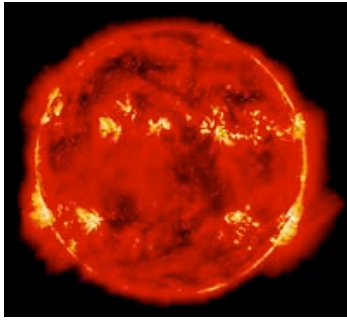


Our Star, the Sun



(Image Credit: NASA/Transition Region & Coronal Explorer)

Note: The above image of the Sun is an X-ray view rather than a visible light image.

In this Exploration, find out:

- *How do the distances of stars compare to our scale model solar system?.*
- *What is a light year?*
- *How long would it take to reach the nearest star to our solar system?*

Stellar Distances Teacher Guide

In this exercise students will plan a scale model to explore the distances between stars, focusing on Alpha Centauri, the system of stars nearest to the Sun. This activity builds upon the activity Sizes of Stars, which should be done first, and upon the Scale in the Solar System activity, which is strongly recommended as a prerequisite. Stellar Distances is a math activity as well as a science activity.

Necessary Prerequisite: Sizes of Stars activity

Recommended Prerequisite: Scale Model Solar System activity

Grade Level: 6-8

Curriculum Standards: The Stellar Distances 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)

Time Frame: The activity should take approximately 45 minutes to 1 hour to complete, including short introductions and follow-ups.

Purpose: To aid students in understanding the distances between stars, how those distances compare with the sizes of stars, and the distances between objects in our own solar system.

Key Concepts:

- Distances between stars are immense compared with the sizes of stars.
- The planets are much closer to the Sun than the next closest star.

Supplies:

- A copy of the student instruction sheet for each student
- 2 large grapefruits or 14 cm yellow balls (for the Sun and Alpha Centauri A)*
- 1 orange (for Alpha Centauri B)*
- 1 cherry tomato or small red ball (3 cm or about 1")*
- A meter stick
- 1 map of your state, region, or province per group of 3-5 students (The maps need not be identical; the students can bring them from home or print maps from the Web.)
- At least one globe or map of the world, (One for each group of 2-4 students is preferred.)
- A calculator for each student (optional)

*Objects should be the same as you used in Sizes of Stars for G,K, and M class stars.

Introduction:

Ask students the following question: Can we include both the Sun and the nearest star to the Sun, Alpha Centauri, on a scale model using the same scale factor we used to model the sizes of stars?

The questions given in the student handout should be attempted by the class one at a time, with an opportunity in between for class discussion and further instructions.

Note: The use of <i>italics</i> indicates information or instructions from the student version
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Review the Scale Factor:

The scale factor for this scale model is 1:10 billion, and is the same as the scale for the Sizes of Stars and Scale Model Solar System activities in Stars and Planets.

If your students have done both of these activities, simply remind them that the scale factor is the same. If they have done the Sizes of Stars activity, but not the Scale Model Solar System activity, discuss that distance is on the same scale as size was in the previous model.

Every centimeter in the model equals 10 billion real centimeters. Similarly, a kilometer in this scale model equals 10 billion kilometers.

Ask the students how far away they think the nearest star to the Sun would be on a model with a scale factor of 1:10 billion.

Introduce the Nearest Star to the Sun:

Introduce your students to Alpha Centauri, the nearest star to the Sun. Alpha Centauri A triple star system composed of a G class star, a K class star, and a faint M class star, Alpha Centauri is visible from the Southern Hemisphere.

The G class star, Alpha Centauri A, is very much like our Sun, and all three are main sequence stars.

Refer to the chart in the student handout that gives the classes of the three stars and their classes, and ask the students what objects should represent each star. The objects should be the same as those for the G, K, and M class stars in the Sizes of Stars activity. Bring out the objects to represent the stars in the Alpha Centauri system and the Sun, and place them where they can be seen by the entire class. This will aid the students in developing a mental model of the stars in the Alpha Centauri system.

Now that we have modeled the sizes of main sequence stars, we will examine the distances between stars using the same scale factor of 1:10 billion.

Alpha Centauri, the closest star to the Sun, is actually a triple star. Multiple stars are very common. Fifty to seventy-five percent of all stars are in such systems.

