Astronomy

The Branch of Science that deals with Celestial Objects, Space and the Universe as a whole.

Prepared by Chris Houlberg

Astronomy Merit Badge (Requirements)

1. Know the hazards and how to prevent or mitigate them.
   Know first aid for the hazards you may encounter.
   Know safety precautions for day and night observations.
2. Explain how light and air pollution affect observations.
3. Know how and why binoculars and telescopes are used.
   Know how different types of telescopes are used.
   Explain the purpose of at least three instruments used with telescopes.
   Know how to care and store binoculars and telescopes.
4. Identify at least 10 Constellations (four in the Zodiac).
   Identify 8 conspicuous stars (five magnitude 1 or greater).
   Sketch the Big Dipper at two time several hours apart (show North Star and Horizon with the date and time).
   Explain what we see when looking at the Milky Way.

Astronomy Merit Badge (Requirements Cont.)

5. List the names of the five most visible planets and which can appear in phases and why.
   Make a table or chart of when these five planets will be visible in the sky during the next 12 months.
   Describe the motion of the planets across the sky.
   Observe a planet and describe what you saw.
6. Sketch the moon labeling 5 Seas and Craters.
   Sketch the phase and position of the moon at the same hour and place for four nights and explain the changes.
   List the factors keeping the Moon in orbit around the Earth.
   With diagrams, explain the relative position of the Sun, Earth and Moon at time of lunar and solar eclipses and during the new, first quarter, full and last quarter lunar phases.

Astronomy Merit Badge (Requirements Cont.)

7. Describe the composition of the Sun, compare to other stars and what effect its radiation has on Earth's weather and communications.
   Define Sunspots and how they effect solar radiation.
   Identify at least one red star, blue star and yellow star (other than the Sun) and explain the meaning of these colors.
8. Do one of the following:
   a. Visit a Planetarium or Astronomical Observatory and submit a report.
   b. Plan and participate in a three-hour observation session using binoculars or a telescope and prepare a log or notebook on what you hope to observe and what you see.
   c. Plan and host a star party for your Scout troop or other group and show and use binoculars or a telescope to show and explain explain celestial objects to the group.
   d. Help an astronomy club hold a star party that is open to the public.
   e. Take a series of photos on the movement of the Moon, a planet, an asteroid, meteor or comet. Show all position on a star chart or map.
9. Find out about three career opportunities in astronomy.

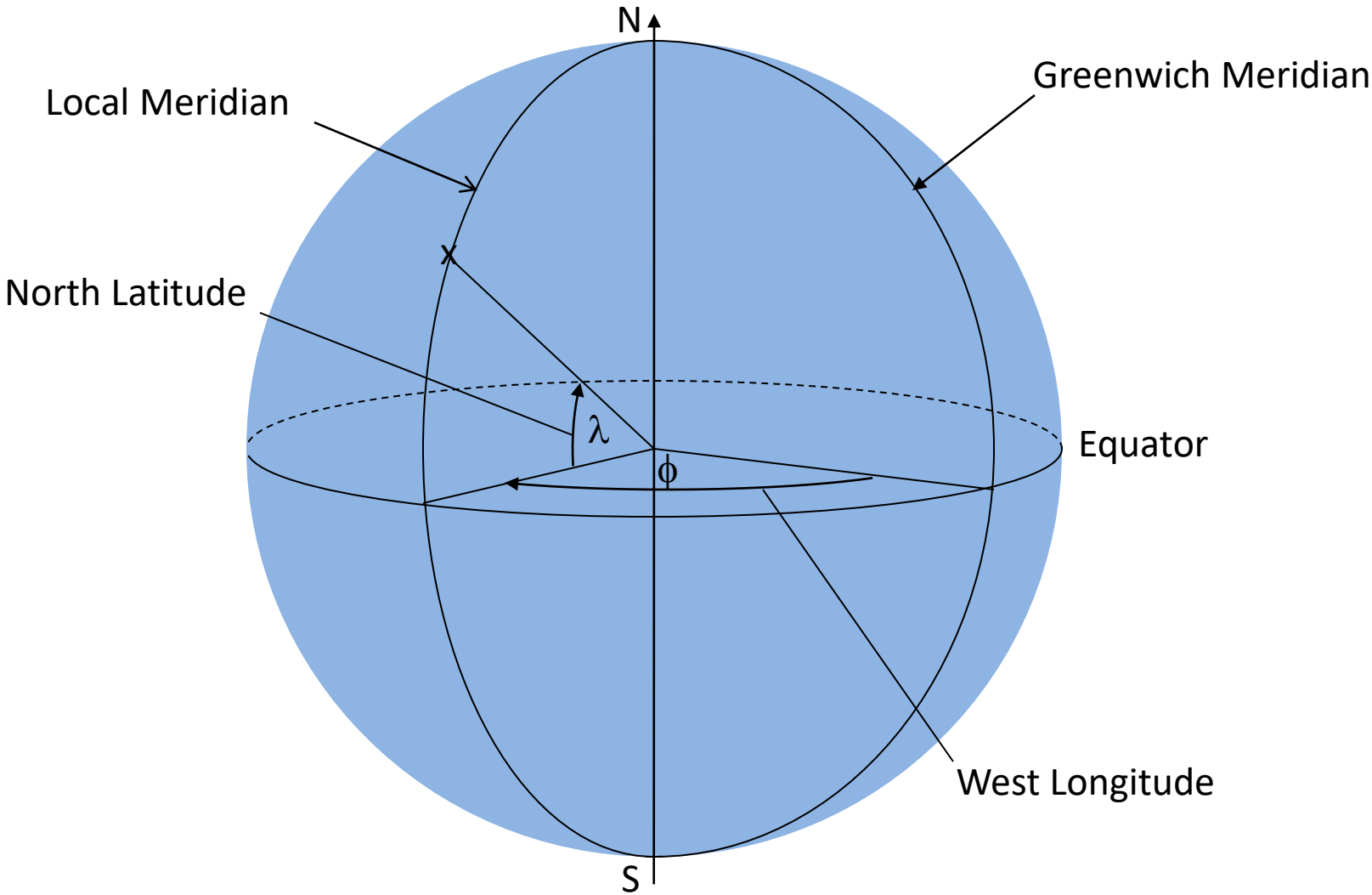
Astronomical Observations

- When making astronomical observations you need to know five things so others can see what you saw.
  1. What am I looking at?
  2. What instrument am I using?
  3. Where is the object relative to me?
  4. What time is the observation?
  5. Where am I?

