Observing the Night Sky: Locating Objects

As I looked outside last night around 8:00 PM there was a large bright light above and to the left of my neighbors house (approximately East). I wonder what that object is?

We can use a variety of reference materials to determine what those objects are if we know where and when we see them (and maybe some other bench marks). In order to determine *where* we will need to define a coordinate system(s)

Locating Objects

A coordinate system is defined so that we may use a set of numbers to locate an object

The Coordinate System is defined by specifying an origin and the nature (direction) of the coordinates.

Locating Objects

To locate an object on a flat (two-dimensional) surface (classroom arrangement, surface of the earth) two coordinates are necessary.

To locate an object in space (three-dimensions) three coordinates are necessary.

Locating Objects on Earth

Two angular coordinates, Latitude and Longitude, are used to locate objects on the surface of the Earth

The Earth rotates about an imaginary axis the passes through the North and South geographic poles. The Equator is an imaginary circle on the surface of the Earth located midway between the North and South poles. It is a Great Circle in that the plane containing it divides the Earth into two *equal* halves, the Northern and Southern hemispheres.

Latitude

The Equator is the origin (or zero point) for the Latitude coordinate.

Latitude: is the angle between the equator and any geographical location

Longitude

Longitude: is the angle around the equator to the point nearest the object to be located.

Where do we begin? The longitude line passing through Greenwich, England is the origin (zero point) of the longitude coordinate and is called the Prime Meridian. (direction, East or West is usually specified)

Angle Units

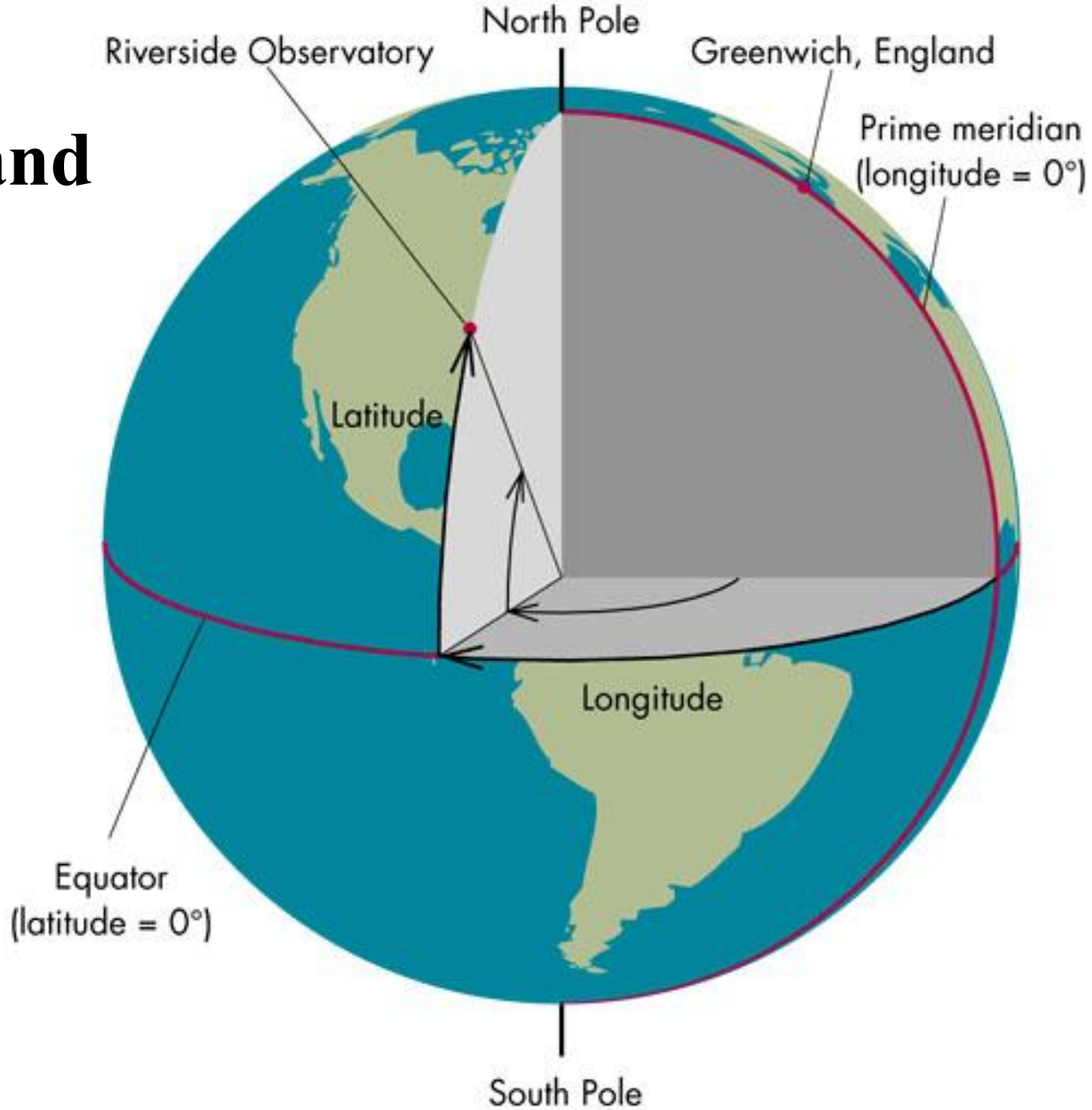
Latitude and Longitude are angular coordinates and are measured in:

Degrees

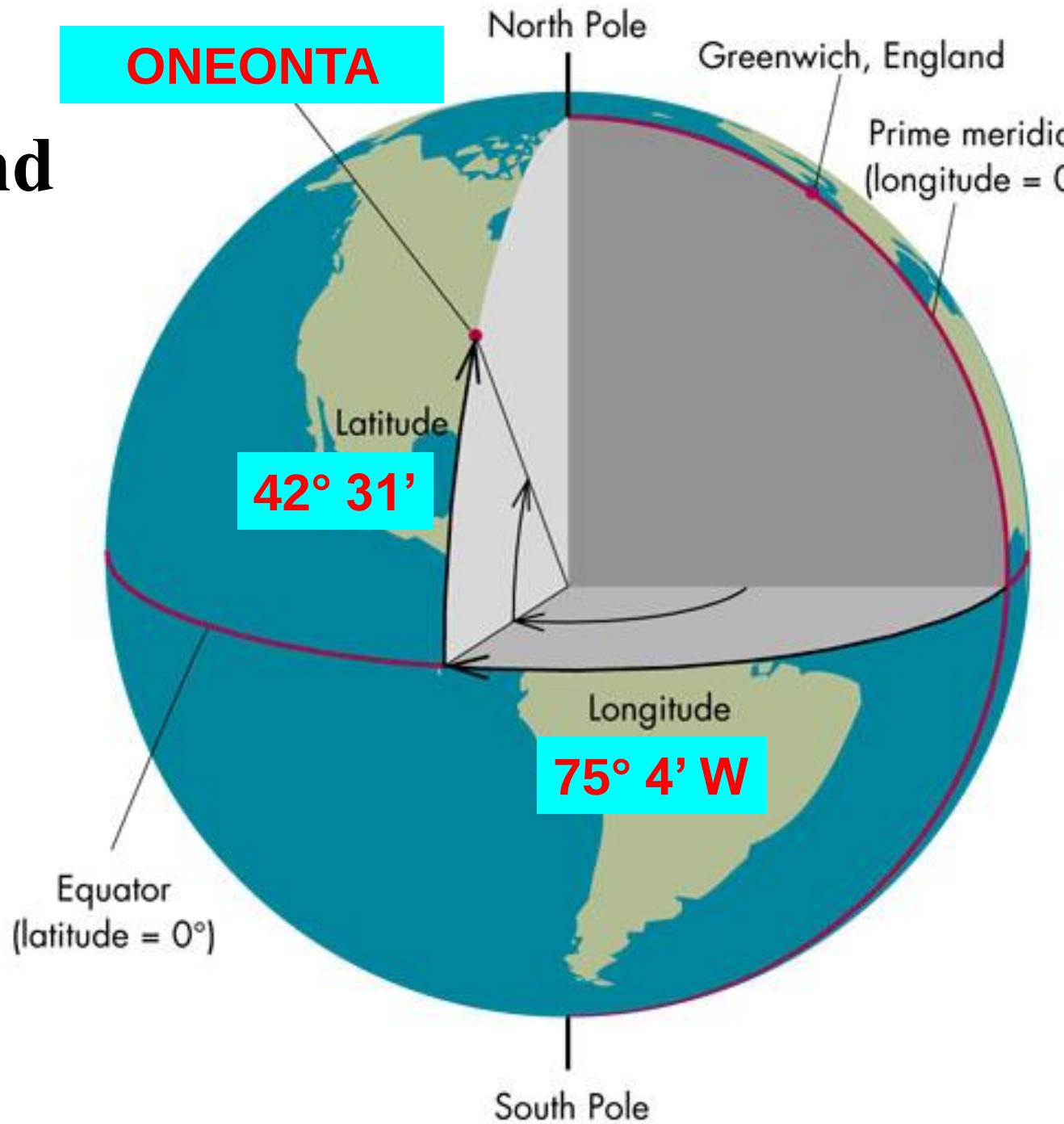
Minute of Arc is 1/60th of a degree

Second of Arc is 1/60th a minute of arc

Longitude and Latitude



Longitude and Latitude



Locating Objects: Horizon System

We can identify objects in the local sky using a coordinate system that is analogous to the latitude-longitude system.

In our local sky, the stars appear as lights on a dome (half of the Celestial Sphere). If we imagine that they do exist on a imaginary dome then two angular coordinates are needed to specify the position of any object

Zenith is the point directly over head in the celestial sphere

The Celestial Horizon is a circle consisting of all points 90 degrees from zenith.

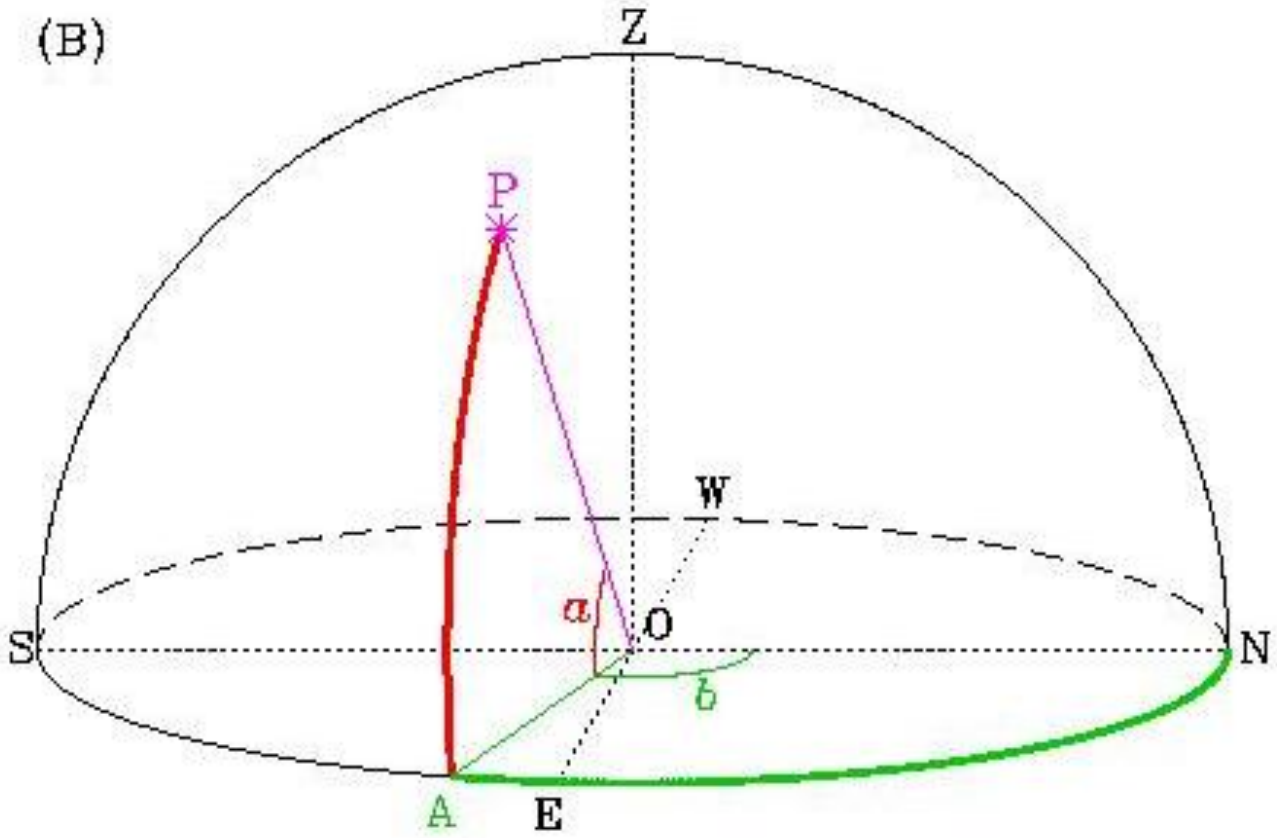
Altitude and Azimuth are the coordinates used to locate objects in the local sky.

