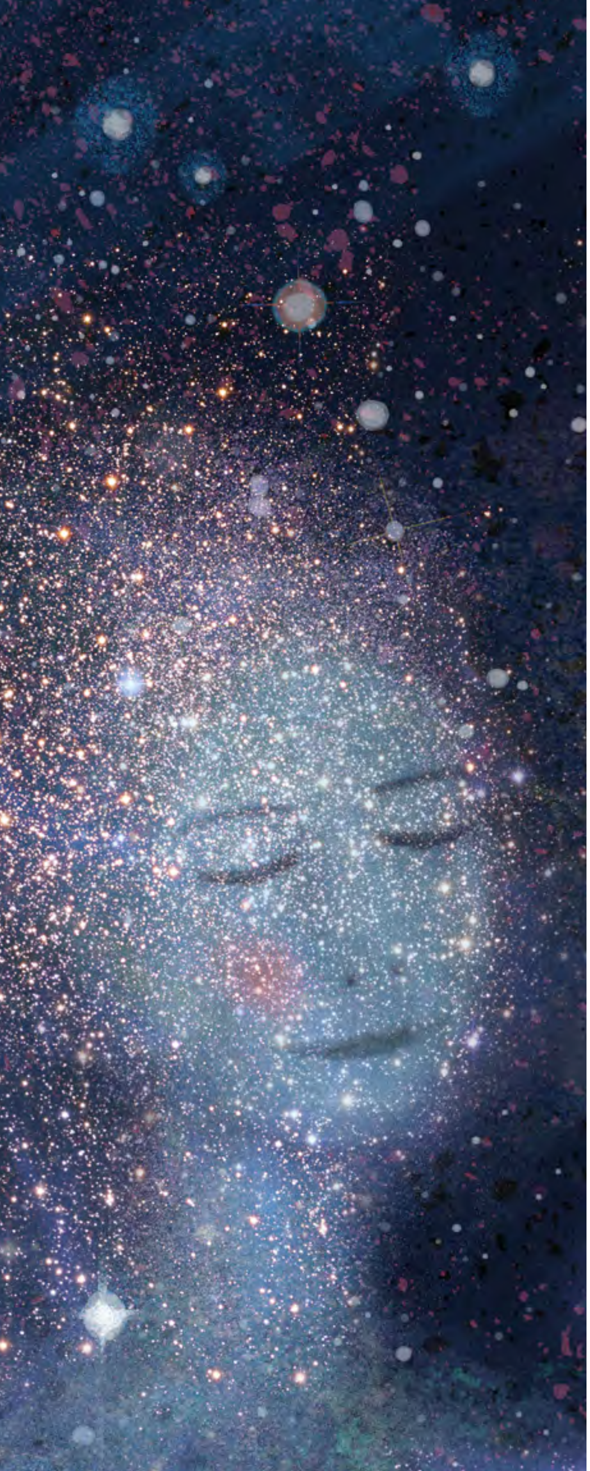


Courtesy: NASA

Space Science Expert

"It takes a cosmos to make a human; we are all made of stardust."
—Jill Tarter,
Trustee and Emeritus Chair for
SETI Research at SETI Institute

