Orion Star Trails

(Image Credit: David Malin, AAO)

In this Exploration, find out:

- How is energy and light given off by stars?
- How do the different classifications of stars in the main sequence compare in size and mass?
- How do the sizes of stars compare to the sizes of our Sun and Earth?

Sizes of Stars

Our galaxy, the Milky Way, is filled with more than 200 billion stars! Stars come in many different sizes, colors, and masses. (The mass of an object is a measure of how much matter is in the object.)

This activity discusses the types of stars that are in the *main part of their "lives"*, which is called the **main sequence,** and the sizes of these different classes of stars. Stars are so big in comparison to anything here on Earth that their sizes are difficult to visualize.

Purpose: To understand the scale of objects beyond the solar system, in this case the sizes of stars, to calculate scale sizes, and compare the sizes of stars to that of our own star, the Sun, and to the Earth.

Why Stars Shine

What are stars made of?

Stars are almost entirely made of the gases hydrogen and helium. While they are on the main sequence, stars shine because they are converting the element hydrogen into the element helium deep inside their **cores**. Energy is given off in the process, and that energy is what allows a star to shine. The process of converting hydrogen into helium is known as **fusion.**

Background

*To help us understand the sizes of stars, we will use a **scale model.** The **scale factor** for the model (like the scale on a map) will be **1:10 billion**.*

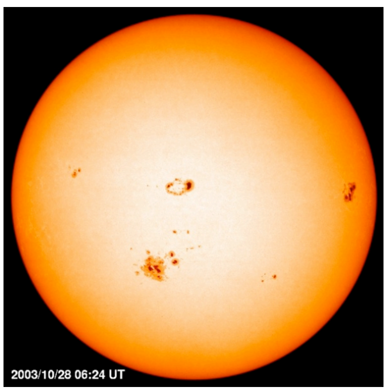
Every centimeter for the model stars will be equal to 10 billion centimeters for a real star.

- *Our own star, the Sun, is about the size of a large grapefruit on this scale.*
- *Earth, is tiny compared with the Sun, and in this model is only the size of a candy sprinkle.*

Nuclear Fusion

Nuclear fusion is the nuclear reaction that converts smaller atoms into heavier atoms. Stars on the main sequence get their energy by converting hydrogen into helium through nuclear fusion.

4 Hydrogen atoms
+ heat and pressure
=
1 Helium atom + energy



(Image Credit: NASA's Solar Heliospheric Observatory)

Our Sun is a main sequence G class star. Nuclear fusion is the source of all of the Sun's energy. Deep inside our star is its core. Fusion can only happen in the hot dense core of the Sun.

A star will stay on the main sequence until there is no more hydrogen in the star's core that can be converted to ***helium.***

Our own star has been a main sequence star for the last 4.5 billion years, and will continue to convert hydrogen to helium for the next 5 billion years. Not all stars are the same, however. Some stars take longer than the Sun to convert the hydrogen in their cores into helium, and other stars use up their hydrogen much more quickly.

Even though fusion releases a tremendous amount of energy, a lot of heat and pressure is required to make it work. **Where does the heat inside a star come from initially so that fusion can begin?** The answer is **gravity**. When a star is forming from the gas and dust particles in space, gravity pulls the material in towards the center. As a forming star collapses, it heats up. When the core is sufficiently dense and hot, fusion begins. The energy released by fusion keeps the star from collapsing much further.

The **more mass a star has, the hotter the interior of the star** will be, and the higher the pressure will be in the core. Hydrogen atoms are more quickly converted into helium when temperatures and pressures are higher. **The more mass a star has, the faster it will convert its hydrogen fuel into helium.**

The energy produced by the fusion of hydrogen into helium is given off as heat. In high mass stars, fusion happens more rapidly than in low mass stars, so they produce more heat and are hotter than low mass stars.

- Star colors are a function of temperature, with blue for a hot star and red for a cool star.
- The surfaces of stars are all very hot, ranging from about 3,000 K (5,000^{o}F) to 40,000 K (70,000^{o}F).
- Our own Sun has a surface temperature of 5,800 K (about 10,000^{o}F).
- The cores of stars on the main sequence can be tens of millions of degrees. Our Sun has a core temperature of about 15 million K.

Blue is Hot?

Red seems hot to us because many things that are hot here on Earth glow red, such as fires, or hot coals, or even hot lava coming out of volcanoes. However, fires and hot materials on the Earth are typically much cooler than the surfaces of stars. If a burner on an electric stove is white hot, it is hotter than a burner that is glowing red. All stars are hot. How hot the surfaces of the stars are will determine the color we see.

