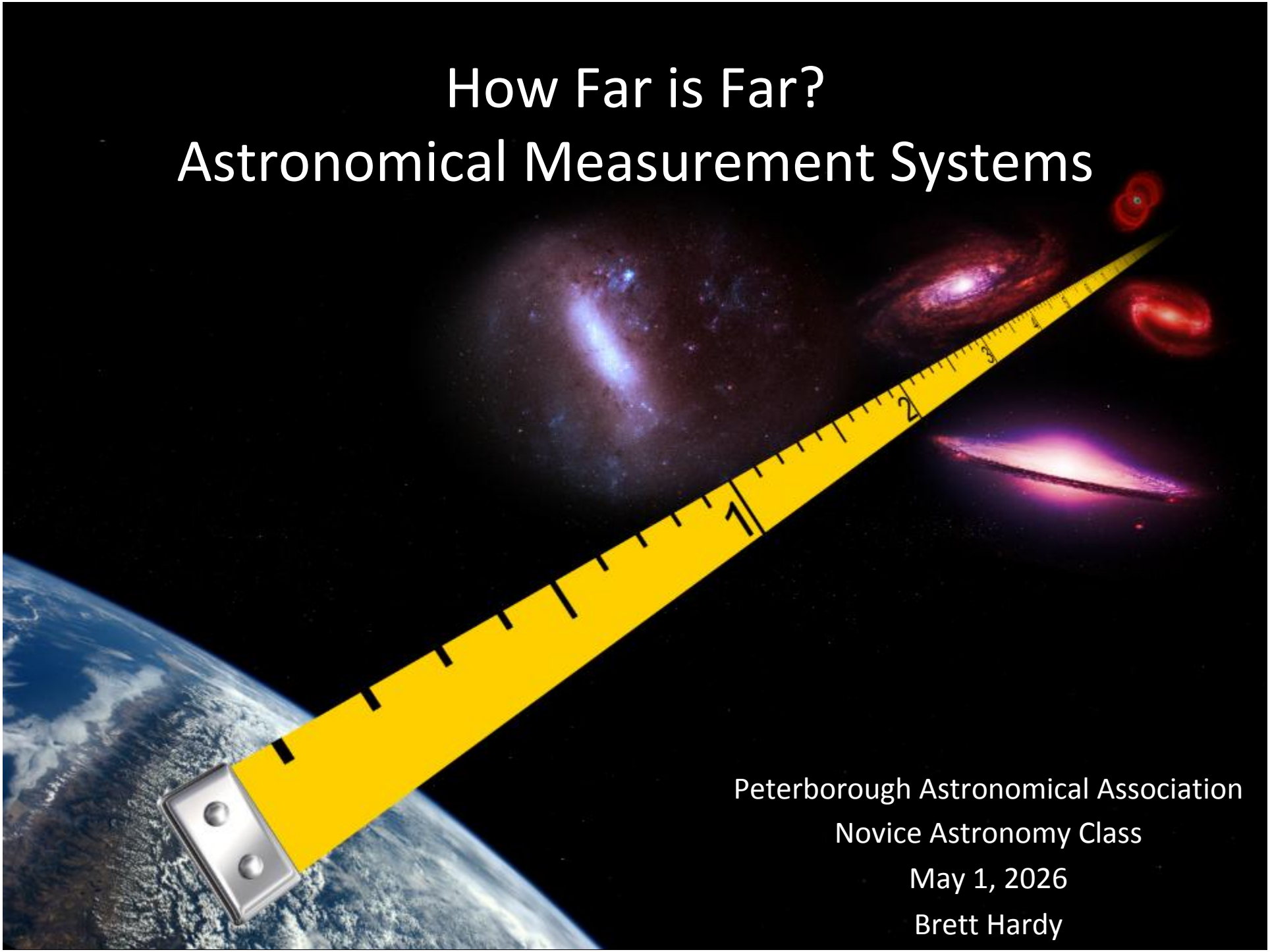
How Far is Far?
Astronomical Measurement Systems



Peterborough Astronomical Association
Novice Astronomy Class
May 1, 2026
Brett Hardy

Light is the Key

- Universal speed limit: 300,000 km/s
- Moon 1.3 light seconds
- Sun 8.3 light minutes
- Light year ~ 9.46 trillion km
- Space-time continuum
- Astronomy is time travel – how cool is that?