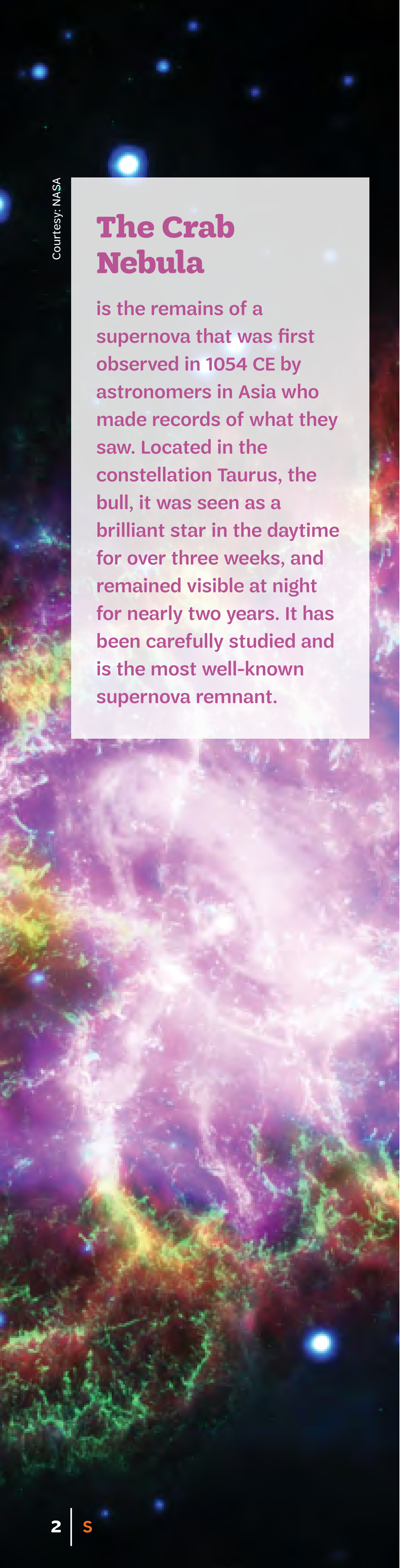
For most of human history, the planets and stars have only been tiny points of light, floating in a dark sky many millions—or even trillions—of miles away. People began by organizing the sky into constellations, cataloging the stars by brightness, and, then the invention of the telescope harnessed the power of light and expanded our view! Now, it's your turn to explore light and discover what it teaches us about the Universe!

Steps

1. **Uncover the stuff you're made of**
2. **Explore the brilliance of the stars**
3. **Discover telescopes as light collectors**
4. **Find the light in the darkness**
5. **Share your knowledge**

Purpose

When I've earned this badge, I will understand more about the Universe—my place in it and how light is used to make discoveries about it.



Courtesy: NASA

The Crab Nebula

is the remains of a supernova that was first observed in 1054 CE by astronomers in Asia who made records of what they saw. Located in the constellation Taurus, the bull, it was seen as a brilliant star in the daytime for over three weeks, and remained visible at night for nearly two years. It has been carefully studied and is the most well-known supernova remnant.

Every step has three choices. Do ONE choice to complete each step. Inspired? Do more!

STEP 1 Uncover the stuff you're made of

When a massive star explodes at the end of its life—an event called a supernova—the star's elements scatter into space. Over time, elements made during the supernova, including those heavier than iron, are recycled into new stars and planets. The naturally occurring elements found on Earth were once at the heart of a star. Since humans are made up of the elements, we are literally made of stardust.

CHOICES—DO ONE:

☐ **Make a stardust self-portrait.** An infographic transforms information from a set of numbers into a compelling visual image—it makes data more interesting, appealing, and easier to understand. The four chemical elements that make up most of the atoms in your body are hydrogen (62%), oxygen (24%), carbon (12%), and nitrogen (1.1%), with traces of calcium, phosphorus, potassium, sulfur, sodium, and chlorine that collectively make up about .6%, and a variety of trace elements adding up to about .3%. Use this data to create an infographic by drawing an outline of yourself or choosing another shape to represent you. Calculate or estimate how much space each element should take up, and divide your shape accordingly. Then, label and fill in each section using a different color or pattern. Share your infographic with your friends and family, explaining what it means to be made of stardust.

OR

☐ **See how your eyes react to light.** How does light enter your eye? Your pupil is the dark circle in the middle of your iris, the colored part of your eye, and allows light in. Grab a partner and test your eyes to "see" how they react to light.

You'll need:
- Mirror
- Ruler
- Flashlight with red filter
- Pen
- Paper

Look in the mirror and hold a ruler horizontally in front of one eye. How wide is your pupil? Be sure to record your answer. Now, shine a flashlight toward your face for roughly three to five seconds. Measure your pupil again. What happened to it? Did the area increase or decrease? Dim the room and close your eyes. Measure your pupil and explore what happened this time. Closing your eye simulates what happens when you go stargazing. Go outside to a dark place on a clear night with your flashlight and red filter, and look at the sky. What happens? Can you see more stars after being outside for a few minutes? Why do you think that is? This is what astronomers call dark adaption. Under a dark sky, your pupil adapts to the low light level so that you can see better—which allows you to observe more stars. It can take you 20 minutes or more for your pupil to open as wide as possible and for you to become fully dark adapted! This is when you can see the most stars.

