"Mathematics could not progress until the Hindus invented the zero" (ascribed to "the tamer of whales" in João Guimarães Rosa's _Tutaméia_)

That could be, but the Arabs get the credit from many, at least in its naming, as they do for much mathematics.

"How short the centuries are, except for this one!" (ib.)

The Earth, the Celestial Sphere and the Measurement of Time

Earth is a not quite round globe, an ***oblate spheroid***, which spins on an axis as it moves around Sol, its sun, in a not quite circular, ***elliptical***, orbit. The ***poles*** of Earth are defined as the points at which its axis of rotation pierces the surface. The ***North Pole*** is that pole above which rotation appears counter-clockwise. ***East*** is defined as lying in the direction of this rotation. The ***equator*** of Earth is the circle on the surface cut by the plane lying perpendicular to the axis and mid-way between the poles. The ***horizon*** from a given point on Earth is defined by the plane lying tangent to that point.

A position on the surface of the Earth is commonly identified by its latitude and longitude. Both are angular measurements. The ***latitude*** of a location on Earth's surface may be seen as the angle formed between the plane of the equator and a line from Earth's center to the location in question. This is called the ***geocentric latitude*** of the location. However, "latitude" is usually taken to mean ***geographic latitude***, defined as the angle between the equatorial plane and a perpendicular to the horizon. These two definitions of latitude are equivalent on the equator and at the poles but differ between them due to the oblateness of Earth's shape. Any location on the equator lies at zero degrees latitude while the latitude of the poles is ninety degrees. By convention, northern latitudes are positive while southern latitudes are negative.

The latitudes of zero, plus and minus 90° have precise physical definitions and significance. There are others which do also. The ***tropics*** are defined by the ***obliquity of the ecliptic***, the angle of approximately 23.5° at which Earth's equatorial plane intersects the ***ecliptic***, the plane of Earth's orbit around the sun. The tropics are the latitudes which lie at the geographic latitudes of the positive (northern) and negative (southern) value of the obliquity of the ecliptic. These are the extreme latitudes which intersect the plane of the ecliptic. At the moments of extreme inclination of the axis toward the sun, the ***solstices***, the tropical summer noon sun would appear directly overhead. At all other times the tropical noon sun will incline at least slightly toward the opposing pole, as it always does at latitudes beyond the tropics. The tropics thus may be seen as the extremes of the sun's yearly excursions to the north and south.

The northern tropic, passing through central Mexico, northern Africa, the Arabian peninsula, India and southern China, is the ***Tropic of Cancer***, so named because the northern summer solstice, at which the sun reaches this limit, occurs with the sun's entry into the zodiacal sector of Cancer. The southern tropic, passing through Paraguay, southern Africa and central Australia, is the ***Tropic of Capricorn***.

The ***Arctic*** and ***Antarctic circles*** are also defined by the angle of Earth's equator from the ecliptic. They lie at latitudes of approximately 66.5°, beyond which sectors of the ecliptic, ranging from single points at these latitudes through half the ecliptic at the poles, remain always above or below the horizon. As a result, during periods centered on the times of the solstices, so does the sun. The duration of this "midnight sun" and "noon darkness" increases to a maximum of half the year at the poles. The southern Antarctic circle almost exactly encloses the continent of Antarctica while the Arctic circle cuts through northern Alaska and Canada, central Greenland, the northern Scandinavian countries and Russia.

Longitude, by contrast to latitude, is an angular measurement of rotation around Earth's axis. Here, unlike as for latitude, there is no physical basis for marking the starting point of this rotation. By convention, the longitude of the Greenwich Observatory near London was chosen as marking zero degrees longitude. Proceeding eastward, east longitude is commonly represented as negative, increasing through

90° in the middle of Russia and the Indian Ocean between Africa and Australia and on to 180° on the opposite side of the globe, through the northeastern tip of Russia and the western end of the Aleutian chain in the north and near Fiji and New Zealand in the south. In the opposite direction, west longitude increases positively from the zero of Greenwich through 90° at New Orleans and the Galapagos Islands and on to the same central 180° mark approached from the other direction. The half circle through the poles at any given longitude is said to be the ***meridian*** at that longitude.

Celestial longitude is analogous to terrestrial longitude but, rather than being measured along the equator or parallel to it, it is measured on the plane of the ecliptic, around the orbital path of the Earth. The origin of celestial longitude, its zero point, is defined as lying along the intersection of the planes of the ecliptic and the equator in the direction of the sun at the northern vernal equinox. Unlike terrestrial longitude, measured out to 180° either east or west of zero, celestial longitude is measured from zero rotating a full 360 degrees eastward, counter-clockwise as viewed from above the northern pole, in the direction of Earth's rotation.

Celestial latitude is defined as the angle lying between the plane of the ecliptic and a line from Earth's center to a point in question.

Nightly passage of the stars is related much more immediately to Earth's daily rotation than to its yearly orbit so it is often more convenient to relate celestial directions to the ***celestial equator***, a projection of Earth's equator outward through the celestial sphere, rather than to its orbital plane. Angular direction around the celestial equator is called ***right ascension***. Like celestial longitude, it is measured counter-clockwise, eastward from the intersection of the planes of the equator and the ecliptic in the direction of the vernal equinox. Zero right ascension is equal to zero degrees of celestial longitude along the planes of the ecliptic and the equator, but this equivalence holds only at 0°, 180° and the 90° points between them.

It is convenient and conventional to measure right ascension in terms of hours, minutes and seconds rather than in degrees since the earth makes a complete rotation approximately every 24 hours, during which the sky and its stars appear to rotate full circle above us. Note, however, that these units of "sidereal time" are not exactly equal to corresponding units of solar time.

Sidereal time is commonly used to refer to the right ascension lying on the meridian at a given time and location. It is more properly considered as a sidereal *position of revolution* but is measured in units of time for the reason mentioned above. ***Hour angle*** of a given right ascension at a given place and time is also measured in units of time. It is this right ascension subtracted from the current local sidereal time and, thus, the amount of sidereal and, approximately, "clock" time since or until the coincidence of that right ascension with the meridian.

The celestial analogy to latitude is ***declination***. It is measured exactly as terrestrial latitude, from Earth's center to a point in the sky relative to the plane of the celestial equator. Currently the star Polaris lies at approximately 90° declination. Sigma Octans lies near -90°. Just as terrestrial longitude is effectively meaningless at the Earth's poles, from which every direction is north or south, so is right ascension at 90° declination, from which every direction is toward the opposing celestial pole.

An example of the contrast between equatorial and longitudinal positioning of stars is Spica, which lies in Virgo, 2° below the ecliptic at celestial longitude 204°. This is equivalent to right ascension $13^h\ 25^m$ and declination -11°. The right ascension of Spica is 201° in angular terms. The closeness of this to its celestial longitude can be expected since Spica lies close to the planes of both the equator and the ecliptic and, hence, to their intersection at 180° longitude and 12^h right ascension.

In addition to the planes of the equator and the ecliptic, a third plane, that of the horizon, is the most natural plane of reference from the surface of the earth. Points in the sky are commonly identified by their altitude and azimuth. ***Altitude*** of a point is defined as the angle (equal to or less than 90°) from the plane of the horizon to that point. ***Azimuth*** of a point is defined as the geographical direction on the horizon to the perpendicular on which the point lies. Azimuth is always taken as increasing with clockwise rotation from a reference direction. Depending on context, zero degrees may be taken as either due South (***westerly azimuth***, common in astronomical contexts) or due North (***easterly azimuth***, common in terrestrial navigation). Azimuths beyond 180° may be stated in either positive or negative terms. At the poles, all directions are toward the opposite pole and astronomical azimuth defaults to the hour angle of the direction in question or its negative at the northern and southern poles respectively.

A ***sidereal year*** is defined as the time elapsed during one complete orbit of Earth around the sun. It may be observed and measured as the period between two successive appearances of the sun in the identical position against the backdrop of the celestial sphere. Position of the sun relative to Earth can be denoted by placing it in the division of Earth's path around the ecliptic into the signs of the ***zodiac***, 12 sectors defined by easily recognizable constellations lying along it.

Earth's distance from the sun varies in its orbit with a ***perihelion*** (closest point) of around 147 and an ***aphelion*** (furthest point) of around 152 million kilometers. This corresponds to a variation of +/– 1.67%, the approximate ***eccentricity*** of Earth's elliptic orbit. An ***anomalistic year*** is defined as the period between successive perihelions or other reference points in the orbit. The elliptic path of Earth's orbit itself rotates about the sun so that the perihelion advances by about 25 minutes per calendar year (Schütte, p182).

Earth's perihelion occurs around January 3rd of the year 2000 (M&P, p87) and moves a day forward every 58 or so years. This variation in distance over the year must have a measurable, but small and probably not easy to isolate, effect on Earth's climate. Another factor which must have similar effect is that of short term conditions on the sun, such as its sunspot cycle. Both affect the amount of solar radiation the Earth receives.

But it is not Earth's position in its orbit around, nor cycles of, the sun which dominate the definition of Earth's year, especially not in its temperate and polar regions. It is the seasons which tell some when to fly south and when to fly north, others when to reap and when to sow. The seasons are defined primarily, not by Earth's orbital position around the sun, but by the resulting change in orientation of Earth's axis to it. The period between two successive identical angular orientations of Earth's axis to the sun is defined as a ***seasonal, solar*** or ***tropical year***.

If the direction along which Earth's axis lies did not change, if it lay between fixed celestial poles, the sidereal and solar years would be equivalent. Each time the Earth returned to a given position in its orbit its axis would be identically inclined toward the sun. The orientation of Earth's axis does change, however. This change is due to several factors including gravitational effects due to changes in Earth's texture and also to its moon. The dominant effect is one of an approximately circular rotation of the angular inclination of Earth's axis to the plane of the ecliptic around a perpendicular to the ecliptic. This rotation is clockwise as viewed from above the northern pole, opposite to that of Earth's spin and orbit. Its period is approximately 25,800 years. This cycle has been called a ***Platonic year***.

Because of this rotational wobble the identical inclination of Earth's axis to the sun occurs slightly earlier in each succeeding revolution about the sun. This produces the effect known as ***precession of the equinoxes***, the falling of the equinoxes slightly earlier in each of Earth's cycles around the sun. The precession is about 50.225 seconds of arc per seasonal year and continues cyclically back through the zodiac, through the thirty degrees (and, approximately, days) of each complete sign every 2,150 or so years. It results in the seasonal or tropical year's being 20'23" or so shorter than the sidereal year.

