

Measuring Distance in Astronomy



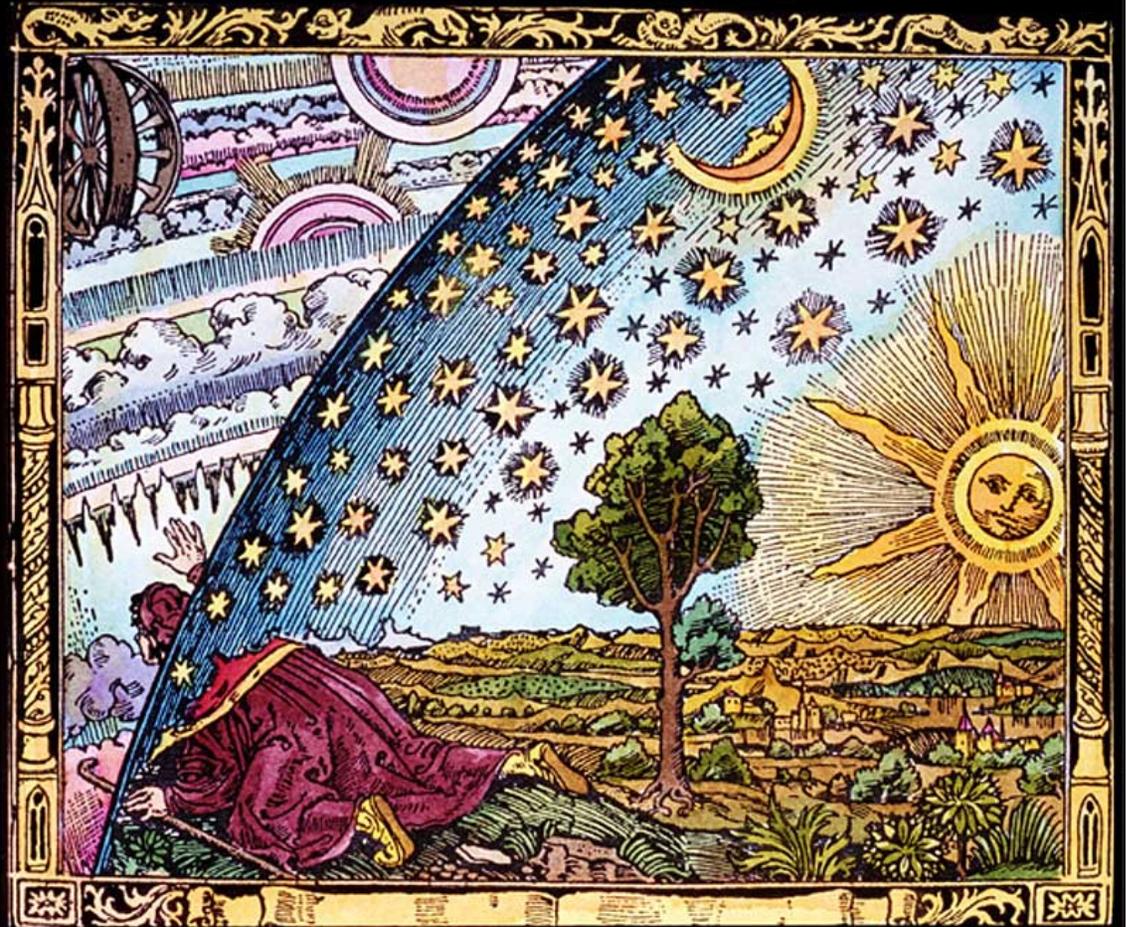
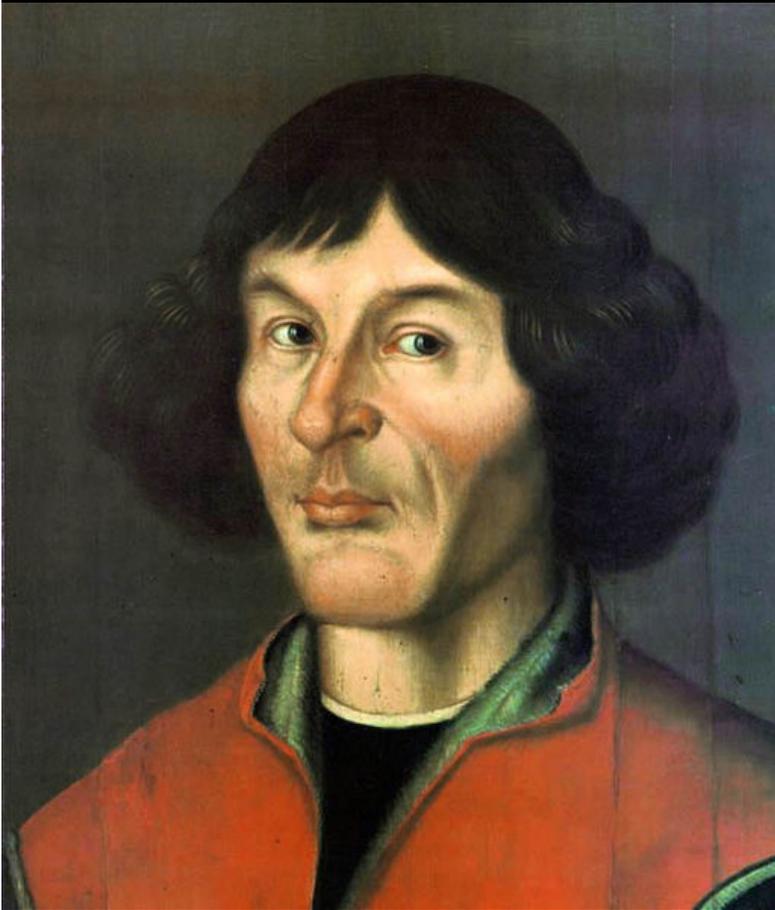
Peterborough Astronomical Association
Novice Astronomy Class #24
September 6, 2024