Locating Objects: Horizon System

Altitude **is the angular distance above the celestial horizon (analogous to latitude)**

Azimuth **is the angular distance measured eastward from north along the celestial horizon to a point closest to the object (analogous to longitude)**

Horizon Coordinate System



Local Sky: Altitude Azimuth Plot

- http://www.tecepe.com.br/cgi-win/cgiasvis.exe
- City:
  Date: 24/1/2008
  Time: 03:00:00 GMT
  Latitude: 42°50.0'N
  Longitude: 75°00.0'W

- http://www.fourmilab.ch/cgi-bin/uncgi/Yoursky

Night Sky: Motion of Objects

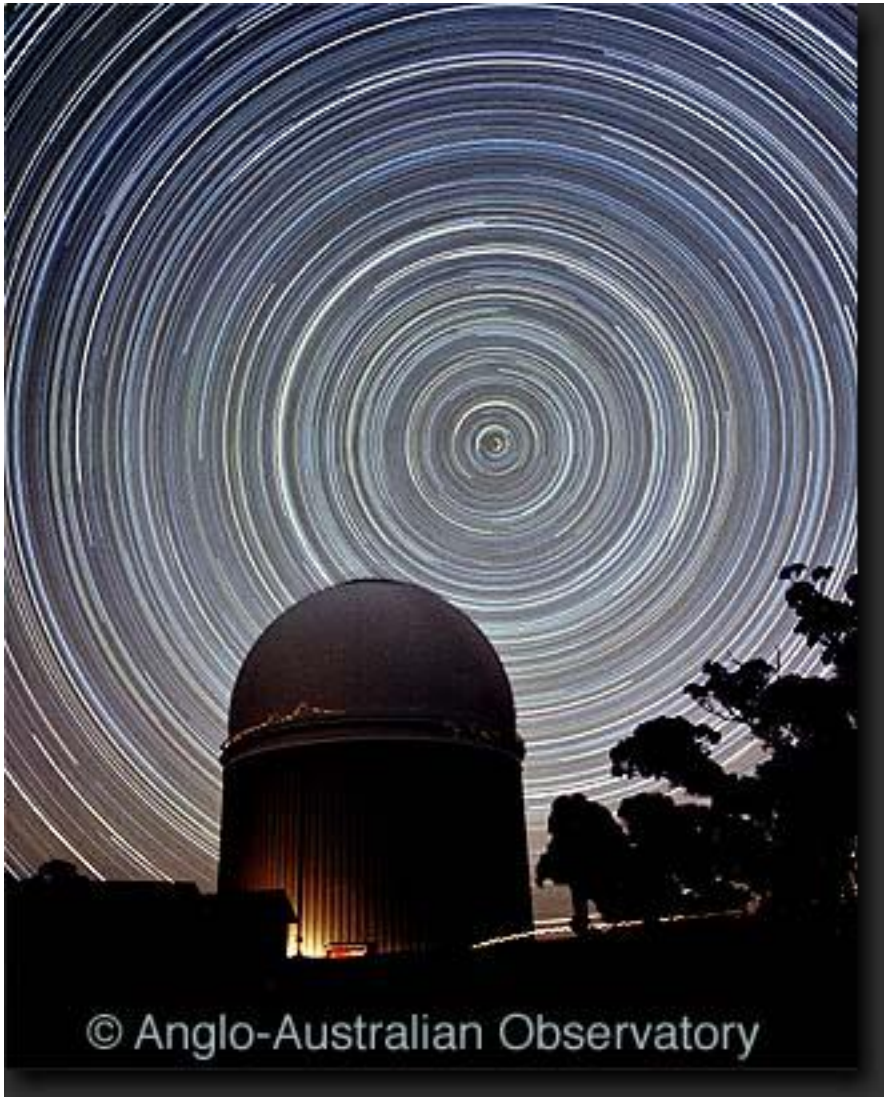
Through history, patterns in the motion of objects in the sky have been observed and recorded most notably:

The diurnal motion of the sun and stars

The annual motion of the sun and stars. (This could be observed by noting how the location of an object at set time changes from night to night)

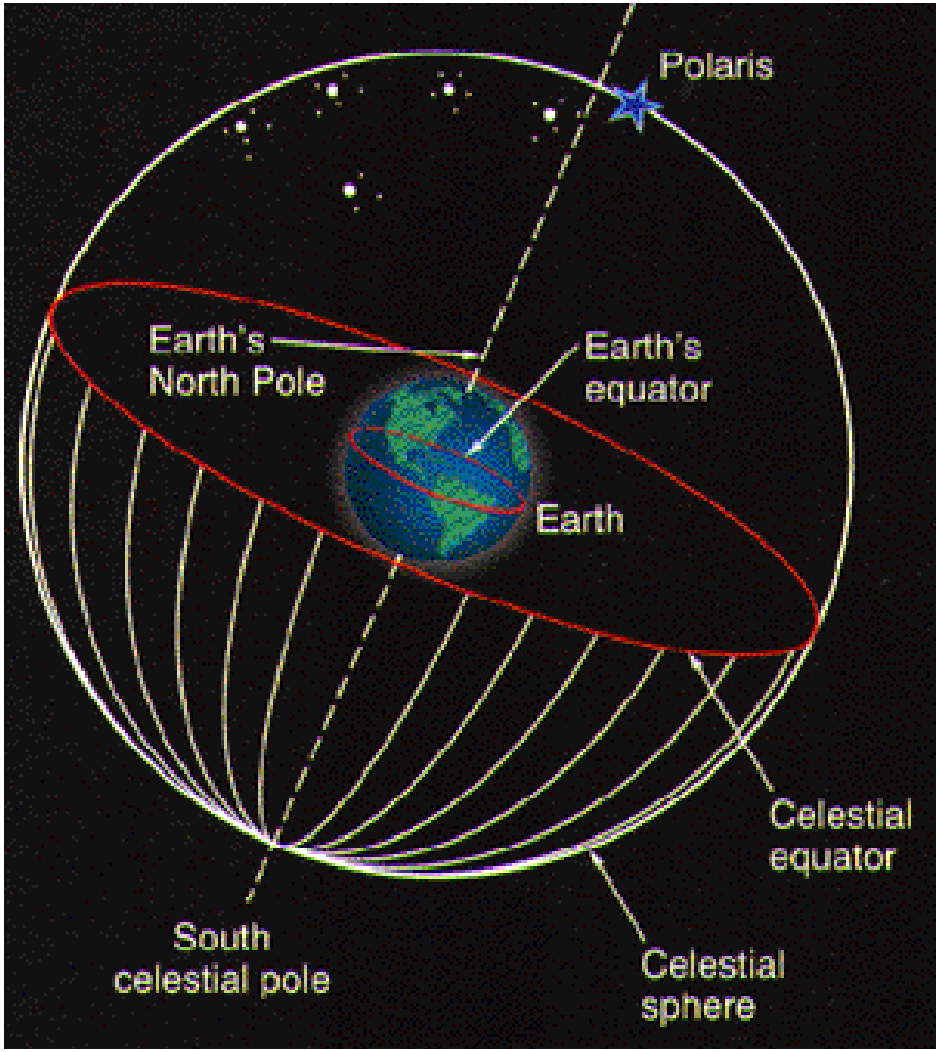
Features (phases, retrograde motion) of planetary motion.

Circumpolar Stars



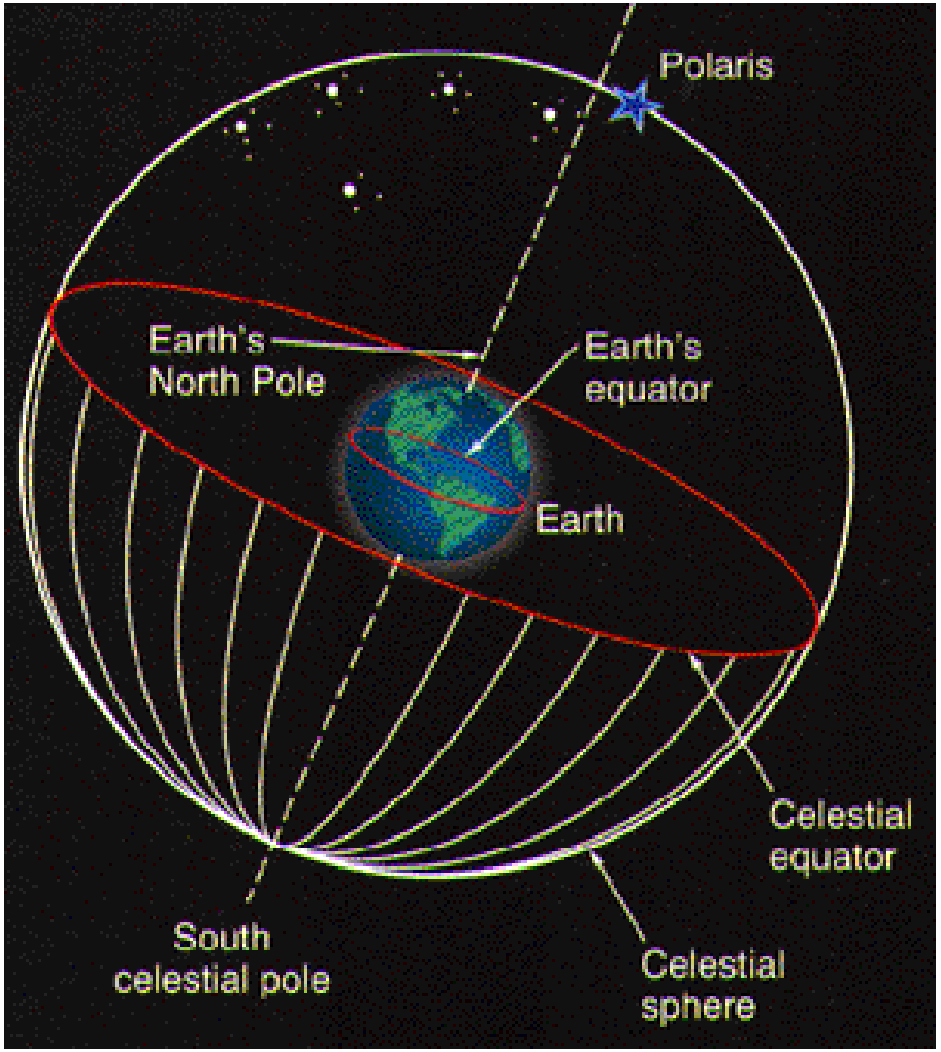
Day long exposure shows the paths traveled by the stars during the day (diurnal motion)

Celestial Sphere



- The stars may be thought of as residing on a large spherical dome known as the celestial sphere.

Celestial Sphere



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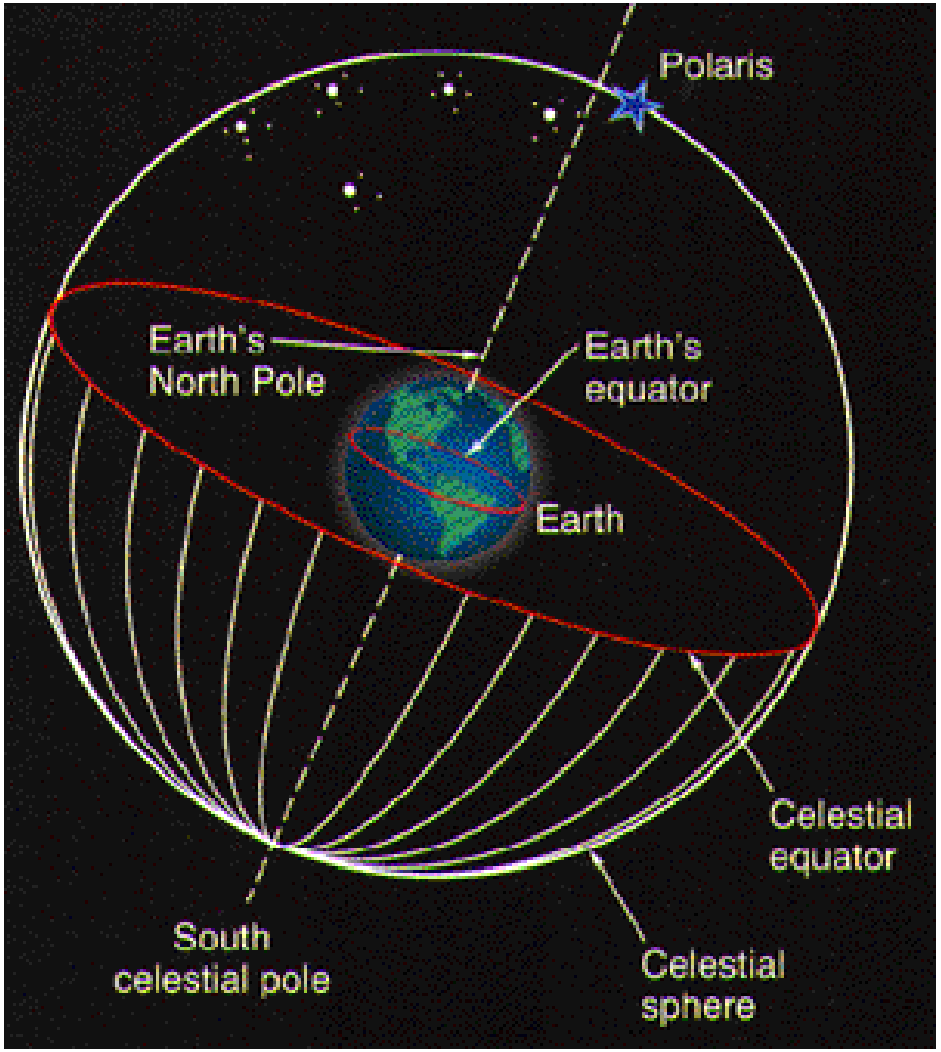
- The line coinciding with the Earth's rotational axis intersects the celestial sphere at the north and south celestial poles.

Celestial Sphere



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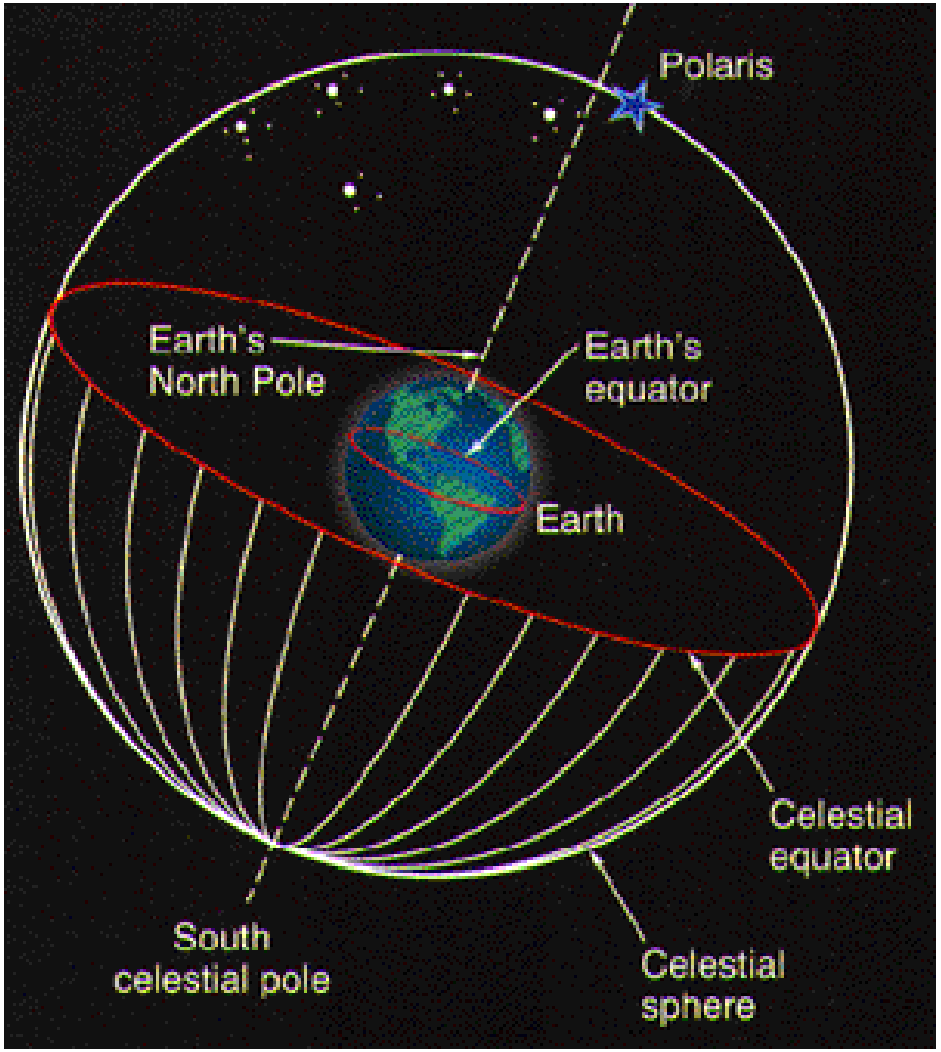
- The line coinciding with the Earth's rotational axis intersects the celestial sphere at the north and south celestial poles.

- An infinite plane containing the equator of the Earth intersects the celestial sphere in great circle known as the celestial equator.

