Pleiades Star Cluster

Eventually these “seven sisters” will drift apart.

Image *Credit:* *NASA, ESA and AURA/Caltech*

An open cluster of stars, like the Pleiades, is a group of stars that started together in a stellar nursery.

In this exploration, find out:

- What determines how long a star can live?
- How do lifetimes of other stars compare to our star, the Sun?
- How do lifetimes of stars compare to major events in the history of the Earth?
- Why do the lifetimes of stars matter to astronomers?

Lifetimes of Stars Teacher’s Guide

In this exercise, students will make a scale model of time, and compare the lifetimes of different masses of stars both to each other and to the geologic timeline for the Earth. Students will then make predictions about what classes of stars might have planets with interesting (as defined by the students) life forms, assuming that the history of life on Earth is typical.

Recommended Prerequisites: Sizes of Stars and Star Birth

Grade Level: 6-8

Time Frame: The activity will take one to two class periods (45 minutes to one hour each) to complete. To save time, consider having students use the pre-made timeline template.

Curriculum Standards: The Lifetimes of Stars lesson is matched to:

- National Science and Math Education Content Standards for grades 5-8.
- National Math Standards 5-8
- Texas Essential Knowledge and Skills (grades 6 and 8)
- Content Standards for California Public Schools (grade 8)

Purpose: To aid students in understanding the wide variation in the ages of stars and how the lifetime of a star depends upon its mass. Students will also learn how the lifetimes of stars relates to the reason stars of a certain mass range are the focus of searches for Earth-like planets beyond the solar system.

Key Concepts:

- How long a star shines is very dependent on its mass.
- Low mass stars have less hydrogen to convert to helium than do high mass stars, but live much longer.
- Our sun has lived about half of its “life” as a main sequence star (fusing hydrogen into helium in its core).
- For most of the history of the Earth (and the Sun), bacteria and other microorganisms were the only forms of life on our planet.
- The lifetimes of stars are relevant to the search for life on planets outside our solar system.

Required Supplies:

- A copy of the Stellar Lifetimes Table for each student
- A copy of the Table of Major Events on the History of the Earth
- A copy of the student instruction sheet for each student
- Nine sheets of 8 1/2" x 11" paper or timeline*
- A ruler *
- A pair of scissors *
- Tape*
- Pencil*
- Colored pencils or markers

*For each student or small groups of students

Note: The use of *italics* indicates information or instructions from the student version

Introduction:

Begin by asking the class a few questions about the lifetimes of stars, and discuss the answers the students give.

- How long do stars shine? Note: you may need to review why stars shine, discussed in the activity Sizes of Stars.
- How long do they stay on the main sequence (converting hydrogen to helium as their energy source)? How old is the Sun?
- How much longer will the Sun stay a main sequence star?
- Do stars all “live” the same amount of time?
- Which types of stars “live” longer, high mass stars or low mass stars?

After this introductory discussion, give each student a copy of the Student Instruction Sheet and the student version of Table 1: Lifetimes of Stars. Consider having the students read through the explanatory material in class, or alternatively, send the sheet home to be discussed the next class period.

Comparing (Main Sequence) Lifetimes of Stars:

The time stars spend on the main sequence is often called the "lifetime" of stars. Stars will stay on the main sequence until they run out of hydrogen fuel in their cores. When a star runs out of hydrogen fuel, it has begun to die.

> ***Remember: Main Sequence***
>
> *Main sequence of stars is when they are in the main part of their lives, using Hydrogen in their cores*
>
> *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:*
>
> ***O**h **B**e **A** **F**ine **G**orilla **K**iss **M**e!*

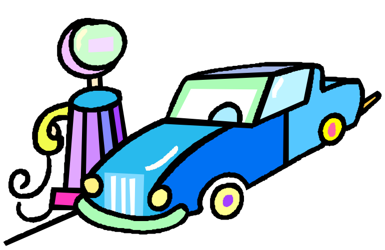
What determines how long a star can live?

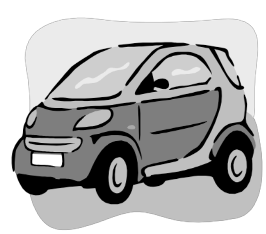
➢ *Available Hydrogen*

How long a star can rely on converting hydrogen to helium for its fuel depends on two main factors. How much hydrogen it has available is one. But how fast the hydrogen is used up in the core of the star is at least as important. Stars are made mostly of hydrogen, but only about 1% of the hydrogen in a star can be converted into helium. That 1% is in the core, where temperatures and pressures are high enough for fusion to take place. A star 40 times the mass of the Sun will have about 40 times as much hydrogen available to convert to helium. Because of this, it would seem to make sense that high mass stars should live longer than low mass stars. But this isn't true.

