Announcements

- Just reminders to let me know if you have any questions about your grade
- And not to use AI to complete your labs

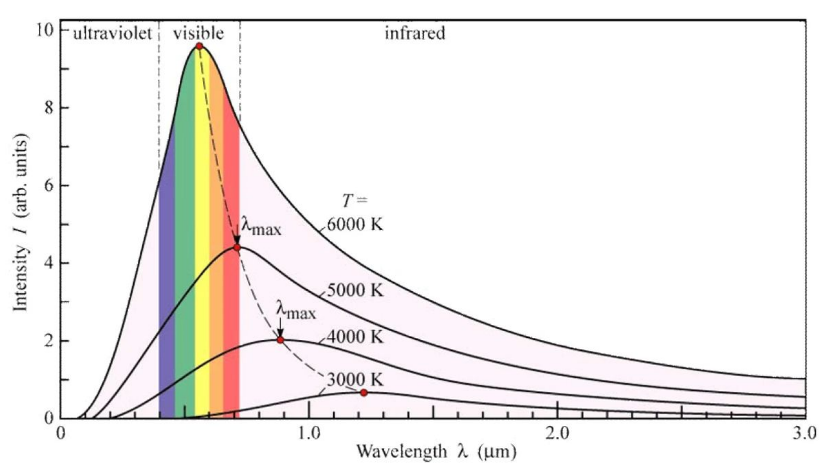
HR Diagrams

One Star, Two Star,
Red Star, Blue Star

First, Some Physical Laws

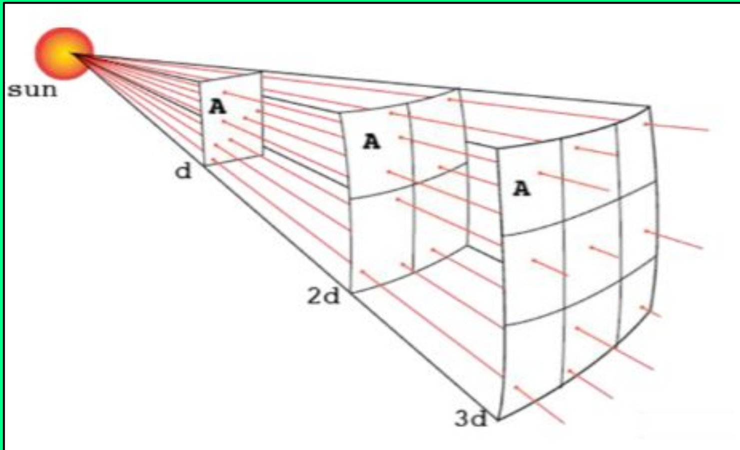
Wien's Law

- $\boxed{\lambda_{peak}\, T = 2.9 \times 10^6}$
  - Note that the constant on the right is given in units of nanometers (in this case)
  - The temperature is in Kelvin
- Relates the peak wavelength (λ) of emitted light to the temperature (T) of an the object
  - Peak wavelength means the wavelength that more of the light is at than any other wavelength



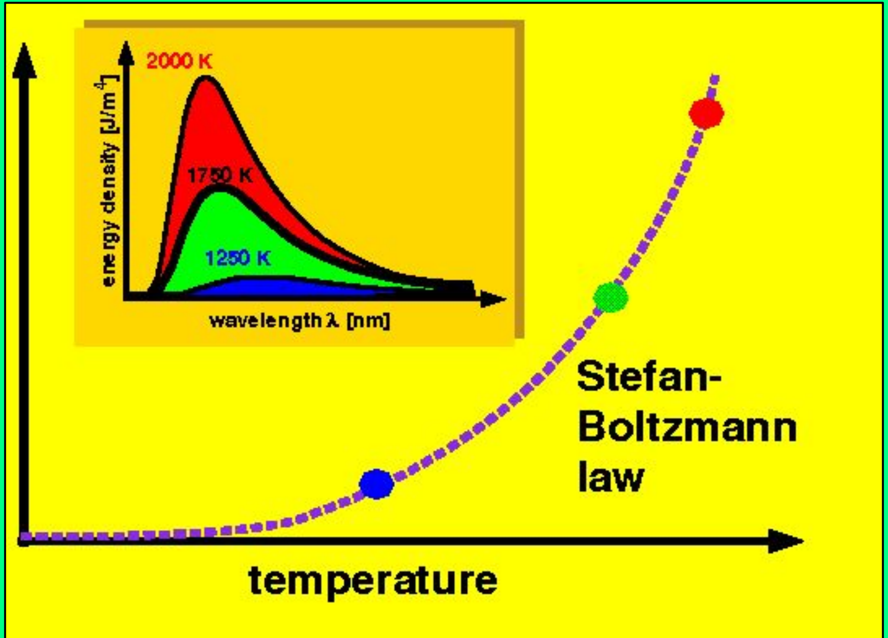
Inverse Square Law

- $$I = \frac{P}{4\pi r^2} = \frac{\frac{\text{energy radiated}}{\text{time}}}{4\pi r^2}$$
    - The $4\pi r^2$ on the bottom is the surface area of a sphere
    - Because light (or sound) spreads out in every direction - which means it spreads spherically
    - The bigger the sphere (the bigger the radius - how far you are from the source) the more spread out the light is
        - So, as you get further away, the light intensity decreases by the square of that radius
            - 2 times further away, $2^2=4$ times less light
            - 3 times further away, $3^2=9$ times less light
            - 5 times further away, $5^2=25$ times less light
            - etc.



