Stellar Properties

Physical Sciences

Broward College

Prepared for AST 1002

Horizons in Astronomy

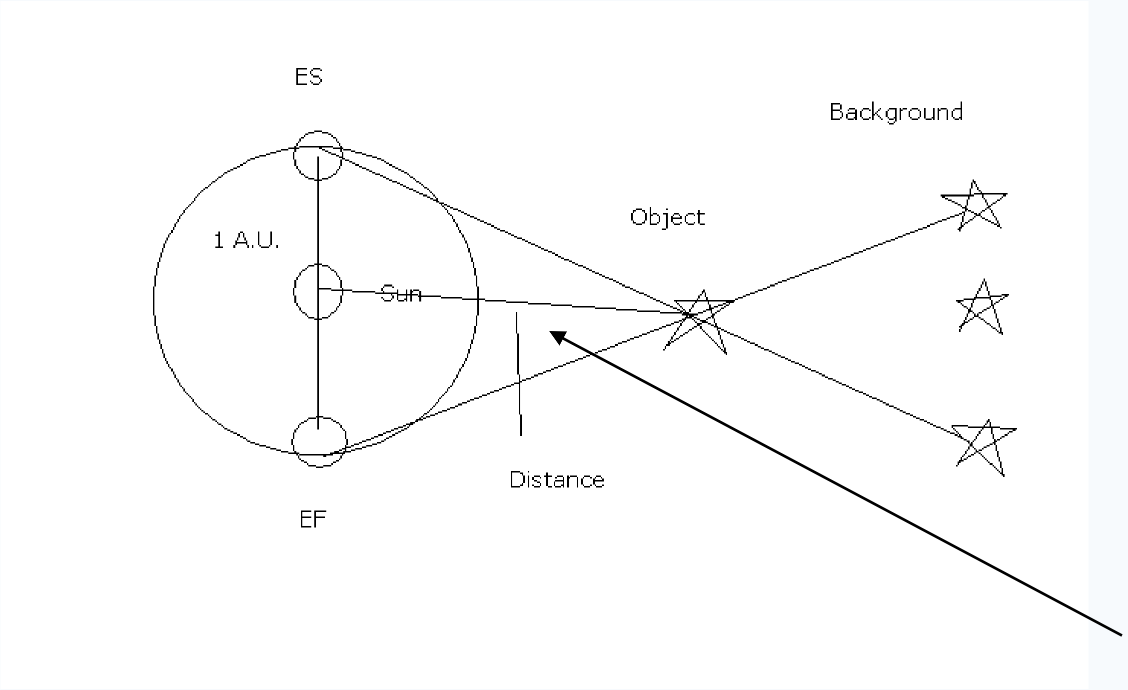
What is a Star?

- A star is a mass of dust and gas that accretes enough material that it can produce fusion at its core.
- A star burns its fuel and provides energy to it home system.
- Star are grouped into constellations and star clusters. The brightest star in constellation is called Alpha (α), the second brightest is called (β), and so on in the Greek alphabet. Some stars have common names like α Canis Major is also called Sirius.
- Larger stars live shorter lives while smaller stars live longer lives.
- Stars are at large distances. We measure the distances to stars in light years (ly), the distance that light travels in a year (9.4605284×10^{12} km); and parsecs (pc) which is 3.26 light years ($3.028X10^{15}$ km). We use the distances to also tell us about what age the area around the star because nothing in our observable Universe travels further than light; so if a star is 65 light years away, the light left that star 65 years ago.

Stellar Views – The Lion King

- There were three views of the stars in 1900's: mystical, planetary, or stellar. The mystical people believed the stars controlled their lives through mystical forces. The planetary people believed the stars were giant planets burning brightly. The stellar people thought the stars were balls of the gas.
- Only though observation and classification were we able to correctly model the stars.
- Click on the image to see the clip.