Celestial Sphere



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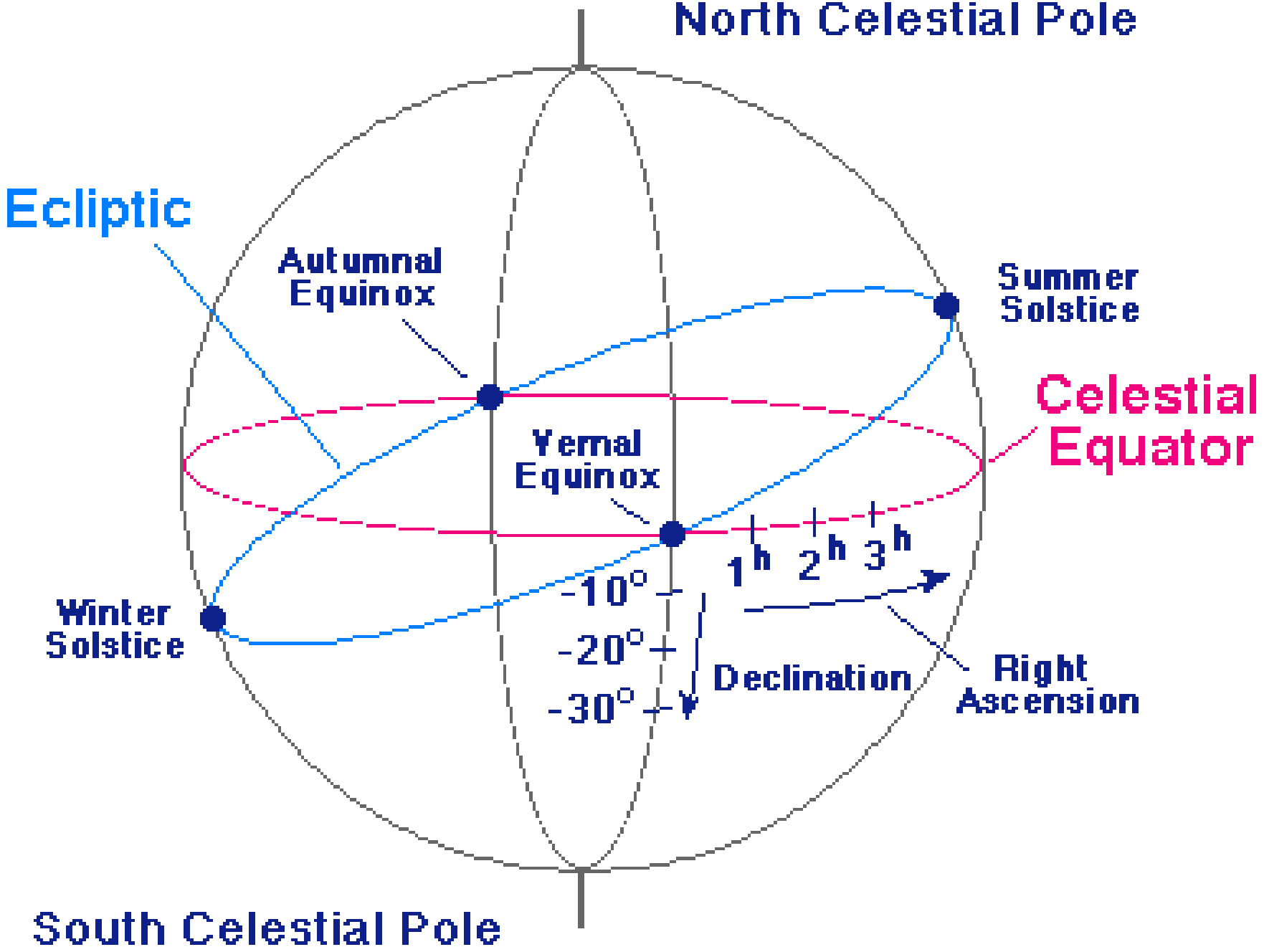
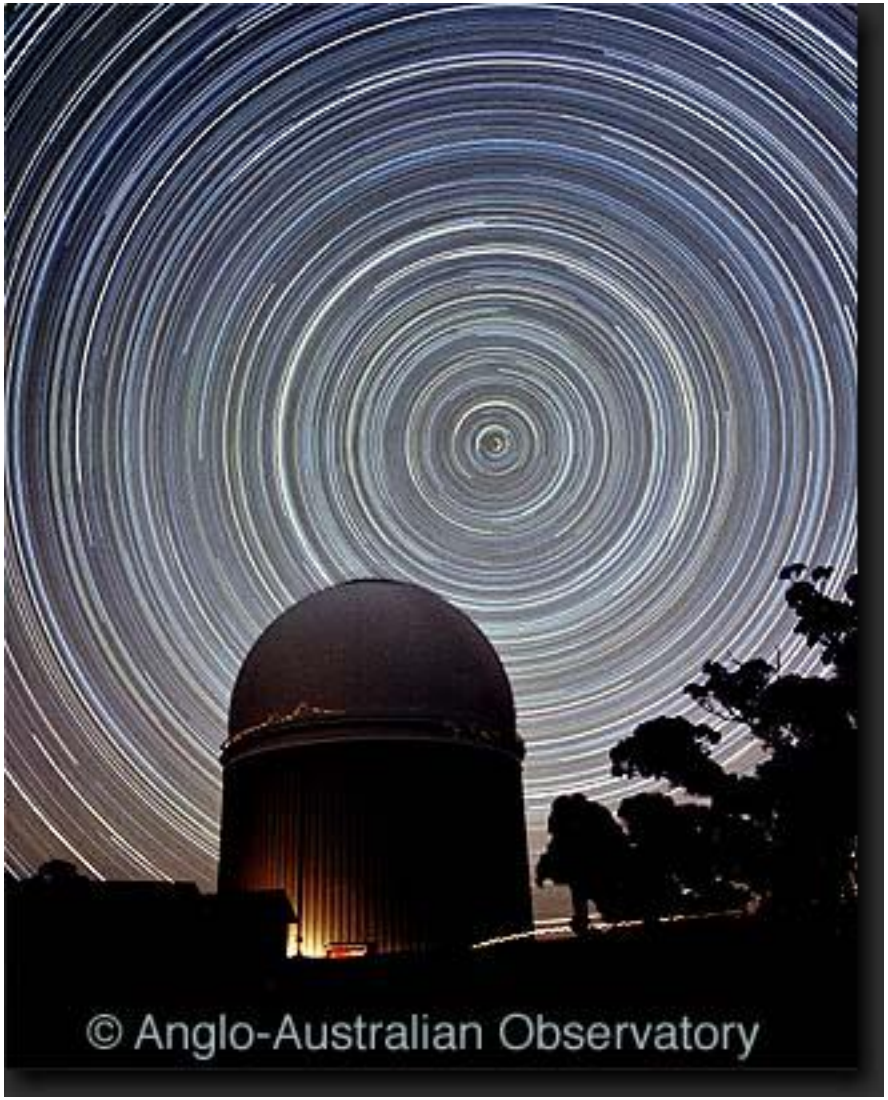
- Counterclockwise rotation of the Earth produces the same effect as clockwise rotation of the celestial sphere


North Celestial Pole
Ecliptic
Autumnal Equinox
Summer Solstice
Celestial Equator
Vernal Equinox
1h
2h
3h
-10°
-20°
-30°
Declination
Right Ascension
Winter Solstice
South Celestial Pole

- As observed from Earth, what is the daily (diurnal) motion of the stars?
- How does this apparent motion change with latitude?

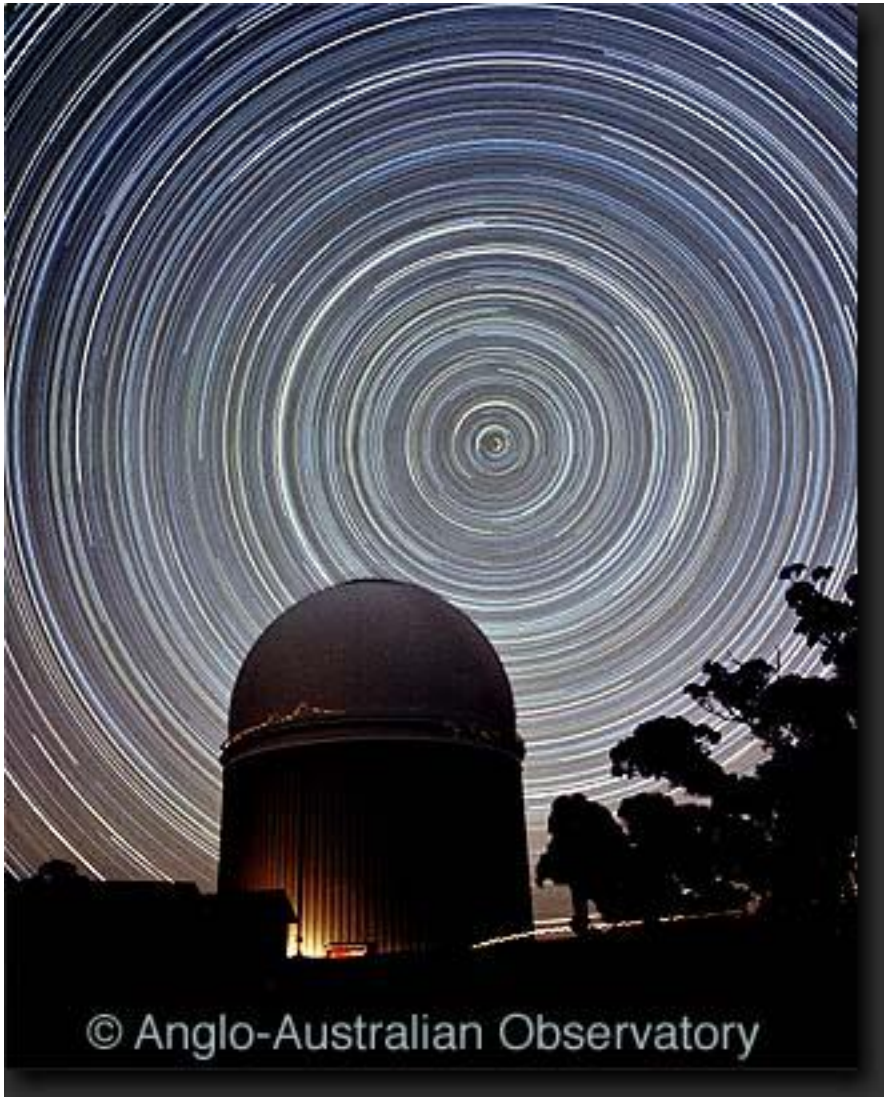
Circumpolar Stars



Day long exposure shows the paths traveled by the stars during the day (diurnal motion)

The stars appear to move in a circle about the celestial pole (in the northern hemisphere circles are centered approximately on Polaris, The North Star)

Circumpolar Stars



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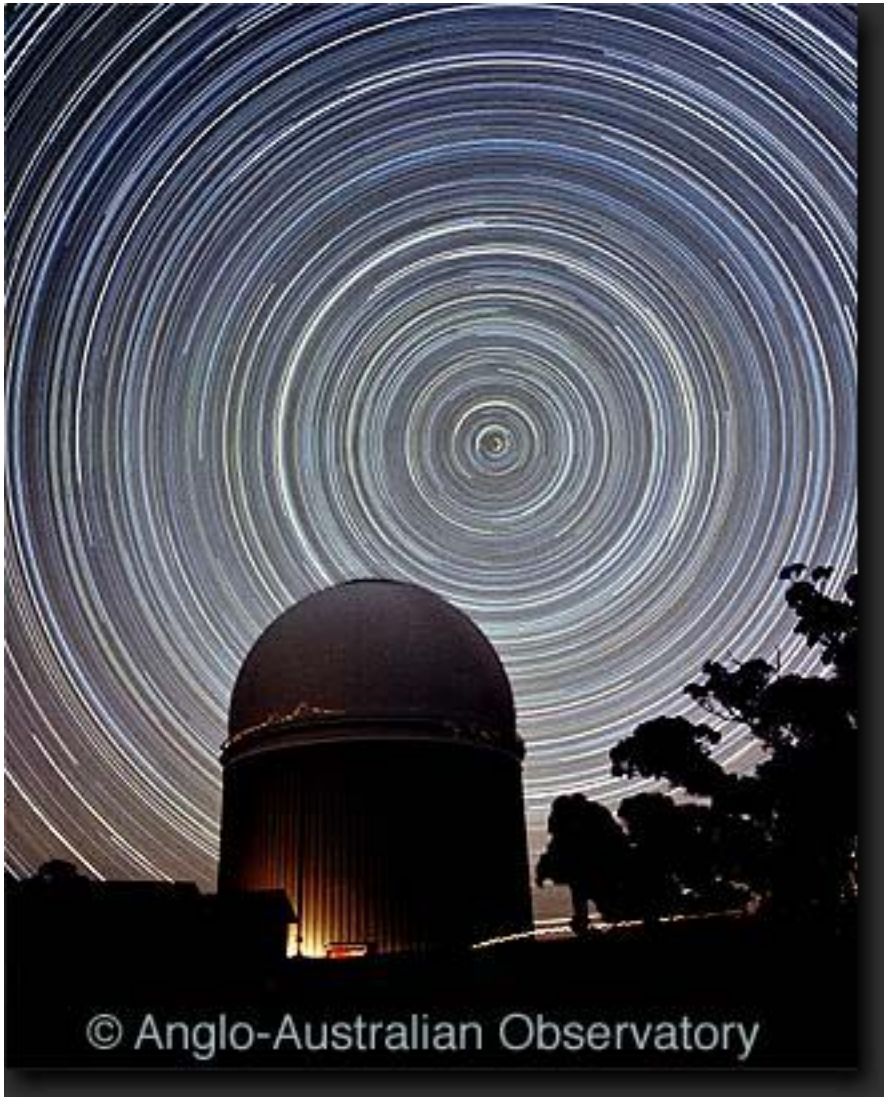
The altitude of the North Celestial Pole is Equal to the latitude of the observer.

