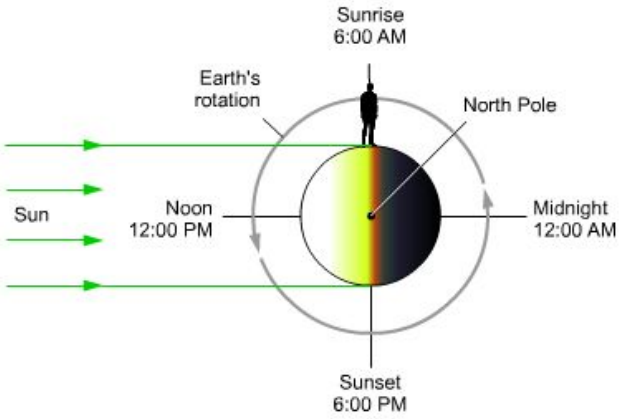
Module 1 - The Sky

Stars

- Stars appear to lie on a “great celestial sphere” around the Earth, but actually they lie at different distances to each other (Some may be further out from Earth)
- Earth rotates west to east, (CC from North Pole), so it makes the “celestial sphere” appear to be rotating from east to west
    - Appears that the stars are moving

Time of Day

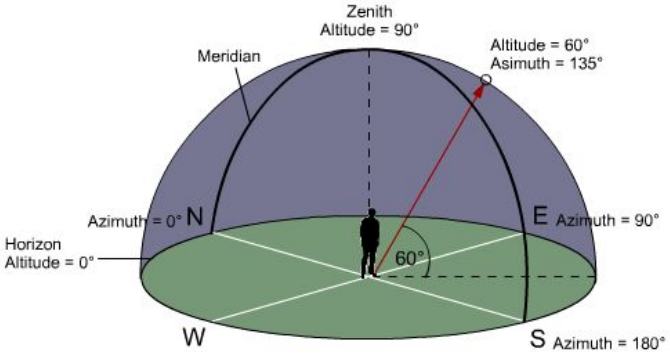
- Based on Earth’s axial rotation (Which side is facing the sun)



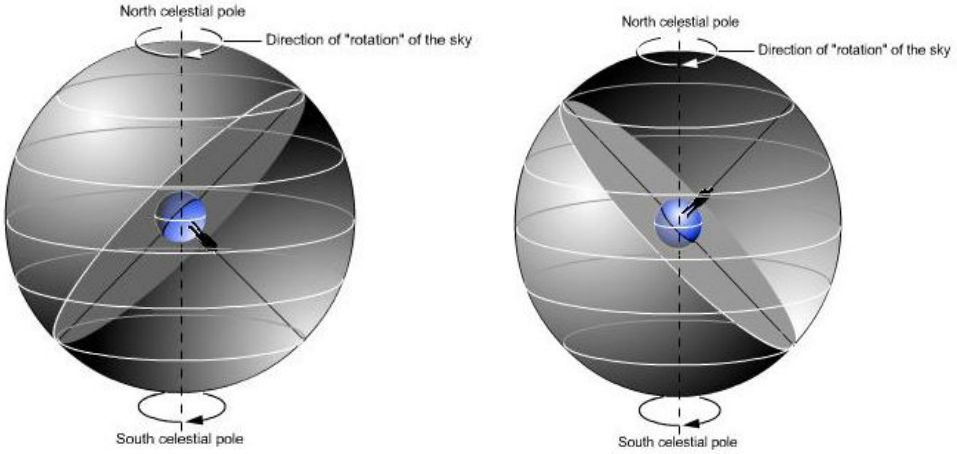
- In order to identify things in the sky, we cannot just use longitude and latitude
    - **Latitude** - N/S angular distance
    - **Longitude** - E/W angular distance
    - Latitude is able to give us the declination
    - Longitude cannot be used because sky “moves” every 24 hours, with stars constantly changing
        - Must fix this by using **right ascension**
            - Measured in hrs, min, sec - arbitrarily fixed zero point in the sky
- Angular positions in the skies are measured in degrees, arcminutes, or arcseconds
    - 1° = 60 arcmin = 3600 arcsec or 1° = 60’ = 3600’’