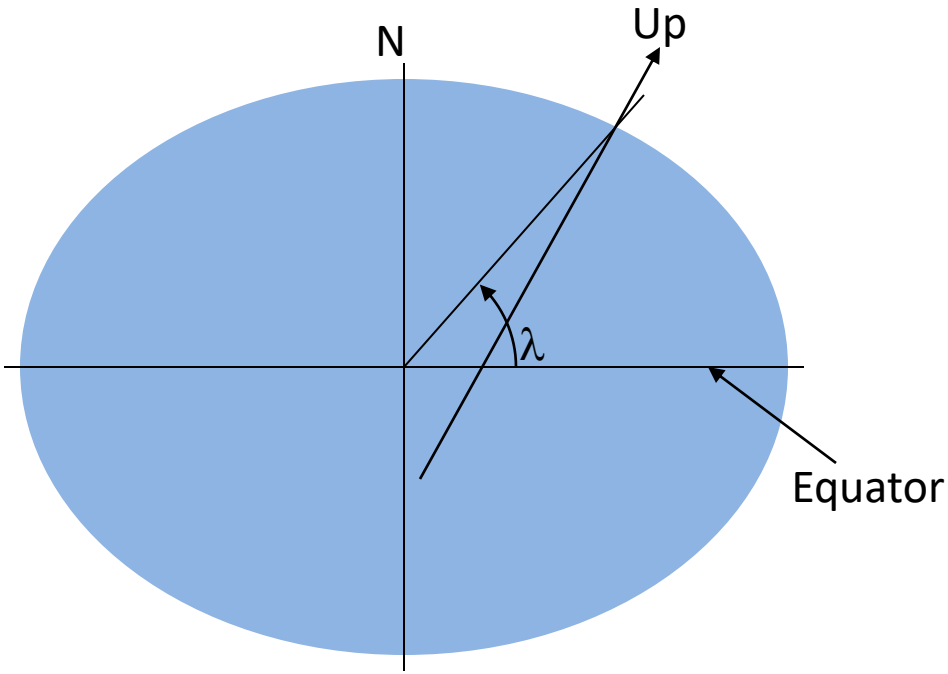
Where am I?
(Where on the Earth or in Space)

- On the Earth we use Latitude, Longitude and Altitude which you can find with a map application on your phone (World Geographic Survey in 1984 - WGS-84).
- In space one of several coordinate systems and reference frames are used:
  - For satellites the Cartesian Coordinate System is usually used and the reference frame would be either Earth-centered Inertial (ECI) or Earth-centered, Earth-fixed (ECEF).
  - A more general reference frame is a barycenter frame (center of mass of several bodies – i.e. Earth-Sun or Earth-Moon) an example of which is the International Celestial Reference Frame (ICRF) with its origin at the barycenter of the solar system.

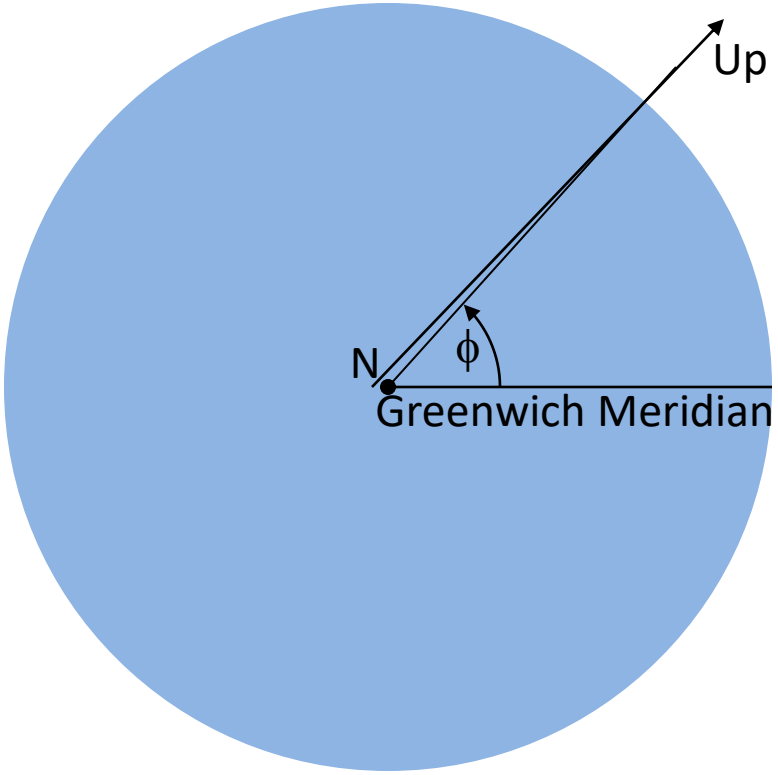
Latitude (λ) and Longitude (ϕ)



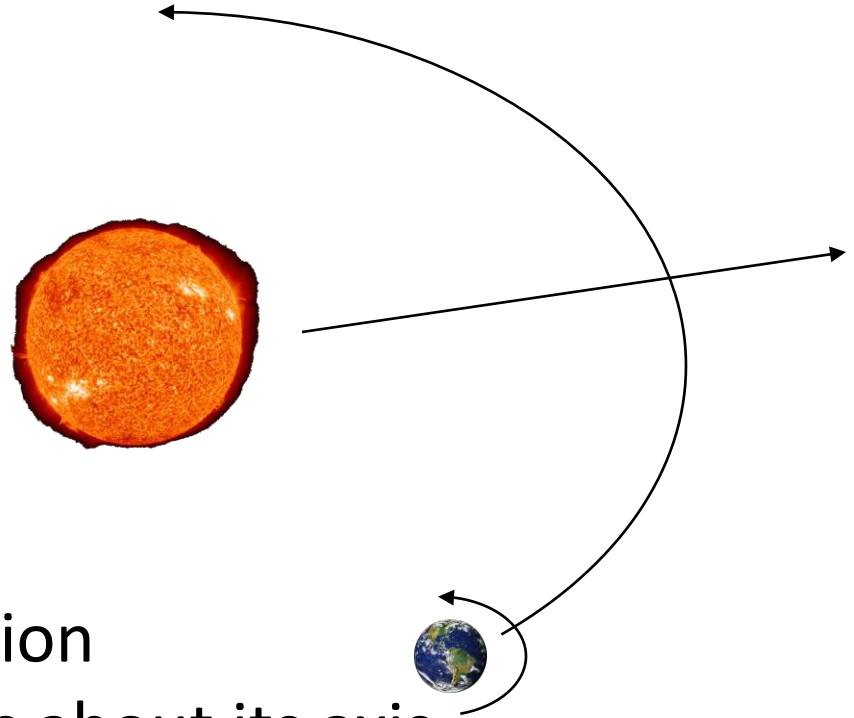
Problems with Latitude and Longitude (Earth is Lumpy and not a Sphere)