There are other effects changing the orientation of Earth's poles, producing minor variation in the dominant circular wobble of precession. The most significant of these is the ***nutation*** of polar orientation caused by gravitational interaction between the Earth and its moon, whose orbit lies slightly off the ecliptic. This produces a small rotation of Earth's polar orientation about that predicted by simple precession. A complete cycle of nutation results from the cyclic variation in the tilt of the moon's orbit from the ecliptic over a period of 18.6 or so years. Position in this cycle is commonly identified by the moon's ***ascending node***, the longitude at which its orbit crosses the ecliptic, rising above it. This longitude decreases over time so that nutation rotates in the same direction as precession – clockwise as viewed from above the northern pole. Over a complete cycle of the moon's ascending node the equinoxes can be seen to be at their precessed values, to decrease from them, to return to them and then to increase before returning once again to their mean values. The nutational variation in the equinoxes ranges over approximately +/– 17 arc seconds. A corresponding range of variation in the obliquity of the ecliptic is +/– 9 arc seconds (M&F, pp124, 154).

Just as an Earth year can be defined as one entire orbit around the sun but defined more meaningfully as the slightly shorter period defining the seasons, so may a day be defined as a full 360° rotation of Earth in space but is better defined, from the perspective of life on the planet, in terms of daily passage of the sun overhead. Just as the two definitions of the year would be equivalent if Earth did not wobble on its axis, so would the solar and sidereal days be equivalent if Earth did not move in its orbit around the sun. Since it does, however, and since the rotational and orbital directions are the same, it requires slightly more than one full rotation of the Earth from one noon or other reference time to the next.

Earth's day is defined as a ***solar day***, the elapsed time between the sun's passage from meridian to meridian at a given spot on the planet. Solar noon, 12:00 at any given location, is defined as the instant that the sun crosses the meridian there. This definition is preserved in our continuing usage of "AM" and "PM" (*ante* and *post meridiem*) to differentiate between morning and afternoon/evening times. ***Solar time***, the position of the sun at a given moment and location on Earth, is defined as the hour angle of the sun, commonly with 12 added from midnight through morning hours so that they run from 00:00 to 12:00 at noon.

Equally lengthed units of time have become almost essential to the way many look at things but, due to the ellipticity of Earth's orbit and other effects, solar days and their resulting subdivisions are not of equal length over the year. If the Earth merely rotated on its axis and did not orbit the sun then solar days and their subdivisions might be of equal length. But it does and they are not. Thus did a measure of time divided into equal units come to diverge from "true" solar time. The practical measure of a day is a ***mean solar day***, an average over a year. The mean solar day is divided into the 24 hours of practical timekeeping loosely referred to as ***mean solar*** or ***civil time***.

Greenwich Mean Time, kept at England's Greenwich observatory, was defined as mean solar time at longitude zero and became the standard by which time was kept and clocks set world-wide through the first half of the twentieth century. ***Universal Time (UT*** or ***UT1)*** was a refinement on this idea. It formally defined mean solar time in terms of observed sidereal time (the rotational position of Earth in a fixed celestial frame of reference) and Earth's orbital parameters.

Fairly recent awareness of minor but measurable variation in the rate of Earth's rotation led, in the late 1950s, to an international definition of a second (and thus of minutes, hours, days, etc.) based on the length of a specific year, 1900 (Schütte, p. 186). This became the ***Ephemeris Second***, the standard unit in which ***Ephemeris Time (ET)*** is reckoned. Ephemeris time is commonly used in calculation of solar system interactions based upon Newtonian theory.

The impreciseness of definition and measurement of ephemeris time, along with advances in electronic engineering and nuclear physics, led, in 1967, to the adoption of the definition of an ***International System of Units (SI) second*** stated in terms of an atomic cycle of cesium 133. This has become the current ***civil second***. This unit was intended by measurement to be equal to the ephemeris second. It is said, however, that recent studies have shown that a mean solar day was exactly 24 SI hours around the year 1820.

International Atomic Time (TAI) is measured in SI units by use of atomic clocks as observed under standard conditions on Earth. It was established to be synchronized with universal ("solar") time on around January 1, 1958. Variations on TAI, some of more theoretical than practical interest, include the following, abstracted from United States Naval Observatory and similar sources.

Terrestrial or ***Terrestrial Dynamical Time (TT*** or ***TDT)*** is based on a frame of reference centered on the Earth. TDT was greater than TAI, and, therefore, UT1 by approximately 32.184 seconds at the latter two's time of synchronization in 1958. It has replaced ephemeris time for geocentric calculations.

Barycentric Dynamical Time (TDB) is based on a frame of reference centered on the gravitional center of the solar system. It is used in calculations with reference to that point. TDB differs theoretically from TDT due to relativistic effects of periodic gravitational variation as Earth orbits the sun.

Related to these are ***Geocentric Coordinate Time (TCG)*** and ***Barycentric Coordinate Time (TCB)***. These are mentioned in recommendations of the International Astronomical Union (IAU) made in 1991 and intended to further compensate for relativistic effects predicted by motion and gravitation of coordinate systems. TCG differs from TT by TCG - TT = Lg x (JD -2443144.5) x 86400 seconds, with Lg = 6.969291e-10. TCB differs from TDB by TCB - TDB = Lb x (JD -2443144.5) x 86400 seconds, with Lb = 1.550505e-08.

The solar system, however, with or without compensation for relativity theory, moves neither in synch with cesium atoms nor just as it did in the year 1900. Variation in Earth's rate of rotation, while very slight, combines long term trends with both cyclical and irregular components. These include effects of factors such as the lunar orbit and the sloshing about of Earth's oceans and innards as it goes along its way. Variation in Earth's orbit, of even lesser prominence, might also be considered although it usually isn't.

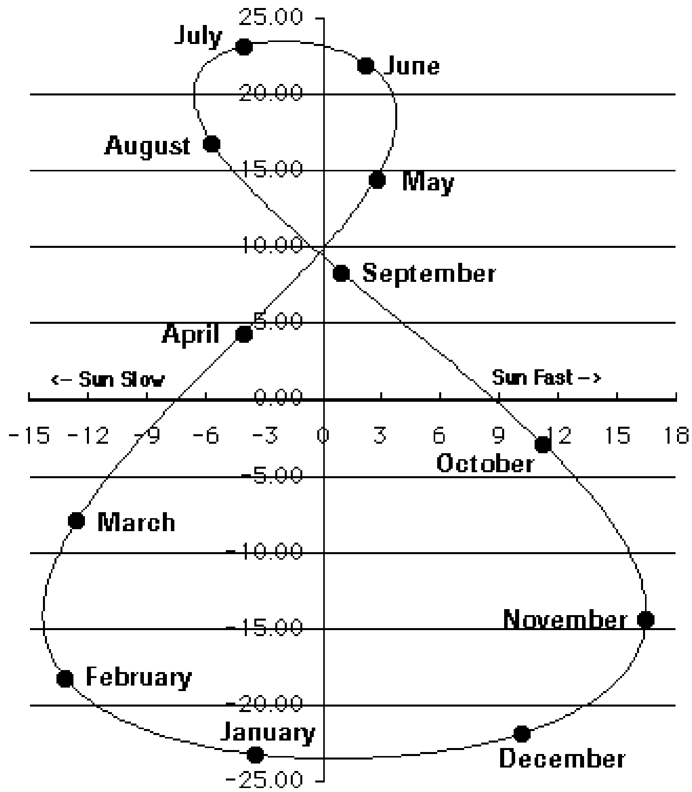
Governing, as it does, things such as when the sun rises and sets, the true movement of the solar system is still of some interest to humanity. Thus arose, in 1972, ***Coordinated Universal Time (UTC)***, the current international basis of civil time. It is measured in SI seconds but, at certain internationally agreed upon times of the year, UTC is adjusted by ***leap seconds*** in an effort to keep the difference between UTC and UT1 to within 0.9 seconds. The first of these leap seconds was introduced on June 30, 1972 for a total of 22 over the 27 years until January, 1999. They have always been added, never subtracted, indicating that Earth's rate of rotation has been predominantly decreasing, its days lengthening since those of the year 1820.

Global Postioning System (GPS) Time is also measured in SI units and was synched to UTC on January 6, 1980 but has not been adjusted thereafter by leap seconds.

Apart from such fine points of space and time, back down to Earth, standard zones based on longitude have long been established wherein a common ***mean standard time*** is kept so that clocks in these zones might keep a common time. Standard time zones are typically 15º wide so that standard time changes by one hour across their boundaries. Furthermore, various seasonal adjustments to civil time, such as ***Daylight Savings*** or ***Summer Time***, have evolved.

The relation between true solar and basic civil (mean solar) time, of interest in subjects such as the building and interpretation of sun dials, is often called the ***equation of time***. It expresses the difference of mean solar subtracted from true solar time at any given moment. Of related interest is the variation in altitude of the sun at a given reference time from day to day. This is usually presented as its declination, that of the ecliptic at the right ascension along which the sun lies at the time. The equation of time and similar calculations can account for and predict most orbital effects very accurately if correctly calculated with accurate values of their variables.

The equation of time commonly is represented in diagrammatic form as an ***analemma of time*** showing both solar declination and the difference between true and mean solar time over the course of a year. Although it must be noted that the analemma changes from year to year, the change is minute and very slow. An analemma calculated for a given year will serve many generations of observers of a sun dial. A typical, although not very precise, diagram is shown below (see Schütte, p202, for a more detailed version). It portrays the approximate equivalence of true solar with mean solar time in mid-April, mid-June, the end of August and late December. Solar time leads by around 2 minutes at the December solstice, 4 minutes in mid-May, 7 1/2 at the September equinox and 16 minutes in early November. It lags by around a minute at the June solstice, 7 1/2 minutes at the March equinox, 6 at the end of July and 14 minutes in mid-February.



The analemma of time (from www.analemma.com)

Declination is shown on the vertical axis of the analemma. At the equinoxes it is zero. At the solstices it takes on its extreme values, the positive and negative obliquity of the ecliptic.

A ***sidereal day***, by contrast with a solar day, is defined as one complete rotation of the Earth in an assumed fixed reference system. It may be measured as the time elapsing between successive appearances of a given star on the meridian. A sidereal day is 3 minutes 55.9 seconds of solar time shorter than a mean solar day. Sidereal time is also measured in hours, minutes and seconds but is more a measure of angular rotation and is defined as the right ascension of the meridian at a given place and time. At the time of the northern vernal equinox the sun lies exactly at 0^h r.a., or, in other words, the sun is at the ***first point of Aries*** as defined and locked to our seasonal year. Thus solar noon around this equinox is equivalent to within a few minutes of sidereal "midnight" (i.e., 0^h is near the meridian). One sidereal day, one full revolution of Earth, requires only 23 hours 56' 04.1" of mean solar time so that sidereal time advances approximately 3^m 56.55^s beyond one full rotation with each mean solar day. This equates to 12 sidereal hours over half a solar year so that solar noon at the September equinox is near sidereal "noon" and then again approaches 24^h 0^m 0^s in the following March.

Sidereal time can be used as a way to estimate solar time. In the northern hemisphere the pointer stars of the big dipper both currently lie at almost exactly 11^h r.a. The line through them appears to sweep counter-clockwise around Polaris as Earth rotates. When they appear above Polaris, pointed straight down, due north and south, they lie on the local meridian, and it is therefore approximately 11:00:00 sidereal time at that location. 6 sidereal hours later 17^h r.a. lies on the meridian and 11^h r.a., along which the pointers and Polaris lie, has rotated 90°. The pointers then appear horizontally left, westward from Polaris. One quarter revolution later, in 6 more sidereal hours at 23^h, the pointers now point directly upward toward Polaris. Finally, at 5^h sidereal time, the pointers appear once again horizontal, but now eastward, to the right of Polaris. Sidereal time may then be converted to local solar time on the basis of their being 12 hours opposed at around the March equinox with local solar time leading sidereal time by 6 hours at the June solstice, in synch at the September equinox and lagging 6 hours at the December solstice.

Conversely, local time can be used to determine right ascension at the meridian as an aid in locating visible stellar features whose right ascension is known. For local timekeeping and, in particular, in consideration of sidereal time, correction both for longitude and the equation of time must be applied to standard civil time. For longitude, add or subtract 4 minutes for each degree east or west of the longitude of the standard meridian. To calculate sidereal time corresponding to a given standard time at a given longitude, correct the standard time of an equinox or solstice for longitude and for the equation of time, apply the sidereal offset and then add the sidereal time interval between the given and reference times.

For precision, it is important to note that the stellar coordinate system of right ascension and declination is based on the orientation of the axis of the equinoxes and that this orientation is constantly changing due to precession. This is dealt with by stating stellar coordinates and other parameters for ***"standard epochs."*** Coordinates and most other values given here are intended as accurate at SE J2000 (12:00 UT, January 1, 2000).

Formulas are provided below for correction for precession and also for calculating celestial longitude and latitude given right ascension and declination and vice versa. These formulas can be used to estimate the time at which the northern vernal equinox will move backwards out of Pisces into Aquarius. This requires only commonly available astronomical data and the assumption that the star Spica marks 29° of the constellation Virgo (F&F, p55). Note in this context that the vernal equinox can be thought of both as a time of year and, here and commonly in astronomical literature, as a celestial direction along the intersection of the planes of the ecliptic and the equator. The northern vernal equinox is often referred to as the first point of Aries in an historical but increasingly inaccurate allusion to the Piscean astrological zodiac.

The right ascension of Spica is stated in charts calculated for standard epoch 2000.0 as $13^h\ 25^m\ 12^s$ at declination -11° 09' 41" (P/M). Adjusted for the spring equinox of 1997, it will then lie at $13^h\ 25^m\ 02^s$ right ascension and -11° 08' 45" declination. Spica's location, 29° of the quite real and visible northern spring constellation of Virgo, currently equates to 203.80° longitude. 203.80° before 29° Virgo, where the vernal equinox points in 1997, is 5.20° Pisces. The equinox will precess to 0° Pisces or 30° Aquarius in 373 or so years at 50.225^s of precession per year. Thereafter, for the next 2150 years or so, the northern vernal equinox will fall within Aquarius. If one assumes that ***astrological age*** is defined by this mechanism, the age of Aquarius will begin in around the year 2370 as the age of Pisces seems to have begun around the year 220.

As I think on these things and write them down as clearly as I can, at least so that I can look back and understand the way it seems to fit together, I look out in the clear mountain sky at Taurus, Gemini, Cancer, Leo and Virgo arcing across the ecliptic and see Mars lying at around 9° of Virgo (as estimated from Spica and Regulus). So, since astrological reckoning is running about 25° ahead of reality these days, the astrological position of Mars should be at around 4° of Libra. The ephemeris in Llewellyn's Daily Planetary Guide for 1997 states it at a little over 4°. Not too bad for rough visual estimates. The question is whether we should say that Mars is in Libra tonight or that it's in Virgo. Well, it looks to me like it's in Virgo and that we're still 5° within the age of Pisces.

What does it all mean? It means that people have been paying attention to the way the solar system works for a long time, for one thing. But also it seems interesting to consider that the way of looking at the sky which gave us Piscean astrology seems to have been frozen, stopped like a broken watch, at the defining instant of the beginning of the age of Pisces. Also striking is the parallel progression of potent religious symbols from the Taurean golden calf which Moses overthrew in favor of the Arian ram's horn of Judaism, followed in turn by the Piscean fish of Christianity. One wonders how the symbol of the water bearer might manifest itself and what might be lost of Pisces in the coming age.

But meaning and truth in language often are not as firm as they may seem. The "astrological age," as identified above, may be called a "Platonic month" by some – 1/12 of a Platonic year. It may have great metaphorical significance for some and for others be merely a convenient way of identifying a space of 2150 or so years. The words "astronomy" and "astrology" themselves may reveal much of human understanding and lack thereof.

Considering both its roots and also modern usage, the word "astronomy" would seem to refer to the practice of classification and naming of the stars, a practice largely of observation. "Astrology," on the other hand, would seem to connote more the study and understanding of the stars and their mechanisms. While a basic astronomer may be content to observe the celestial sphere, an astrologer may be more concerned with how it takes that appearance, in the noting and prediction of phases and occultations, conjunctions and oppositions, risings and culminations, rather than their mere observation.

How then might it have come to be that, while its practice still involves much recourse to trigonometry and tables of planetary motion, astrology seemed to turn its attention largely away from the stars and planets to distantly related topics such as how one might recognize and deal with opportunities and challenges of personal life in the course of daily events?

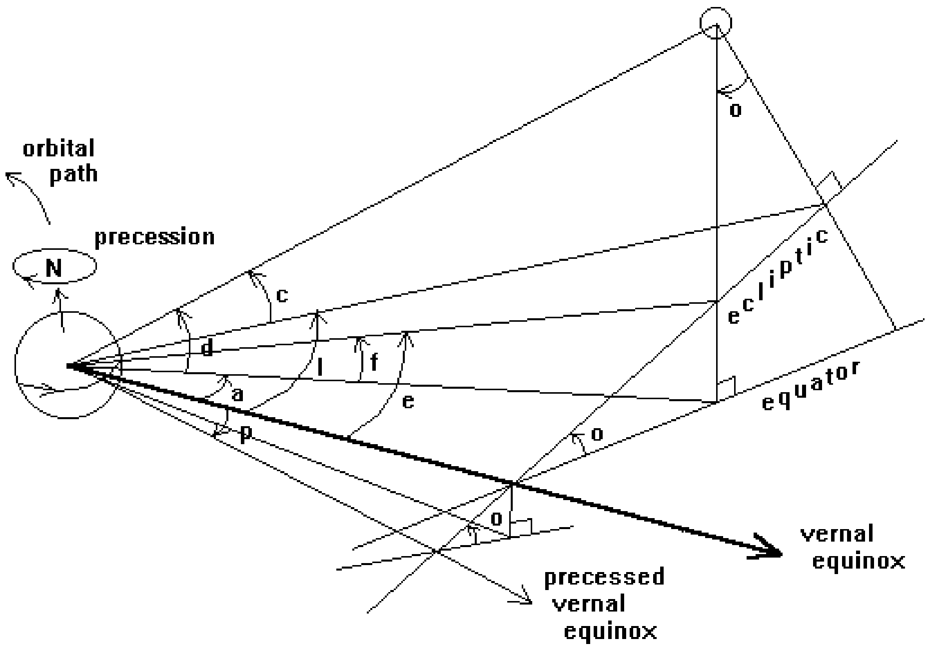
Astrology and astronomy seem to have had their modern roots in Babylon, the cultural center of Babylonia, also known as Chaldea, near modern Baghdad, 18 or so hundred years before Christ. This was at the beginnings of the Platonic month of Aries, at around the likely time of Moses. The Babylonians were careful observers and documented their observations well, in a tradition that led up to the master Hipparchus who, in Greece and Egyptian Alexandria some 150 years BC, identified and documented the effect of precession of the equinoxes. Hipparchus passed his legacy on to Ptolemy who, in Alexandria in the second century of our modern era, at what appears to be the end of the age of Aries, as Roman and Persian empires collapsed and Christianity began to spread, wrote, in what was called by Arabic scholars *Almagest*, "the Great Work," "the last word on the constellations until the 16th century, when European voyages of discovery took navigators into southern latitudes," forcing them to reckon time and place according to new stars (P/M, p133).

The Babylonians no doubt took note of the calendar, as we still do, and logged things such as the births of children and other events of greater and lesser significance. While they are credited with using abstract calendars long before the rise of their astronomy it cannot be doubted that they rooted their calendar systems in observation of the skies. Thus, perhaps, an old one may have written, when the tower of Babel was struck down, "Mars lay in the paws of the lion and Venus was occulted by the moon in Scorpio," etc. or "The archer was rising and Jupiter rested in the balance of Libra" when a child was born who would later turn out to be notable. The following is said to be a translation of an actual cuneiform birth record of 410 BC: "Month Nisan night of the 14th (?); Son of Shuma-usur, son of Shumaiddina, descendant of Deke, was born; At that time the moon was below the horn of the scorpion; Jupiter in Pisces, Venus in Taurus, Saturn in Cancer," etc. (from www.zodiacal.com).

Whether due to the sheer complexity of their degree of development, the disruptions and destruction of revolution and war or yet other causes, astronomical and other intellectual traditions of Europe and the middle east fell into a long period of obscurity with the onset of the age of Pisces. Yet still phrases such as "Mars in the paws of the lion" and their association with events good or bad must have reverberated in peoples' minds as signs and omens long after their use to log specific events was forgotten, the events having paled into insignificance or been shrouded in the mists of time. In such a way might have arisen what can only be called "Piscean astrology."

But in any case, as Alice Bailey put it in <u>A Treatise on Cosmic Fire</u>, in advice which might apply equally well to astrophysicists as astrologers: "<many> factors have to allowed for in any consideration of the factor of time and cycles, and the true esoteric knowledge is not to be gained by the study of figures by the lower mind."

The Mechanism of Precession



Correction for precession may be approximated with the following formulas (quoted from P/M) or by calculating the longitude of a point, adding precession and then re-calculating the resulting precessed declination and right ascension.

$a = a_0 + n(3.074 + 1.336\sin\{a'\}\tan\{d_0\})$ (correction term in seconds of r.a.)
$d = d_0 + n(20.04\cos\{a'\})$ (correction term in angular seconds)

where a = corrected right ascension
a_0 = right ascension at standard epoch
a' = a_0 in angular terms
d = corrected declination
d_0 = declination at standard epoch
n = number of years from standard epoch (negative if before)

The following formulas (inspired from formulas stated in F&F and derived from the sketch above) may be used to calculate longitude and latitude given right ascension and declination or vice versa:

$e = \arctan[\tan\{a\}/\cos\{o\}]$
$f = \arcsin[\sin\{e\}\sin\{o\}] = \arctan[\sin\{a\}\tan\{o\}]$
$a = \arctan[\tan\{e\}\cos\{o\}]$

$c = \arcsin[\sin\{d\}\cos\{o\} - \cos\{d\}\sin\{o\}\sin\{a\}]$
$l = \arccos[\cos\{d\}\cos\{a\}/\cos\{c\}]$

$d = \arcsin[\sin\{c\}\cos\{o\} + \cos\{c\}\sin\{o\}\sin\{l\}]$
$a = \arccos[\cos\{c\}\cos\{l\}/\cos\{d\}]$

where l = celestial longitude
c = celestial latitude (from ecliptic plane)
a = right ascension (in angular terms)
e = celestial longitude on the ecliptic at r.a. a
f = declination on the ecliptic at r.a. a
d = declination (from equatorial plane)
o = obliquity of the ecliptic

Note: longitude and right ascension lie in the same quadrant unless dec. and r.a. lie on different sides of the x axis and the product of sin(r.a.) and cot(dec) is less than the absolute value of the tangent of the obliquity of the ecliptic. Use the following identities for inverse functions as required:

$\tan\{x\} = \tan\{180 + x\}$ (same for cot)
$\sin\{x\} = \sin\{180 - x\}$
$\cos\{x\} = \cos(360 - x)$

ZODIACAL POSITIONS (S.E. 2000.0)							
Constel-lation	**Const. 1st pnt. Long. / RA / Declin.**	**Astrol. 1st pnt. Long. / RA / Declin.**	**Representative Star**	**Right Ascension / Declination**	**Longitude / Latitude**	**Const. posi-tion**	**Astrol. posi-tion**
Aries	24° 50’ 35” $01^h 32^m 03^s$ 09° 37’ 19”	00° 00’ 00” $00^h 00^m 00^s$ 00° 00’ 00”	α Ari (Hamal)	$02^h 07^m 10^s$ 23° 27’ 45”	37° 39’ 42” 09° 57’ 47”	13°	8° Tau
Taurus	54° 50’ 35” $03^h 29^m 57^s$ 18° 58’ 55”	30° 00’ 00” $01^h 51^m 38^s$ 11° 28’ 26”	α Tau (Aldebaran)	$04^h 35^m 55^s$ 16° 30’ 33”	69° 47’ 17” -05° 28’ 17”	15°	10° Gem
Gemini	84° 50’ 35” $05^h 37^m 32^s$ 23° 20’ 35”	60° 00’ 00” $03^h 51^m 16^s$ 20° 09’ 14”	β Gem (Pollux)	$07^h 45^m 19^s$ 28° 01’ 34”	113° 12’ 56” 06° 40’ 49”	28°	23° Cnc
Cancer	114° 50’ 35” $07^h 47^m 06^s$ 21° 09’ 49”	90° 00’ 00” $06^h 00^m 00^s$ 23° 26’ 37”	δ Cnc	$08^h 47^m 00^s$ 18° 00’ 00”	129° 17’ 36” 00° 04’ 12”	14°	9° Leo
Leo	144° 50’ 35” $09^h 48^m 31^s$ 13° 14’ 36”	120° 00’ 00” $08^h 08^m 44^s$ 20° 09’ 14”	α Leo (Regulus)	$10^h 08^m 22^s$ 11° 58’ 02”	149° 49’ 40” 00° 27’ 44”	5°	0° Vir
Virgo	174° 50’ 35” $11^h 41^m 04^s$ 02° 02’ 58”	150° 00’ 00” $10^h 08^m 22^s$ 11° 28’ 26”	α Vir (Spica)	$13^h 25^m 12^s$ -11° 09’ 41”	203° 50’ 35” -02° 03’ 08”	29°	24° Lib
Libra	204° 50’ 35” $13^h 32^m 03^s$ -09° 37’ 19”	180° 00’ 00” $12^h 00^m 00^s$ 00° 00’ 00”	α^2 Lib (Zubenelgenubi)	$14^h 50^m 53^s$ -16° 02’ 30”	225° 05’ 01” 00° 20’ 12”	20°	15° Sco
Scorpio	234° 50’ 35” $15^h 29^m 57^s$ -18° 58’ 55”	210° 00’ 00” $13^h 51^m 38^s$ -11° 28’ 26”	α Sco (Antares)	$16^h 29^m 24^s$ -26° 25’ 55”	249° 45’ 39” -04° 33’ 58”	15°	10° Sgr
Sagit-tarius	264° 50’ 35” $17^h 37^m 32^s$ -23° 20’ 35”	240° 00’ 00” $15^h 51^m 16^s$ -20° 09’ 14”	σ Sgr (Nunki)	$18^h 55^m 16^s$ -26° 17’ 48”	282° 23’ 08” -03° 26’ 43”	18°	12° Cap
Capri-corn	294° 50’ 35” $19^h 47^m 06^s$ -21° 09’ 49”	270° 00’ 00” $18^h 00^m 00^s$ -23° 26’ 37”	θ Cap	$21^h 07^m 00^s$ -17° 30’ 00”	314° 00’ 26” -00° 54’ 40”	19°	14° Aqr
Aqua-rius	324° 50’ 35” $21^h 48^m 31^s$ -13° 14’ 36”	300° 00’ 00” $20^h 08^m 44^s$ -20° 09’ 14”	α Aqr (Sadalmelik)	$22^h 05^m 47^s$ -00° 19’ 11”	333° 21’ 11” 10° 39’ 49”	9°	3° Psc
Pisces	354° 50’ 35” $23^h 41^m 04^s$ -02° 02’ 58”	330° 00’ 00” $22^h 08^m 22^s$ -11° 28’ 26”	δ Psc	$00^h 48^m 00^s$ 07° 30’ 00”	13° 57’ 30” 02° 09’ 47”	19°	14° Ari

Miscellaneous Data

Obliquity of (angular inclination of Earth’s equatorial plane to) the ecliptic - 23° 26’ 21.4” (23.43928°).
Sidereal day - 23 hours 56’ 04.1” (23.9345 hours) mean solar time (1.0027378^h per mean solar hour).
Precession - 50.225” of orbital rotation per seasonal year (between vernal equinoxes).
Solar/Tropical (seasonal) year - 365 days 5 hours 48’ 46” (365.2422 mean solar days).
Sidereal year - 365 days 6 hours 09’ 09” (365.2564 mean solar days).
Vernal equinox relative to true Aries (standard epoch 2000.0) - 335° 09’ 25” (5° 09’ 25” of true Pisces).
Ephemeris second (1960) – 1/31,556,925.9747 of solar year SE 1900 (Schütte, p186).
SI second (1967) – 9,192,631,770 atomic cycles of cesium 133.

Formulas

$\phi - \phi' = 695.65\sin2\phi - 1.17\sin4\phi$ {difference in seconds between geographic latitude ϕ and geocentric latitude ϕ' – Schütte, p166}

$\tan\phi' = 0.993277\tan\phi$ {a different expression relating geocentric and geographic latitude (F&F, p203)}

$Alt_e = 90 - Abs(\phi - \delta_e)$ {Altitude of the ecliptic at declination δ_e on the meridian as seen from latitude ϕ ($\phi > \delta_e$ => inclination toward the south; $\phi < \delta_e$ => inclination toward the north)}

$Az_w = \arccos(-\sin\delta_e / \cos\phi)$ {Westerly azimuth of the intersection of the ecliptic at declination δ with the horizon at latitude ϕ (0° => south, 90° => west, 180° => north, 270° => east) – corresponding easterly azimuth is 360° – Az_w}

$\delta_e = \arcsin(\sin\varepsilon\sin\lambda)$ {Declination of the ecliptic at longitude λ (ε is obliquity of the ecliptic)}

$\varepsilon = 23° 26' 21.448'' - (46.8150J + 0.0059J^2 - 0.001813J^3)''$ {where ε is obliquity of the ecliptic and J = Julian centuries from 12^h, Jan 1, 2000 – M&P, p15}

$Alt = \arcsin(\cos\delta\cos\tau\cos\phi + \sin\delta\sin\phi)$
$Az_w = \arctan(\tan\tau/\sin\phi - \cot\delta\sin\tau/\cos\phi)$

{altitude and westerly azimuth of declination δ and right ascension α at hour angle τ at latitude ϕ, where τ = sidereal time $\theta - \alpha$ (to calculate θ at a given time and place, see p5 and M&P, p40)} {Schütte, p169 and M&P, p37. The latter avoids problems at ϕ = +/-90 & 0, δ = 0 and at τ = +/-90 (6 hours) by first calculating cartesian coordinates

$x = \cos\delta\sin\phi\cos\tau - \sin\delta\cos\phi$
$y = \cos\delta\sin\tau$
$z = \cos\delta\cos\phi\cos\tau + \sin\delta\sin\phi$

and then

$Az_w = \arctan2(y,x)$ (+ 360 if negative) {where arctan2
$Alt = \arctan2(z,\sqrt{(x^2 + y^2)})$ returns 0 if $x = y = 0$, $\arctan(|y|/|x|)$ if $|x| > |y|$ or $90 - \arctan(|x|/|y|)$ if not and then, if $x < 0$, 180 – the result and if $y < 0$, its negative}

whence

at ϕ = +/-90, Az_w = +/-τ
at ϕ = 0, $Az_w = \arctan(-\cot\delta\sin\tau)$
at τ = +/-90, $Az_w = \arctan(-/+ \cot\delta/\cos\phi)$
at δ = 0, $Az_w = \arctan(\tan\tau/\sin\phi)$
at $\delta = \phi = 0$, $Az_w = 90$ & $Alt = 90 - \tau$
etc.

References

Schütte: Schütte in Astronomy: A Handbook, ed. Roth, translated and revised by Beer, Springer, 1975
M&P: Montenbruck & Pfleger, translated by Dunlop: Astronomy on the Personal Computer, 3rd ed., Springer, 1998
F&F: John and Peter Filbey: Astronomy for Astrologers, Aquarian Press, 1984
P/M: Pasachoff/Menzel: A Field Guide to Stars and Planets, 2nd ed., Houghton Mifflin, 1983

Constellation names (including the genitive form used with star names)

And - Andromeda (Andromedae), the Daughter of Cepheus and Cassiopeia {Pt}
Ant - Antlia (Antliae), the Airpump {L}
Aps - Apus (Apodis), the Bird of Paradise {By}
Aql - Aquila (Aquilae), the Eagle {Pt}
Aqr - Aquarius (Aquarii), the Water Bearer {Pt}
Ara - Ara (Arae), the Altar {Pt}
Ari - Aries (Arietis), the Ram {Pt}
Aur - Auriga (Aurigae), the Charioteer {Pt}
Boo - Bootes (Bootis), the Herdsman {Pt}
Cae - Caelum (Caeli), the Chisel {L}
Cam - Camelopardalis (Camelopardalis), the Giraffe {Bt}
Cap - Capricornus (Capricorni), the Sea-goat {Pt}
Car - Carina (Carinae), the Keel {Pt}
Cas - Cassiopeia (Cassiopeiae), the Wife of Cepheus {Pt}
Cen - Centaurus (Centauri), the Centaur {Pt}
Cep - Cepheus (Cephei), the King of Ethiopia {Pt}
Cet - Cetus (Ceti), the Whale {Pt}
Cha - Chamaeleon (Chamaeleonis), the Chameleon {By}
Cir - Circinus (Circini), the Drawing Compass {L}
CMa - Canis Major (Canis Majoris), the Great Dog {Pt}
CMi - Canis Minor (Canis Minoris), the Little Dog {Pt}
Cnc - Cancer (Cancri), the Crab {Pt}
Col - Columba (Columbae), the Dove {Pl}
Com - Coma Berenices (Comae Berenices), Berenice's Hair {TB}
CrA - Corona Australis (Coronae Australis), the Southern Crown {Pt}
CrB - Corona Borealis (Coronae Borealis), the Northern Crown {Pt}
Crt - Crater (Crateris), the Cup {Pt}
Cru - Crux (Crucis), the Southern Cross {Bt}
Crv - Corvus (Corvi), the Crow {Pt}
CVn - Canes Venatici (Canes Venaticorum), the Hunting Dogs {H}
Cyg - Cygnus (Cygni), the Swan {Pt}
Del - Delphinus (Delphini), the Dolphin {Pt}
Dor - Dorado (Doradus), the Swordfish {By}
Dra - Draco (Draconis), the Dragon {Pt}
Equ - Equuleus (Equulei), the Foal {Pt}
Eri - Eridanus (Eridani), the River {Pt}
For - Fornax (Fornacis), the Furnace {L}
Gem - Gemini (Geminorum), the Twins {Pt}
Gru - Grus (Gruis), the Crane {By}
Her - Hercules (Herculis), Hercules {Pt}
Hor - Horologium (Horologii), the Clock {L}
Hya - Hydra (Hydrae), the Female Watersnake {Pt}
Hyi - Hydrus (Hydri), the Male Watersnake {By}
Ind - Indus (Indi), the Indian {By}
Lac - Lacerta (Lacertae), the Lizard {H}
Leo - Leo (Leonis), the Lion {Pt}
Lep - Lepus (Leporis), the Hare {Pt}
Lib - Libra (Librae), the Balance {Pt}
LMi - Leo Minor (Leonis Minoris), the Little Lion {H}
Lup - Lupus (Lupi), the Wolf {Pt}
Lyn - Lynx (Lyncis), the Lynx {H}
Lyr - Lyra (Lyrae), the Lyre {Pt}
Men - Mensa (Mensae), the Table {L}

Mic - Microscopium (Microscopii), the Microscope {L}
Mon - Monoceros (Monocerotis), the Unicorn {Bt}
Mus - Musca (Muscae), the Fly {By}
Nor - Norma (Normae), the Square {L}
Oct - Octans (Octantis), the Octant {L}
Oph - Ophiuchus (Ophiuchi), the Serpent-bearer {Pt}
Ori - Orion (Orionis), the Hunter {Pt}
Pav - Pavo (Pavonis), the Peacock {By}
Peg - Pegasus (Pegasi), the Flying Horse {Pt}
Per - Perseus (Persei), the suitor of Andromeda {Pt}
Phe - Phoenix (Phoenicis), the Phoenix {By}
Pic - Pictor (Pictoris), the Painter's Easel {L}
PsA - Piscis Austrinus (Piscis Austrini), the Southern Fish {Pt}
Psc - Pisces (Piscium), the Fishes {Pt}
Pup - Puppis (Puppis), the Ship's Stern {Pt}
Pyx - Pyxis (Pyxidis), the Ship's Compass {Pt}
Ret - Reticulum (Reticuli), the Reticle {L}
Scl - Sculptor (Sculptoris), the Sculptor's Studio {L}
Sco - Scorpius (Scorpii), the Scorpion {Pt}
Sct - Scutum (Scuti), the Shield {H}
Ser - Serpens (Serpentis), the Serpent {Pt}
Sex - Sextans (Sextantis), the Sextant {H}
Sge - Sagitta (Sagittae), the Arrow {Pt}
Sgr - Sagittarius (Sagittarii), the Archer {Pt}
Tau - Taurus (Tauri), the Bull {Pt}
Tel - Telescopium (Telescopii), the Telescope {L}
TrA - Triangulum Australe (Trianguli Australis), the Southern Triangle {By}
Tri - Triangulum (Trianguli), the Triangle {Pt}
Tuc - Tucana (Tucanae), the Toucan {By}
UMa - Ursa Major (Ursae Majoris), the Great Bear {Pt}
UMi - Ursa Minor (Ursae Minoris), the Little Bear {Pt}
Vel - Vela (Velorum), the Sails {Pt}
Vir - Virgo (Virginis), the Virgin {Pt}
Vol - Volans (Volantis), the Flying Fish {By}
Vul - Vulpecula (Vulpeculae), the Fox {H}

Credit for identification or naming of each constellation is shown in curly brackets as follows:

{Pt} - Ptolemy, 2nd century AD
{Pl} - Plancius, 16th century
{TB} - Tycho Brahe, 1602
{By} - Bayer, 1603
{Bt} - Bartsch, 1624
{H} - Hevelius, 1687
{L} - Lacaille, 1750

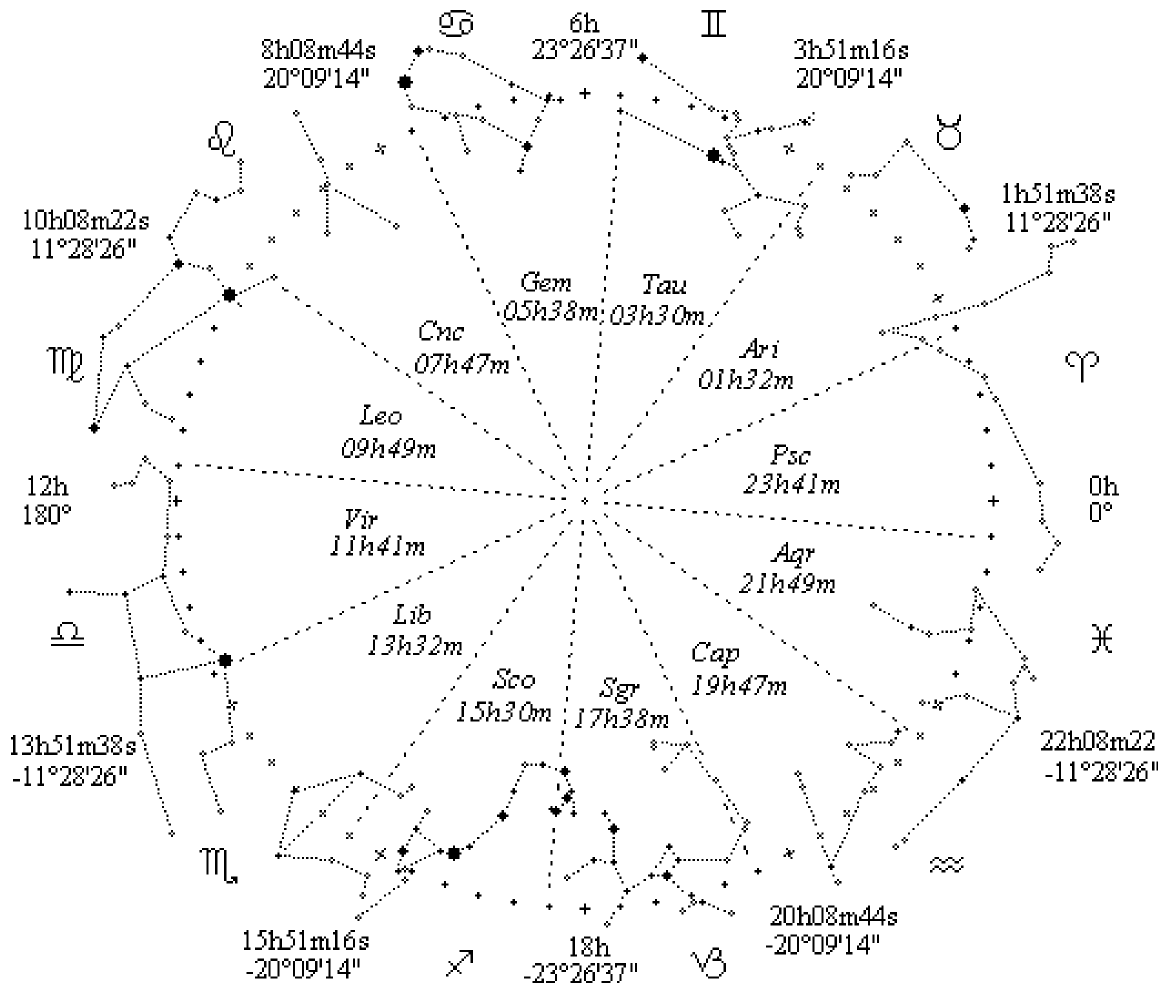
ASTROLOGICAL SYMBOLS

☉	Sun	♈	Aries		
☽	Moon	♉	Taurus		
☿	Mercury	♊	Gemini	☌	0° - conjuction
♀	Venus	♋	Cancer	⚺	30° - semi-sextile
♂	Mars	♌	Leo	∠	45° - semi-square
♃	Jupiter	♍	Virgo	⚹	60° - sextile
♄	Saturn	♎	Libra	□	90° - square
♅	Uranus	♏	Scorpio	△	120° - trine
♆	Neptune	♐	Sagittarius	⚼	135° - sesquiquadrate
♇	Pluto	♑	Capricorn	⚻	150° - quincunx
		♒	Aquarius	☍	180° - opposition
		♓	Pisces		

The Greek Alphabet

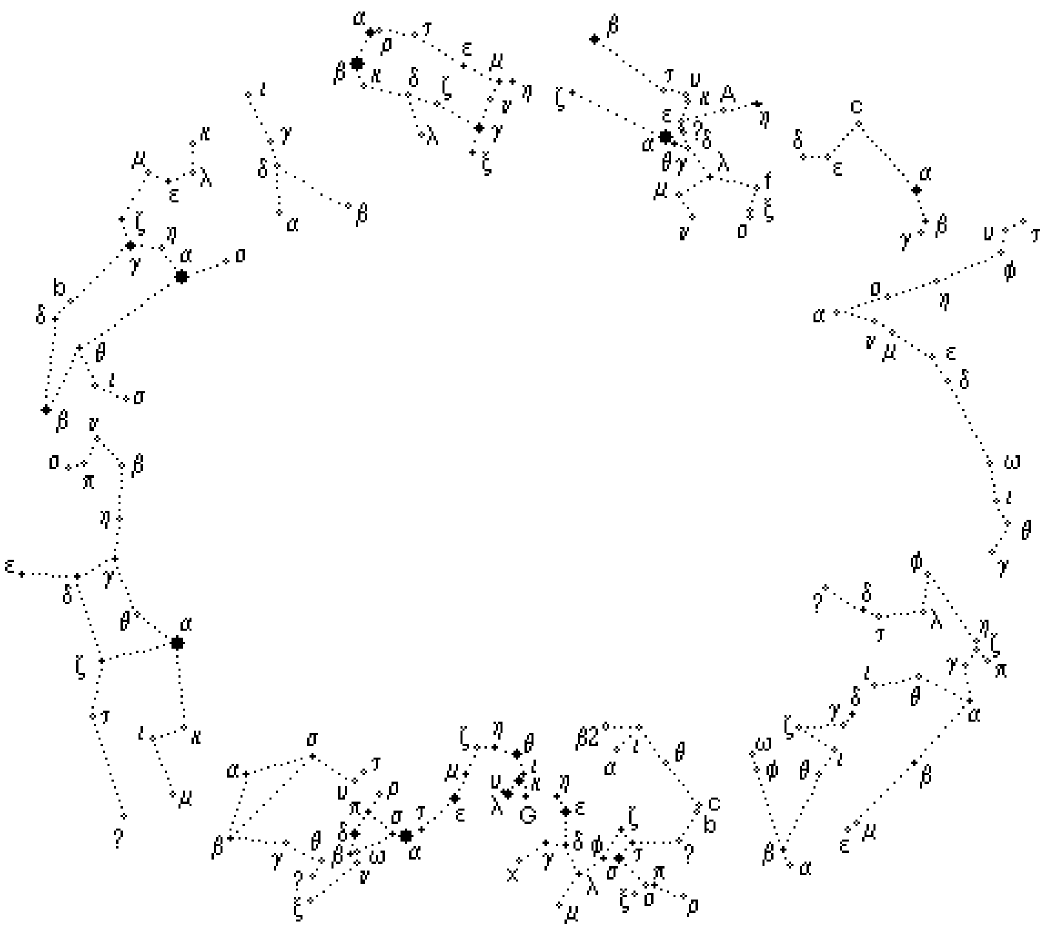
α	Α	alpha
β	Β	beta
γ	Γ	gamma
δ	Δ	delta
ε	Ε	epsilon
ζ	Ζ	zeta
η	Η	eta
θ	Θ	theta
ι	Ι	iota
κ	Κ	kappa
λ	Λ	lambda
μ	Μ	mu
ν	Ν	nu
ξ	Ξ	xi
ο	Ο	omicron
π	Π	pi
ρ	Ρ	rho
σ	Σ	sigma
τ	Τ	tau
υ	Υ	upsilon
φ	Φ	phi
χ	Χ	chi
ψ	Ψ	psi
ω	Ω	omega

THE WHEEL OF THE ECLIPTIC (northern view)



This is the wheel of the constellations of the zodiac as they lie along the ecliptic. The sectors are divided based on α Virgo (Spica) lying at 29° Virgo. Each sector is labeled with the right ascension of its first point based on 0°, the vernal equinox, of standard epoch 2000.0. Tic marks appear every 5° starting with 0°. The Piscean astrological signs, astrological (and astronomical) "months", are indicated beginning with Aries at 0°, now almost entirely overlapping the constellation of Pisces. Right ascension and declination are provided at the 30° "monthly" intervals. Both northern and southern views are shown along with separate illustrations in which the stars are labelled with their current astronomical identifiers. These can be used as reasonably accurate visual guides to the stars of the zodiac. The effect of precession is that the wheel rotates approximately 1/72 of a degree per year. This rotation is counter-clockwise in the northern view and clockwise in the southern view. Diurnal rotation, the daily rising and setting of the stars produced by Earth's rotation, is in the opposite direction - clockwise in the northern view and counter-clockwise in the southern view.

MAJOR STARS OF THE ZODIAC (northern view)



These circular projections of the zodiac are drawn with position of the sun at the vernal equinox (longitude = $\theta = 0°$ in the northern views and 180° in the southern views) to the right. Points at longitude θ on the ecliptic (latitude = $\alpha = 0°$), plotted on a cartesian grid with x increasing from zero to the right and y increasing from zero downward (as with WINDOWS' "Paintbrush") and with center (x_0, y_0) and radius r, lie at

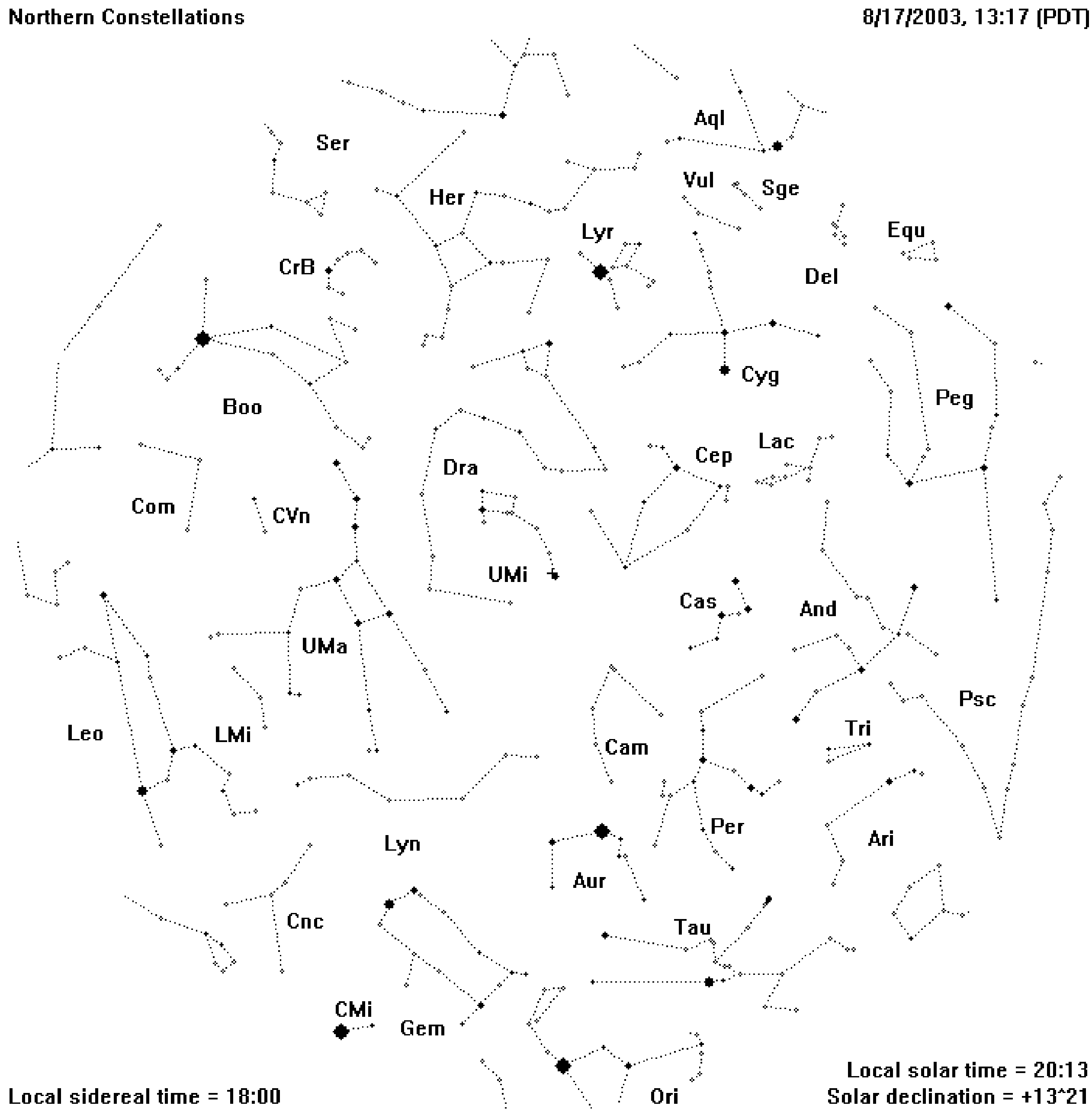
$x = x_0 + r\cos\theta$ and	$x = x_0 - r\cos\theta$ and
$y = y_0 - r\sin\theta$ in the northern view	$y = y_0 - r\sin\theta$ in the southern view

Projection of points lying off the ecliptic at latitude α is along a circle of radius r in the z direction so that

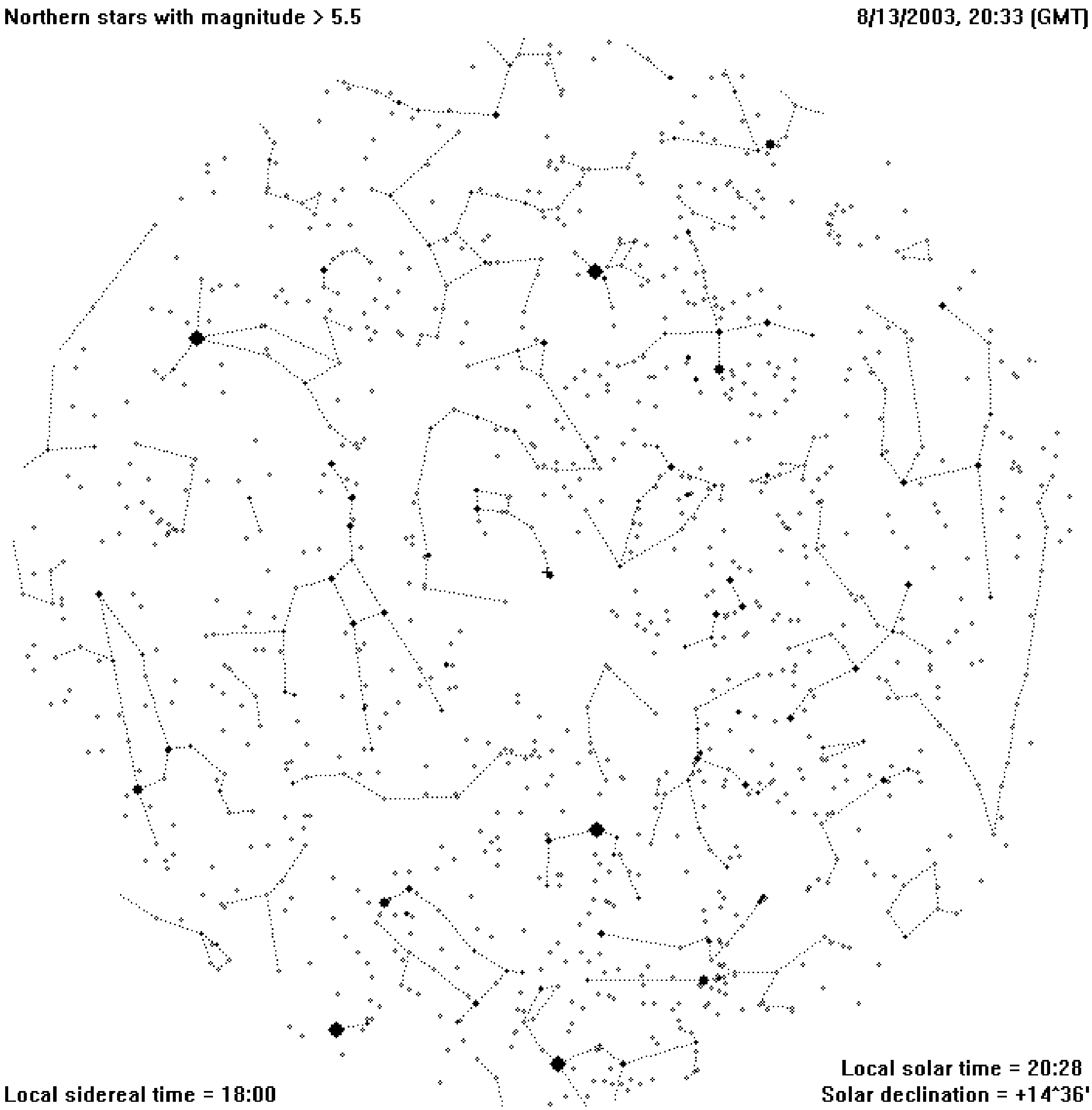
$x = x_0 + r(\sin\alpha + 1)\cos\theta$ and	$x = x_0 + r(\sin\alpha - 1)\cos\theta$ and
$y = y_0 - r(\sin\alpha + 1)\sin\theta$ in the northern view	$y = y_0 + r(\sin\alpha - 1)\sin\theta$ in the southern view

