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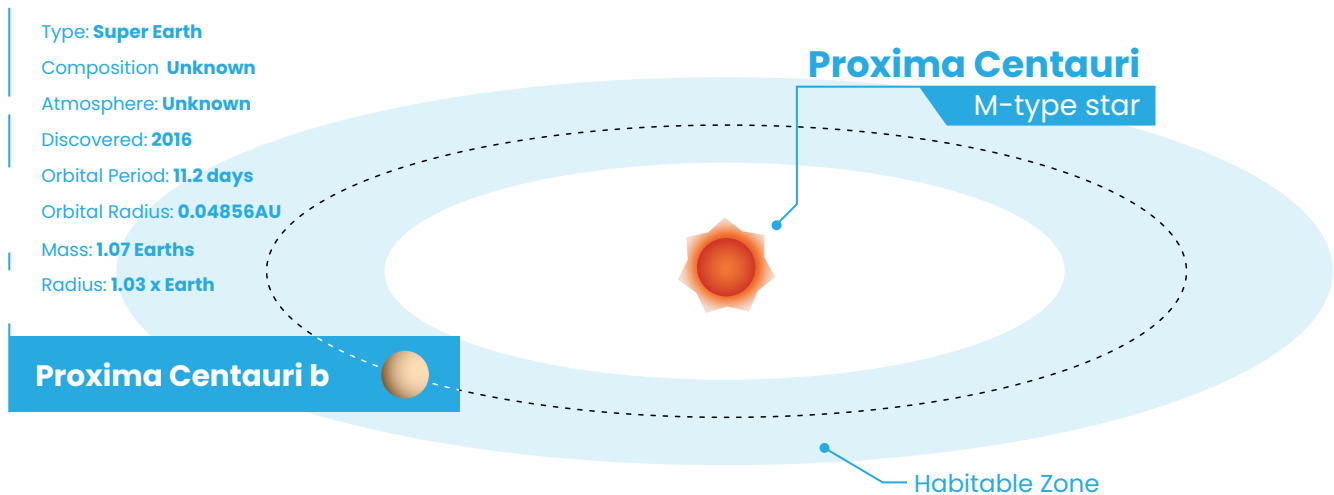
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What Are Exoplanets?

Exoplanets, or **extra-solar planets**, are planets that exist outside of our solar system. They orbit other stars, in many different solar systems across the universe.

The nearest known exoplanet, **Proxima Centauri b**, orbits its star Proxima Centauri, 4 light years from Earth. That means it is approximately 24 trillion miles (36 trillion kilometers) away! Even with Earth's fastest aerospace technology, it would take humans millions of years to reach this extra-solar neighbor.



What Is The Habitable Zone?

The **habitable zone** is the distance from a star at which an orbiting planet could support the existence of liquid water, which is an important building block for life.

Proxima Centauri is a M-type star, also known as a red dwarf, which means it is smaller and cooler than our Sun. This cooler temperature allows for a habitable zone that is much closer to the star. While Proxima Centauri b is located within the habitable zone, scientists have been unable to determine whether the planet has surface water or an atmosphere. The downside of the planet's proximity to its star is that it is also closer to the star's radiation, which can strip away atmospheric particles and make it harder to maintain an atmosphere.



What Does A Planet Need To Support Life?

What are the essential attributes that make a planet habitable? We use the habitable zone to identify planets that may be the ideal temperature for **liquid water**, because on Earth, liquid water is essential to life. Since all known Earthly organisms require water, it is reasonable to hypothesize that extraterrestrial organisms might also need water.

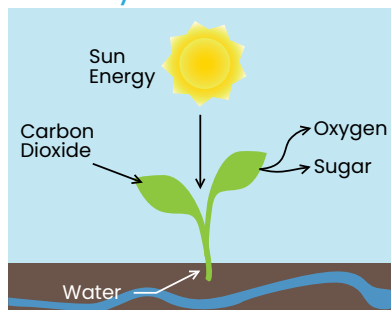
Elements Of Life ▼

Carbon 6 C 12.011	Hydrogen 1 H 1.0079	Nitrogen 7 N 14.007	Oxygen 8 O 15.999
Phosphorus 15 P 30.974	Sulfur 16 S 32.065		

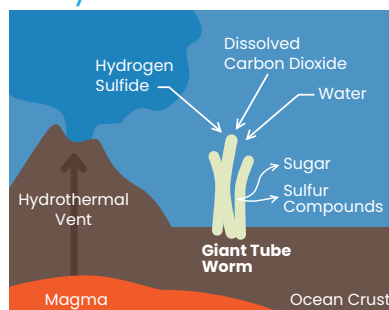
We also need to look for the specific chemical elements that combine in diverse ways to form organic matter. These **fundamental elements** are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. The presence of these elements or water does not guarantee that life is present, but it does encourage a closer look.

Life needs a **source of energy**. On Earth, for example, we mostly depend on the Sun to power photosynthesis. This process allows plants to grow, and these plants, in turn, feed other organisms including humans. Additionally, other potential sources of energy to support life could include geothermal energy, which is used by organisms in deep-sea vents on Earth; chemical energy from redox reactions, which involves the transfer of electrons between molecules and releases energy that supports certain bacteria on Earth; and radioactive elements from radiation, which some extremophiles on Earth can utilize.