Exaggerated flattening of Earth



What time is the Observation



Everything is in motion

- The Earth rotates about its axis
- The Earth orbits around the Sun
- The Sun orbits around the center of the galaxy
- The galaxy moves through space

Where is the Object relative to Me?

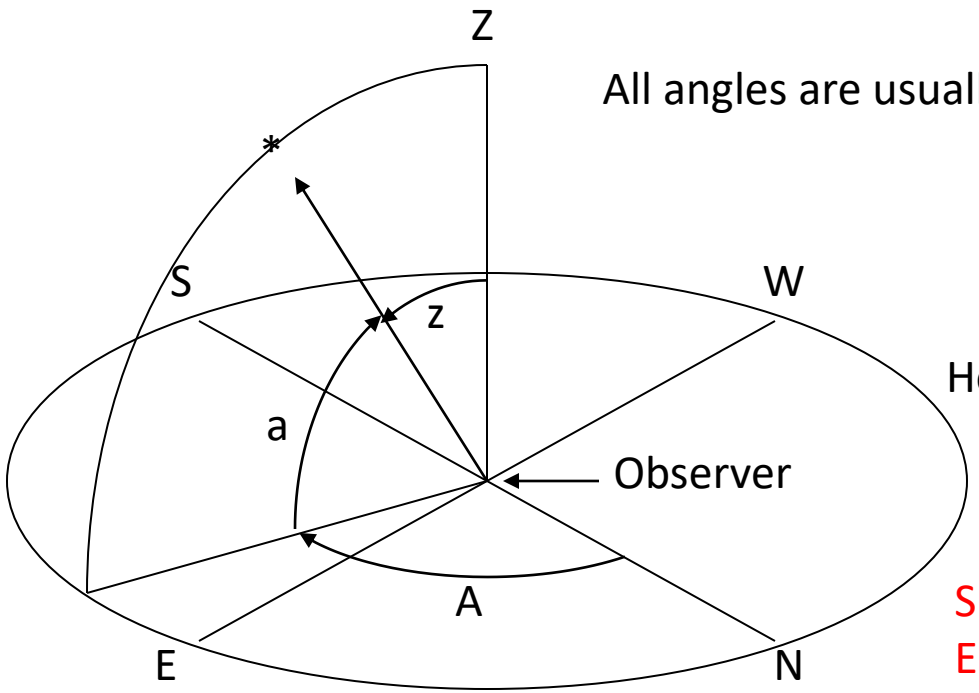
- One of several coordinate systems and reference frames can be used:
  - Horizon Coordinates
  - Equatorial Coordinates
  - Ecliptic Coordinates
  - Galactic Coordinates

Horizon Coordinates

a – Altitude angle measured up from the horizon

A – Azimuth angle measured from the north clockwise.

z – Zenith angle measured from the vertical and may be substituted for the altitude angle.



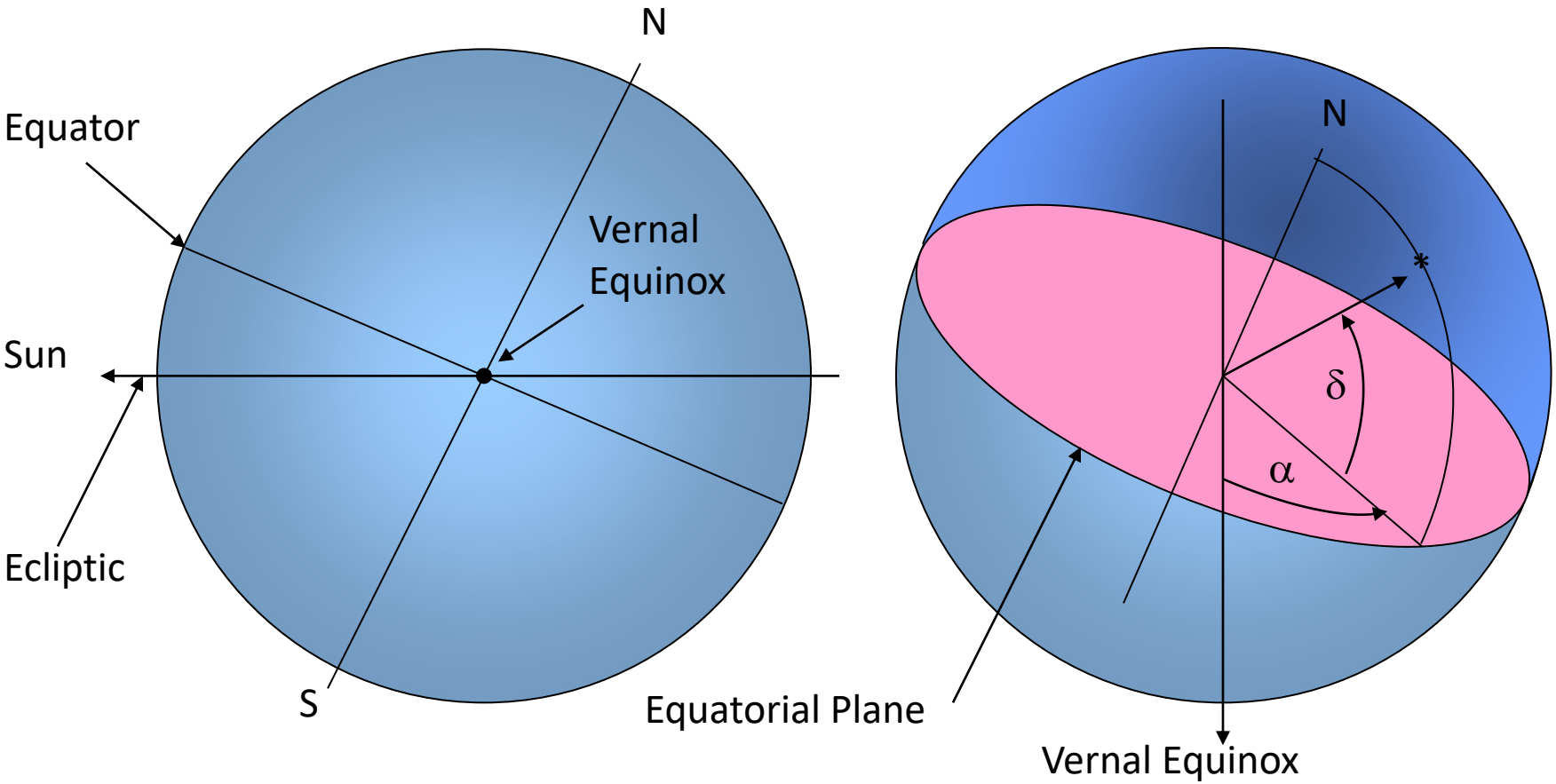
All angles are usually measured in degrees.