NASA/JPL - Caltech

Brett Hardy

An Old Question

- Crystal Spheres
- Nicolaus Copernicus 1473-1543



Empedocles Breaks Through the Crystal Spheres

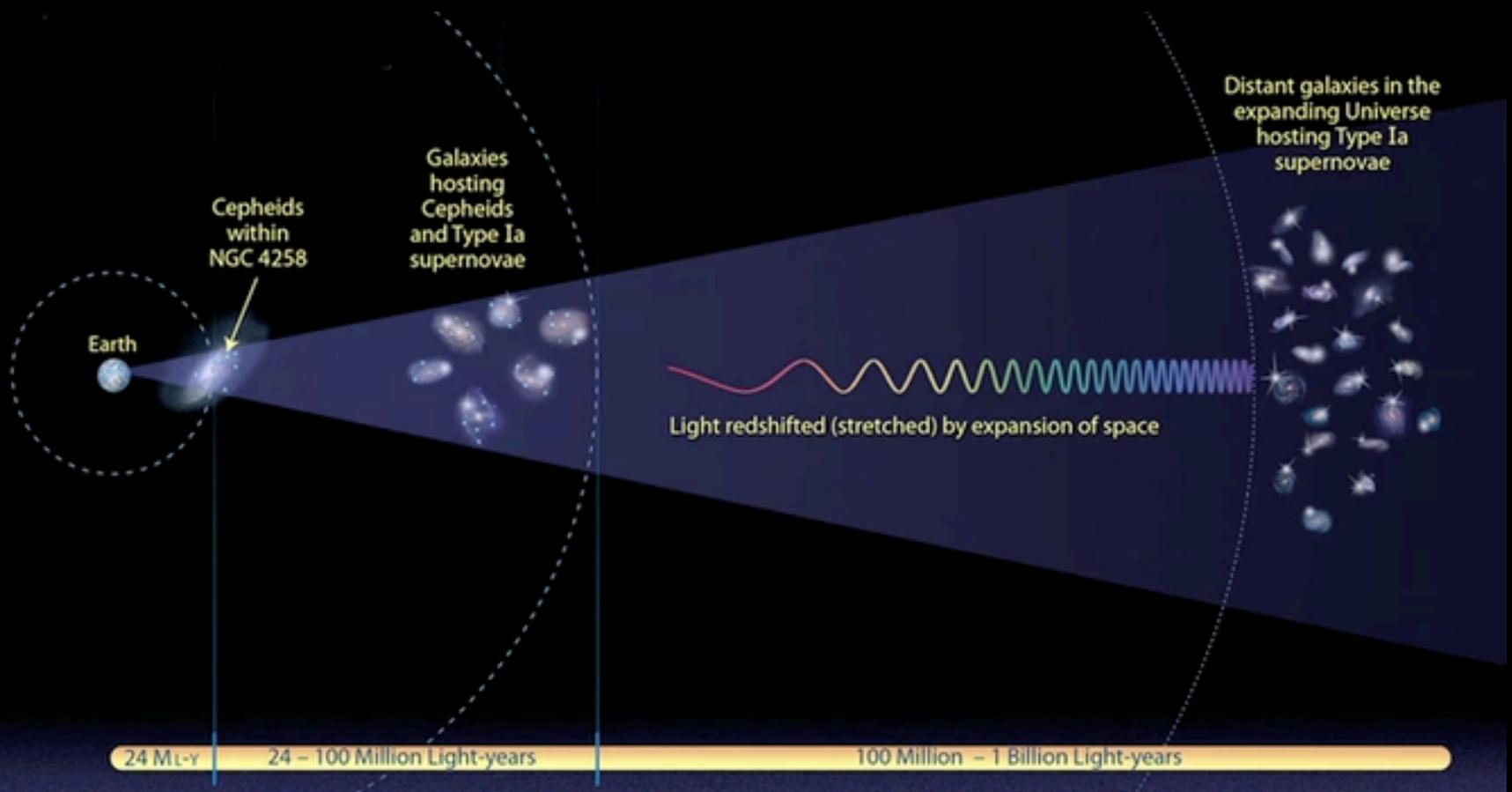
Early History

- Eratosthenes 200 BCE
 - Earth's circumference 40,000 km
- Hipparchus of Nicaea 189 BCE