Circumpolar Stars



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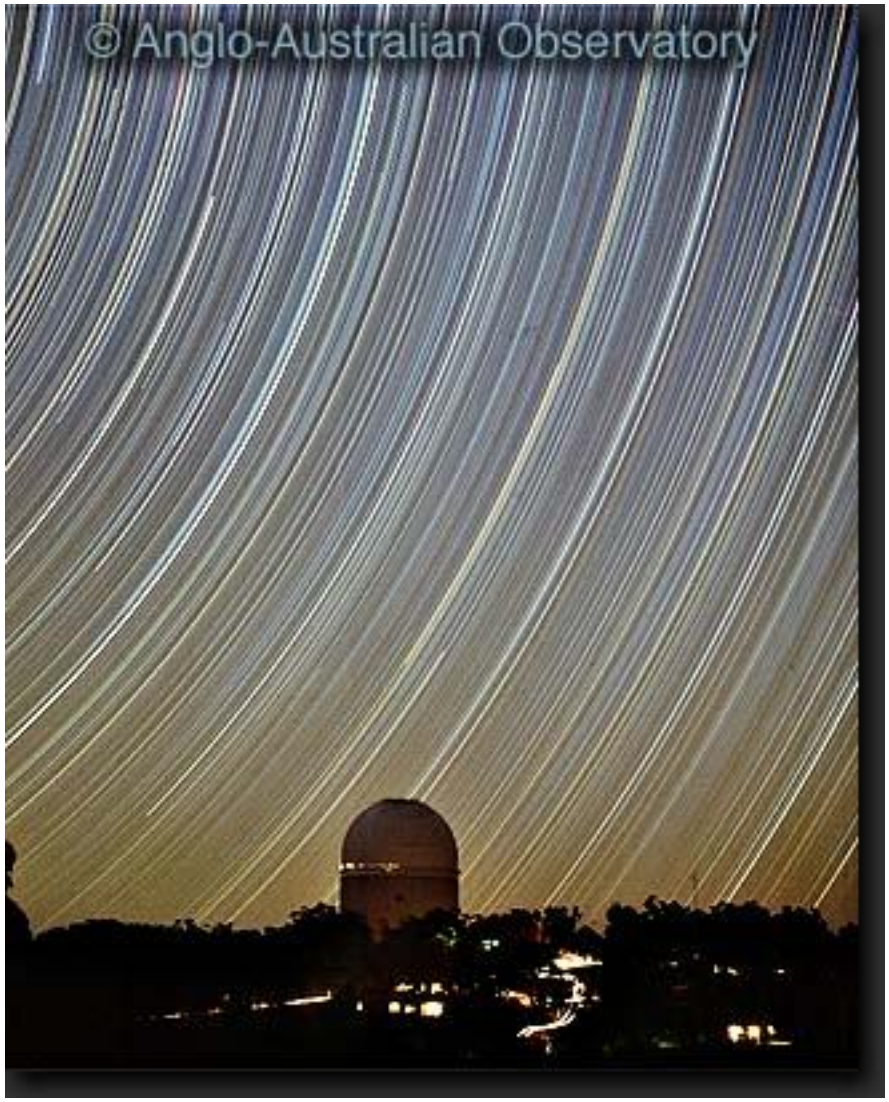
The altitude of the North Celestial Pole is Equal to the latitude of the observer.

Stars that never go below the horizon are known as Circumpolar Stars

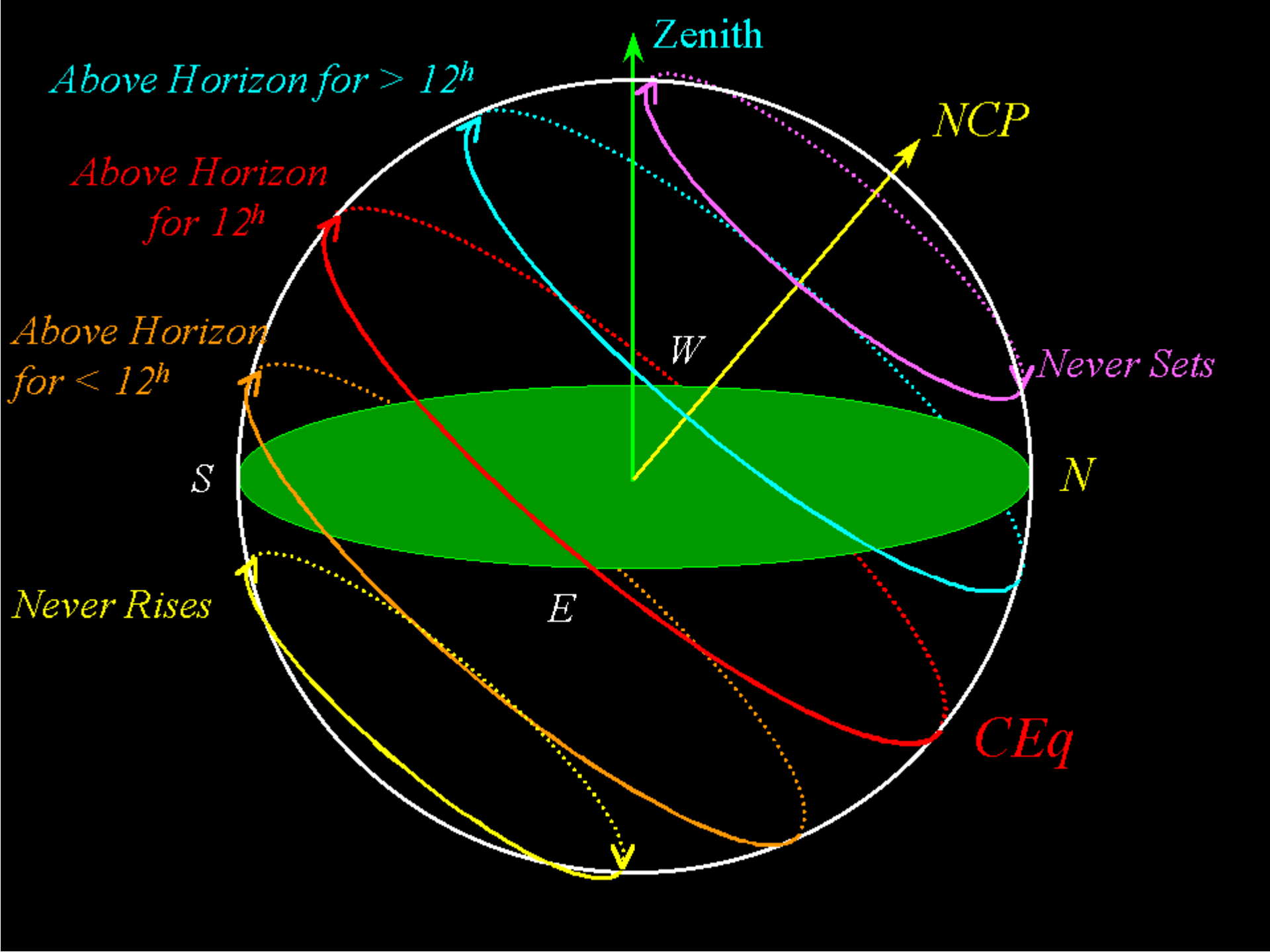
Circumpolar Stars

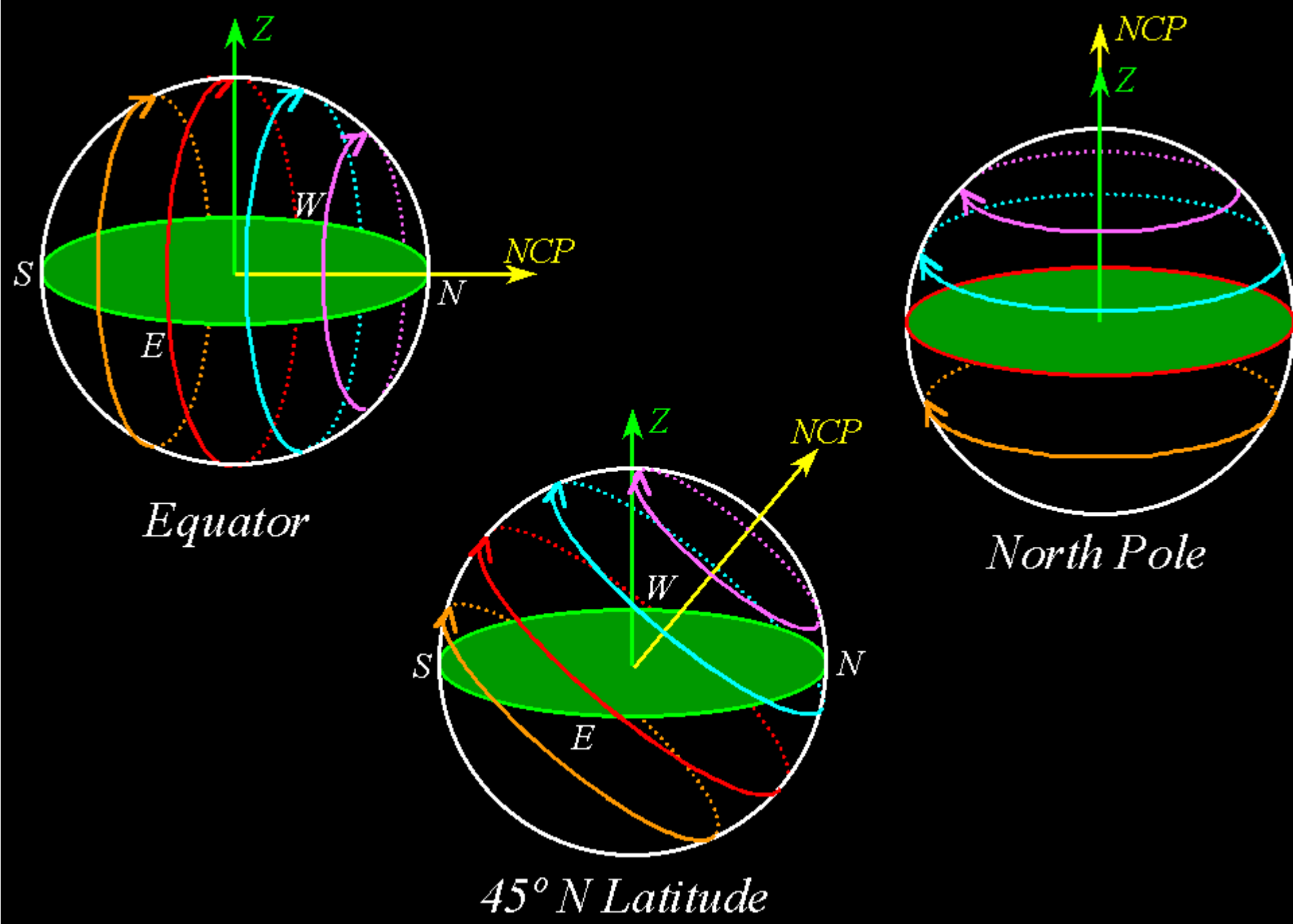


As one moves towards the equator, the altitude of the north (or south) celestial pole decreases.

The number of circumpolar stars decreases (more stars are rising and setting).

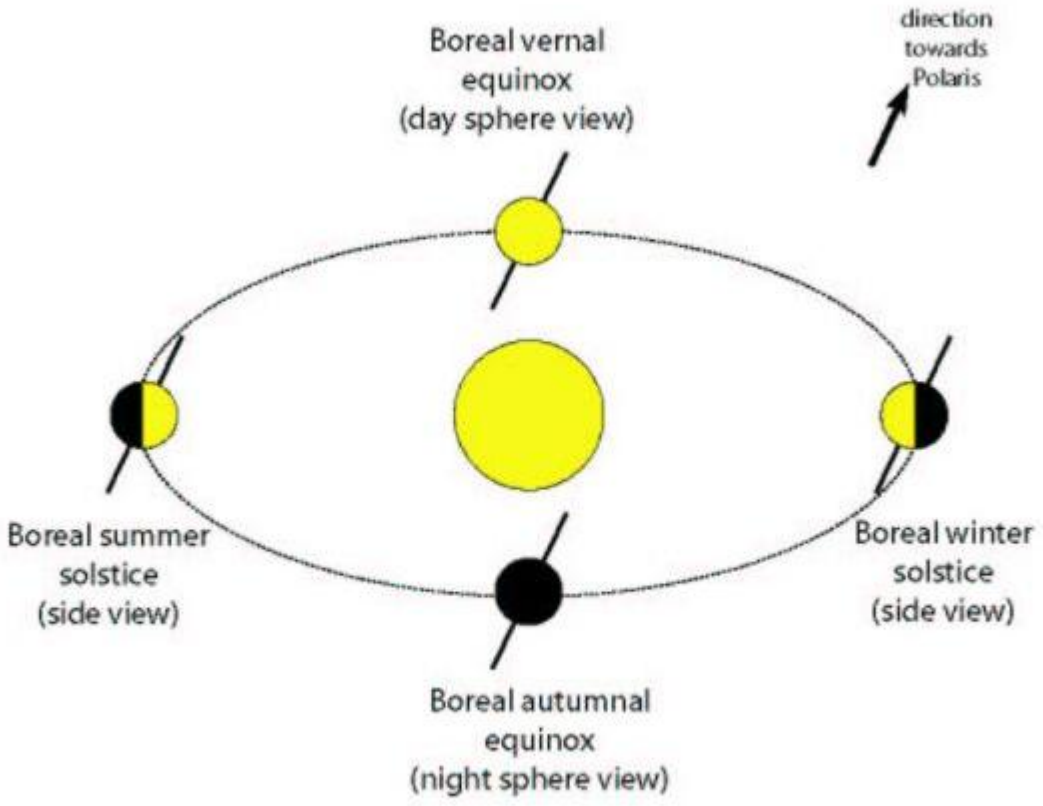
The stellar paths are more like straight lines.

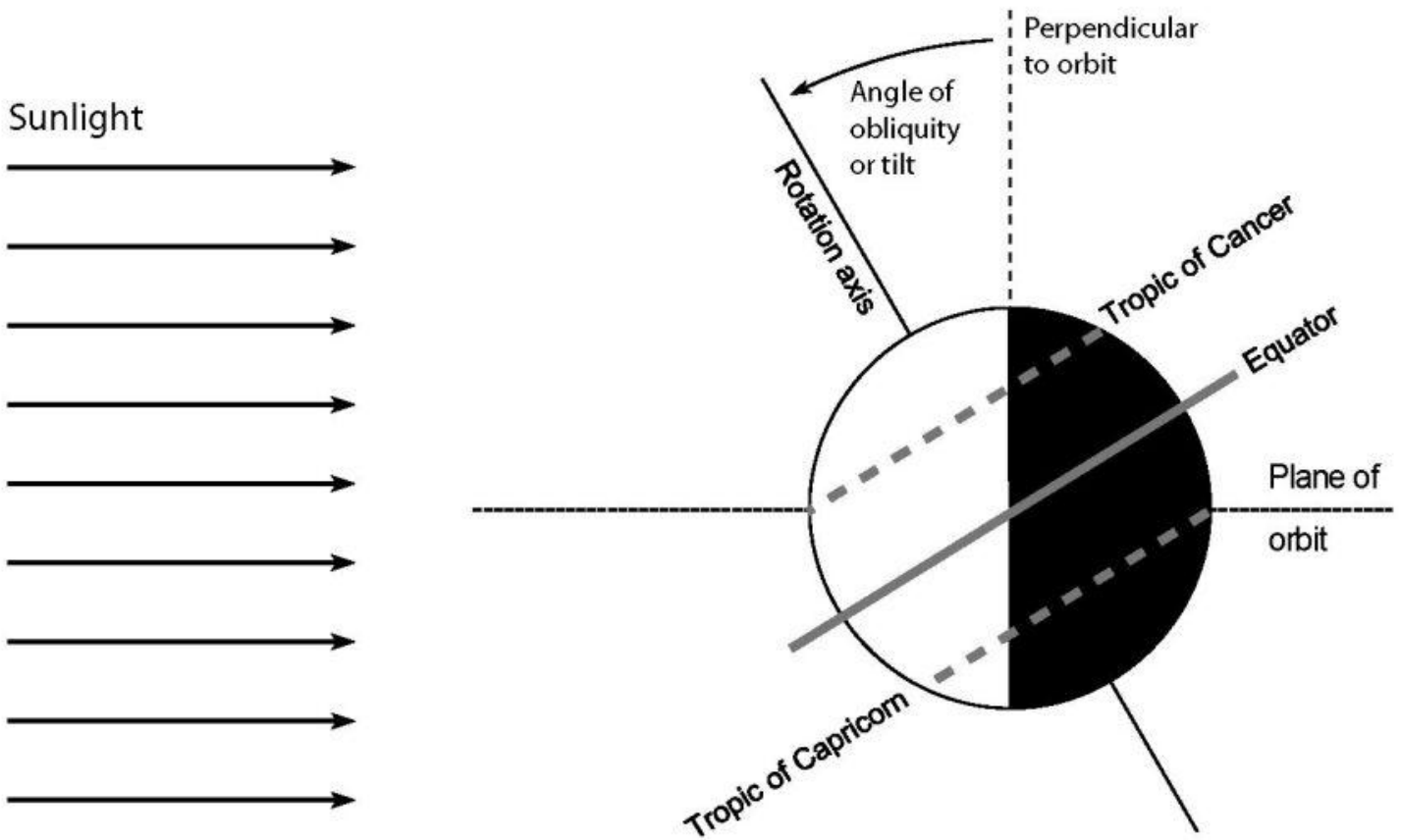

Zenith
Above Horizon for > 12h
NCP
Above Horizon for 12h
Above Horizon for < 12h
W
Never Sets
S
N
Never Rises
E
CEq