➢ *Mass, Pressure, and Heat*

The more mass a star has, higher the pressure will be in the core, and the hotter the interior of the star will be. Hydrogen atoms are converted more quickly into helium when pressures and temperatures are higher. The more mass a star has, the faster it will convert its hydrogen fuel into helium. It turns out that high mass stars, even though they have more fuel, use up that fuel much more quickly than low mass stars can. So, low mass stars have much longer lives than high mass stars! It's like the way a gas guzzling car with a big gas tank can run out of gas before a fuel efficient car with a smaller gas tank will.





Comparing the Lifetimes of Stars

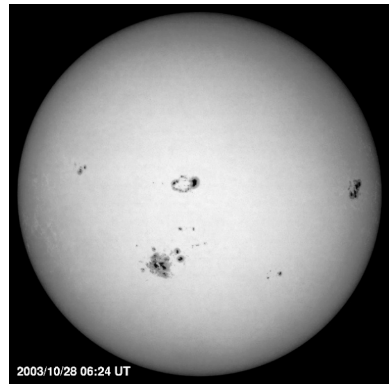
How do the main sequence lifetimes of stars of different masses compare with one another?

*Take a look at the **Lifetimes of Stars** table (**Table 1**).*

- *How does the lifetime of each mass of star in the table compare with the lifetime of the Sun (the G class star)?*

- *Which stars born at the same time as the Sun have left the main sequence?*

Our Star the Sun



(Image Credit: NASA's Solar Heliospheric Observatory)

The Sun has been a main sequence G class star for about 4.5 billion years, and will stay on the main sequence for another 5 to 6 billion years or so.

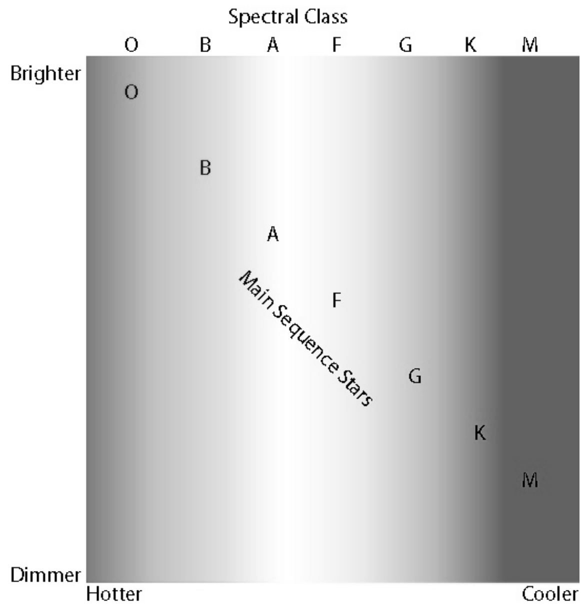
Why do the lifetimes of stars matter to scientists?

Lifetimes of stars matter for several reasons. Short-lived high mass stars often help continue the process of star formation in the same stellar nurseries in which they are born when they become supernovae. Dying high-mass stars also send rock-forming elements into interstellar clouds. These elements can eventually form planets around other, lower mass, stars.

Astronomers are searching for planets around other stars, and have already found many giant planets. NASA is working on ways to find small rocky planets like the Earth around other stars, too. One of the reasons scientists would like to find Earth-like planets, is the hope of finding evidence of life on a world outside the solar system. How long different masses of stars live will affect the chances that a planet around a star will have life, and what type of life it may have.

Hertzsprung - Russell Diagram

The H-R is a diagram illustrating where a star is categorized based on spectral class, temperature, and brightness. Stars on the main sequence make a diagonal line in this diagram.



Remember:

- *Low mass main sequence stars are cooler, and are reddish.*
- *High mass stars main sequence stars are hotter, and are white or blue white.*
- *High mass stars are also much brighter than low mass stars, because they produce much more energy.*

Scale Model of Time Activity:

If you choose to provide your students with the timeline template, the stars are pre-drawn. Students will need to assemble their timelines using many of the same steps described in their handout, but will skip adding the stars. You may also wish to use the template as an example, and have students create their timelines from plain sheets of paper.

Scale models can be used to represent time as well as sizes and distance. In a timeline, distance is used to model time. This scale model of time will be made using a timeline made from nine sheets of paper.

If you are short on time, the Timeline Template, in either color or b&w. Representing the lifetimes of the classes of stars with colored lines is highly recommended. Students can use markers or colored pencils to trace over the

lines representing the lifetimes of stars in the b&w version. For A class stars, black can be used instead of white. F class stars can be represented with a dashed yellow line.