Magnitude Scale

- Hipparchus develops magnitude scale of star brightness
- Scale: 1 − 6
- Today this scale extends far beyond this range
- Each whole number increase or decrease represents a 2.5 times change in brightness

Hipparchus of Nicaea

A Map of the Milky Way

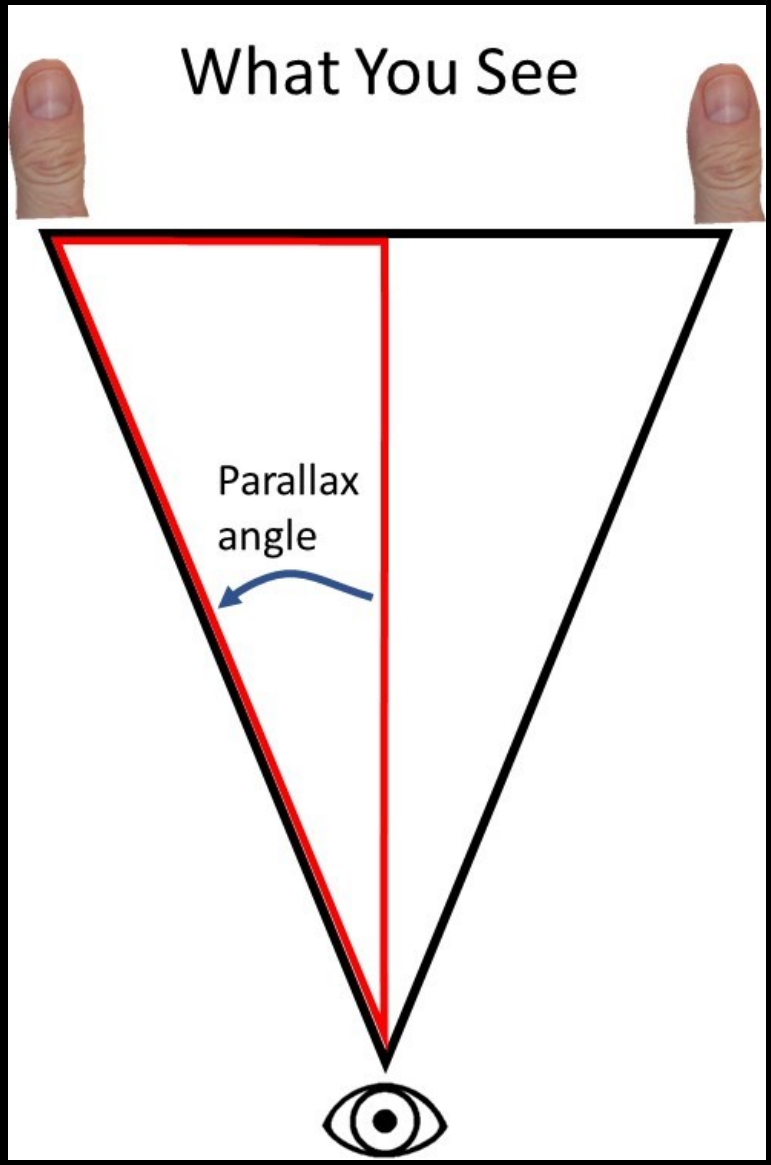
- 1785
- Important principle of light
  - Inverse Square Law
- If one can accurately measure the actual brightness of a star and its apparent brightness, distance can be measured
- Herschel began by making the assumption that all stars had the same actual brightness
- Therefore, differences in apparent brightness would be determined solely by their distance from Earth

But, there is a problem

William Herschel

How Far is Up?

