitude and longitude for the plate, the time zone, the colors used to draw the astrolabe and other values that describe the size and shape of the image. The content of the astrolabe is described by the setting of the switches (e.g. whether Messier objects are included) and the status of daylight savings time, manual mode, free running mode, etc.. You can specify the exact content of the Electric Astrolabe by selecting values for these variables and including them in the program file. You can also describe other combinations and file them in small files that can be retrieved separately. In this way you can customize the display to your location, color preference and screen content and you can save particularly interesting conditions for immediate recall.

When you save or restore the Electric Astrolabe definitions, ALL values that are controlled from the keyboard are saved. Thus, when a set of definitions is invoked the display content is completely defined. For example, if you wanted to save the exact conditions of the solar eclipse of July 11, 1991, you would set date, time and location, set manual mode and file the definitions. When you retrieve this set of values the time will be set to the time saved because manual mode was in effect when the values were stored. If manual mode is not active, the time displayed when a set of definitions is restored is the current computer clock time.

You can use the Program Control screen to customize the Electric Astrolabe. This page contains variables that specify your location, how you want the astrolabe to look and the switches that are set when the program is started. You can change the customization variables at any time and the new values will be in effect until you stop the program. Or, you can define new default values for a single session, reload the default values in use when the Electric Astrolabe was originally started and/or write the new default values to disk thus defining a new set of permanent defaults. Some of the values shown on this screen are duplicated on other screens and are included here only for the convenience of being able to see the settings while defining defaults. Note that ALL operating parameters are stored when the defaults are saved or filed including values that are not shown on this screen.

```
------------------------------- PROGRAM CONTROL ---------------------------------
 Latitude=  48 52   Longitude=   -2 20     Time Zone=  -1    Home Zone=   5

 Aspect Ratio= 1.000  Video= V  Alt/Az= 10  Phase= 249  Numeral Scale= 0.36

   Orbit Scale= 220  Inner Orbit=  1   Outer Orbit=   4 Tic Marks   4   8  12

               COLOR    R  G  B  SWITCH                    COLOR    R  G  B

  Background      0  □  0  0  0              Venus           8   □ 63 63 63
  Plate           1  □ 63  0  0   On         Earth           9   □  0  0 42
  Numerals/Tic    2  □ 63 63 63              Mars           10   □ 63 21 21
  Shading         3  □  0  0  0   On         Saturn         11   □ 63 48 32
  Stars           4  □ 21 21 63   On         Uranus         12   □ 21 63 63
  Rule            5  □ 63 63 63   On         Neptune        13   □ 50 25  0
  Ecliptic        6  □ 63 63 63   On         Sun            14   □ 63 63 21
  Objects(Mercury)7  □ 42 42 42   On         Phase Shadow   15   □ 21 21 21

                  TEXT                               HIGHLIGHTED TEXT

    Background  9     Foreground  8        Background  7     Foreground  9

Description: Paris

Action:            File: ASTRO.EXE                Status:
```

Figure 16. Progam Control Screen.

Following is a description of the customization values and how to save and recover customized configurations. Colors are discussed in the next section.

LATITUDE, LONGITUDE AND TIME ZONE

The normal definition. These coordinates will be stored as the current location when a the program controls are stored in a default file. When the Electric Astrolabe is started, the coordinates of the first city in the city list are used.

HOME ZONE

Home Zone designates the time zone reflected by the computer clock. The Electric Astrolabe needs to know the time zone for times read from the computer in order to calculate Universal Time and local times correctly when the display is set for a location in a different time zone. Normally, this value needs to be set only once when the initial defaults are defined.

SCREEN ASPECT RATIO

It is not always immediately obvious that lines drawn on a graphics screen are not the same length when drawn in the x (horizontal) and y (vertical) directions. The aspect ratio is defined as the length of a line in the x direction divided by the length of a line containing the same number of dots in the y direction. For VGA displays it is supposed to be 1.0 but it isn’t always depending on the specific display and graphics adapter. If your display has controls for horizontal and vertical size, adjust them until the VGA astrolabe is exactly round with the aspect ratio set to 1.0. The aspect ratio will be correct for all modes after it has been set for VGA if your monitor is working correctly. If your display does not have horizontal and vertical size adjustments and your display is not exactly round with an aspect ratio of 1.0, carefully measure the x and y diameters of the astrolabe and calculate the aspect ratio and enter it on the program control screen. For example, if you display the astrolabe plate with the aspect ratio = 1.0 and the circle is not round, measure the length of the horizontal (i.e. x axis) diameter. Say the result is 175 mm. Measure the length of the vertical (i.e. y axis) diameter. Say the result is 183 mm. The aspect ratio is then x/y = 175/183 = 0.956 The measurement does not have to be very precise since you can easily fine tune the value by changing the aspect ratio on this screen. You should adjust your display for an aspect ratio as close to 1.0 as possible for VGA. Once it is set correctly on your display it will be correct for all VGA application. Aspect ratios greater than 1.0 might cause some of the images to contain black lines.

Some newer monitors will display SVGA images with an aspect ratio of 1.0. If your astrolabe is round in VGA mode with an aspect ratio of 1.0 and oval in SVGA mode with an aspect ratio of 0.88, reset the aspect to give a round SVGA image and FILE the result to ASTRO.EXE.

Note that for printing on a matrix printer the aspect ratio may be wildly different than for the screen. An IBM ProPrinter, for example, requires an aspect ratio of 0.831 to get round figures when using the DOS GRAPHICS command and Print Screen. Laser printers should print perfectly round images using the DOS GRAPHICS program.

VIDEO

VIDEO= controls the graphic screen resolution and requires a little explanation.

All computers that are equipped to run the Electric Astrolabe have a video graphics adapter that supports VGA (which was developed by IBM and stands for "Video Graphics Array"). All VGA adapters, regardless of the manufacturer, support several graphics modes but the one most commonly used provides a picture area that is 640 dots wide and 480 dots high with 16 colors displayed at a time. The dots in a graphic picture are called "pels" (for PictureELementS) or "pixels". 640x480, 16 color graphics has several advantages: it is supported by almost all graphics cards, has sufficient clarity and flexibility for most applications, does not require a fancy or expensive display and is supported by almost all software. On the other hand, 640x480 pel resolution is really not sufficient resolution for applications that display pictures (images) and 16 colors is simply not enough to properly represent color images. Therefore, the graphics card manufacturers have developed graphic adapter cards that offer higher resolution and more colors for graphics applications.

When you bought your computer or upgraded your graphic adapter card you probably got one that advertised “SVGA” (“Super VGA”) with resolutions of 800x600 and 1024x768 pels and claimed to offer these resolutions at up 256 concurrent colors or more. These claims are true. What you may not have realized is that each card manufacturer provides these graphics modes in a different way and each card requires special software to use them. A hint that this is the case is that you probably received some software “drivers” for specific applications such as Windows that needed to be installed before you could use the card in the higher resolution modes. You also may not have realized is that the higher resolution modes require a higher quality display. This may not become obvious until you try higher resolution and find the picture is fuzzy or worse.

In an attempt to make some sense out of the chaos resulting from every manufacturer offering the same function in different ways, an organization called the *Video Electronics Standards Association* (VESA) has published a programming standard that allows software developers to program specific functions that will work on a wide range of graphics cards. All of the legitimate graphic card manufacturers offer a piece of software that will convert the VESA standard to their specific implementation. You probably received the software when you bought your computer or card but, if you didn’t, the VESA software can be downloaded from CompuServe and other subscription services. Some of the newest cards implement the VESA standard in the card itself. For those that don’t, it is necessary to load the VESA interface as a little resident program that is used by application programs such as the Electric Astrolabe.

The Electric Astrolabe supports standard VGA (VIDEO= V) or 800x600, 16 color SVGA(VIDEO= S or H). In order to use SVGA you must have either a graphics adapter that supports VESA in hardware or have loaded the VESA interface program. You will have to refer to your graphics adapter card literature to see if you can use SVGA. For reference, the VESA SVGA 800x600, 16 color mode is 102H and the VESA standard hardware mode is 6AH (the H after the number means that it is a base 16 or *hexadecimal* number).

Before going further it is should be pointed out that there is really no need to use SVGA. The screen resolution is a little better and the display will use a little bit more of the glass but you can't see anything that you can’t see with regular VGA. Also, the higher resolution means that the Electric Astrolabe must process more pels so the performance is slower by 20-30%. But, if you have a really fast computer and graphics adapter and a really good monitor, you will want to use the higher resolution.

If your graphics card supports VESA in hardware then all you have to do to use 800x600 graphics is specify VIDEO= H (but see the technical note below). If it does not support this mode then load your VESA interface program before starting the Electric Astrolabe. This is most easily done by starting the Electric Astrolabe with a BAT file that loads the VESA program and then starts the Electric Astrolabe (you can also load the VESA program automatically when you start your computer by making an entry in your AUTOEXEC.BAT file). Then, put an “S” in the MODE field on the PROGRAM CONTROL screen. If your computer does not support VESA or the VESA software is not loaded the message, “VESA not available.” will appear in the **Status:** field. If everything is working correctly, the Electric Astrolabe will change to SVGA mode. You will notice that the aspect ratio is changed to 0.880 and the roman numeral scale changes to 0.50 and that the planet and Messier object images are smaller. Everything else works the same but you might want to change the Orbit Scale to about 280 and the Phase picture size to about 200.

There is one other complicating factor. Some card manufacturers supply VESA programs that do not supply the correct information on text character sizes. This is most likely to show up when you display the constellation or planet names. If all the names are on the top row, your VESA program is lying to the Electric Astrolabe about the character sizes.

Default and color files that are LOAD’ed or RESTORE’d use the current video mode regardless of the mode in effect at the time they were SAVE’d or FILE’d.

IMPORTANT: Some display monitors will not support 800x600 graphics. If your screen starts to roll or break up, turn off the computer IMMEDIATELY. Your display and graphics adapter card can be physically damaged if driven beyond their capability for a long period of time.

The Electric Astrolabe is guaranteed to work in VGA mode.

Technical Note: Video Mode 6AH assumes the following parameters: 800x600 resolution, 16 colors, 4 plane planar memory organization, 100 bytes per row, text x-width = 8 pels, text y-height = 14 pels and identical controller port and register usage to VGA mode 12H. If your card does not support these exact specifications then it is safer to use Video Mode = S (but try H to see if it works)

Alt/Az

Alt/Az= controls the resolution of the astrolabe plate by defining the number of degrees between the altitude and azimuth arcs. Valid values are 5 and 10. The altitude and azimuth arcs for each 10° are drawn in the plate color (color 1) and, if 5° resolution is chosen, the 5° arcs are drawn in the background color (color 0) and will only be visible when shading is on. You may find that the 5° resolution makes the screen a little busy during the day when the sky background is blue. You can control the visibility of the 5° arcs at night by choosing a background color that has low contrast such as a fairly dark gray.

PHASE

The Phase= field is used to define the size of the enlarged pictures of the planet phases. The number entered is the width of the picture in pels and can be any number between 100 and 250. The size of the box containing the image is adjusted for the specific planet being displayed. The box for Jupiter and Saturn are much larger in order to hold the entire picture.

NUMERAL SCALE
The roman numerals around the limb of the astrolabe are stored as vectors that can be scaled to any size. You can make them larger or smaller by changing this value.

ORBIT SCALE
The sizes of the orbits on the orrery are determined by dividing this number by the length of the semi-major axis in AU for the largest orbit being displayed. You can make them larger or smaller by varying this value. The default value of 220 in VGA mode uses about 92% of the screen but causes the orbit of Mercury to go off of the screen when it is the only orbit displayed due to its large eccentricity. A scale of 280 for SVGA mode works well.

INNER ORBIT, OUTER ORBIT
Allows you to change the default for which orbits are displayed. Normally, a maximum of four orbits can fit on the screen together but you can use these values to change the number of orbits displayed. For example, if you want only Earth and Mars, set the inner orbit to 3 and the outer orbit to 4. To go back to four orbits on the screen just select the outer planet on the orrery screen with the number keys. You can define up to 8 orbits to be on the screen together but the center gets very congested. A realistic maximum is Mercury (1) to Jupiter (6) or Earth (3) to Neptune (8).

TIC MARKS
You can change the length of the tic marks on the ecliptic and around the limb by changing the values. These values are the number of dots that make up each tic mark line.

SWITCHES AND COLORS

Default switch values can be defined on this page as can the colors you prefer as described below.

DESCRIPTION
The description field can be used for a brief text description of a FILE'd set of defaults. For example, if you have saved the positions of the planets and stars as they would have appeared at Sunrise at the summer solstice at Stonehenge in 1500 BC you could make a note to that effect in the description field. This description is saved with the defaults and displayed when the file is LOAD'ed as reminder of what is in the file. The city name of the current location is normally displayed in this field.

ACTION:
This field defines the actions you can take with the Program Control values. To select an action, put the cursor in this field and press Enter until the action you want is displayed. Then press **Ctl+Enter** to cause the action to occur. The extra key (Ctl) and the relatively inconvenient location of the field on the screen (hopefully) provide a small safeguard against accidentally invoking an action you did not want. The action options are:

> (blank). No action.
>
> **SAVE** makes the values defined on the screen the defaults for this session. The values are not stored to disk. This allows you to experiment, save a set of values and continue to experiment. The status message, "Defaults SAVE'd" is displayed in the status message when the operation completes.
>
> **RESTORE** makes the default values active. That is, make the program control values that were in effect when the program was started (or the last set SAVE'd) the current values. The message,

"Defaults RESTORE'd" is displayed in the status area. All program parameters are reinitialized. If the RESTORE'd values include manual mode, the program will be initialized to the stored date and time. When a set of values is RESTORE'd the screen automatically switches to the astrolabe display.

FILE writes the current values to disk. If the file name is ASTRO.EXE, you will create a new set of program defaults that will be used each time the program is started. This allows you to customize the Electric Astrolabe for your location, time zone, color selection and screen contents. You can update an ASTRO.EXE file in any directory by specifying the directory name in the **File:** field but the ASTRO.EXE file must already be in the directory or you will get a "File not found" message. If the file name is not the same as the program file, you will create a small file in the specified directory containing the program control variables. This is the file name you use in the LOAD option above. You can name the file anything you want but the file type (sometimes called the extension) should not be .EXE, .COM or .BAT . **SAVING TO ASTRO.EXE MUST BE DONE UNDER NATIVE DOS UNDER WINDOWS 95!**

LOAD reloads the default values from a file stored on disk. This option can be useful if you have FILE'd several sets of defaults. The file from which to load the values is shown in the **FILE NAME:** field on this page. LOAD causes the current values to be replaced. Any values SAVE'd will not be affected. To make the LOAD'ed values the permanent default, issue a FILE command to ASTRO.EXE. If the file does not exist in the specified directory, a "File not found" message is displayed in the status area. If the specified file exists but is not a set of default values, the message "Not a default file" is displayed. Defaults can be LOAD'ed from the ASTRO.EXE file. LOAD causes all values to be recalculated for the current date and time as defined by the file being LOAD'ed. The screen switches to the astrolabe display when the LOAD is complete.

FILE:
File name for FILE and LOAD. You can enter any valid file name in this field. Note that any character can be entered in the file name so the keys that normally change switch settings or jump to a field for entry are not active when the cursor is in this field. This is also true for the Action field.

For example, say you have set the display for the time Neil Armstrong first set foot on the moon (9:56:15 PM CDT on July 20, 1969, Julian day 2440423.62240) as seen from the Manned Space Flight Center in Houston (29 34 N, 95 06 W). You would make sure the display is in manual mode, go to the Program Control page, type something like, "Sky at Houston when Apollo 11 landed.", set the file name to something meaningful (e.g. APOLLO11.LUN), put the cursor in the Action field, press Enter until FILE is displayed and, finally, press Ctl+Enter. The complete set of times, places and formats will be stored in the file APOLL11.LUN in the current directory. For what it is worth, the Apollo 11 mission liftoff was at 9:32 AM EDT on July 16, 1969, from Cape Kennedy, Florida.

MENU shows that the file name specified is a menu file.

IMAGE means that the file name specified is a .GIF image file.

You might also want to store some color variations in default files as you test different combinations. Once you settle on a preferred set of colors and astrolabe contents you can update the ASTRO.EXE file by executing FILE with file name set to ASTRO.EXE.

COLORS

Most of the colors used on the Electric Astrolabe graphic displays can be changed to suit personal preference. Up to 16 colors, numbered 0 - 15, can be displayed at one time on a VGA display. The colors used by the Electric Astrolabe are **not** the standard colors used by DOS or Windows:

The default colors are:

Color Number	Use	Default Color
0	Background	Gray
1	Astrolabe Plate	Red
2	Numerals and Tic Marks	White
3	Shading	Variable
4	Stars	Blue
5	Rule	Yellow
6	Ecliptic	White
7	Mercury/Messier objects	Light Gray
8	Venus/Jupiter stripes	White
9	Earth	Light Blue
10	Mars/Jupiter red spot	Red
11	Saturn	Peach
12	Uranus/Jupiter stripes	Cyan
13	Neptune	Brown
14	Phase shadow	Dark Gray

TEXT AND HIGHLIGHTED TEXT

The numbers define the color to be used as the foreground and background colors for normal and highlighted text. They are same colors as defined in color blocks above. Any combination can be chosen.

CHANGING COLORS

Each color is made up of a red, green and blue component. The amount of each color is defined by a number between 0 and 63 with 0,0,0 being black and 63,63,63 being bright white. New colors can be defined by varying the basic color proportions. To change the colors, position the cursor under the R (Red), G (Green) or B (Blue) component and either type in a new number or use the Shift+Big+/- keys to vary the value. Changes are instantly reflected in the color block.

The shaded sky color can be changed when shading is on AND the Sun is above the horizon. The sky color during twilight is calculated depending on the Sun's altitude and cannot be changed.

Note that some of the planet colors are used in multiple places and that the text screen colors are chosen from the same palette of 16 colors that is used for the astrolabe and planets. If you change one of these colors you will change the text screen colors. Conversely, you can change the text screen colors by changing the planet colors. It is fun to play with the colors.

There are many opportunities to modify the Electric Astrolabe display by manipulating the colors. The default colors have been chosen to maximize contrast in order to make reading the display as easy as possible. However, other combinations create interesting displays. For example, a brass colored background (R=63, G=44, B=0) looks nice with various combinations of colors for the plate and numerals. If you make the plate lines a medium gray (30 or so) you get an interesting shading effect during twilight as the Sun rises or sets.

Another option is to make the plate color the same as the sky shade (R=36, G=58, B=63) so the altitude/azimuth lines disappear in the daytime. You can also manipulate the colors to highlight the area of interest such as the Messier objects. A color combination that reduces contrast when shading is in effect is to set the background to a medium gray (R=G=B=30), set the Ecliptic color to a lighter gray (48) and set the rule to lighter gray still (54). This sort of color scheme reduces the sky contrast during daylight hours and makes the night sky stand out. A "starter set" of color combinations is supplied with the Electric Astrolabe.