Stefan-Boltzmann Law

- $\frac{\text{Energy radiated}}{\text{Time}\times\text{Area}} = \sigma T^4$ Or (in terms of luminosity) $L = \sigma T^4 \times 4\pi {r_p}^2$
  - Where: $\sigma = 5.67 \times 10^{-8}\ \text{W/m}^2\text{K}^4$
- Relates the total energy (light - including heat) emitted to the temperature of the object



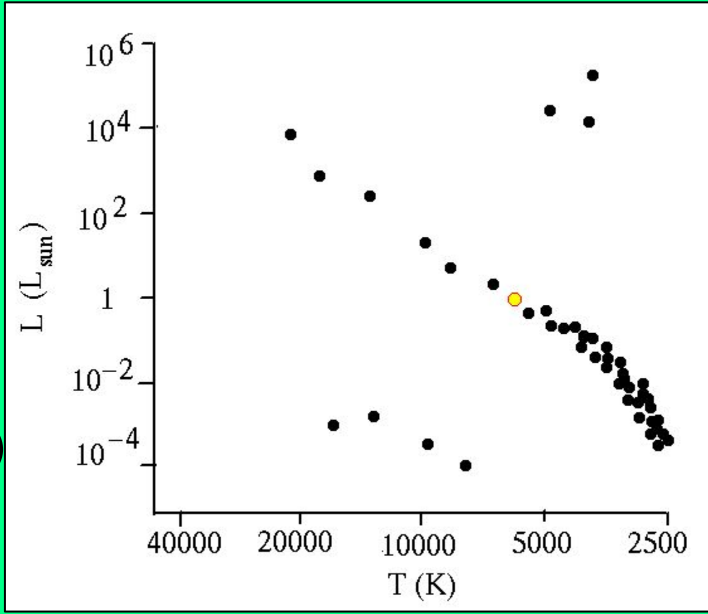
What These Mean Together

- Together these allow us to determine many characteristics of a star based on what we can see - how bright it is and what color it is
  - We can see the color → Wien's Law gives us surface temperature
  - We can see the magnitude (brightness) and calculate the distance → Inverse Square Law gives us the Luminosity
  - Now we know temperature and luminosity → Stefan-Boltzmann Law gives us the star's radius

Now, The HR Diagram

The HR Diagram

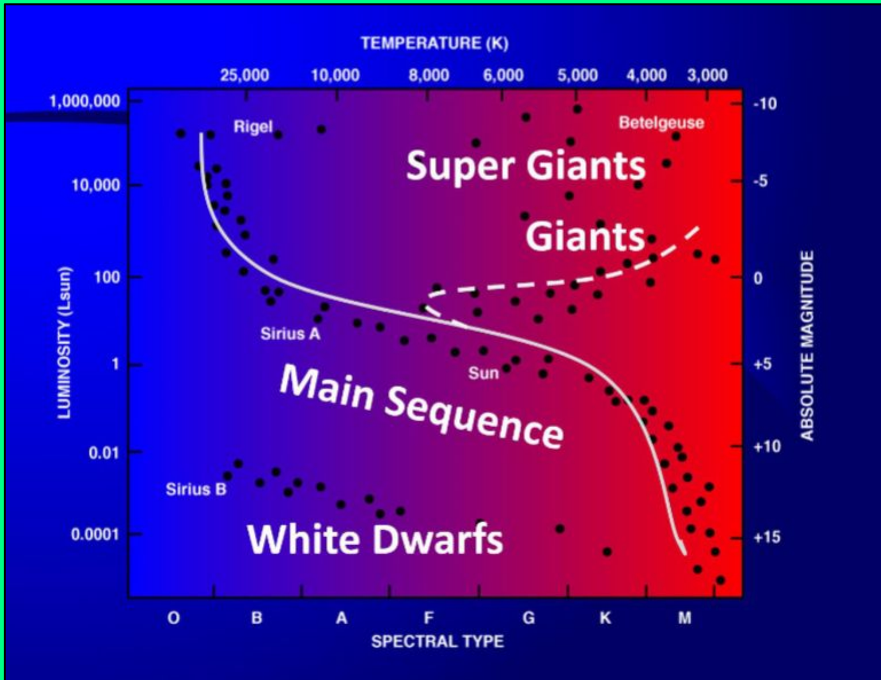
- Full name is Hertzsprung-Russell Diagram
  - Named after its creators, E. Hertzsprung and H. N. Russell
- It is a graph, the x-axis is the temperature (or color) and the y-axis is their luminosity (or absolute magnitude)
- X-axis units are typically Kelvin (no degrees), wavelength/frequency, or color
  - Color is typically shown as “B-V”, or blue minus visible
    - It is the brightness in blue wavelengths minus the brightness in visible (or green) wavelengths
      - Smaller numbers (i.e. negative) are bluer while bigger numbers are closer to red
- Y-axis units are typically L□u□ (or $L_\odot$) (luminosity) or Absolute Magnitude
  - Rarely, it will be luminosity in units of power like watts or ergs/s



