



Blackbody Radiation and Wein's Law

AS-Level Astronomy

Classroom Activity

Material List:

- Internet Access
- Pen/pencil
- Calculator

Outline

Use a combination of NAAP labs and interactive applications to explore blackbody radiation and spectral classification.

Including use of a Hertzsprung-Russel diagram and graphs.

Procedure:

1

Go to NAAP Labs 'Blackbody Curves and Filters Explorer' available at: <http://astro.unl.edu/naap/blackbody/animations/blackbody.html>

2

Make sure you know how to use it, add and remove curves, change the temperature of each curve, adjust the vertical and horizontal scales of the plot.

3

Create a blackbody curve of temperature 6000 K and draw the shape below. Does it have a peak? Is it symmetric about this peak?



4

Create a second curve using the add curve button and use the temperature slider to vary its temperature. Can you find a blackbody curve of another temperature that intersects the 6000 K curve?

Do you believe this would be true for two curves of any temperature?

5

Make sure that there is only one curve and tick the box for 'indicate peak wavelength'. Vary the temperature of the curve and note how the peak wavelength changes. Formulate a general statement relating the peak wavelength to temperature.

Compare this statement with Wien's Law.

6

Select the highlight area under curve option and lock the vertical scale. Vary the temperature of the curve and note how the area under the curve changes. Formulate a general statement relating the area under the curve to temperature.

**7**

(Calculator Required) Complete the following table below. The “Area Ratio” is the area for the curve divided by the area for the curve in the row above. This will tell you how many times greater the new ratio is compared to the previous one.

| Curve temperature | Area under curve (W/m²) | Area Ratio |
|--------------------------|---|-------------------|
| 3000K | | |
| 6000K | | |
| 12000K | | |
| 24000K | | |

Can you specify a more precise statement relating the area under the curve to the temperature? Is this consistent with the Stefan-Boltzmann Law?

**8**

Go to the 'Hertzsprung-Russel Diagram' Lab and open the 'Spectral Classification' page: https://astro.unl.edu/naap/hr/hr_background1.html

9

Use the interactive application to complete the table below:

| Star | Surface Temp (K) | Spectral Type | Colour |
|---------------|------------------|---------------|--------------|
| Betelgeuse | | M2 | |
| Arcturus | 4,300 | | |
| | | G2 | Yellow |
| Procyon A | | F5 | Yellow-white |
| Sirius A | | A1 | White |
| Rigel A | 11,000 | | |
| Delta Orionis | | O9 | |

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Go back and select the 'Luminosity' page (<https://astro.unl.edu/naap/ebs/luminosity.html>) use the interactive application to complete the table:



| Radius (R_{\odot}) | Temperature (T_{\odot}) | Luminosity (L_{\odot}) |
|------------------------|-----------------------------|----------------------------|
| | 1 | 1 |
| 1 | 2 | |
| | 1 | 9 |
| 1 | 0.5 | |

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Using Stefan's Law, calculate the luminosity of the Sun in J/s. Check your answer using the interactive application on the 'Luminosity' page (the radius of the Sun is 6.95×10^5 km, and surface temperature is 5800K).

12

Now familiarise yourself with the controls of the 'HR diagram Explorer' (<https://astro.unl.edu/naap/hr/animations/hr.html>)

13

Make sure you know how to change the axes of the HR diagram, move the position of the star (marked by a red cross) around the HR diagram (and how this affects the temp and luminosity of the star), change the properties (luminosity, temperature and radius) of the star marked by a red cross (and how this changes the position of the star in the HR diagram).

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Which region of the HR diagram corresponds to each description in the following tables:



| Description | Top | Right | Bottom | Left |
|----------------------------------|-----|-------|--------|------|
| Hot stars are found at the: | | | | |
| Faint stars are found at the: | | | | |
| Luminous stars are found at the: | | | | |
| Cool stars are found at the: | | | | |

| Description | Upper left | Upper right | Lower right | Lower left |
|--|------------|-------------|-------------|------------|
| Large, blue stars are found at the: | | | | |
| Small, red stars are found at the: | | | | |
| Small, blue stars are found at the: | | | | |
| Really large red stars are found at the: | | | | |

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Select the 'show luminosity classes' box. This green region (dwarfs V) is known as the main sequence and contains all stars that are fusing hydrogen into helium as their primary energy source. Over 90% of all stars fall in this region on the HR diagram.