Stellar Parallax



$$\text{Distance (parsec)} = \frac{1}{\text{Parallax Angle ('')}}$$

Figure 1. Parallax

- Stellar parallax is observed due to the Earth orbit the Sun.
- The Earth makes different angles with a nearby star with respect to a background star making the star appear to "move" through the sky. The angle the star makes is called the proper motion angle.
- We can measure the distance to the star using the parallax angle (p) using geometry. The parallax angle is half of the proper motion angle.
- The closer the star the bigger the angle.
- If the object is moving with respect to the Sun, we calculate either a too large or small distance.
- The distance we measure is called parsecs.

Parallax of a Star Example

- What is the distance of a star that has a parallax of 0.2”?

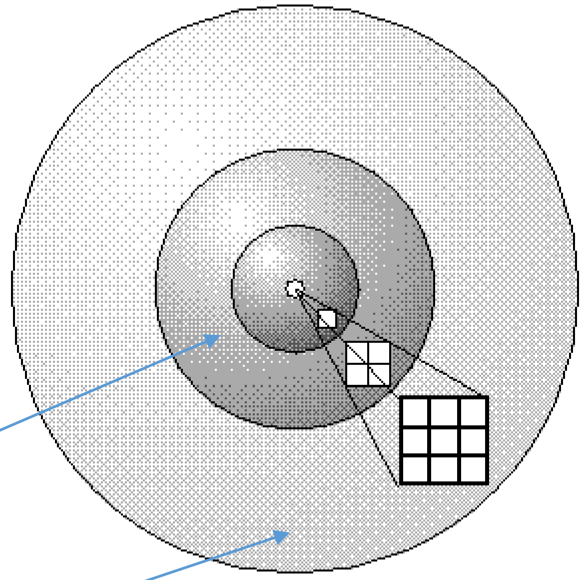
$$\text{Parallax} = 0.2''$$

$$\text{Distance} = \frac{1}{\text{Parallax}}$$

$$\text{Distance} = \frac{1}{0.2''} = 5 \text{ parsecs}$$

Stellar Brightness

- There are three ways of measuring the energy emanating from stars: magnitude, flux, and luminosity.
- Magnitude (m or M) is a number assigned to star based on how bright the star compared to the stars. Hipparchus gave the brightest stars in the sky magnitude 1 while the dimmest was 6. Christian Huygens standardized the measurements using sizes of pinholes in a pie; a magnitude 1 star filled one size pinhole while a magnitude 6 filled another size hole.
- Flux (f) is power over area (Watts/m^2). N.R. Pogson determined that 1^{st} magnitude stars emit 100X more flux than a 6^{th} magnitude star.
- Luminosity (L) is power (Watts). It relates to both the flux of the star and magnitude of the star. As a star is bigger, hotter, or closer; it is more luminous. Conversely, if a star is small, cooler, or distant; it is less luminous.



Light spreads out with the **square** of the distance. Through a sphere twice as large, the energy covers an area **four** times larger. Through a sphere three times as large, the energy covers an area **nine** times larger.

Figure 2. Luminosity over different size spheres. (Strobel, 2014)

Differential Magnitude (Differential Flux between Two Stars)

$$-2.5\log\left(\frac{f_2}{f_1}\right) = m_2 - m_1$$

$$\log\left(\frac{f_2}{f_1}\right) = \frac{m_2 - m_1}{-2.5}$$

$$\log\left(\frac{f_1}{f_2}\right) = \frac{m_2 - m_1}{2.5}$$

F_2 and F_1 are the fluxes of the two stars; and m_2 and m_1 are the magnitudes of the two stars, respectively.

$$\frac{f_1}{f_2} = 10^{\frac{m_2 - m_1}{2.5}}$$

$$\frac{f_1}{f_2} = 2.5^{m_2 - m_1}$$

Differential Magnitude Example

- Two stars have a magnitude of 7 and 3. How much brighter is the star with a magnitude of 3 than the star with a magnitude of 7?