- Parallax



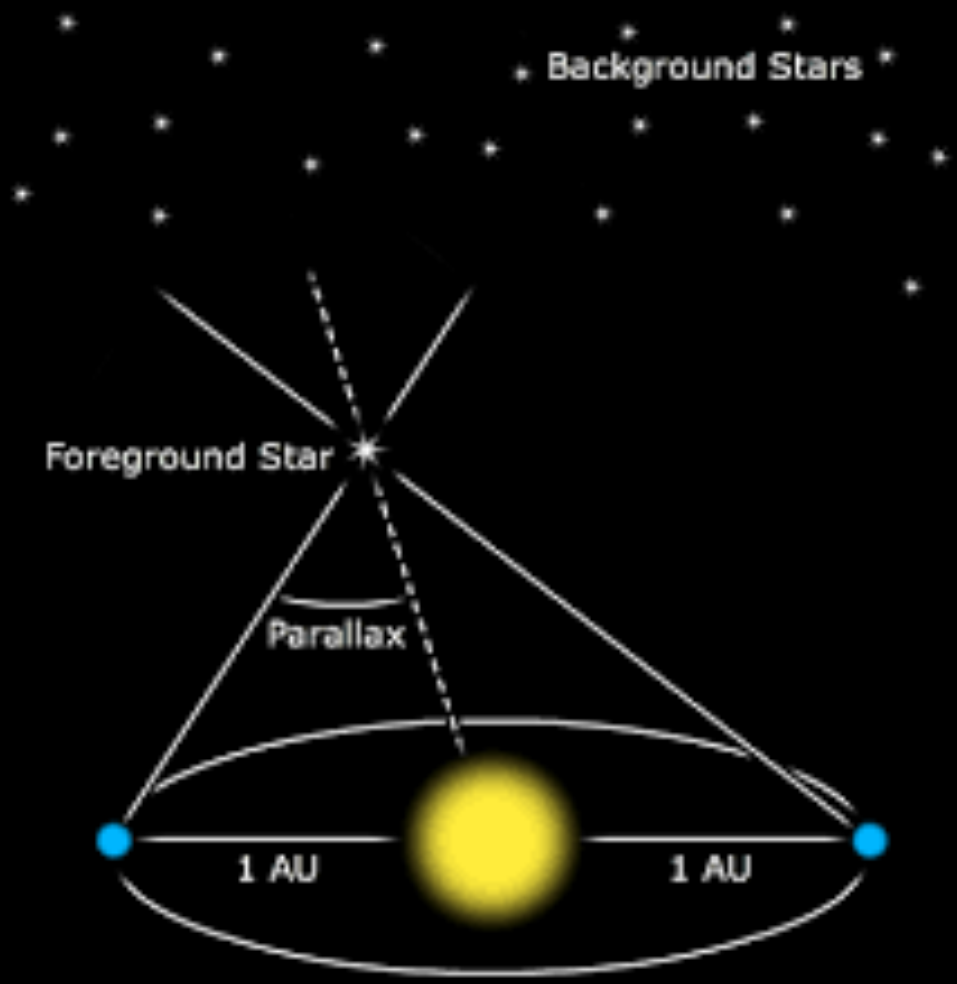
Russ Colson

Stellar Parallax

- Change in location of a star relative to background stars 6 months apart
- Difference in angle = parallax (p)

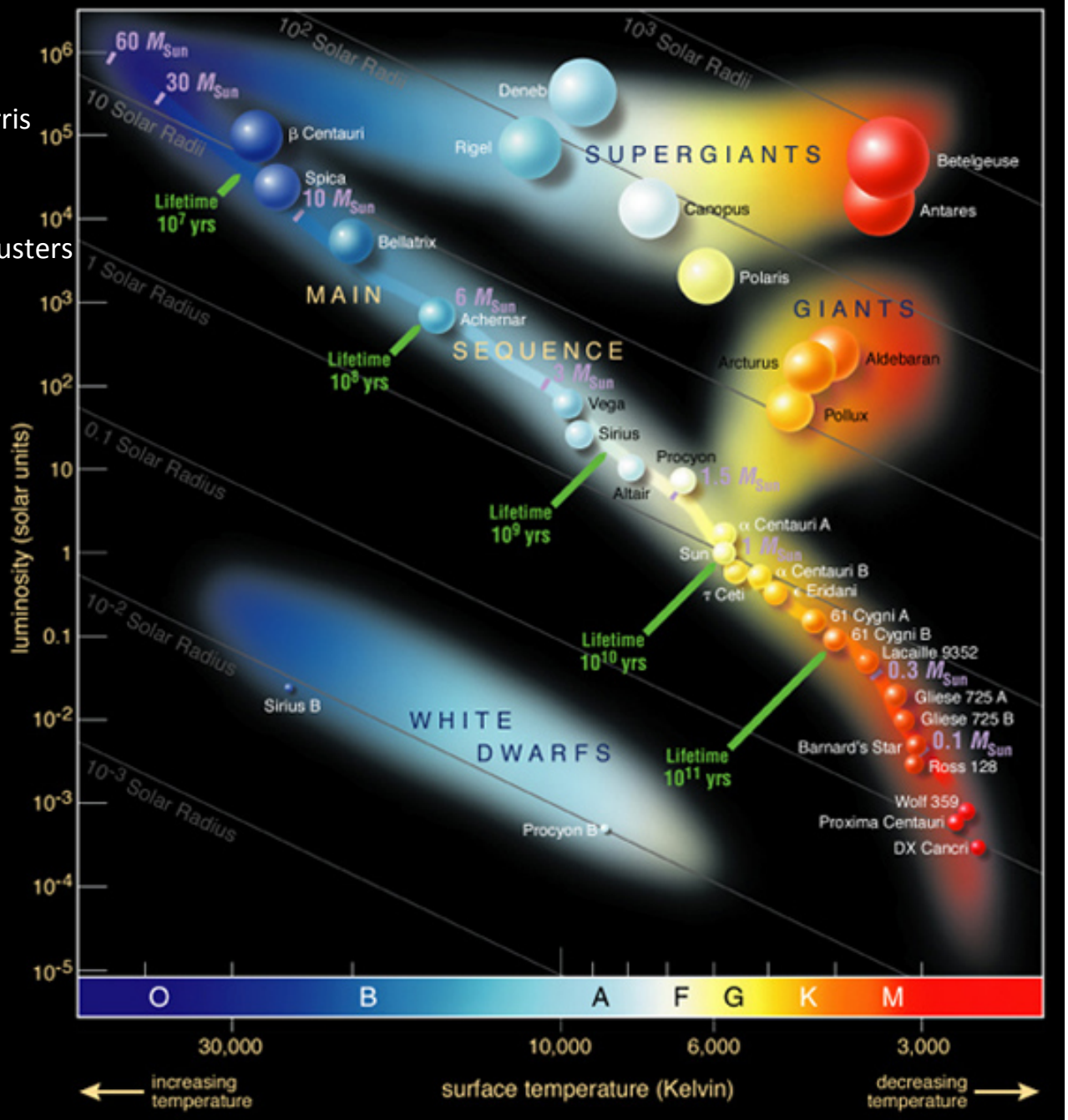
- Friedrich Bessel 1838
  - 61 Cygni
  - parallax angle 0.28”
  - 11.64 ly

