

The Hertzsprung-Russell Diagram

Objective: Students will plot, label and interpret the Hertzsprung Russell Diagram.

Background: You are about to create your own HR Diagram, a chart that revolutionized the study of stars. You will have a labeled chart and a series of points to plot. From these points, you can deduce a lot of information about stars! Please read the directions in each step of the activity closely before answering questions.



Each of the star data points has the following information:

- ★ Star Name: the common or catalog name of the star
- ★ Temperature: the temperature of the surface of the star
- ★ Brightness: the number of times brighter the star is than our Sun (a fractions means it is dimmer than our Sun)
- ★ Expected Lifetime: the number of years the star is expected to exist based on color and brightness

Getting Started: Making the HR Diagram

1. Hand out the “stars” to each member of your group. Have each person put 4-5 stars on the chart. Write down 3 observations about what you see so far.

****This is a great time to work on observation skills and to get students to ask inquisitive and scientific questions about what they are seeing before getting to the answers! Many students will focus on color and be surprised that stars come in so many. These observations will likely also include temperature, brightness, and lifespan information. If your students are not familiar with or confident in scientific notation, this is a good time to talk about what numbers like 10^4 and 10^{11} mean. ****

2. Work together to put the rest of the stars on the HR diagram. Then make 2 additional observations about what you see.

****After observing the completed HR Diagram, students should start to see the trend line of the main sequence as well as notice that some stars are outliers from this trend line.****

3. Describe the 2-3 groups of stars that fall outside of the main trend line the chart.

****This is where students should start to notice white dwarfs, red giants, and supergiants on the HR Diagram.****

- There are light blue stars that are colder than the other light blue stars that follow the trend line.
 - There are red stars that are slightly brighter and significantly brighter than the red stars that follow the trend line.
4. What variable is located on the x-axis? **Temperature**
 5. What variable is located on the y-axis? **Brightness or Luminosity**

6. Fill in the following chart with information from the stars on the chart.

****Students will have a variety of stars to choose from so their numbers will vary, but the information in the chart and the Color and Magnitude sections below should show the same.****

Color	Temperature (K)	Brightness	Lifetime
Dark Blue	40,000 K	10,000 Suns	10^4 years
Light Blue	20,000 K	480 Suns	10^9 years
Yellow	4,800 K	1 Sun	10^{10} years
Orange	4,200 K	0.28 Suns	10^{10} years
Red	3,000 K	0.0003 Suns	10^{11} years

Color (6 points)

7. The temperature of the hottest stars is **40,000 K**.
8. The color of the hottest stars is **blue**.
9. The temperature of the coldest stars is **3,000 K**.
10. The color of the coldest stars is **red**.
11. The life expectancy of a very hot star is **10^4** years.
12. The life expectancy of a very cold star is **10^{11}** years.

Magnitude (6 points)

13. The temperature of the brightest stars is **40,000 K**.
14. The color of the brightest stars is **blue**.
15. The temperature of the dimmest stars is **3,000 K**.
16. The color of the dimmest stars is **red**.
17. The life expectancy of a very bright star is **10^4** years.
18. The life expectancy of a very dim star is **10^{11}** years.

Fusion (2 points)

19. Look up the word fusion in your textbook and *define it in your Glossary*. Explain why the hottest, brightest stars have a very different life expectancy from the coldest, dimmest stars.

Fusion is the thermonuclear reaction in which nuclei of light atoms join to form nuclei of heavier atoms, such as the combination of deuterium atoms to form helium-3 atoms. The hottest, brightest stars burn through their fuel by undergoing fusion more quickly than colder, dimmer stars which go through the stages of fusion more slowly.

Labeling the HR Diagram

Star Name	Brightness	Temperature (K)
Betelgeuse	9000 Suns	3,000 K
Mu Geminorum	310 Suns	3,100 K
Proxima	0.00005 Suns	2,900 K
Barnard s	0.0003 Suns	3,000 K