$$m_1 = 3; m_2 = 7$$

$$\frac{f_1}{f_2} = 2.5^{m_2 - m_1} = 2.5^{7-3} \approx 40X$$

Distance Modulus

$$m_2 = m$$

$$m_1 = M$$

$$f_2 = \frac{\mathrm{L}}{4\pi d^2}$$

$$f_1 = \frac{\mathrm{L}}{4\pi(10\text{parsec})^2}$$

$$-2.5\log\left(\frac{f_2}{f_1}\right) = m_2 - m_1$$

- We compare the absolute magnitude and the apparent magnitude.
- Apparent: The magnitude as observed from Earth. Sometimes reddened by the interstellar dust, so we have to map out the dust to eliminate this from our calculations.
- Absolute: The intrinsic magnitude of the object. If an object is intrinsically dimmer, it will be observed to be further than its true distance. If an object is intrinsically brighter, it will be observed closer that its true distance.
- We also receive the distance in parsecs from this calculation.

Distance Modulus

$$-2.5\log\left(\frac{\dfrac{L}{4\pi d^2}}{\dfrac{L}{4\pi(10)^2}}\right) = m - M$$

$$-2.5\log\left(\frac{10}{d}\right)^2 = m - M$$

$$-5\log\left(\frac{10}{d}\right) = m - M$$

$$5\log\left(\frac{d}{10}\right) = m - M$$

$$5\log d + 5\log 10 = m - M$$

$$5\log d = m - M + 5$$

$$d = 10^{\frac{m-M+5}{5}}$$

Distance Modulus Example

- A star has a absolute magnitude of -5 and apparent magnitude 4. What is its distance?

$$d = 10^{\frac{m-M+5}{5}} = 10^{\frac{4+5+5}{5}} = 630\,pc$$

Annie Jump Cannon

Figure 3. Annie Jump Cannon (Wiki)

- 1863 – 1941 A.D.
- Born and grew up in Dover, Delaware.
- Entered Wellesley College
- Worked under Edward C. Pickering at Harvard University to classify spectra of stars
- 1911 - 1914: Created the Henry Draper Catalogue
- 1914: Honorary in the Royal Astronomical Society
- 1918: Doctorate Degree

Spectral Types

- Blue O stars are the hottest while red M stars are the coolest because O is the most massive while M is the least massive.
- As we decrease in temperature of the star, there are more electrons to absorb energy.

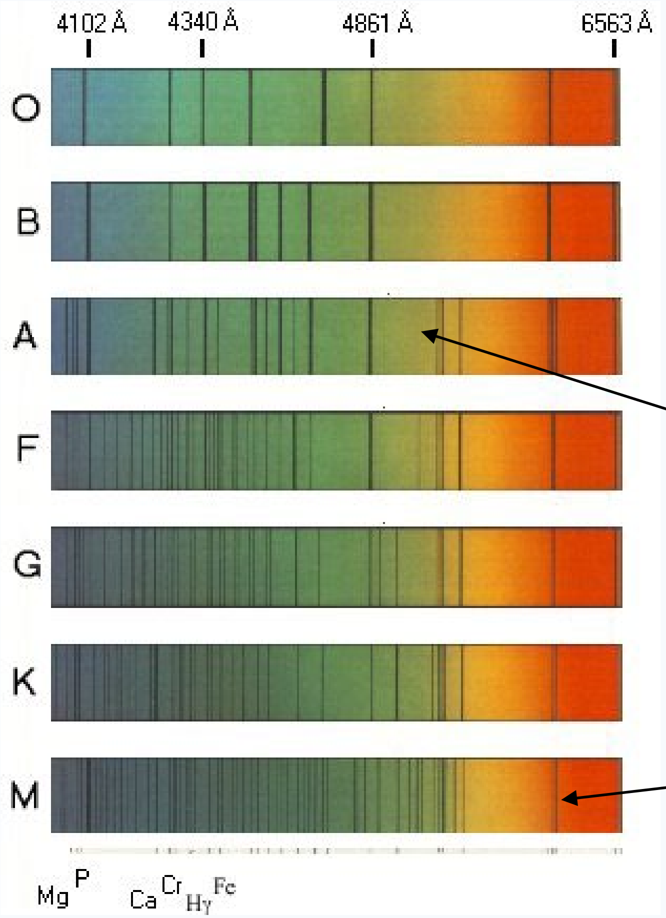


Figure 4. Spectra Types of Stars (Veh, 2015)

The different types of stars have some elements in greater abundances. We can type a star by the strength of the line and the presence of lines.