There is a lot room for experimentation with colors.

PRINTING

It is possible to print both the graphic and text screens on your computer printer using the Print Screen function of DOS or the Windows Clipboard. There are also some excellent screen capture programs available. The results are quite good and the process is easy with a little practice.

You can print the text screens under Windows by copying the screen to the clipboard (Alt+PrintScrn) and then pasting the clipboard into any Windows word processor. You will have to change to a fixed pitch font such as Courier to get the text page columns to line up. You can then edit and print the word processor file.

The Windows Clipboard will capture the VGA graphics screens (but not SVGA!) screen in black and white but the operation seems to depend on the Windows version. Some versions treat the background color as white and all other colors as black. Therefore, the shaded area above the horizon (color 3) comes out completely black. You can draw the astrolabe without the shading color by causing the plate to be redrawn with shading OFF. This can be done in several ways: do a SAVE with shading OFF (X) and then RESTORE, turn shading off and switch to the southern projection and back to the northern projection (Alt+N) or invoke a new city with shading off and return to the current location (=). This format is suitable for copying the astrolabe to the Clipboard and then printing as described above. Windows 98 copies the VGA astrolabe in color to the clipboard.

The Windows clipboard requires the background color to be something other than black (0,0,0) to capture the image in blank and white.

You can print directly to the printer with the DOS GRAPHICS function under DOS. Just start GRAPHICS before you start ASTRO and then use Shift+Print Screen to copy the screen to the printer. You may have to modify the aspect ratio and colors to get a good printout. The IBM ProPrinter graphics have become "standard" for many screen copy programs. With this technique you will have to change the screen aspect ratio to about 0.831. Other values may be needed for other printers. The print screen program uses various shadings of black to simulate colors. You may find it advantageous to set up a default file for printing that uses the colors and aspect ratio that works best for your printer. For example, you might make everything white except the plate. You can SAVE the current screen, LOAD the print default file, print the screens using Print Screen and then RESTORE. With matrix printers you may be able to get the astrolabe screen and the V text screen on a single page which is very handy for taking outside for casual observing. Laser printers rotate the graphics image so it is larger, thus preventing putting both screens on a single page.

Your printer's standard character set (sometimes called a *code page*) must be one that includes the forms design characters in order to get a proper printout of the text screens. This code page goes by various names such as 837 or the PC-8 symbol set. All printers support this code page but you may have to invoke it on your printer if it not the standard one you use.

If you have a laser printer that will print HP Laserjet II data streams you can get good quality prints without modifying the aspect ratio. Just load the DOS graphics print program by keying GRAPHICS LASERJETII under DOS and invoke the graphics screen copy function with Shift+Print Screen. Note that the DOS GRAPHICS function works only for VGA mode. It will not print an SVGA screen.

You can use the GRAPHICS function of DOS to print the graphics screens under Windows but you must start both GRAPHICS and the Electric Astrolabe in a DOS session. If you start GRAPHICS under DOS and then start the Electric Astrolabe under Windows, the GRAPHICS function is not recognized.

CUSTOMIZATION

You will want to customize the Electric Astrolabe for your location and color preferences. In order to customize The Electric Astrolabe you will set up all of your color and location preferences and FILE the configuration to ASTRO.EXE. The following steps might be useful in customizing:

1. Put your location (city name, latitude, longitude, time zone) as the first city on the page of city names.

2. Make your location the active city by moving the cursor to the first city and pressing Ctl+Enter..

3. Change your time zone and home zone to the correct values on the Program Control page.

4. Select the color combination you want to use.

5. Make sure the switch settings are the way you want since the switches define which astrolabe components are displayed when the Electric Astrolabe is started. Some people prefer to leave out the ecliptic and objects. Pay particular attention to Manual Mode and Precession since you will probably want them OFF.

6. Add any cities of interest to the list on the cities page.

7. Add any deep space objects of interest to the list of added objects.

8. Make sure ASTRO.EXE is in the File: field. Put the cursor in the ACTION field and press ENTER until you display FILE, then press Ctrl+ENTER to save the startup configuration.

9. You might also want to name the color combination you like the best and save a separate file that describes the overall color combination (e.g. GRAY). This will allow you to continue to experiment with the various display parameters and load previous values.

Of course, the defaults can be changed at any time and you will want to experiment with colors.

Note that under Windows 95 or Windows 98 you **must** 'Exit to MS-DOS' to store the changes in ASTRO.EXE. This is not necessary under Windows XP.

There is an alternative way to customize The Electric Astrolabe under Windows 95/98 that does not require restarting your computer in MS-DOS mode.

You can create a file containing your location and display default and initialize The Electric Astrolabe with this file when you start the program. The following steps outline the procedure:

1. As above, set the defaults you want for latitude, longitude, time zone, colors, etc.

2. Make the first city the active location by moving the cursor to the city name and pressing Ctl+Enter.

3. Go to the Program Control page (C) and type the name of the location you want in the Description: field. This is the city name that will be used when you start The Electric Astrolabe.

4. FILE the set of defaults using any easy to remember name such as HERE, HOME or any other convenient name.

5. Edit the properties of the shortcut that starts The Electric Astrolabe. Right click on The Electric Astrolabe icon on your desktop or use Explorer to find the shortcut you use to start The Electric Astrolabe and select the Program tab. Change the "Cmd line:" entry to ASTRO.EXE /F filename (e.g. ASTRO.EXE /F HERE) and click OK. This will cause The Electric Astrolabe to use your file of default settings whenever it starts. Similarly, if you start The Electric Astrolabe from DOS, use ">astro /f here" as the command to start the program.

RUNNING THE ELECTRIC ASTROLABE UNDER WINDOWS and DOSBox

The astrolabe graphics screens must be run full screen under Windows XP and before. The text screens can be reduced to a window and returned to full screen with Alt+Enter.

It's easy to put The Electric Astrolabe on your desktop. Just right click on astro.exe and send it to the desktop. An icon for Windows is supplied in the file ASTRO.ICO. To apply the icon to your desktop, right click the Electric Astrolabe on the desktop, select Properties/Program, change icon and select the Electric Astrolabe icon.

Window's evolution has created new opportunities to excel in the face of adversity. It works well on all versions of Windows through XP. Windows Vista and 7 will not allow a DOS program to access the VGA screen directly so The Electric Astrolabe will not run by itself. You can, however, run it under a free program called DOSBox that can be downloaded. Just install DOSBox and follow the instructions to run The Electric Astrolabe. The graphics screens will display in a window or full screen.

You can configure DOSBox to start The Electric Astrolabe directly. There is a little DOSBox file named dosbox.conf you can edit to define how it starts. Dosbox.cnf is in \Program Files\DOSBox-0.74 (or whatever version you have). You can modify the file with any text editor to select the startup mode (window of full screen), screen resolution (640x480 or 600x800), etc.

To make DOSBox run The Electric Astrolabe when started, add the following lines to the bottom of the file:

```
[autoexec]
# Lines in this section will be run at startup.
mount c c:\astrov (use your folder name here)
c:
astro
```

You can put DOSBox on your desktop and change the icon to The Electric Astrolabe icon if you like.

Performance under DOSBox is far, far slower than running natively, but you can speed it up some using Ctrl + F12. Also, animation speed is dependent on which elements are displayed on the graphics screen. You should reduce the displayed content, such as turning of ecliptic labels, unequal hours, bright stars, objects, etc., to the minimum required for what you are doing.

The DOSBox documentation is fairly sparse, but complete. It is not difficult to set up with a little persistence.

Note: Use the latest version of DOSBox, (0.74 as of this writing). Include the following statement in dosbox.cnfg to get full graphics function in all display resolutions.

```
machine=svga_et4000
```

Experiment with `cycles=` in the `[cpu]` section to get smooth and fast animation.

THE ORRERY

The orrery display shows the planets in their orbits around the Sun. The planet images used are the same as those on the astrolabe display with the addition of the Earth which is, of course, blue. The position of Earth's moon is also shown.

Refer to Figure 14. Up to four orbits, selected with the number keys, can be shown at once (but see Inner and Outer orbit on the program control page). The orbits selected are determined by the number of the outer planet. For example, to display the orbits of Venus, Earth, Mars and Jupiter press "5", Jupiter being the 5th planet from the Sun.

The orbits are drawn and oriented accurately to the resolution of the display. The sizes of the planets and the moon are, of course, not remotely to scale. The relative sizes of the orbits are to scale, but the distance of the moon from the Earth is not.

The vernal equinox is an imaginary horizontal line extending to the right from the Sun. Perihelion is shown as a dot the color of Venus (default = white) on the orbit. The ascending node is shown by a dot the color of Mars (default = red). Note that Earth does not have an ascending node. Thus, a glance at the orrery display will give you a feel for the position of the planets relative to each other, their distance from the Sun and whether they are above or below the ecliptic.

The planets can be moved in their orbits using the big + and - keys to advance or retard one time interval or in free running mode by pressing the "F" key. The date and time of the display can be shown with the manual mode "M" key as on the astrolabe display. The animation rate can be slowed down and speeded back up with the big - and + keys on the keypad.

Use of the orrery function can be useful for illustrating planetary phenomena such as conjunction, opposition, elongation, synodic period, etc. Referring to the glossary, the page of calculated planetary values (Alt+V) and the orrery display is instructive in getting an intuitive feel for orbital parameters and how they apply to the real planets. The moon's position is useful for visualizing lunar phases and understanding lunar position measurements such the phase angle.

IF YOU ARE DISPLAYING THE ORBITS FOR A TIME SEVERAL HUNDRED YEARS FROM THE PRESENT THE ORBITS WILL HAVE TO BE REINITIALIZED TO ACCOUNT FOR THE CHANGE IN POSITION OF PERIHELION AND THE ASCENDING NODE. TO REINITIALIZE SIMPLY SAVE AND RESTORE ON THE PROGRAM CONTROL PAGE.

The planet phases and Jupiter's moons can also be displayed on the orrery screen. There is one slight difference; to display a phase picture press Shift+ the planet number. To remove the display press the same pair of keys. Animation of Jupiter's satellites is clearer on the orrery display.

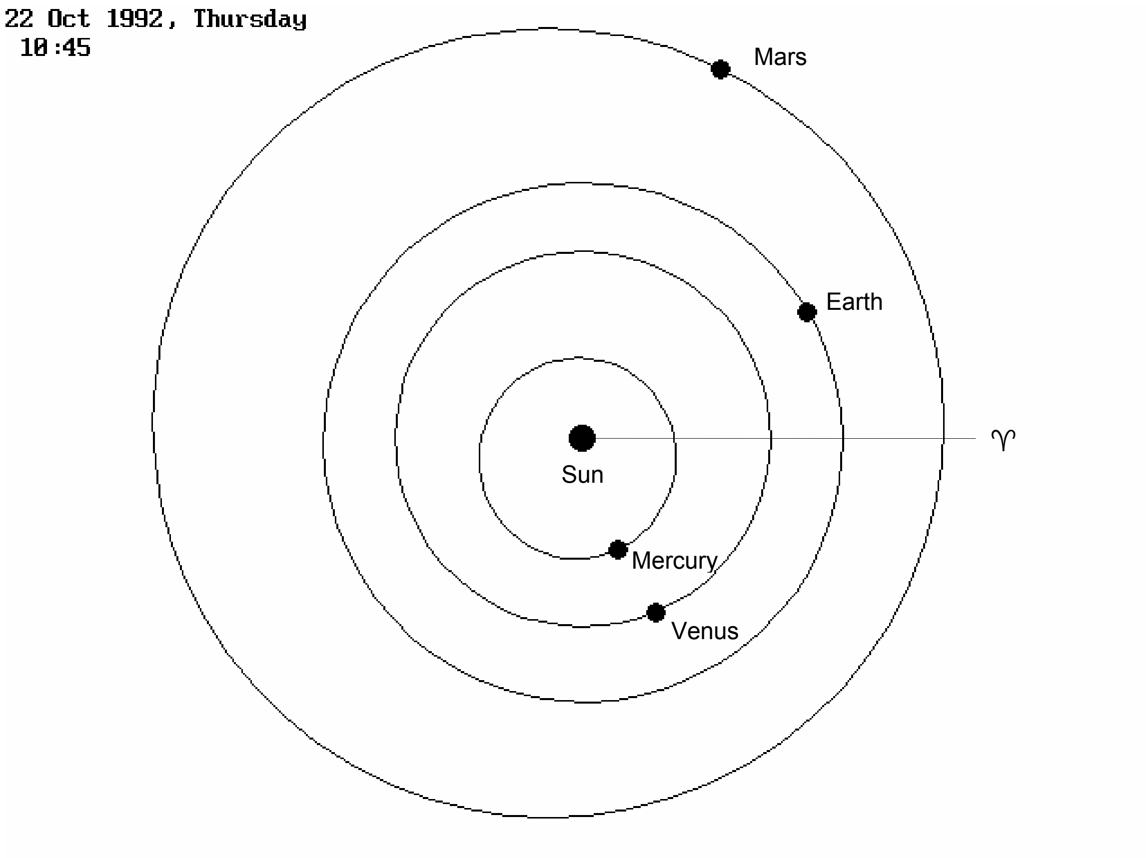


Figure 17. Orrery Mercury to Mars

MENUS

The Electric Astrolabe can execute without intervention for tutorials, exhibits and to eliminate typing to recreate sequences of interesting astronomical events or to display sequences of images. MENU mode allows the Electric Astrolabe to execute without manual intervention by reading commands from a stored file. Menu mode is invoked by Ctl+M. The menu will run continuously until ESC is entered from the keyboard or the menu file ends.

Menu mode was implemented in order to support a public display of the The Electric Astrolabe at the Adler Planetarium. It is rather specialized and this chapter can be skipped entirely unless you are planning an exhibit. On the other hand, some advanced users have come up with some interesting and entertaining automated animations.

The Electric Astrolabe can be started in menu mode by entering /M on the command line as:

C:\ASTRO>**ASTRO /M {FILEPATH]**

astro /m menu.eam starts the menu stored in MENU.EAM when the Electric Astrolabe begins execution. Any valid file path may be used to specify the menu file to be used.

To stop the menu and return to interactive operation, press Esc or Ctl+M.

You do not want display users to be able to stop the menu when the Electric Astrolabe is to be used in a public display. Starting the display with C:\ASTRO>**ASTRO /D {FILEPATH]** removes the ability to stop the display with Esc or Ctl+M. The /D switch should not be used until you are confident the display functions as desired. The only way to stop the display under DOS when it is started with /D is to reboot. If the display is started from AUTOEXEC.BAT, the system will have to be rebooted from a diskette to allow changes to AUTOEXEC.BAT.

The display can be started automatically under Windows by creating a shortcut that specifies C:\ASTRO\ASTRO /D (using a shortcut to start the display allows you to specify the default directory and specify the needed XMS memory). Under Windows, the DOS session for the display can be ended with Ctl+Alt+Del to return to Windows.

The MENU file:

Creation of a menu file requires a high level of understanding of Electric Astrolabe commands.

- The menu file can be any name. The default menu file name is MENU.EAM (EAM = Electric Astrolabe Menu).

  The menu file must be an ASCII file. ASCII files can be created with any text editor.

- The menu file can contain Electric Astrolabe commands, comments and labels. Menu commands are described below. Comments can be used to make notes in the file about functions the menu is performing. Labels are used to identify sections of the menu file.

- The file must begin with the letters EAMENU so the program can be sure it is a menu file. Each line in the file is a command, comment, label or blank line. There can be only one command to a line. Comment lines must begin with *. Comments can be to the right of any command delimited by *. Blank lines are ignored. Labels begin with a colon (:).

Following are examples of valid menu file lines:

```
EAMENU
*  Menu sample
:BEGIN
A 3        *Turn plate on and wait 3 seconds.
```

- Menu commands are not exhaustively validity checked. Only the commands for the graphic pages are supported. If the file contains an invalid command, there will be a beep to warn you that the menu file contains an error. The menu will execute up to the invalid command and return to the astrolabe display. A brief error message is displayed in the status area on the program control page. If the TRACE file is active, the error message is written to the trace file (see ^C below).

- Each command has an associated time in seconds. The minimum time delay is approximately 0.055 sec (1/18 sec. which is the timer interrupt frequency). The result of commands with a 0 delay time are not displayed. This allows you to change one or more display elements without causing an annoying flicker on the screen.

- Menu entries are the command, any prompt values, time to next command (may be 0) separated by blanks or any punctuation mark. Command codes may be either upper or lower case.

  Command key {Prompt values| Switches} time

  N.B. Prompt values are not validity checked by MENU and the proper number of prompt responses and formats must be entered in the Menu file. All prompt responses must be enclosed in double quotes (" "} so the program can know the embedded blanks are part of the response. If a response is expected and none is in position, the program will beep twice and return a null response. Null responses (just Enter with no value) are entered as "#".

  Examples:

  A 3 = Execute A command and wait 3 seconds. The same command could be entered as: A 3 sec. The sec are ignored. A 3 seconds is also valid. A - turn off plate, 3 sec. is NOT valid (next non-blank character to right of command must be valid input.

  D "3/7/1949" 10 = change date to March 7, 1949 and wait 10 seconds.

  L "41 28" "73 30" "New Fairfield" 5 = change latitude to 41° 28′ and longitude to 73° 30′. Place = New Fairfield and wait 5 seconds.

  L "38 58" "#" "#" 1 = Change Latitude to 38° 58′, no change in longitude and no entry for place name. One second delay.

- Commands that use the Ctl key are prefixed with ^. Commands that use the Alt key are prefixed with @.

  ^E 5 = Label ecliptic and wait 5 seconds.
  @S "18:32" 0 sec = Set sidereal time to 18:32 and immediately execute next command.

- A SAVE is executed when MENU is entered and a RESTORE is executed when the menu ends to preserve astrolabe settings while the menu is running. The astrolabe display screen is set to a known state with all elements OFF when menu mode is entered.

- Function keys are identified as Fn.

  F6 0 = Set interval to one day and immediately execute next instruction.

- Commands that use punctuation are entered exactly as from the keyboard. Punctuation key commands are ; (DST), + (increment one interval), - (decrement one interval), = (here).

- The Start Free running mode command (F) uses the time parameter differently. Instead of seconds you specify the number of free running cycles.

