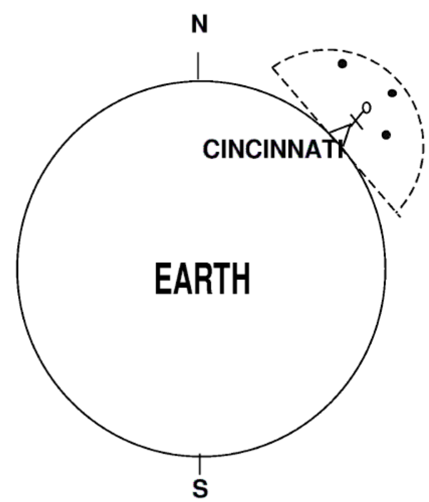
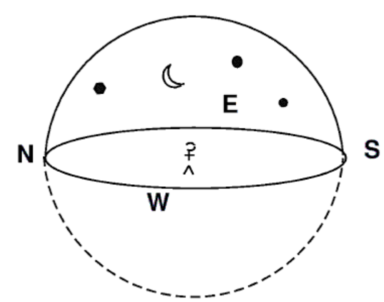
# ASTRONOMICAL COORDINATE SYSTEMS

## *CELESTIAL SPHERE*



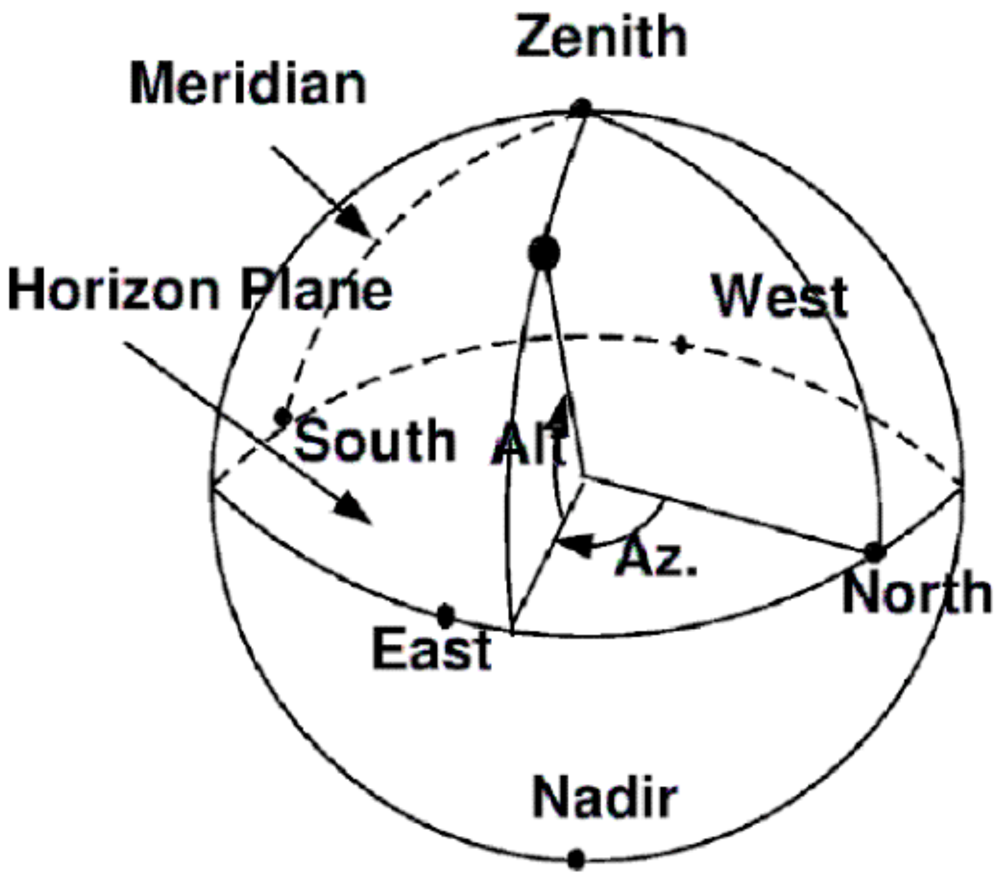

To the naked eye, stars appear fixed on the sky with respect to one another. These patterns are often grouped into constellations. Angular measurements (°,',") can be made on this sphere.