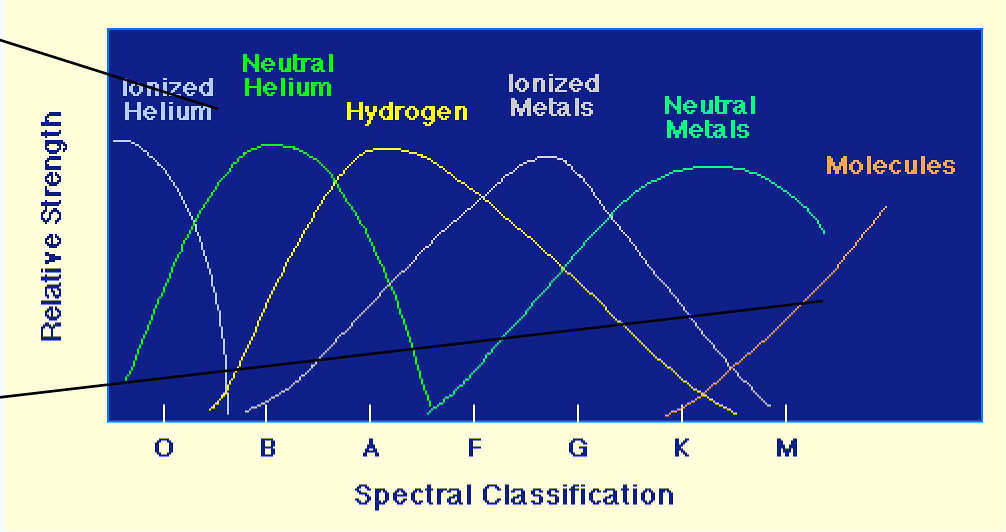
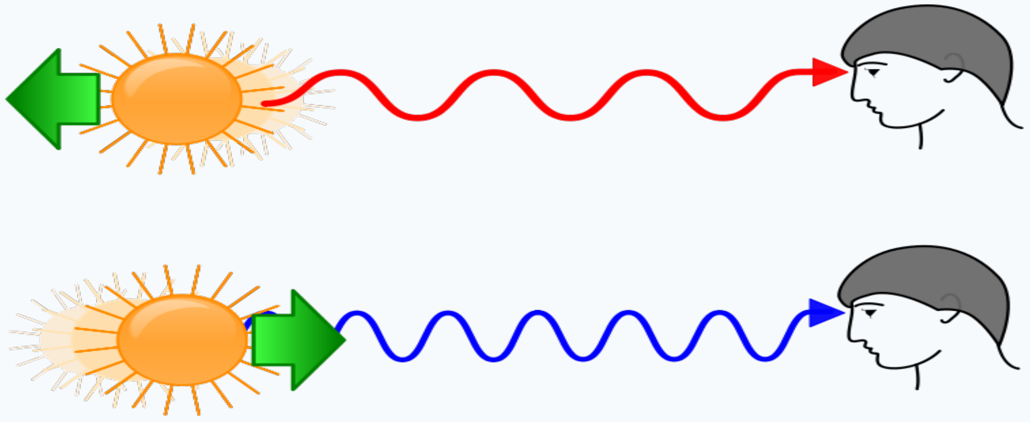


Figure 5. Relative Strength of Spectral Line in Different Types of Stars (Guidry, 2015)

A Complication – Moving Stars: Doppler Shift

Figure 6. Red Shift and Blue Shift due to the Doppler Shift (Wiki)



Christian Doppler observed that spectra shifted when the object emitting that light moved; the light appeared more red when the object moved away and more blue when it approached. We see this shift in stars as well due to rotation, revolution, and outside forces (i.e. Extrasolar Planets. Sometimes we do not determine the correct type for our stars