  F6 0 *Set time interval to 1 day
  F 90 *Free running mode for 90 days

- Changed commands are: > = up one page, < = down one page, ^< = switch to orbit mode page (equivalent to Ctl+PgDn). ^> = switch to astrolabe page (equivalent to Ctl+PgUp)

- Functions not supported in menus:

  a. Speed up/ Slow down free running mode (this can be done with an interval specification, sort of). The animation rate used is the rate in effect when the menu starts.
  b. Program controls (home zone, video mode, etc.)
  c. Add objects and cities.
  d. SAVE, RESTORE, FILE, LOAD defaults.
  e. QUIT (Q)
  f. Input for updating values on text pages are not supported for menus (J, tab, insert, delete, backtab, rubout, etc.)
  g. ESC to return to previous page.
  h. Ctl+PgUp and Ctl+PgDn to go directly to astrolabe or orrery. Use successive > and < with time = 0.
  i. The screen resolution cannot be changed in a menu. The resolution in use when the menu starts is used throughout.

- Invalid commands in the menu cause a beep and return to normal operation with the state of the astrolabe as left by the menu commands that have executed so far. The last command in the menu file should be ^M for an orderly end to the menu. This will cause the astrolabe to be restored to the state it was in when the menu started.

- The display components are set OFF (i.e. to a blank screen) when menu mode is entered. All switches are set OFF. This always gives you a known state for the screen. The astrolabe elements will have to be turned on by the menu to display. Switches that do not affect the content of the display are not reset (precession, high precision calculations, dynamical time).

MENU COMMANDS

Following are definitions for commands that are unique to menu mode.

I DISPLAY .GIF FORMAT GRAPHIC FILES

The I command is used to display .GIF format graphics files. It is a very common command when the Electric Astrolabe is used as a display or tutorial

Command is: I {file path} {switches} Time

e.g. I INTRO.GIF 5 sec.

The file path must precede any switches. The maximum length of the file path is 18 characters. Image switches can be used to control how the image file is processed. Valid switches are:

/Sn Save image in memory as index number n. Redisplay of an image saved in memory is much faster than reading from a disk file. n can be from 1 to 9. If the save index is the same as a previously saved image that has not been cleared, the current image will replace the saved image. n must be specified. If n is not specified, no action takes place.

example: I COVER.GIF /S1 10 will draw the image COVER.GIF on the screen for 8 seconds and save the image in memory as #1.

/Dn Draw image saved as index n. e.g. I /D1 8 will redraw the image store as index #1 and keep it on the screen for 8 seconds. n is required.

/Cn Clear stored image n. This switch removes image n from memory. Only one image can be cleared in a single command. If multiple C switches are on a line, only the last one is used.

/L Image list. A sequence of images can be displayed without the annoying screen flicker caused by switching display modes.

I COVER.GIF /S1 /L 5	*Display and save COVER.GIF
I OVERLAY.GIF /T /L 5	*Overlay COVER.GIF with OVERLAY.GIF
I /C1 0	*Clear COVER.GIF

/N No display. The /N switch allows images to be decoded and stored in memory for later fast display. This function is useful if the images in the menu will be used many times.

/F I|O|N|B Fade control. The parameter controls whether and how images fade in and out. I = fade **I**n, O = fade **O**ut (default), N = **N**o fade, B = **B**oth, fade in and fade out.

/T[n] Transparent Image. A transparent image does not display the background color. This allows images to be built up in layers on the screen. The background color is determined by the color of the top left hand pixel of the image. When the image is displayed, all colors are drawn on the screen except the background. Transparent images can be prepared with a draw program by setting the background to any solid color. Most draw programs will not export a .GIF image of full size unless the background color is specifically set. Therefore, leaving the background blank when creating the transparent image will not normally provide a full size image. The transparent image must be the same resolution as the image being overlaid. Note also that transparent images use the same color definitions as the image overlaid so color renditions may vary depending on the image being overlaid. The image being overlaid **must** be in a list of images (/L) in order to prevent the display from being reset when this image is shown. You will normally not want to specify fade out (/F O) for the previous image. You can override the color displayed in the transparent image to make overlays partially color compatible. If the overlay image is text only, all of a single color, you can specify which color of the background image to use. For example, if the dominant color in the background image is color 7, you can specify that the transparent image should use only color 7 by using /T7 in the menu specification for the image. You can determine the colors of the background image (0-255) by displaying it using the "I" command on the astrolabe display and pressing "I" again to show the background image's color map. Note that if a number is specified for the transparent image, **only** that color is displayed for the overlay. You can also use the override color to make text overlays of different colors by selecting the colors from the background image.

.GIF images are centered on the screen. The .GIF display program attempts to provide a suitable background color for images that are smaller than the full screen by filling in the rest of the screen with the color of the upper left hand pixel of the image. The background color can be changed by manipulating the color of the upper left hand pixel with a draw program or an image processing program such as HiJaak PRO.

TEXT BLOCKS.

You can specify a block of text to be displayed on the astrolabe screen. The specified text is displayed in the block exactly as entered. The location of the center of the text block can be specified using /x and /y following the text. Text block text is enclosed in double quotes ("") optionally followed by the location. The text block will be centered on the screen if a location is not specified. If /x is not specified, the text block is centered horizontally, similarly, is /y is not specified the text block is centered vertically on the screen. x and y are specified as the percent of the screen size. For example, /Y 75 centers the text block 75% of the screen from the top. /X 25 centers the box 25% of the width of the screen from the left side. Specifying /X and /Y as the percent of the screen size makes the text independent of the screen resolution used to display the astrolabe.

Example: "This is a computer created astrolabe plate." 6 will draw a text block in the center of the screen and wait 6 seconds. The text block will have a border of one blank line at top and bottom and one character space on each side of the text.

```
"
        A different plate is needed for each location.

                This plate is for Chicago.
" /Y 75 5
```

will center the text block 75% of the screen height from the top (at line 450 on an 800x600 screen) and wait 5 seconds before processing the next menu command. Notice that padding lines are used to provide more blank space in the block.

The text block stays on the screen until a command is issued that causes the astrolabe to be redrawn. A command has been added that is active only in menu mode to make this easy. The W command redraws the astrolabe with the current settings. The following command sequence will write a text block, keep in on screen for 10 seconds and then restore the screen to the astrolabe:

```
" Text " 10     *Write text box
W 0             *Rewrite screen and clear text box.
```

CONTROL FUNCTIONS

A new command for menu mode has been added to perform certain control functions such as changing astrolabe colors, controlling which astrolabe elements are displayed and debugging menus. The command is:

^C {/n R,G,B} | {/P HHHH} | {/T + | - | " text"}

Only one function can be executed in each instance of the ^C command. Note that no delay time is used.

/n R,G,B changes color n to the values R,G,B where R = Red, G = Green and B = Blue. Color values can range from 0 to 63. For example, /0 0,0,0 changes the background color to black and /1 63,0,0 changes the plate color to red. The color changes take effect immediately regardless of the delay time value.

/P HHHH specifies which plate elements are to be displayed. HHHH is a hexadecimal word which identifies the plate elements to be displayed. The default is FFFF which displays all elements. The plate elements are:

Pos.	Value	Element
15.	8000	Horizon
14.	4000	Altitude arcs
13.	2000	Azimuth arcs
12.	1000	Roman numerals on limb
11.	0800	Time tic marks
10.	0400	Degree tic marks on limb
9.	0200	Tropic of Capricorn
8.	0100	Equator
7.	0080	Tropic of Cancer
6.	0040	Latitude label
5.	0020	Altitude labels
4.	0010	Twilight arcs
3.	0008	Meridian line
2.	0004	East/West line
1.	0002	Not used
0.	0001	Not used

To determine the value of HHHH, add up the elements to be displayed as a hexadecimal number. For example, the value 8200 will display just the horizon and Tropic of Capricorn and 8380 will cause the horizon and tropics to display.

/T controls a special file, the trace file, that can be used to debug menus. /T + turns the trace file on. /T - turns the trace file off. When the trace file is on, all menu commands and menu messages are written to a file named TRACE.EAM. The file is an ordinary ASCII file that can be displayed with any text editor. The file will contain all menu commands executed and all generated messages from the time the file is turned on with /T + until it is turned off with /T -. The trace file is started from the beginning whenever a /T + is encountered in the menu. Note that only the first line of each command in the menu file is written to the trace file. Therefore, multiple line commands, such as may occur with text blocks, will show only the first line.

"text"causes the text to be written to the trace file as a note to yourself that a certain point in the menu was reached. For example, ^C /T "Entering uses submenu" causes the command including the text, "Entering uses submenu" to be written to the trace file if it is open. No action is taken if the trace file is not open.

DISPLAY ALTITUDE AND AZIMUTH ARCS.

A new command has been added to display the astrolabe plate elements that is active only from a menu. The Y command will draw an altitude or azimuth arc in a selected color. The command syntax is:

Y {/C n} {/A d | /Z d} t

where /A specifies that an altitude arc is to be drawn and /Z to draw an azimuth arc. d is the angle of the azimuth or altitude arc. d **must** be evenly divisible by 5 or 10. /C optionally specifies the color number. If /C is not specified, color 1, the plate color, is used. For example:

Y /C 8 /A 0 3

draws the horizon (altitude angle = 0) in white (color 8) and hold for 3 seconds. The highlighted arc will stay on the screen until the screen is refreshed by another command.

To cause the altitude arc to blink, you can use:

Y /C 8 /A 20 0.5	*Draw 20° altitude in white
Y /A 20 0.5	*Restore 20° altitude to plate color

Y /C 14 /Z 30 3 draws the 30° azimuth in yellow (color 14 = sun's color) and waits 3 seconds.

Note: An azimuth angle of 0 or 180 is ignored.

INTERACTIVE OPERATION.

You can leave the menu temporarily to allow interactive operation of the Electric Astrolabe using ^I, a command that is unique to menu mode. The commend syntax is:

^I n where n is the number of **minutes** to allow interactive operation.

At the end of n minutes, the menu resumes at the next command. All astrolabe elements are turned off on return from interactive execution just as if the menu were starting. The astrolabe state that is restored when the menu ends is the state it was in when the menu started, not the state at the end of interactive execution. If the Quit command is entered during interactive execution, the menu resumes.

N.B. In the Adler version, the only keys that are active in interactive mode are the unshifted function keys for changing location.

If the ^I command is the last command in the menu file, the menu starts over at the beginning.

A small amount of interactive control can be achieved with "Wait for Any Key"; @K. When a @K command is encountered in the menu, the display pauses for the user to press any key. The command syntax is @K t where t is the maximum time in seconds to wait. Normally, a text block or an image should be displayed before the @K command instructing the user to "Press any key to continue".

LABELS AND SUBMENUS

Menus can be broken into sections that can individually executed. A section of a menu is identified by a *label.* Labels are a word, beginning with a colon (:) on a line by themselves. Labels **must** start on the first character of the line. Examples of labels are :BEGIN or :Reset. There are two types of labels. Labels that begin with a colon (:) identify routines. Labels that begin with a slash (/) refer to places within a routine. In general, labels beginning a colon (:) are the only ones needed. /labels are only used to restart a routine at a specific point.

A menu section can be executed by pressing a key defined with the K command (see below). This allows long menus to be constructed in pieces that can be executed in any order. A section of a menu that is executed as a unit is called a *submenu.* The astrolabe tutorial is constructed using submenus. Submenus can be defined with a label or can be separate files. Any Electric Astrolabe menu file can be executed as a complete menu or as a submenu file.

The state of the astrolabe is cleared when a submenu begins execution. That is, all astrolabe elements are OFF and all key definitions (see K command below) are reset.

A complete menu can contain a maximum of 10 submenus.

Submenus begin with a label that identifies the submenu and end with either ^Z, to terminate the submenu, or ^Z :label to execute another submenu. The ^Z command is:

^Z - End submenu or
^Z {:label} - Start the submenu at :label in this file

When a ^Z command is encountered in the currently executing menu, the section of the menu containing the ^Z command ends and a new submenu execution begins at the specified label. If no label is specified, execution resumes after the last command executed when this submenu was invoked (if the submenu was invoked by a key specified with the K command, the return is to the same command that was executing when the key was pressed - this allows returns to menu screens). A ^M in a submenu terminates the entire menu and returns control to the Electric Astrolabe. A ^M in a submenu file returns control to the menu file that was executing when the submenu file was invoked. ^Z and ^M are equivalent if the ^Z is encountered in the main menu. This allows submenu files to be tested independently.

When a new submenu is started, the astrolabe is set with all switches off and all key definitions are cleared.

Keys to invoke submenus are specified with the K command:

K key [:label | \filepath | ^Z]

key is the letter or number which is being defined. Alphabetic, numeric or the characters :, ;, <, =, >, ?, @ can be specified. Upper or lower case alphabetic character can be specified but the case of entered keys does not matter. A label in the current menu file, the path of another menu file or ^Z to end this submenu can be specified. :label is a label in this menu file. The label must be entered **exactly** as it appears in the file (e.g. if the label is :BEGIN, neither :Begin nor :begin will work). filepath is the path for a valid menu file. The filepath must begin with \. The special case of the K command with ^Z allows you specify that the key definition is used to end the submenu. You should not end a submenu with a key definition that points to a label followed by ^Z as this will treat the label as a new submenu and the ^Z will merely return control to the previous submenu level that was active when the key was pressed.

K commands, which would typically be placed at the beginning of the main menu or submenu, specify a label where execution is to begin when the key is pressed. For example:

K A :OVERVIEW

specifies that the submenu :OVERVIEW is to be executed when the A (or a) key is pressed. The label :OVERVIEW must be in the current menu file. Similarly,

K C \USES.EAM

specifies that the menu file \USES.EAM is to be executed when the C (or c) key is pressed.

If the label is not in the current menu file exactly as specified or the filepath does not specify a valid menu file, the program will beep when the key is pressed and ignore the key.

```
K R /RESTART
```

will cause execution to begin at the command following the /RESTART label in the same routine. That is, since /RESTART is in the same routine, all settings and hot spot definitions are preserved.

A section of a menu can be executed repeatedly while waiting for a key to be pressed by using the J (for Jump) command:

```
J :label
```

When a J command is encountered in a menu, execution resumes at the command following :label. J does not create a submenu and the astrolabe and key definitions are not reset. Use ^Z if you need different interrupt key definitions in a section of the menu.

Following is an example of how submenus might be combined into a complete menu. The intention is to present a brief sequence of screens that provide menu options and to execute the options depending on which key is pressed.

```
EAMENU

*       Main Menu

K A :OVERVIEW          *Execute OVERVIEW submenu if A is pressed
K C \USES.EAM          *Execute USES.EAM submenu file if C is pressed
K Q ^Z                 *Exit menu if Q is pressed
:BEGIN
I WELCOME.GIF 5        *Display WELCOME .GIF image
I MENU.GIF 10          *Display key options ( A for overview, C for uses, Q for quit)
J :BEGIN

*       Overview submenu

:OVERVIEW
K P \PLATE.EAM         *Execute PLATE submenu file if P is pressed  (Return to this menu on ^M)
K R :RETE              *Execute RETE submenu if R is pressed
K Q ^Z                 *Return to main menu if Q is pressed (Allows submenu to be interrupted)
I OVERVIEW.GIF /L 10   *Display key options
^Z                     *End submenu and return to menu screen if key not pressed in 10 sec.

*       RETE submenu

:RETE
.
.                      *Submenu commands
.
^Z                     *Return to Overview loop
```

Notice how the J command can be used to cause sections of the menu to execute repeatedly. Also notice that the same key (Q) can be used for different purposes in different submenus.

Use of the K and ^Z commands provide enormous flexibility in constructing interactive menus.

In some situations it is important to know the exact state of the astrolabe display. The **%** command (with no time parameter) does a complete reset of all astrolabe components. The following example illustrates the use of the % command. This submenu executes an example and then gives the user the option to repeat the example or continue to the next subject (the .GIF file CKPRST16.GIF contains two “buttons”: “Repeat” and “Next”. If Repeat is selected, the routine restarts at /RUSES. If Next is selected, the next command is executed (note that no function is associated with the X key emitted by the second hotspot).

```
/RUSES
%                  *Reset Astrolabe - this command required to reset astrolabe if routine is reexecuted
^Q 0                *Set quiet mode
L "41 52" "90 00" "Adler Planetarium" 0  *Set to center of time zone
A 0                *Plate on
X  0               *Shading on
W 0                *Draw screen
D "9/1/1994" 0     *Set date so EQT = 0
T "12:00" 0         *Set the time
E 2                *Ecliptic on^E 2
@A 0               *Sun only
P 2                *Planets on
R 2                *Rule on
F1 0               *Interval = 1 minute
F 168              *Rotate to 14:48
Y /A 40 /C 9 0.5   *Turn alt = 40 on

"
The rule points to the time: 2:48PM.
" /Y 75 1
K R /RUSES                             *Set R to jump to /RUSES
^H /U 17 541 /L 124 580 204 R          *Restart hot spot
^H /U 670 540 /L 777 583 204 X         *Continue hot spot
I \GIF\NXTPRV16.GIF /L /T14 /F N 60    *Display option screen
.
.
```

Note: Any option screen that overlays an Electric Astrolabe screen must be a transparent image stored as an 800x600, **16 color** .GIF file.

Three actions are possible: 1. Select R to reexecute from /RUSES, 2. Immediate execution at next command if X selected, 3. Image display times out and falls through to next command.

Menu Command Reference

- Menu files must be ASCII text files. The file can be any size up to the amount of memory remaining when the Electric Astrolabe is running.
- The first characters in the menu file **MUST** be **EAMENU** to identify the file as an Electric Astrolabe menu.
- The default menu file name is MENU.EAM. The name of the menu file can be changed on the program control page with the MENU option.

The following list of commands is provided as a convenient reference for the syntax of menu commands.

Format:

- @ = Alt shift key
- ^ = Ctrl shift key
- Parameters in braces ({}) are optional. Where one of a choice of parameters must be entered, the parameters are separated with |.
- Lower case letters are integers.
- t is a time in seconds (decimals are allowed).
- # is a null entry.
- Parameters can be separated by any number of spaces.
- With the exception of text blocks ("), commands must be on a single line.
- Blank lines are allowed.
- Lines beginning with * are comments.
- Text to the right of * on a command line are treated as comments.

"text" {/X n} {/Y n} t	*Text block centered at X, Y. n = percent of screen size (default = 50)
%	*Reset astrolabe
; t	*DST on/off.
= t	*Here.
0 t	*Longitude = 0°
n t	*Display phase for key n.
A t	*Turn plate display on or off.
@A t	*Display sun only when planet display is on.
B t	*Turn bright star display on and off.
@B t	*Display all stars
^C {/n C,C,C} | {/P HHHH} t	*Control colors and plate elements. n = color, C=color value, H = hex
D "mm/dd/yyyy" t	*Specify date. m = month, d = day, y = year.
E t	*Ecliptic display on/off.
^E t	*Label ecliptic with zodiac symbols.
F n	*Free running mode for n cycles.
Fn t	*Function key n (set interval to function key n value).
G t	*Gregorian/Julian calendar switch
I {"fn.GIF"} {/Cn} {/Dn} {/L} {/N} {/Sn} t	*Display image. n = image index number.
J :label	*Jump to :label
K c [:label | filepath]	*Specify interactive key target as :label (this file) or menu file on key c
@K t	*Wait for any key to be pressed for maximum of t seconds.
L "d {m}|#" "d {m}|#" "p|#" t	*Specify latitude/longitude. d = degrees, m = minutes.
M t	*Manual mode on/off
^M	*End menu and return to normal Electric Astrolabe operation
N t	*Now. Set to system date/time.
@N t	*North/south projection switch.
O t	*Display Messier objects on/off.
@O "m" t	*Maximum object magnitude to display. m = magnitude, 0-12.