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

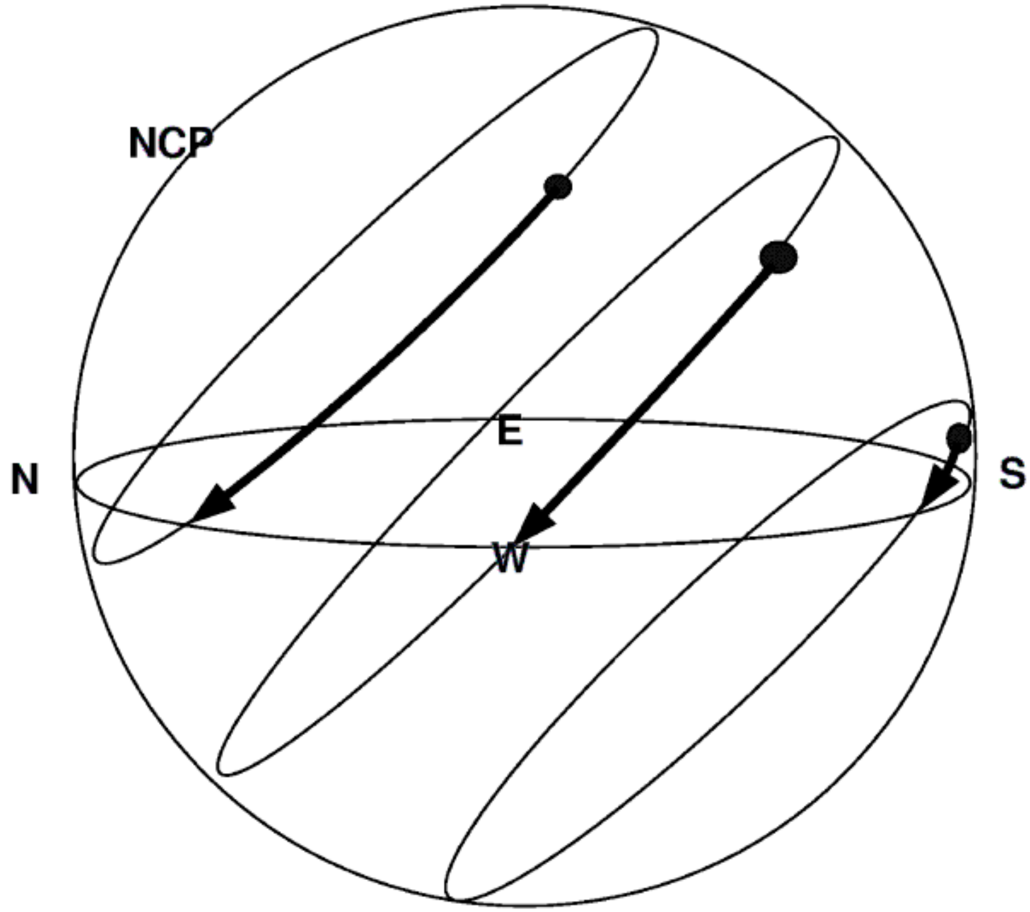


***ALTITUDE-AZIMIUTH SYSTEM***

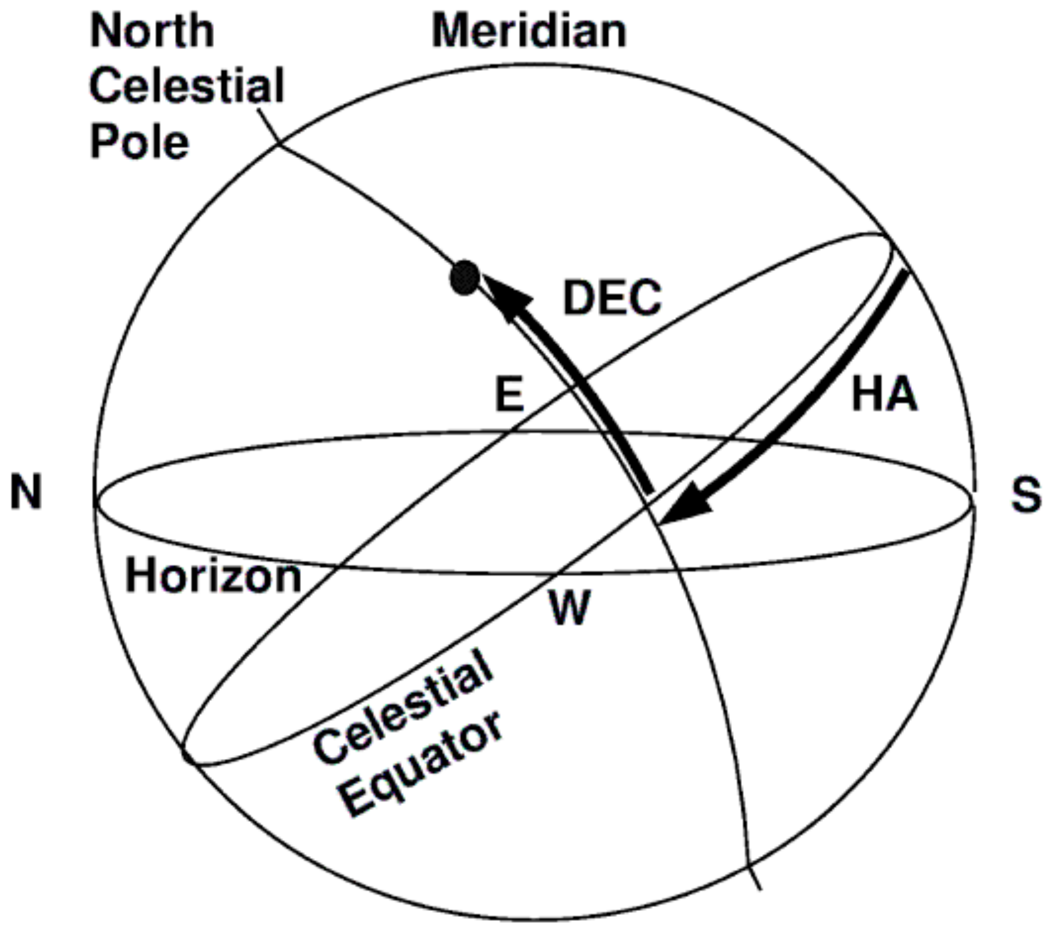
Horizon
Cardinal Points
Zenith & Nadir
Altitude
Azimuth