- Low mass stars are cooler, and are reddish.
- High mass stars are hotter, and are white or blue white.
- Extremely high mass stars may even shine a pale violet, which is more "blue" than blue white. High mass stars are also much brighter than low mass stars, because they produce much more energy.

Types of Stars

Astronomers classify stars by the light they *emit* (or give off). Stars can be divided into seven categories (or *classes*) based on color: O, B, A, F, G, K, and M. (O class stars are the hottest, and M class stars are the coolest.)

One way to remember the classes of stars is by using the phrase:

Oh **B**e **A** **F**ine **G**irl (Guy, Gorilla), **K**iss **M**e!

Any phrase will do, as long as the words start with the letters O, B, A, F, G, K, and M.

- ❖ What phrase can you come up with to help you remember the classes of stars?

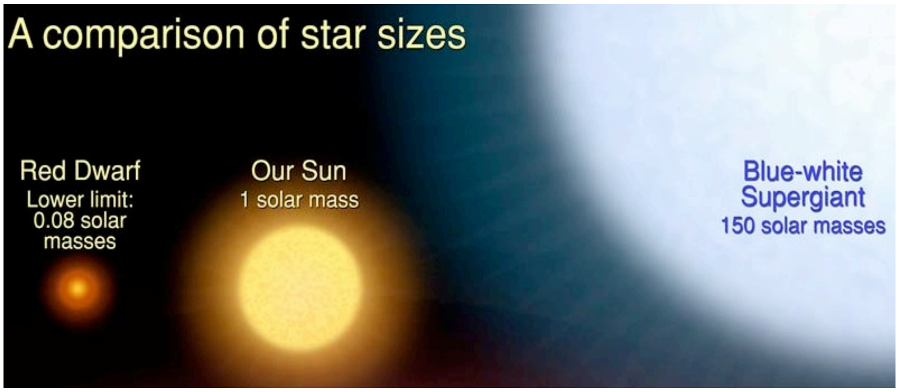
Colors of Stars

You can see stars of different colors in the night sky. Star colors are easier to see when the sky is very dark. City lights can make it hard to see star colors. You will also need to let your eyes have a chance to adapt to the dark, which usually takes a few minutes. Only very bright stars have visible colors.

Some examples of colored stars are:

- Betelgeuse (pronounced beetle juice), a red star in the constellation Orion;
- Rigel, a blue white star, also in Orion; and
- Aldebaran, a red star in the constellation of Taurus.

Star Sizes and Colors



On the main sequence, star sizes and colors are directly related. Larger stars are hotter and more massive than smaller stars.
(Illustration Credit: NASA, ESA and A. Feild (STScI))

Scaled Sizes of Stars Activity

Stars are very big in comparison with the Earth, but they are also very far away.

Just how big are main sequence stars? **Look at your STAR CLASSES TABLE.**

The <u>diameters</u> of stars of different classes are given in the STAR CLASSES Table, along with the <u>mass and color</u> of the stars in that class.

- The diameters, masses, and colors given are for a star in the **middle** of the class (except G).
    - Our Sun is a G class star, and is about 10% more massive than a star in the middle of the G class. Use the Sun for our G class star just to make things easier.

Convert the real diameters of the stars to the scaled diameter.

- All of the diameters of the stars are given in centimeters to make it easier for you to figure out the scaled sizes of the different stars for our model from the scale factor of 1 to 10 billion.
- For example, the diameter of the Sun is 140 billion centimeters. If you divide 140 billion centimeters by 10 billion centimeters, you will get the size of the model Sun, which is 14 centimeters (or about 5 inches).
- A large grapefruit is a good object to represent the Sun because it is about the right diameter and is yellow.
- Using the scale factor, calculate the scaled sizes of the other six classes of stars.

What objects can you think of to represent the stars in our model?

- Try to think of objects that are close to the right size and color.
- Use your ruler/meter stick to measure approximate sizes (you do not have to be exact, all of the star classes have a size range within them.)

Discussion Questions:

1. How did your chosen objects compare to other groups? To the teacher's?

2. How much bigger or smaller than the Sun is each star? How does your answer change if you compare volumes instead of diameters?

3. How much bigger than the Earth is each star? (The Earth has a diameter of 1.3 billion centimeters, so it is only 0.13 centimeters or 1.3 millimeters in diameter on this model.)

4. What did you find most surprising about the model?

5. The Sun is only a medium sized star. Why do you think the Sun seems so big and bright to us compared with the other stars in the sky?