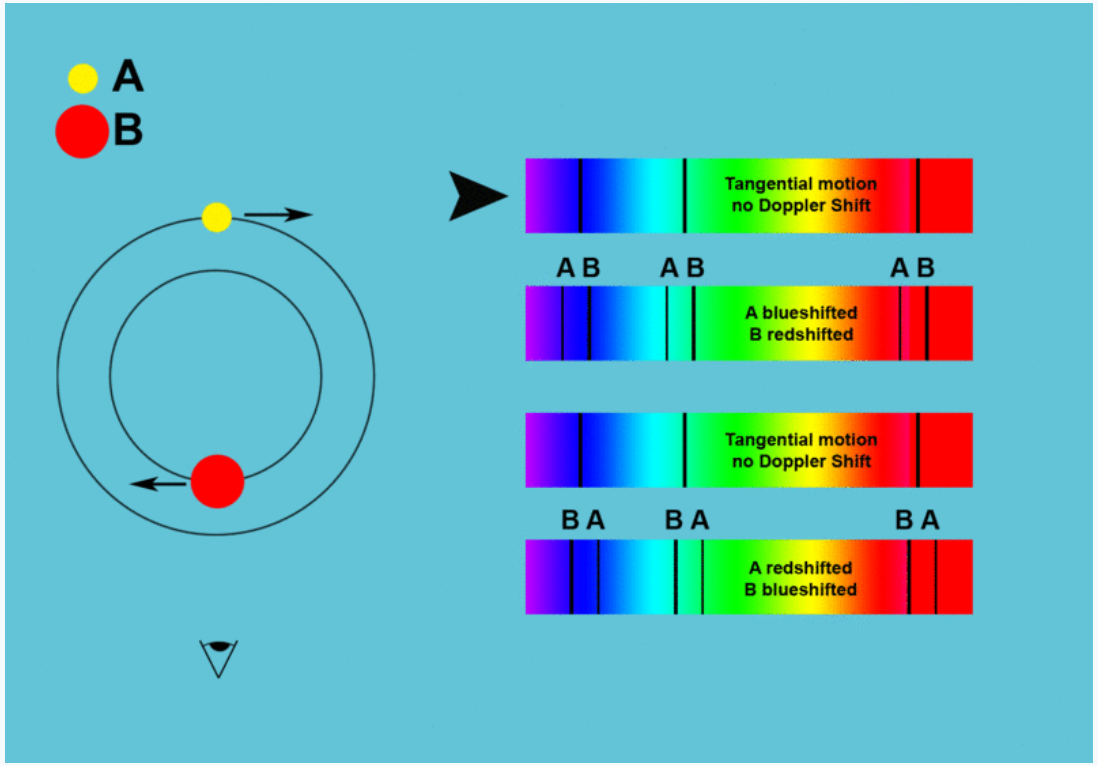


Figure 7. Spectral Shift due to Stellar Motion (Wiki)