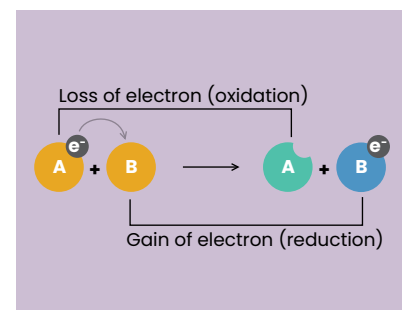
Photosynthesis



Geothermal or Hydrothermal



Redox Reaction



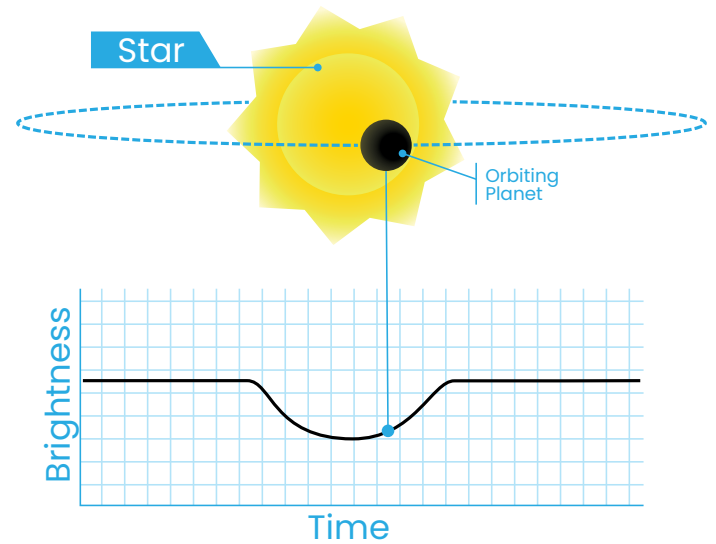
How Do We Detect Exoplanets?

How do we find these mysterious exoplanets? We start by closely observing what we can see, the stars. With space telescopes, humans have been scrutinizing star light for decades and have devised several methods of exoplanet detection.

Transit Method

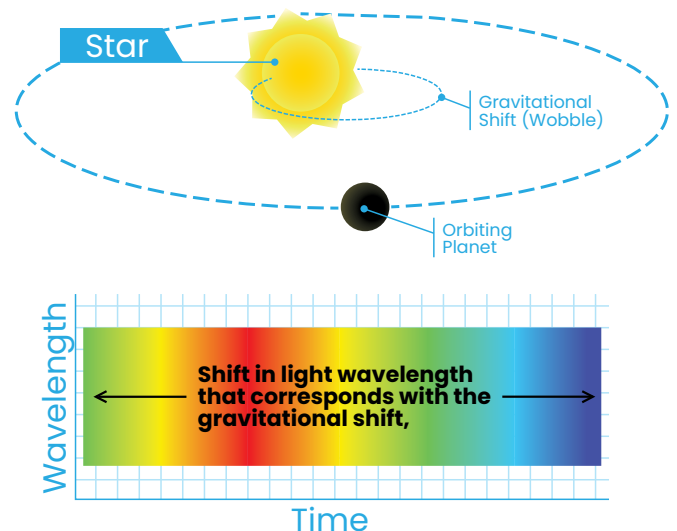
The first method of exoplanet detection we will discuss here is the Transit Method.