## DAILY MOTION OF STARS

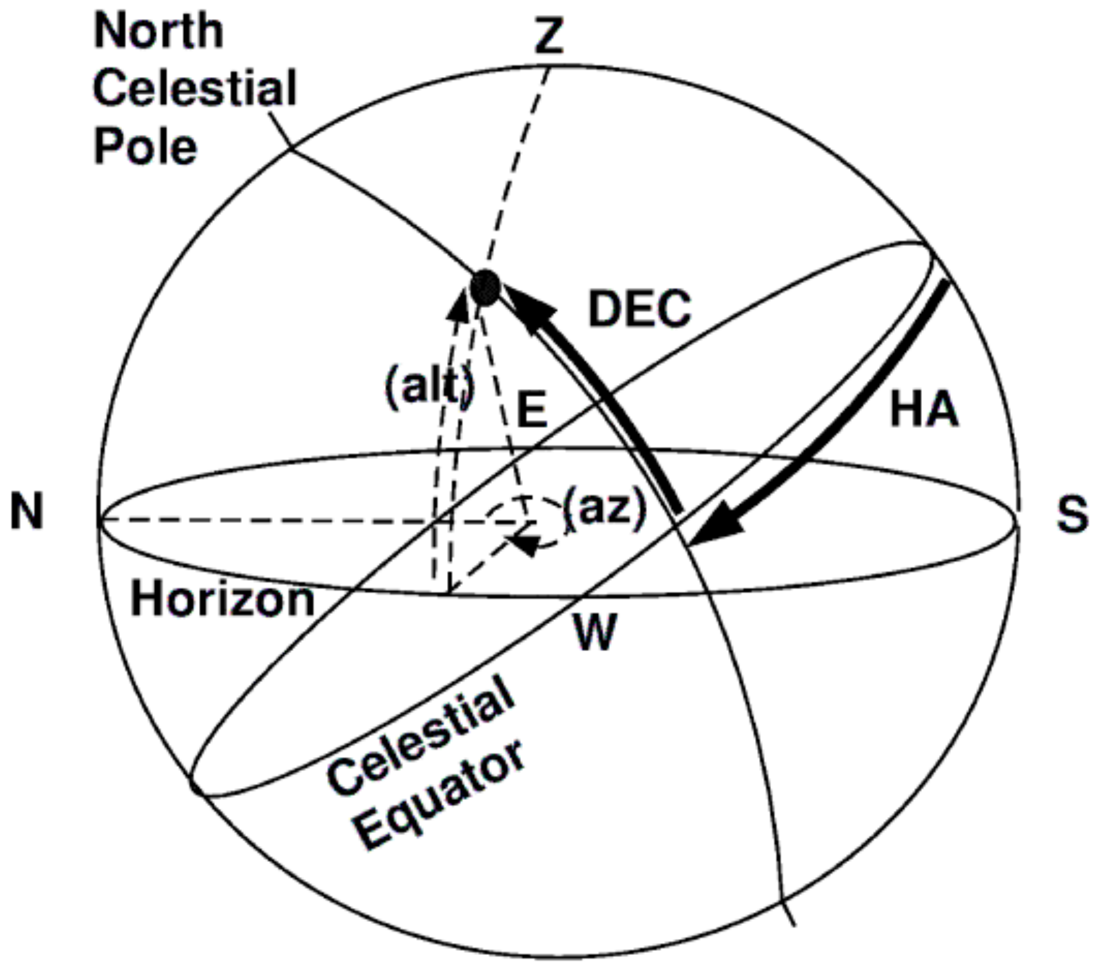


*EQUATORIAL SYSTEM*



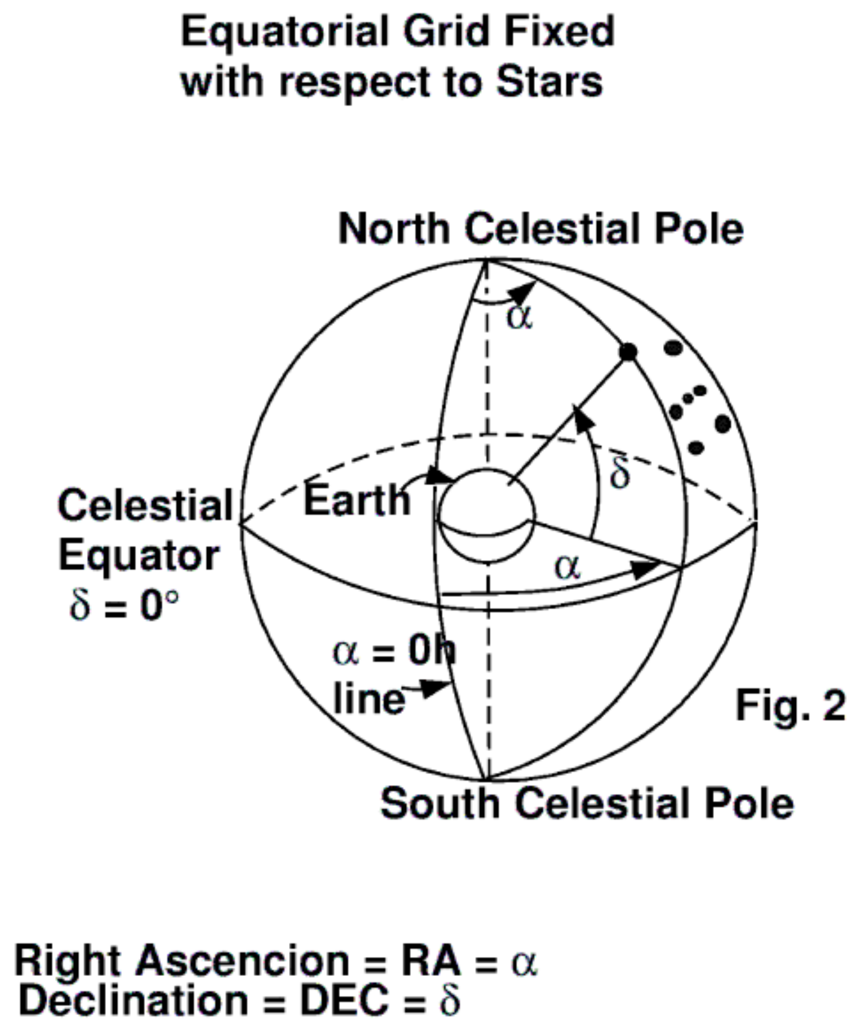
Meridian
Celestial Poles
Celestial Equator
Hour Angle (HA)
Declination (DEC or δ)
Right Ascension (RA or α)

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

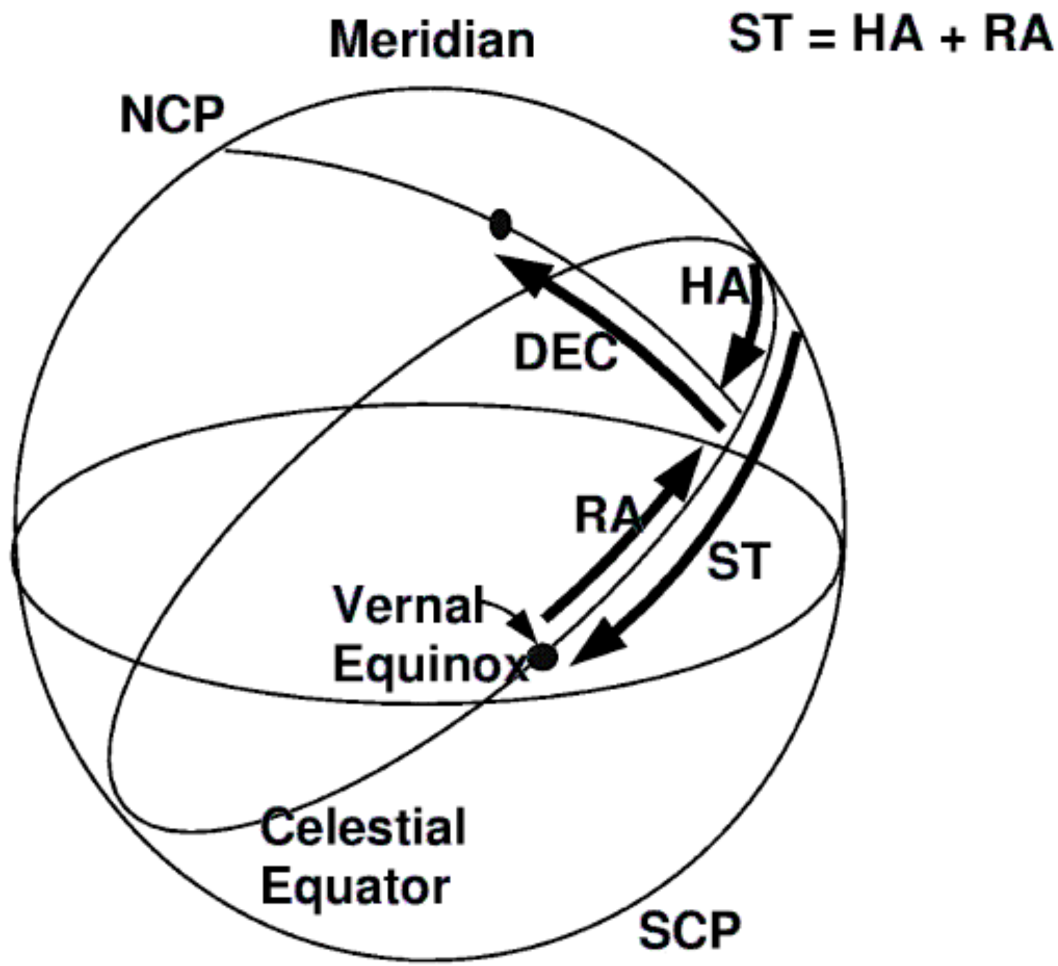


We would like a system that is truly fixed to the sky.