Hertzsprung-Russel Diagram

Theoretical H-R Diagram

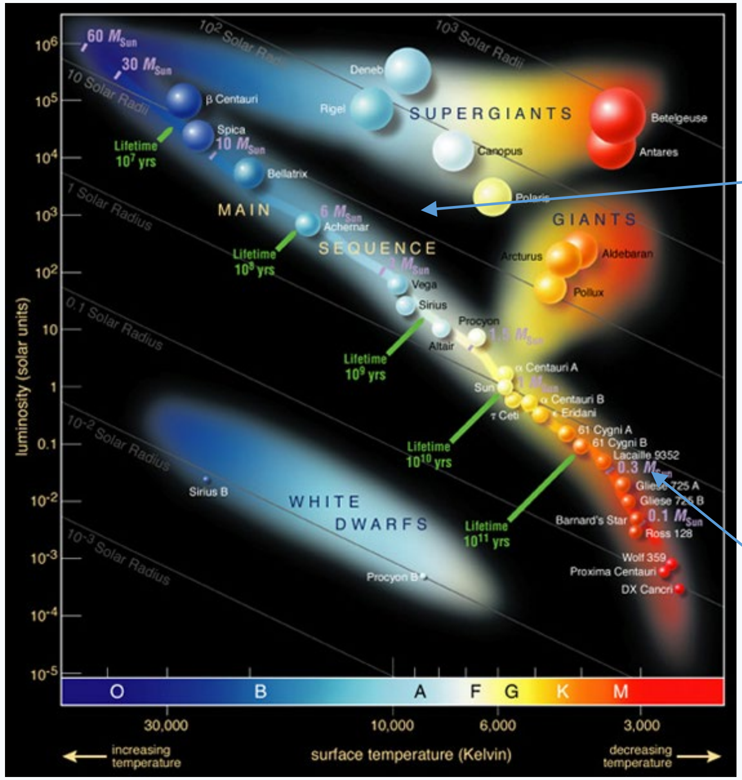


Figure 8. Theoretical H-R Diagram (Wiki)

- There are populations of stars: Population I and II.
- Population I tend to metal rich and on the upper main sequence. They were created out of the