OR

Explore a Universe without supernovae. Play a game by yourself or with some friends to determine what the Universe would look like without supernovae. Print out the element and item cards from the link below and divide them into groups by color. Pull one of the green item cards. Then, look at the blue cards to see if any of the elements there are found in the item on your green card. If the item on your green card is made up of elements from one of the blue cards, this means it is made from elements produced by stars that go supernovae—set it aside. In a Universe without supernovae, this object wouldn't exist. Go through all of your object cards and see which ones you're left with. Are you surprised?

Print out the game cards here:
www.girlscouts.org/SpaceScienceSupernovaeCards

Create a Notebook

Go retro! Carrying a notebook is a quick, low-tech way to make sure you're always ready to capture your ideas and discoveries. Successful scientists record everything—including their wildest ideas, the exact details of an experiment's setup, and all the things they've learned. Sometimes the results are surprising or even puzzling, which means that more experiments and observations may be needed!

Where did the elements come from?

A supernova is a violent explosion that happens at the end of a massive star's life. When a star, at least eight to ten times the mass of the Sun, dies, it produces so much energy that it shines brighter than the hundreds of millions of stars in its galaxy. The energy of the explosion creates elements, heavier than iron, that are required for life as we know it, while most of the other elements, those lighter than iron, are made inside stars during their lifetimes.

Life Stages of a Star

Stars, like people, have a lifecycle—we can think of a star's lifecycle in human terms like this:

- **Prenatal:** Stars are created in large clouds of gas and dust called "nebula," or stellar nurseries.
- **Birth:** When there is enough mass for hydrogen to fuse into helium at its center (or core), a star is born! They're ready to move out of the cloud and into their place in the Milky Way Galaxy.
- **Adulthood:** A star will spend most of its life steadily converting hydrogen into helium and not changing in size very much. The largest stars have the shortest lifetimes, millions of years, and the smallest have the longest—billions of years.
- **Crisis:** When a star runs out of hydrogen fuel, it undergoes rapid structural changes, making the star expand and contract.
- **Death:** Different things occur when stars die. A small star's outer layers will gently expand as a planetary nebula, a shell of gas, and its center will become a white dwarf. A massive star will have a more violent end—a fiery supernova explosion, with its core becoming either a high density neutron star or compressing into a stellar black hole.

STEP

2 Explore the brilliance of the stars

Elements, the basic building blocks for all things, are everywhere. Cars, buildings, trees, birds, and even our bodies are made of the elements—but where did they come from? Scientists have discovered that most of the elements were made in stars! The iron in your blood and the calcium of your bones were once part of a star! In this step, explore what happens when stars live and die.

CHOICES—DO ONE:

☐ **Play a game.** Sorting helps us understand complex systems by highlighting similarities and differences between items. Cut out each photo and make a set of cards to sort. When you sort things, it's important to define the parameters for sorting at the beginning. Start sorting the cards by using their distance from the Earth—then, try size and, after that, age. Once you've tried those, what other sorting criteria can you come up with? Try predicting what order the cards will go in before you start. Compare your notes and see if your predictions were correct. After you've tried a few different sorting criteria, cut out the information cards. Then, match the photo cards to their corresponding information cards. Did any of the matches surprise you? After the photo cards are matched with their information cards, try sorting the pairs—think of new sorting criteria you haven't used yet. Make note of your predictions and compare them to your results. Were you correct? What surprised you?

OR

☐ **Scrapbook the lives of stars.** Make a scrapbook comparing the lifecycles of stars and humans to share with friends or family. Start with the formation stage and end with supernova remnants or planetary nebula. Use the **Life Stages of a Star** outline to the left and the list of stars to the right for reference. Then, go online and use photos as inspiration to draw or paint in your scrapbook. Or, just print out pictures and place them in your book—but be sure to be creative.