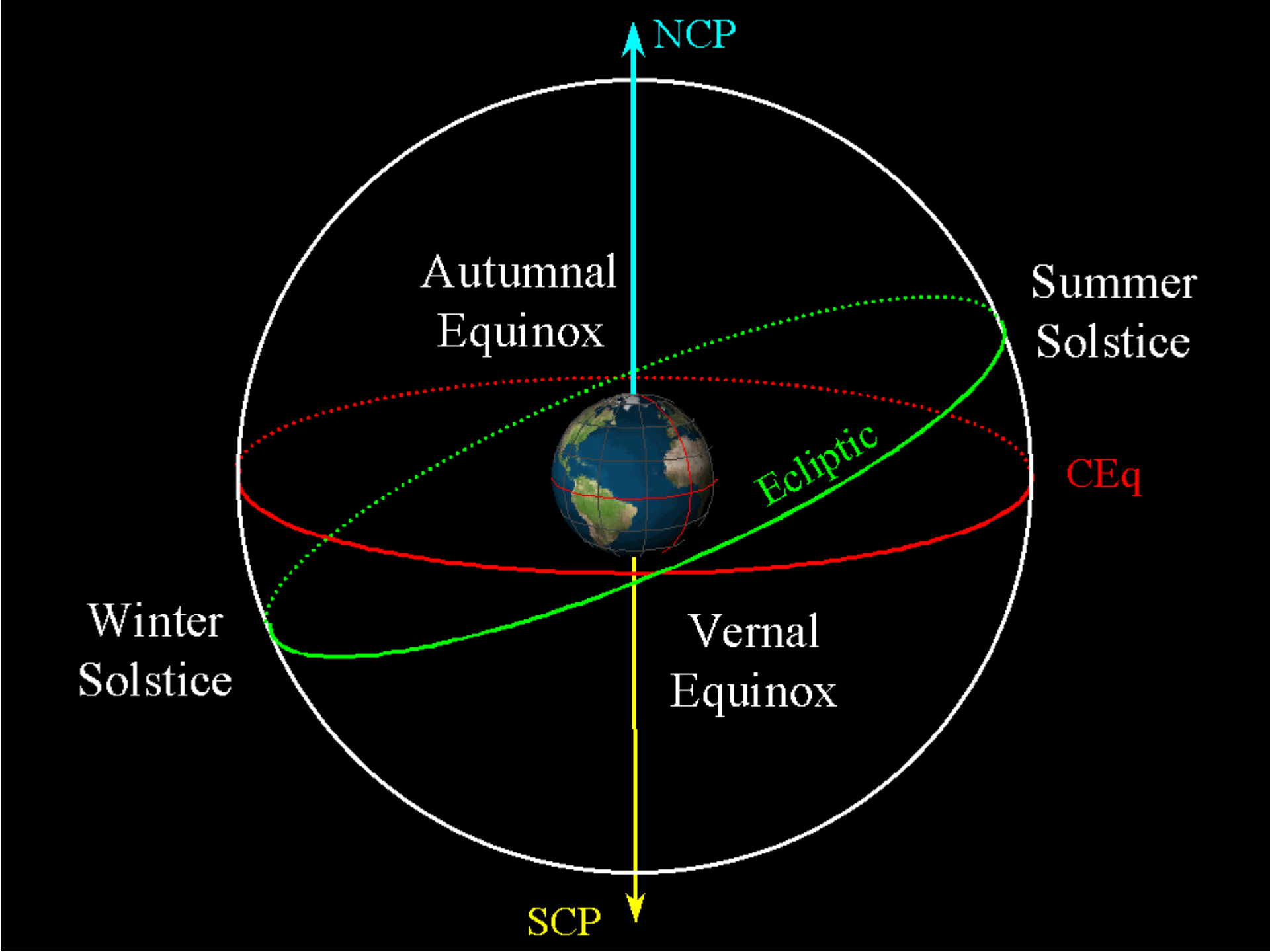

Z
W
S
NCP
N
E
Equator
NCP
Z
North Pole
Z
NCP
W
S
N
E
45° N Latitude

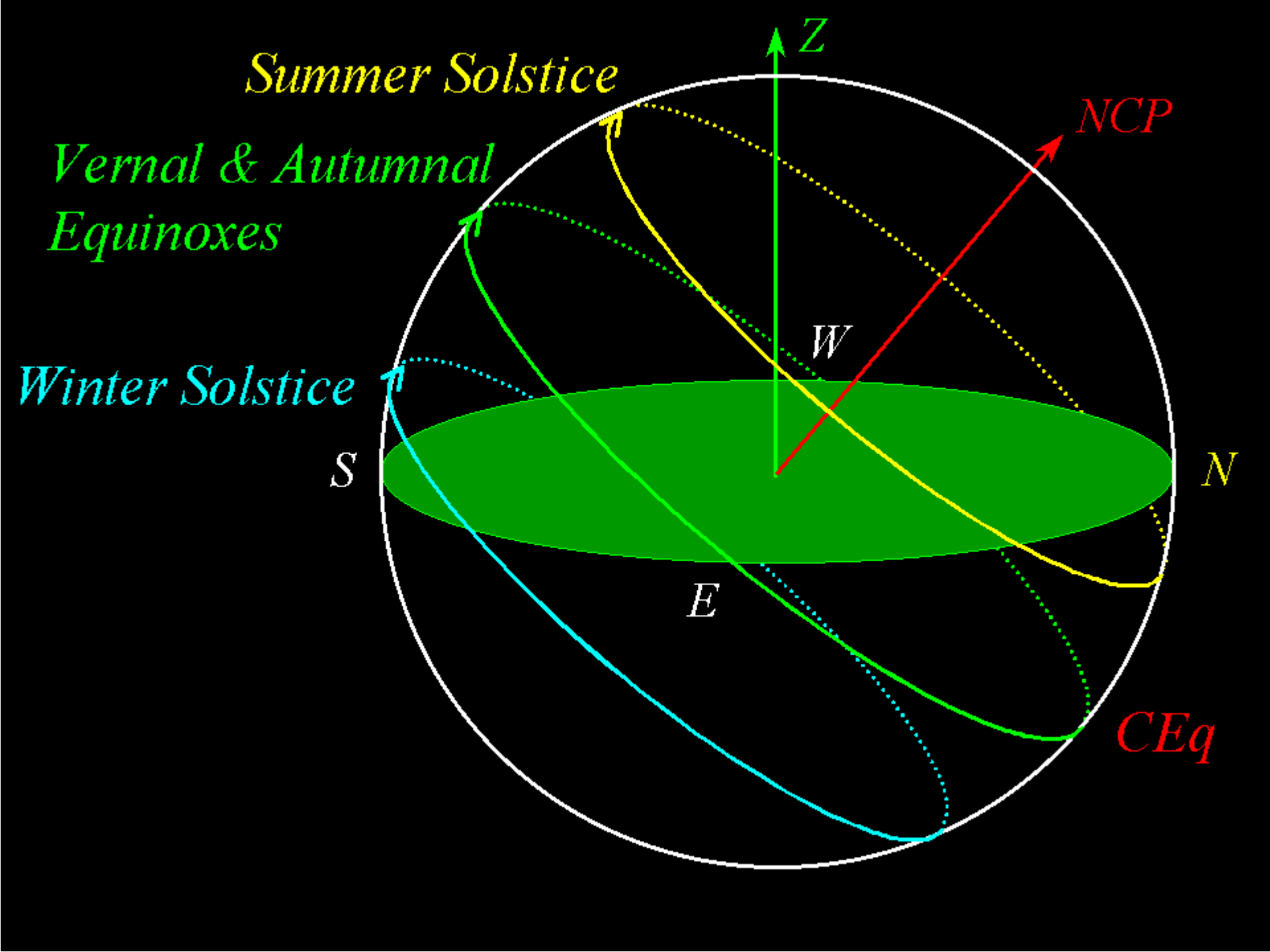
- How does the Sun appear to move through out the year?
- How is this apparent motion of the Sun (caused by the 23.5 tilt of the earth's rotational axis) related to the seasons?

Earth Rotational Axis Tilt in Annual Revolution About the Sun




Sunlight
Perpendicular to orbit
Angle of obliquity or tilt
Rotation axis
Tropic of Cancer
Equator
Plane of orbit
Tropic of Capricorn


NCP
Autumnal
Equinox
Summer
Solstice
Ecliptic
CEq
Winter
Solstice
Vernal
Equinox
SCP

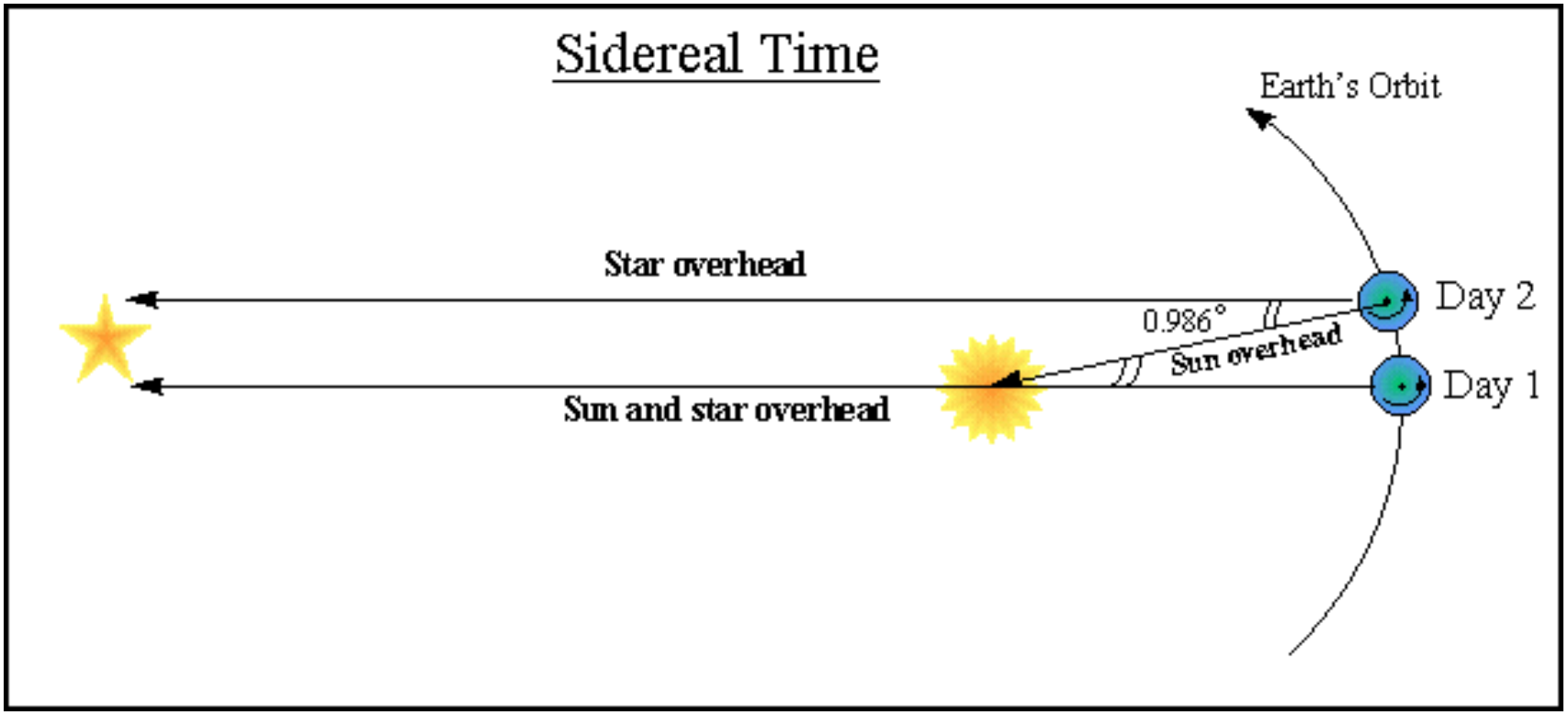

Summer Solstice
Vernal & Autumnal Equinoxes
Winter Solstice
Z
NCP
W
S
N
E
CEq

Rotation of the Earth

The Earth completes one rotation (360 degrees) every 23 hours and 56 minutes (and ~4 seconds). This period is known as a Sidereal Day.

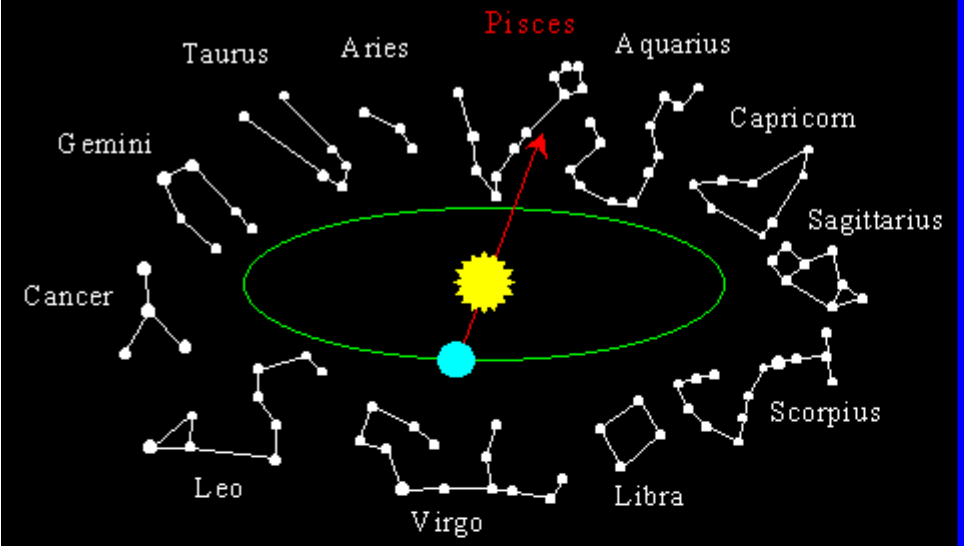
Due to its revolution about the Sun, the Earth must rotate a little more than 360 degrees for the Sun to appear in the same place. The time it takes for the Sun to appear at the same place is about 24 hours (Solar Day).