recycled material from nova and supernovas.
- Population II tend to be metal poor and on the lower main sequence. They have been around since the beginning of the Universe.

Observational H-R Diagram

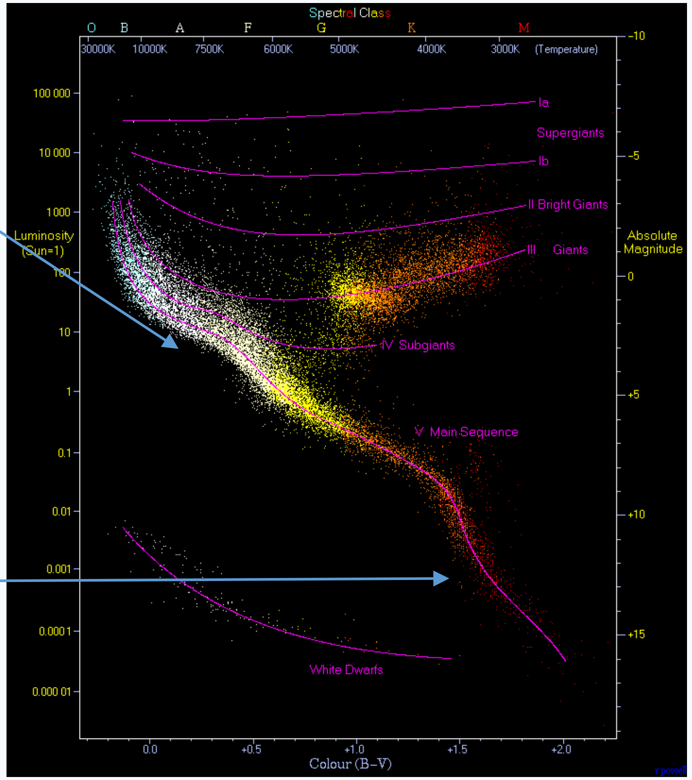
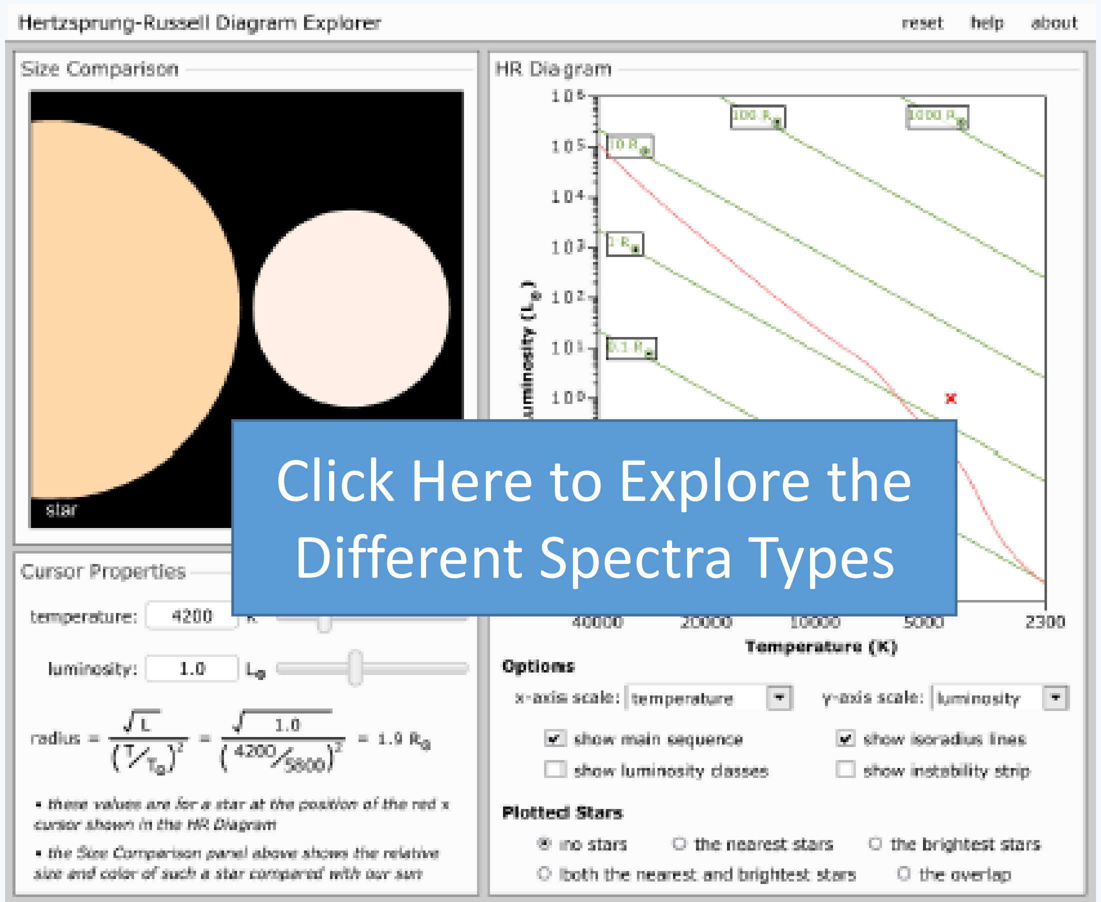