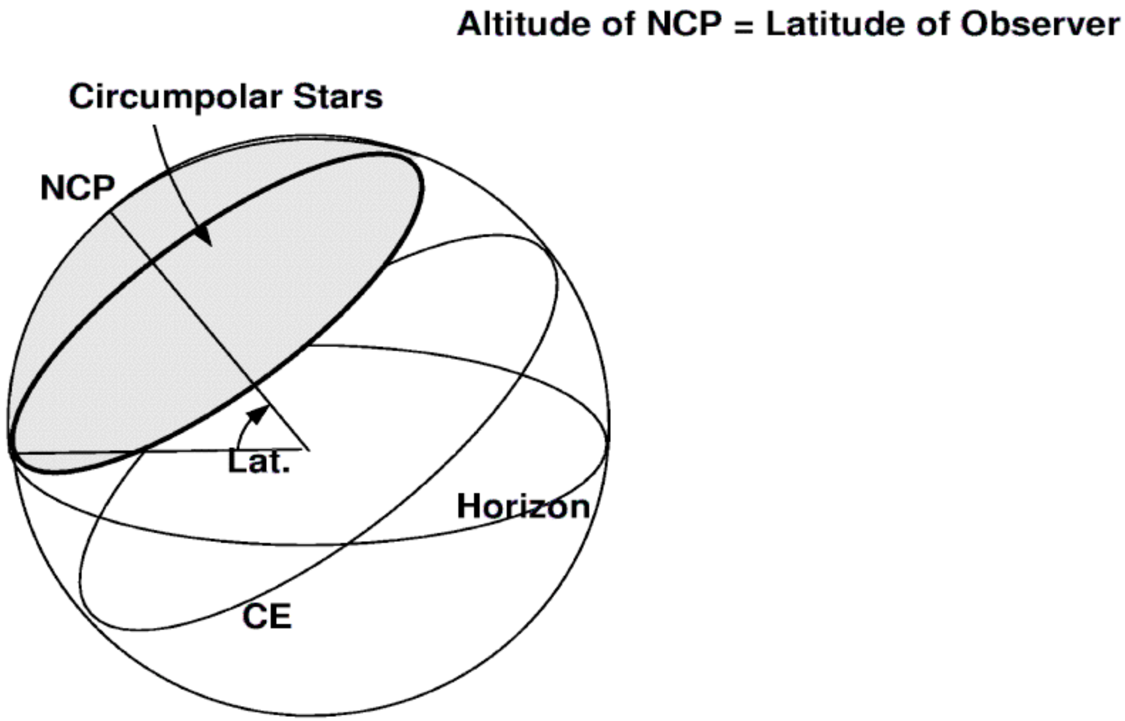
*Equatorial System with RA*



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



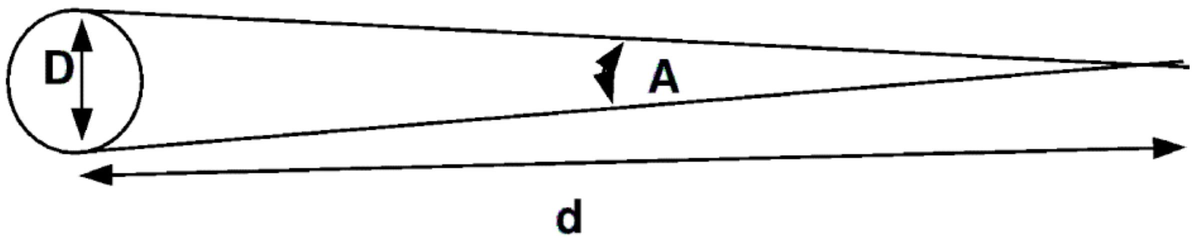
There are some consequences of having a tilted coordinate system. For example, some stars never set nor rise, but instead have their declination circles always above the horizon. These are the circumpolar stars. Strictly speaking, those that never rise are also circumpolar, but since we do not, by definition, 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°. The width of the index finger is about 1°. The width of the four knuckles is about 10°, while the lengths of the sections of the index finger are 3, 4, and 6°. The "Pointers" in the Big Dipper are about 5° apart.

*Small Angle Formula*




$$A = (D/d) \times 206{,}263 \text{ arc sec}$$

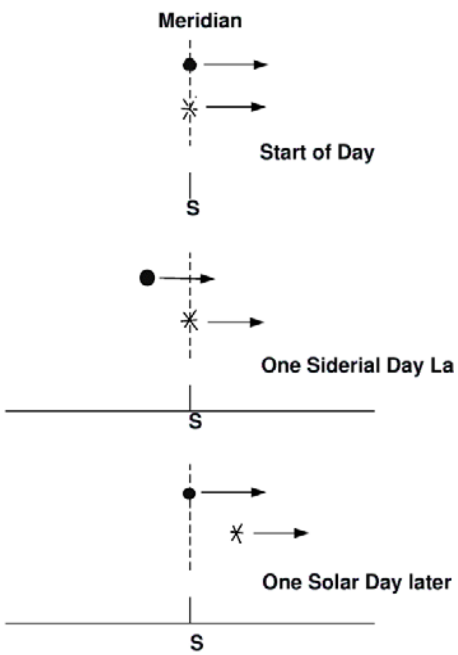
$$D \approx \frac{d \times A}{206{,}265} \; where\ A\ is\ in\ seconds\ of\ arc$$

