Teacher Guide: H-R Diagram

Learning Objectives

Students will ...

- Classify stars based on their color, temperature, luminosity, radius, and mass.
- Identify relationships between different star characteristics.
- Construct an H-R diagram.
- Explain the relationships illustrated by an H-R diagram.
- Describe characteristics of main sequence, giant, supergiant, and white dwarf stars.
- Use an H-R diagram to categorize a star and describe a star’s life cycle.

Vocabulary

giant, H-R diagram, luminosity, main sequence, star, supergiant, white dwarf

Lesson Overview

In a very similar fashion to living things, stars go through a life cycle. Stars are born, grow old, and then die. As stars go through this cycle, their temperature and luminosity, or brightness, changes. Because of this, astronomers can use a star’s temperature and luminosity to categorize a star and determine its age. An H-R diagram is a graphical plot astronomers use to classify and interpret the life cycles of stars.

With the H-R Diagram Gizmo™, students can compare star characteristics, use an H-R diagram to categorize stars, and predict the life cycle of our own star—the Sun.

The Student Exploration sheet contains three activities:

- **Activity A** – Students determine the relationship between a star’s color and temperature.
- **Activity B** – Students determine the relationships between a star’s luminosity, radius, and mass.
- **Activity C** – Students create and interpret an H-R diagram.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Using graphs to compare characteristics** (15 – 25 minutes)

   Have students choose two different characteristics of their classmates, such as eye color, hair color, height, shoe size, head circumference, or arm length, and make a graph plotting one characteristic against the other. The class should analyze the graphs to determine whether they think there is some sort of relationship between the characteristics chosen by each student.
2. **Prior to using the Gizmo** *(10 – 15 minutes)*

*Before* students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** *(15 – 20 minutes per activity)*

Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** *(15 – 30 minutes)*

As students are working or just after they are done, discuss the following questions:

- Is a yellow star like the Sun hotter or cooler than a red star?
- How can plotting two different characteristics on a graph help you find relationships between the characteristics?
- Blue main sequence stars have shorter lives than red main sequence stars. Why do you think this is the case? [Blue stars are hotter, so quickly use up their fuel.]
- Amongst main-sequence stars, how does temperature relate to luminosity?
- Describe how a star’s luminosity and surface temperature change as it ages.

5. **Follow-up activity: Make an H-R diagram** *(30 – 45 minutes)*

Have each student do research on a star not listed on the Gizmo. Students should record the star’s name, color, luminosity, temperature, and radius. Draw temperature and luminosity axes on the board, and have each student plot their star on the class H-R diagram. After all the stars have been plotted, classify each star as a main sequence, giant, supergiant, or white dwarf star.

**Scientific Background**

In the 1800s, scientists started measuring the *absorption spectra* of stars. An absorption spectrum is created when light passes through a group of atoms and some of the wavelengths of light are absorbed, causing dark bands to appear on the spectrum. Scientists realized a star’s spectrum is directly related to both the star’s color and temperature. Thus, scientists used spectra to classify stars.

Stars are also classified by their brightness, or luminosity. To determine a star’s luminosity, scientists have to take two factors into account: a star’s apparent brightness (how bright it seemed from Earth) and the star’s distance from Earth. [To find out how a star’s distance from Earth can be determined, see the Math Connection on the next page.]

In the early 1900s, two astronomers working independently—Ejnar Hertzsprung of Denmark and Henry Norris Russell of the United States—decided to combine the two star classification systems to see if a pattern emerged. Both astronomers made graphs plotting a star’s luminosity against its spectral classification. The graphs were later changed to luminosity vs. temperature. Graphs plotting a star’s luminosity vs. its temperature are now called Hertzsprung-Russell diagrams, or H-R diagrams, and they have changed the way astronomers classify stars.
H-R diagrams are useful because they show a unique pattern. In most stars, known as main sequence stars, luminosity increases with surface temperature and mass as you move from the bottom right of the diagram to the upper left. However, in a group of very bright stars outside the main sequence, both Hertzsprung and Russell noticed that surface temperatures were lower than expected. These stars are now known as giants and supergiants. Many supergiants form from very massive main sequence blue stars. The surface temperatures of giants and supergiants are lower because they are older, dying stars.

Another group of stars, the white dwarfs, became evident to Hertzsprung and Russell while analyzing their graphs. White dwarfs are relatively hot, but also quite dim. Astronomers now know that white dwarfs are all that is left behind of a giant or supergiant that has lost its outer layers. A white dwarf is the dying core of a giant at the end of its life cycle—the last glowing ember of a fading star.

**Math Connection: Parallax**

To calculate a star’s luminosity, you must know how far away it is located. Scientists use a phenomenon called stellar parallax—the apparent movement of a star when seen from different positions—to find the distances to stars. Stellar parallax occurs because Earth’s movement around the Sun causes stars to appear to move in the night sky.

As you can see in the diagram, the line of sight for a star is different in January than in July. Earth’s positions during these months and the star’s position form a triangle. Thus, a method known as triangulation can be used to determine the star’s distance.

The smaller the parallax angle, the farther away the star is located. Conversely, the larger the parallax angle, the closer to Earth is the star. The exact distance can be found known when you know the base of the triangle (2 astronomical units) and the parallax angle. Stars generally have a parallax of less than 1 arc-second, or 1/3,600 of a degree.

**Selected Web Resources**

Star spectra: [http://imagine.gsfc.nasa.gov/docs/science/how_l1/spectra.html](http://imagine.gsfc.nasa.gov/docs/science/how_l1/spectra.html), [http://www.astronomygcse.co.uk/AstroGCSE/New%20Site/Topic%203/o_b_a_f_g_k_m.htm](http://www.astronomygcse.co.uk/AstroGCSE/New%20Site/Topic%203/o_b_a_f_g_k_m.htm)


H-R diagram simulator: [http://www.astro.ubc.ca/~scharein/a311/Sim/hr/HRdiagram.html](http://www.astro.ubc.ca/~scharein/a311/Sim/hr/HRdiagram.html)


Parallax: [http://www.astronomynotes.com/starprop/s2.htm](http://www.astronomynotes.com/starprop/s2.htm)

Related Gizmo: