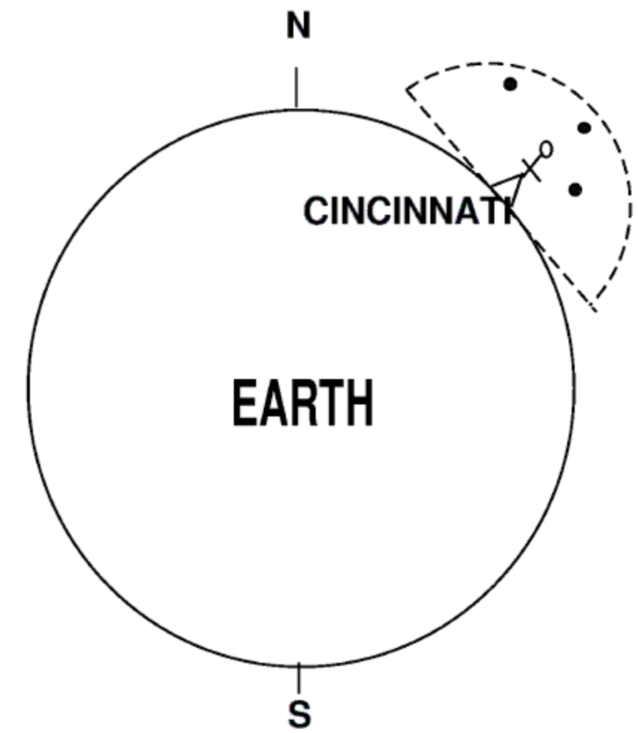
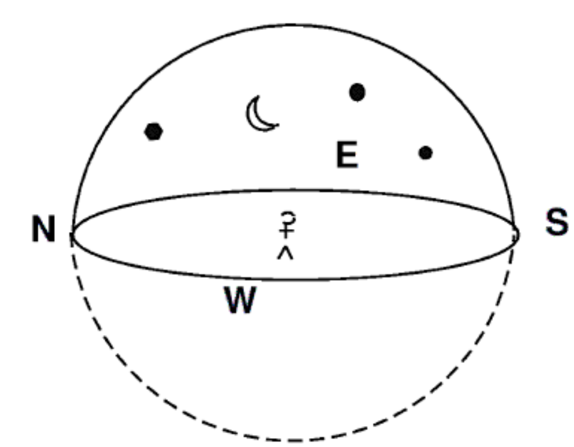
ASTRONOMICAL COORDINATE SYSTEMS



CELESTIAL SPHERE

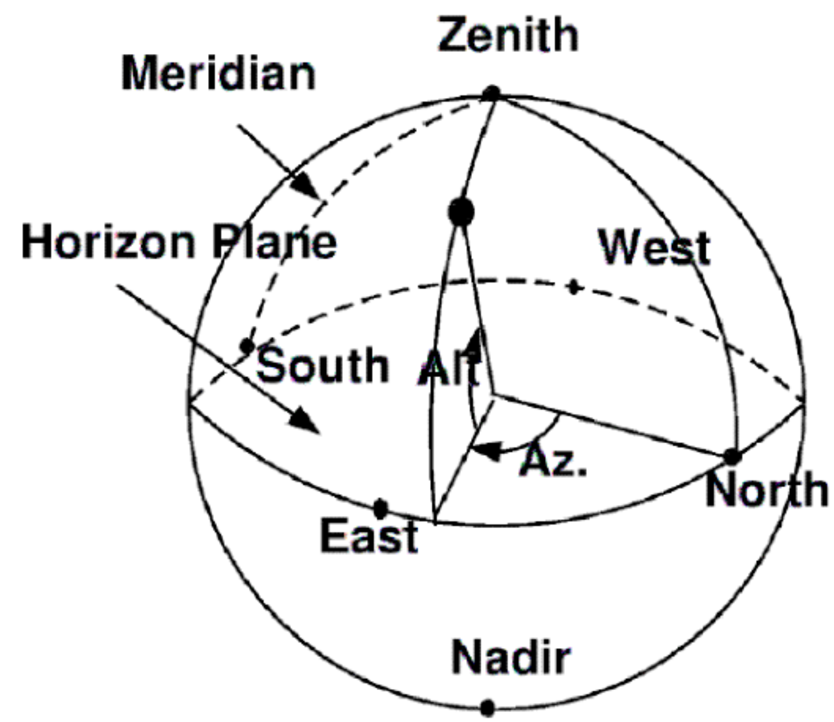
To the naked eye, stars appear fixed on the sky with respect to one another. These patterns are often grouped into constellations. Angular measurements - degrees, minutes and seconds of arc - $^{\circ}$,',″ - can be made on this sphere. (Note that astronomers frequently use the term “arcsec” as a shorthand for “seconds of arc”)

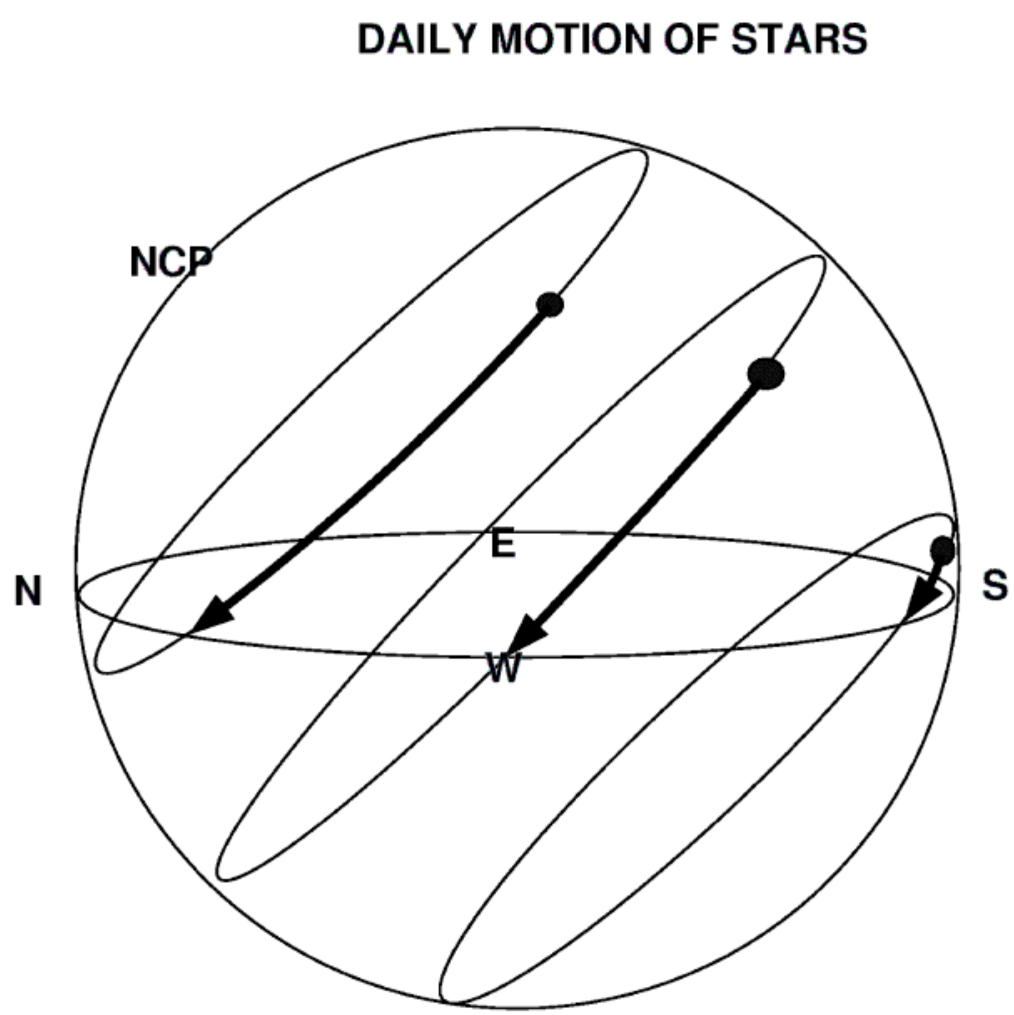
360° = full circle ; 60' = 1° ; 60″ = 1'