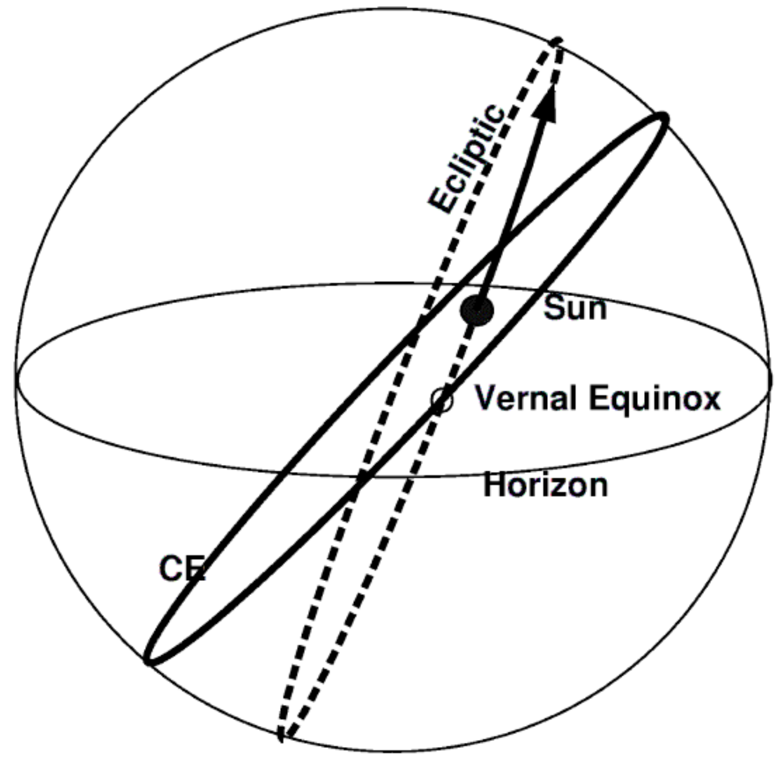
*SUN'S MOTION*

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

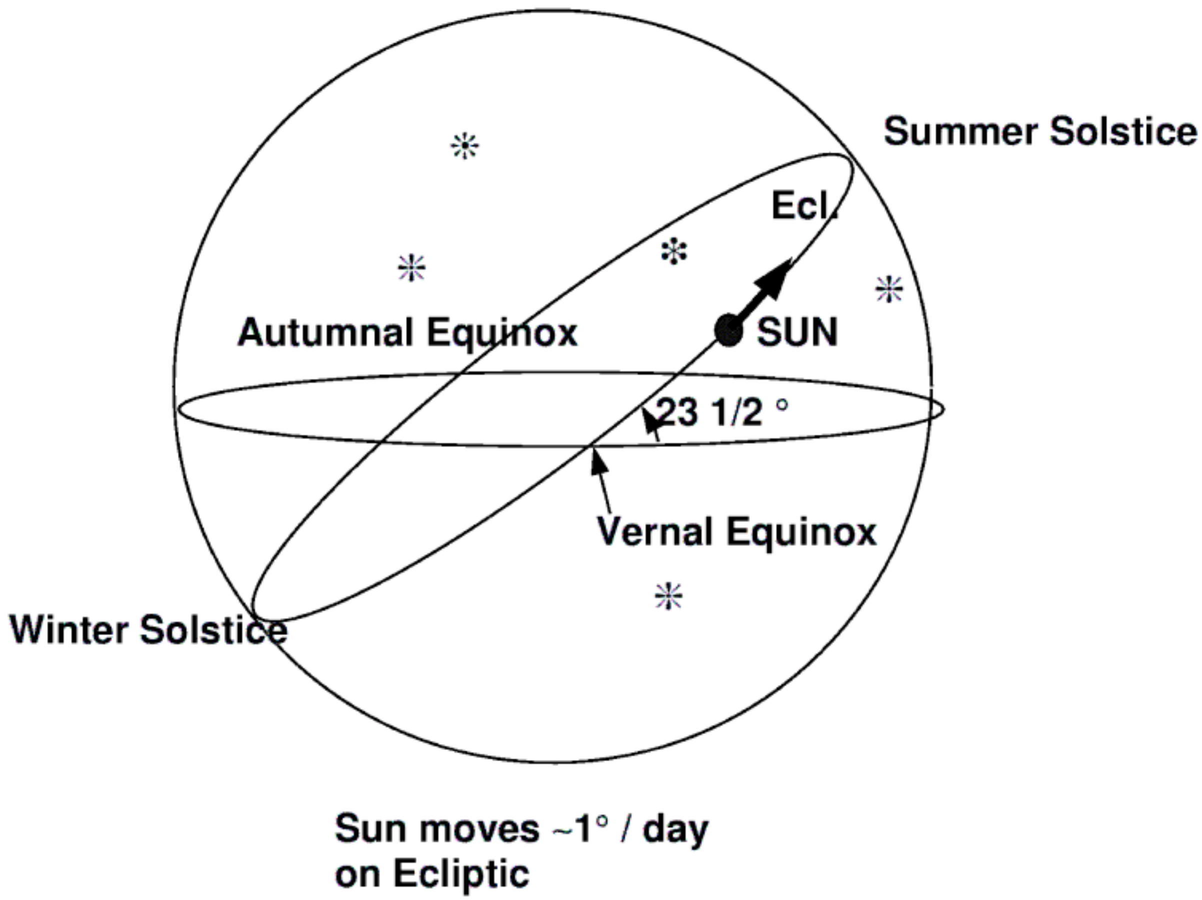
Annual Motion of Sun w.r.t. stars is about 1°/day W to E

Ecliptic
Equinoxes
Solstices



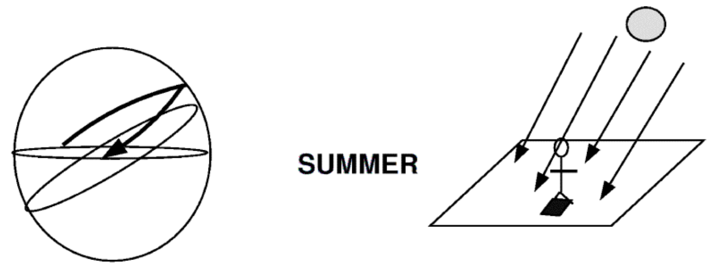



Redrawing this, ignoring the horizon circle, etc.:

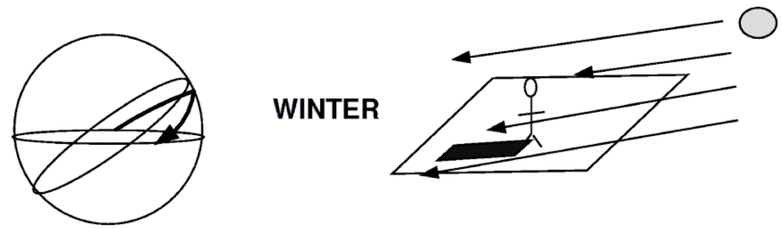


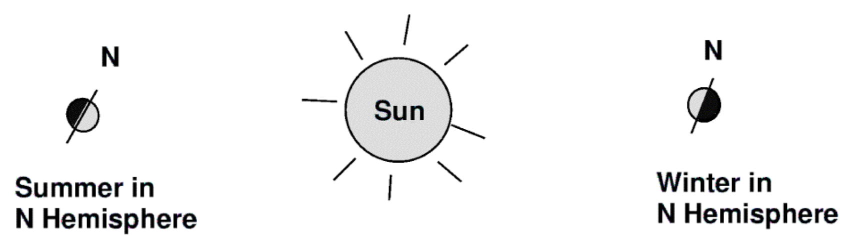

Note: The Vernal Equinox is chosen as the zero point for RA. Precession changes the RA, DEC of an object with time.