- Useful measurement distance ~ 3,500 ly



Hertzsprung-Russell Diagram

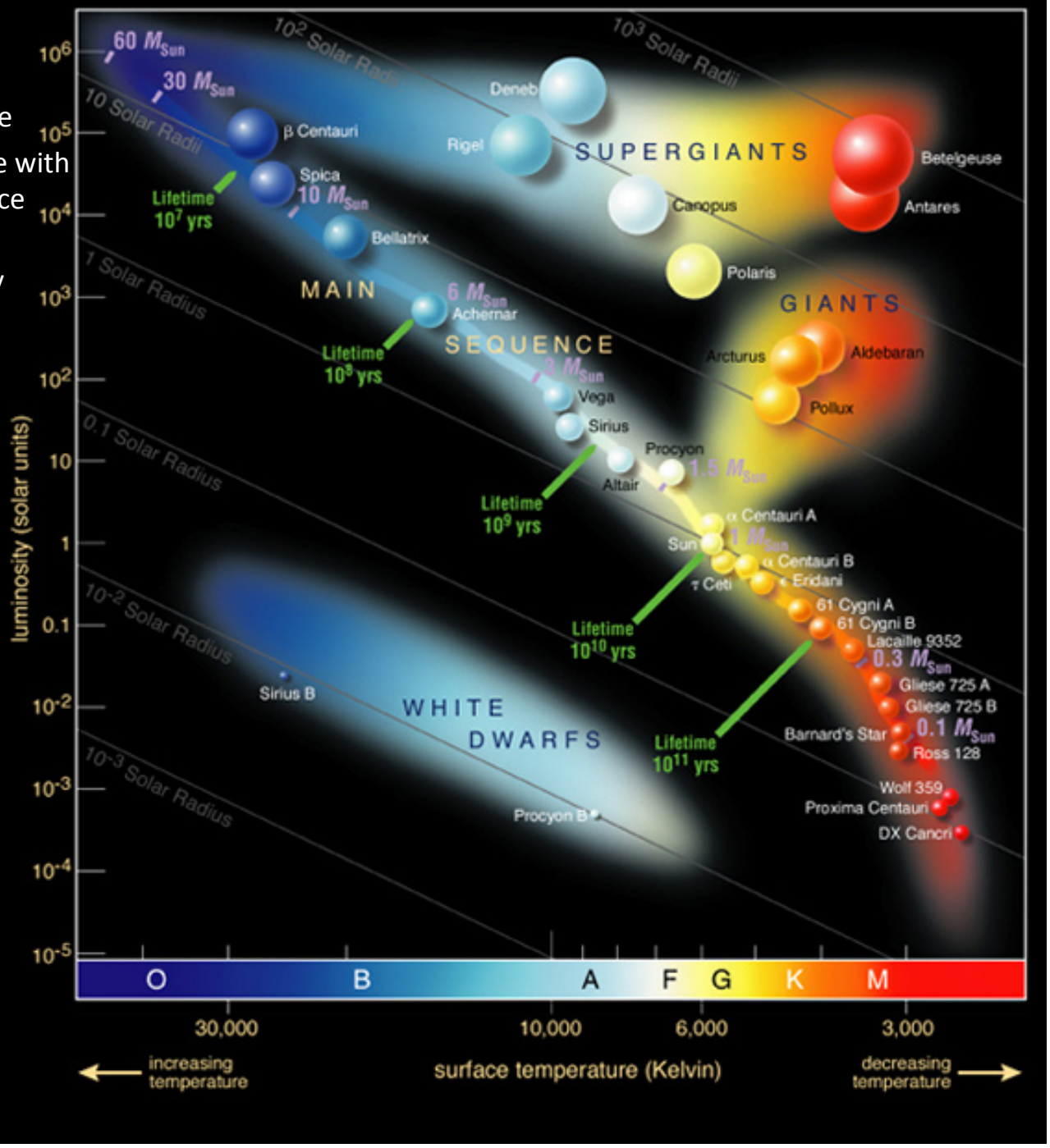
- Ejnar Hertzsprung & Henry Norris Russell
- Created around 1911
- Developed using nearby star clusters