The effect of this projection is to distort the apparent distance between points lying off the ecliptic at given longitudes (the projected distance is greater outside the circle of the ecliptic and lesser inside) but this preserves longitude as measured along a radius through a given point regardless of its latitude.

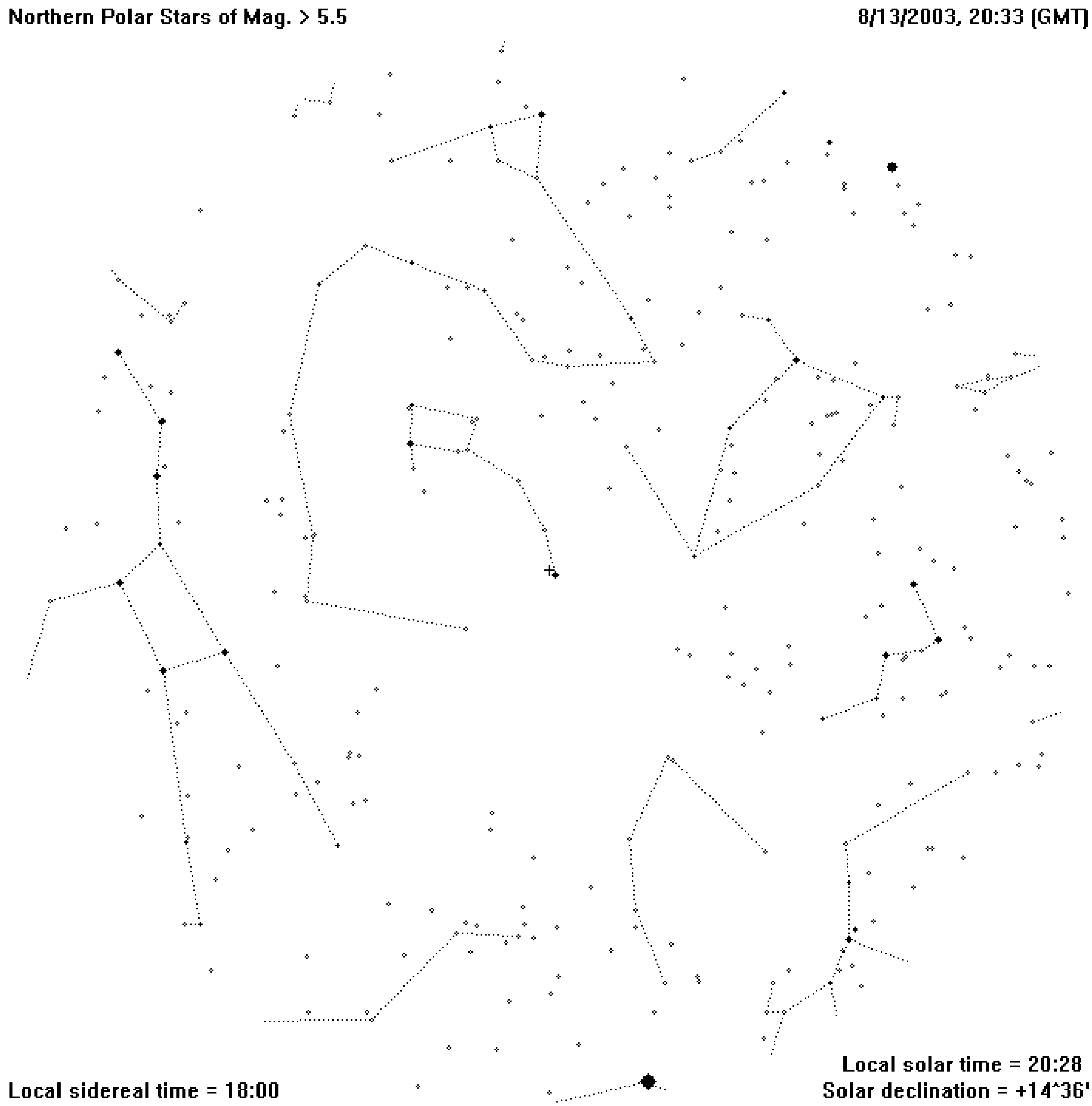
CONSTELLATIONS OF THE NORTHERN HEMISPHERE
(from pole at center to equator; CW from 00:00 RA at center right)



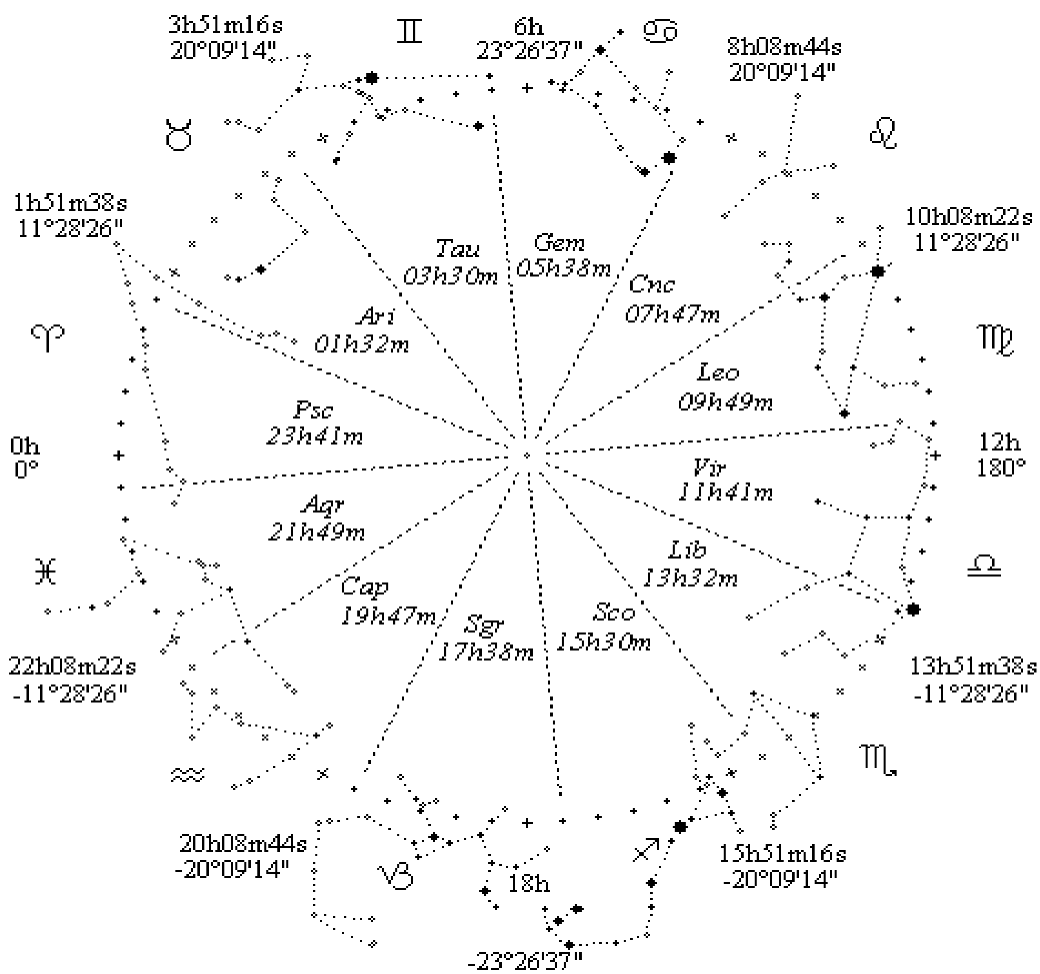
MAJOR STARS OF THE NORTHERN HEMISPHERE
(from pole at center to equator; CW from 00:00 RA at center right)