"Scrapbook the lives of stars" activity is modified from "Starry Lives, Starry Skies," by Andrew Fraknoi and Marni Berendsen at the Astronomical Society of the Pacific.

Stellar Nursery/Prenatal Stage: The Orion Nebula (M42), The Rosette Nebula (NGC 2237), The Trifid Nebula (M20), The Cone Nebula (NGC 2264), The Eagle Nebula (M16)

Protostars/Birth: Star Cluster in the Center of the Rosette (NGC 2244), The Pleiades (M45), The Wild Duck Cluster (M11)

Main Sequence Stars/Adulthood: The Sun, Alpha Centauri (the nearest star to the Sun), Spica, Vega, M13 Globular Cluster, Proxima centauri

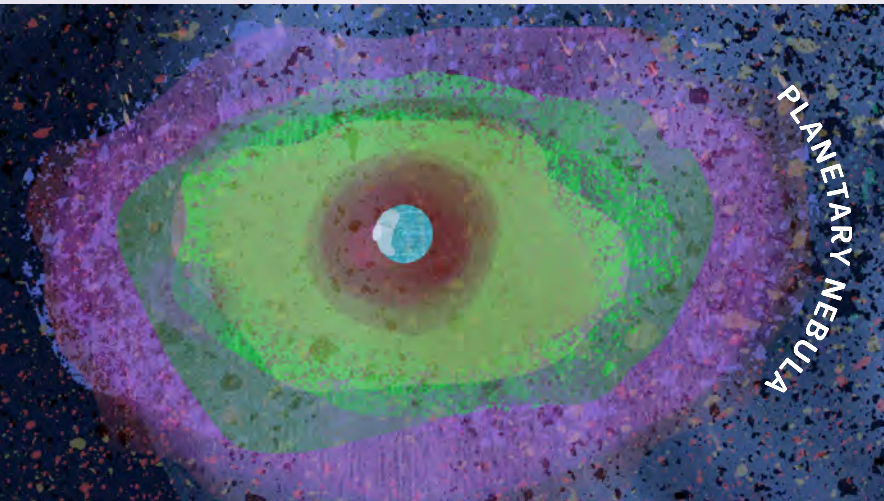
Red Giant and Red Supergiants/Aging Stars: Betelgeuse, Antares; **Red Giant:** Aldebaran; **Blue Supergiants:** Rigel, Deneb

Planetary Nebula/Death: The Ring Nebula (M57), The Helix Nebula (NGC 7293), The Dumbbell Nebula (M27)

Supernovae/ Death: The Crab Nebula (M1), The Veil Nebula (NGC 6960 & 6992)

OR

- [ ] **Go on a nighttime scavenger hunt.** With a telescope, pair of binoculars, or simply your eyes, see if you can find several different types of objects in the sky. Get some help from an amateur astronomer by attending a stargazing event in your area (learn more at: www.girlscouts.org/SpaceScienceNSN), use a stargazing app, or download a sky map at www.girlscouts.org/SpaceScienceSkyMaps. Draw pictures and take notes of what you see. Here's a list of suggestions to get you started:
  - [ ] The Moon
  - [ ] A planet
  - [ ] A star with an exoplanet
  - [ ] A double star
  - [ ] A nebula
  - [ ] A star cluster of ordinary stars
  - [ ] A red star
  - [ ] A blue star



STEP 3 Discover telescopes as light collectors

Telescopes are tools that expand your ability to explore the Universe. They gather more light than just your eyes, enabling higher resolution, and magnify the image you're observing. Let's see why bigger telescopes help you see more.

CHOICES—DO ONE:

☐ **Compare your eyes to telescopes.** At night, have you noticed that distant cars look like a single light, and as they get closer they "resolve" into two headlights? With a friend or family member, experiment with resolution. Poke two tiny pinholes about one-eighth inch apart in a piece of aluminum foil and wrap the foil over the end of a flashlight—now you are able to project two "stars." Have your friend back away while keeping the flashlight pointed toward you and watch as the "stars" fade away. How far away is she when they merge into one "star"? Measure the distance. Then switch roles and try it again. Is the distance the same? A telescope with a 6-inch diameter can resolve your "stars" at 875 feet!