Note the Direction of the x-axis

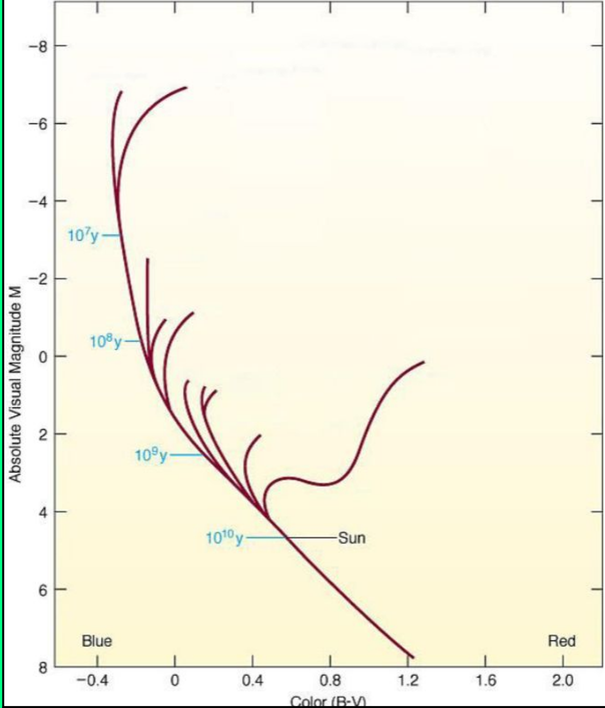
The HR Diagram Cont. (Regions)

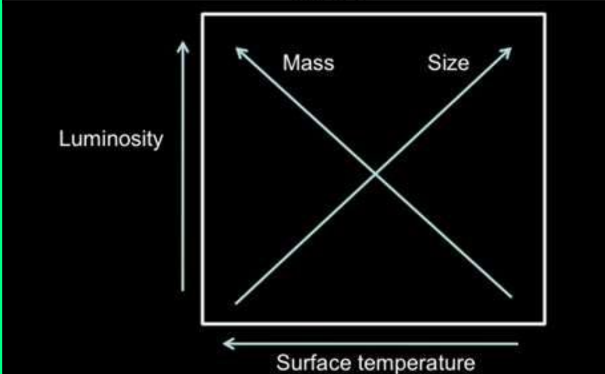
- When you plot a large number of stars on the HR Diagram, you will see them in several groups or regions
- The Main Sequence
  - Which contains most stars, including the Sun
- The Giants and Super Giants
  - Fairly self-explanatory
- White Dwarfs
  - Remnants of Sun-like stars
  - Small and white-blue in color
- Stars leave the Main Sequence when they run out of Hydrogen to “burn” and start burning Helium
  - Then they can become giants
    - And eventually die, leaving behind a neutron star or black hole, or becoming a white dwarf (depending on size)



The HR Diagram Cont. (What it Tells us)

- Because of the way stars work, the HR Diagram can help us identify more information about them
- The mass and size (radius) of the stars increase diagonally on the diagram
  - Size from left to right, and mass from right to left
- We can also determine the age of the cluster of stars plotted on the HR Diagram
  - This is because less massive stars burn through their Hydrogen more slowly - so they take longer to run out
    - They leave the Main Sequence later
  - We can assume all stars in a cluster formed at more or less the same time
    - So by looking at the turnoff points of a HR Diagram (the top-left most stars still on the main sequence), we can estimate the age of the cluster





Today

- You are going to be using the Starry Night (SN) software to collect data
  - Search for each star in the table on page 6, and fill in all the information about them from what Starry Night says
  - Then work through questions 1-9 and plot the stars from the table on your own HR Diagram (page 13)
- Then you will create a HR Diagram in Starry Night
  - And answer questions 10-16
- Notes on Questions:
  - Question 7 is worded unclearly, it is asking about the physical size of the stars
    - Not the number of stars in the group
  - Question 9 is asking about the mass of the stars
    - Also, ignore the first sentence, start with "In other words…"
  - Question 4 is extra credit as are parts b and c of question 8
    - Part a of question 8 is required as normal
- A fair amount of math in this lab:
  - Take your time
  - Show your work
  - Use a calculator
  - Ask for help

- Note: SN may not recognize all of the star names due to being such an old version
  - Try Sirius instead of Sirius A
  - Particularly Wezen - Put Delta Canis Majoris when searching for it
  - It should recognize the name 2 Hya. But if not, search 2 Hydrae instead