Spectroscopic Parallax

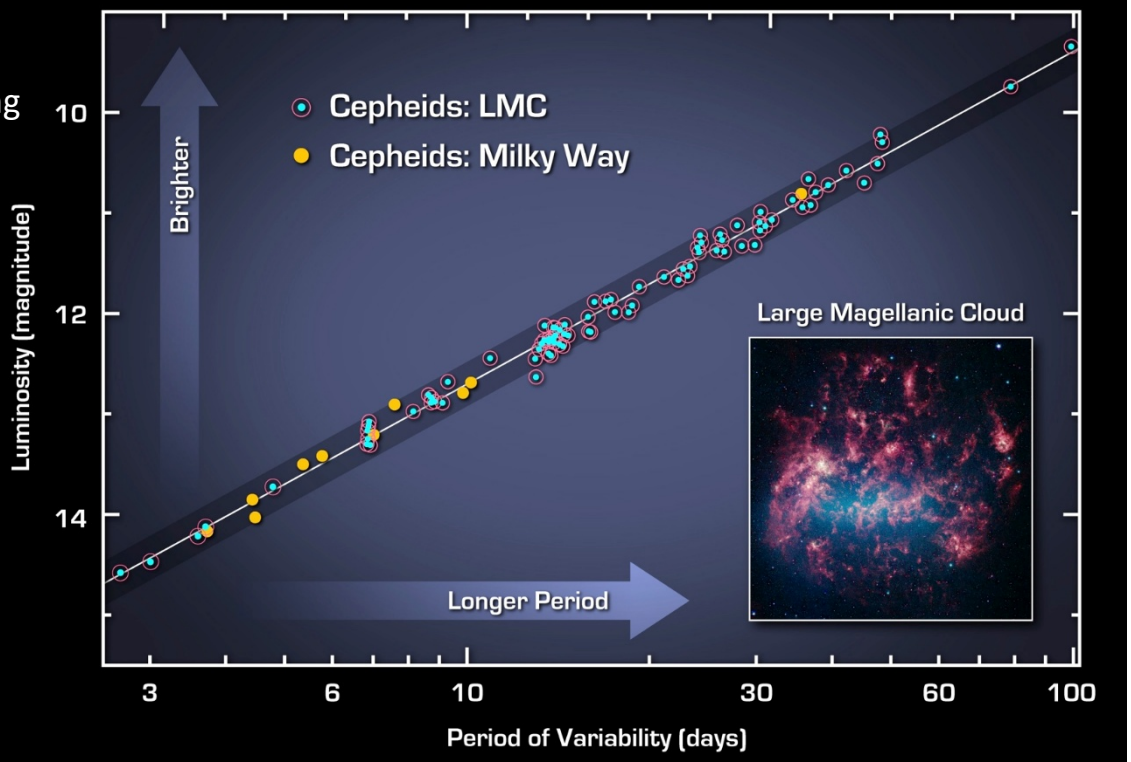
- Determine distance by star type
- Compare colour & temperature with luminosity to determine distance
- Useful measurement distance includes most of the Milky Way