For More **FUN:** Have a friend hold a penny so you can see it. Walk away until you can no longer distinguish the penny from her fingers. How far did you go? A telescope with a six-inch diameter can resolve the penny from one mile away.

OR

☐ **Create a pointillist image.** Modern astronomical images, taken by ground and space-based telescopes, are made with CCDs divided into pixels. A CCD is a charged-couple device—the same type of imaging device in digital cameras and smartphones. Zoom in on a digital photo and you'll see the pixels, but from farther away, the pixels blend into an image.

Pointillism is an artistic technique that uses small dots placed next to each other to make a picture—the same way digital cameras make images from pixels. It's your turn to experiment by creating a picture using just dots. Do you think the size of the dots matters? What happens if you make all the

It's diameter that matters!

Resolution is the detail an image has—higher resolution means more image detail. Magnification is a measure of how much an image is enlarged.

You will often see telescopes in toy stores that advertise "200 times magnification!" What does that mean? You can magnify an object, but unless the telescope also collects enough light, you will be disappointed with the image. For example, the larger the lens or mirror, the more light telescopes collect. And the more light they collect, the higher the resolution/image detailing—which means the more we can see. So, the size of the lens or mirror, or the light collected, directly correlates to the amount of detail we can see through a telescope. It is important to note that quality also plays a role in resolution of small diameter telescopes.

dots the same size? What happens when you place blue and yellow dots next to each other? Cotton swabs are excellent for making pointillist images with paint. You can also use crayons, stickers, or markers. Give it a try.

OR

☐ **Discover why telescopes are so powerful.** Binoculars and telescopes collect light using large lenses or mirrors. Let's explore the amount let into light collectors of different sizes.

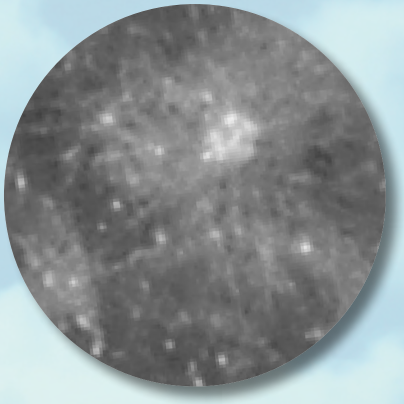
You'll need:
- 2 sheets of paper
- Ruler
- Drawing compass
- Pencils
- Bag of dried beans or lentils

Draw three circles. The first circle should have a diameter similar to that of the pupil in the human eye, the second one should be the same size as a lens on a pair of binoculars, and the third should be comparable to the lens or mirror of a backyard telescope. Fill each circle with a single layer of beans or lentils—let's imagine that one bean, or lentil, is about the size of your pupil, representing the amount of light your eye can collect. How many beans or lentils fit in each circle? How does the amount of light collected by binoculars compare to your naked eye? Refer to the chart and see if you can figure out how many beans or lentils the Webb telescope could hold. As you complete the activity, think about the relationship between diameter and area. Record your observations, but be creative. You can draw, create a 3-D model, or use graphics from the computer to capture what you've discovered.

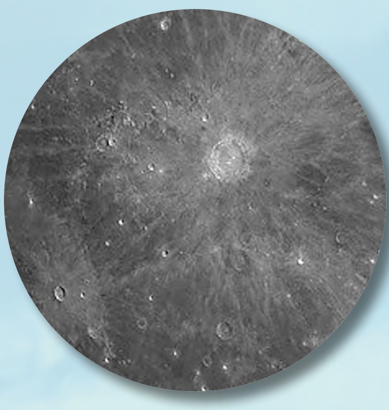
Light collector	Diameter (inches)	Diameter (mm)	Area (number of beans, lentils—or "eyes")
Human eye	1/4 inches	7 mm	1
Binoculars	2 inches	50 mm	
Small backyard telescope	4 inches	100 mm	
Common backyard telescope	8 inches	200 mm	
James Webb Space Telescope (~1,000 times the diameter of the human pupil)	256 inches	6,500 mm	

Take a look:

A 3-inch lens telescope that magnifies 70 times will see the whole Moon like this.