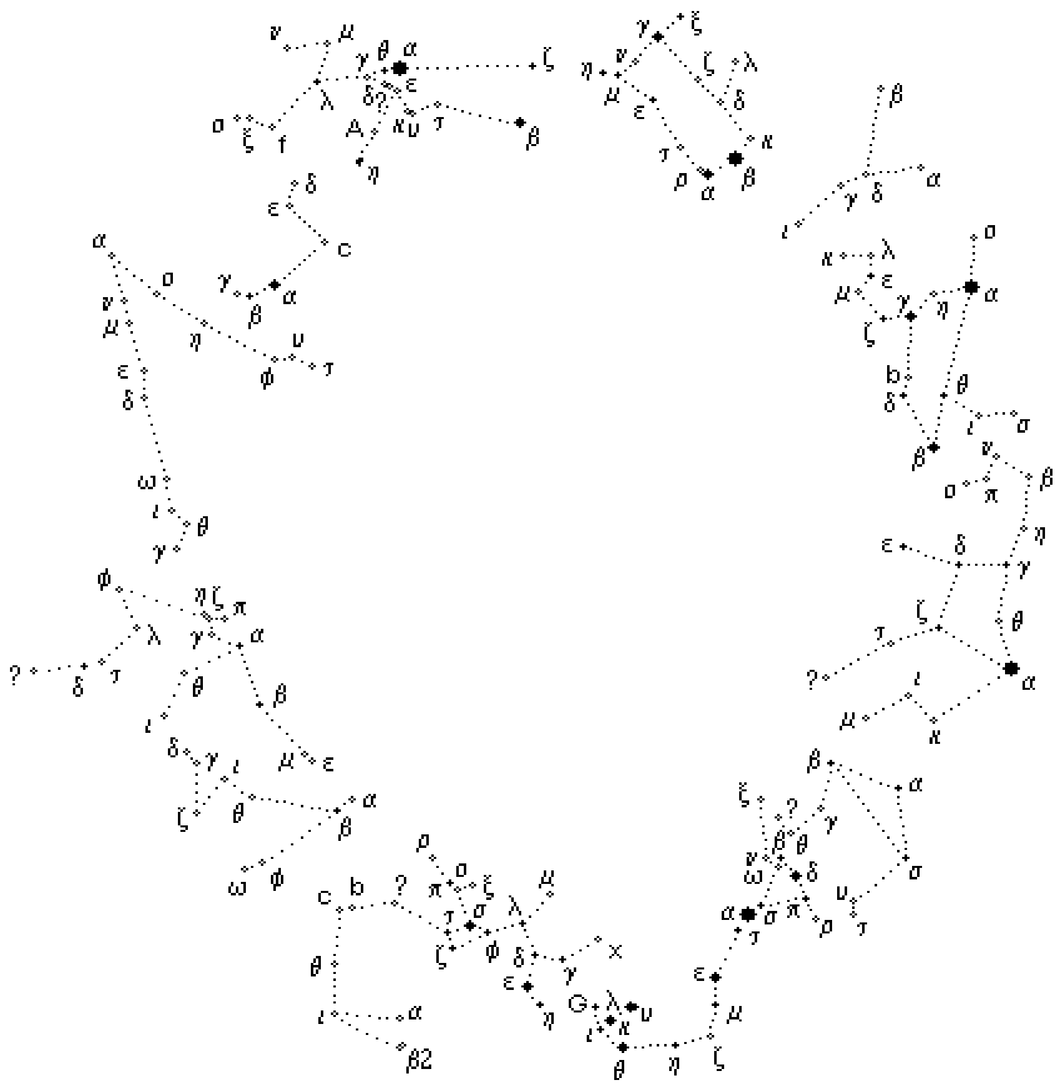
MAJOR STARS OF THE NORTHERN POLAR REGION
(from pole at center to 45°; CW from 00:00 RA at center right)



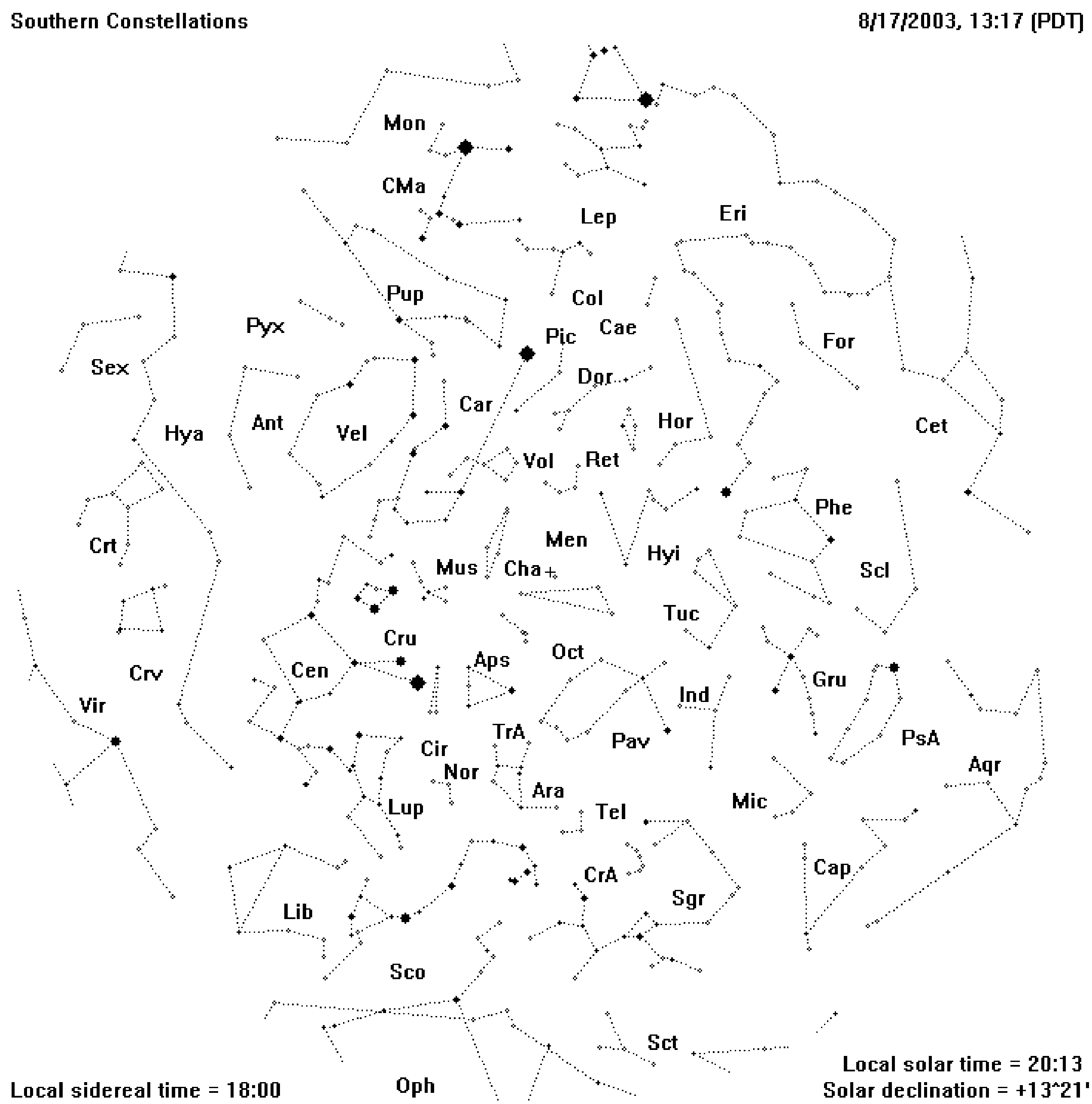
THE WHEEL OF THE ECLIPTIC (southern view)



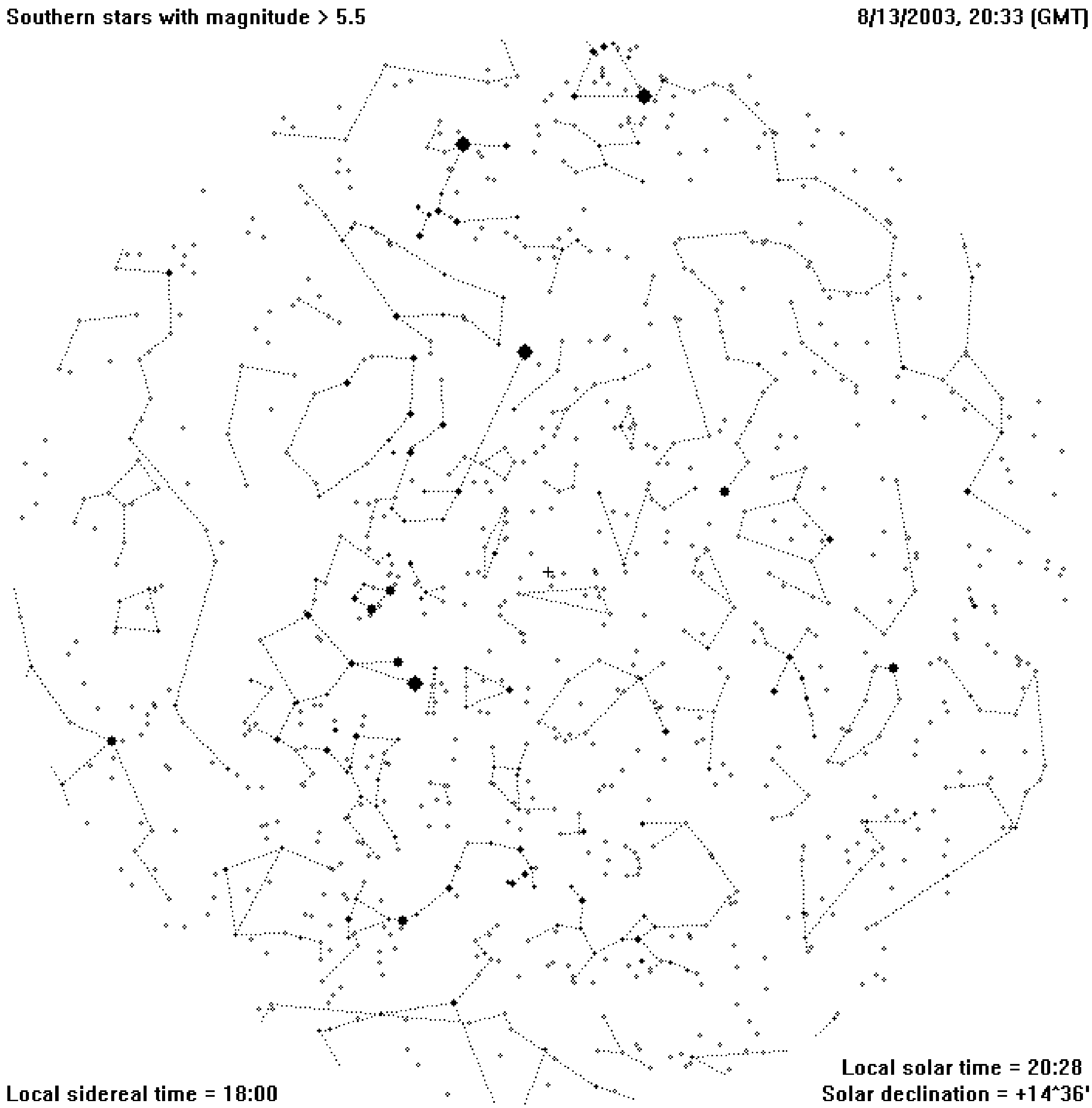
MAJOR STARS OF THE ZODIAC (southern view)



CONSTELLATIONS OF THE SOUTHERN HEMISPHERE
(from pole at center to equator; CCW from 00:00 RA at center right)



MAJOR STARS OF THE SOUTHERN HEMISPHERE
(from pole at center to equator; CCW from 00:00 RA at center right)



MAJOR STARS OF THE SOUTHERN POLAR REGION
(from pole at center to 45°; CCW from 00:00 RA at center right)