Show view with Stellarium
Enable Azimuth Grid

Equatorial Coordinates

δ – Declination is the angle a ray makes from the center of the Earth to the object above the equatorial plane in a northerly direction.

α – Right Ascension is the angle the projection of the above ray on the equatorial plane makes from the Vernal Equinox in a easterly direction.



Equatorial Coordinates (Cont.)

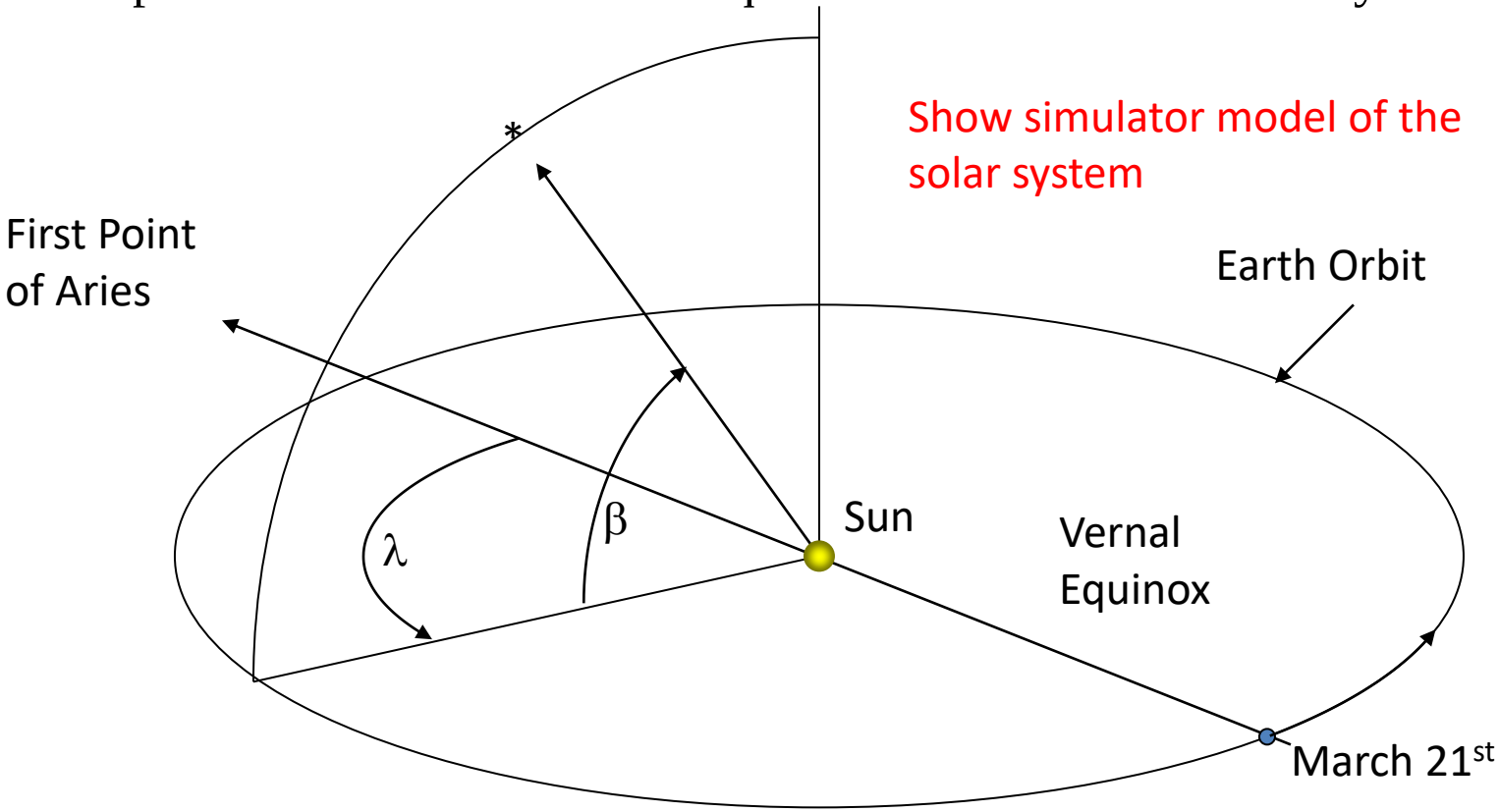
- Vernal Equinox (γ)
  The direction that lies along the line of the intersection of the plane of the Earth's equator with that of the Earth's orbit around the sun. Reference a globe
  - By definition this is the direction toward the Sun on March 21st the Spring Equinox.
  - Also referred to as the First Point of Aries even though it points to the constellation Pisces.
- Hour Angle (H) where $H = LST - \alpha$
  - LST = Local Sidereal Time
  - The Vernal Equinox replaces the Sun in time calculations.