 - Moon's distance 563,300 km
- Jean Picard 1669-1670
 - Earth's radius 6,375 km
- Giovanni Cassini & Jean Richer 1671
 - Sun's distance from Earth 140 million km



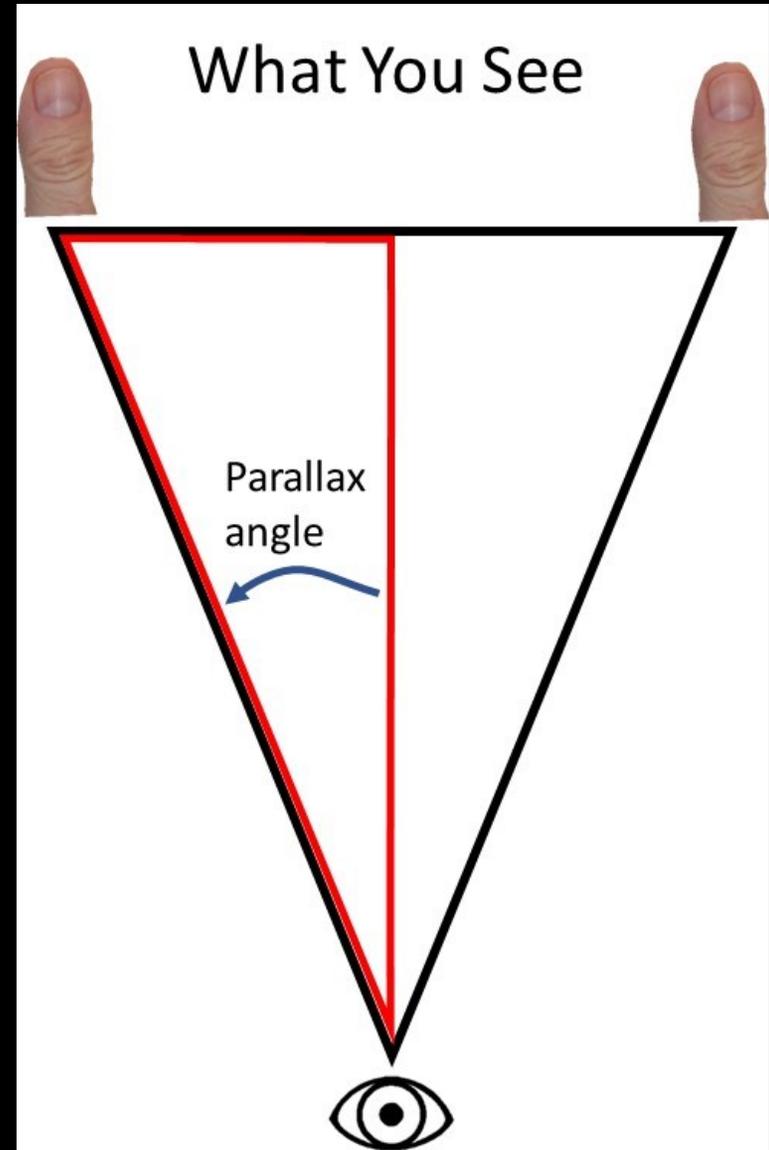
Hipparchus of Nicaea

Cosmic Distance Ladder



How Far is Up?