Figure 9. Observational H-R Diagram (Wiki)

Hertzsprung-Russel Diagram Explorer



Click Here to Explore the Different Spectra Types

Mass-Luminosity Relationship of Stars

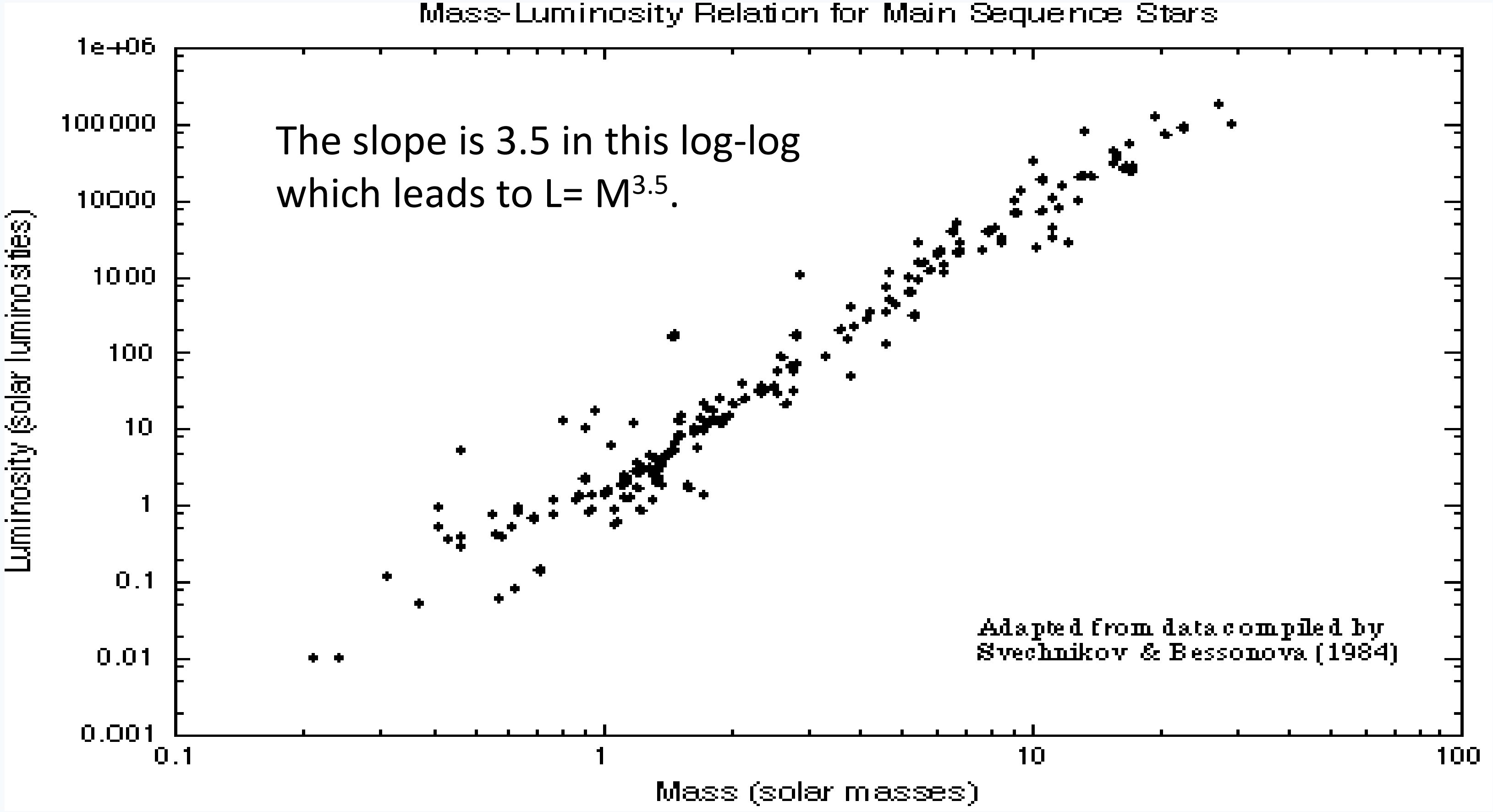


Figure 10. Mass-Luminosity Relationship (Strobel, 2014)

Mass – Luminosity Example

- A star has a mass of $5M_{\odot}$, how much brighter is this star than the Sun?

$$M = 5M_{\Theta}$$

$$\frac{L}{L_{\Theta}} = \left(\frac{M}{M_{\Theta}}\right)^{3.5} = \left(\frac{5M_{\Theta}}{M_{\Theta}}\right)^{3.5}$$

$$\frac{L}{L_{\Theta}} = 280$$

Book/Course Reference Images

- Guidry, M. (2015) *The Spectral Sequence as a Temperature Sequence* Retrieved from: http://csep10.phys.utk.edu/astr162/lect/stars/spectra.html
- Strobel, N. (2014) *Astronomy Notes* Retrieved from: http://www.astronomynotes.com
- Veh, A. (2015) *Measuring Stars* Retrieved from: http://chinook.kpc.alaska.edu/~ifafv/lecture/lecmeas.htm

Wiki Commons/Wikipedia Image References

- Annie Jump Cannon: "Annie Jump Cannon 1922 Portrait" by New York World-Telegram and the Sun Newspaper - http://www.britannica.com/EBchecked/topic/92776/Annie-Jump-Cannon. Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Annie_Jump_Cannon_1922_Portrait.jpg#/media/File:Annie_Jump_Cannon_1922_Portrait.jpg
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