^O t	*Display Messier object number on/off.
P t	*Planet display on/off.
@P t	*Precession on/off.
^P t	*Label planets on/off.
^Q t	*Quiet mode on/off.
R t	*Rule display on/off.
R t	*Refresh screen
S t	*Star display on/off.
@S “hh{:mm}” t	*Set sidereal time
^S t	*Label constellations on/off.
T “h{:m}” t	*Specify time. h = hour, m = minutes
@T t	*Display time as 24hr/AM-PM.
^T t	*Dynamical time on/off.
U “h{:m}” t	*Specify universal time.
W t	*Write screen. Refreshes screen to current settings.
X t	*Turn shading on and off
@X t	*Display planets as +, on and off.
^X t	*High precision calculations on and off.
Y {/C c} /A|/Z d t	*Display altitude or azimuth arc. c = color (default = 1), d = angle
Z “z” t	*Specify time zone. z = zone from Greenwich.
^Z	*End submenu
^Z {:label}	*Start submenu at :label in this menu file.

Hints

1. Most commands **must** have a delay. Forgetting to include a delay time is the most common error. Commands with no delay time can produce unpredictable results. If you get a blank screen or other erratic behavior, this is the first thing to check.

2. The screen is not redrawn if the delay time is zero. If you need to redraw the screen, use the W command.

3. Don’t forget that commands that change the time put the Electric Astrolabe in manual mode which displays the date and time in the upper left hand corner. If you do not want the date and time displayed you need to use Quiet mode (^Q).

4. All astrolabe display elements are turned off when the menu or submenu is started. If you are confronted by a blank screen it is probably because you forgot to turn the astrolabe elements on.

5. If you specify /L for the last image in a list of images, you will get a blank screen. The last image in a list should generally not have the /L switch set.

6. Forgetting to put a closing “ at the end of an input parameter will cause unpredictable results.

7. When writing a menu it is a good idea to keep a log of the screen components that are on and off. It can get confusing and time consuming if screen elements do not appear when you expect.

Note: The commands in the menu file are processed as if they were entered from the keyboard but it is possible to specify commands in a menu file that would be impossible to enter from the keyboard. When this happens, the results are wildly unpredictable and the results can be range from being merely confusing to bringing the computer to a complete halt.

EXERCISES

Following are some suggested exercises for getting familiar with the operation of the Electric Astrolabe. Many other uses will occur to you as you gain familiarity with the program

SUNRISE / SUNSET

Make sure shading is ON (X).
Set the interval to 1 hour (F5) and move the Sun image near the eastern horizon.
Set the interval to 1 minute (F1) and hold down the Big+ or big- until the Sun is very close to the horizon.
Sunrise is just before the shading turns from gray to blue.

If you want to be quite precise, go to the V page, press F1 to set the time interval to one minute and use the big+ or big- key to adjust the time until the altitude of the Sun is about -0.833°. This is the defined time of Sunrise.

Repeat for Sunset.

Now for a little more difficult exercise: Find the day of the year with the earliest Sunset; it is not the Winter Solstice. (Answer: about December 9). Why is this the earliest sunset?

THE SEASONS

Find the times of the equinoxes and solstices. That is, find the exact times when the right ascension of the Sun is 0h, 6h, 12h or 18h. Refer to the orrery to see the position of the Earth relative to the Sun. Notice the little white dot on the Earth's orbit. This is the point of perihelion, when the Earth is closest to the Sun. You will see that the Earth is quite a bit closer to the Sun in the northern hemisphere winter than in the summer.

LATITUDE

Use the city page (Alt+C) to display the sky in Stockholm (put the cursor on "Stockholm" and press Ctl+Enter). Notice how the horizon is nearly a circle. Find the times of Sunrise and Sunset for different times of the year. See how the astrolabe projection gives a graphic view of how an extreme northern latitude affects the length of the day during the year. Now, do the same for Singapore which is nearly on the equator and notice how the length of the day is nearly constant all year.

LONGITUDE

Go to the astrolabe display and press "0" to set the longitude to Greenwich. Notice that the distance of the Sun from the rule equals the equation of time. Use "=" to return to your location and see the combined effect of the equation of time and your difference in longitude from the center of your time zone to change the distance of the Sun from the rule. For an extreme example, select Madrid from the city page. The time zone in Madrid is European Continental time but Madrid's longitude is actually west of Greenwich, resulting in over an hour difference between the Sun and the clock!

CIRCUMPOLAR CONSTELLATIONS

The circumpolar constellations never set. The circumpolar constellations depend on your latitude. Set the interval to 10 min. (F3) and press F to go to free running mode. Notice that some of the constellations never go below the horizon. These are the circumpolar constellations. Now try the same for a fairly northern city such a Copenhagen and a fairly southern one such as Miami. You will see a significant difference in which constellations never set.

PLANNING

Find a night when Saturn is on your meridian at about 9:00 PM and there is no moon. As a search strategy, try setting the time to 21:00 (9 PM), set the interval to 1 day (F6) and go to free running mode. When Saturn gets near the meridian turn free running mode off and find a night without a moon using Big+/-.

Your sailing club (scout troop, family, ...) wants to have an evening sail (campout, picnic, ...) this summer. In the interest of safety and esthetics it is desirable to have as full a moon as possible. Find the Saturday night this summer with the best conditions. Start with the first possible Saturday, set the time interval to 7 days on the Help screen and then find the Saturday with the best conditions.

SIDEREAL TIME, RIGHT ASCENSION AND DECLINATION

By definition, the sidereal time is the right ascension that is on the meridian. Using sidereal time, notice how you can find the right ascension of any object on the display by adjusting the display until the object of interest is on the meridian and then reading the sidereal time from the point that extends from Aries 0° on the ecliptic. Use the big dipper as a test case. The right ascension of the “pointer” stars is almost exactly 11 hours. Also note that the declination can be estimated by adjusting the time until the rule is over an object and reading the declination from the rule scale. You can set the rule over any object by using the long rule (Ctl+R) and rotating the rule with Ctl+ big+ or big-.

For circumpolar objects you can take an alternate approach. Set the latitude to 90°. At this latitude the horizon matches the equator so you can read declination directly from the altitude circles. Read right ascension as above; position the object on the meridian and read the sidereal time pointer.

THE CALENDAR

You are in London on September 10, 1752. What is the day of the week? First, go to the city page, put the cursor on London and press Ctl+Enter to make London the current location. Now, press “D” to get the date prompt and enter 9/10/1752. The day of the week shows on the upper left corner with the date. Right? Wrong! There was no September 10, 1752 in England. See the Gregorian Calendar entry in the glossary.

RETROGRADE MOTION

Put the Electric Astrolabe on February 11, 1984. Remove everything from the display except the planets and stars. Set the time so Mars is near the meridian, set the interval to a sidereal day (F9), and enter Free Running Mode. Watch Mars go from posigrade to retrograde to posigrade motion. It is very close to Saturn during this period and you will see Mars and Saturn separate and than close back up as Mars goes back to posigrade motion. If you watch closely you will see that Mars, Jupiter and Saturn all exhibit retrograde motion at the same time. Go to the orrery at the same time and observe the conditions when planets exhibit retrograde motion.

DECLINATION OF THE SUN

Put the Sun on the meridian, remove everything from the display except the plate and planets. Go to free running mode with an interval of 1 day and watch the declination of the Sun change and trace out the analemma for the location. The analemma defines the “Equation of Time” which is the difference between the time shown by a Sundial and the time shown by a clock. The variation has two components. One component is due to the fact that the Earth travels at different speeds around its orbit and is called the "equation of the center" (equation in this context is used in the archaic sense as a value that is added to make both sides of an equality match). The other component is due to the fact that civil time is based on an artificial "Sun" that travels at a constant rate on the equator which is inclined to the true path of the Sun on the ecliptic and is called "the reduction to the equator". The values are added to derive the equation of time. (Note: the earliest Sunset is not at the winter solstice because of the equation of time).

EXPLORING THE ECLIPTIC

Note that at a latitude of 90° minus the obliquity of the ecliptic (about 66° 33′ North) the horizon is the same as the ecliptic. If you set the latitude to this value and, using manual mode, position the ecliptic to 18 hours sidereal time, the ecliptic and horizon circles will match. At this latitude the zenith is the ecliptic pole and the altitude and azimuth lines correspond to geocentric latitude and longitude. Therefore, you can read geocentric latitude and longitude of stars and planets directly from the plate (you can always read the geocentric longitude of the planets directly from the ecliptic divisions since that is how the ecliptic is divided).

THE ORRERY

Interpreting the orrery completely takes a little practice. Here are a few pointers. Orbital longitude is measured from the vernal equinox (an imaginary horizontal line from the Sun to the right edge of the screen) to the planet. This value is tabulated on the page of orbit calculations as True Longitude. True Anomaly is measured from perihelion to the planet location. Perihelion is shown as a white dot on the orbit. You should be able to relate the tabulated values to the screen positions.

All of the planet orbits are inclined a few degrees to the ecliptic. The point where the orbit crosses the ecliptic plane from south to north is called the ascending node. The ascending node is shown as a red dot on the orbits and the longitude of the ascending node is tabulated as "Ascending Node". The descending node (the point where the orbit crosses the ecliptic from north to south is directly opposite the ascending node). All of the planets move counterclockwise around the Sun when viewed from the north. When a planet passes its ascending node it will be above the ecliptic and the tabulated Ecliptic Latitude will be positive. Similarly, when it passes the descending node it will be negative. A glance at the orrery shows whether the ecliptic latitude is positive or negative.

ECLIPSES

An eclipse can occur whenever the moon is near one of its nodes (i.e. is close to the ecliptic) and is either full or new. Specific eclipse conditions are rather more complicated but the Electric Astrolabe can be used as a first order approximation of potential eclipses.

Some dates of lunar eclipses are: June 15, 1973, March 2, 1961, and April 24, 1967. Solar eclipses visible in the United States were on July 9, 1945, June 30, 1954, March 7, 1970, October 2, 1978, and May 30, 1984. Set the Electric Astrolabe to these dates and see if you can determine the conditions of the eclipse. Remember that the short line at the center of the astrolabe shows the line connecting the nodes of the lunar orbit.

See Gingerich, Owen, "The Making of a Prize Eclipse", *Sky and Telescope*, (July, 1991), pp. 15-17, for a table of eclipse conditions between 1990 and 2010.

CONJUNCTIONS AND OPPOSITIONS

A planet is in conjunction with the Sun when the planet and the Sun have the same longitude (i.e. there is a straight line from the Earth to the Sun through the planet). If the planet is on the same side of the Sun as the Earth the conjunction is called Inferior Conjunction and if the planet is on the opposite side of the Sun it is called Superior Conjunction. Only the inner planets can have Inferior Conjunctions. If the longitude of a planet differs from the longitude of the Sun by 180° the planet is said to be in Opposition. Only the outer planets can be in opposition with the Sun. Here is a list of some dates of conjunctions and oppositions. See the table below. Set the Electric Astrolabe to these dates and see the results.

	Superior Conjunction	Inferior Conjunction	Opposition
Venus	Jun. 22, 1960	Apr. 10, 1961	
	Jan. 27, 1962	Nov. 12, 1962	
	Nov 9, 1966	Aug. 30, 1967	
	Jan. 22, 1978	Nov. 7, 1978	
Mars			Sep. 10, 1956
			Nov. 16, 1958
			Aug. 10, 1971
			Jan. 22, 1978
Jupiter			Jun. 20, 1960
			Dec. 18, 1965
	Jul. 10, 1978		
Saturn			Jul. 19, 1961
			Aug. 24, 1964
	Aug. 27, 1978		Feb. 16, 1978

When the conditions for conjunction and opposition are firmly fixed in your mind it will be easy to predict future ones.

TRANSITS OF VENUS

A transit of Venus (or Mercury) occurs when the planet goes across the Sun's disk. The conditions are very similar to a solar eclipse but occur much less often: a transit will occur when the inner planet is at inferior conjunctions **and** near a node in its orbit. Transits of Venus occurred in 1639, 1761 and 1769. Find the exact dates and conditions of the transits. The fastest way is to use the Orrery to find when Venus is near a node and between the Earth and the Sun. Then use the Astrolabe and the text pages to fix the exact dates and times. Note that the diameter of the Sun is about a half degree.

THE MOON

The motion of the moon is quite complicated but there are some exercises that may add understanding. One interesting thought exercise is to think through why the winter full moon is so much higher in the sky than the full moon in summer.

Note that the moon's orbit is inclined 5° to the ecliptic. Find a time when the moon's ascending node is aligned with the vernal equinox (use the calculated values to find a time when the longitude of the moon's ascending node is nearly zero) and note the effect on the moon's declination and altitude when it is full. Do the same for when the descending node is aligned with the autumnal equinox. These conditions result in the minimum and maximum declination of the moon (23½° ± 5°).

HISTORICAL EVENTS

History is rich with astronomical events that can be duplicated with the Electric Astrolabe. Following are few examples. You will encounter many more in books and magazines.

HISTORICAL ECLIPSES

See "Historical Eclipses" by F. Richard Stephenson (*Scientific American*, October, 1982, pp 170-183) for an interesting treatment of eclipses in history. Use the Electric Astrolabe to investigate the eclipse conditions (remember to account for calendar differences).

BOSTON TEA PARTY

There is a famous US stamp block commemorating the Boston Tea Party. In the upper right hand corner is a waxing crescent moon. Is the moon on the stamp historically accurate or an artistic invention? The Boston Tea Party was held December 16, 1773.

PRECESSION

The effect of precession is dramatic for times far in the past. For example, Aristotle is thought to have observed a conjunction of Jupiter and a star in Gemini on December 5, 337 BC. If you set this date (12/5/-336) and set the precession switch (Alt+P) ON, you will see that Jupiter is, indeed, near Gemini on the this date. With precession OFF, Jupiter is not even close to Gemini (see "Aristotle and a Star Hidden by Jupiter" by Sheldon M. Cohen, "Astronomical Computing", *Sky and Telescope*, June, 1992). Note that the star in question is 1-Geminorium which is far down the "toe" of the Gemini asterism. Use the following steps to confirm the result: set the date to 12/5/-336, set precession ON (alt+P), go to the page of added objects (alt+C) and add 1-Geminorum at its J2000 coordinates (Right Ascension = 06 hr 04 min, Declination = 23° 16′). When you return to the astrolabe, the symbol you have chosen will be in the correct position but you will have to turn to the planets off to see it since it is covered by Jupiter.

Another interesting exercise is to determine when, in the modern calendar, the heliacal rising of Sirius signaled the rising of the Nile in ancient Egypt. For the purposes of this exercise, assume a latitude of about 26° (which is about the latitude of the Valley of the Kings) and a date around 2800 BC.

COLUMBUS' LANDING IN THE NEW WORLD

Columbus first sighted land in the eastern Bahamas islands at about 2 A.M. on October 12, 1492. According to his log he saw the reflection of breaking waves lighted by the moon which was behind him. Confirm that the moon would have provided the needed illumination that night. The exact location of Columbus' first landfall is somewhat controversial. For the purposes of this exercise it is adequate to assume a position of 23° 30′ N. latitude by 74° W. longitude. For reference see, "Where Columbus Found the New World" by Joseph Judge (*National Geographic*, November, 1986).

KEPLER AND CONJUNCTIONS OF JUPITER AND SATURN

Kepler was mortally affected by his analysis of the conjunctions of Jupiter and Saturn. When he drew the longitude of the conjunctions on a circle divided by the ecliptic and connected lines of the longitude of successive conjunctions he saw that the lines intersected in the shape of a circle. He noticed that the ratio of the diameter of the inner circle to the outer circle is the ratio of Jupiter's orbit to Saturn's. This led him on his unproductive search for the "harmony of the spheres" that consumed so much of his life. Conjunctions of Jupiter and Saturn occur about every 20 years at a longitude roughly eight zodiacal signs in advance of the previous one. If you would like to duplicate this bit of analysis, Kepler used the conjunctions of 1583, 1603, 1623, etc.

THE RISING TIME PROBLEM

The one of the most difficult problems of ancient astronomy was determining the length of the day for any time of year at any latitude. The search for a solution to this problem could very well have provided the motivation for Hipparchus to apply the stereographic projection to quantitative astronomical problems and eventually led to the development of the astrolabe. The problem was stated as, "How many equatorial degrees cross the horizon in the same time as a given number of ecliptic degrees?" After a little reflection one realizes that the length of a day is equal to the number of equatorial degrees that have passed between Sunrise and Sunset converted to units of time at 15° per hour. The number of ecliptic degrees that pass in the same amount of time depends on the latitude and the season. The problem is expressed in this way because in those days hours were defined as 1/12 of time between Sunrise and Sunset and, thus, the length of an hour varied depending on the time of year. The use of fixed length so called "equinoctial hours" did not come into use until much, much later. Early Persian astrolabes did not have an hour scale but did have scales for reading the unequal hours. On these instruments the limb was divided into degrees. On an astrolabe equipped with a rule and hour scale the solution is trivial: the length of the day is the difference in time between Sunrise and Sunset.

On a Persian astrolabe that had neither it was solved in a clever way. Notice that the winter solstice at Capricorn 0° is 90° or six hours earlier than the vernal equinox. Right ascension is the angle of something along the equator from Aries 0°. Sidereal time is the right ascension of objects that are currently on the local meridian. Therefore, for a given sidereal time, Capricorn 0° points to the right ascension of the point on the equator that is just rising. To solve the rising time problem (i.e. find the length of the day in terms of equatorial degrees) the astrolabe is set for Sunrise for a given date and the right ascension of the point of the equator that is rising is noted from the position of Capricorn 0° (Persian astrolabes had an indicator at this point called the "muri"). Then the astrolabe is set for Sunset and equatorial right ascension is noted. The difference is the number of equatorial degrees that passed during the day and, thus, the length of the day.

THE ISLAMIC CALENDAR

The astrolabe was prominent in the early days is of Islam and you may find dates in your astrolabe reading that need to be converted from the Islamic calendar. The Islamic calendar has 12 lunar months. Each month begins when the tiny crescent following a new moon can be observed just after sunset. For religious purposes, the crescent must actually be observed so there are differences in the start of months, even between neighboring communities, so it is often difficult to reconstruct a specific date unless the day of the week is also specified. You can use the Electric Astrolabe to find the earliest date on which a month can begin. Experiments have proved that it is impossible for a naked eye observer to see the first lunar crescent if the altitude of the Moon is less than 7° greater than the Sun. When the azimuth of the Moon is close to the Sun, the Moon must be at least 10° above the Sun for reliable observation. If the Moon's azimuth is 10° from the Sun, it may be possible to observe the crescent when the altitude of the Moon is 8° and when the azimuth is greater than 15°, 7° difference in altitude is a reasonable minimum.