*SEASONS*



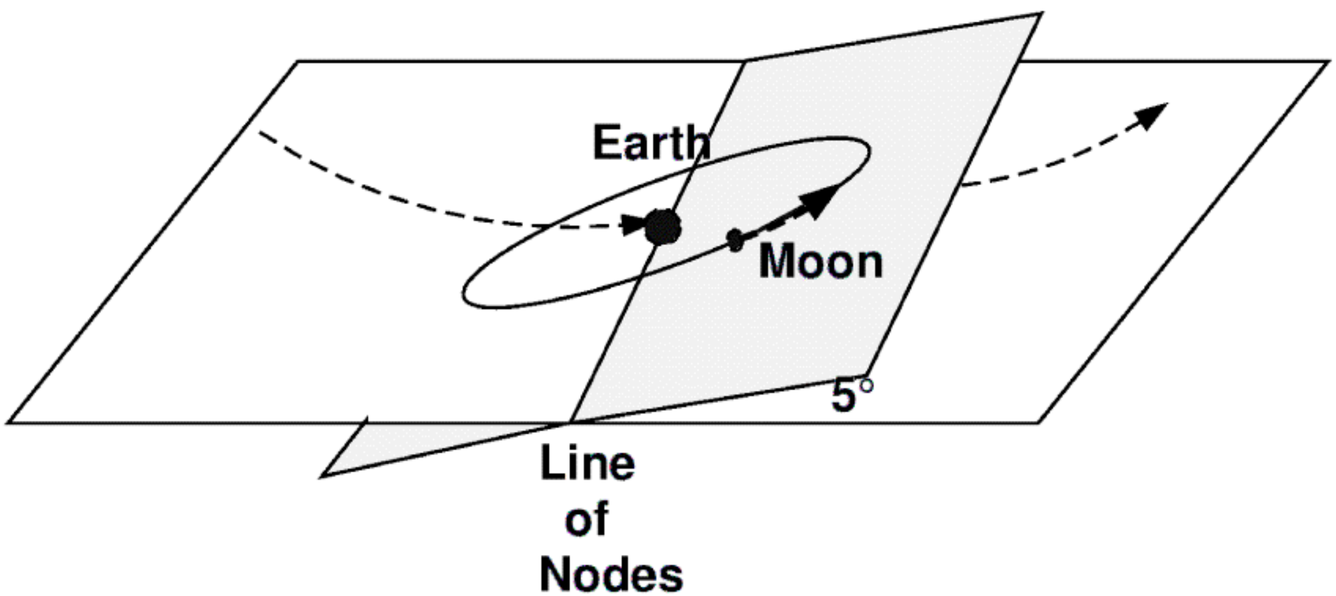

***Seasons are NOT due to variations in the earth-Sun distance, but due to the obliquity of the ecliptic.***



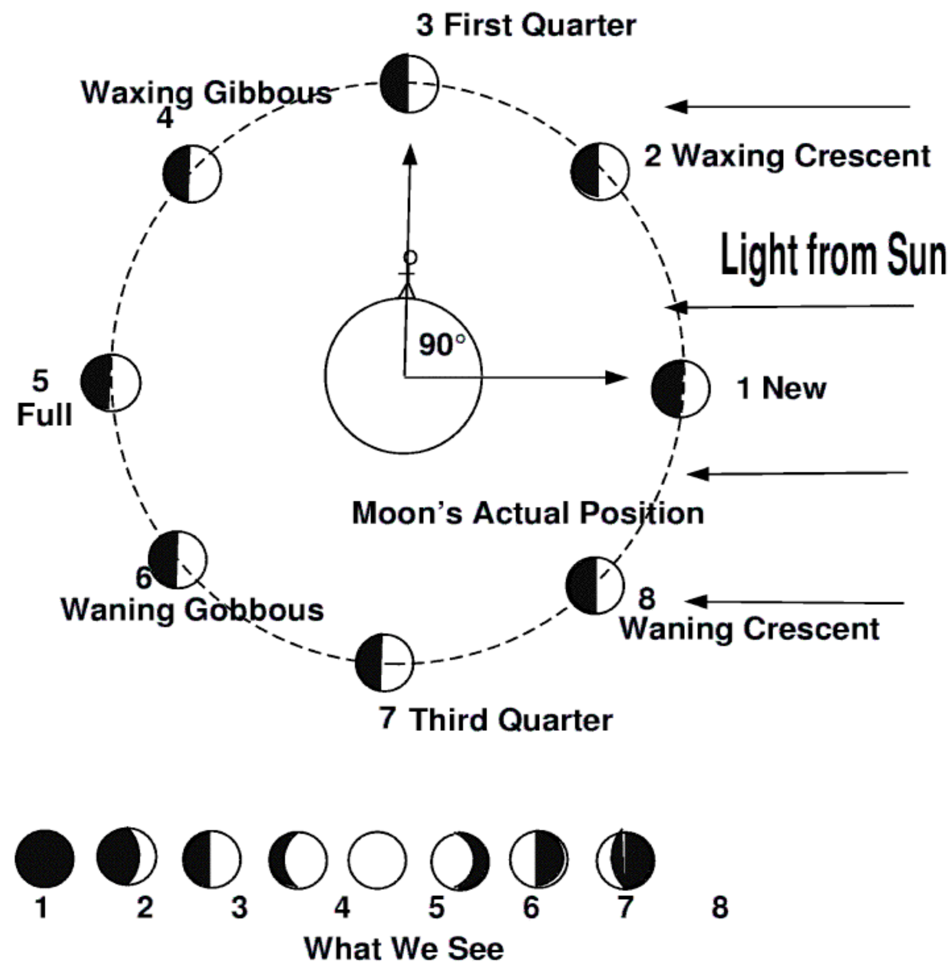
*MOON'S MOTION*

The Moon moves about 13°/day w.r.t. the stars, on a path near, but not on, the ecliptic. The inclination of the moons orbit to the ecliptic varies somewhat from year to year, but is approximately 5°. The intersection of the Moon's orbital plane with the ecliptic defines the Line of Nodes. The Ascending Node is that which the moon passes through when going through the ecliptic from south to north, while at the descending node it goes through the ecliptic from north to south.