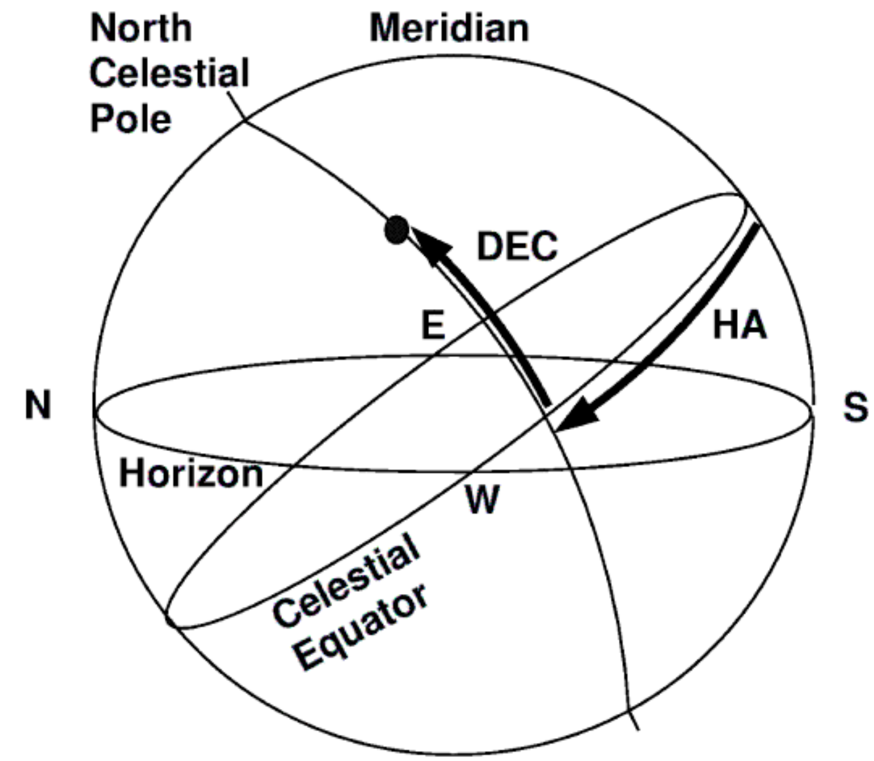
ALTITUDE-AZIMIUTH SYSTEM

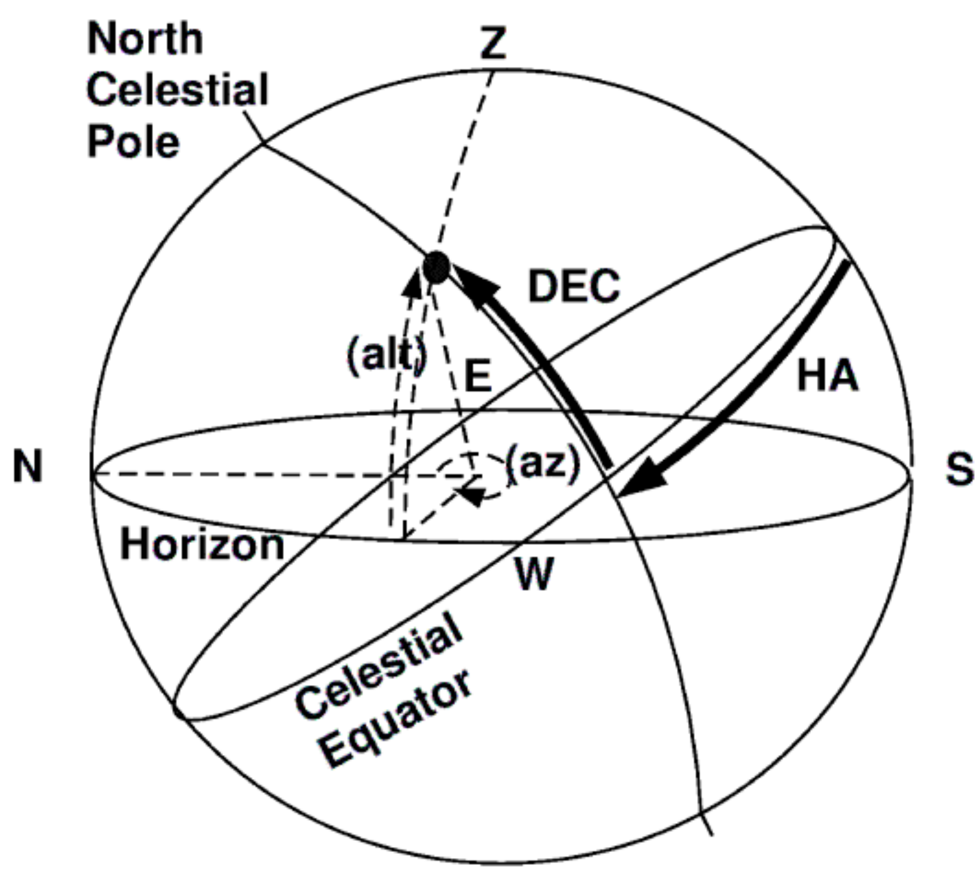
Horizon
Cardinal Points
Zenith & Nadir
Altitude
Azimuth





EQUATORIAL SYSTEM



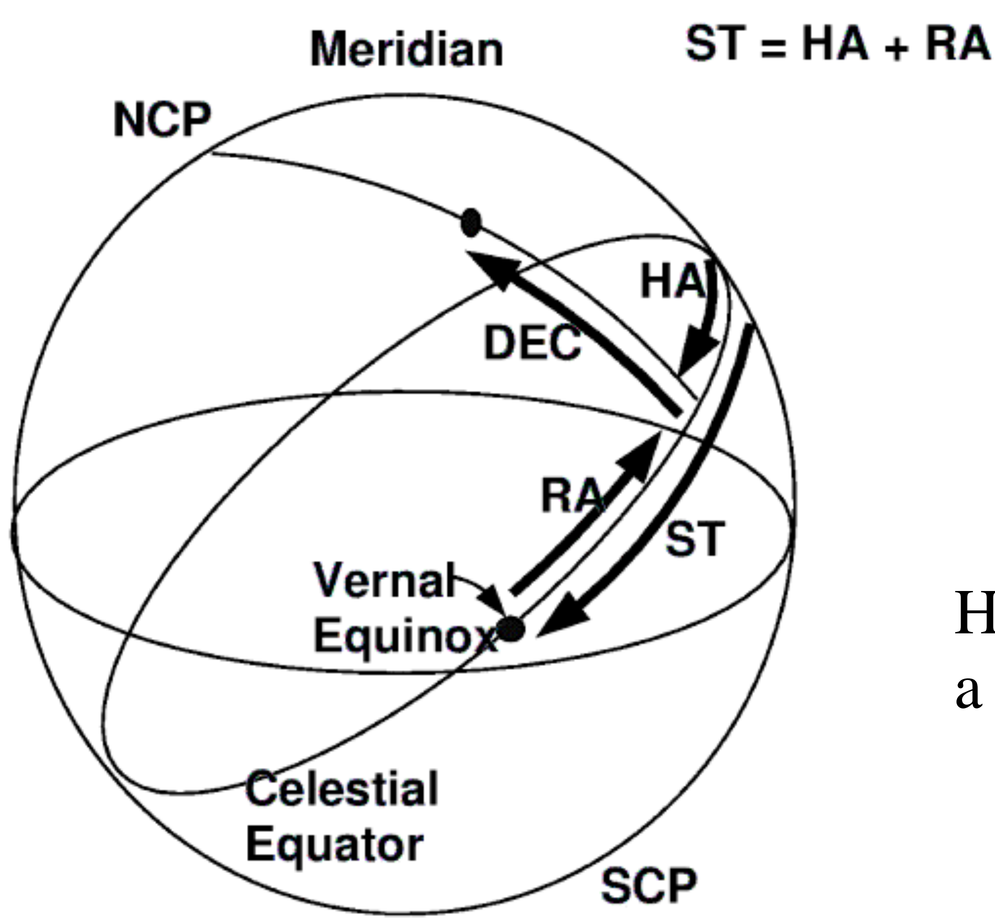


Meridian
Celestial Poles
Celestial Equator
Hour Angle (HA)
Declination (DEC or δ)
Right Ascension (RA or α)

Of course these systems can both be used to find the same object.....

We would like a system that is truly fixed to the sky.

Equatorial System with RA



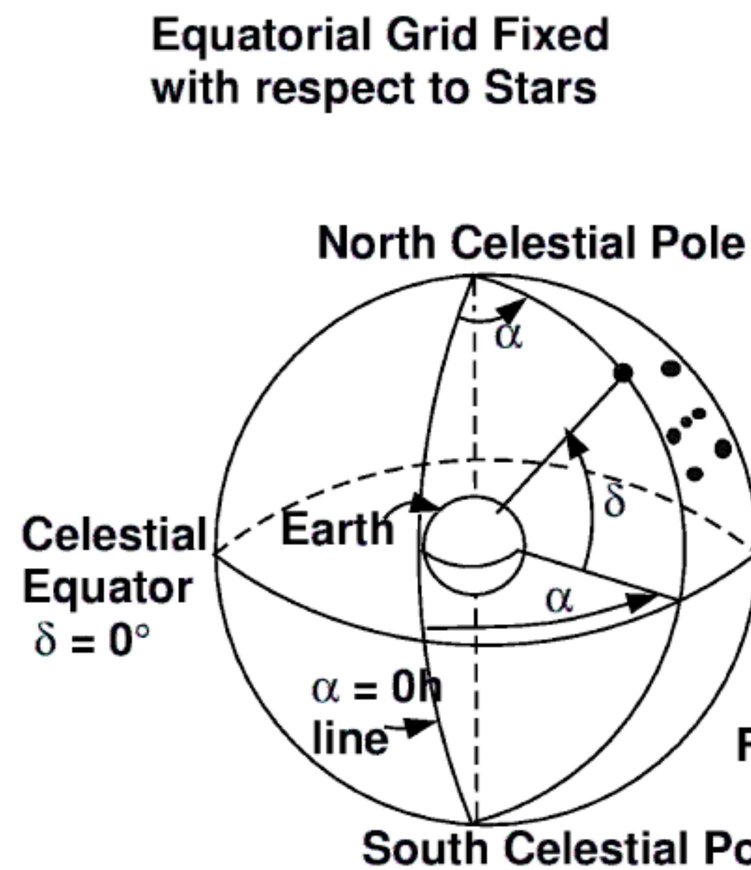
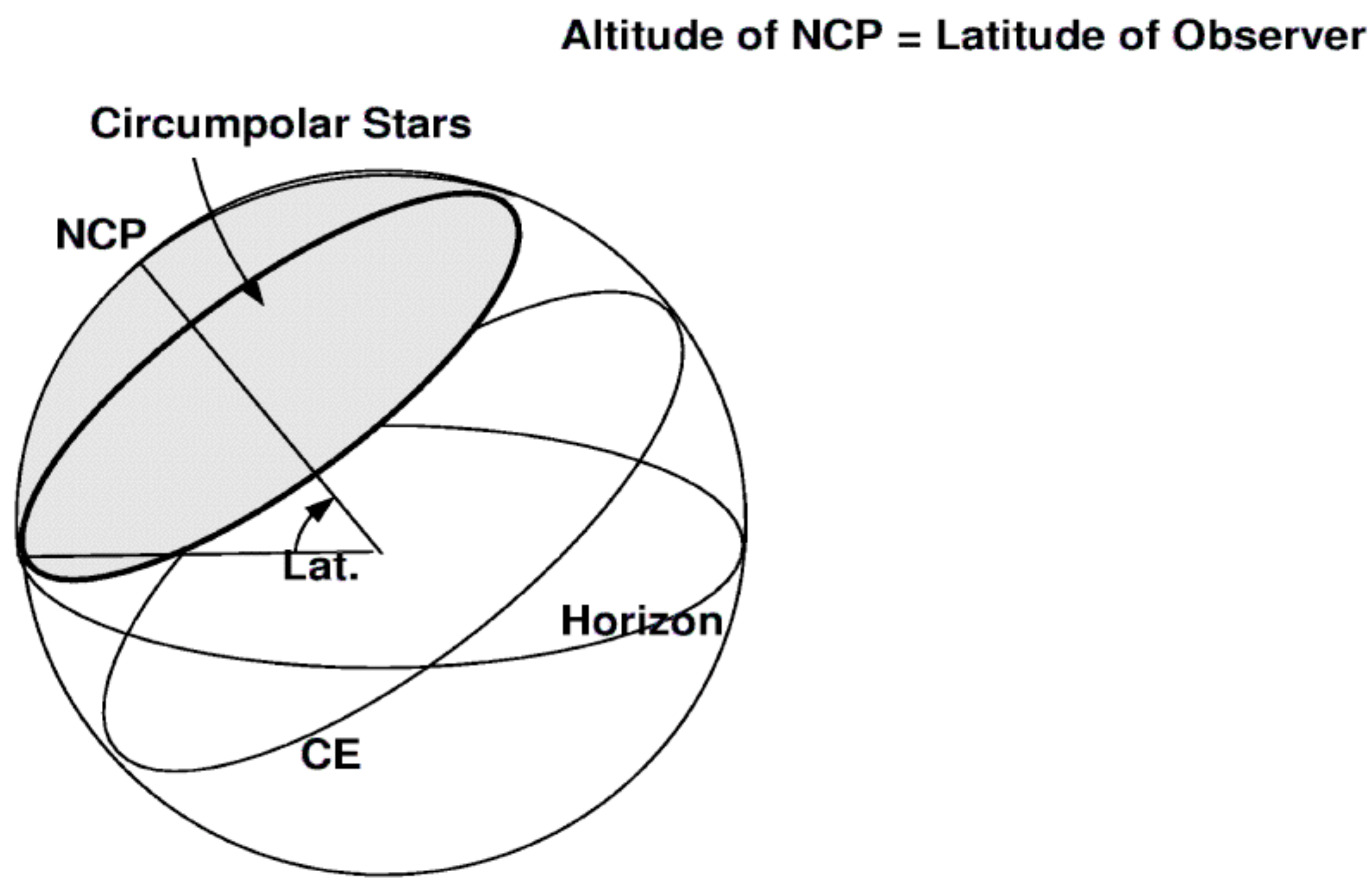


Fig. 2

Right Ascencion = RA = α
Declination = DEC = δ

Here we measure the east-west coordinate from a point in the sky called the *Vernal Equinox*.