For astronomical and calendric conversions, the Islamic calendar has fixed rules for dates. The Islamic calendar begins on Thursday, 15 July AD 622 (Julian date 1948439), the day when Muhammad fled from Mecca to Medina (the *hijra* or hegira). Years are stated in the era of the Hegira (AH). Months have 30 or 29 days, alternatively, except for the twelfth month which can have either 29 or 30 days. In 30 Islamic years, 19 have 354 days and 11 have 355 days. The intercalary years of 355 days are years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26 and 29 of the 30 year cycle. Therefore, 30 Islamic years have $19 \times 354 + 11 \times 355 = 10631$ days, which is very close to 360 lunations, so the error is very small.

Many historical dates specify only the year. To find the Julian date of the beginning of a year AH, you find the number of days that have elapsed in the Islamic calendar. For example, the Julian date of the beginning of the year AH500 is found as follows:

In 499 years there are 16 complete 30 year cycles with a remainder of 19 years. From the list of intercalary years above we see that in 19 years there are seven years with 355 days and 12 with 354 days. Therefore, in 499 years there are $16 \times 10631 + 12 \times 354 + 7 \times 355 = 176829$ days. The Julian date of the beginning of the year AH500 is 1948439 + 176829 = 2125268 or 1 Sep AD1106. AH1415 begins on 9 Jun 1994.

SPECIAL EVENTS

Set the time, date and location to the place and time of your birth. Do you see anything remarkable in the universe to mark your arrival into it?

ASTROLOGY NOTE

Much of history of the astrolabe was tied to astrology. In fact, some of the most respected astronomical minds in history including Johannes Kepler and Regiomantanus were as occupied with astrology as with astronomy. The astrolabe was a convenient way to determine the aspects of a horoscope because much astrological stress was placed on the position of the ecliptic. Of particular interest was the ecliptic angle on the eastern horizon (the ascendent), the ecliptic degree on the western horizon (the descendent) and the ecliptic degree on the meridian (the degree of mid-heaven). In use, the astrolabe is set to the time and date of interest (birth, death, coronation, etc.) and the ecliptic degrees are read directly. It should also be noted that many European instruments included additional astrological information on the plates most notably the “12 Houses of Heaven”. Some lovely clocks with astrolabe dials went even further in including rotating indicators showing more sophisticated aspects such as trines. Such decoration has not been included in the Electric Astrolabe.

ADVANCED TOPICS: ORBITS

A few fundamental orbital mechanics terms must be understood in order to completely appreciate the planetary information provided by the Electric Astrolabe. Following is a non-technical and non-mathematical description of planetary orbits:

Refer to Figures 15 and 16. Figure 15 shows a planet's orbit in space. The orbit in the figure is much more eccentric than any of the real planetary orbits in order to highlight the concepts. You may recall from basic science that Johannes Kepler discovered the fundamental rules of planetary orbits. In particular, planets travel around the Sun is elliptical orbits with the Sun at one focus. **f** in the figure is the focus. **P** is perihelion; the point on the orbit where the planet is closest to the Sun. **A** is aphelion; the point on the orbit where the planet is farthest from the Sun.

The position of the planet in its orbit is described as the angle of the planet from the line that connects perihelion and aphelion (the major axis of the ellipse). Angles measured from this line are called **anomalies**. The angle ν is called the **true anomaly** and is the angle from the orbit's major axis to the planet measured from the focus (i.e. the Sun). Kepler used an auxiliary angle (**E**) called the **eccentric anomaly** measured from the center of the orbit ellipse to calculate the true anomaly.

However, none of the planetary orbits have the same major axis. Therefore, if we are to describe planetary positions in a consistent way it is necessary to measure the planet's position from a fixed point that is common to all the planetary orbits. Such a point is the vernal equinox. As seen from the Earth, the vernal equinox is a fixed point in space that is easily and consistently measured and, incidentally, falls on both the ecliptic plane and the plane of the equator which makes conversion between ecliptic and equatorial coordinate systems rather simple. Planetary positions measured from the vernal equinox (♈) are called **longitudes**. The **true longitude** (θ) of a planet is the angle of the planet from the vernal equinox. The angle from the vernal equinox to perihelion is called the **longitude of perihelion** (π in the figure - ϖ is sometimes used for this value but the symbol is so close to ω we prefer π). Thus, the true longitude of a planet is $\theta = \pi + \nu$. Calculation of a planet's position in its orbit is performed using simple formulas developed by Kepler in the 15th century.

However, knowing the position of a planet in its orbit gives no information about where it is in the sky as seen from Earth. In order to calculate the geocentric position of a planet, the position must be measured from some point that is fixed relative to the Earth. A good reference is the ecliptic plane since it is relatively fixed in space and is well defined. A planetary orbit is completely defined by specifying only six values for an orbit (see figure 16). These values define the position relative to the ecliptic and the vernal equinox.

> ι is the angle of the orbit with the ecliptic and is called the orbital **inclination.**
>
> Ω is the angle from the vernal equinox to the point where the path of the planet crosses the ecliptic from south to north: the **ascending node**. Note that Ω is measured in the ecliptic plane.
>
> ω is the angle from the ascending node to perihelion and is called the **perihelion argument**.
>
> **a** is the semi-major axis of the orbit.
>
> The other required parameters are **e**, the eccentricity of the orbit and the exact position of the planet at some specific time.

The precise position of the planet at any time in the past or future can be calculated from these values if the gravitational effects of the planets on each other is ignored. These effects are, however, meaningful, particularly for the very large outer planets. The gravity of the planets pull on each other and, depending on where they are relative to each other, will change the orbits eccentricity, inclination and orbital speed. These effects are called **perturbations**. Such effects are beyond the scope of this discussion.

All of the values that are calculated from these parameters are defined in the glossary.

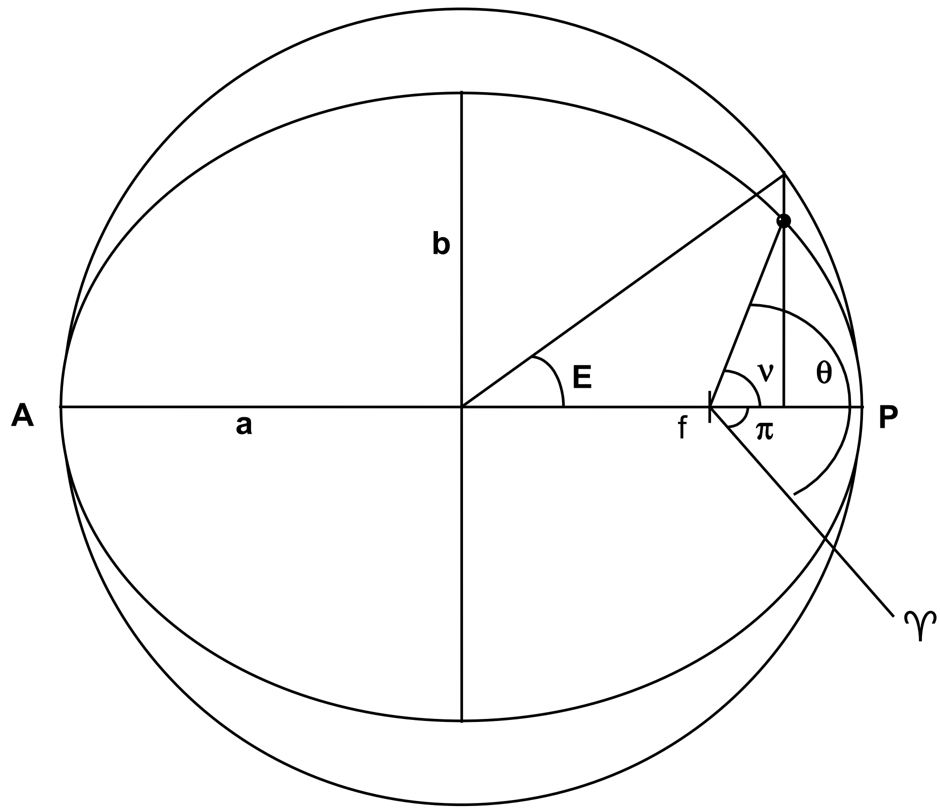


Figure 18. The Orbit in Space

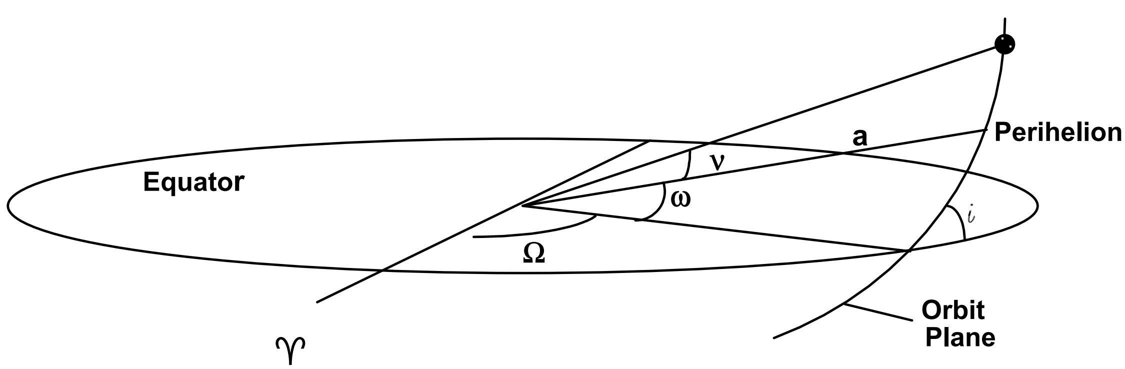


Figure 19. Orbital Parameters

APPENDIX A. STARS AND MESSIER OBJECTS

This appendix contains complete lists of all of the stars and Messier Objects displayed by the Electric Astrolabe.

STARS

The Electric Astrolabe stores the constellation asterisms as vectors (i.e. as sequences of connected line segments). Star positions are defined to the program as right ascension and declination for J2000.0 taken from *Starlist 2000* by Richard Dibon-Smith (John Wiley & Sons 1992). The asterism vectors are defined by an indicator for each star; 0 means start a new line segment, 1 means draw a line segment to this point from the previous point. The following list of stars is taken directly from the program. Shown are the vector indicator, right ascension (HHMMSSs), declination (DDMMSS), star designation within the constellation, name (if any) and apparent magnitude (v designates variable) :

Ursa Major - 9 stars

```
IND  RA       DECL
'0','1103436','614503'    ;alpha "Dubhe" (1.49)
'1','1101504','562256'    ;beta "Merak" (2.37)
'1','1153498','534141'    ;gamma "Phecda" (2.44)
'1','1215255','570157'    ;delta "Megrez" (3.31)
'1','1254017','555735'    ;epsilon "Alioth" (1.77v)
'1','1323555','545531'    ;zeta "Mizar/Alcor" (2.27/3.95)
'1','1347323','491848'    ;eta "Alkaid" (1.86)
'0','1103436','614503'    ;Dubhe
'1','1215255','570157'    ;Megrez
```

Ursa Minor (Polaris) - 1 star

```
'0','0231436','891551'    ;alpha "Polaris" (2.02v)
```

Orion - 11 stars

```
'0','0540455','-015634'   ;zeta "Alnitak" (2.05)
'1','0555103','072425'    ;alpha "Betelgeuse" (0.50v)
'1','0535082','095603'    ;lambda (3.66)
'1','0525078','062059'    ;gamma "Bellatrix" (1.64)
'1','0532004','-001704'   ;delta "Mintaka" (2.23v)
'1','0514322','-081206'   ;beta "Rigel" (0.12)
'1','0547453','-094011'   ;kappa "Saiph" (2.06)
'1','0540455','-015634'   ;Alnitak
'1','0532004','-001704'   ;delta
```

Canis Major - 2 stars

```
'0','0645089','-164258'   ;alpha "Sirius" (-1.46)
'1','0622419','-175722'   ;beta "Murzim" (1.98v)
```

Cassiopeia - 5 stars

```
'0','0009106','590859'    ;beta "Caph" (2.27v)
'1','0040304','563215'    ;alpha "Shedir" (2.23)
'1','0056424','604300'    ;gamma (2.47v)
'1','0125489','601407'    ;delta "Ruchbah" (2.68v)
'1','0154236','634013'    ;epsilon "Segin" (3.38)
```

Auriga - 6 stars

```
'0','0516413','455953'    ;alpha "Capella" (0.08)
'1','0559317','445651'    ;beta "Menkalinan" (1.90v)
'1','0559432','371245'    ;theta (2.62v)
'1','0526175','283627'    ;gamma "El Nath" (aka beta tauri)
'1','0456596','330958'    ;iota "Hasseleh" (2.69)
'1','0516413','455953'    ;Capella
```

Cygnus - 6 stars

```
'0','2041258','451649'    ;alpha "Deneb" (1.25v)
'1','2022136','401524'    ;gamma "Sadr" (2.20)
'1','1930452','275755'    ;beta "Albireo" (3.08)
'0','2046126','335813'    ;epsilon "Gienah" (2.46)
'1','2022136','401524'    ;Sadr
'1','1944584','450751'    ;delta (2.87)
```

Lyra (Vega) - 1 star

```
'0','1836562','384701'    ;alpha "Vega" (0.03v)
```

Bootes - 6 stars

```
'0','1415396','191057'    ;alpha "Arcturus" (-0.04)
'1','1431497','302217'    ;rho (3.58)
'1','1432046','381829'    ;gamma "Seginus" (3.03v)
```

'1','1501566','402326' ;beta “Nekkar” (3.50)
'1','1515301','331853' ;delta (3.47)
'1','1415396','191057' ;Arcturus

Canis Minor (Procyon) - 1 star

'0','0739181','051330' ;alpha “Procyon” (0.38)

Aquila (Altair) 1 star

'0','1950469','085206' ;alpha “Altair” (0.77)

Pegasus (Great Square) and Andromeda - 10 stars

'0','0008232','290526' ;α And & δ Peg “Alpheratz”
'1','0013141','151101' ;gamma Peg “Algenib” (2.83v)
'1','2304456','151219' ;alpha Peg “Markab” (2.49)
'1','2303464','280458' ;beta Peg “Scheat” (2.42v)
'1','0013141','151101' ;gamma Peg “Algenib” (2.83v)
'0','0008232','290526' ;α And & δ Peg “Alpheratz”
'1','0109439','353714' ;beta And “Mirach” (2.06)
'1','0203539','421947' ;gamma And “Almach” (2.18)
'0','0109439','353714' ;beta And “Mirach” (2.06)
'1','0049488','410444' ;nu And (4.53)
'1','0109301','471431' ;phi And (4.25)

Ophiucus - 6 stars

'0','1734559','123336' ;Alpha “Ras Alhage” (2.09)
'1','1657400','092230' ;Kappa (3.20)
'1','1614206','-034139' ;Delta (2.72)
'1','1637094','-103402' ;Zeta (2.57)
'1','1710226','-154329' ;Eta “Sabik” (2.46)
'1','1743283','043402' ;Beta “Cheleb” (2.77)
'1','1734559','123336' ;Alpha “Ras Alhage” (2.09)

Hercules (Keystone) - 4 stars

'0','1642537','385520' ;Eta (3.46)
'1','1641171','313610' ;Zeta (2.81)
'1','1700173','305535' ;Epsilon (3.92)
'1','1715027','364833' ;Pi (3.13)
'1','1642537','385520' ;Eta (3.46)

The Zodiac

Aries - 2 stars

'0','0154383','204829' ;beta (2.64)
'1','0207103','232745' ;alpha (2.00)

Taurus (Hyades) - 3 stars

'0','0435552','163033' ;alpha “Aldebaran” (0.85v)
'1','0419475','153739' ;gamma (3.65)
'1','0428369','191049' ;epsilon (3.53)

Gemini - 9 stars

'0','0718055','163225' ;lambda (3.58)
'1','0720073','215856' ;delta “Wasat” (3.53)
'1','0745189','280134' ;beta “Pollux” (1.14)
'0','0720073','215856' ;delta “Wasat” (3.53)
'1','0704065','203413' ;zeta “Mekbuda” (3.79v)
'0','0744268','242353' ;kappa (3.57)
'1','0711083','301443' ;tau (4.41)
'0','0734359','315318' ;alpha “Castor” (1.58)
'1','0643559','250752' ;epsilon “Mebsuta” (2.98)

Cancer - 5 stars

'0','0858292','115128' ;alpha “Acubens” (4.25)
'1','0844410','180915' ;delta (3.94)
'1','0846418','284536' ;iota (4.02)
'0','0844410','180915' ;delta (3.94)
'1','0816309','091108' ;beta “Altarf” (3.52)

Leo - 10 stars

'0','1114143','152546' ;theta (3.34)
'1','1114064','203125' ;delta “Zosma” (2.56)
'1','1149035','143419' ;beta “Denebola” (2.14v)
'1','1114143','152546' ;theta (3.34)
'1','1008222','115802' ;alpha “Regulus” (1.35)
'1','1007199','164545' ;eta (3.52)
'1','1019586','195025' ;gamma “Algeiba” (2.28)
'1','1016414','232502' ;zeta (3.44)
'1','0952458','260025' ;mu (3.88)
'1','0945510','234627' ;epsilon (2.98)

Virgo - 5 stars

'0','1325115','-110941' ;alpha “Spica” (0.98v)
'1','1241395','-012658' ;gamma “Porrima” (3.48)
'1','1150416','014553' ;beta (3.61)
'0','1241395','-012658' ;gamma “Porrima” (3.48)
'1','1255361','032351' ;delta (3.38)

Libra - 4 stars

'0','1450411','-155950' ;alpha (5.16)
'1','1517003','-092258' ;beta (2.61)
'1','1535315','-144722' ;gamma (3.91)
'1','1512132','-194730' ;iota (4.54)

Scorpius (11 stars)

'0','1605261','-194819' ;Beta “Graffias” (2.55)
'1','1600199','-223718' ;Delta “Dschubba” (2.34)

'1','1558510','-260651' ;Pi (2.90)
'0','1600199','-223718' ;Delta “Dschubba” (2.34)
'1','1629244','-262555' ;Alpha “Antares” (0.92)
'1','1650097','-341736' ;Epsilon (2.28)
'1','1654349','-422141' ;Zeta (4.80)
'1','1712091','-431421' ;Eta (3.33)
'1','1737190','-425952' ;Theta “Sargas” (1.87)
'1','1747350','-400737' ;Iota (1.87)
'1','1733364','-370613' ;Lambda “Shaula” (1.62)