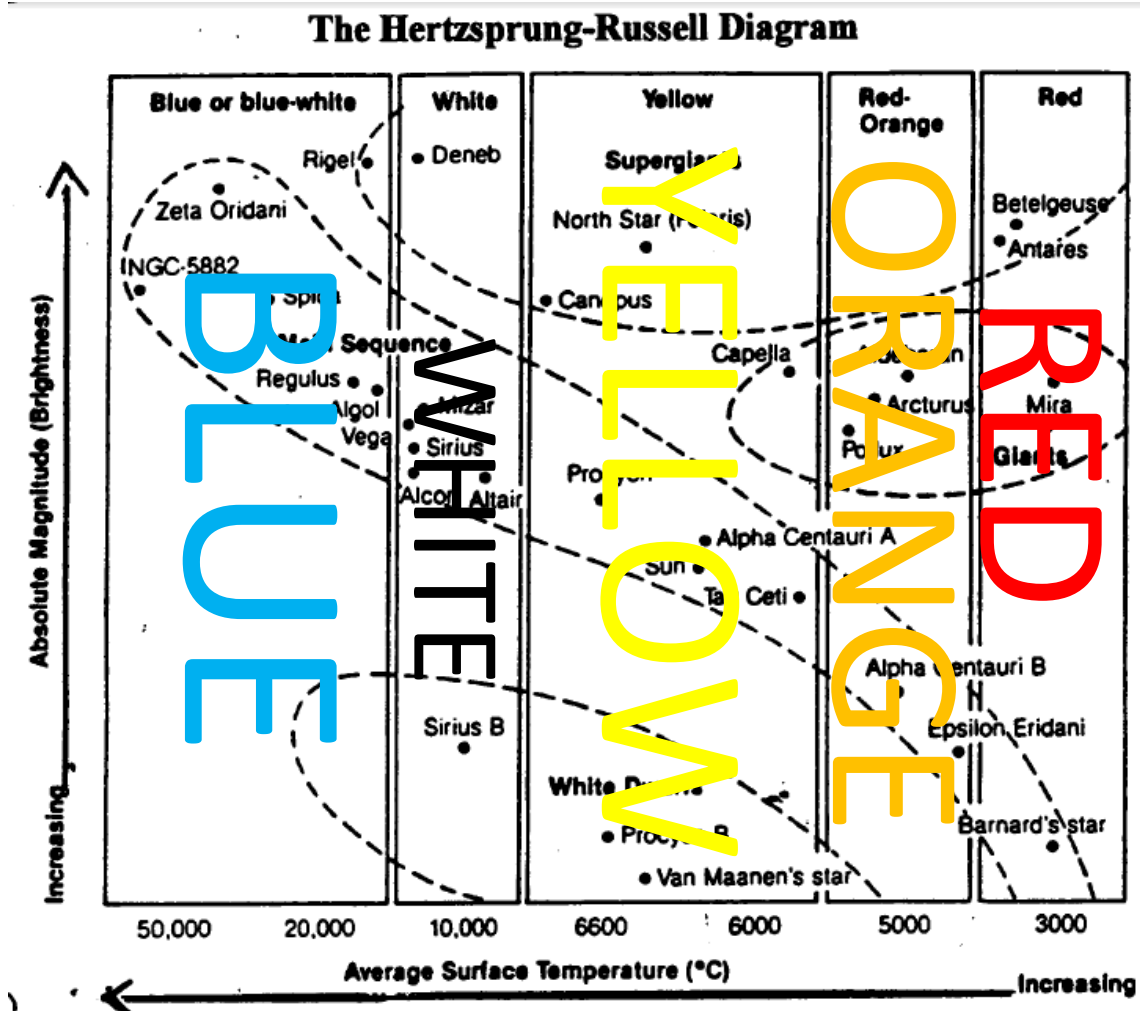
- Take a look at 4 red stars from different parts of the HR Diagram. Record their information in the chart at right.
- Describe the differences between the stars (2 points).

Some of the red stars have a high brightness, while some of them are quite dim. Betelgeuse and Mu Geminorum have brightness of 9,000 Suns and 310 Suns respectively; these stars are much larger than Proxima and Barnard s with brightness of 0.00005 and 0.0003 Suns. The significant difference in brightness with no change in temperature means that Betelgeuse and Mu Geminorum are much larger than the other two stars.

- Use your textbook to define the following terms in your Glossary:
Main sequence, red giant, supergiant, and white dwarf.

****Any definition from your textbook or an internet search will do, students who want to go above and beyond will be sure to include the location of these types of stars on the HR Diagram. At this stage, I typically label each type of star on the whiteboard HR Diagram.****

- Now that you have completed constructing and labeling the HR Diagram, add COLOR to the chart below.



Conclusion Questions



Directions: Answer the following questions in 2-3 complete sentences. Be sure to address all aspects of the question.

****I strongly encourage students to use actual data from the star circles and the HR Diagram on the previous page to support their ideas, rather than just saying “higher” or “lower”.****

- 1.) What is the relationship between temperature/color and brightness in the HR Diagram (2 points)?

Stars with a high temperature are blue and bright, while stars with a low temperature are red and dim. For example, Spica is a blue star at approximately 25,000 K with a high brightness, and Barnard’s star is a red star at approximately 3,000 Suns with with low brightness.

- 2.) What is the relationship between temperature/color and expected lifetime? Which stars will die first and why? (2 points)

The higher the temperature of a star, the shorter the lifetime. The blue stars will die out more quickly since their high temperatures will burn through the fusion fuel elements more quickly than the colder red stars. Blue stars will live approximately 100,000 years, while red stars can live up to 1,000,000,000,000 years.

- 3.) Explain how we know that there are red giants and supergiants on the HR Diagram (HINT: Refer to questions 1 and 2 on page 3) (2 points).

Red giants and supergiants are both cold red stars that do not fall on the main sequence trend line. Red giants like Mu Geminorum are brighter than other red stars and the Sun with a brightness of 210 Suns. However, supergiants are significantly brighter than even red giants. Betelgeuse is an example of a supergiant with a brightness of 9,000 Suns. Since the temperatures of all red stars are cool, red giants are larger, and supergiants are significantly larger, than normal red stars.

- 4.) Compare and contrast the Sun and Antares in terms of brightness, color and temperature using the diagram on the previous page (3 points).

The Sun has a brightness of 1 Sun while Antares has a brightness of 10,000 Suns. The Sun is 4,800 K while Antares is 3,400 K. The Sun has a lifetime of 10^{10} years while Antares would have a lifetime of 10^{11} years. In summary, the Sun is an average-sized yellow star while Antares is a large red star.

- 5.) Explain in 1-2 sentences what the Hertzsprung-Russell diagram shows (1 point).

The HR Diagram shows the relationship between the brightness and temperature of stars. The majority of stars follow a main sequence trend line from red, cold, and dim to blue, hot, and bright with a few outliers like white dwarfs and red giants.