Table 1: Distances in the Alpha Centauri System

	Class	Average Distance from Alpha Centauri A	Scaled Distance from Alpha Centauri A
Alpha Centauri A	G	0 km	0 km
Alpha Centauri B	K	3 billion km	0.3 km
Alpha Centauri C	M	1600 billion km	160 km

What is a Light Year:

A distance of 40,000 billion km or 40 trillion km is almost unimaginably large, and that's just how far it is to the nearest star to the Sun. Using such large numbers to refer to the distances of stars can become awkward very quickly.

*Astronomers use a unit called the **light year** to help deal with this problem.*

A light year is often confused with a measure of time, but is really a measure of distance.

*It is defined as **the distance light can travel in one year. A light year is equal to about 9.5 trillion km or 6 trillion miles.***

The Sun is about 26,000 light years from the center of

Have the students complete Table 1.

The distances given in Table 1 are all from Alpha Centauri A. The stars, however, all orbit the center of mass of the system, which is between Alpha Centauri A and B. Alpha Centauri C, also known as Proxima Centauri, orbits the other two stars. Proxima is also currently the closest star to our Sun.

The image below shows the Sun and the stars in the Alpha Centauri system to scale in size, but not distance.

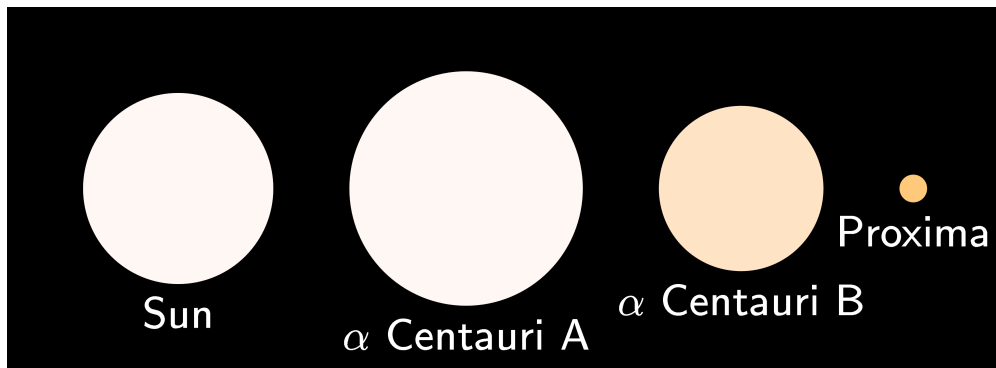


Image credit: David Benbennick, http://en.wikipedia.org/wiki/Image:Alpha_Centauri_relative_sizes.png

1. Using the scale factor of 1:10 billion, how far away from Alpha Centauri A are the other two stars? Fill in the last column of Table 1.

When the students have completed the calculations, either individually or in small groups, discuss the results.

The distance between Alpha Centauri A and B is almost the same as the distance between the Sun and Uranus in the Scale Model Solar System, or about four times the distance between the Sun and Jupiter on the same scale.

Remind the students that the Earth is 15 meters from the Sun on this scale. If the students haven't done the Scale Model Solar System activity, discuss how far the separation of the two stars would be in a model, using familiar landmarks such as your school, and discuss the distance of the Earth from the Sun (150 million km or 93 million miles), which is 15 meters on the scale model.

If your students don't use metric units on a regular basis, converting kilometers to miles or meters to feet might help them to understand the distances in the model. A mile is equal to about 1.6 kilometers, and a meter is equal to about 3.3 feet, so the distance between Alpha Centauri A and B is roughly 1000 ft.

Maps of your state, region, or province will help in discussing distance of Proxima Centauri in the model, which is 160 km or 100 miles away from the other two stars. Separate your students into groups of two - four students. Have each group of students look at a map and suggest a location that is about the right distance from your town for Proxima Centauri on the model.

You may wish to point out to the students that a map is a scale model, too.

- 2. How does the choice of Alpha Centauri A as the star from which the other distances are measured affect the distance for Alpha Centauri C, otherwise known as Proxima Centauri?*

Hopefully, your students will recognize that because two larger stars of the Alpha Centauri system are so close together in comparison with the distance to Proxima Centauri, it really doesn't matter which star is chosen.