If you take that same 3-inch telescope and zoom in on a smaller region so the magnification is 300 times, you'll see this. It's very fuzzy because not enough light is being collected so the **resolution** is poor.



If you look at that same region with a telescope that is 7 inches in diameter, this is the image you will see. It is able to collect more light and give you better resolution. A good telescope will be able to collect enough light to clearly resolve craters on the Moon.

Top moon image is courtesy James Scala; bottom two moon images are courtesy Steve Mandell

Courtesy: American Institute of Physics

Henrietta Swan Leavitt

Henrietta Swan Leavitt was a deaf scientist whose extensive work led her to discover the relationship between a star's brightness cycle and its absolute magnitude—its actual brightness. A star's apparent brightness is its brightness as seen from Earth, while its absolute brightness is the brightness the star would have if it were at a standard distance from the Earth. She discovered that Cepheid variable stars always brightened the same amount in the same period of time, which allowed her to predict their actual brightness. Comparing their absolute versus apparent magnitude, she was able to use the "inverse square law" to calculate how far away the Cepheid stars were. It was this discovery that first allowed astronomers to measure the size of our galaxy, the Milky Way, and the distance between the Earth and faraway galaxies.

STEP

4 Find the light in the darkness

We learn about the Universe by collecting and analyzing light. What can we discover from this light? How far away are the Moon, the planets, and the stars? Are there planets around distant stars? Does light give us these answers? Let's explore some of the ways scientists determine the distances of objects in the Universe.

CHOICES—DO ONE:

☐ **Explore standard candles.** When you look at streetlights down a highway, nearby ones are bright, and distant lights are faint, even though they are all actually the same brightness—it's the distance that affects the way you see them. Objects that all have the same brightness are called "standard candles." Scientists use standard candles to help figure out how close or far away stars and galaxies are. They compare their observed brightness with their known brightness. There are several standard candles scientists use, including Cepheid variable stars and supernovae.

How does this work? You can experiment by using a smartphone light meter app and a bright flashlight in a darkened room. Measure the brightness of the flashlight up close. Try measuring from 1 foot away, 2 feet away, 3 feet away, and so forth. Do you see a pattern? Can you figure out the relationship between the distance and the brightness? Record your observations. Astronomers use this relationship to calculate the distance to stars and galaxies.

OR

☐ **Join the citizen science movement.** Space scientists worldwide collect information—data—as they do their research. With modern technology there is more data than individual scientists can manage alone—they need your help. You can be a part of this people-powered research model. Join volunteers from all around the world and help scientists comb through data for new discoveries. Dive into modern space science information with your computer and explore the Universe as a citizen scientist. You could map Mars, find the next supernova, discover an odd galaxy, catch the signal of a planet orbiting a distant star, or something completely different! The Universe is yours to explore. Visit www.girlscouts.org/NASACitizenScientists to get started.

Courtesy: NASA (2)

OR

☐ **Discover "shifting stars."** Astronomers calculate the distances to the nearest stars by measuring their positions against the background of more distant stars and galaxies. They make the measurements about six months apart when the Earth is on the opposite sides of the Sun. The apparent shift in the nearby star's position is called "stellar parallax." Practice this by holding up your index finger at arm's length in front of you and close your left eye. Line up your finger with an object across the room from you. Now, close your right eye. What happened to the background object? In this practice model, your nose represents the Earth and each eye one of the two observations. Your finger represents the nearby star and the object a more distant star or galaxy. Explore stellar parallax deeper by creating this model. Start by placing the 15 to 20 small pieces of paper in a 10-foot row on a distant wall—this will serve as your starry background. Your ping-pong ball will serve as the nearby star. It should be halfway between you and the starry wall, either on a stand or hung from the ceiling. Place the 6 to 8-foot chalk/string circle on the floor so that the nearby star is between the orbit and starry wall.