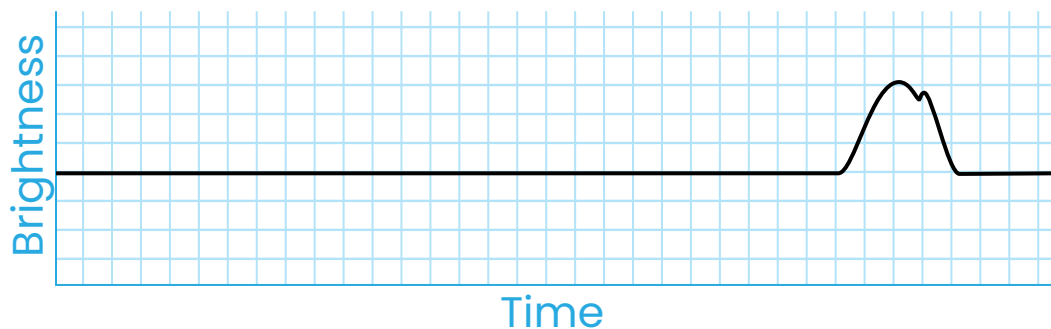
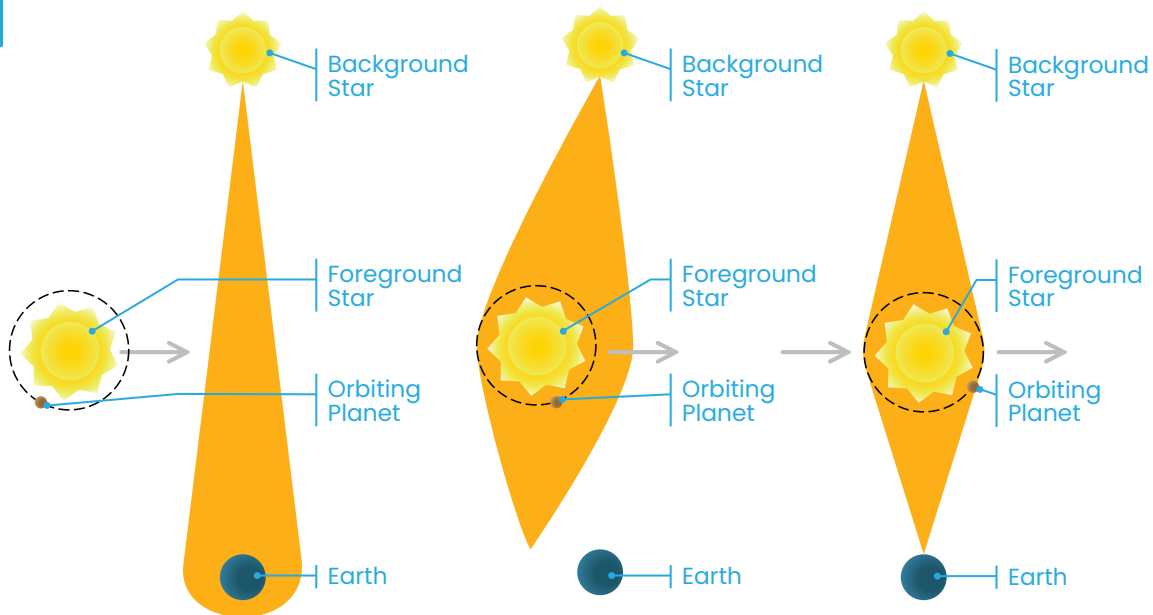
A transit occurs when a planet passes between its star and an observer. During transit, the observer would notice a dimming of the star's light. The depth of this dip tells us the size of the planet, and the time between dips tells us how long its orbit takes. We may even be able to determine the chemical composition of the planet's atmosphere through transit spectroscopy. By analyzing the star light during transit, spectroscopy can reveal specific chemicals present in the atmosphere surrounding the planet, such as water vapor, methane, or carbon dioxide.



Radial Velocity Method

As a planet orbits around a star, it exerts a gravitational tug on that star, causing the star to wobble slightly in its own orbit. From light years away, our telescopes observe this wobble as a periodic shift in the starlight's wavelength, caused by the Doppler effect as the star moves towards and away from us.





Microlensing Method

This method of exoplanet detection uses gravity's ability to bend or warp light. As one star (the foreground star), passes in front of another (the background star), the gravity of the foreground star focuses or intensifies the light of the background star, which results in a spike of brightness in the light observed from the background star. As demonstrated in the illustration above, when the foreground star has a planet orbiting it, the brightness level will see another smaller spike caused by the additional gravity of that planet.





Communicate With Spacecraft

Grade Levels: 4, 7-12
Time Required: 1-2 Hours



Have you ever wondered how we communicate with telescopes millions of miles away in space? In this exercise, students will model how antennas work on spacecraft and observatories, using sound waves as a stand in for light waves. This will demonstrate the basic principles of wave communication and how data is transmitted over long distances.

Materials:

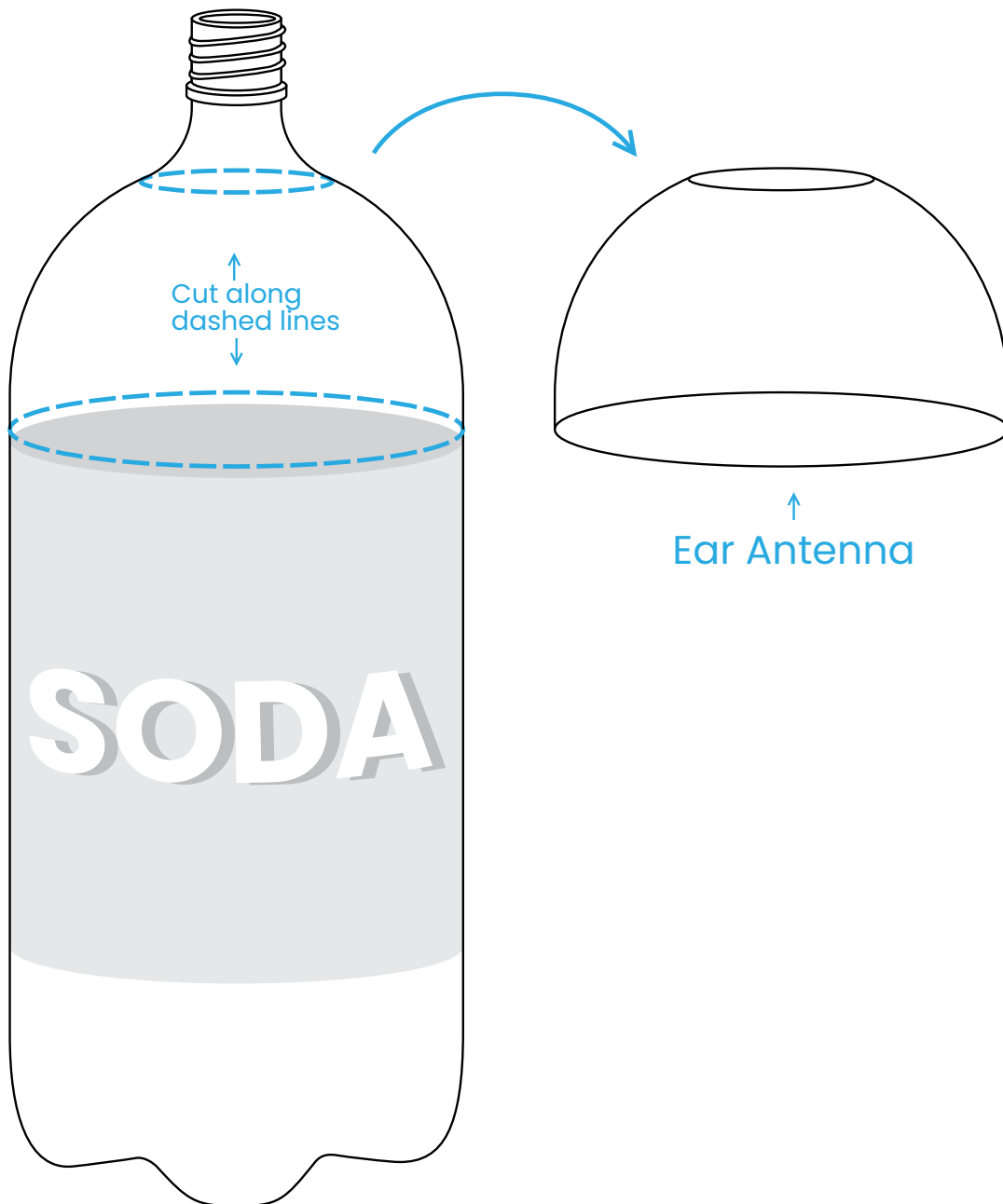
- 1 large golf umbrella (parabolic in shape)
- Empty 2-liter soda bottles (1 per student)
- Ear antenna pattern, on cardstock (1 per student)
- Scissors
- Tape
- Mobile device with a metronome app, programmed to beep once every second. A smaller device will be easier to hold close to the shaft of the umbrella.
- An open area of at least 120 meters in length.
- Long metric measuring tapes or trundle wheels. Standard football field yard line markings could be used for measurement instead of measuring tape.
- Student worksheet (1 per student)
- (Optional) Additional umbrellas of various sizes (parabolic in shape)





Soda Bottle Instructions

Very carefully cut soda bottle just above the label and just below where the neck meets the curve of the bottle. Remove any jagged edges or cover with small amount of tape. Take care not to cut yourself or your classmates.