An analogy might help if any of your students are confused by why the choice of Alpha Centauri A or B doesn't really matter; talk about how distances are measured between towns. If your friend lives a few blocks away, the distance to the next town or city from your house or your friend's house can be treated as the same because that distance is much larger than the separation between the two houses.

The Distances Between the Sun and the Nearest Stars:

Your students may already be surprised by the distances between Alpha Centauri A, B, and the tiny red star, Proxima Centauri. Now, they will discover that the distance between that that distance is tiny in comparison with the distance between Alpha Centauri and the Sun.

The distance between the Sun and the Alpha Centauri System is 40,000 billion km.

- 3. How far away would the Sun be from Alpha Centauri on our scale model?*

The Sun and Alpha Centauri are about 4,000 km (or 2,500 miles) apart on this scale model. This is about the distance between San Francisco and New York, or the width of the continental United States.

4. *Where would you place the Sun on the scale model if Alpha Centauri A is at your school?*

A globe or world map works well for this portion of the activity. If each group of students has a globe, ask the students to take a few minutes to choose one or more locations to put the Sun on the model.

Query one or more groups for their locations, and ask the rest of the class if they agree or disagree with the choice(s) of the selected group(s). Two groups of students can share a globe or map, if necessary.

If you only have one globe or map for your classroom, you might wish to consider doing this part of the activity with the entire class. A student volunteer can measure out 4,000 km or 2,500 miles using the scale bar on the globe/map, and choose a location for the class. Pass the globe/map on to a second student volunteer to see if he or she agrees or disagrees with the choice of the other student.

Introduce the Light Year:

Distances to astronomical objects outside of our solar system are usually given in terms of light years. The light year is discussed in the text box on the 2nd page of the student handout.

A distance of 40,000 billion km or 40 trillion km is almost unimaginably large, and that's just to the nearest star to the Sun. Using such large numbers to refer to the distances of stars can become awkward very quickly. Astronomers use a unit called the **light year** to help deal with this problem. A light year is often confused with a measure of time, but is really a measure of distance. It is defined as the distance light can travel in one year, and is equal to about 9.5 trillion km or 6 trillion miles.

A possible analogy to use with your students to help them understand that the light year is a measure of distance is a trip in an automobile. If a car is on the highway and traveling at a constant 65 mph, then 65 miles would be equal to a highway "car hour". The speed of light is a constant 300,000 km/sec.

Table 2: The Twelve Nearest Star Systems to the Sun

Name	Number of Stars	Class	Distance from the Sun
<i>Alpha Centauri</i>	3	G K M	4.3 light years
<i>Barnard's Star</i>	1	M	6.0 light years
<i>Wolf 359</i>	1	M	7.5 light years
<i>BD+36°2147</i>	1	M	8.2 light years
<i>L726-8</i>	2	M M	8.8 light years
<i>Sirius</i>	2	A white dwarf*	9.5 light years
<i>Ross 154</i>	1	M	9.5 light years
<i>Ross 248</i>	1	M	10 light years
<i>L789-6</i>	1	M	10 light years
<i>eta Eridani</i>	1	K	11 light years
<i>Ross 128</i>	1	M	11 light years
<i>61 Cygni</i>	2	K K	11 light years

* A white dwarf is a very small, hot star that is no longer on the main sequence

A star 11 light years from the Sun is more than 100 trillion km away, or 10,000 km away on our scale model!

Sirius, also known as the Dog Star, is the brightest star in sky. It is a hot, bright, A class star with a small companion. However, most of the stars in Table 2 aren't very bright in our sky because they are small and dim M class stars. Ancient astronomers didn't name them, so they were given designations like BD+36°2147 by modern astronomers.

Elaborate - *Traveling to the Stars:*

The following problems may be quite challenging for your students. You may wish to consider having the students work in their small groups to try and solve the problems. You might also give the three problems as homework to more advanced students, or doing the calculations with the entire class.

How long would it take for a spacecraft to reach the nearest star?

We know it will take longer than 4.3 years, because nothing travels faster than light. Let's start by looking at how long it took spacecraft to reach objects in our solar system.