Ecliptic Coordinates

The Ecliptic is the plane containing the Earth's orbit around the Sun.

β – Ecliptic Latitude is the angle a ray from the Sun to the object makes above the Ecliptic.

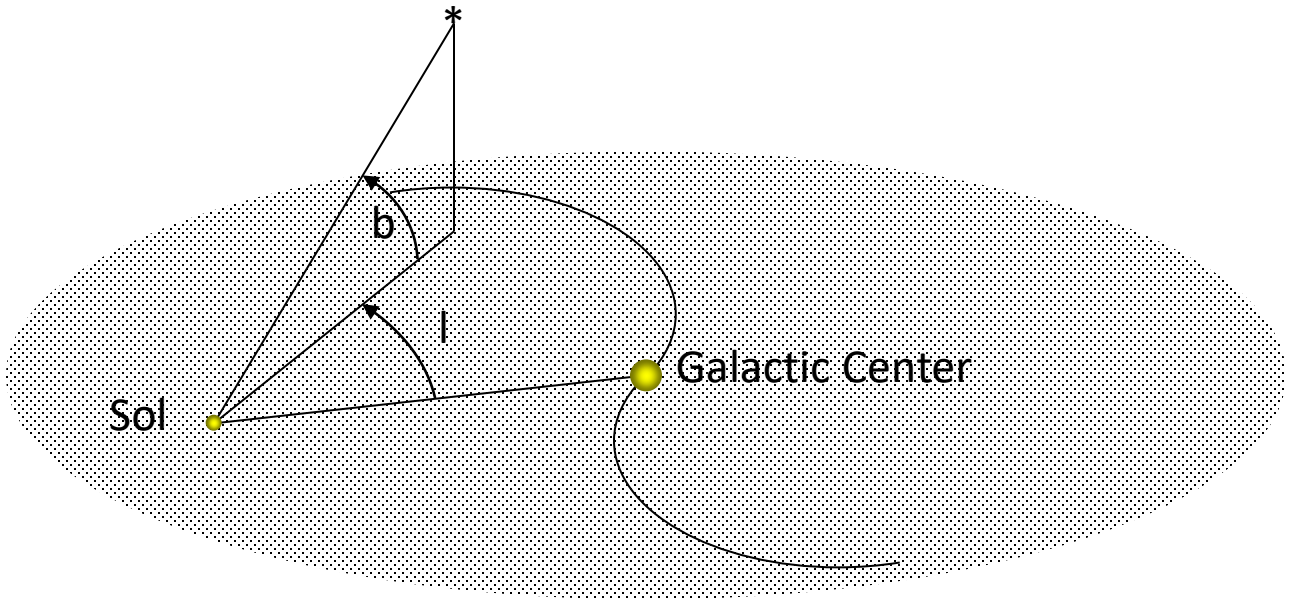
λ – Ecliptic Longitude is the angle the projection of the above ray on the Ecliptic makes from the vernal equinox measured in an easterly direction.



Galactic Coordinates

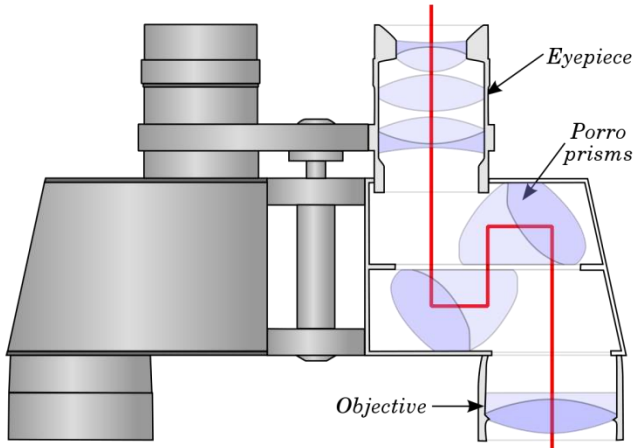
b - Galactic Latitude is the angle a ray from the Sun to the object makes above the plane of the Galaxy.

l - Galactic Longitude is the angle the projection of the above ray on the Galactic plane makes from the direction of the center of the Galaxy. This angle increases in the same direction as right ascension.

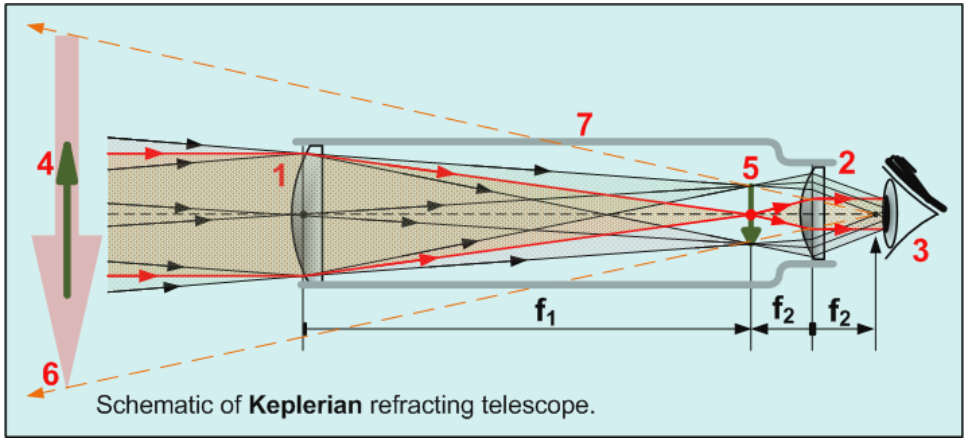


Note: Star Trek Galactic Coordinates are measured from the center of the galaxy.