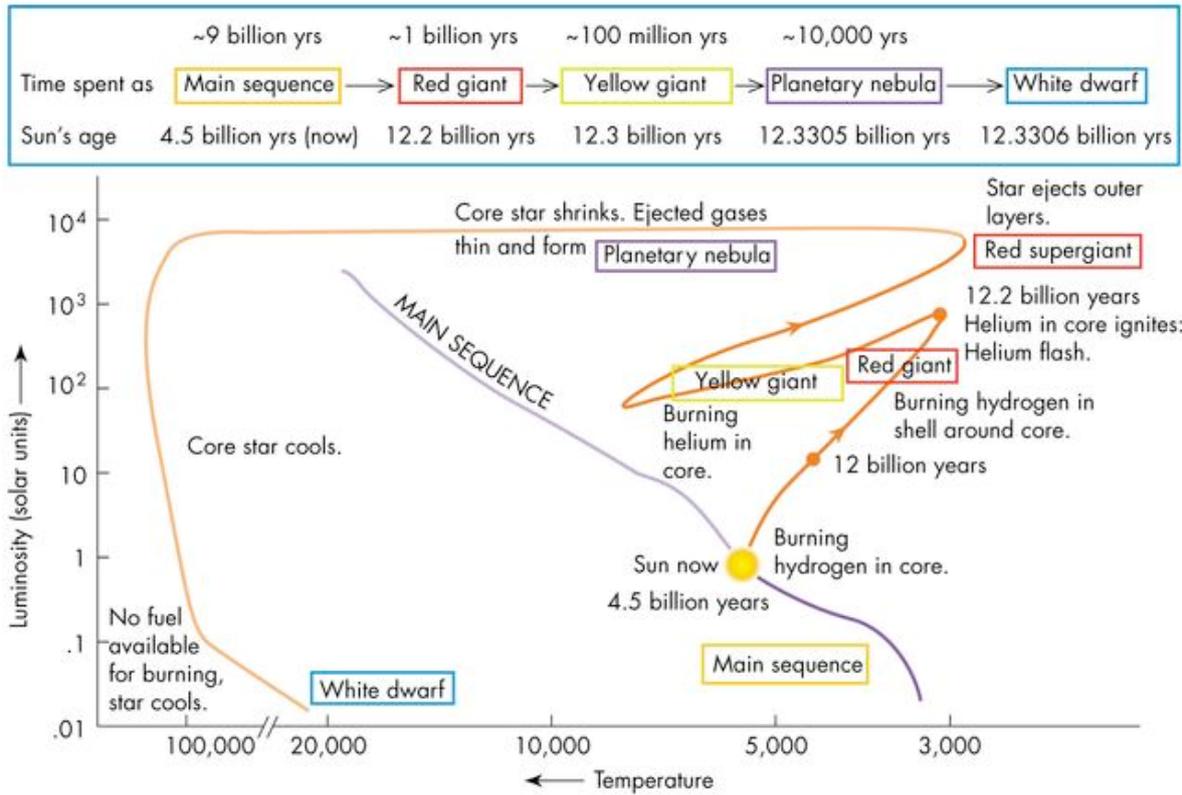
Move your star up and down the main sequence and explore the different values of stellar radius.

Describe the sizes of stars along the main sequence. What are stars like near the top of the main sequence, the middle, and the bottom?



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The diagram below shows the evolution of a star like the Sun, from its position on the Main Sequence, through the Red Giant phase, to its death as a planetary nebula and eventual fate as a white dwarf.



Using the HR Diagram Explorer and the diagram above, state the approx. temperature, luminosity and radius of the Sun at each of the following stages of its life:

| Stage | Temperature (K) | Luminosity | Radius (R_{\odot}) |
|---------------|-----------------|------------|------------------------|
| Main Sequence | | | |
| Red giant | | | |
| White dwarf | | | |