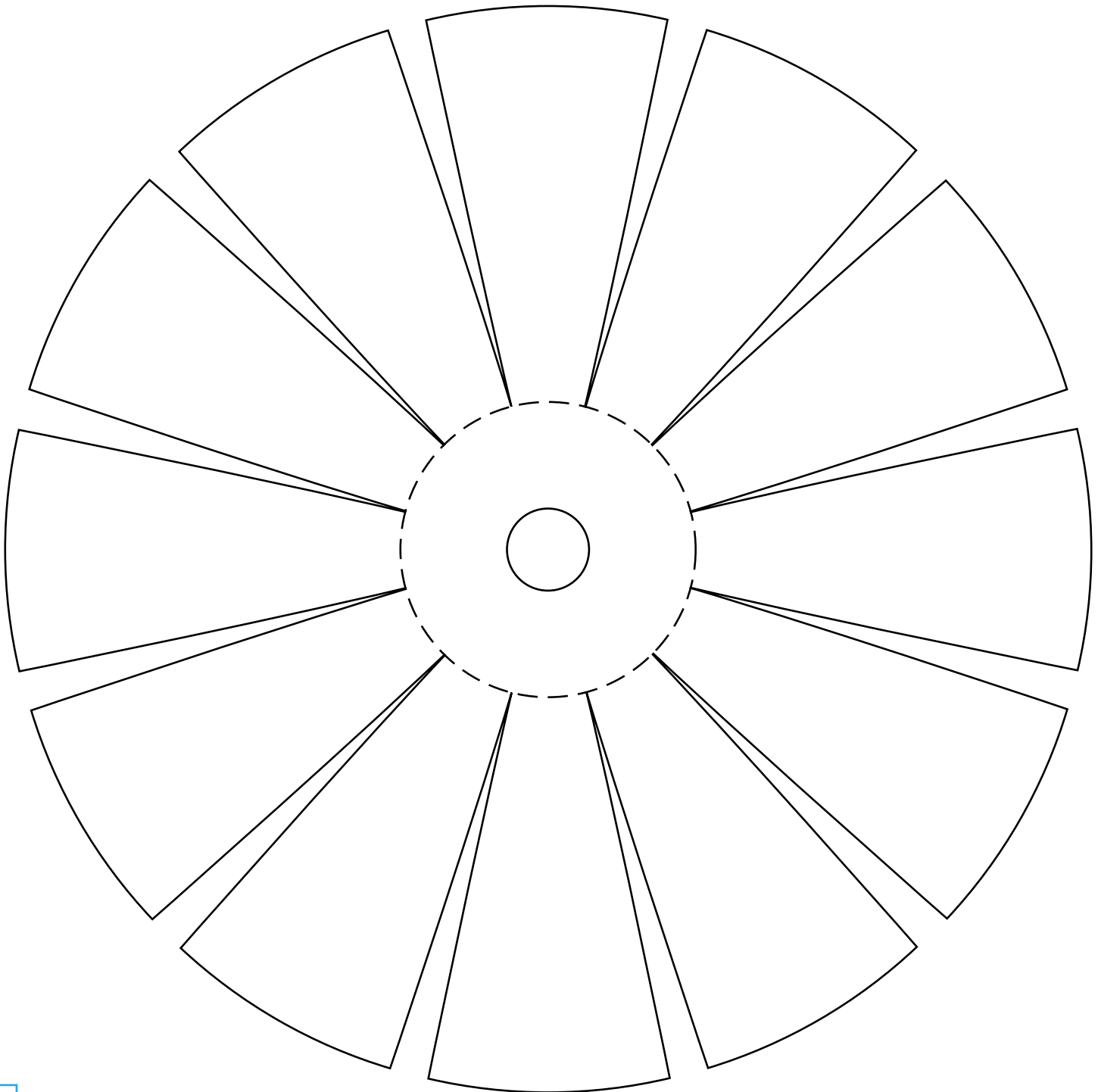




Cardstock Ear Antenna

Cut along the solid lines around the outside of the shape, then cut out the smallest circle at the center of the antenna. Leave the dashed line uncut.

Overlap one petal slightly over the next and tape in place, continue this step for each petal. The result should be a small curved dish with a hole at its center.



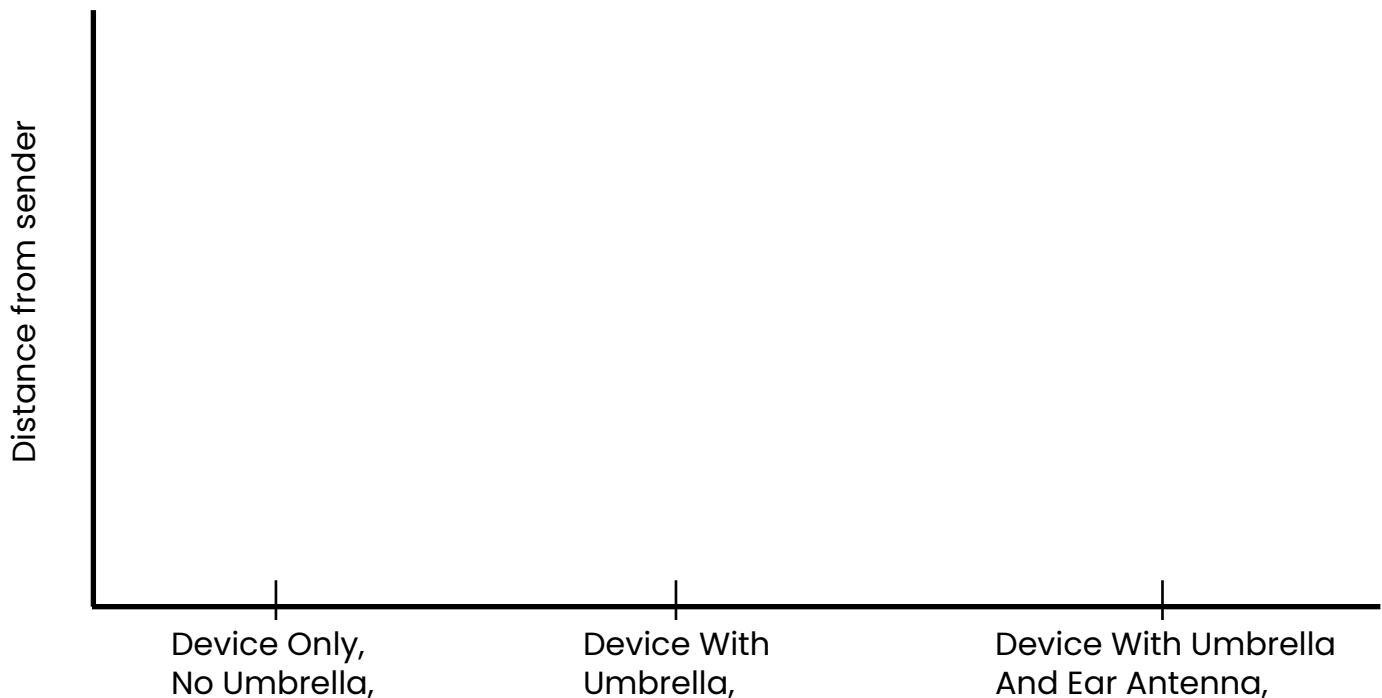


Communicate With Spacecraft Data Log

Record your predictions and trial results in the table below.