Sidereal and Solar Day

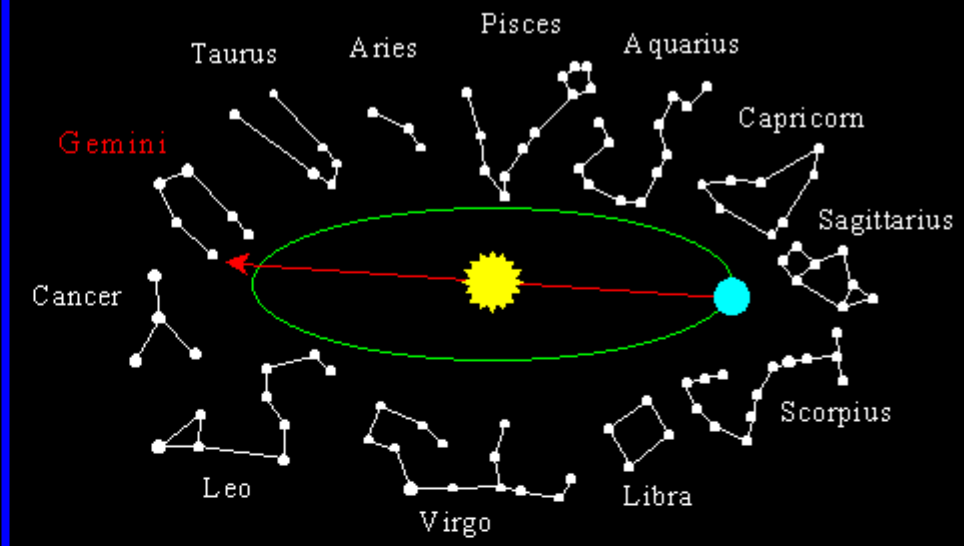


Our time keeping is based on the (Mean) Solar Day and thus stars a star that appears at one location at a certain time will be at that same location the next day approximately four minutes earlier.

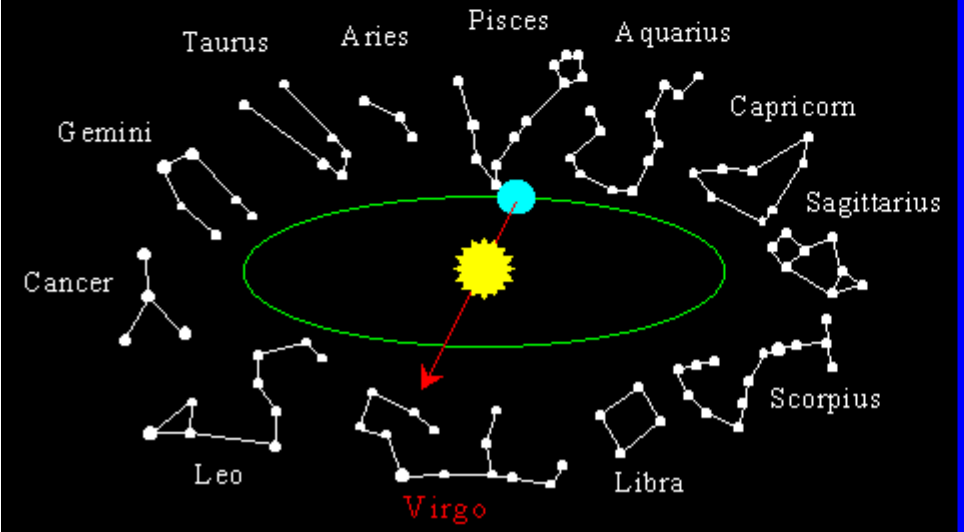
March 2000: Sun in Pisces



June 2000: Sun in Gemini



September 2000: Sun in Virgo



December 2000: Sun in Sagittarius

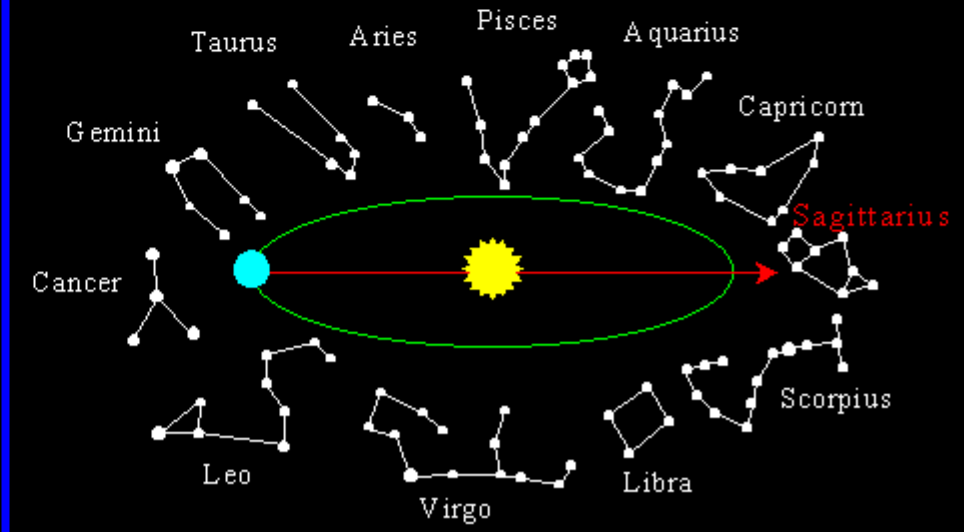
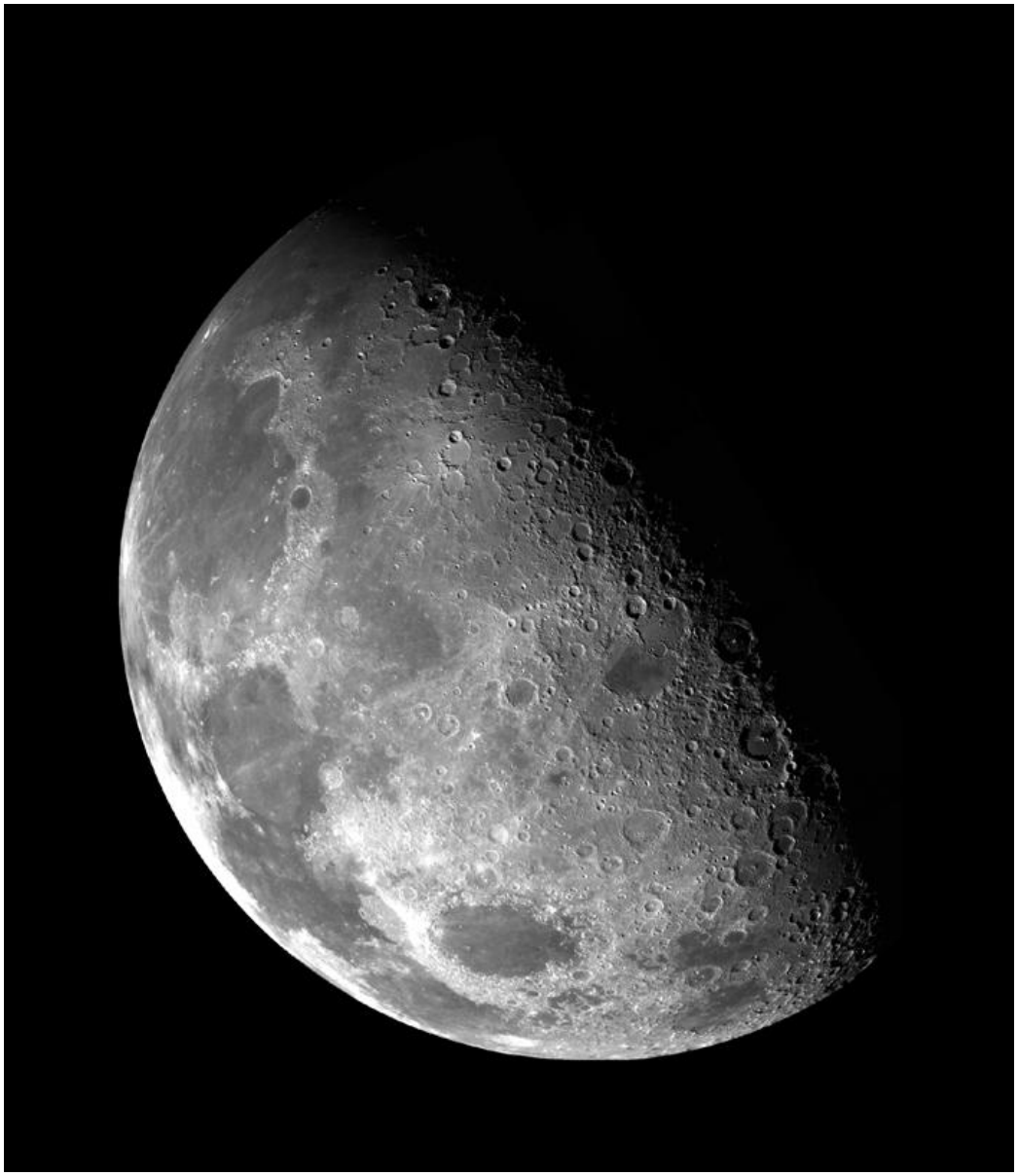


Image of the Moon from the Galileo Space Craft



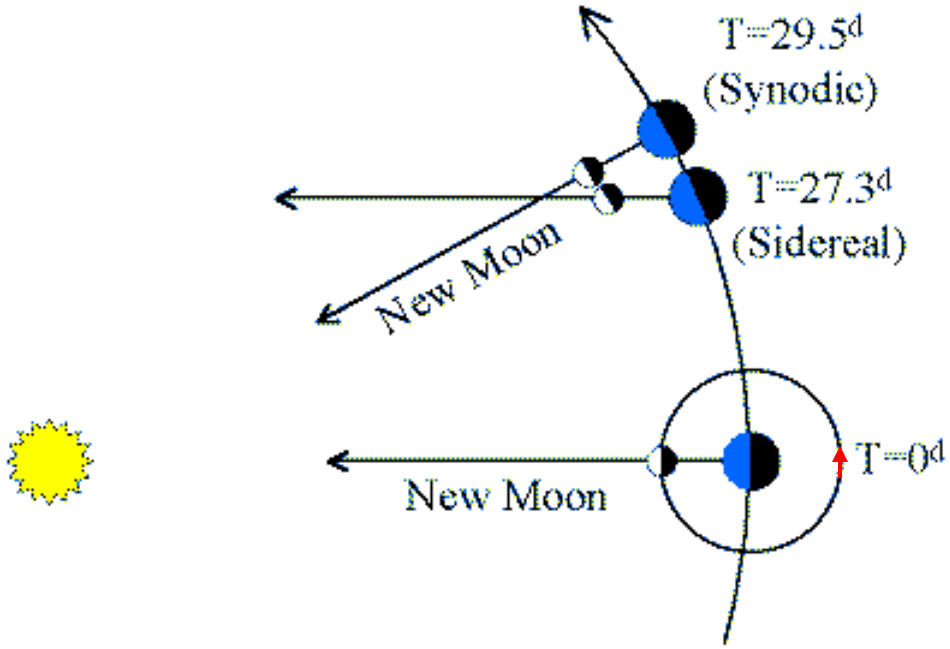
Moon: Overview

Due to its size (diameter 3476 km, Mercury's diameter is 4880 km) and composition, the moon is sometimes considered as a terrestrial planet along with Mercury, Venus, Earth and Mars.

In addition to being the only body visited by humans, it is also the only object from which physical sample have been brought back to Earth (Radioactive dating found the youngest rocks formed 3 .1 billion years ago and the oldest formed 4.4 billion years ago).

In addition to centuries of Earth bound observations, several space based missions have made observations of the Moon: Apollo (Dates), Clementine, Lunar Prospector

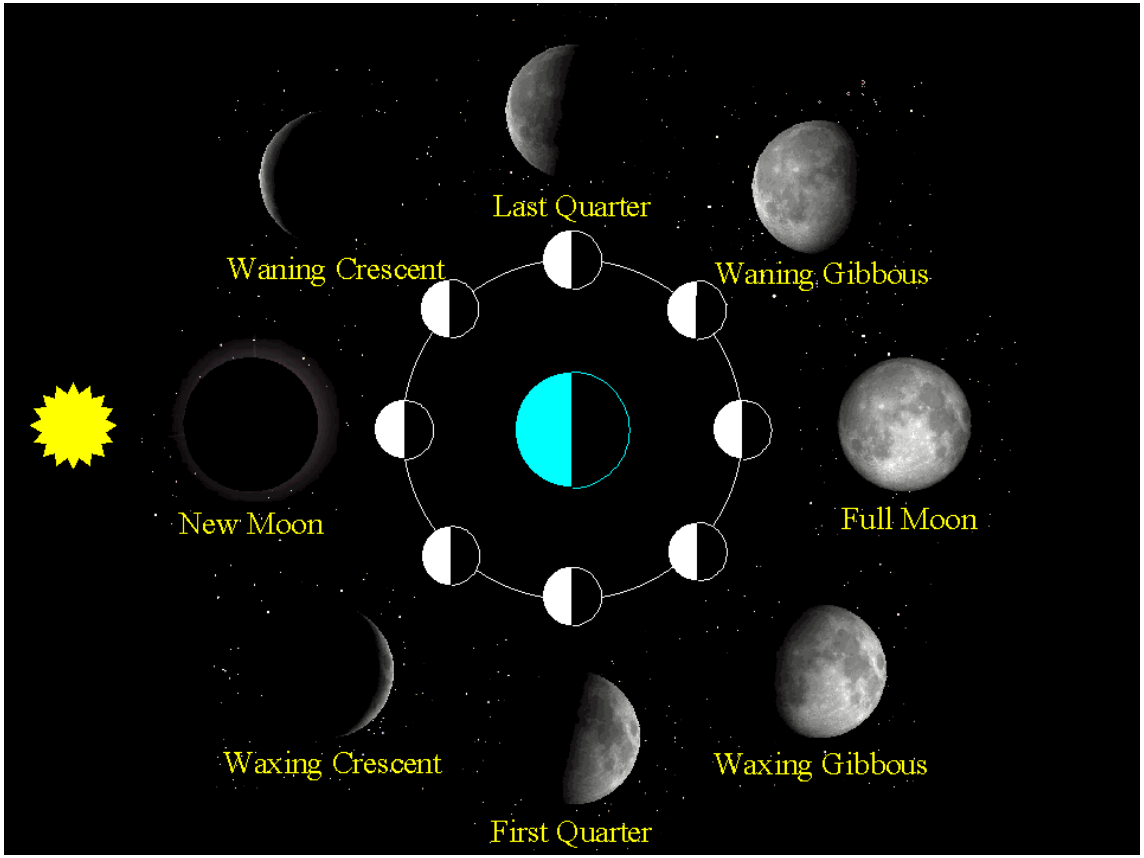
Moon: Revolution



The Moon revolves around the Earth in 27.3 days (Sidereal Period, revolution in the same sense as Earth about the Sun).

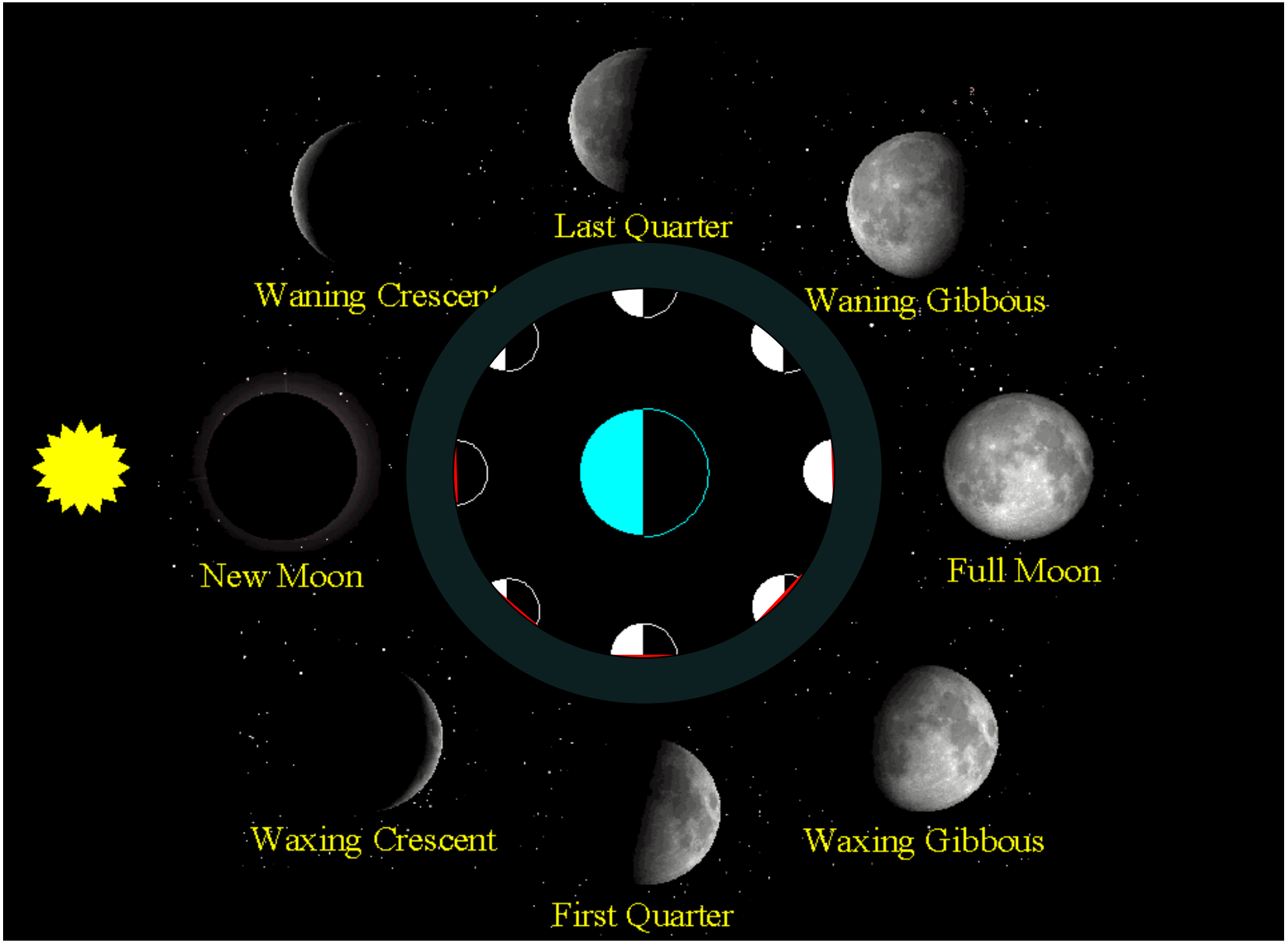
Since the Earth moves in its orbit about the Sun (~27 during this time) it takes about 2 more days for the moon to return to the same position relative to the Earth and Sun. Thus the Synodic Period is 29.5 days.

Moon: Revolution



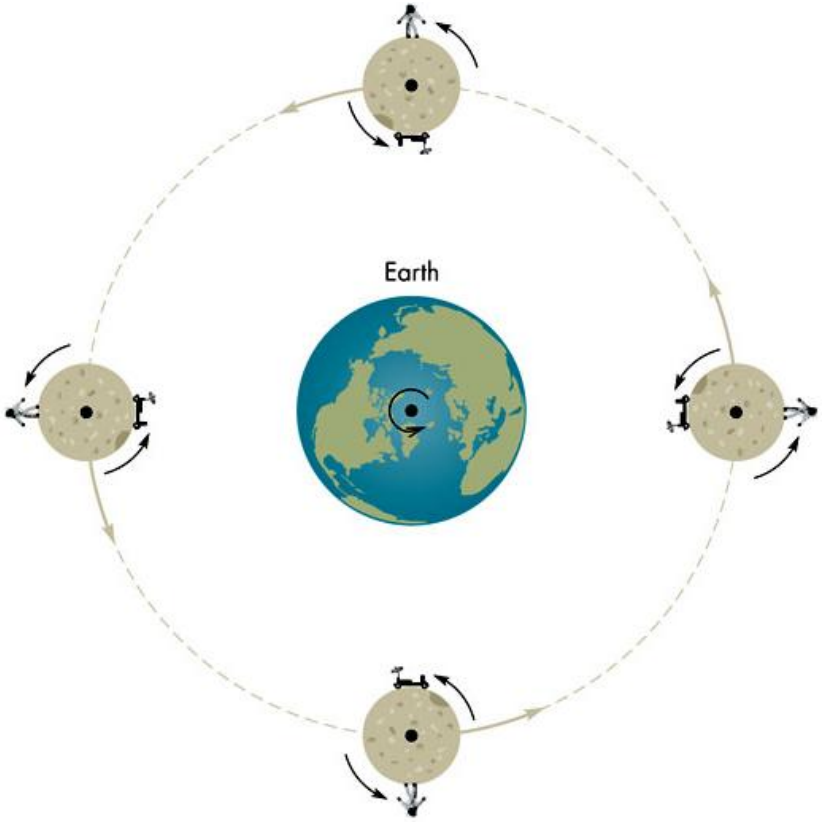
The revolution of the moon about the Earth produces the phases of the moon which complete one cycle during the synodic period.

Moon: Revolution



http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/lunation.gif

Moon: Rotation



B Synchronous rotation: Only one face visible from Earth

The moon rotates with a period of 27.3 days, which is the same as the sidereal period. When the period of rotation and revolution of an object are the same, it is in synchronous rotation. In synchronous rotation, the same side of the Moon (called the near side) always faces Earth.

Eclipses

- **Eclipses occur when the Sun, Earth and Moon are in a line.**
- **Lunar Eclipses occur near Full Moon when the Earth is between the Sun and Moon. The Earth casts its shadow on the moon.**
- **Solar Eclipses occur near New Moon when the Moon is between the Earth and the Sun. The Moon casts its shadow on the Earth.**

Eclipses

- **Because the plane of the Moon's orbit is tilted relative to the plane of the Earth's orbit (by approximately 5 degrees). The Earth, Sun and Moon do not form a line at every New and Full Moon. Consequently, eclipses do not occur at every New and Full moon**

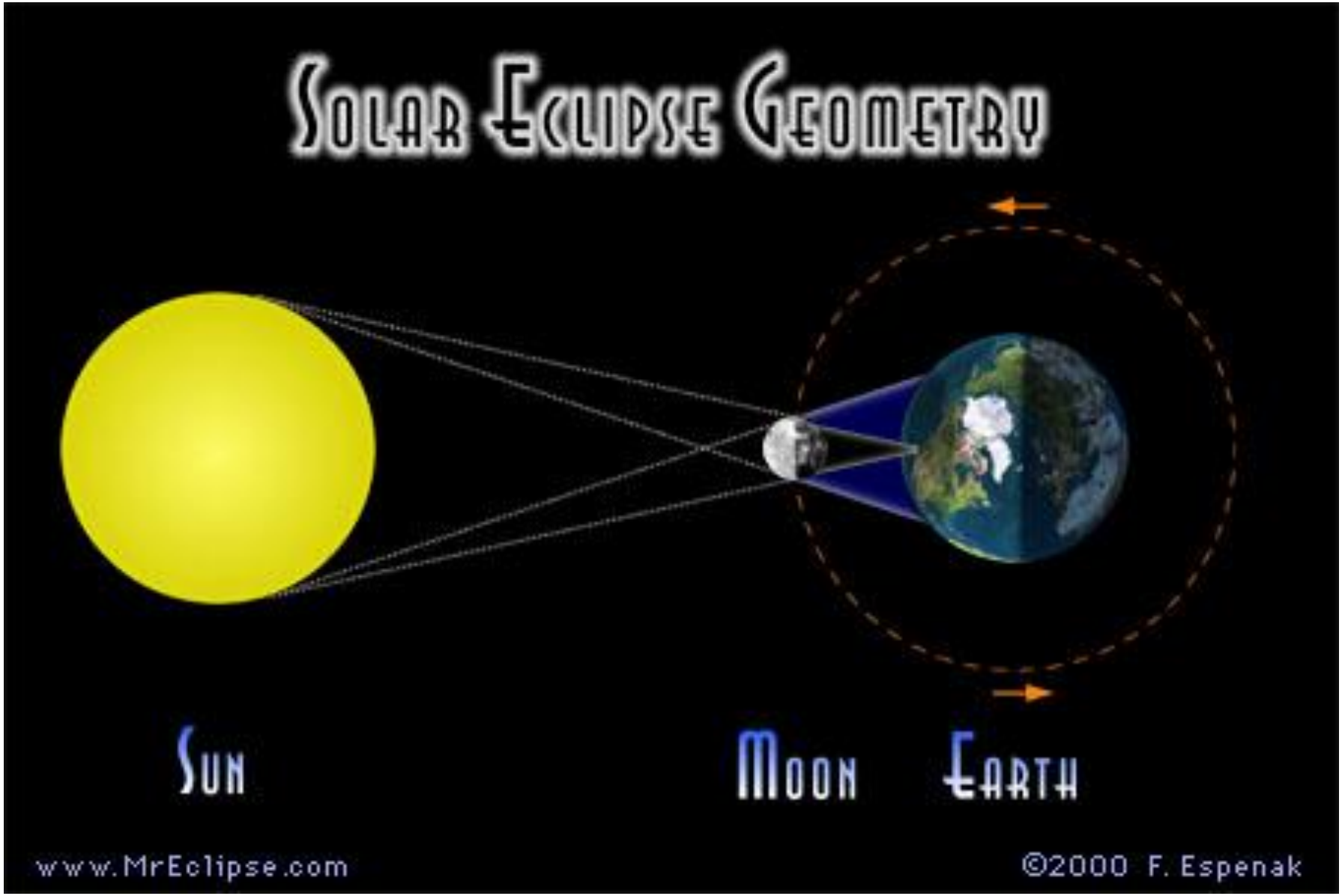
Eclipses

There are two primary regions in the shadows cast by celestial bodies

Umbra: central darkest region of the shadow where there is in theory no sunlight light

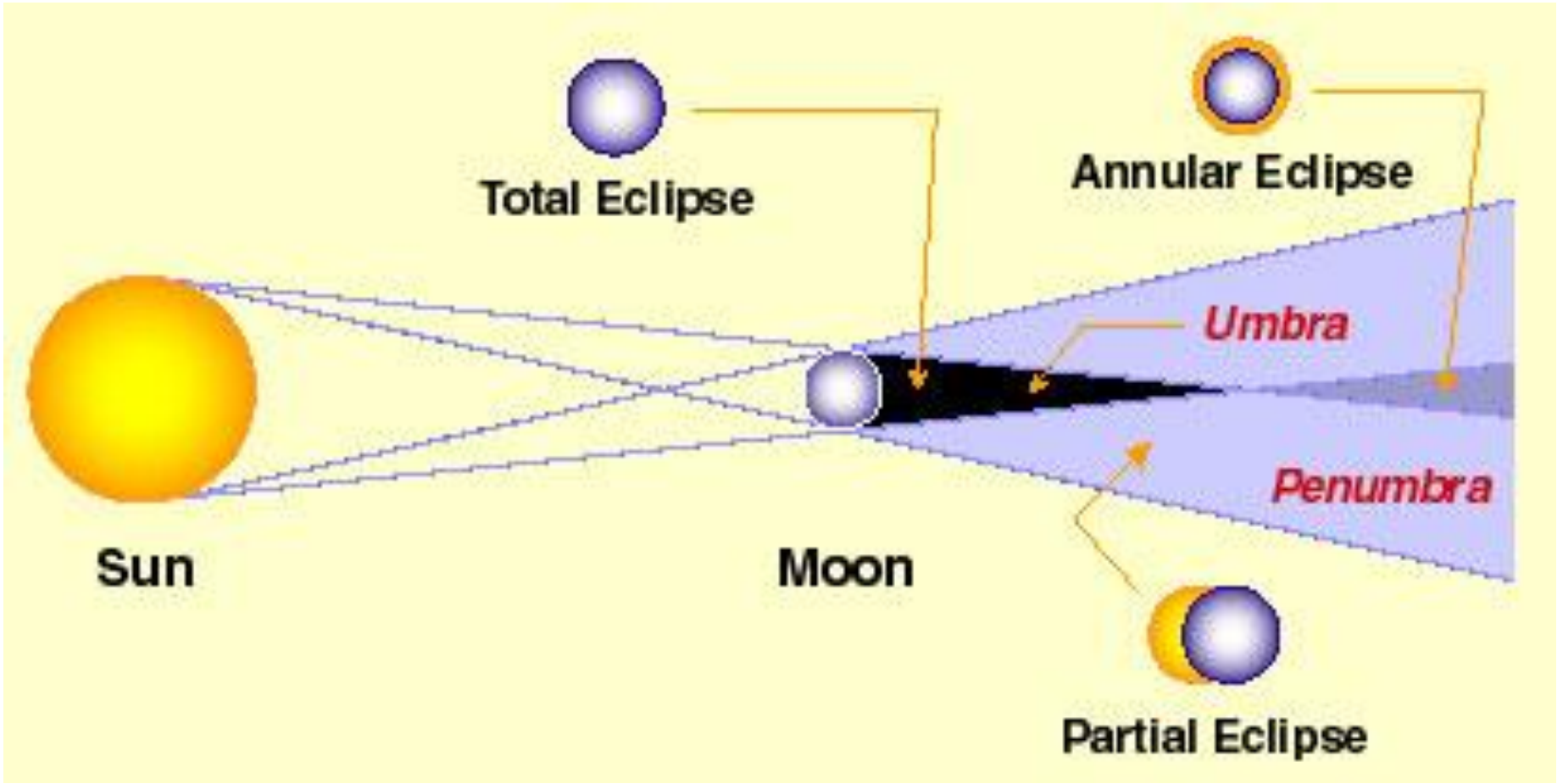
Penumbra: outside region region of the shadow that receives limited sunlight