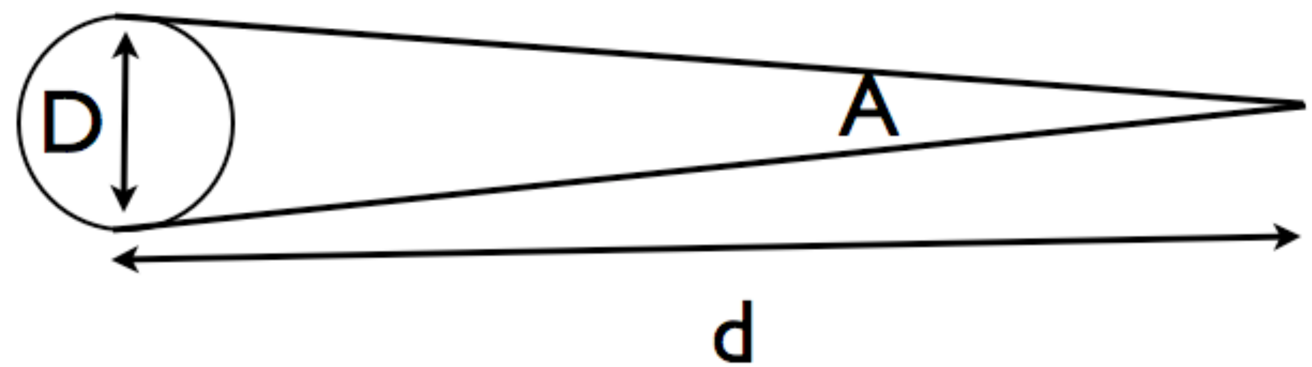
There are some consequences of having a tilted coordinate system. For example, some stars never set nor rise, but instead have their declination circles always above the horizon. These are the circumpolar stars. Strictly speaking, those that never rise are also circumpolar, but since we do not, by definition, see them, they will not be discussed further.



Notes on Measuring Angles:

One can crudely estimate sky angles using the lengths of your outstretched hand, fingers, etc. From the tip of your little finger to the tip of your thumb is about 18^o. The width of the index finger is about 1^o. The width of the four knuckles is about 10^o, while the lengths of the sections of the index finger are 3^o, 4^o, and 6^o. The "Pointers" in the Big Dipper are about 5^o apart.

Small Angle Formula

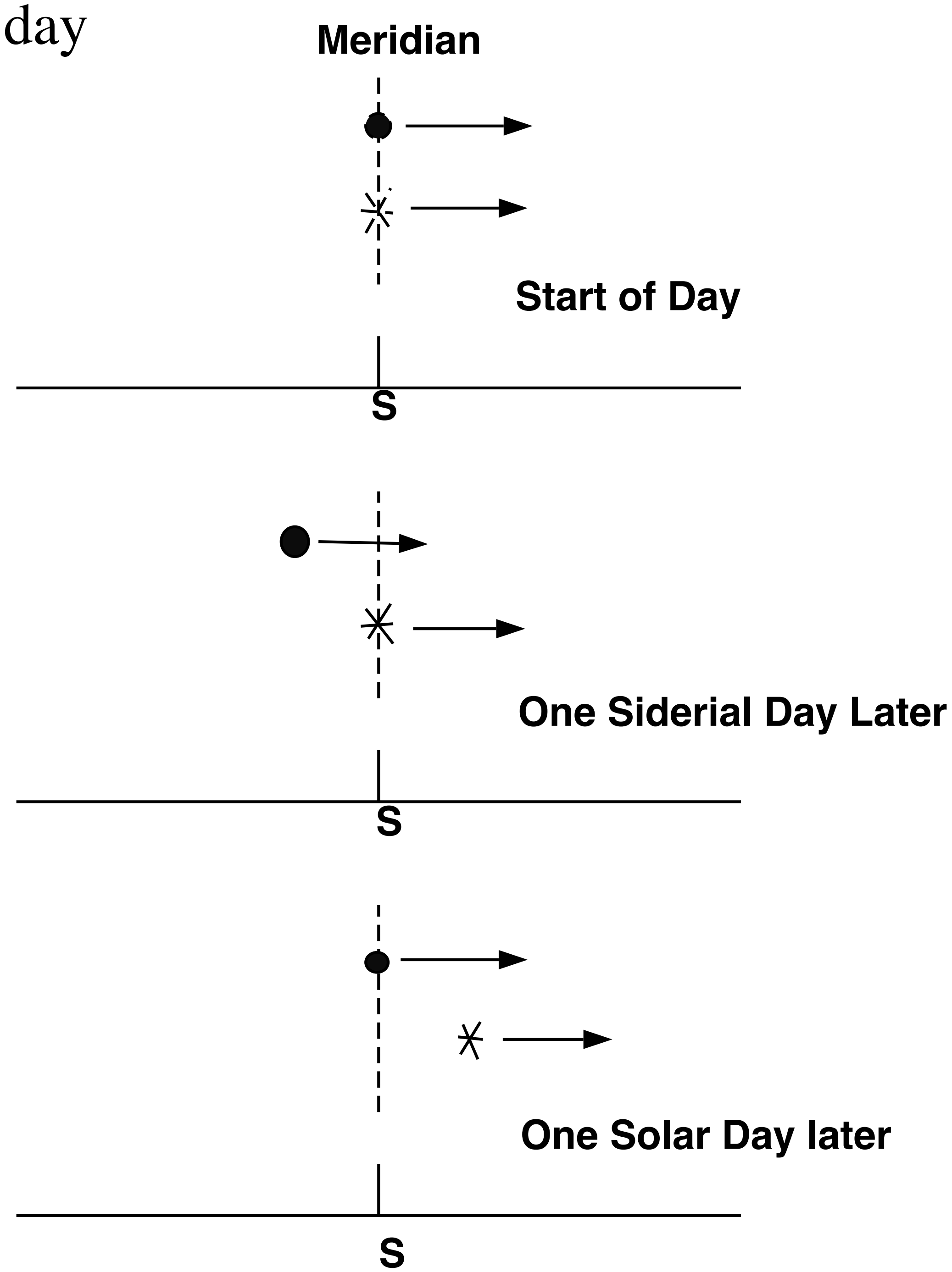


$$A \approx \left(\frac{D}{d}\right) x206{,}265 \ arcsec \quad (1 \ radian = 206{,}264.806...arcsec)$$

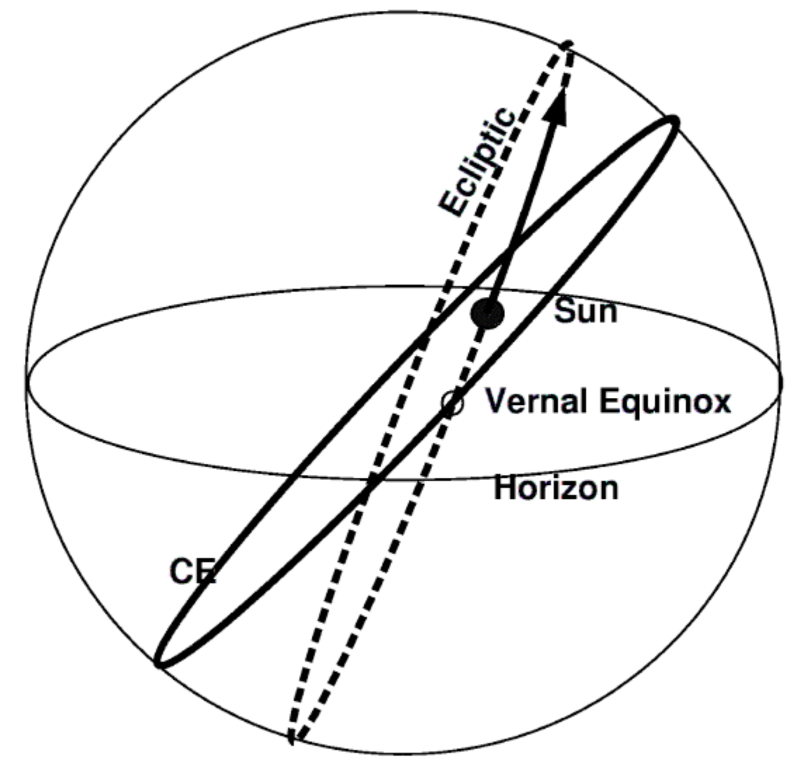
$$D \approx \frac{dxA}{206{,}265} arcsec$$

SUN'S MOTION – Solar versus Sidereal Day

Diurnal Motion E to W at about 360/day
Length of day using Meridian Crossing
    Solar Day versus
    Sidereal day

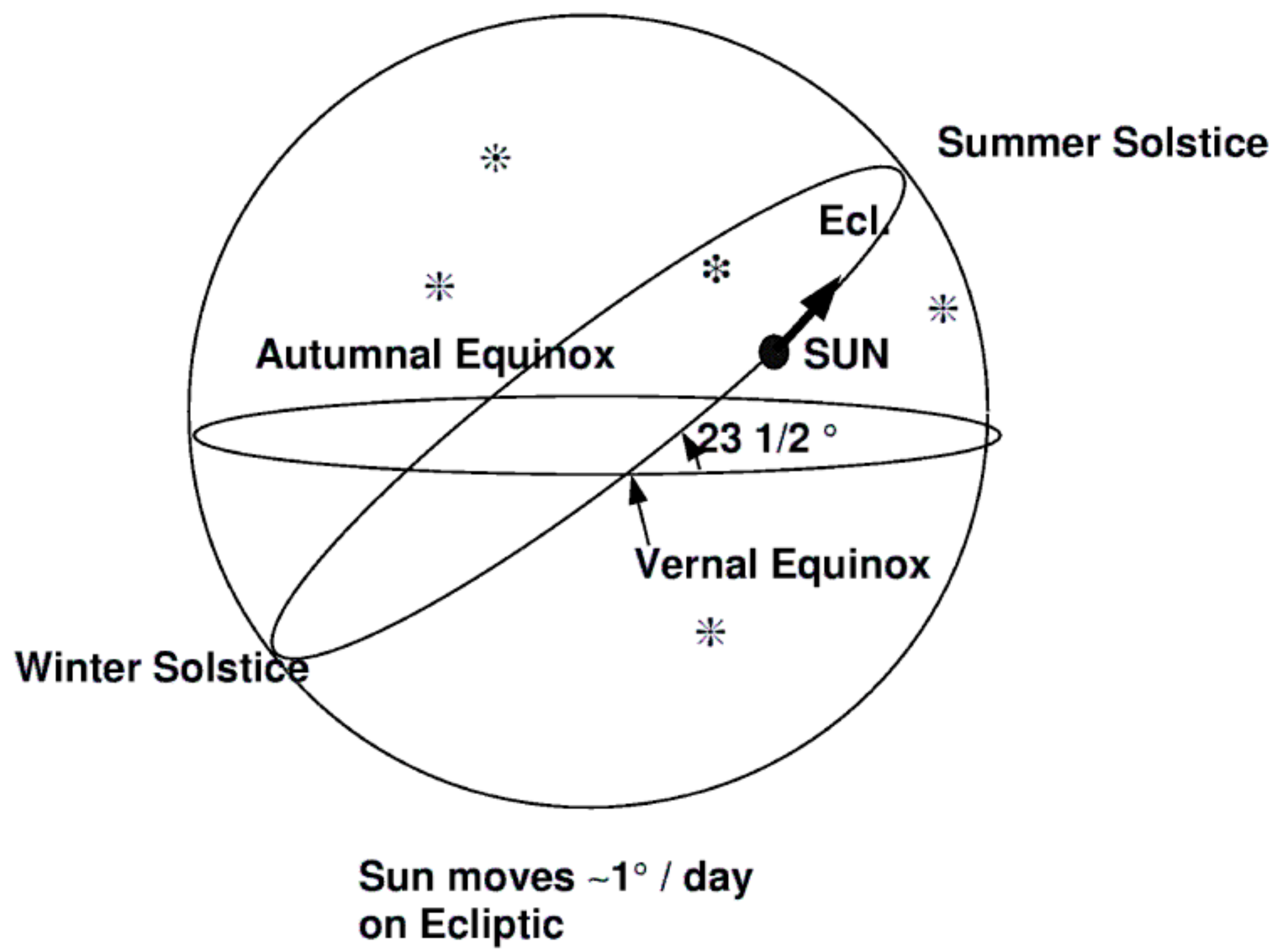


Annual Motion of Sun w.r.t. stars is about 1°/day W to E



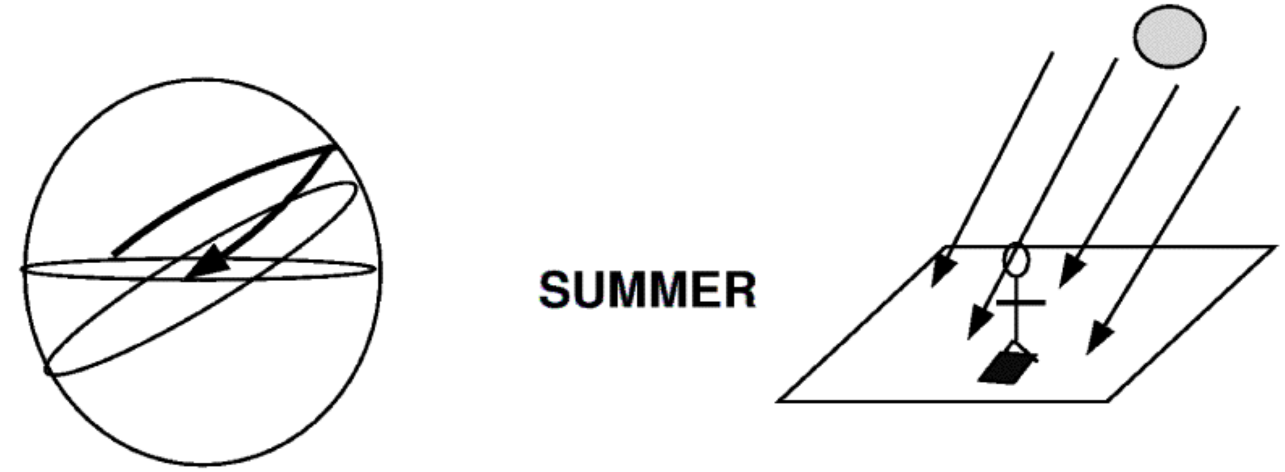
Ecliptic
Equinoxes
Solstices

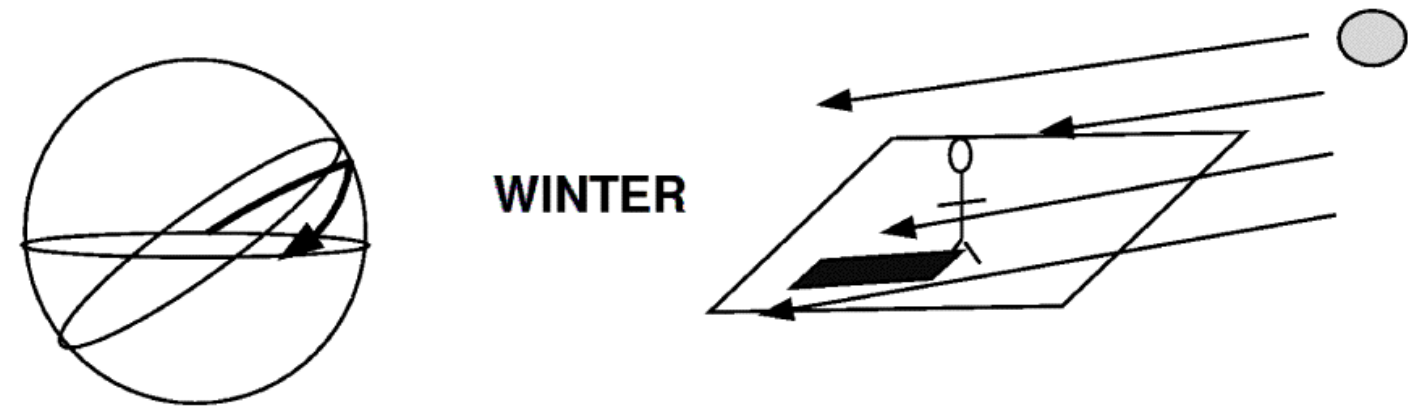
Redrawing this, ignoring the horizon circle, etc.:

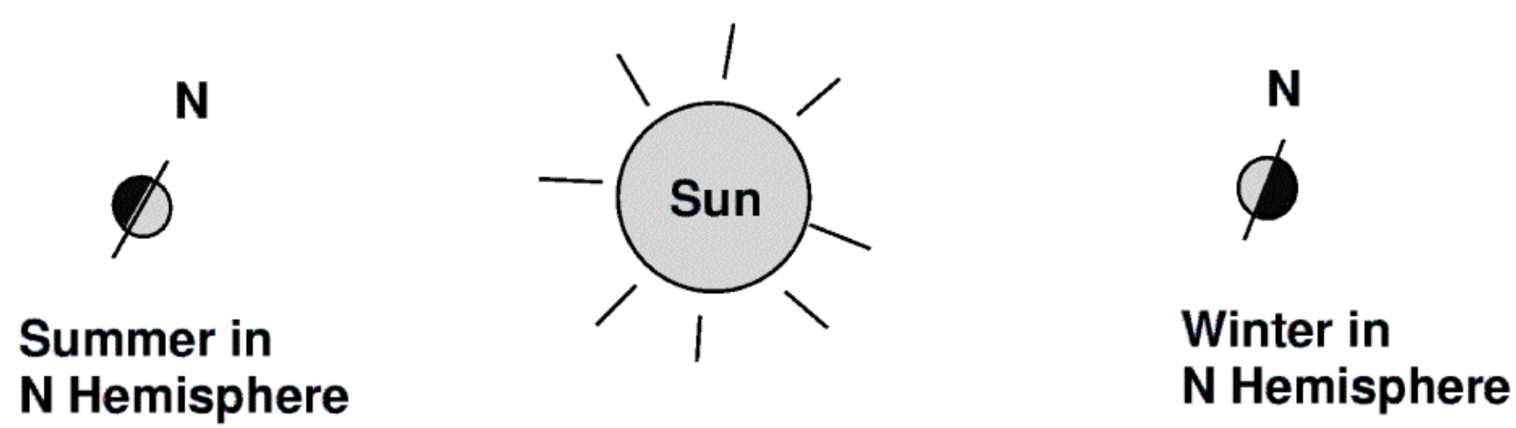


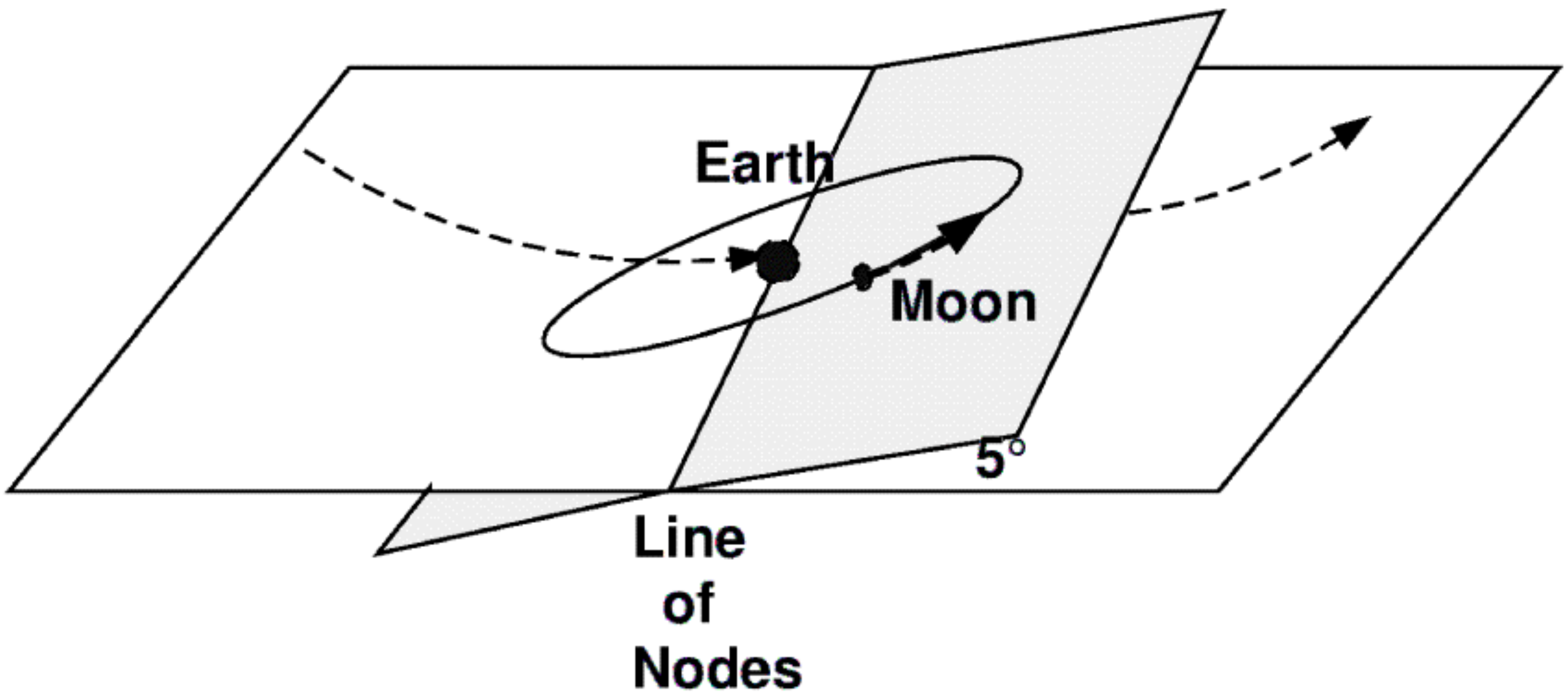
Note: The Vernal Equinox is chosen as the zero point for RA. *Precession of the Equinoxes* changes the RA, DEC of an object with time.