	Device Only, No Umbrella, Distance (m)	Device With Umbrella, Distance (m)	Device With Umbrella And Ear Antenna, Distance (m)
Prediction			
Trial 1			
Trial 2			
Trial 3			
Average of Trials			

Using the data you collected above, create a scatter plot below.





Background:

NASA's Deep Space Network (DSN) enables communication with distant spacecraft. The DSN consists of large, highly sensitive antennas located in three global complexes—California, Australia, and Spain—ensuring continuous contact as the Earth rotates. These antennas, equipped with powerful amplifiers and advanced noise-reduction technology, are essential for detecting extremely weak signals sent by spacecraft, which have very low transmission power. The parabolic dishes and precise tracking focus and amplify these faint signals, overcoming challenges from background noise and equipment interference.

Instructions:

1. Gather students in the assigned area and set a metronome app to beep at one-second intervals. Inform students that the metronome sound will represent signals sent between spacecraft and observation bases on Earth. Note that, while this demonstration uses sound waves, actual spacecraft communication utilizes light. Have students estimate the distance at which they will no longer hear the beep and record their predictions on the data table worksheet.
2. Instruct students to form a hypothesis about how using a parabolic antenna might affect their ability to hear the signal at varying distances.
3. Establish a baseline by observing the metronome without a parabolic antenna. Students form a circle around the individual holding the metronome, keeping it close to their body. Students indicate, by raising their hands, if they can hear the metronome. The sender should rotate to face each student so all can hear the beep at the initial distance. Discuss how the sender's direction affects signal strength.
4. Have students step back one meter from the sender with each metronome beep until the sound is inaudible. Record the distance where the beep is no longer heard.
5. Repeat the previous step three times, recording results each time. Students calculate the average distance across trials and compare the results. Discuss possible reasons for differences in the measured distances.





6. Introduce an umbrella as a makeshift antenna. The sender holds the metronome along the umbrella post and locates the focal point by adjusting its position for optimal sound. Mark or tape the metronome at the focal point, maintaining this placement during the experiment.
7. Repeat the distance test with the umbrella antenna. Students step back one meter from the sender with each beep until the sound is inaudible. Conduct three trials, record the greatest distance each time, and calculate the average.
8. Proceed with adding ear antennas. If students have not yet constructed these, return to the classroom to follow the provided instructions for making either cardstock or soda bottle antenna models.
9. Return to the testing area. Students stand in groups of four spaced across the field and use their ear antennas, directing them toward the sender. The sender maintains the metronome at the identified focal point on the umbrella.
10. Conduct three trials of this test, each time recording the greatest distance at which the metronome is audible. Students then calculate the average distance for the trials.
11. Students create scatter plots using the averages from each test, comparing and discussing the results.
12. Compile all student data to produce an overall scatter plot. Discuss trends in the data and, for older students, evaluate whether patterns are linear, quadratic, or otherwise.
13. How do the antennas increase the distance at which the signal can be heard? What mathematical properties are utilized to create amplification?

The Inverse Square Law:

$$I = \frac{k}{d^2}$$

I = Intensity
k = Source Intensity
d = Distance

Math Extension:

The inverse square law states that the intensity of certain influences, like light, gravity, and sound, is inversely proportional to the square of the distance from the source. For example, if you double the distance from a light source, the intensity of the light becomes one-fourth as strong. How does this law affect this experiment?





Build Your Own Spectrometer!

Grade Levels: 6–11
Time Required: 2+ Hours

How do we know if a planet has a breathable atmosphere or possesses the chemical building blocks for life? Spectroscopy! This vital tool allows astronomers to analyze the spectrum of light that passes through or reflects off an exoplanet and identify the presence of specific gases and molecules in its atmosphere. In this exercise, students build a simple spectrometer using an empty cereal box and a CD to study household light sources and model how astronomers study the absorption, emission and reflection spectra of exoplanets.

Materials:

One set of materials for each group.

- Half of a compact disc (For safety, break CDs in half for students. Wear work gloves to protect your hands. Place CD halfway over the edge of a desk or table. Place a book over the portion of the CD that's on the table. Brace the book as you break the CD over the straight edge of the table)
- Empty cereal box
- Duct tape
- 4–6 light sources. For example: lamps, overhead lights, computer monitor, candle, indirect sunlight (direct sunlight is harmful for eyes).
- Colored pencils or markers.
- Emission Spectra Data Log worksheets





Emission Spectra Data Log

Complete the emission spectra data table for each light source.