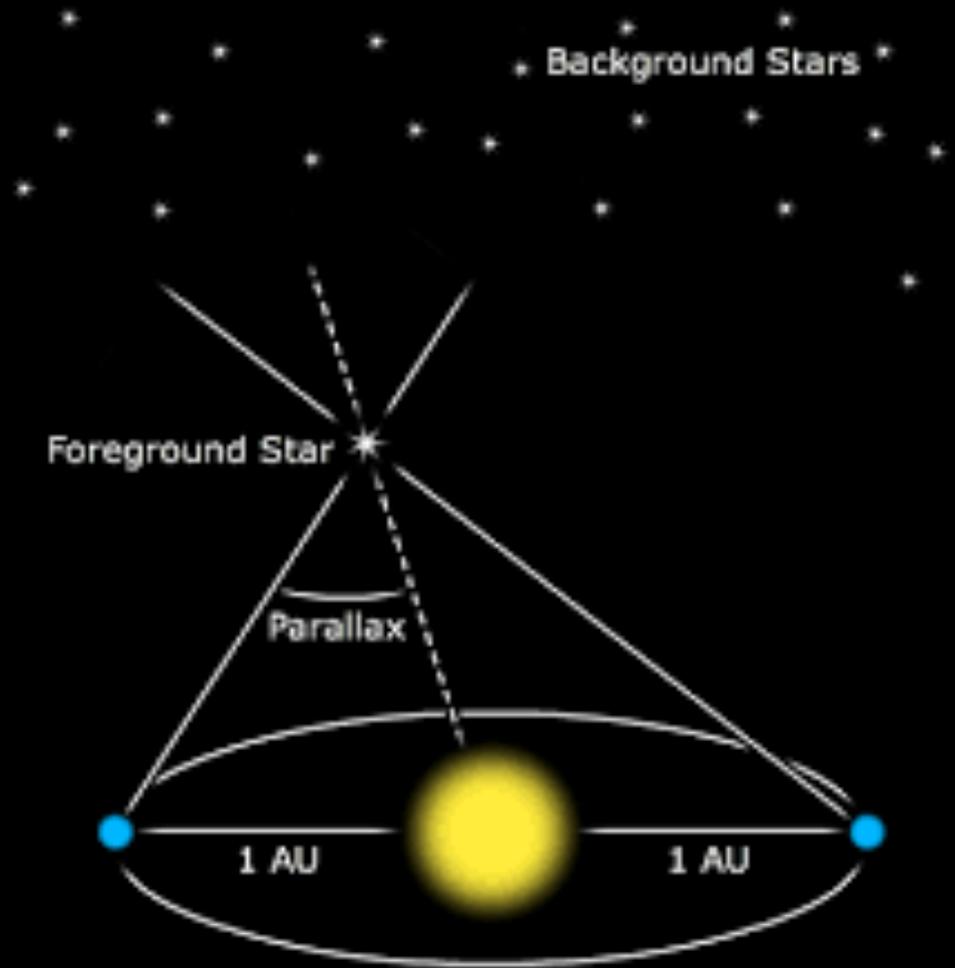
- Parallax



Russ Colson

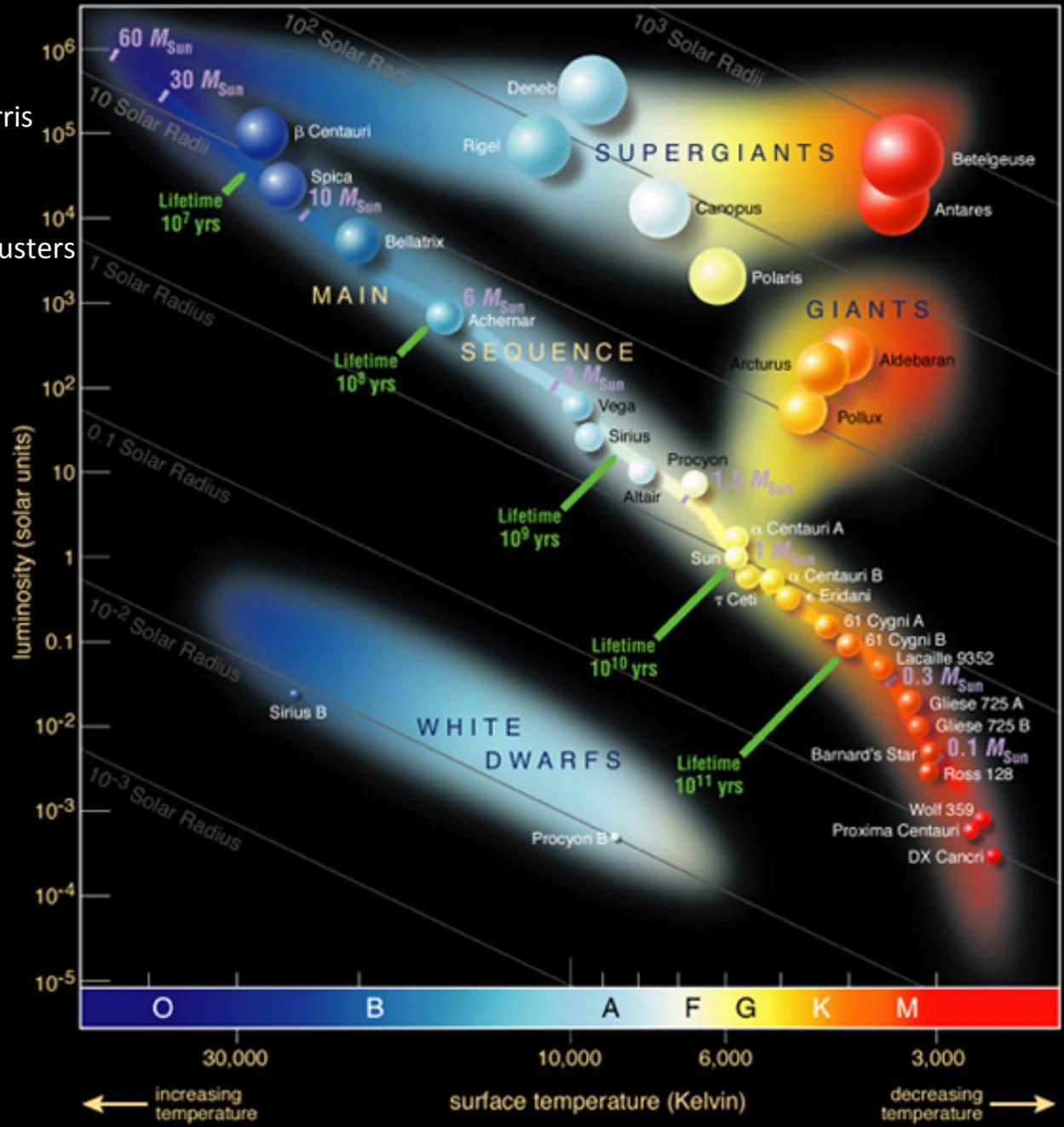
Stellar Parallax

- Change in location of a star relative to background stars 6 months apart
- Difference in angle = parallax (p)
- Friedrich Bessel 1838
 - 61 Cygni