Local Coordinates

- Local coordinates (Earth seeing things in the sky) depends on:
    - Location
    - Time
    - Where Earth is in it’s orbit around the Sun
- Usual coordinates are altitude and azimuth
    - Altitude - 0° is horizon, 90° is overhead.
    - Azimuth - 0°is due north, 90° due east



- What we see in the sky varies with latitude



- The amount of time where something is visible is dependent on where we are on the Earth and where it is in the sky
    - Someone in figure a) will never be able to see something close to the North Celestial Pole, and vice versa

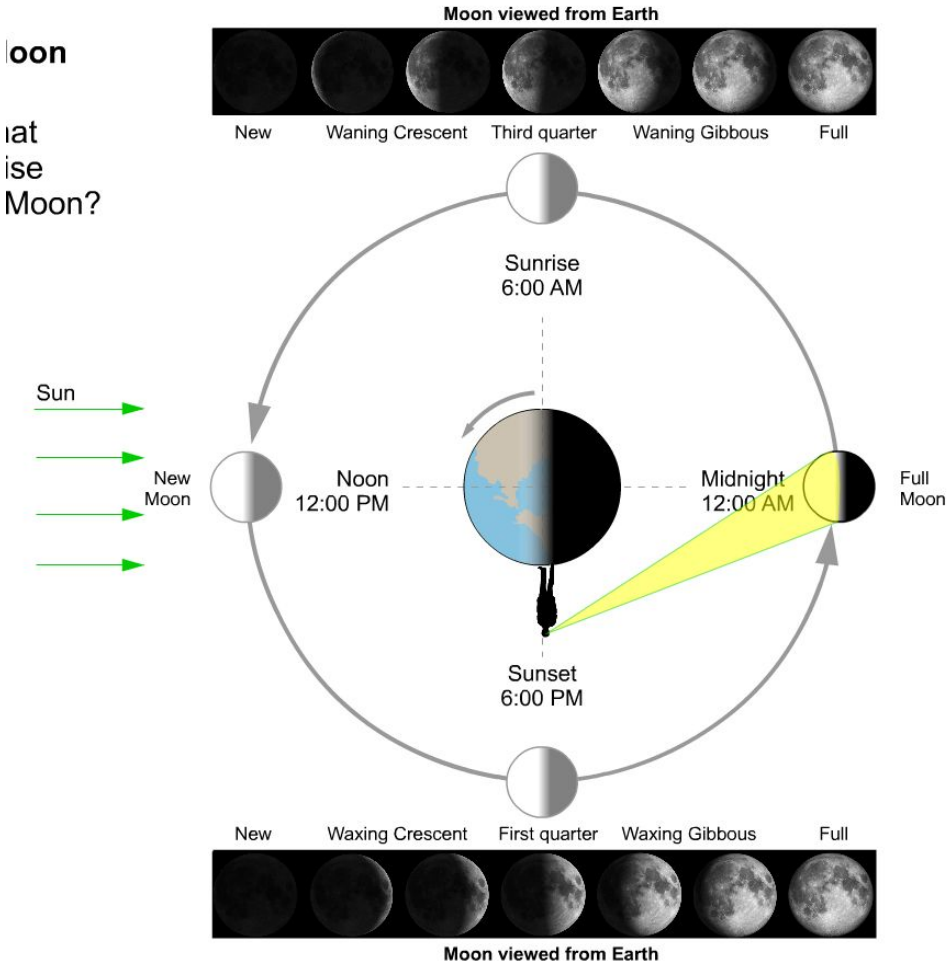
<u>Angular Separation of Objects in the Sky</u>

- We measure an angular separation (usually is a few arcseconds) in order the find out positions in the sky
- In order to find the real physical distance, we have to find d.
- Assumption made: Two objects in the sky are the same distance from us
    - (We assume their separation from each other is 0)

- Even for a large angle (60 degrees) the percent difference between s and a is small
- **Imprecise ways to measure angular separation**
    - If given d and Θ, ways to find s incorrectly:
        - tan (dtanΘ - this assumes Θ is small, at right angles to two other angles
        - cosine law
        - sine law
        - These would all give inaccurate answers - not enough digits to accurately represent s, because it is magnitudes smaller than d.