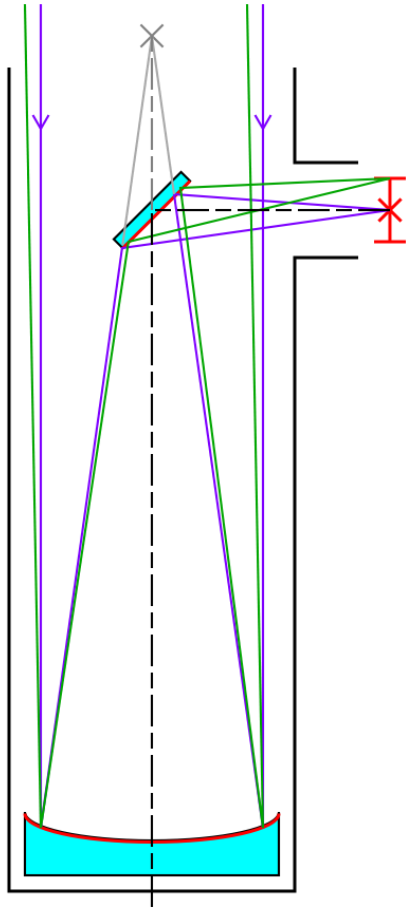
What Instrument am I using?



Binoculars



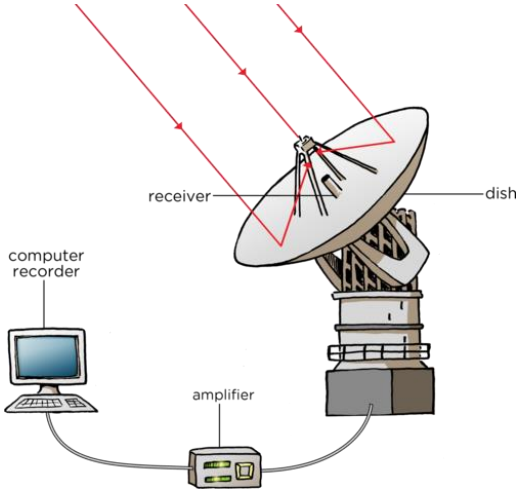
Schematic of **Keplerian** refracting telescope.

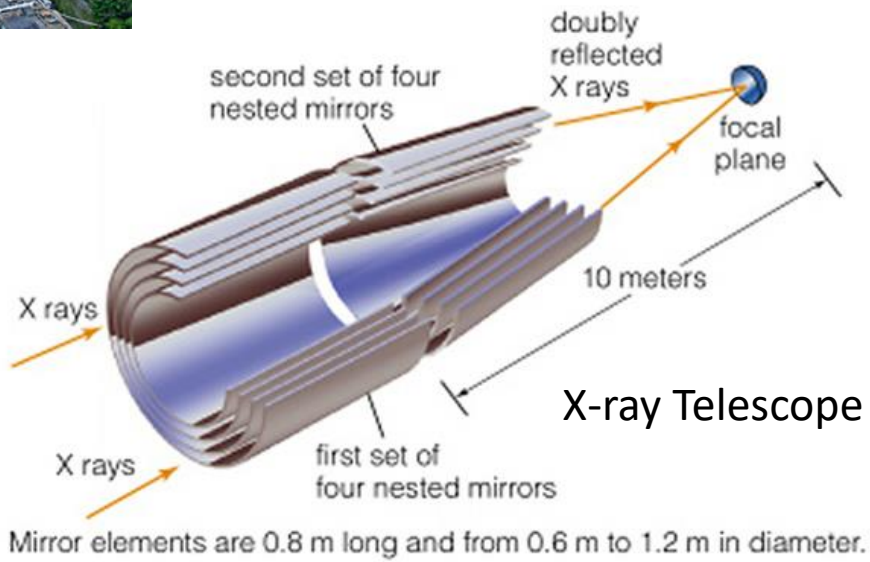


Reflecting Telescope

Other Instruments

Arecibo Radio Telescope





X-ray Telescope

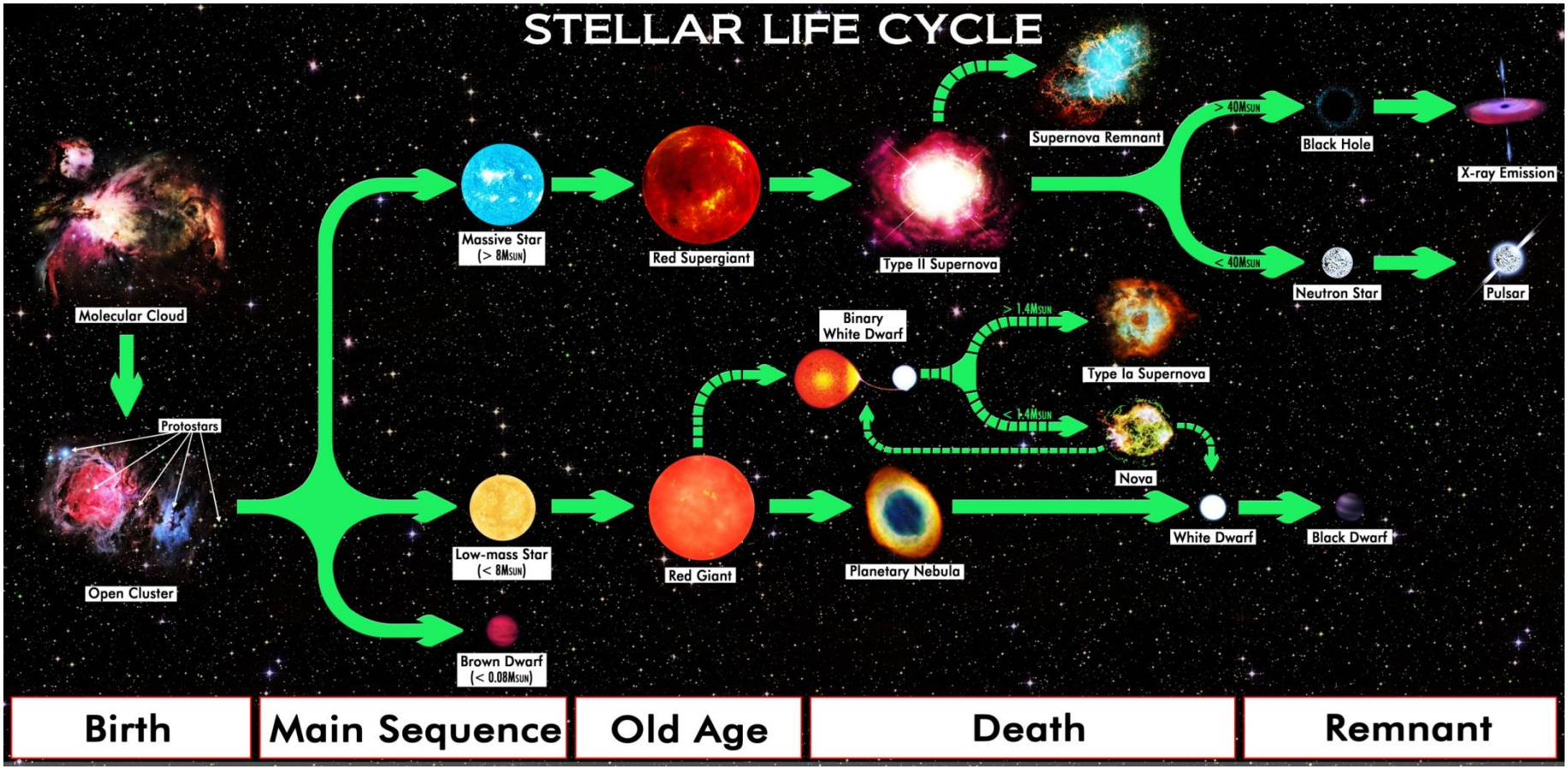
What am I looking at?