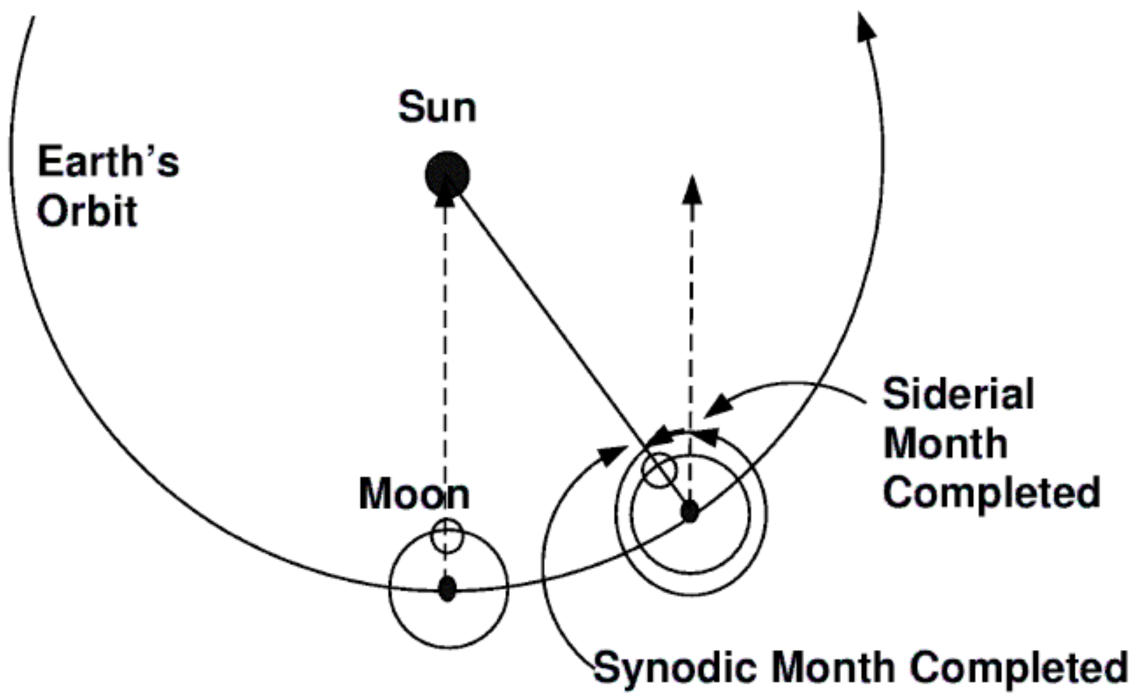
*LUNAR PHASES*

As the Moon travels around the earth, we see various degrees of its surface illuminated, what we call phases.

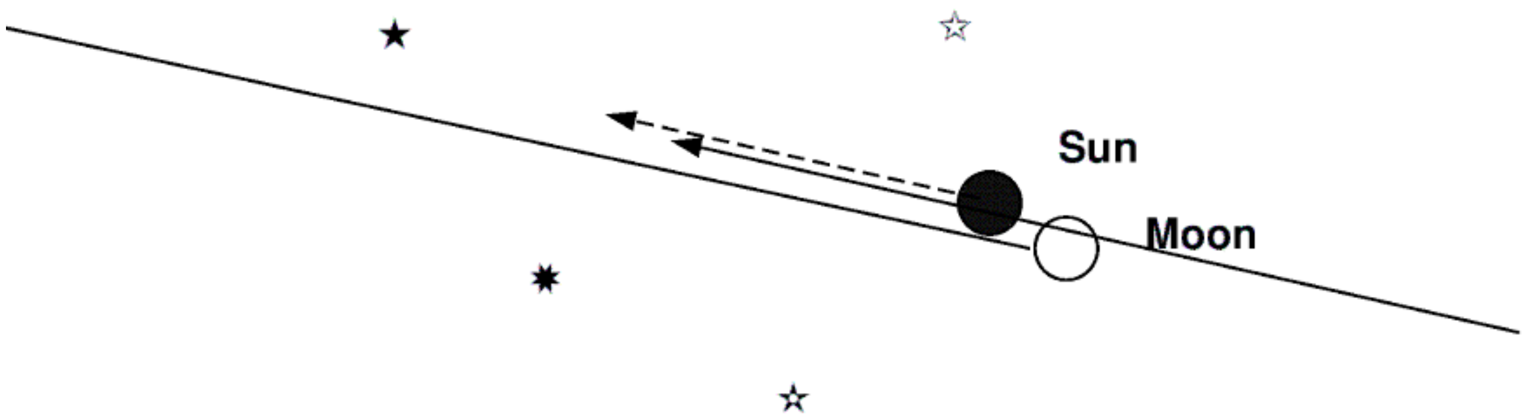


*LUNAR MONTHS*

Due to the fact the Earth moves around the Sun as the Moon orbits the Earth, the length of time it takes for the moon to pass through all of its phases is slightly longer that its true orbital period in space. We therefore distinguish between the Sidereal (true orbit) Period - 27.3 days, and the Synodic Period - 29.5 days. One way of thinking of this is that it takes 27.3 days for the moon to line up with the same star in the sky, but in the meantime, the sun has moved a little bit, so, for example at New Moon, it takes longer for the Moon to catch up to the Sun.

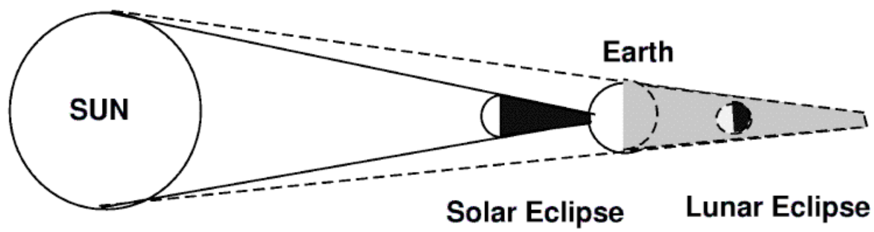


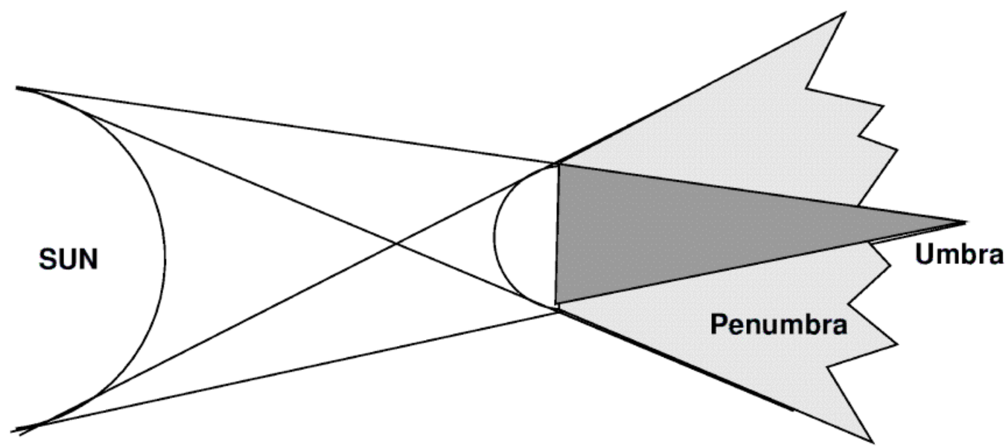
Looking at how this is seen from the vantage point of the Earth:



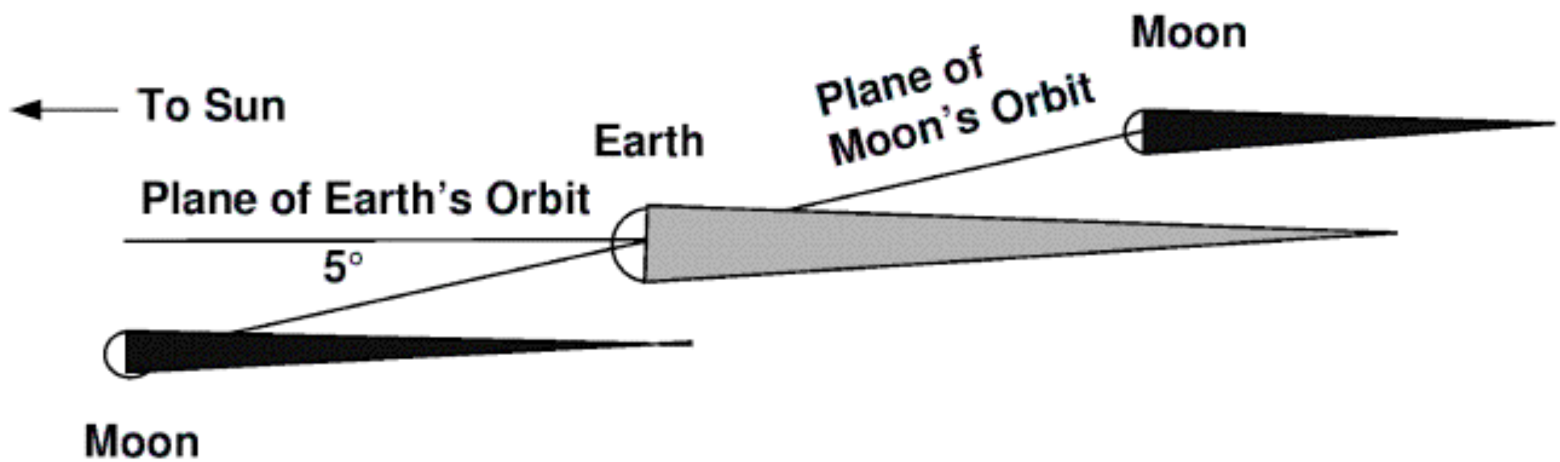
*ECLIPSES*

When the Moon passes between the Earth and the Sun, we may see a Solar Eclipse. When the Moon passes into the shadow cast by the Earth, we get a Lunar Eclipse. If an observer is located inside the Umbra, where the light from the Sun is totally blocked out, they would see a Total Solar Eclipse. If some sunlight is visible, the observer is in the Penumbra, and it is a Partial Solar Eclipse. Due to the varying distance of the Moon from the Earth, sometimes its shadow does not reach the surface of the earth, and and a narrow ring or annulus of the Sun is visible - an Annular Eclipse. Similarly, the Moon can be totally within the Earth's Umbra (total lunar eclipse) or not (partial lunar eclipse). Notice that when a total lunar eclipse occurs, it is visible from half the Earth, while only a small part of the earth can witness a total solar eclipse.



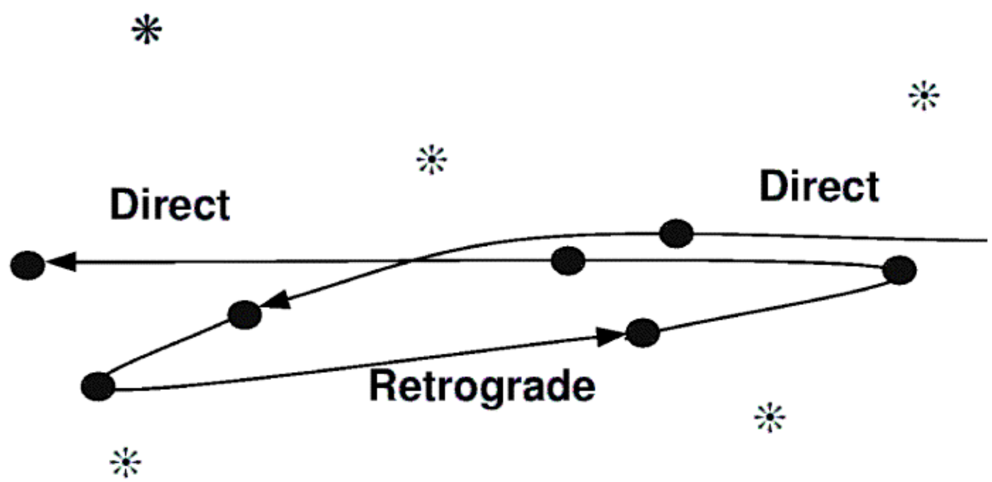
Furthermore, because of the tilt of the Moon's orbit w.r.t. the ecliptic, an eclipse does not occur at every new or full phase. It can only happen when the Moon is near the ecliptic (near one of the nodes).



*PLANETARY MOTION*

Observations:

1. Planets usually move W to E with respect to stars - **Direct Motion**
2. Sometimes move E to W w.r.t. stars - **Retrograde Motion**
3. Always near the ecliptic (but not always on it).
4. All reach **Conjunction** with the Sun
5. Not all reach **Opposition**
   Mercury - 23° maximum elongation from Sun
   Venus - 46° maximum elongation from Sun
6. Mars, Jupiter, Saturn are brightest at Opposition




IT IS THIS MOTION WHICH BAFFLED EARLY ASTRONOMERS AND DROVE THEM TO (EVENTUALLY) DEVISE/REVISE MODELS TO EXPLAIN IT.

MODEL - a conceptual picture (or analogy) of how something works.

***Earliest Astronomy***

Universe is Finite, Geocentric, run by Gods.

Babylonians - As early as 3800 BC they were observing star positions, planetary motions, making calendars and star charts. But they apparently made no real attempt to explain "how" or "why".

The Greeks attempted to try to explain these motions on the basis of mathematical/geometry models. One of these, developed by Aristarchus, placed the Sun at the center of the planetary system, which included the Earth as a planet. This model was refined further by Copernicus over 1500 years later, and given its correct form by Johannes Kepler, the first person to derive realistic physical laws of nature, his **Three Laws of Planetary Motion**. These laws were given a physical foundation by Isaac Newton, and accurately describe the motions of the planets, their moons, as well as all other objects in the universe.