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



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

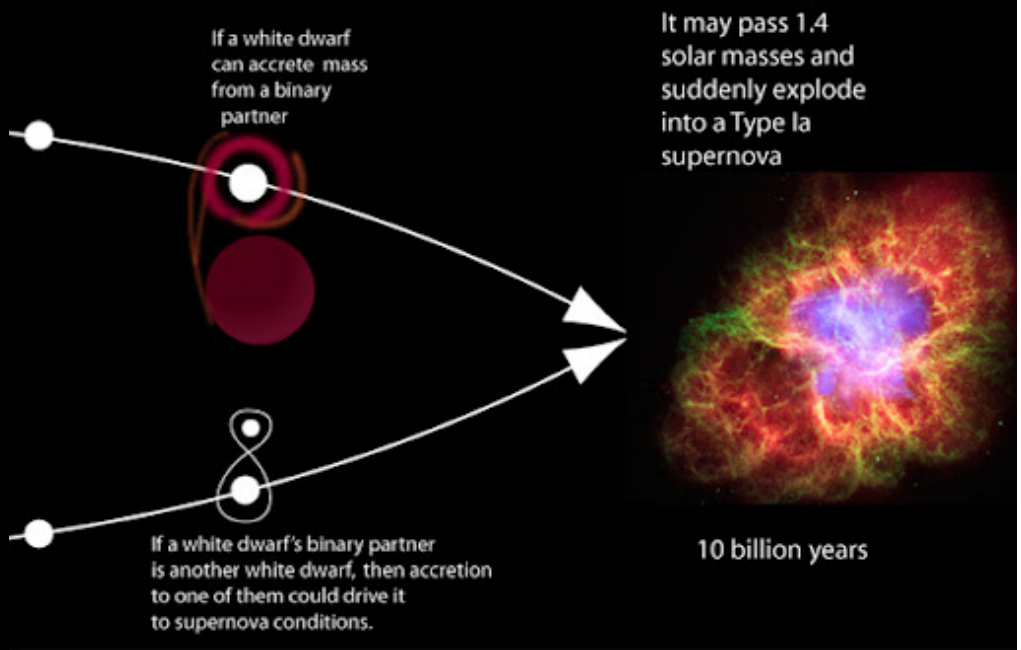


Calibrated Period-luminosity Relationship for Cepheids
NASA / JPL-Caltech / W. Freedman (Carnegie)

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

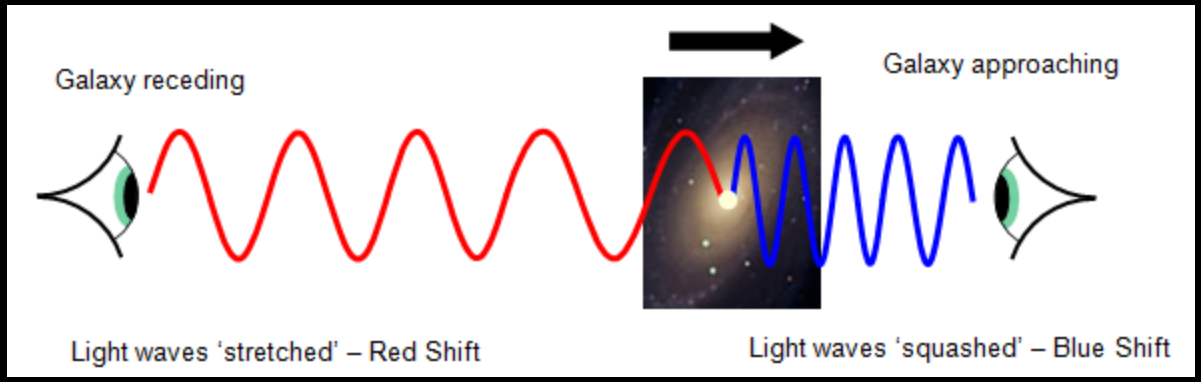
B.J. Fulton, Las Cumbres Observatory Global Telescope Network