- Types of Local Solar System Objects:
  - Sun, Planet, Moon, Asteroid, Comet
- Types of Interstellar Objects:
  - Comet, Rogue Planet, Star, Galaxy, Nebula, Pulsar, Quasar
  - Constellations: Size, Shape
  - Nebulas: Size, Shape
  - Stars: Color or Spectrum, Brightness or Magnitude
  - Pulsars: Pulse Rate
  - Magnetars: Magnet field strength
  - Galaxies: Size, Shape
  - Quasars: Brightness
  - Black Holes: Observed by lens type distortion of space.
- Space is composed of much more than the above.

Types of Stars

- Proto Stars – Gas collapsed from a giant cloud.
- T Tauri stars – Gravity is not enough to generate fusion.
- Main Sequence stars – Vary in size and color
  - Blue Giants (like Betelgeuse) are short lived (millions of years).
  - Small yellow stars (like the Sun) will last billions of years.
  - Red Dwarfs (like Proxima Centauri) will last trillions of years and have a mass of .08 to .5 solar masses.
  - Brown Dwarf stars can't fuse hydrogen as they are at least twice the size of Jupiter but less than .08 solar masses.
- Red Giant stars have exhausted hydrogen and burn helium.
- White Dwarf stars exhausted their hydrogen and can't fuse.
- Stellar Remnants – Black Dwarf stars, Neutron stars (Pulsars and Magnetars) and Black Holes.