<u>The Month</u>

Phases of the Moon

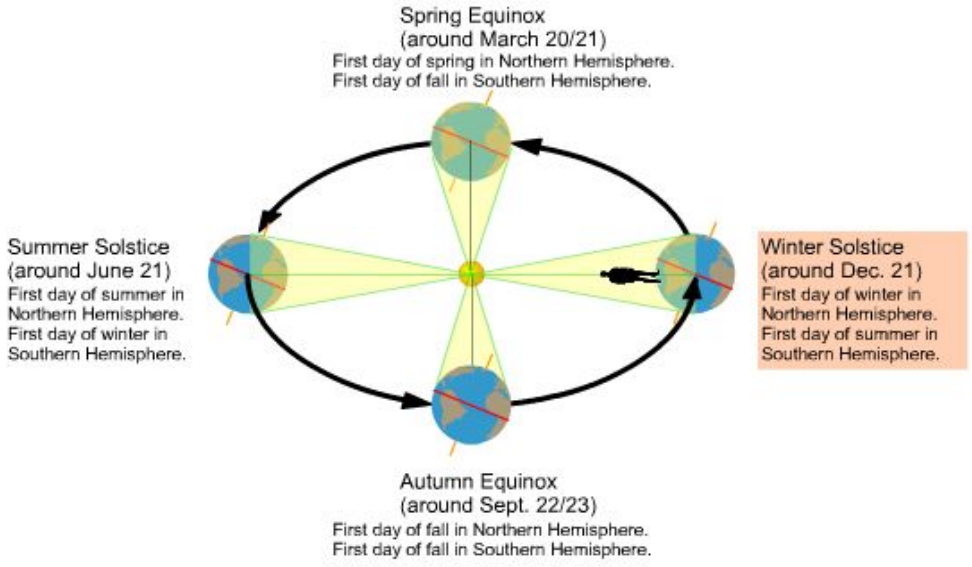


<u>The Year</u>

- Sun appears to line up with the 12 signs of the Zodiac as the Earth orbits it
- **Ecliptic:** Path followed by the sun over a year - close to path of each of the planets across the sky
    - It is actually the “reflex”, or opposite of the Earth’s motion around the sun
    - Not in same path as Equator
    - Inclined to Equator by 23.5°

Seasons

- Caused primarily by Earth's tilt (rotation axis to its orbital plane)



<u>The Calendar</u>

- **Synodic Time -** Time according to the Sun, or **Solar time**
- **Sidereal Time -** time according to the stars
- Each year is 0.57 seconds longer than the previous
- Seconds are now defined by a "hyperfine transition of cesium"
    - With frequency of 9,192,631,779 per second (Atomic Time)
    - 1 synodic second / 1 atomic second = $1 + 1.8 \times 10^{-8} \times t$
        - t is # of years

Solar Day vs Sidereal Day

- Earth travels roughly 1° per day around its orbit as it rotates
    - One solar day needs 361° of rotation
        - A solar day is ~4 mins longer than a sidereal day

Units of Time

- With stars - one sidereal day is 23 hours, 56 mins, 4.091 sec.
- Apparent solar time - time measured by Sun's position in the sky
- Mean Solar time - Average length of a Solar day
- Standard Time - all places on Earth in a 15° wide (longitude) timezone use same mean Solar time
- Sidereal year is 365.6366 mean Solar days
- Tropical year (time from one spring equinox to the next - against Sun) is 365.242199 mean Solar days