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

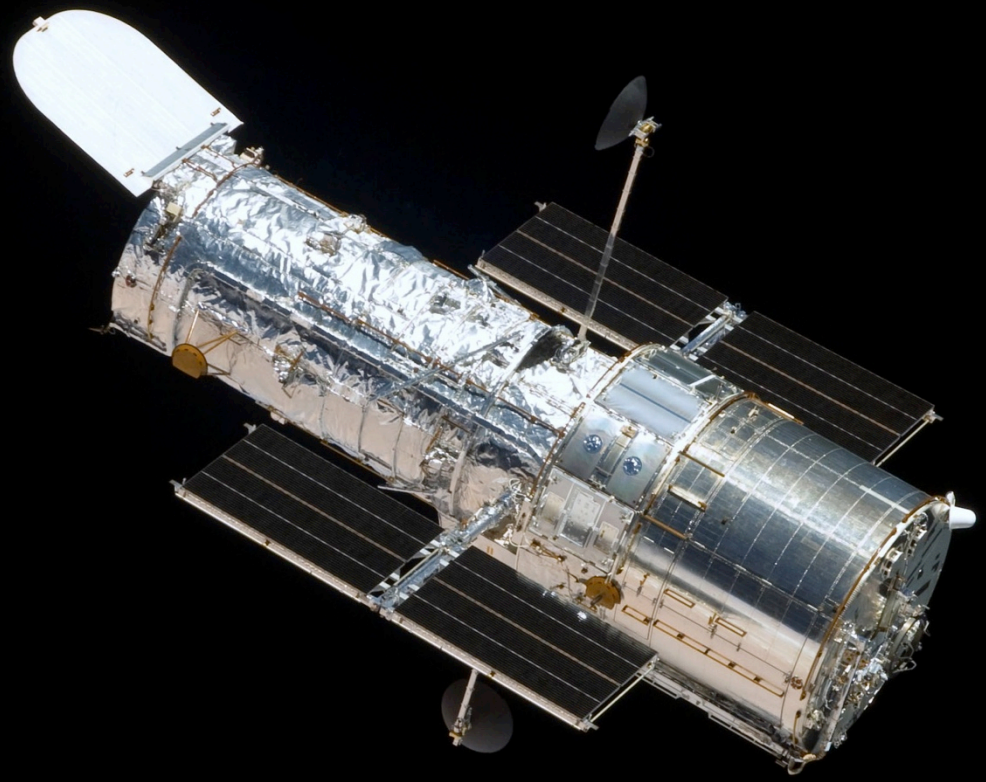
Vesto Slipher

Edwin Hubble



Hubble Space Telescope (HST)

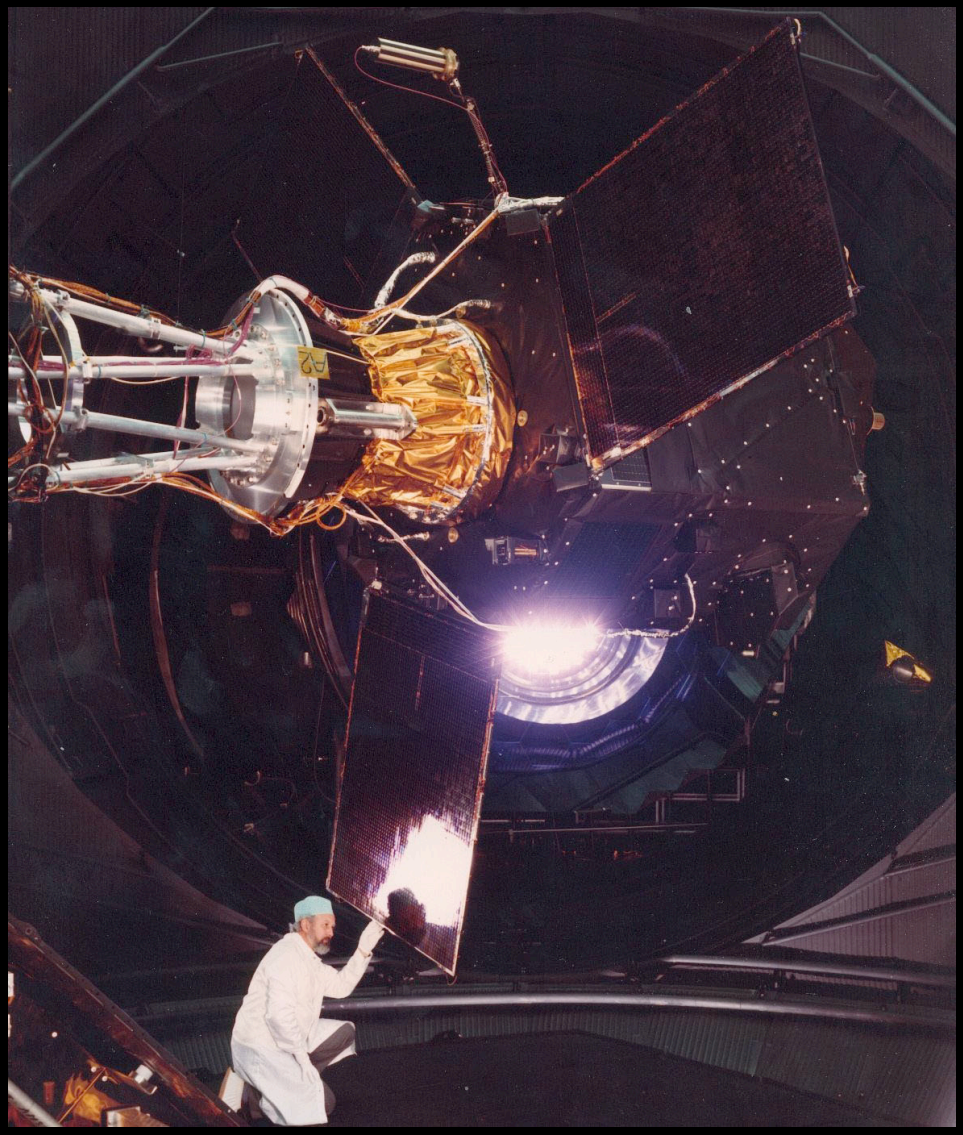
- National Aeronautics and Space Administration (NASA)
- Launched 1990
- Hubble Constant: measure of the expansion of the Universe
- H_0 = 69.8 km/s/Mpc