Instructions for making the timeline:

1. *Take 9 sheets of notebook or typing paper. Trim each sheet so that it is 25 cm (just under 10 inches) long.*
2. *Lay two pieces of the trimmed paper down on a desk or table lengthwise so that the edges are touching, but not overlapping.*
3. *Tape the right edge of the first piece to the left edge of the 2nd piece. Now, add another sheet of paper to the first two the same way.*
4. *Repeat until all nine sheets of paper are taped together into one long sheet. Because the sheet will be getting very long, try folding it up like an accordion, bending at the taped edges. When all nine sheets are added, the long sheet should be roughly 2 1/4 meters long (or 9 x 25 cm).*
5. *Now, place the folded "accordion" of paper lengthwise on your desk. Using a ruler, draw a horizontal line 8 cm from the bottom across the entire length of the first page.*
6. *Repeat on the remaining 8 sheets of paper, so that if you unfold your "accordion" you'll have one long line across all 9 pages.*
7. *Next, go back to first page and place a "0" at the far left end of the horizontal line. This "0" represents the time of the formation of the Earth.*

On the timeline, each **sheet of paper** will equal 500 million years and every **centimeter** will equal 20 million years.

Add stars of different classes to the timeline

Next, draw horizontal lines on your timeline for the lifetimes of each of the seven classes of main sequence stars.

- *Start about 12 cm above the bottom of the pages for the first star class.*
- *Add a separate line above the first one for each class of star. Make them about one cm apart.* ***Colored lines matching the color of each class of stars are recommended.***
- *Some star classes will be longer than the span of 4.5 billion years (the total of your pages). In these cases, on the last page use an arrow at the end of the line for that star to indicate a longer life span than is shown on the timeline.*

You are now ready to add events to your timeline.

Give each student, or small group of students, a copy of **Table 2: Some Major Events in the History of the Earth**. The times for the events are given in two different forms: years since the Earth's formation or years ago. The students can therefore measure distance on their timelines from the beginning of the timeline, or from the present, which ever is easier.

Go over the example of how to calculate the distance of an event from both the beginning and the end of the timeline.

Example: *The oldest surviving rocks on the Earth are about 4 billion years old, so they formed about 0.5 billion or 500 million years after the formation of the Earth.*

How far from the beginning of the timeline do we mark this event?

(Time of Event from Beginning of Timeline)/ Scale Factor
= Distance from Beginning of Timeline

so

500 million years / 20 million years per cm = 25 cm
(which also happens to be one sheet of paper).

- *How would this change if you wanted to calculate the distance on your timeline measured from the end of the timeline (the present)?*

Put major events from the history of the Earth on the timeline

Take the events given in the ***Table 2****:* ***Some Major Events in the History of the Earth*** *and mark each of them on them on the timeline. You may use the space both above and below your timeline.*

- *The times of the events in the table are given in both years from Earth's formation and years from the present (how many years ago an event occurred). Both numbers have been provided so that you can easily work from either end of your timeline.*

Comparing Stellar Lifetimes to the History of Life on Earth.

Which classes of stars have shorter lifetimes than the Earth has had so far?

Assume that a star of each class was born at the same time as our own sun. For each class of stars with lifetimes shorter than the age of the Earth, answer these questions:

- *What was the Earth like over the time period that the star would have been on the main sequence?*
- *Did life exist on the Earth before the star died? If so, what type?*

Follow-up:

After each group has completed Table 1, the timeline, and answered the questions in the student handout, discuss with the students how the comparison of the history of life on Earth relates to the search for planets around other stars.

Assuming that the history of life on Earth is typical, what classes of stars do the students think astronomers should focus on?

- What criteria are the students using for their answers?
- Do the students think astronomers should look for stars that could have planets:
  - capable of having bacteria or other microbes,
  - or planets with larger life forms like plants and animals,
  - or just for stars with planets that could have creatures capable of making a civilization?
- What do your students think of the assumption that the history of life on Earth is typical?
- Would they expect life on another world to resemble life on Earth?

The Sun has only lived roughly half its lifetime as a main sequence star, and should be habitable for another billion years or more*. Ask your students how they imagine future life on Earth might be different than life on Earth today.

*The Sun, like all stars is getting brighter as it ages. In one to two billion years, the Sun will grow bright enough that Earth's oceans will begin to dry out from evaporation and the water in the atmosphere will be lost to space. Many planetary scientists think that in someday the Earth will be very much like the planet Venus is today: very hot, extremely dry, and inhospitable to life.