The Seasons

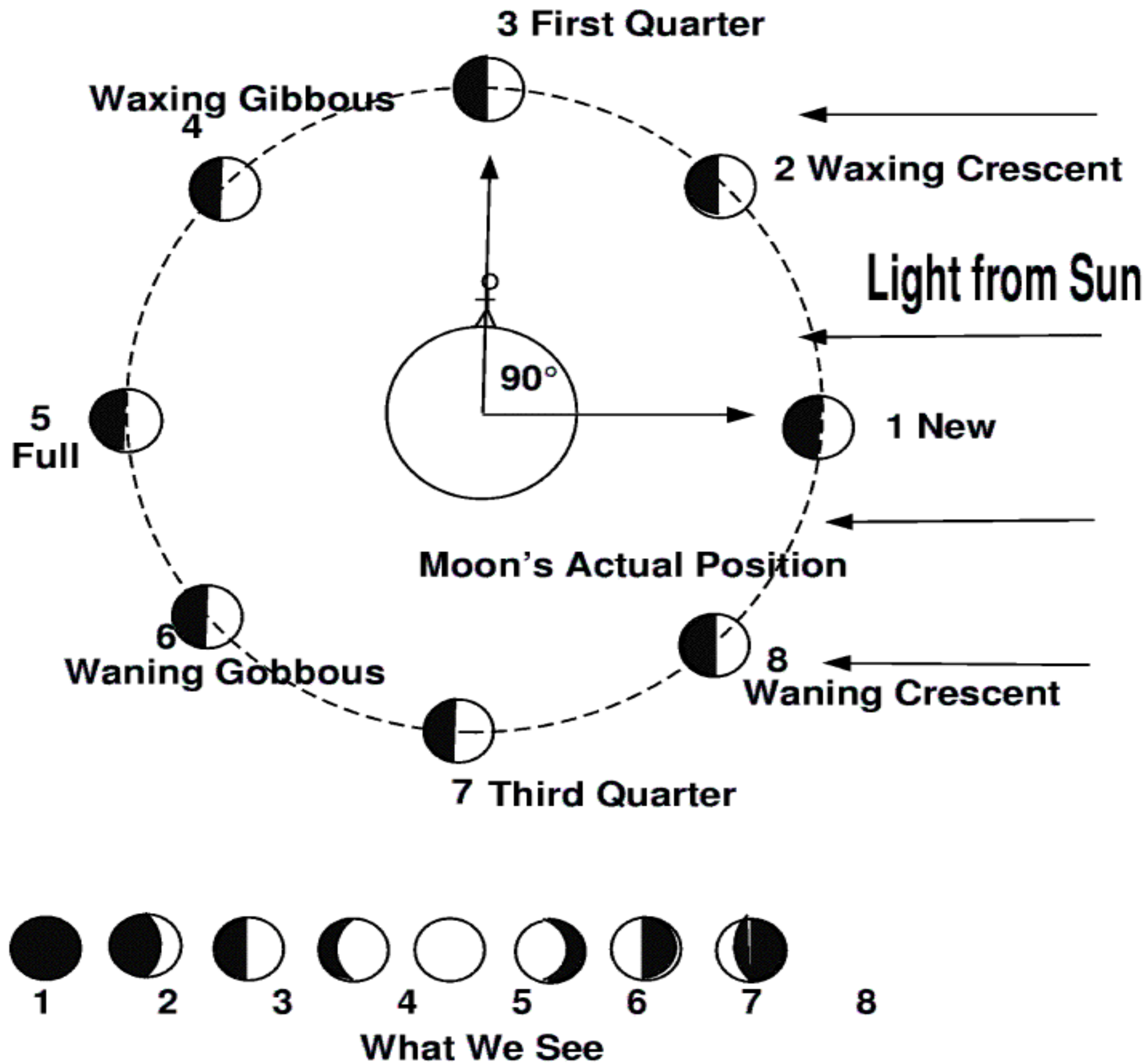

SUMMER


WINTER

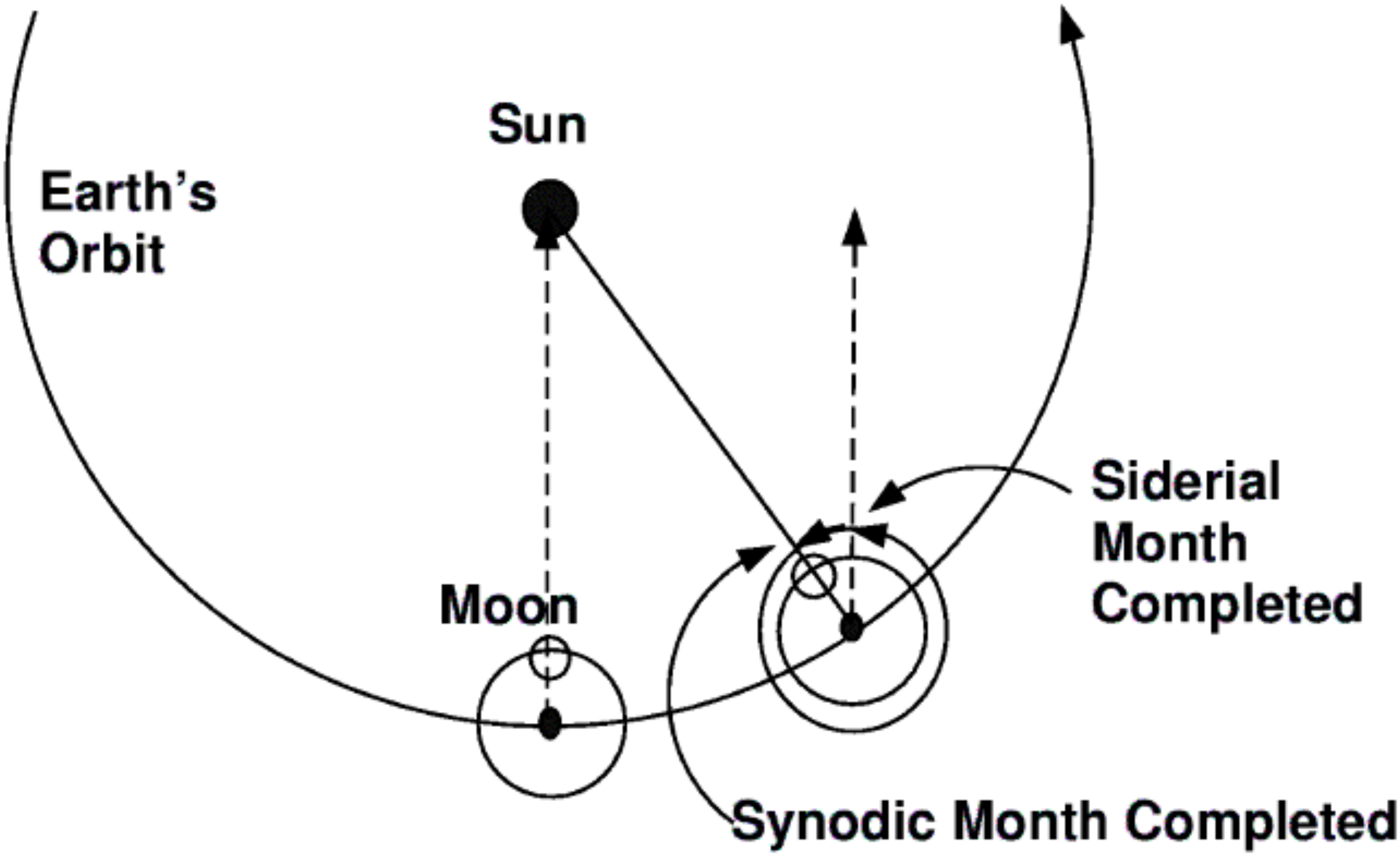

N
Sun
N
Summer in
N Hemisphere
Winter in
N Hemisphere

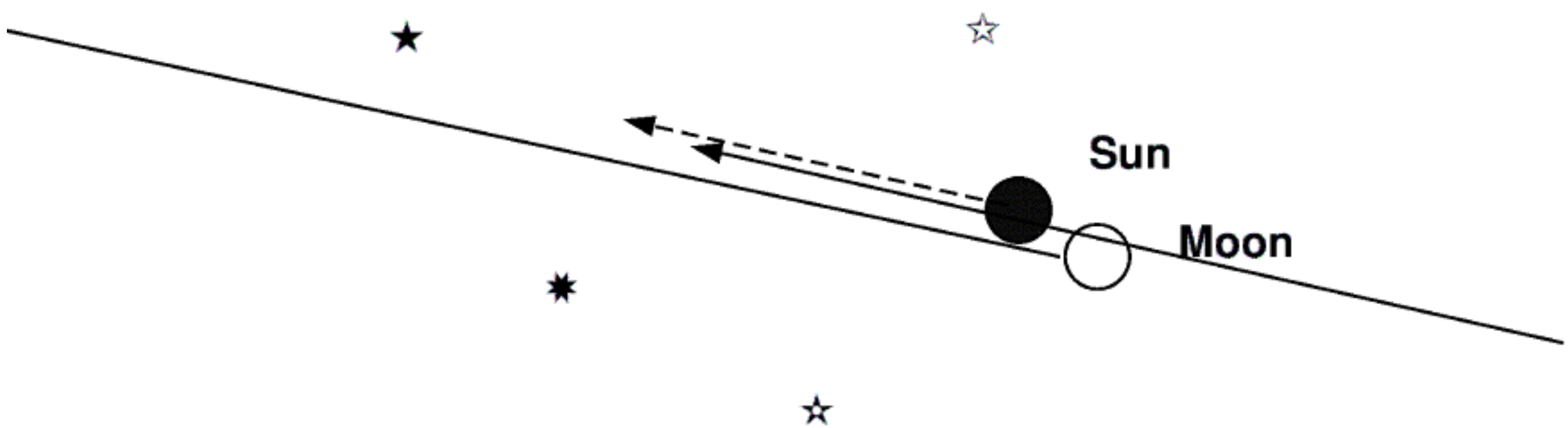

Earth
Moon
5°
Line
of
Nodes

Lunar Phases

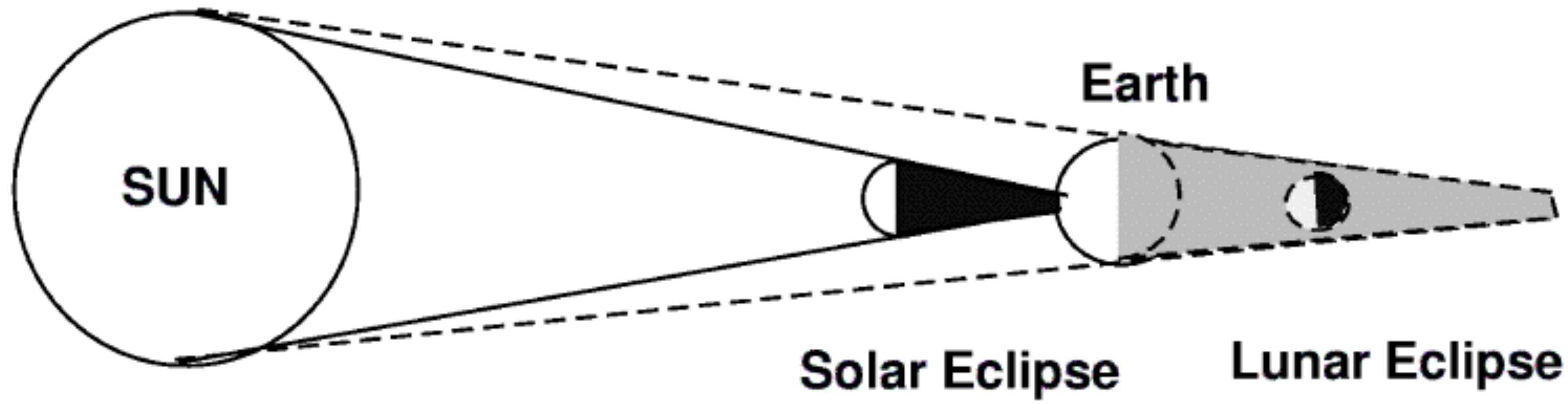


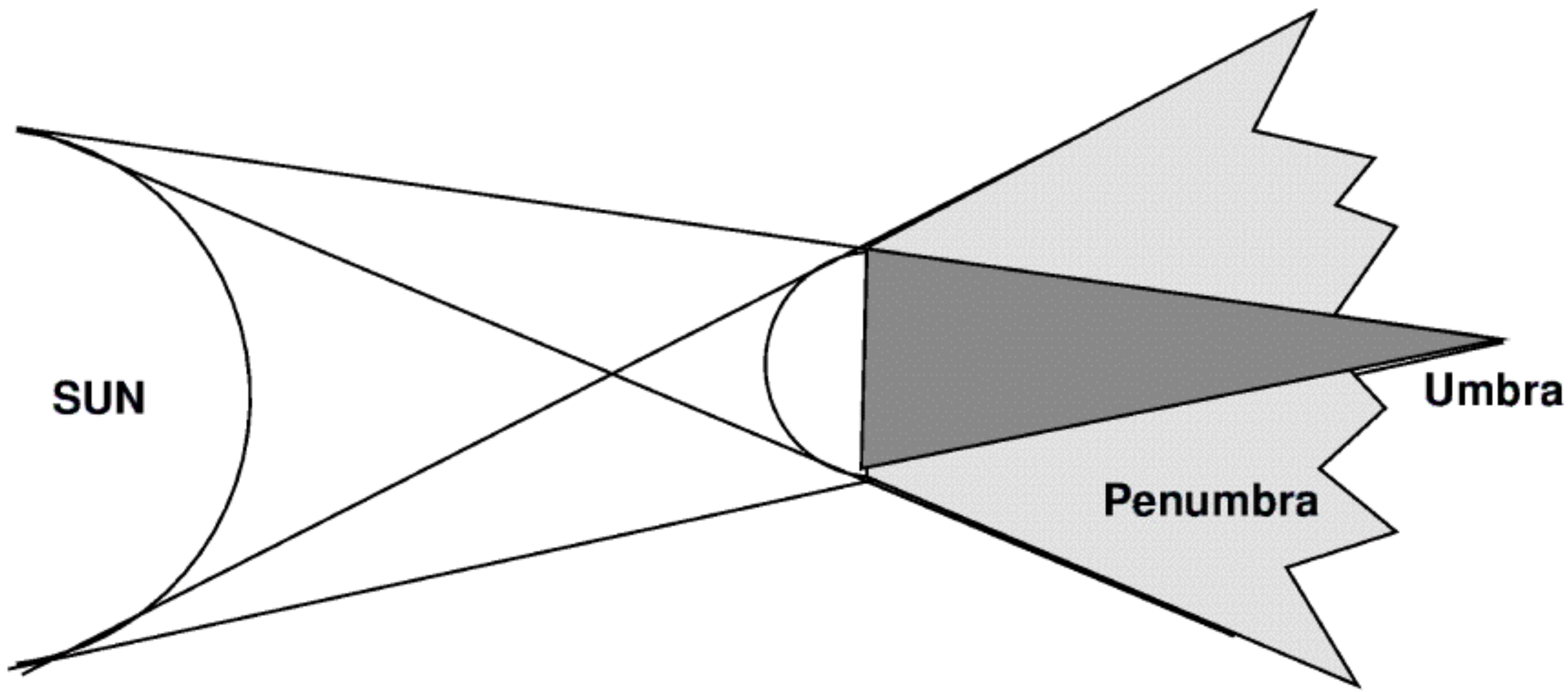
Sidereal versus Synodic Month




Sun
Moon

Eclipses





PRACTICAL ASPECTS OF TIME

The most familiar sort of time we use is Mean Solar Time. This is essentially the HA of the Sun.

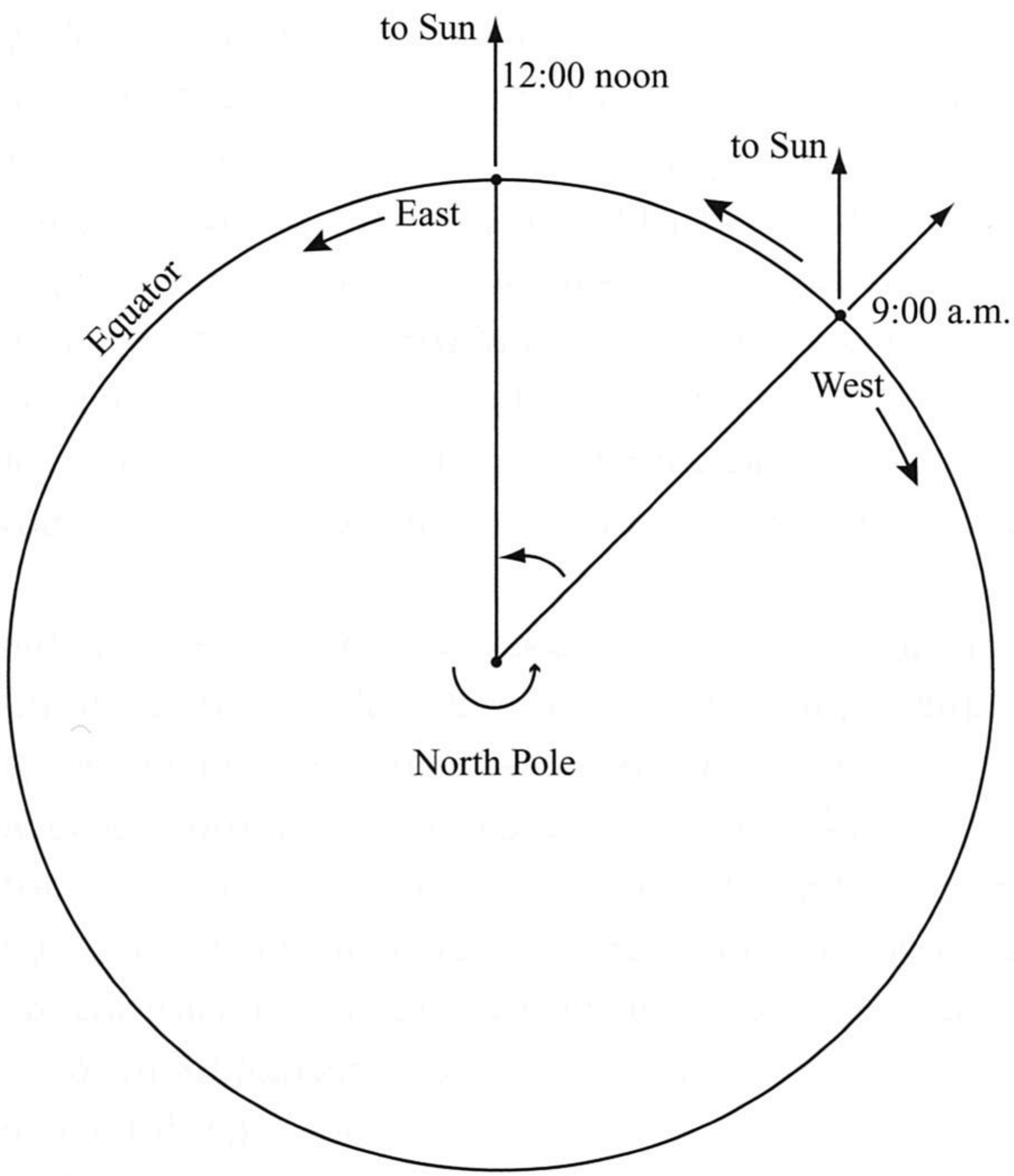


Figure 2.4. Solar time depends upon the longitude of the observer.

But because the Earth's speed in its orbit changes with where it is, and because the Sun does not move along the CE, the Sun may lead or lag the HA one would get for uniform motion along the CE. This correction is referred to as the *Equation of Time*.

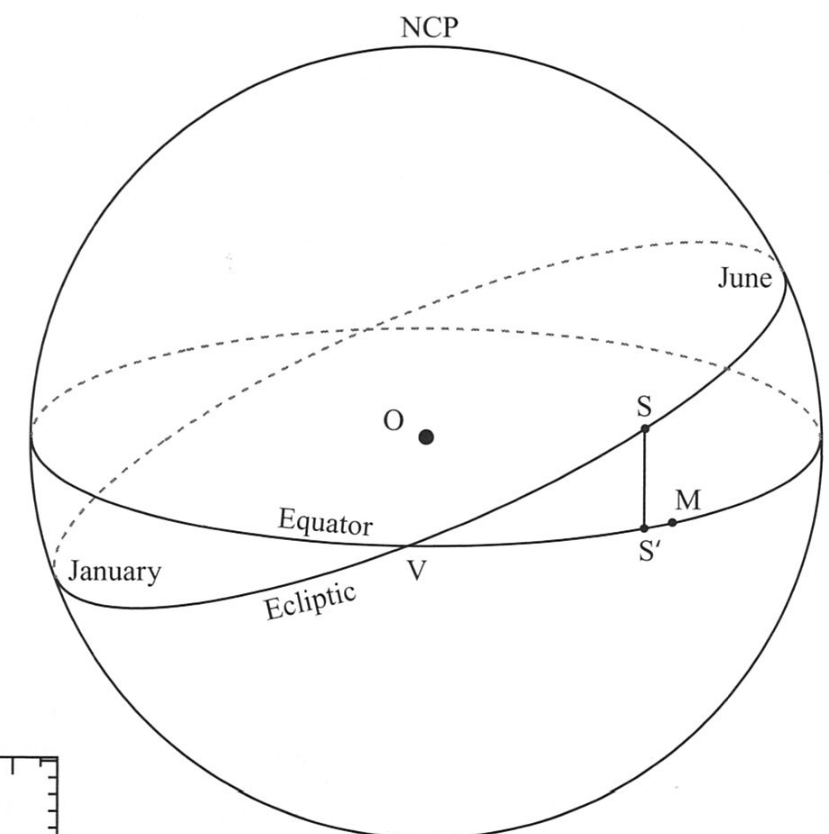


Figure 2.2. The true Sun projected to S′ is lagging behind the mean Sun at M. The angles VOS and VOM are equal.

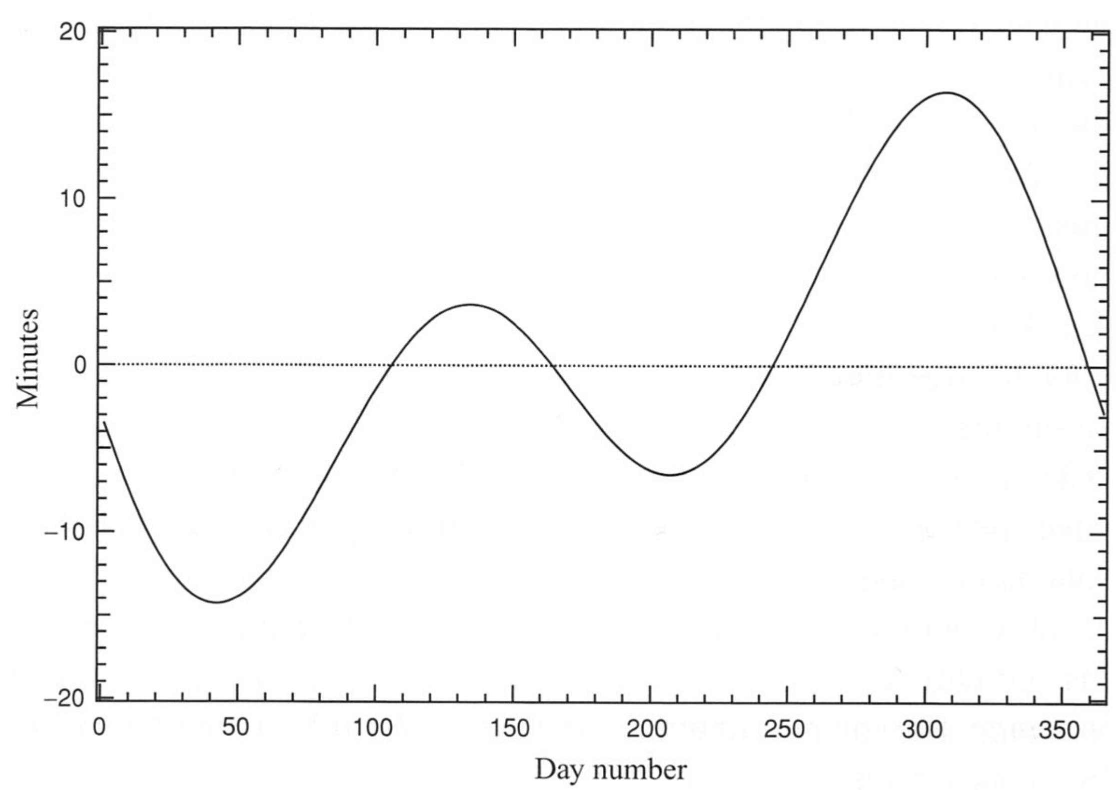
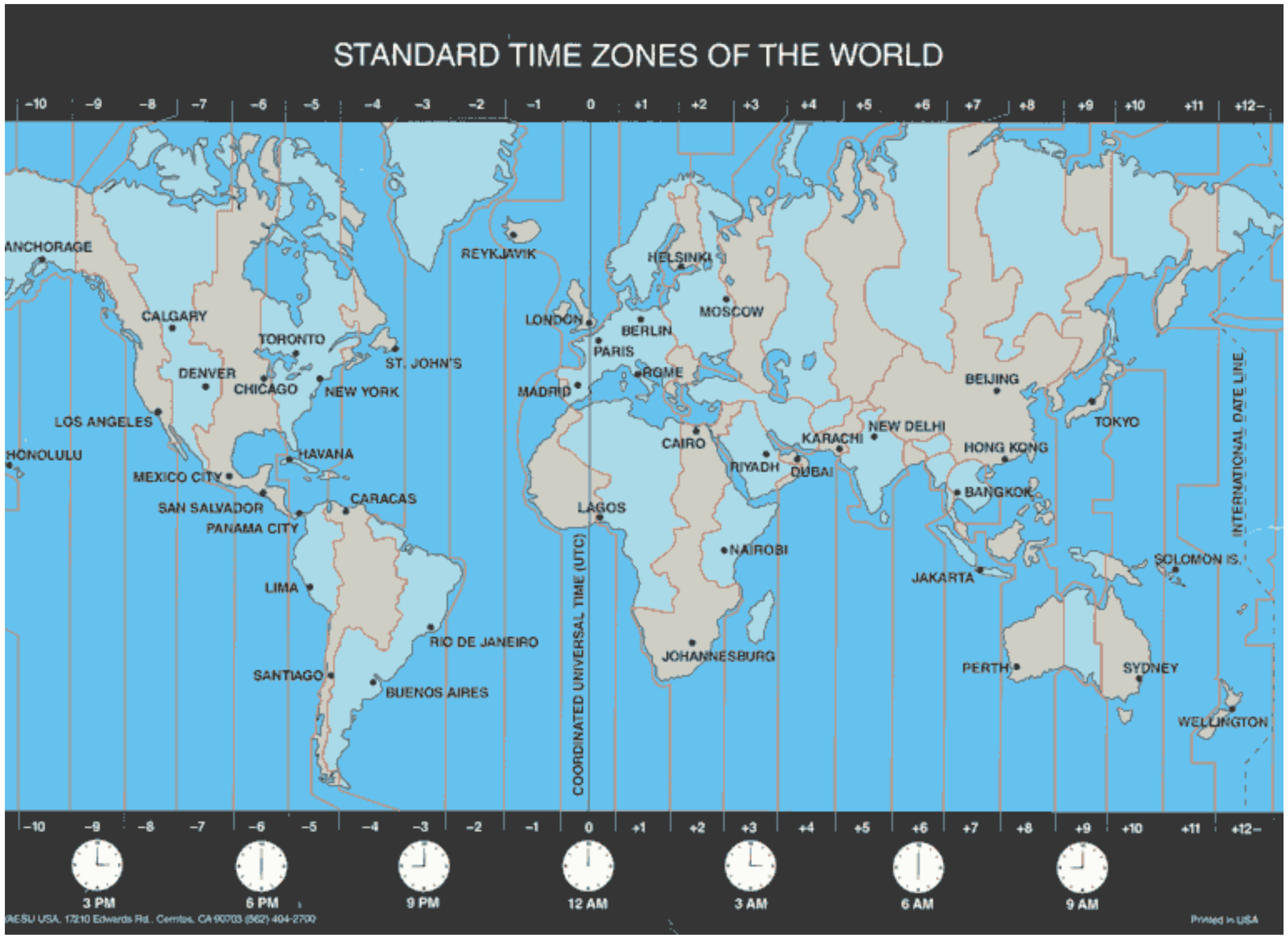


Figure 2.3. Variations in the equation of time throughout the year.