Sagittarius (Teapot) - 12 stars

'0','1824103','-342305' ;epsilon (1.85)
'1','1820596','-294941' ;delta (2.70)
'1','1827581','-252518' ;lambda (2.81)
'1','1845393','-265927' ;phi (3.17)
'1','1902366','-295249' ;zeta (2.60)
'1','1824103','-342305' ;epsilon (1.85)
'1','1805484','-302527' ;gamma (2.99)
'1','1820596','-294941' ;delta (2.70)
'1','1845393','-265927' ;phi (3.17)
'1','1855158','-261748' ;sigma (2.02)
'1','1906563','-274014' ;tau (3.32)
'1','1902366','-295249' ;zeta (2.60)

Capricorn - 6 stars

'0','2017388','-123030' ;alpha (3.57)
'1','2105567','-171358' ;theta (4.07)
'1','2147023','-160738' ;delta “Al Giedi” (2.87v)
'1','2126399','-222441' ;zeta (3.74)
'1','2051492','-265509' ;omega (4.11)
'1','2017388','-123030' ;alpha (3.57)

Aquarius - 4 stars
'0','2131333','-053416' ;beta (2.91)
'1','2205469','-001922' ;alpha (2.96)
'1','2221393','-012314' ;gamma (3.84)
'1','2254389','-154915' ;delta (3.27)

Pisces - 10 stars

'0','0202027','024549' ;alpha (4.33)
'1','0131289','152045' ;eta (3.62)
'1','2339570','053735' ;iota (4.13)
'1','2327580','062244' ;theta (4.28)
'1','2317099','031656' ;gamma (3.69)
'1','2326559','011520' ;kappa (4.94v)
'1','2342027','014648' ;lambda (4.50)
'1','2339570','053735' ;iota (4.13)

Southern Constellations

Crux (Southern Cross) - 4 stars

'0','1226359','-630556' ;Alpha (1.58)
'1','1231099','-570647' ;Gamma (1.63)
'0','1247433','-594119' ;Beta (1.25v)
'1','1215086','-584456' ;Delta (2.80v)

Ara - 9 Stars

'0','1806377','-500530' ;Theta (3.66)
'1','1731504','-495234' ;Alpha (2.98)
'1','1725179','-553147' ;Beta (3.66)
'1','1731059','-604101' ;Delta (3.62)
'0','1725179','-553147' ;Beta (3.66)
'1','1658371','-555924' ;Zeta (3.13)
'1','1659350','-530938' ;Epsilon (4.06)
'0','1658371','-555924' ;Zeta (3.13)
'1','1649470','-590229' ;Eta (3.76)

Carina - 9 stars

'0','0623572','-524144' ;Alpha "Canopus" (-0.72)
'1','0756467','-525856' ;Chi (3.47v)
'1','0822308','-593034' ;Epsilon "Avior" (1.86)
'1','0947054','-591631' ;Iota (2.25)
'1','0947061','-650418' ;Nu (2.96)
'1','0913121','-694302' ;Beta "Miaplacidus" (1.68)
'1','1013443','-700216' ;Omega (3.32)
'1','1042574','-642340' ;Theta (2.76)
'1','0947054','-591631' ;Iota (2.25)

Centaurus - 9 stars

'0','1439362','-605007' ;Alpha (-0.01)
'1','1403494','-602222' ;Beta (0.61v)
'1','1339532','-532759' ;Epsilon (2.30v)
'1','1355323','-471718' ;Zeta (2.55)
'1','1435303','-420928' ;Eta (2.31v)
'1','1406408','-362212' ;Theta (2.06)
'1','1320357','-364244' ;Iota (2.75)
'1','1241309','-485734' ;Gamma (2.17)
'1','1339532','-532759' ;Epsilon (2.30v)

Grus - 6 stars

'0','2208139','-465740' ;Alpha "Al Nair" (1.74)
'1','2229161','-432945' ;Delta (3.97)
'1','2242400','-465305' ;Beta (2.10v)

```
'1','2310215','-451448'    ;Iota (3.90)
'0','2153556','-372154'    ;Gamma (3.01)
'1','2229161','-432945'    ;Delta (3.97)
```

Triangulum Australe - 4 stars

```
'0','1648399','-690140'    ;Alpha "Atria" (1.92)
'1','1555084','-632540'    ;Beta (2.85)
'1','1518546','-684046'    ;Gamma (2.89)
'1','1648399','-690140'    ;Alpha "Atria" (1.92)
```

Vela - 5 stars

```
'0','0809319','-472012'    ;Gamma (1.78)
'1','0907597','-432557'    ;Lambda (2.21v)
'1','0922068','-550038'    ;Kappa (2.50)
'1','0844422','-544230'    ;Delta (2.02)
'1','0809319','-472012'    ;Gamma (1.78)
```

False Cross - 4 stars

```
'0','0822308','-593034'    ;Epsilon Carinae
'1','0922068','-550038'    ;Kappa Velae
'0','0947054','-591631'    ;Iota Carinae
'1','0844422','-544230'    ;Delta Velae
```

BRIGHT STARS

The bright stars that are highlighted with the “B” key are:

```
  RA      Decl.          Name (mag.), Constellation

'0555103','072425'    ;"Betelgeuse" (0.50v) - Orion
'0525078','062059'    ;”Bellatrix" (1.64) - Orion
'0514322','-081206'   ; "Rigel" (0.12) - Orion
'0547453','-094011'   ; "Saiph" (2.06) - Orion
'1103436','614503'    ; "Dubhe" (1.49) - Ursa Major
,'1101504','562256'   ; "Merak" (2.37) - Ursa Major
'1153498','534141'    ; "Phecda" (2.44) - Ursa Major
'1215255','570157'    ; "Megrez" (3.31) - Ursa Major
'1254017','555735'    ; "Alioth" (1.77v) - Ursa Major
'1323555','545531'    ; "Mizar/Alcor" (2.27/3.95)  - Ursa Major
'1347323','491848'    ; "Alkaid" (1.86) - Ursa Major
'0231436','891551'    ; "Polaris" (2.02v) Ursa Minor
'0645089','-164258'   ; "Sirius" (-1.46) Canis Major
'0009106','590859'    ; "Caph" (2.27v) - Cassiopeia
'0040304','563215'    ; "Shedir" (2.23) - Cassiopeia
'0056424','604300'    ;gamma (2.47v) - Cassiopeia
'0125489','601407'    ; "Ruchbah" (2.68v) - Cassiopeia
'0154236','634013'    ; "Segin" (3.38) - Cassiopeia
'0516413','455953'    ; "Capella" (0.08) - Cassiopeia
'2041258','451649'    ; "Deneb" (1.25v) - Cygnus
'1836562','384701'    ; "Vega" (0.03v) - Lyra
'1415396','191057'    ; "Arcturus" (-0.04) - Bootes
'0739181','051330'    ; "Procyon" (0.38) Canis Minor
'1950469','085206'    ; "Altair" (0.77) - Aquila
'0435552','163033'    ; "Aldebaran" (0.85v) - Taurus
'0745189','280134'    ; "Pollux" (1.14) - Gemini
'0734359','315318'    ; "Castor" (1.58) - Gemini
'1008222','115802'    ; "Regulus" (1.35) - Leo
'1325115','-110941'   ; "Spica" (0.98v) - Virgo
'1824103','-342305'   ; (1.85) - Sagittarius
'1629244','-262555'   ; "Antares" (0.92) - Scorpius
'1737190','-425952'   ; "Sargas" (1.87) - Scorpius
'1747350','-400737'   ;Iota (1.87) - Scorpius
'1733364','-370613'   ; "Shaula - the sting" (1.62)
'1824103','-342305'   ;epsilon (1.85) - Sagittarius
```

Southern Bright Stars

'0623572','-524144' ;Alpha "Canopus" (-0.72) - Carina
'0137429','-571412' ;"Achernar" - Eridanus
'2025388','-564407' ;"Peacock" - Pavo (Globular cluster NGC 6752)
'2257390','-293720' ;"Fomalhaut" - Pisces Austrinus
'1439362','-605007' ;Alpha Centauri (-0.01) - Centaurus

MESSIER OBJECTS

Messier Objects are defined to the program by right ascension, declination, type and magnitude. The types are:

N = Nebula

C = Globular Cluster

O = Open Cluster

G = Spiral Galaxy

E = Elliptic Galaxy

The source for Messier Object information is *The Messier Album. An Observer's Handbook*, by John H. Mallas and Evered Kreimer (Sky Publishing, 1978).

Messier Objects in numeric order (RA, DECL, Type, Magnitude) are:

RA	DECL	Type	Mag	No.	Name	Constellation
0534	2201	N	8	1	Crab Nebula	Taurus
2134	-0049	C	7	2		Aquarius
1342	2823	C	6	3		Canes Venetici
1624	-2631	C	6	4		Scorpio
1519	0205	C	6	5		Serpens
1740	-3212	O	4	6		Scorpio
1754	-3449	O	3	7		Scorpio
1804	-2423	N	5	8	Lagoon Nebula	Sagittarius
1719	-1831	C	8	9		Ophiuchus
1657	-0406	C	7	10		Ophiuchus
1851	-0616	O	6	11		Scutum
1647	-0157	C	7	12		Ophiuchus
1642	3628	C	6	13	see unaided	Hercules
1738	-0315	C	8	14		Ophiuchus
2130	1210	C	7	15		Pegasus
1819	-1347	O	6	16		Serpens
1821	-1610	N	6	17	Horseshoe Neb.	Sagittarius
1820	-1708	O	7	18		Sagittarius
1703	-2616	C	7	19		Ophiuchus
1802	-2302	N	6	20	Trifid Nebula	Sagittarius
1805	-2230	O	7	21		Sagittarius
1836	-2354	C	6	22		Sagittarius
1757	-1901	O	7	23		Sagittarius
1818	-1825	O	5	24		Sagittarius

1832	-1914	O	5	25		Sagittarius
1845	-0924	O	10	26		Scutum
2000	2243	N	8	27	Dumbbell Nubula	Vulpecula
1825	-2452	C	8	28		Sagittarius
2024	3831	O	7	29		Cygnus
2140	-2311	C	8	30		Capricorn
0043	4116	G	4	31	Andromeda Gal.	Andromeda
0043	4052	E	9	32	near M31	Andromeda
0134	3039	G	5	33		Triangulum
0242	4247	O	6	34		Perseus
0609	2420	O	5	35		Gemini
0536	3408	O	6	36		Auriga
0553	3233	O	6	37		Auriga
0529	3550	O	6	38		Auriga
2132	4826	O	6	39		Cygnus
1222	5805	O	10	40	double star	Ursa Major
0647	-2046	O	5	41		Canis Major
0535	-0523	N	5	42		Orion
0535	-0516	N	9	43		Orion
0840	2000	O	4	44	Beehive Cluster	Cancer
0347	2407	O	2	45	Pleides	Taurus
0742	-1449	O	6	46		Puppis
0737	-1429	O	5	47		Puppis
0814	-0548	O	6	48		Hydra
1230	0800	E	9	49		Virgo
0703	-0821	O	6	50		Monoceros
1330	4712	G	8	51	Whirlpool Gal.	Canes Venatici
2324	6136	O	7	52		Cassiopeia
1313	1810	C	8	53		Coma Berenices
1855	-3028	C	8	54		Sagittarius
1940	-3057	C	7	55		Sagittarius
1917	3011	C	8	56		Lyra
1854	3302	N	9	57	Ring Nebula	Lyra
1238	1149	G	9	58		Virgo
1242	1139	E	10	59		Virgo
1244	1133	E	10	60		Virgo
1222	0428	G	10	61		Virgo
1701	-3007	C	7	62		Ophiuchus
1316	4202	G	10	63		Canes Venetici
1257	2141	G	9	64		Coma Berenices
1119	1306	G	9	65		Leo
1120	1300	G	10	66		Leo
0851	1148	O	6	67		Cancer
1239	-2645	C	8	68		Hydra
1831	-3221	C	9	69		Sagittarius
1843	-3217	C	9	70		Sagittarius
1954	1847	C	8	71		Sagitta
2053	-1232	C	10	72		Aquarius
2059	-1238	O	10	73		Aquarius
0137	1547	G	10	74		Pisces
2006	-2155	C	9	75		Sagittarius
0142	5134	O	11	76		Perseus
0243	-0001	G	8	77	Seyfert Galaxy	Cetus
0547	0004	N	10	78		Orion
0524	-2431	C	8	79		Lepus

1617	-2259	C	8	80		Scorpio
0956	6904	G	8	81		Ursa Major
0956	6942	G	9	82		Ursa Major
1338	-2952	G	7	83		Hydra
1225	1253	E	9	84		Virgo
1225	1811	E	9	85		Coma Berenices
1226	1257	E	10	86		Virgo
1231	1223	E	9	87		Virgo
1232	1425	G	10	88		Coma Berenices
1236	1233	E	10	89		Virgo
1237	1310	G	10	90		Virgo
1235	1430	G	10	91		Coma Berenices
1717	4308	C	6	92		Hercules
0745	-2353	O	6	93		Puppis
1251	4107	G	8	94		Canes Venatici
1044	1142	G	9	95		Leo
1047	1149	G	9	96		Leo
1115	5501	O	11	97	Owl Nebula	Ursa Major
1214	1454	G	11	98		Coma Berenices
1219	1425	G	10	99		Coma Berenices
1223	1549	G	11	100		Coma Berenices
1403	5421	G	8	101/102		Ursa Major
0000	0000	0	20	(102)		(Does not exist)
0133	6042	O	6	103		Cassiopeia
1240	-1137	G	8	104		Virgo
1048	1235	E	11	105		Leo
1219	4718	G	8	106		Canes Venetici
1632	-1303	C	9	107		Ophiuchus
1112	5540	G	10	108		Ursa Major
1158	5322	G	10	109		Ursa Major
0040	4141	E	9	110		Andromeda

The Magellanic Clouds are not Messier Objects but are treated as such by the program:

0530	-6900	N	2	"111"		Large Magellanic Cloud
0055	-7230	N	2	"112"		Small Magellanic Cloud

SATURN'S RINGS.

The following assumptions on the sizes of Saturn's rings were synthesized from a variety of sources:

Saturn's equatorial radius to cloud top = 37,550 miles

Cloud top to C ring = 8,750 miles (The D region is not shown in the Saturn image).

Width of C ring = 10,885 miles

Width of B ring = 15,861 miles

Width of Cassini division = 2,800 miles

Width of A ring = 9,143 miles

These assumptions give an overall width of the ring system of 169,930 miles

GALACTIC CENTER.

The galactic center position at 17:44, -28°59′ was taken from *Burnham's Celestial Handbook*, Vol. 3, pg. 1638 (Dover, 1978).

APPENDIX B. ABOUT THE ELECTRIC ASTROLABE

The Electric Astrolabe consists of about 32,000 80386/80387 assembler statements in 36 modules coded for the Borland Turbo Assembler. About 20,000 statements are executable instructions, the rest being definitions of various types. All of the program code is completely original including VGA geometry routines for drawing circles, arcs and lines and controlling the VGA controller directly, trigonometric functions, data conversion and astronomical calculations. It is written using object oriented principles to facilitate adding new program functions.

The Electric Astrolabe is a DOS program in order to allow high performance animation. Windows did not support high speed animation at the time The Electric Astrolabe was written. It does now, but the effort required to recode the program for Windows is enormous. A Windows version will be written some day.

In addition to the base program memory requirements, the Electric Astrolabe acquires 76,800 bytes for storage of two VGA color planes and about 5000 bytes for storage of the star, Messier object, ecliptic, rule and planet draw vectors and acquires additional memory for file buffers as conditions require. Extended memory is used to store images and during the execution of menus.

The text pages are written to an architected interface that allows all of the pages to be managed with a single routine.

The main line routine, ASTRO, consists of only 63 executable instructions. The largest module, which is about 2300 lines, implements the keyboard interface. Next largest is the module that calculates and displays planet and lunar positions with about 1700 lines. The VGA routines that draw images, points, lines, circles, arcs, etc. total about 1200 lines. The routine that calculates and draws the plate is about 1800 lines of code. The orrery is only about 350 lines. The VSOP calculations require only 375 instructions which act on 7390 constants.

According to the Borland Turbo Profiler, the slowest part of the program is the actual drawing of the astrolabe by the VGA adapter which takes about 34 msec on a 25 MHz 386 system with an ATI Wonder Card. Planet and moon position calculations require only about 5 msec. Calculating a plate for a new latitude takes 3.6 msec. By far the most time is spent in the VGA adapter data transfer from memory to the screen.

Execution times on fast 486 and Pentium processors are too short to measure accurately with the available tools.

Execution on 486 and Pentium processors is so fast that special code was added to slow down the display during animation. On older machines, the best opportunity for significant performance improvements is to use a faster VGA adapter. A faster computer will help but not as much except for the higher precision planetary calculations, in which case the faster the better.

The Electric Astrolabe was written and documented in the early 1990's, when Windows was just getting started. This guide has been updated in part to reflect changes in computers since it was originally written, but some of the references and computer commentary is rather dated. Fortunately, the information about astrolabes is ageless.

James E. Morrison is the founder and president of ***Janus***, a small company dedicated to providing wider access to historical astronomical instruments, such as the astrolabe. He has authored, *The Astrolabe,* "The Electronic Astrolabe", International Science Reviews, March, 1994, and "Updating the Astrolabe", Proceedings of the 50th Anniversary of the Institute for the History of Science, Johann Wolfgang Goethe Institute, Frankfort, December, 1993. ***Janus*** also offers a computer created astrolabe reproduction called the "Personal Astrolabe" that is customized for a specific location and date.

The Electric Astrolabe is on display at the Frankfurt City Museum and is available as a student aid at several universities and has been used in public museum events.

ADDITIONAL SOURCES

If you would like to read more about classical astrolabes, astronomical calculations, or the history of astronomy, the following references are recommended:

Morrison, James E., *The Astrolabe*, Janus (2007)

The Astrolabe is the most complete technical treatise on astrolabes and related devices available. It covers the history, use and design of all types of astrolabes and related quadrants along with the required background and advice on making your own instrument. See astrolabes.org/theastrolabe.htm for more details.

North, J. D., "The Astrolabe", Scientific American, **230**:1, 96-106 (January, 1974)

This article is the most easily available general reference on astrolabes. It includes a brief history, an overview of the projection used in astrolabe design and some pictures of classical instruments. It is highly recommended as a good, brief, general introduction.

The Planispheric Astrolabe, National Maritime Museum, 1976.

This booklet from the Greenwich Observatory museum in England is the best popular source on how to use an astrolabe. It also contains basic notes on the astrolabe projection and pictures of some outstanding classical instruments. I do not know if it is available in libraries so you may have to go to Greenwich to get one. It is worth the trip.