The Apollo spacecraft took about three days to travel the 384,000 km between the Earth and the Moon.

5. *If you are an astronaut sent in a spacecraft traveling at the same speed to Alpha Centauri, how many years would it take you to get there? Would you arrive in your lifetime? Remember: Alpha Centauri is 40 trillion (40,000,000,000,000) km away from the Sun. Hint: How far would you travel in one year?*

Rather than using the concept of significant figures, students in grades 6-8 can make this problem easier by using approximations.

$$384,000 \text{ km} / 3 \text{ days} = 128,000 \text{ km/day}$$

$$128,000 \text{ km/day} * 365 \text{ days/year} = 46,720,000 \text{ km/year, or about 47 million km/year}$$

$$40,000,000,000,000 \text{ km} / 47,000,000 \text{ km/year} = \text{about } 850,000 \text{ years}$$

Or, to make the problem even easier,

$$40 \text{ trillion km} = 40,000,000 \text{ million km}$$

$$\text{so, } 40,000,000 \text{ million km} / 47 \text{ million km/year} = \text{about } 850,000 \text{ years}$$

It will take about 850,000 years to reach the nearest star to the Sun, which is definitely longer than a lifetime. If you think your students will have difficulty with this problem as written, try giving them the distance the spacecraft will travel in a year, and let them work out the remainder of the problem on their own.

What if you sent a robotic spacecraft in your place?

Voyager 1 and Voyager 2 are robotic spacecraft that are currently traveling towards interstellar space. Voyager 1, the faster of the two spacecraft, is traveling at a speed of 540 million km per year.

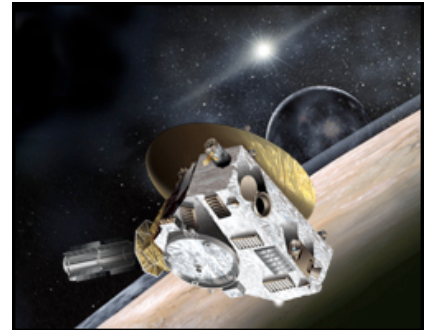
6. *If you sent a spacecraft that travels at the same speed as Voyager 1 to Alpha Centauri, how long would it take to get there?*

$$40,000,000,000,000 \text{ km} / 540,000,000 \text{ km/year} = \text{about } 74,000 \text{ years}$$

Or

$$40,000,000 \text{ million km} / 540 \text{ million km} = 74,000 \text{ years}$$

NASA launched New Horizons in January 2006 to study Pluto and the Kuiper Belt. At launch, New Horizons was the fastest spacecraft yet built, flying the distance between the Earth and Moon in just 9 hours. On February 28, 2007, New Horizons flew by Jupiter, increasing the speed of the spacecraft to about 72,000 kilometers per hour (45,000 miles per hour).



7. *If New Horizons were on its way to Alpha Centauri instead, how long would it continue into space at this rate? How long would take to get to Alpha Centauri at its current speed?*

$$72,000 \text{ km} / \text{hr} \times 24 \text{ hr/day} = 1,728,000 \text{ km/day}$$

$$1,728,000 \text{ km/day} \times 365 \text{ days/year} = 630,720,000 \text{ km/year}$$

or about 630 million km/year

$$40,000,000 \text{ million km} / 630 \text{ million km} = \text{about } 63,000 \text{ years}$$

Follow-up:

Discuss the distances of the planets from the Sun in comparison with the distances between stars. Earth, as discussed earlier, is only 15 meters from the Sun on this scale model. Compared with the size of the model Earth, this distance is immense, but it is nothing compared with the distance between the stars. This is true even for the most distant planet in our solar system, Neptune, and the dwarf planet, Pluto. The average distance of Pluto from the Sun is about six billion km, or about 600 m (about 1/3 mile) from the Sun on a 1:10 billion scale.

Ask your students why no spacecraft have ever been sent to another star.

Have your students imagine that they are trying to observe their model Sun, a grapefruit, in the very distant location they have chosen for it.

Would they expect to be able to see such a tiny object so far away? Explain to the students that the reason we can see the stars is simply because they are so very bright.