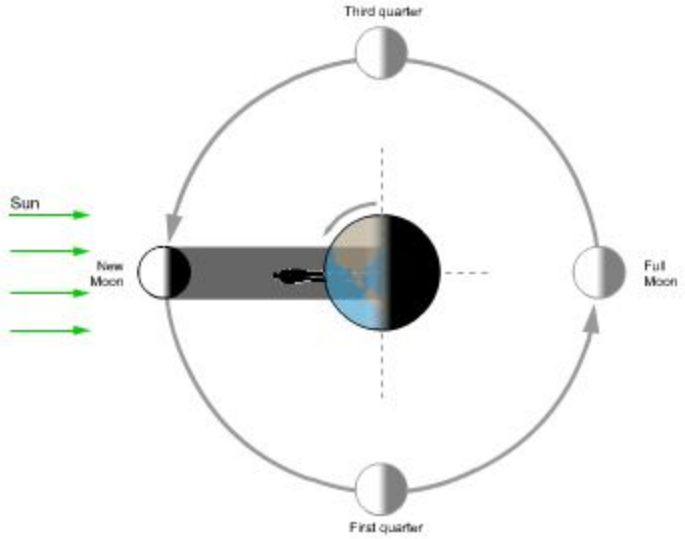
Precession

- Earth spins on its rotation axis

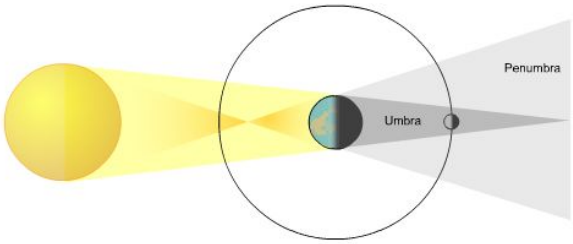
- Other planets (esp Jupiter) exert a “sideways” force on Earth
- A spinning object that is pushed sideways responds by moving at right angles to the “expected” direction
    - Earth’s rotation axis changes direction of spin b/c of forces from other bodies
- Affects orientation of a spinning object’s axis, not tilt
- Earth’s rotational axis will always be 23.5° to orbital plane, but procession will change the direction it’s pointed towards
    - NCP points towards Polaris, but will point towards Vega in 13,000 years

<u>Eclipses</u>

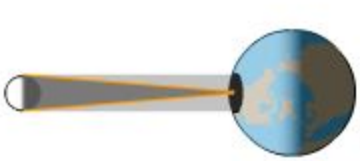
- **Lunar eclipse** occurs when Moon passes through Earth’s shadow (Moon disappears)
    - Can only happen at Full Moon
- **Solar eclipse** occurs when the Earth passes through the Moon’s shadow (Sun disappears)
    - Can only happen at New Moon



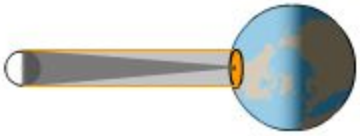
- **Umbra -** sunlight is completely blocked
- **Penumbra -** sunlight is partially blocked



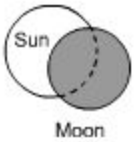
Solar Eclipse



Total eclipse occurs in the umbra of the moon's shadow.



Partial eclipse occurs in the penumbra of the moon's shadow.



Annular eclipse occurs in the penumbra, if the umbra of the moon's shadow does not reach the earth.

Eclipse Seasons

- For an eclipse to occur, Earth, Sun and Moon must all align
- Sun follows ecliptic, but Moon follows a different path bc Earth/Moon orbital plane is inclined 5° to the ecliptic
- These planes only cross twice a year (two eclipse seasons/year)
- Moon orientation always changes
    - “Line of Nodes” (Where lunar path crosses ecliptic) will make a complete loop every 18.6 yrs
- Eclipse seasons occur ~20 days earlier each yr