 - parallax angle $0.28''$
 - 11.64 ly
- Useful measurement distance $\sim 3,500$ ly



Hertzsprung-Russell Diagram

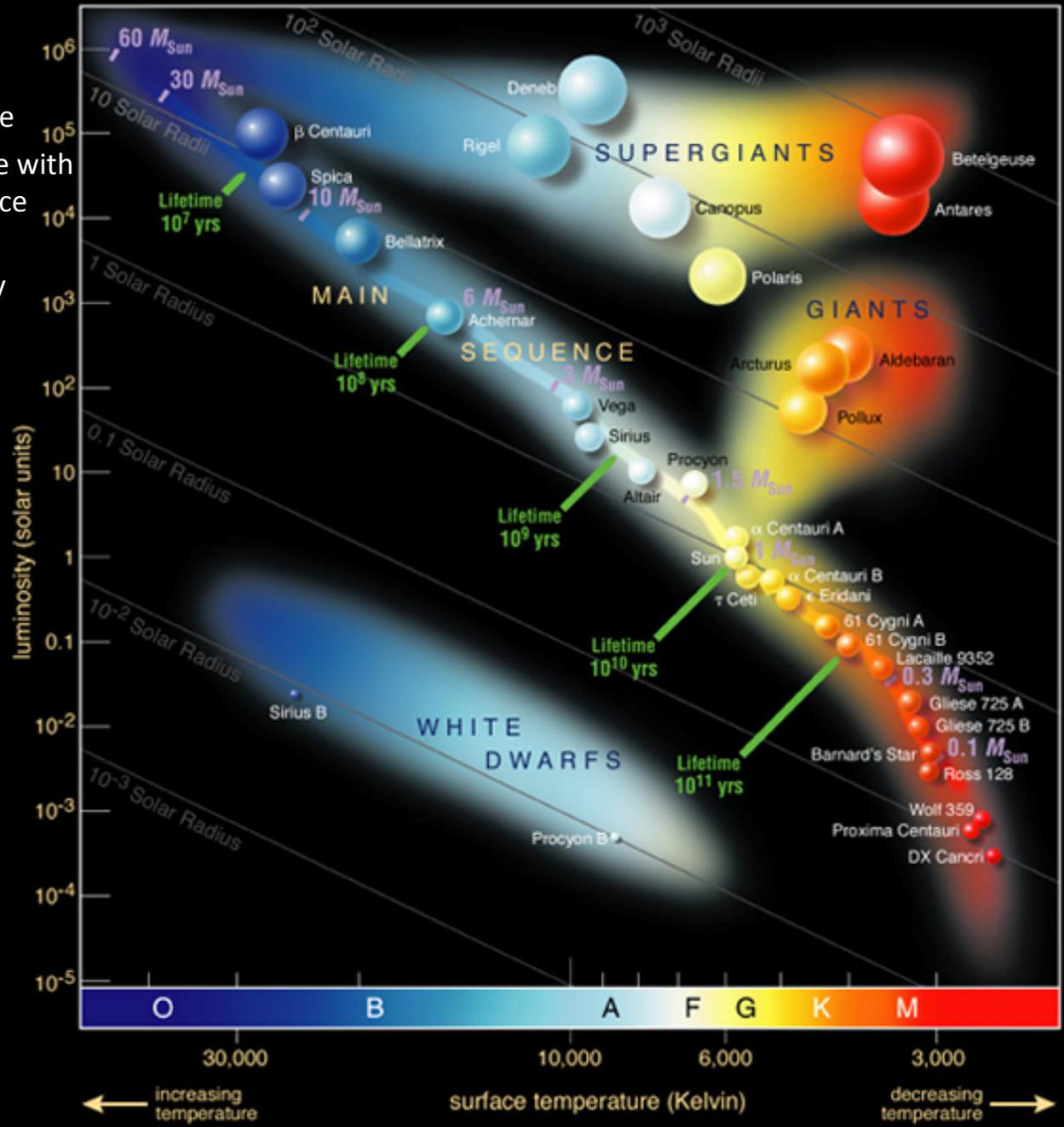
- Ejnar Hertzsprung & Henry Norris Russell
- Created around 1911
- Developed using nearby star clusters



Spectroscopic Parallax

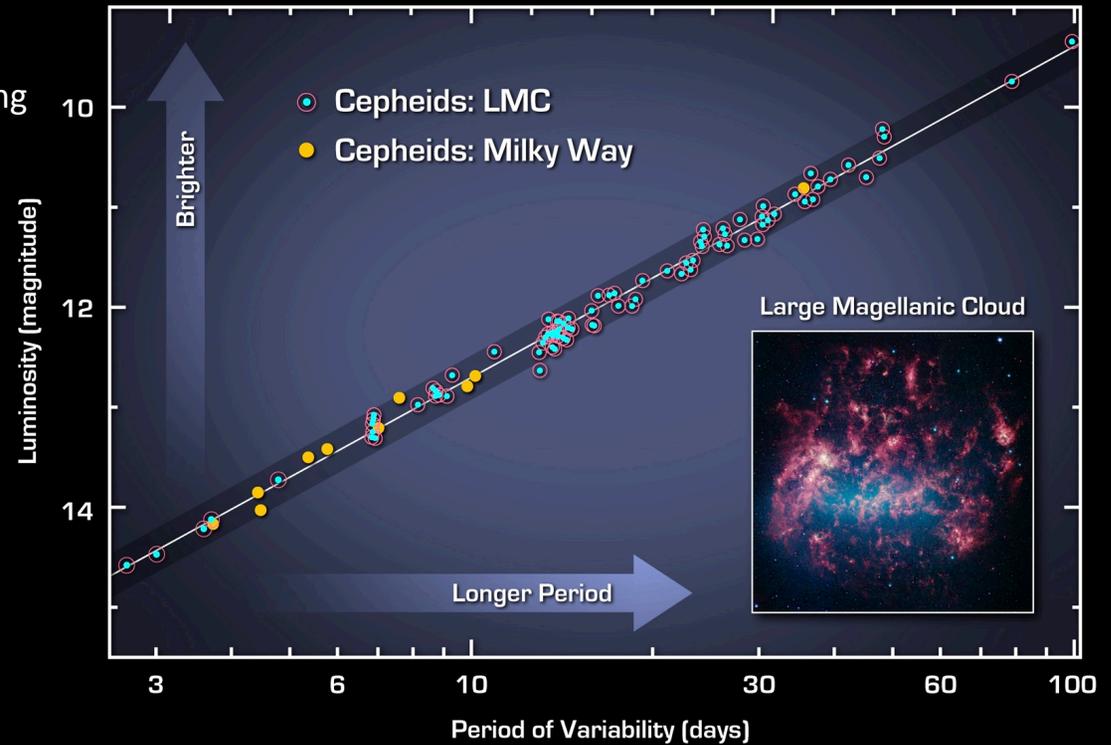
- Determine distance by star type
- Compare colour & temperature with luminosity to determine distance
- Useful measurement distance includes most of the Milky Way

$$F = \frac{L}{4\pi D^2}$$



Cepheid Variable Stars

- Massive stars with short lifespans
- Henrietta Swan Leavitt
- Discovers period-luminosity relationship
- First standard candle useful for measuring distance
- Useful for nearest galaxies
- Edwin Hubble & the nebula controversy
- Useful measurement distance
~ 50 million ly