You'll need:

- 15 to 20 small pieces of paper—various colors
- Ping-pong ball
- Moveable stand to hold a ping-pong ball or materials to hang it from the ceiling
- Chalk/string circle 6 to 8 feet in diameter
- Rolled-up piece of paper or a paper towel roll

Now, walk the orbit of the Earth. Stop on opposite sides of the Sun and check the position of the nearby star (ping-pong ball) against the starry background over a year's time by looking through a rolled-up piece of paper or a paper towel roll as a telescope. What happens to the position of the nearby star (ping-pong ball) relative to the background stars? When astronomers take these two different measurements, they use a formula to triangulate the location of the star—calculating the distance from Earth. Can you think of other ways to use parallax to measure distance? To a tree? A mountain peak? The Moon?

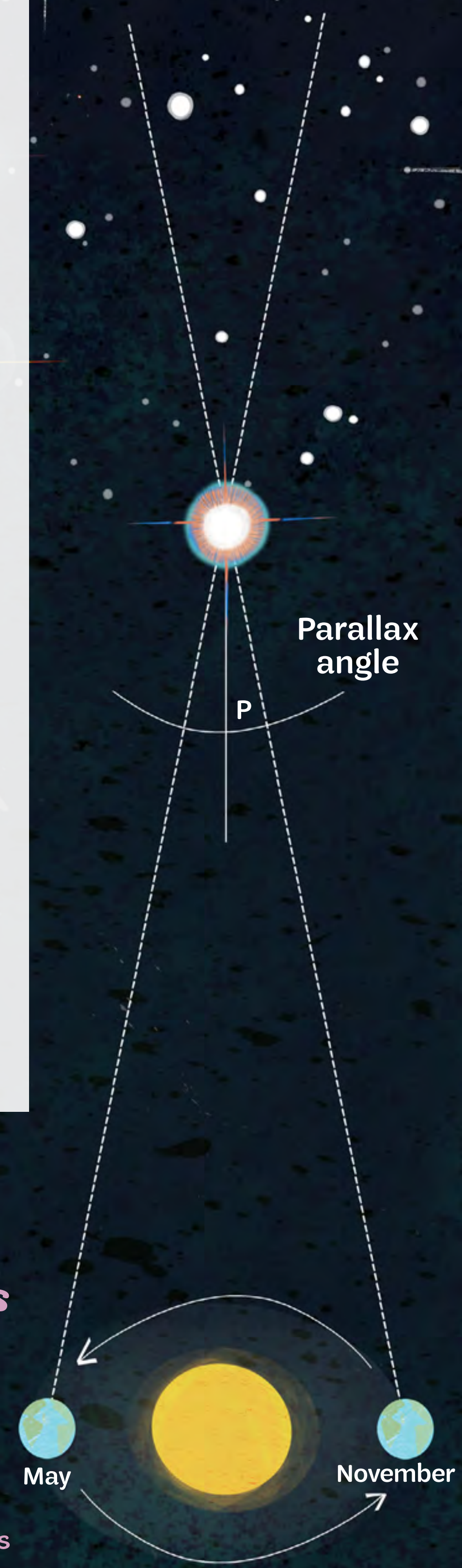


Illustration not to scale

Measuring Distances

How far away can we measure distances? Satellites launched by NASA and the European Space Agency will measure the distance to stars as far as 30,000 light-years away. That's as far away as the center of our galaxy. Eventually, these satellites will be able to measure the distances to more than a billions stars. How can they do this? One way is to use the orbit of Earth as baseline to make their parallax measurements to the nearest stars. Satellites will detect objects 10 billion times fainter than we can see with just our eyes.

STEP
5 Share your knowledge

Now that you've explored the Universe and how we study it, it's time to share your astronomy knowledge with others. Scientists are passionate about sharing their findings and any new questions they may have. Choose a topic that sparks your interest and use your creativity and knowledge to create something that helps make space science compelling to others.

CHOICES—DO ONE:

☐ **Host a cosmic lifecycle performance.** Reflect on the lifecycle of stars. Refer to the information in this badge and online resources like NASA's "The Life Cycles of Stars" article (**www.girlscouts.org/LifeCycleofStars**), and Jet Propulsion Laboratory's "Stellar Evolution" infographic (**www.girlscouts.org/JPLInfographics**) to help get you started. Then, act out the life cycle of a star in a performance art piece. It could be a dance, mime, or a piece of theater—use your imagination. You can work alone or with others as you bring the stars to life for your family and friends!