NASA

Hipparcos Space Mission

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



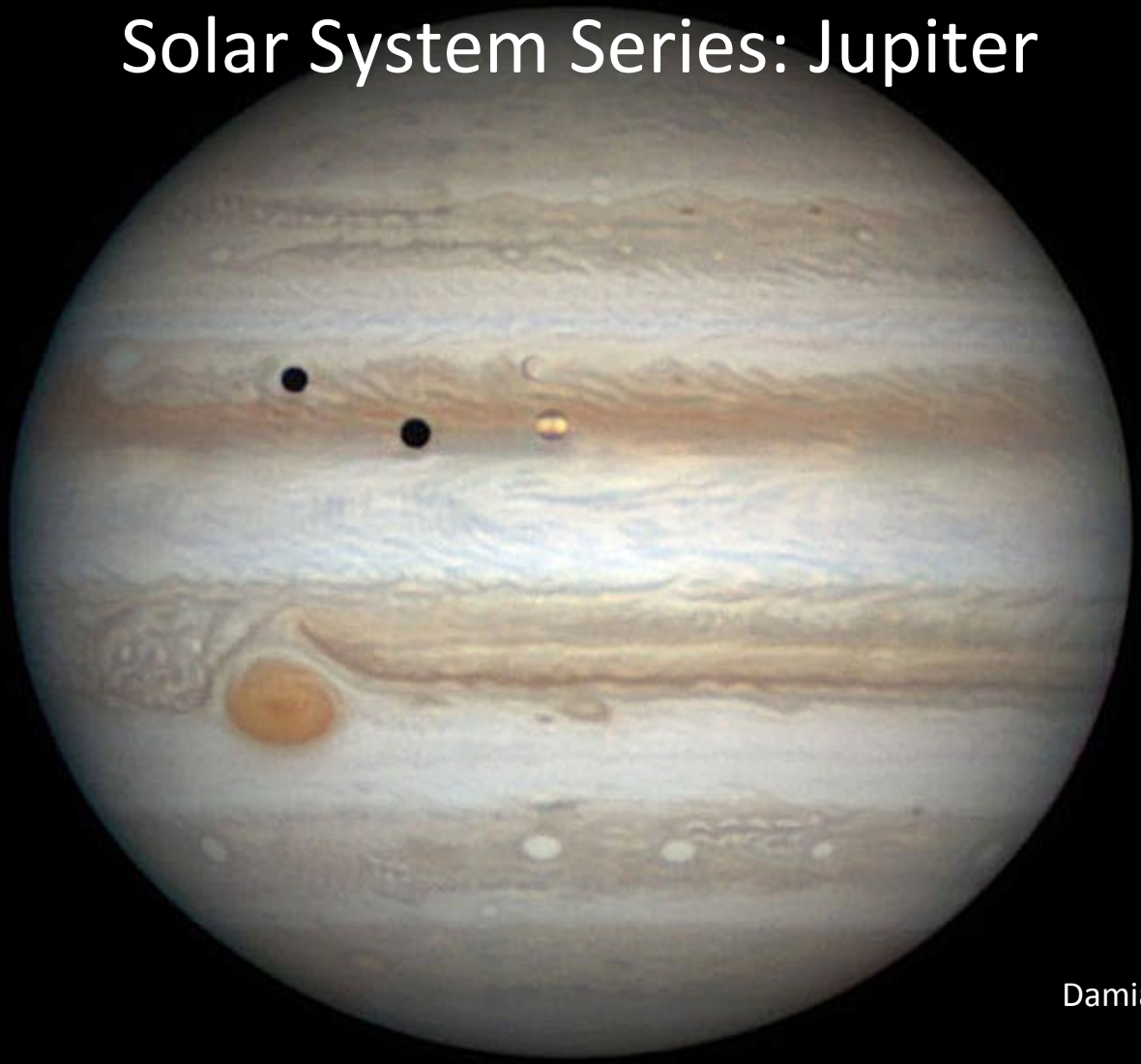
ESA

Gaia Spacecraft

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

ESA

Novice Astronomy Class
June 5, 2026
Solar System Series: Jupiter



Damian Peach