Calibrated Period-luminosity Relationship for Cepheids

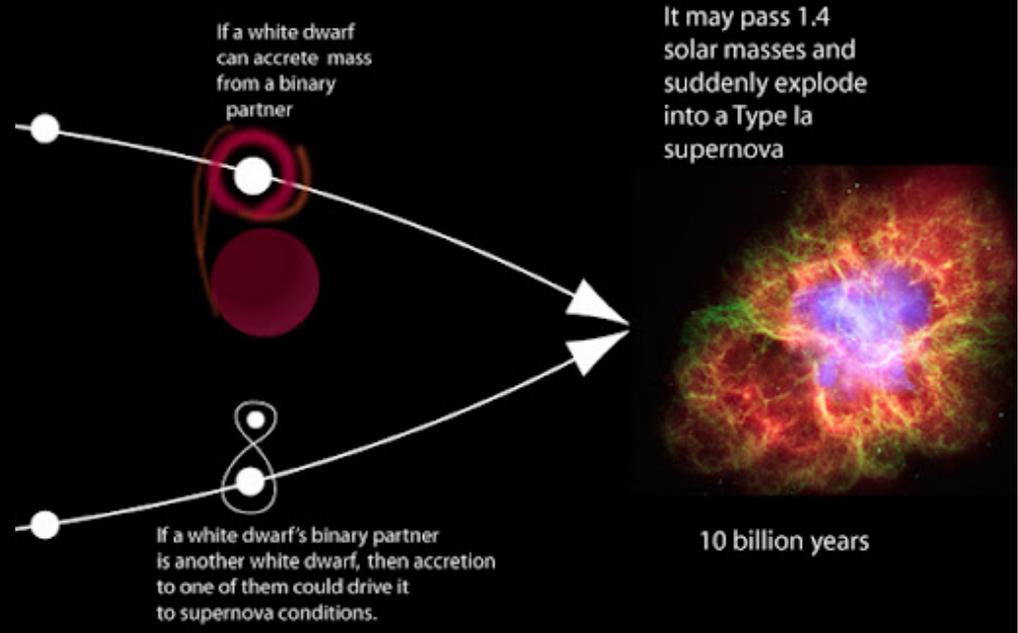
NASA / JPL-Caltech / W. Freedman (Carnegie)

Spitzer Space Telescope • IRAC

ssc2012-13a

Type Ia Supernovae

- Life cycle
 - Binary star system with Sun-like star
 - Red giant
 - White Dwarf
 - Chandrasekhar Limit: 1.44 solar masses
 - Type Ia supernova explosion



R. Nave

Type Ia Supernovae

- Size-luminosity relationship
- Standard candle
- Useful measurement distance several billion ly



B.J. Fulton, Las Cumbres Observatory Global Telescope Network

Cosmological Redshift

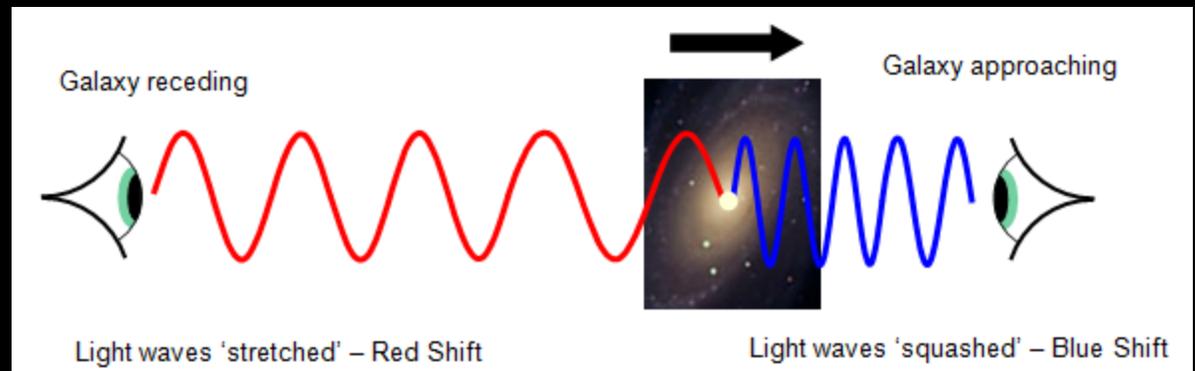
- Vesto Slipher
- Edwin Hubble
- Expansion of the Universe & Cosmological Redshift (z)
- Galaxy spectrum to determine redshift
- Using redshift, Hubble Constant (H_0) and speed of light
- Useful measurement distance to the farthest galaxies



Vesto Slipher



Edwin Hubble



Hubble Space Telescope (HST)