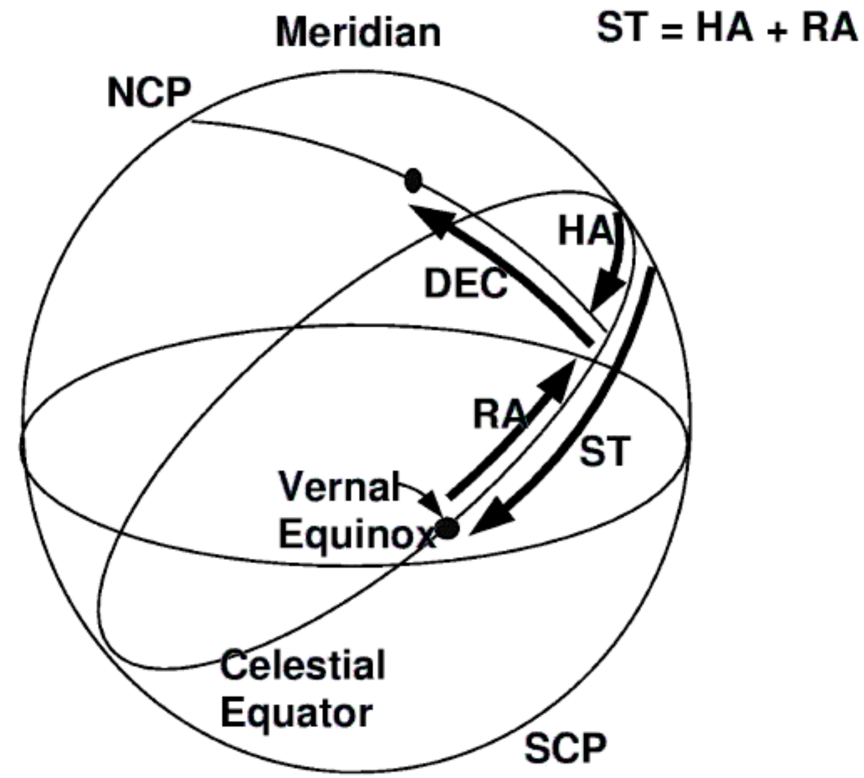
As a practical matter, we do not keep local time this way, or else people on the east side of town would have a different solar time than those on the west. So we divide the world into Time Zones. Most of these are roughly 15 wide (15 = 1 hour, after all…..). But there are some exceptions, determined locally.



Note that, strictly speaking, Cincinnati is more than 7.5 degrees west of the line of longitude that should mark the center of the Eastern Time Zone! If the zone boundaries were drawn precisely evenly, we would be on Central Time. Note that observatories usually record some version of ***Universal Time*** - the time at the Greenwich Meridian.

SIDEREAL TIME

In the same way that the mean solar time is (with the exception of the adoption of time zones and the effects of the equation of time) the HA of the Sun, astronomers define the sidereal time as the HA of the Vernal Equinox. This is necessary as most telescopes point to "fixed" objects on the celestial sphere, not the Sun, so they have to know where these objects are!



For any given object: HA + RA = ST (see earlier slide).

JULIAN DATE

Knowing WHEN something happened is often crucial in astronomy. Rather than dealing with the months, leap days, etc. of the Gregorian calendar, they use a system of sequentially increasing day numbers, Julian Days, beginning on Jan. 1, 4713 BCE, beginning at NOON (this is the basis of "civil time" by the way). The US Naval Observatory has a web page that will convert the common Gregorian day and UT time into JD or vice-versa: https://www.aavso.org/jd-calculator

Star Names

See: **http://www.naic.edu/~gibson/starnames/starnames.html** and **http://simbad.harvard.edu/simbad/** (SIMBAD)

"Arabic Names": Antares, Aldebaran, Sirius, Canopus. …..

Designations with genitive name of constellation:
Scorpius Scorpii, Taurus Tauri, Canis Major Canis Majoris, etc.

There are many, many catalogs of stars that astronomers often refer to when referring to this or that star. Here is a sampling of some of the most commonly used ones (see your textbook for these and others).

Flamsteed Designations: 21 Sco, 87 Tau, 9 CMa
Bayer Designations: α Sco, β Tau, α CMa, γ Cas (NOTE: is sometimes listed as "alpha" but shortened to "alf"!)
Henry Draper Numbers: HD 148487, HD 29139, HD 48915, HD 45348
Smithsonian Astrophysical Observatory Numbers: SAO 184415, SAO 94027, SAO 151881, SAO 234480
General Catalog of Variable Stars: R, S, T, U, V, W, X, Y, Z, A, B, C, D,….RR, RS, RT, ….RA, RB, RC, ….SA, SB, …AA, AB, V# + Constellation. Examples: RR Lyrae, SS Cyg, V1016 Cyg, T Tau

Non-Stellar Objects

Messier: 110 of some of the biggest & brightest clusters, gas & dust clouds, and galaxies. Examples: M31 (Andromeda galaxy), M33 etc.,
New General Catalog: Compiled by Dreyer: another 7840 objects. Example: NGC 2264
Index Catalog. An extension of the NGC.

Coordinates:

Right Ascension & Declination (RA and DEC or α and δ)
Ecliptic - Longitude & Latitude - λ and β
Galactic - Longitude & Latitude - l^{II} and b^{II}

Coordinate Conversion & Finding Things:
https://heasarc.gsfc.nasa.gov/cgi-bin/Tools/convcoord/convcoord.pl

This one's at the Goddard Space Flight Center.

Is it up? Find out with StarAlt: http://www.ing.iac.es/ds/staralt/index.php

Solar System Objects

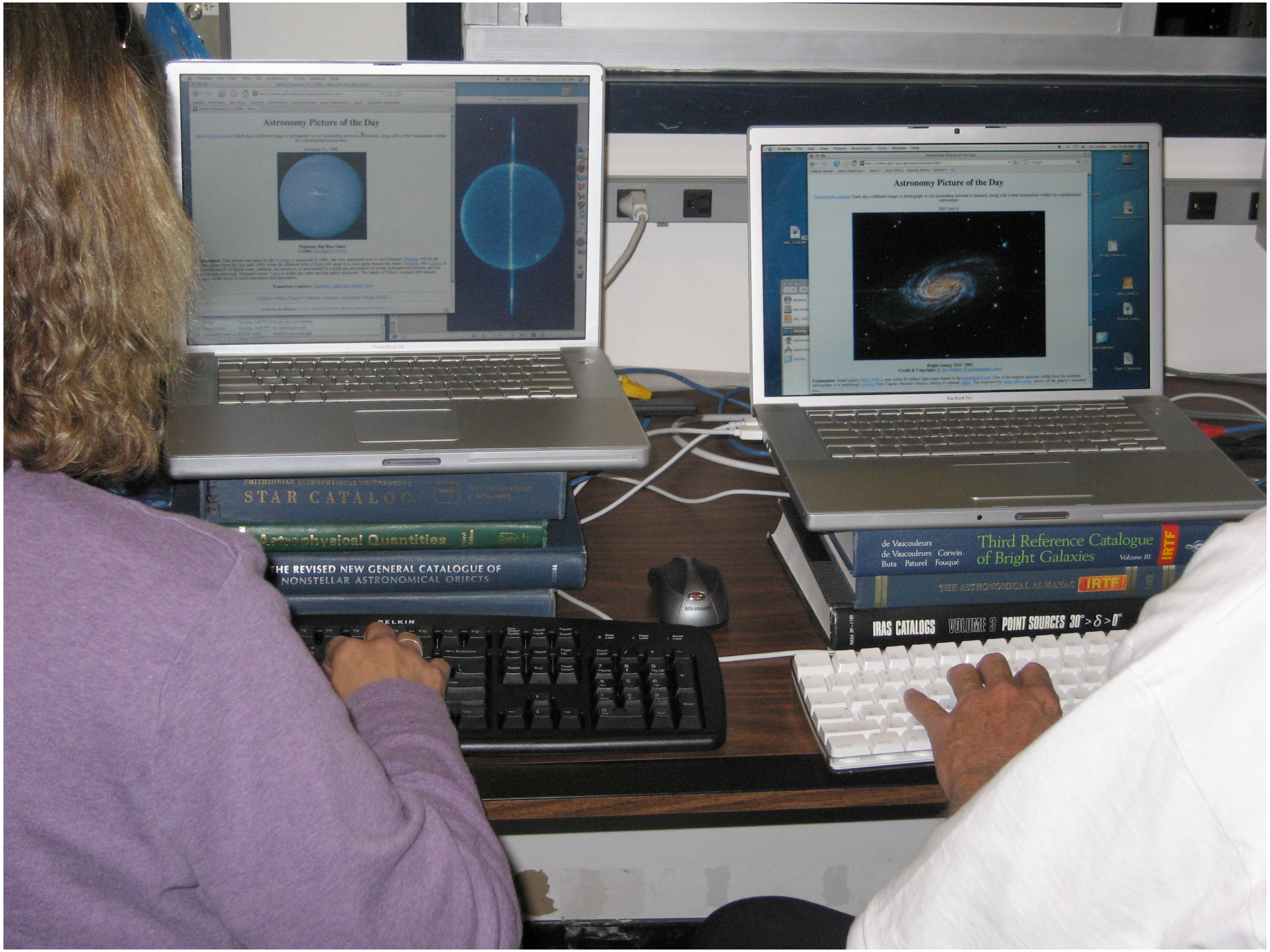
http://ssd.jpl.nasa.gov/?horizons NASA's Horizons system – I use this one extensively for planning observations…

Secchi Yoshida's website http://www.aerith.net/index.html is used even by professional astronomers who study comets.

Publications: ADS and SIMBAD: Astronomers can't survive without these! Get to know them and love them!

http://adswww.harvard.edu/ NASA's Astrophysics Data System (ADS) particularly http://adsabs.harvard.edu/abstract_service.html

and http://simbad.harvard.edu/simbad/ and http://simbad.u-strasbg.fr/simbad/ (there are 2 sites). NOTE: VIRTUALLY ALL ELECTRONIC CATALOGS TODAY SEARCH SIMBAD FOR RESOLVING STAR NAMES AND GETTING THEIR COORDINATES. If SIMBAD is down, you may be out of luck!



Once upon a time, astronomers used to have to search extensively through many volumes of printed catalogs in order to find even the simplest bits of information about a star. Thanks to the internet, we can do this much faster and more completely. Still, the old printed books are not without their uses!