For More **FUN:** Each year, a group of highly creative PhD students go beyond a written dissertation and create "Dance Your Ph.D" videos. Watch a few, and see how they turn complex concepts into friendly and fun video content. Are there any you want to incorporate into your performance?

OR

Practice astrophotography. Use your camera or smartphone to capture images of astronomical phenomena seen through a telescope. Locate a telescope, or find a local astronomy club through the Night Sky Network and attend a stargazing event—**www.girlscouts.org/SpaceScienceNSN**.

You can:

- Photograph the Moon. What surface features can you see?
- Take a photograph of your favorite constellation.
- Photograph that same constellation through a telescope and/or binoculars. What can you see now?
- Take a ten-second exposure of the stars. What can you see? Can you see colors?
- With the help of an amateur astronomer, find three stars that appear to be different colors (tints). Take photos of each and compare. How are they different?

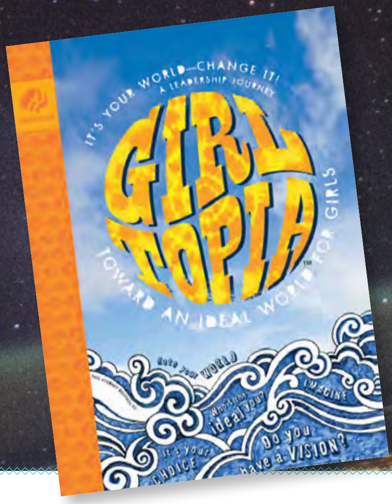
After you've selected your favorite images, consider how you will present and caption them. What technical facts may be of interest to other astrophotographers? What details might interest people who don't know a lot about space? Share your photographs with friends and family in a fun and creative way.

Tips for taking celestial photos:

- Practice makes perfect. You may need to make several photographs to get ones you like.
- To avoid blurry photos, you need a stable camera or smartphone.
- You can hold your smartphone or camera by hand up to the eyepiece of the telescope or binoculars. You can also search for a "digiscope adapter" or "smartphone mount for telescope" to find mounts that connect a smartphone to the eyepiece.
- Get the right app for your smartphone—look for "low light photography."
- Turn off the flash.
- Use a long exposure. Figure out how to take timed photos from one second up to one hour.
- Go to a dark location. City lights wash out the stars and your photos!
- Be sure to pick a safe place, and have an adult with you to help out. Bring warm clothes, snacks, and a flashlight.

OR

- [ ] **Picture a telescope.** Most people know that a telescope is a tool used by space scientists to see things that are far away, but how they work is often a mystery. Help others understand more about telescopes by creating a piece of visual art. Your art can be a drawing, diagram, series of photos, or a video. How might you show the parts of a telescope? How could you depict the path of light from an object to the eyepiece? How might you design your telescope art to be both beautiful and easy to understand? Work from a found image, or from an actual telescope. You could also assemble a simple telescope kit and take photos. Share your visual art with your family and friends—be sure to walk them through it, explaining how a telescope works.



Going on a Journey?
Do some badge work along the way.

Expand your vision and look for inspiration in the cosmos as you complete *GIRLtopia*. Use the skills you gained while earning this badge to influence your creation of an ideal community—envisioning the change you want to see in the world. How can your knowledge of the cosmos affect this change? What have you discovered that can help move your vision forward?

Now that I've earned this badge, I can give service by:

- Joining the citizen scientist movement and contributing to society's deeper understanding of the cosmos.
- Sharing my knowledge of telescopes with younger Girl Scouts—deepening their understanding and awe of our Universe.
- Showing others the important role light plays in making discoveries within our Solar System and beyond.

I'm inspired to:

Courtesy: Scott Kelly/NASA

First published in 2019 by GSUSA
420 Fifth Avenue, New York, NY 10018-2798
www.girlscouts.org

Special thanks to the "Reaching for the Stars: NASA Science for Girl Scouts" partners: The SETI Institute, Astronomical Society of the Pacific, ARIES Scientific, The University of Arizona, and Girl Scouts of Northern California.

Printed in the United States

UPC 64131
7 31955 64131 3