- National Aeronautics and Space Administration (NASA)
- Launched 1990
- Hubble Constant: measure of the expansion of the Universe
- $H_0 = 69.8 \text{ km/s/Mpc}$



Hipparcos Space Mission

- European Space Agency (ESA)
- Launched 1989
- Measured distance, position and motion of > 100,000 stars out to about 1,600 ly



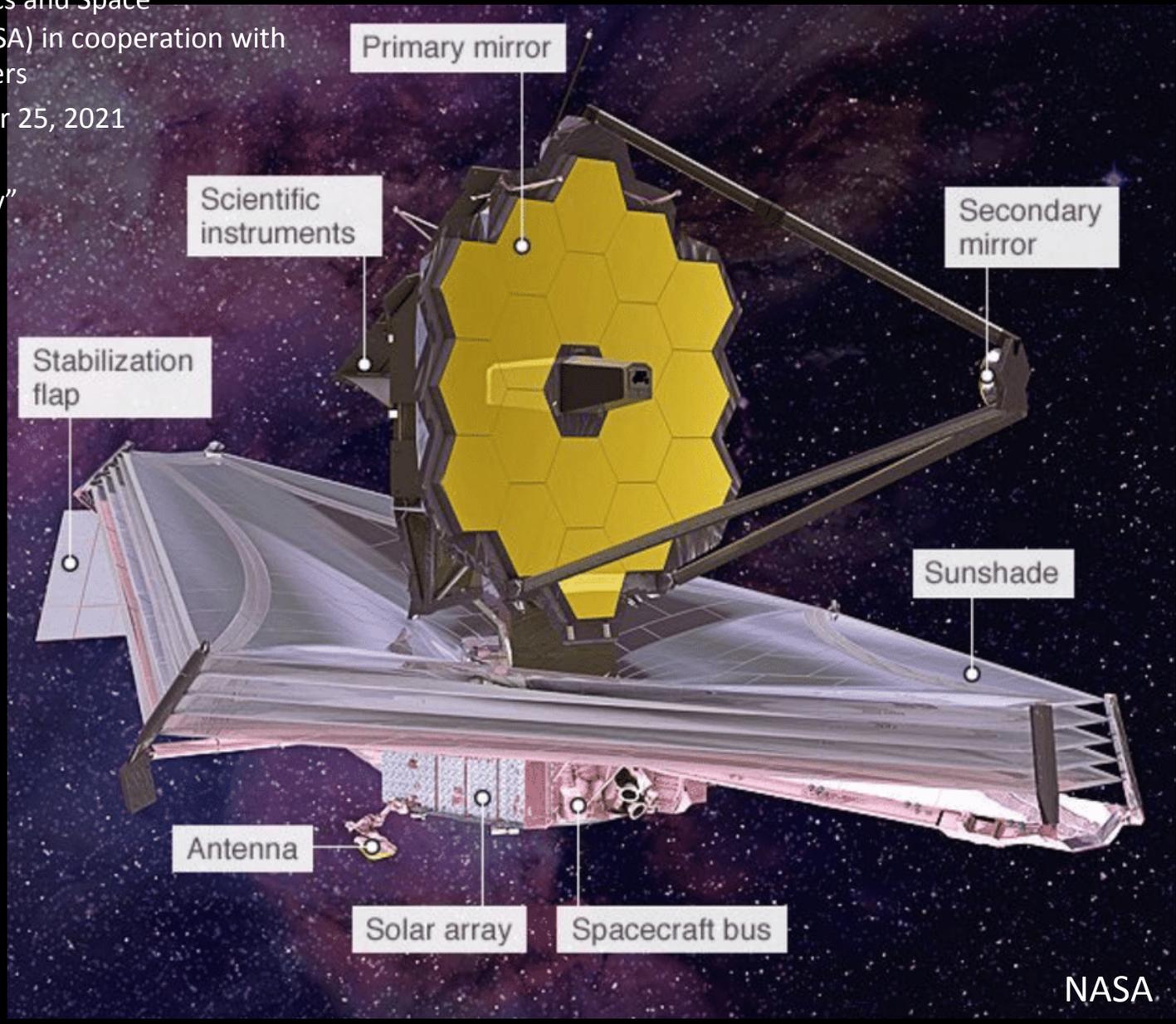
Gaia Spacecraft

- ESA mission launched 2013
- Measured position, distance and motion of > 1 billion stars out to 30,000 ly



James Webb Space Telescope (JWST)

- National Aeronautics and Space Administration (NASA) in cooperation with international partners
- Launched December 25, 2021
- Responsible for the “Crisis in Cosmology”



Novice Astronomy Class #25
Dark Matter & Dark Energy
October 4, 2024