Webster, Roderick S., *The Astrolabe. Some notes on its history, construction and use*, Paul R. MacAlister, Lake Bluff, Il (1974).

The offering consists of a cardboard astrolabe kit done in the classical style and a pretty good booklet on astrolabe theory and use. It is probably available from several sources. One source is Celestaire, 416 S. Pershing, Wichita, Kansas 67218, (316) 686-9785. Another is the Adler Planetarium in Chicago.

Evans, James, *The History and Practice of Ancient Astronomy*, Oxford University Press, New York (1998).

This book is a complete modern reference to the ancient history of astronomy and contains a fairly complete section on astrolabes.

van Cleempoel, Koenraad, *Astrolabes at Greenwich,* Oxford University Press, Oxford. (2005).

A detailed catalog of the astrolabes in the National Maritime Museum collection.

Saunders, Harold N., "The Astrolabe", Devon, 1971. Available with plastic astrolabe from Micro Instruments (Oxford) Ltd., 7, Little Clarendon Street, Oxford, OX1 2HP, England.

This is also a working astrolabe. It is a small plastic astrolabe designed for the latitude of London with two booklets on theory and use. I do not know if it is still available. I had to make a plate for my location. Saunders is also the author of *All the Astrolabes,* Senecio Publishing, Oxford, England, which is very poorly organized and difficult to read but has some good technical material.

Turner, Anthony J., *The Time Museum: Time Measuring Instruments. Part 1. Astrolabes/Astrolabe Related Instruments*, The Time Museum, Rockford, Il, 1985. ISBN 0-912947-02-0.

The ostensible purpose of this book is to record the astrolabes in the collection of the Time Museum but it is far, far more. It is a wonderful book, beautifully presented and has by far the best historical section of any modern reference. Very highly recommended but not inexpensive.

Gunther, Robert T., *Astrolabes of the World*. ISBN 0-87556-604-9 (Saifer). originally published by University Press, Oxford (1932).

This two volume work was the first serious attempt to collect astrolabe information into a single source. It was written when Mr. Gunther was curator of the Museum of the History of Science at Oxford. It is a wonderful reference but also, as a seminal work, has errors. It is available at many large libraries or by inter-library loan.

Gibbs, Sharon with Saliba, George, *Planispheric Astrolabes from the National Museum of American History*, Smithsonian Institution Press, City of Washington (1984).

The book is no longer in print but it can be downloaded as a PDF from the Smithsonian. It contains an excellent overview of astrolabe styles from various times and locations along with pictures and descriptions of the astrolabes owned by the Smithsonian.

Michel, Henri, *Traite de L'Astrolabe*, Librarie Alain Brieux, 48, Rue Jacob, 75006 Paris (1976).

This book is the first attempt at a complete reference on the science of the astrolabe. It is no longer in print and it is in French but, if you read French, it is worth the trouble to find a copy. Note also that it was privately published and there are not many copies around. Michel was a Belgian engineer who studied astrolabes for many years and published several articles in addition to this book on their technical aspects. The book covers not only planispheric astrolabes but also all the other types. The publisher operated a shop in Paris that sells the instruments. An English edition is in preparation.

Neugebauer, Otto A., *A History of Ancient Mathematical Astronomy*, Springer-Verlag (1975) (3 vols), "Astronomy and History: Selected Essays", Springer-Verlag (1983) and "The Exact Sciences in Antiquity", Dover (1969).

These highly respected works are, collectively, a huge source of authoritative information on ancient astronomy and mathematics. They are written at a very high level but are required references for serious study. Of particular interest is "The Early History of the Astrolabe" from the "Essays" reference above.

King, Henry C., *Geared to the Stars*, University of Toronto Press, 1978.

This formidable book is really about astronomical machines including clocks, orrerys and planetarium instruments. It is a wonderful book and has some very interesting examples of astrolabe clock faces and geared astrolabes. It is a book that will be captivating to anyone with an interest in the history of astronomy. I bought a copy at a planetarium bookstore but it should be available from libraries. I often have to take advantage of interlibrary loan services to find books on such obscure subjects. Professor King is also the author of the classic *History of the Telescope*.

Chaucer, Geoffrey, *A Treatise on the Astrolabe, addressed to his son, Lowys*, A.D. 1391, edited by Walter Skeat, London, 1872.

This is among the first books ever published in the English language (subject to stylistic differences that have occurred over the last 600 years). It is not an easy "read" but it should be read by any serious student. It is among the oldest references available, it is a complete description of astrolabes as they were made and used in the 14th century and it gives insight into what they were used for (astrology). An invaluable companion to complete understanding of this book is *Chaucer's Universe* by John D. North, Clarendon Press, Oxford, 1988. A transliteration into modern idiomatic English is available on the web.

Meeus, Jean, *Astronomical Algorithms*, Willmann-Bell, 1991.

This book is the latest and most complete offering in a series of books by the same author. It is the source for some of the astronomical calculations used in the Electric Astrolabe. Other sources used include the Explanatory Supplement to the Astronomical Almanac and lots and lots of college textbooks. If you would like to write an astronomy program, Meeus is an indispensable reference.

Smart, W. M., *Textbook on Spherical Astronomy*, Cambridge, 1931 (6 ed, 1977).

This textbook is among the best at explaining the terminology and considerations required to do astronomical calculations. It is not an easy book but it is written at a far lower mathematical level than later sources. For years the standard reference has been *Celestial Mechanics* by Woolard and Clemence but this is very heavy going, quite theoretical and is of limited use for application of the theory.

This list barely touches the rich literature on the astrolabe. The bibliographies in the above books will suggest many other sources for historical information.

COLLECTIONS

Following is a list of some of the major astrolabe collections available to the public. The number in parentheses is the number of instruments in the collection. Note also that not all of the collections are on public display so it may be necessary to contact the curator of the collection to view them. The worldwide total of genuine instruments is about 1200. Some of the instruments in the large collections are known to be fakes.

Museum of the History of Science, Oxford, England (137)

Adler Planetarium, Chicago (88)

National Maritime Museum, Greenwich (56)

Smithsonian National Museum of Natural History, Washington, D.C. (51)

British Museum, London (32)

Museo di Storia della Scienze a Firenze, Florence (26)

Science Museum, London (17)

Germanisches Nationalmuseum, Nurnberg (16)

Conservatoire National des Arts et Metiers, Paris (14)

Whipple Museum of the History of Science, Cambridge, MA (13)

Museo Naval, Madrid (13)

Observatorio Astronomica di Roma, Rome (13)

Musees Royaux d'Art and d'Histoire, Brussels (10)

The remainder of the known instruments are in small museum collections, primarily in Europe, or are privately owned. North American museums that own instruments are:

Ontario Science Center, Don Mills, Ontario
Royal Ontario Museum, Toronto
Boston Museum of Fine Arts
Corpus Christi Museum, Texas
Detroit Institute of Fine Arts
Fort Caroline National Museum, Jacksonville, FL
Yale University
Brooklyn Museum
Metropolitan Museum of Art, New York
Hayden Planetarium, New York
Mariner's Museum, Newport News, VA
St. Louis City Art Museum
Peabody Museum, Salem, MA
Toledo Museum of Art

GLOSSARY

This glossary contains brief definitions and/or explanations of astronomical terms used in the Electric Astrolabe and in this manual. Consult an astronomical reference book for more detail.

ALTITUDE
The angle of an object in the sky above the **horizon**. For example, an object straight overhead has an altitude of 90°, and an object halfway up in the sky has an altitude of 45°.

ANNUAL EQUATION
A variation in the moon's orbit due to the varying distance of the Earth-moon system from the Sun.

ANOMALISTIC YEAR (MONTH)
The time between successive passages of an orbiting body through **periapsis**. For the Earth, one anomalistic year is 365.2596 days. An anomalistic month is 27.5546 days.

ANOMALY
Measure of position of orbiting bodies. Anomalies are measured as the angle of the body from the point where is nearest the body it is orbiting (perihelion for a planet, perigee for the Moon). Longitudes are measured from the First point of Aries. Longitude = **true anomaly** + **perihelion distance** + **longitude** of **ascending node**.

APHELION
The point in a planet's orbit that is farthest from the Sun.

APOGEE
The point in the Moon's orbit that is farthest from the Earth.

ASCENDING NODE
The point on an orbit where the object (Moon, planet, comet etc.) crosses the **ecliptic** in the direction such that the **ecliptic latitude** changes from south to north. The orbital **inclination** is measured at the ascending node and the longitude of the ascending node is one of the basic orbital determination parameters. Note also that lunar eclipses can only occur near one of the nodes of the Moon's orbit.

APPARENT SOLAR TIME
The time indicated by a sundial.

ASTERISM
An imaginary figure defined for a constellation to make it easier to visualize in the sky. An example of an asterism is the familiar "Big Dipper". Many asterisms are very old and originate in mythology. Others, particularly in the southern sky, were invented in fairly recent times as a way to describe constellations that were not visible from northern latitudes. The history of star names and constellations is an interesting element of astronomy.

ASTROLABE
An astronomical instrument consisting of a stereographic projection of the local coordinate system on the plane of the equator with a rotating stereographic projection of the fixed stars and ecliptic. In order to be properly called an astrolabe, the instrument must also have an alidade and scale to measure the altitude of the Sun and stars and a suspension.

ASTRONOMICAL UNIT (AU)
The average distance of the Earth from the Sun. Used to measure large distances in the solar system such as the distance of a planet from the Sun. The length of the AU determined by radar ranging is 149,597,870 km (92,900,277 miles) or about eight light-minutes.

AZIMUTH
The compass bearing of a celestial object. Azimuth is defined as the angle from north, measured on the local horizon, of the great circle passing through the zenith and the object. In North America, due north is 0° azimuth, due east is 90° azimuth and so on. There are several methods of measuring azimuth. In Europe, azimuth is commonly measured as 0° to 360° moving west from south. Other schemes use + or - 180° from south with west taken as the positive direction.

CALLIPIC CYCLE
A period of 76 mean **tropical years**, or 27,759 days, approximately equal to 940 mean **synodic months**. Discovered by Callipus in the fourth century B.C..

CELESTIAL EQUATOR
The **great circle** on the celestial sphere perpendicular to the Earth's axis of rotation. The exact definition of the celestial equator gets rather complex. Refer to a good astronomy text for the precise definition. For practical purposes it is acceptable to consider the celestial equator to be the projection of the Earth's equator on the celestial sphere.

CELESTIAL SPHERE
The imaginary sphere with the Earth as its center used to defined the positions of celestial objects.

CHRISTIAN ERA (aka COMMON ERA)
The calendar convention adopted by most of the world begins on 1 Jan 1, Julian day 1721424. Dates BCE (Before Christian Era) are counted backward from year 1 BC. Note that the Electric Astrolabe uses the astronomical convention which includes a year 0. A historical date of 35 BC is shown as year -34. Sources must be checked carefully to ensure the correct year BCE is used. The Christian Era was introduced by Dionysius Exiguus (Denis the Little), a Roman abbot, in a table of Easter dates in about 525 in "Liber de paschate" which contained calculated dates of Easter up to 626. The calendar was intended to start at the birth of Jesus in 1 BC but an error in counting the years of the reign of the emperor Augustus caused the result to be off by about three years (Augustus used the name Octavian in his first four years of rule). Modern research places the probable birth date of Jesus in the late summer of 3 BC. See also **Easter (Date of)**.

CIVIL TIME
The time told by an accurate clock according to established international agreement. The official civil time is called Universal Time (UT) and is defined by a mathematical formula based on the sidereal time at Greenwich. Universal time conforms very closely to the average motion of the Sun over a year. In practice, the time broadcast by national time services, such as NIST over radio station WWV, is Coordinated Universal Time (UTC) which is derived from very accurate atomic clocks. Since UT is based on the rotation of the Earth which has random irregularities, UTC and UT are kept within one second of each other by the occasional insertion of a "leap second" to UT. Time zone boundaries are also established by international agreement and do not necessarily conform to geographic longitude in order to accommodate population distributions. For example, Madrid is west of Greenwich but is in the Central European time zone so people in Madrid will be in the same time zone as the rest of Europe. The **longitude correction** for Madrid is nearly an hour and 15 minutes.

COLURE
A **great circle** on the celestial sphere. The most common references are to the equinoctial colure that also passes through the equinoxes and the solstitial colure which passes through the solstices.

CONJUNCTION
Phenomenon when two celestial bodies have the same **longitude** when viewed from a third body. Conjunctions normally refer to the condition when a planet has the same longitude as the Sun. Venus and Mercury are said to have inferior conjunction when they are between the Earth and the Sun. Superior conjunction is when the Sun is between the planet and the Earth. Only the inner planets can have inferior conjunction.

CULMINATION
The instant that a celestial body reaches its maximum altitude. Identical to **meridian passage**. Circumpolar stars have an upper culmination or transit is when the object is closest to the observer's zenith. Lower culmination (also called "culmination below the pole") is when the object passes the meridian farther from the zenith

DYNAMICAL TIME
The current time measurement standard used for astronomical measurements and calculations. Adopted in 1984, dynamical time is based on time intervals from atomic clocks. There are actually two forms of dynamical time; terrestrial dynamical time (TDT) and barycentric dynamical time (TDB). They two forms differ by a very small amount due to relativistic effects due to the Earth's movement in its orbit that can be ignored for all but the most critical applications. Dynamical time is related to **universal time** by the relation, ΔT = Dynamical Time - Universal Time. ΔT depends on the instantaneous speed of rotation of the Earth and is both variable and unpredictable. For the 1990's, ΔT is about one minute.

DECLINATION
The angle of a celestial object from the celestial equator. North is taken as the positive direction. Declination is measured in degrees.

DOMINICAL LETTER
The index of the first Sunday of the year from the sequence A, B, C, ..., G. If the first Sunday is, e.g. January 3, then the dominical letter for the year is C, the third letter in the sequence. All Sundays in the year have the same letter except in leap years, February 28 and 29 have the same letter and the Sunday letter changes after leap day. Thus, leap years have two dominical letters, e.g. C/D. The dominical letter was used in early methods of determining the date of Easter.

DRACONITIC PERIOD
The time between passages of an orbiting body through the ascending orbital node. Primarily used for the moon as an indication of when eclipses can happen. Also called the nodical month (27.2122 days).

EASTER (DATE OF)
The first Sunday after the first full moon after the **vernal equinox**. Note that the Gregorian calendar reform included modified rules for determining the date of Easter. These reforms use a hypothetical mean **lunation** and are used to determine the date of a hypothetical mean full moon which is in excellent agreement with the mean moon but ignore the physical moon resulting in potential differences of up to a day. If the time of full moon is very near the vernal equinox the ecclesiastical fixing of the date of Easter may vary widely from the astronomical view. While this sounds unrealistic at first glance there is justification. Full moon occurs at an instant which will be on different dates in different parts of the world. The ecclesiastical rules fix Easter for the entire world in a rational way.

The date of Easter has an interesting history in itself. The New Testament fixes the date of Jesus' crucifixion at the beginning of Passover. Passover begins on Nisan 14 which is defined as the date of the first full moon after the vernal equinox. The first Council of Nicaea (325) decided that Easter should fall on Sunday, the Christian day of worship, and made the appropriate adjustment and adopted the, so called, "Alexandrine Rule", credited to Anatolius of Laodicea (d. ca. 282), of the 19 year lunar cycle (but see **Metonic Cycle**) to calculate future Easter dates. The rules were changed to use the **Epact** and striclty alternating lunar months of 29 and 30 days when the **Gregorian Calendar** reform was implemented in 1582. The Orthodox Church did not adopt the reforms and Orthodox Easter can vary from the Latin Easter by up to five weeks. The determination of astronomically determined moveable Christian religious celebrations is called "Computus" and was required learning for every educated person in the middle ages and, until recently, was taught to all priests.

EVECTION
A perturbation in the moon's orbit due to changes in the orbital **eccentricity** caused by the gravitational effect of the Earth and Sun. The moon's eccentricity can vary from .066 when a perigee passage occurs at a new or full moon to .044 when it occurs at the first or third quarter.

ECCENTRIC ANOMALY
A mathematical construction used in the solution of orbital problems. Eccentric Anomaly (E) is found from Kepler's Equation: $M = E - e \sin E$, where M is the **mean anomaly** and e is the orbital **eccentricity**. Note that this is a transcendental equation that cannot be solved directly but can be solved using iterative techniques. The eccentric anomaly is used to calculate the **true anomaly**.

ECCENTRICITY
The "shape" of a planetary orbit, ranging from 0 to 1. 0 means the orbit is a perfect circle with the value increasing as the orbit becomes more elliptical. The Earth's orbit is nearly circular with an eccentricity of about .0167. The orbit of comet Halley is highly elliptical with an eccentricity of about .967. The eccentricity of an orbit is defined in exactly the same way as the eccentricity of any ellipse and is defined as the ratio of the distance from the center to the focus to the length of the semi-major axis. An orbit with an eccentricity of 1 is parabolic and, thus, not periodic.

ECLIPTIC
The plane described by the orbit of the Earth around the Sun.

ECLIPTIC LATITUDE
The angle of a celestial object above the ecliptic as seen from the Sun.

ECLIPTIC LONGITUDE
The angle of a celestial object from the **vernal equinox** measured along the **ecliptic**.

ELONGATION
The angle from the Sun to a planet as seen from the Earth.

EPHEMERIS
The old name of the Astronomical Almanac, which is published jointly by the United States Naval Observatory and Royal Greenwich Observatory. Also any listing of planetary positions.

EPACT
The age of the calendar moon in days on the first day of the year. Defined as the number of days since the last astronomical full moon less 1 day. Thus the epact is the number of days since the start of the last lunar month of the previous year. Used for finding the date of the ecclesiastical vernal full moon and thus, fixing the date of Easter and other moveable Christian religious celebrations.

EQUATION OF THE CENTER
The difference in the angle of the mean Sun and the true Sun measured along the **ecliptic** = (Sun's **mean anomaly**) - (Sun's true anomaly). It is the difference in the actual angular position of a planet and the position the planet would have if it had a uniform orbital speed. Determination of the equation of the center was a critical element of Ptolemaic astronomy. It is currently used as part of the equation of time.

EQUATION OF TIME
The difference in the time of the fictitious mean Sun, upon which civil time is based, and the time of the true, physical Sun. The precise definition is the difference in right ascension of the true Sun and the fictitious mean Sun. The fictitious mean Sun is the basis for civil time and is defined as a fictitious Sun

that travels at a fixed rate on the equator. The equation of time = (hour angle of the Sun) - (hour angle of mean Sun) = (right ascension mean Sun) - (right ascension of the Sun) = (Sun's mean longitude) - (Sun's right ascension) = (Sun's true longitude) - (Sun's right ascension) - (equation of the center). The term (Sun's true longitude) - (Sun's right ascension) is called the "reduction to the equator" and accounts for the time difference resulting from the fictitious mean Sun traveling on the equator instead of the ecliptic. The equation of time is used to correct the time shown by a sundial to zone time and is used in celestial navigation.