Stellar Life Cycle

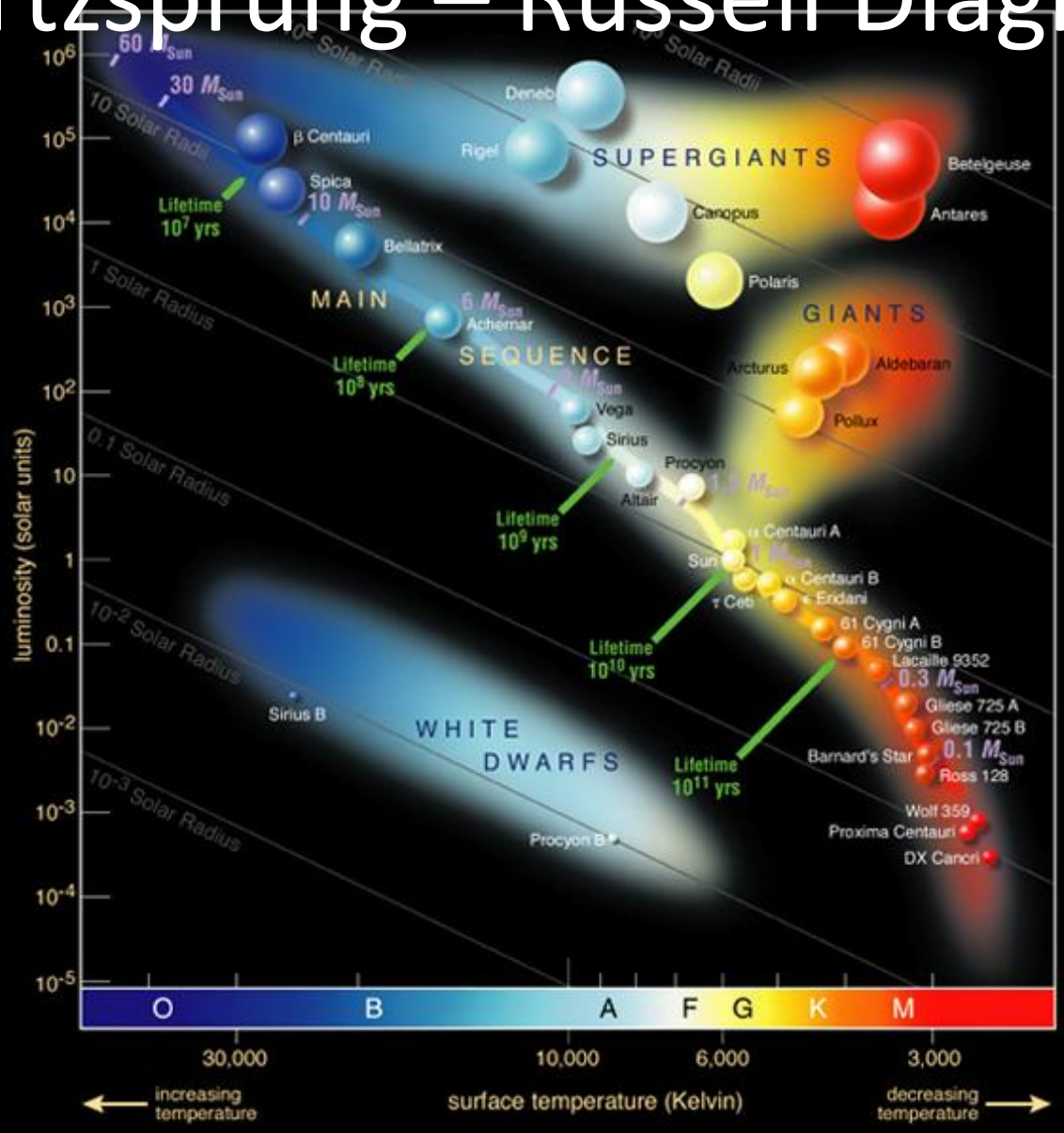


What Stars Burn and How Long

Fusion Process	Stellar Mass (Suns)				
	< 0.08	0.08 - 0.5	0.5 to 25	25 to 40	> 40
H -> He		X	X	X	X
He -> C		X	X	X	X
C -> Ne				< 600 yrs	X
Ne -> O				< 1 year	X
O -> Si				< 0.5 year	X
Si -> Fe				< 1 day	X
Final Result	Brown Dwarf	White Dwarf	White Dwarf	Neutron Star	Black Hole

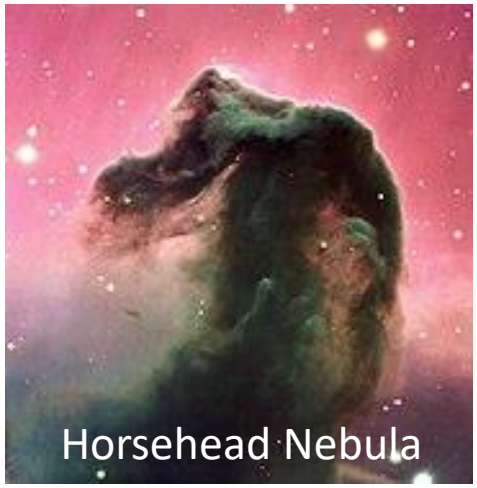
Stellar Mass (Suns)	0.1	1	1.5	3	10	30	60
Time (Billions of years)	1000s	10	3	0.37	0.032	0.011	0.003
Spectral Type	M7	G2 (Sun)	F5	A5	B4	O7	O3

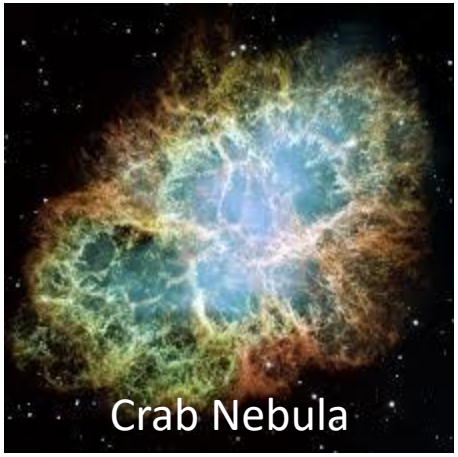
Hertzsprung – Russell Diagram

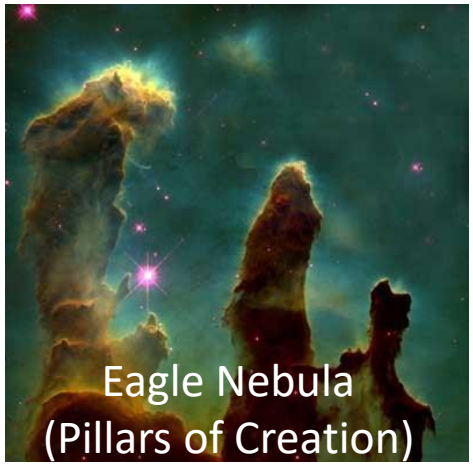


Examples of Celestial Objects

Earth's Moon







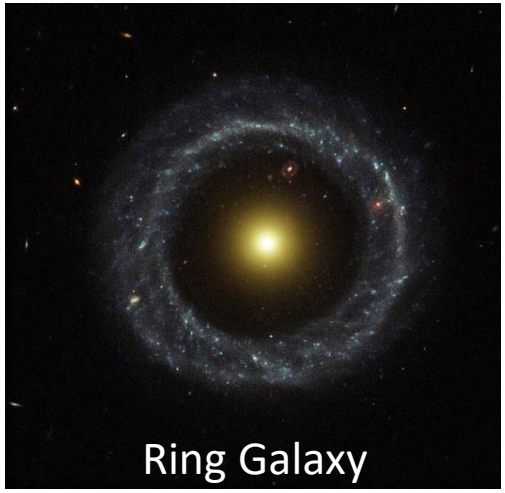
Sample Constellations

Show Stellarium
Speed up Earth rotation

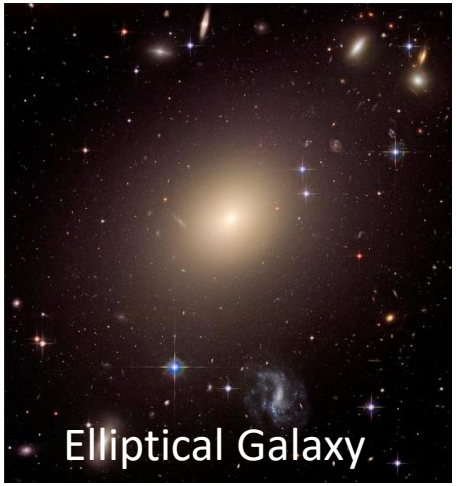
Sample Galaxies


Andromeda (spiral galaxy)


Sombrero (spiral galaxy)


Ring Galaxy


Colliding Galaxies


Elliptical Galaxy

Dark Matter and Dark Energy

- What is Dark Matter?
  - No one knows.
  - Galaxies rotate too fast to hold onto their stars.
  - Galaxies appear to have more mass (more gravity) than we can see.
  - Is our understanding of gravity correct?
  - Could mass affect space in some way we haven't accounted for?
- What is Dark Energy?
  - No one knows (can't account for it).
  - Something appears to be accelerating the expansion of the Universe.
  - Perhaps the yardstick used to measure the distance of celestial objects is off.
    - Are the stars used as a Standard Candle all the same?
    - Do Type 1a Supernovas truly emit a fixed amount of energy?
- Maybe you can solve these puzzles.

Empty Space?
(no such thing)