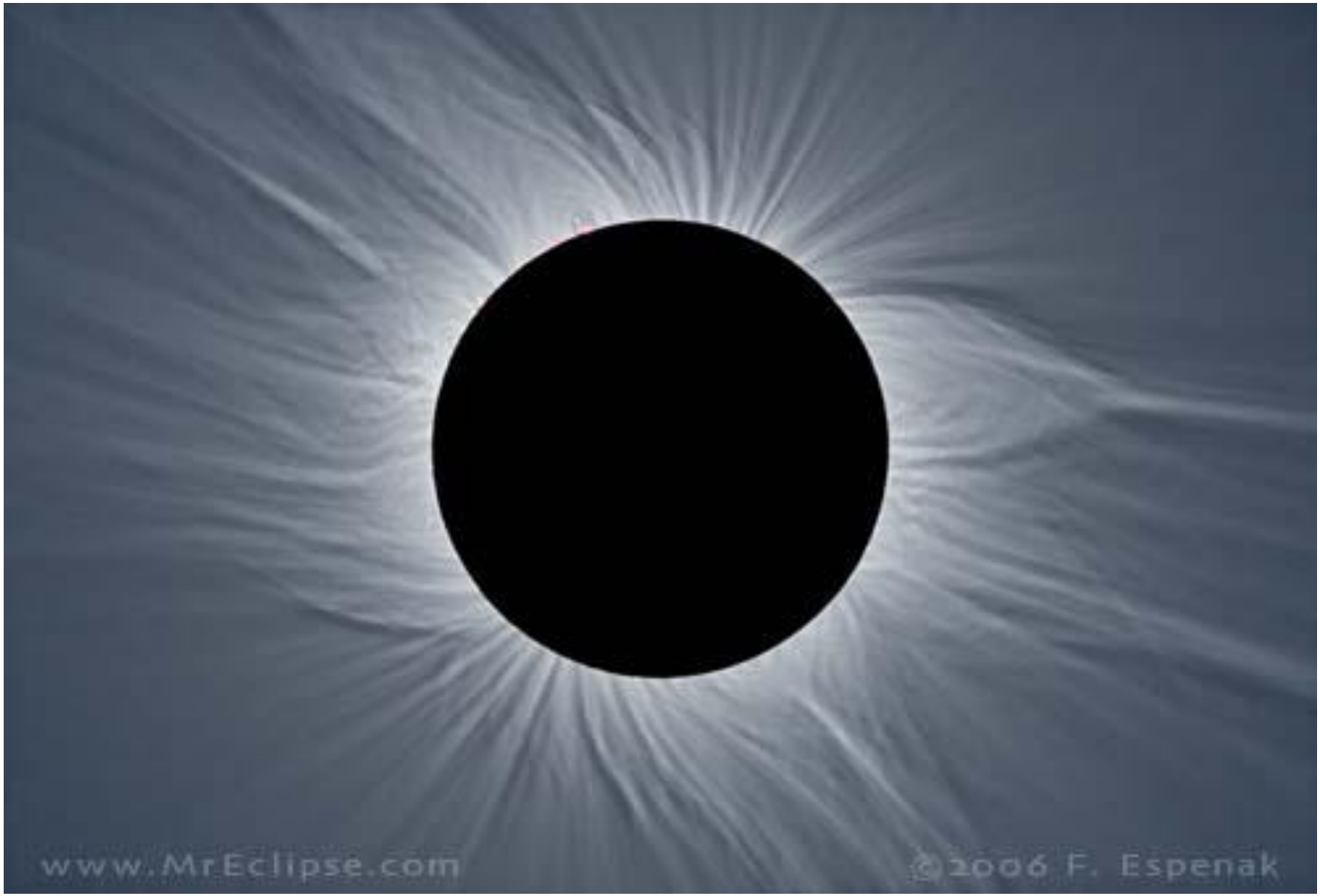
Lunar Eclipse


Solar Eclipse Geometry
Sun
Moon
Earth
www.MrEclipse.com
©2000 F. Espenak

Solar Eclipse

- **Total eclipse: When and where the Moon's Umbra traverses the Earth. Despite their different sizes, the moon and sun have about the same angular size in the sky.**


Total Eclipse
Annular Eclipse
Umbra
Penumbra
Sun
Moon
Partial Eclipse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Solar Eclipse

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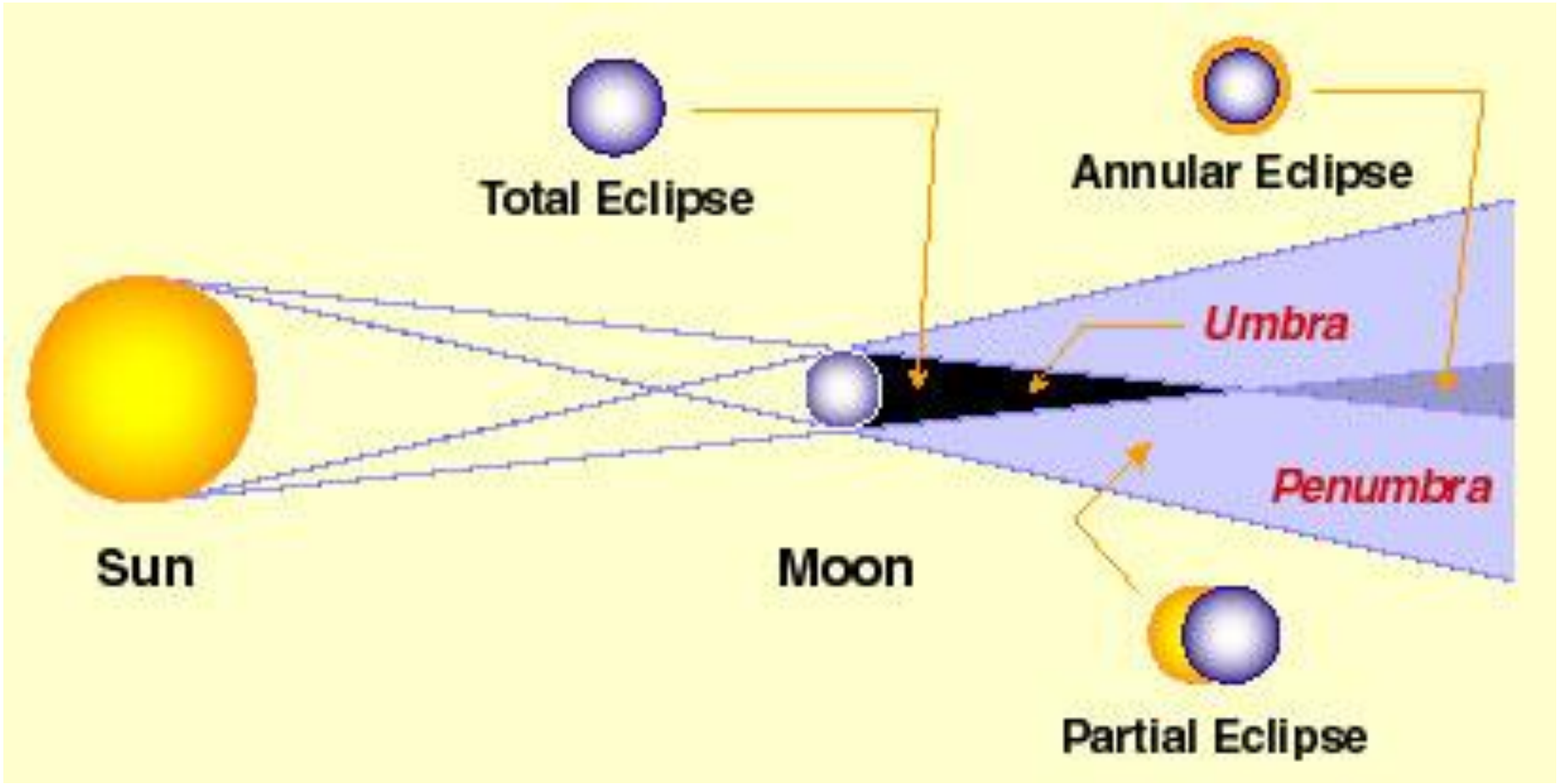
- **Partial Eclipse: When and where the Moon's Penumbra traverses the Earth**


Total Eclipse
Annular Eclipse
Umbra
Penumbra
Sun
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Partial Eclipse

Solar Eclipse

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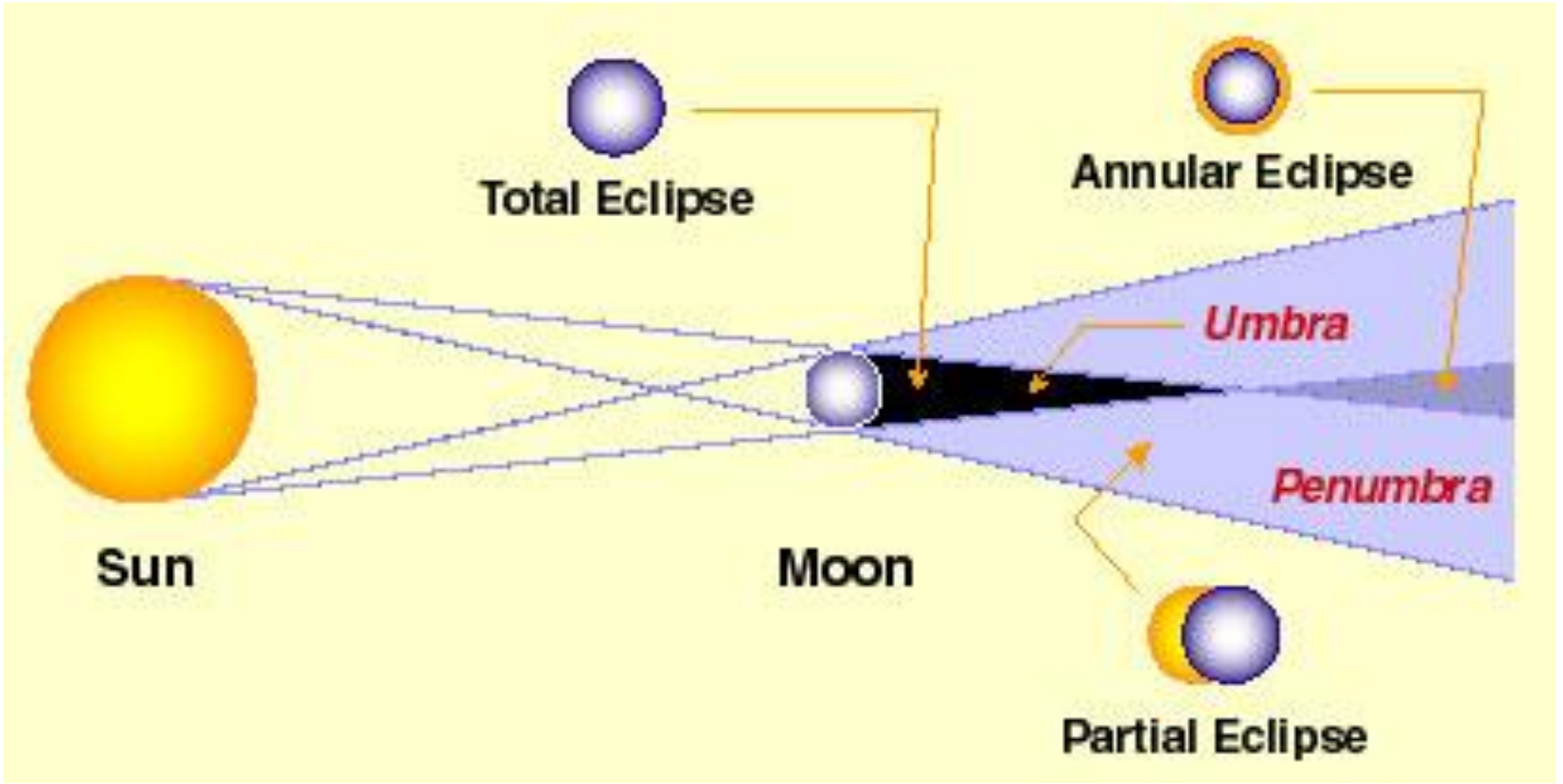
- **Partial Eclipse: When and where the Moon's Penumbra traverses the Earth**
- **Annular Eclipse: When the Moon is further away in its orbit such that the Umbra does not quite reach Earth.**


Total Eclipse
Annular Eclipse
Umbra
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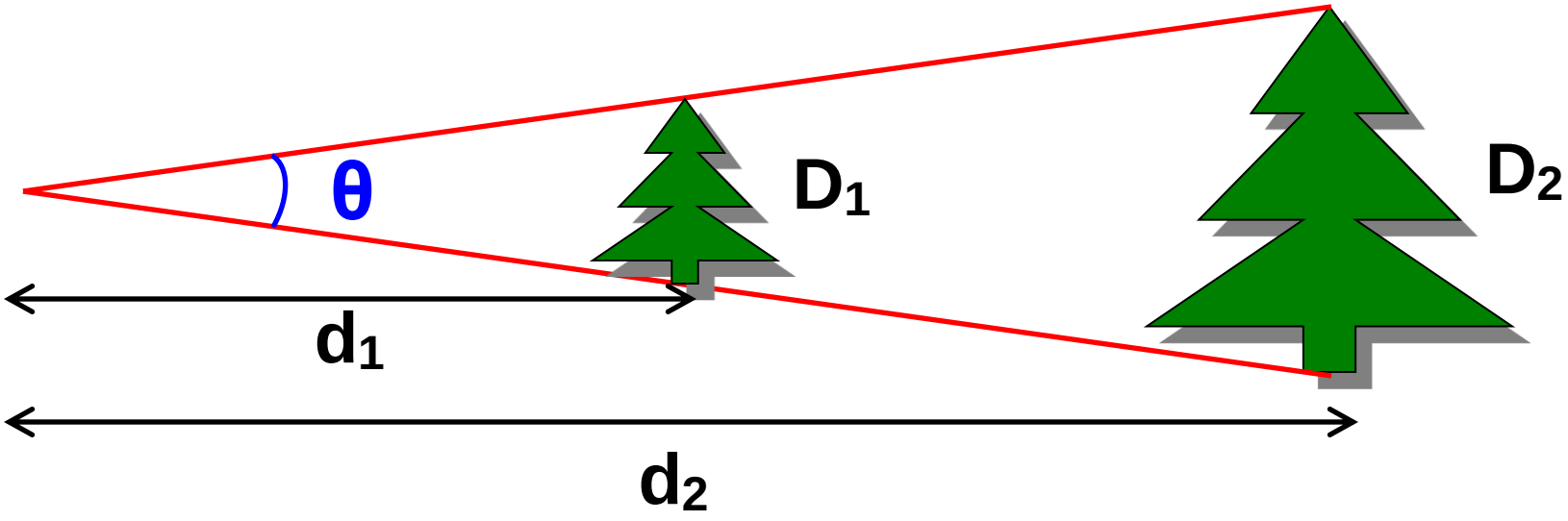
Greek Astronomy: Angles and Distance



Note: d is distance to the object, D is the linear size of the object.

While both trees subtend the same angle, they clearly have different sizes because of their distance (however d/D will be constant.

Greek Astronomy: Angles and Distance

The relationship between distance and angle is routed in the formula for the circumference of a circle

$$c = 2\pi r$$

$$D = \text{Angle (radians)} * d$$