EQUATOR
The **great circle** on the surface of a body that is perpendicular to the axis of rotation.

EQUINOX
Point where the celestial equator meets the **ecliptic**. When the Earth passes through one of its equinoxes the length of the day and night are equal. The Vernal Equinox is about March 21 and the Autumnal equinox is about September 23.

FIRST POINT OF ARIES (♈)
The point on the celestial sphere where the equator crosses the ecliptic and the declination of the Sun changes from negative to positive. Also known as the **vernal equinox**. Note that the position of the First Point of Aries changes due to the precession of the equinoxes. Orbital positions are always measured from a specified equinox which may be fixed at some specific time (epoch) such as J2000.0 or referred to the actual equinox at a given time (the mean equinox of date). The First Point of Aries is no longer related to the constellation Aries.

FULL MOON
Condition when the Moon is at **opposition**, i.e. the longitude of the Moon differs from the longitude of the Sun by 180º.

GEOCENTRIC
Centered at the center of the Earth. Some tabulated geocentric values are actually centered at the center of mass of the Earth-Moon system. Right ascension and declination are geocentric.

GEOCENTRIC LATITUDE
The angle of a celestial object above the **ecliptic** as seen from the Earth.

GEOCENTRIC LONGITUDE
The angle of a celestial object from the First Point of Aries measured along the **ecliptic** as seen from the Earth. That is, the Earth is considered to be at the center of the ecliptic. The signs of the zodiac are divided into segments of 30° in geocentric longitude.

GOLDEN NUMBER
The year in the 19 year lunar cycle (see **Metonic Cycle**). Calculated as the remainder of [(year +1)/19] with 0 taken as 19 and expressed in Roman numerals. The Golden number for 1996 is II. Used in the calculation of the date of Easter.

GREAT CIRCLE
The plane defined by a circle on sphere that passes through the center of the sphere. Examples of great circles are the **equator** and **meridian**. A small circle does not pass through the center of the sphere. The circles defined by latitudes are small circles except for the equator.

GREGORIAN CALENDAR
The calendar proposed by Aloysisus Lilius, a physician from Naples, and adopted by Pope Gregory XIII in accordance with instructions from the Council of Trent (1545-1563) to correct for errors in the older Julian Calendar. In the Gregorian Calendar, leap years are every four years, as in the Julian Calendar, except that century years not divisible by 400 are not leap years. 2000 is a leap year. Thus, there are 97 leap years

every 400 years making the average length of the **tropical year** of 365.2425 days compared to the true value of about 365.2422 days or an error of only about 26 sec. in 400 years. Presumably, the Gregorian Calendar will be updated at the appropriate time to eliminate years evenly divisible by 4000 as leap years. This modest correction will reduce the 4000 year error in the mean tropical year to 4 sec. The Gregorian calendar was introduced in Italy, Spain, Portugal, France and Poland on October 4, 1582, a date that was followed by October 15, 1582. Other Catholic countries followed in 1583 (Holland, Flanders and the German Catholic States). Protestant countries delayed introduction with the German and Dutch Protestant states and Denmark in 1700, Britain and British dominions waiting until September 2, 1752 (followed by September 14), Sweden in 1753, Japan in 1873, China and Albania in 1912, Bulgaria in 1916, Soviet Russia in 1918, Rumania and Greece in 1924 and Turkey in 1927. Adoption of the Gregorian calendar was often accompanied by other calendar changes. For example, the British Calendar New Style Act of 1750 also included changing New Year's Day from March 25 to January 1, a custom that had been adopted in Scotland in 1600. Calendar dates must be examined carefully to determine the calendar in use at the time and even then can be very confusing. See also **Easter (Date of)**.

HELIOCENTRIC
Centered at the Sun. Ecliptic longitudes and latitudes and planetary orbital parameters are heliocentric.

HELIACAL RISING
The condition when a star rises with the Sun. Heliacal rising was the basis for many ancient calendars, the most famous of which was in Egypt where the heliacal rising of Sirius signaled the beginning of the agricultural year. Other stars have been used by other cultures. For example, there is evidence that North American plains Indians used the heliacal rising of Aldebaran to signal mid-summer.

HORIZON
The plane perpendicular to the line from the observer to the zenith. The astronomical horizon is a **great circle** and the local horizon is tangent to the surface of the Earth. They are indistinguishable for most astronomical applications.

HOUR ANGLE
The angular distance measured westward along the celestial equator from the **meridian** to the hour circle passing through the celestial object. The hour circle is a **great circle** passing through the object.

INFERIOR CONJUNCTION
The condition where Mercury or Venus is directly between the Sun and the Earth.

J2000.0
The Julian day that represents the exact beginning of the year 2000, dynamical time. The Julian ephemeris day at J2000.0 is 2451545.0 and is the basis for calculating celestial positions in the current epoch. That is, the star positions given in catalogs are for J2000.0 from which positions at other dates can be calculated.

JANUS
The Roman god of doorways and beginnings. January, the first month of the year, is named after Janus. Janus (pronounced Jaynus), is depicted with two faces, one looking to the future, and the other reflecting on the past to remind us that the future is a product of the past. Also the name of the company that produces the Electric Astrolabe and the Personal Astrolabe.

JULIAN CALENDAR
Calendar introduced by Julius Caesar in the "Year of Confusion", 46 BC, to correct for the non-integral number of days in a year through the introduction of Leap Years. At its introduction, 80 days were added to bring the vernal equinox to the desired date and to make the new year start on January 1. In the Julian Calendar there is a leap year every fourth year in which February has 29 instead of 28 days. The "Leap Day" (probably from Old Norse *hlaupa,* "to leap") was originally inserted after February 23, which was six days before the Kalendae or beginning of March and was called *sexto-kalendae*. The leap day, when added, was the day after; *bis-sexto-kalendae*. Thus, leap years are called bissextile. The number of days in

the months were also changed when the Julian calendar was introduced and ammended by Augustus in 8BC to the values in use today. Also, due to misunderstanding by the Pontifices, the leap days were inserted every three years instead of every four years for 36 years. Augustus corrected the error by omitting bissextile years from 8 BC to AD 8. Therefore, corrections must be applied to dates in the Julian calendar from the period 46 BC to AD 8. Later superseded by the **Gregorian Calendar**. In the Julian calendar, the length of the year is taken as 365¼ days, exactly.

JULIAN DATE
A convention for timekeeping that is independent of specific calendars and is thus ideally suited for astronomical purposes since the number of days between observations is immediately known from the differences in Julian dates. Julian dates are counted in sequence from noon UT on January 1, 4713 BC. Note that Julian dates begin at noon UT. Julian dates are shown as an integer day number with a fraction of a 24 hour day. Thus, Julian date 2436116.31 corresponds to October 4, 1957 at 19:26 (the launch time of Sputnik I). The Julian period is formed by the product of the 19 year cycle of the Moon used to determine the "golden number" of a year for use in determining the date of Easter, the solar cycle of 28 years which is the shortest period in which the same date occurs on the same day of the week in the Julian calendar and the 15 year cycle of indiction which was introduced by Constantine in 313 for setting the period of property taxation (i.e. property was reassessed each 15 years). Its length is 19 x 28 x 15 = 7980 years. In this period no two dates can have the same Julian date in all three cycles. All of these cycles began in January 1, 4713 BC so the Julian Period covers all of recorded history. Will there be another Julian date 0.0 in 3267? Many people make an intuitive association between Julian dates and the Julian calendar introduced by Julius Caesar. There is a vague relationship. The Julian period was introduced by Joseph Justis Scaliger (1540-1609) of Leyden in *De emendatione temporum* (Paris, 1583) and is named after his father, Julius Caesar Scalinger. Other than this, the two systems are not related.

LIMB
The edge of a planet or the Moon or any celestial object with a disk. On an astrolabe, the limb is the ring of the instrument outside of the Tropic of Capricorn which usually contains the hour numbers and a degree scale.

LINE OF APSIDES
The line connecting the ascending and descending **nodes** of an orbit.

LONGITUDE CORRECTION
The difference in time between a specific longitude and the center of the civil time zone. Since civil time zones are centered at 15º intervals, the difference in the sidereal time at the center of the time zone and another location in the same time zone can be significant. Madrid, for example, is over an hour from the center of the time zone used in Spain.

LUNATION
The time between new moons (29.5306 days). See also **Synodic Period.**

MEAN ANOMALY
The position of an orbiting body if it is assumed to have a circular orbit with a constant orbiting rate. Used to calculate **eccentric anomaly**.

MEAN LONGITUDE
The angle of an orbiting body from the **First Point of Aries** measured in the direction of rotation assuming the orbit is circular with a constant rotation rate.

MERIDIAN
The **great circle** passing through north, south and the **zenith** for a specific location. The meridian defines the directions of north and south and is the north-south (vertical) line on the astrolabe plate.

MERIDIAN PASSAGE
The instant that a celestial body crosses the **meridian** from east to west. Identical to **culmination** or transit.

METONIC CYCLE
The 19 year (235 lunation) period over which the moon's phase repeats. That is, if a full moon occurs on a certain date it will occur on the same date 19 years later. Attributed to Meton of Athens ca. 432 BC but probably known earlier.

NEW MOON
Condition when the Moon is at conjunction with the Sun, i.e. the longitude of the Moon is the same as the longitude of the Sun.

NODE
The point of an orbit where the orbit crosses the **ecliptic** plane. (see also, Ascending Node).

OBLIQUITY OF THE ECLIPTIC
The angle the Earth's **equator** makes with the **ecliptic**.

OPPOSITION
The condition where the Earth is directly between a planet and the Sun, i.e. the longitude of the planet is 180º from the Sun.

ORBITAL PARAMETERS
Any orbit is completely described by the following parameters: period (i.e. how long it takes to complete one orbit), eccentricity, longitude (or right ascension) of ascending node, inclination, semi-major axis and perifocus argument (perihelion argument for planets). The position of any orbiting body can be calculated for any time using these six parameters and a known position (such as perifocus passage) at some specific time.

PERIAPSIS
The general term for the point on an orbit that is closest to the body being orbited. See also perigee and perihelion. Similar words are used for orbits around Jupiter, Saturn, etc.

PERIGEE
The point in the moon's orbit that is closest to the Earth.

PERIHELION
The point in a planet's orbit that is closest to the Sun.

PERIHELION ARGUMENT (PERIHELION DISTANCE)
The angle on an orbit from the **ascending node** to **perihelion** measured in the plane of the orbit.

PHASE ANGLE
The angular distance from the Sun to the Earth as seen from the Moon or a planet.

PLATE
The part of an astrolabe display consisting of the horizon and twilight lines, altitude circles, and azimuth curves. Also known as the "tympan".

POSIGRADE MOTION
When a planet's longitude increases. That is, it moves from west to east relative to the stars.

POSITION OF BRIGHT LIMB
A measure of the orientation of the phase of the Moon or a planet. The position of the bright limb is

measured as the angle from north of a line connecting the cusps of the shadow.

PRECESSION OF THE EQUINOXES
The gradual movement of the point of the equinoxes (but usually described by the movement of the vernal equinox only) in the celestial sphere. Precession is caused by the slightly irregular shape of the Earth and the fact that the moon's orbit is not exactly on the ecliptic. Precession is approximately 50″ in longitude per year.

RADIUS VECTOR
Distance of a planet from the Sun in AU's.

RETE
The part of an astrolabe which contains pointers to the stars, or in the case of the Electric Astrolabe, the constellations and Messier objects and the ecliptic. The rete rotates once in a sidereal day. The word is pronounced "reet" by most people although some scholars prefer "reetee" as it would be pronounced in Latin. Rete is the Latin word for "net". It is also called the "spider" in various languages.

RETROGRADE MOTION
When a planet's longitude decreases. That is, it moves from east to west relative to the stars over a period of a few days. Copernicus used the retrograde motion of Mars to illustrate the validity of his heliocentric solar system theory.

RIGHT ASCENSION
The east-west position of a celestial object on the equator of the celestial sphere. Right Ascension is measured in hours and minutes beginning at the First Point of Aries, from 0:00 to 24:00, increasing to the east. The name "right ascension" derives from the rising times of the ecliptic when viewed from the equator (*sphaera recta*). At this location, the rising time for a section of the ecliptic is found directly. The "rising time at sphaera recta" is "ascensio recta" or right ascension.

RULE
The "clock hand" on an astrolabe pointing to the current clock time. The point where the rule crosses the ecliptic circle is the position of the mean Sun in the ecliptic. Note also that the point where the rule crosses the ecliptic shows the Sun's **geocentric longitude**. The rule is sometimes graduated in declination.

SAROS
Time period of about 18 years, 11 months after which eclipses occur with the same circumstances. The Saros is a combination of 223 synodic months of 29.5306 days (6,585.32 days), 19 Draconitic years of 346.6201 days (6,585.78 days) and 239 anomalistic months of 27.55455 days (6,585.54 days). When all three cycles coincide the Moon/Sun relationship is repeated. If the cycle is started at a solar eclipse, similar eclipses will occur 6,585 days in the future or occurred the same number of days in the past. The Saros does not exactly restore all elements and the character of consecutive eclipses gradually change finally resulting in no eclipse at all. Therefore longer cycles must be constructed. The current Saros series (numbered 136) began in 1306 and will continue until 2622 and contains 71 eclipses. Note that successive eclipses occur about 120° west of the previous one. After three Saros an eclipse will occur at the same longitude but shifted north or south. The word *Saros* derives from a Babylonian word meaning "universe". The use of this term was popularized by Halley in the late 16th century

SIDEREAL TIME
The **right ascension** of celestial bodies that are on the **meridian** for a specific place at a given instant. Mean sidereal time is referred to the mean equinox of date (i.e. corrected for precession). Apparent sidereal time is corrected for nutation (the so called equation of the equinoxes) and is referenced to the true equinox of date.

SIDEREAL YEAR (MONTH)
The time for the Earth's successive returns to the same position relative to the stars as seen from the Sun

(365.2564 days). A similar definition applies to the moon. A sidereal month is 27.3217 days.

SUPERIOR CONJUNCTION
The condition where the Sun is directly between a planet and the Earth.

SYNODIC PERIOD
The average period of time between successive **conjunctions** of a pair of planets or of a planet and moon. A synodic month is, therefore, the time between new moons (29.5306 days).

SYZYGY
The points on the orbit of a planet (or the moon) when it is in opposition or conjunction. Also a terrific Scrabble or Hangman word.

TROPICAL YEAR (MONTH)
The time from one **vernal equinox** to the next. Also the basis for the calendar year. Equal to 365.242191 days. For the Moon, a tropical month is the time between new moons and is equal to 29.5306 days.

TRUE ANOMALY
The angular distance on an orbit from **perihelion** to the current position measured from the focus of the orbit.

TRUE LONGITUDE
The angular distance on an orbit from the **vernal equinox** to the current position. Calculated as the **true anomaly** plus the longitude of perihelion.

UNIVERSAL TIME
Universal time is the basis for civil timekeeping. Universal time is defined as 12h plus the hour angle of the fictitious mean Sun that is assumed to orbit the Earth in a circular orbit on the equator. Time services (such as WWV) broadcast Coordinated Universal Time (UTC) which is kept in step with atomic clock times by the occasional insertion of one second steps called “leap seconds”. Universal Time has become extremely complex. Interested readers are referred to *The Astronomical Almanac* for precise definitions. A good overview is in Howse, Derek, “Greenwich time and the discovery of the longitude”, Oxford University Press, 1980, which also has an interesting history of time keeping in general.

VARIATION
An inequality in the moon’s orbit due to differences in the Sun’s attraction during a **synodic month**.

ZODIAC
The division of the ecliptic into the twelve astrological signs: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces. The zodiac begins at the vernal equinox (the “First Point of Aries”) and continues in 30 degree sections through the twelve signs. Note that, due to the precession of the equinoxes, the constellations that give the sections of the zodiac their names no longer fall in the section with that name. Thus, the zodiac is an arbitrary division of the ecliptic into 30 degree sections of geocentric longitude and is a convenient way to describe planetary positions.

USER'S REFERENCE

COMMAND KEYS

A	Display astrolabe plate.
Alt+A	Display Sun only.
B	Display bright stars.
Alt+B	Display stars as dots.
C	Go to Program Control page.
Alt+C	Go to page of cities and inserted objects.
D	Enter new date (MM/DD/YYYY).
E	Display ecliptic.
Ctl+E	Label ecliptic with zodiac symbols.
F	Start/stop Free Running mode.
G	Switch between Gregorian and Julian calendars.
H	Go to Help screen.
Ctl+H	Star positions
I	Display .GIF image
Alt+I	Create .bmp file of graphic screen
L	Enter new latitude and longitude.
M	Go to Manual mode.
Ctl+M	Start menu mode.
N	Now. Set time and date to system clock values.
Alt+N	Switch between northern and southern astrolabe projection.
O	Display Messier objects.
Alt+O	Select brightness of Messier objects to display.
Ctl+O	Switch between Messier object symbols and numbers.
P	Display planets.
Alt+P	Turn stellar precession on and off.
Ctl+P	Label planets.
Q	Quit program and return to DOS.
Ctl+Q	Quiet mode.
R	Display rule.
Ctl+R	Display long rule.
S	Display stars. B = Bright stars.
Alt+S	Specify sidereal time.
Ctl+S	Label constellations.
T	Specify a new time (HH:MM)
Alt+T	Display time as AM/PM.
Ctl+T	Use dynamical time.
U	Specify a new Universal Time.
Ctl+U	Display unequal hours
V	Go to page of calculated values
Alt+V	Page of complete calculations.
Ctl+V	Page of high precision values.
X	Turn shading on and off.
Alt+X	Display planets as +.
Ctl+X	High precision calculations.
Z	Specify a new time zone.
Esc	Return to previously page.
0	Set longitude to 0 degrees.
=	Here. Set latitude, longitude and time zone to first city in cities list.
;	Turn daylight savings time on and off.
'	Automatic DST on and off.
Big+/-	Advance time by current time interval setting. Vary animation rate in free running mode. Move long rule (Ctl+). Use [and] on laptops.

FUNCTION KEYS (Alt+Fn reverses direction of change. Ctl+Fn = City n)

F1	1 minute
F2	5 minutes
F3	10 minutes
F4	30 minutes
F5	1 hour
F6	1 day
F7	5 days
F8	10 days
F9	0.997269568 day (one sidereal day)
F10	29.53059 days (one lunation or tropical month) The F10 value is replaced by an interval entered on the Help screen.
F11	1 second (0.000011574 day)
F12	365.242191 days (tropical year)

PHASE IMAGE KEYS

1	Mercury
2	Venus
3	Moon
4	Mars
5	Jupiter's moons
6	Saturn's rings
7	Lunar Eclipses

ZODIAC SYMBOLS

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