Source:

Red	Orange	Yellow	Green	Blue	Indigo	Violet

Other Notes:

Source:

Red	Orange	Yellow	Green	Blue	Indigo	Violet

Other Notes:

Source:

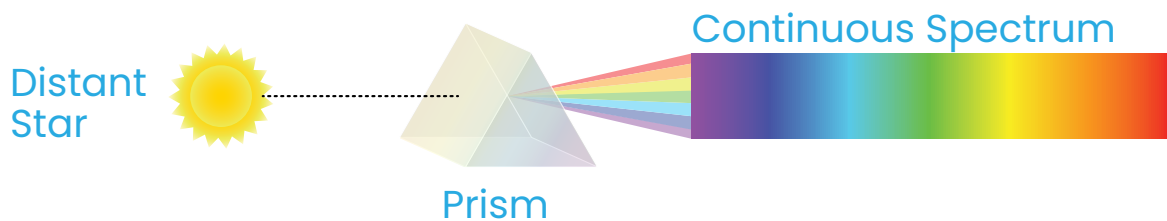
Red	Orange	Yellow	Green	Blue	Indigo	Violet

Other Notes:

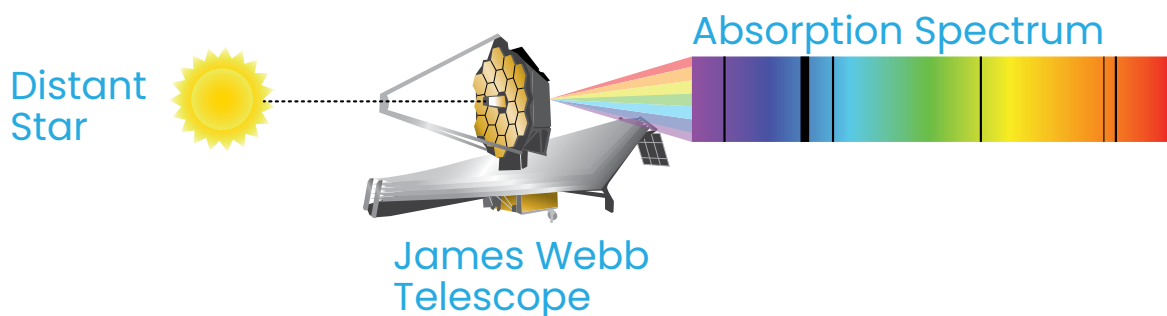


Background:

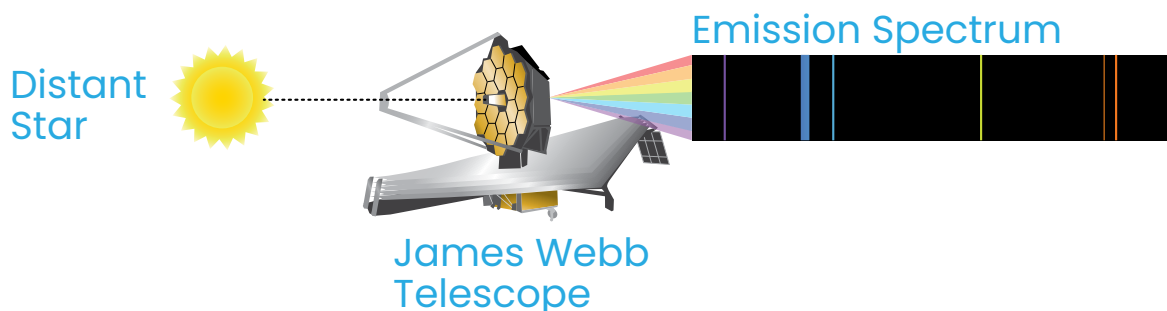
Continuous spectra: Light that is emitted by an object that radiates heat, such as the sun or an incandescent light bulb, where every wavelength is present without interruption.



Absorption spectrum: When light passes through a gas, that gas will absorb specific wavelengths of light, leaving gaps or lines in the color spectrum. Each element has a unique pattern of absorption, analyzing an absorption spectrum can reveal the atoms and molecules present in the gas.



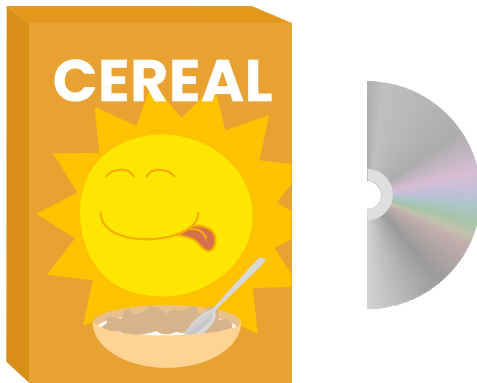
Emission spectrum: When a gas emits light, it emits light at specific wavelengths. We see this as bright lines of color in an otherwise dim spectrum, in a unique pattern for each element.



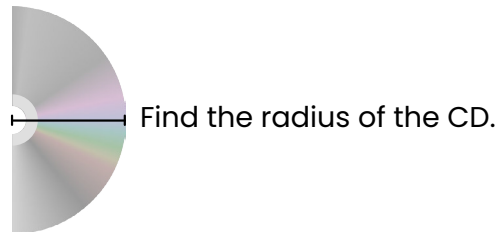


Instructions:

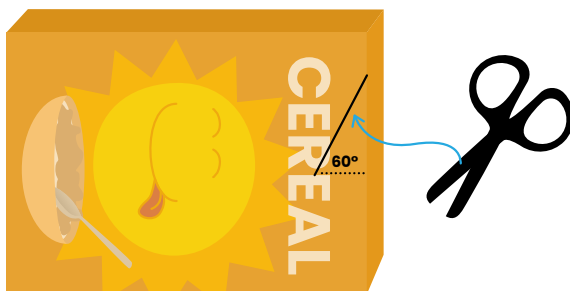
Start



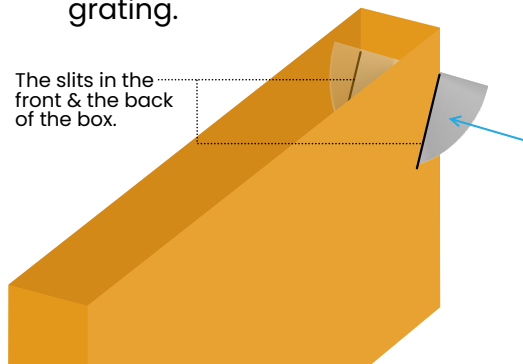
1.



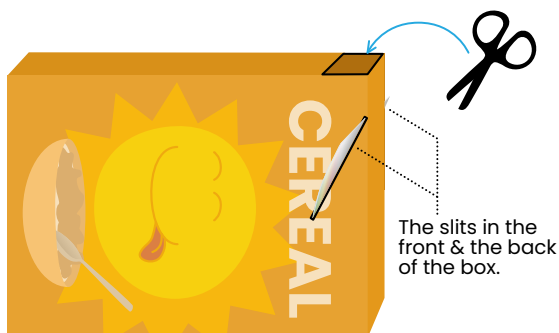
2. Cut a slit on the **front and back** faces of the cereal box, at a 60° angle and the same length as the CD radius.



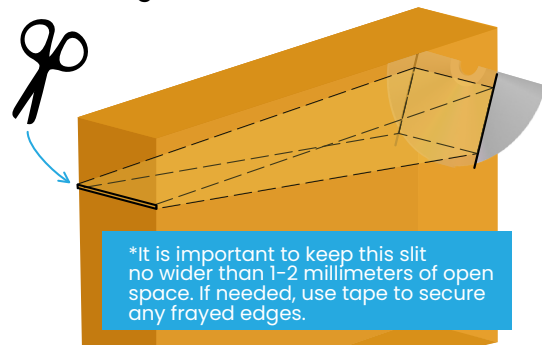
3. Insert the CD half into the slot, and use tape to secure the CD into place. The CD will be our diffraction grating.



4. Cut a small square on the side of the box, this will be the view finder.

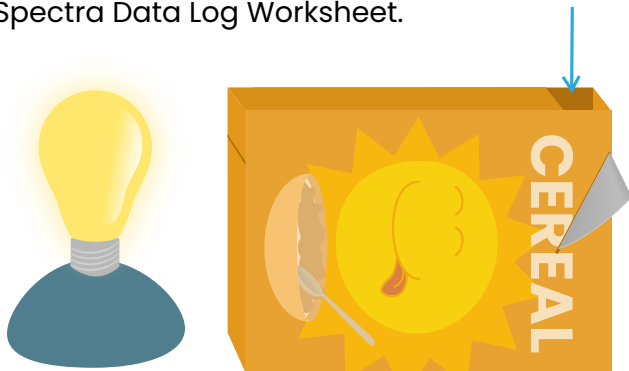


5. Cut another slit on the side of the box opposite from the CD diffraction grating. This is where the light will enter the box.



Instructions continued:

6. Set up the box and the light source, making sure they are close together. Look through the view finder and record your observations in the Emission Spectra Data Log Worksheet.



*Do not point your device directly at the sun, you could damage your sight. Use indirect light, by reflecting sunlight off of white paper instead.

Discussion:

How might our atmosphere affect the results we find? Our spectrometer is observing a light source in a room filled with the air we breathe, which is made of mostly nitrogen and oxygen.

What elements do you expect to see in the results?

Can you describe how this technique could be used to observe exoplanets?

Emission Spectra Examples:

Hydrogen



Neon



Helium



Iron



Oxygen



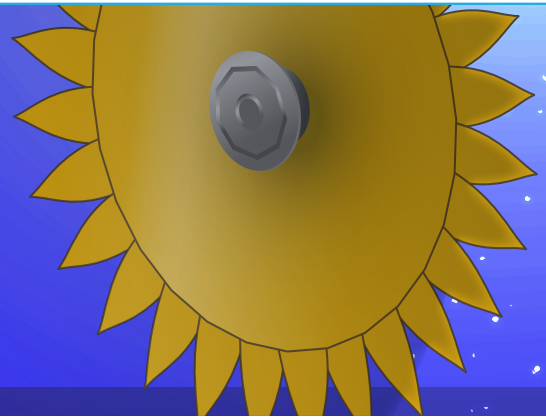
Nitrogen





Origami Starshade

Grade Levels: 4–12
Time Required: Under 30 Mins



Have you ever had to raise a hand to block out the bright light of the sun to get a better look at an object in the distance? NASA has engineered a device, named Starshade, that helps to block the overwhelming light of distant stars from interfering with spacecraft cameras, as they photograph exoplanets. Craft your own origami Starshade to see how it works!

Materials:

- Starshade template (included)
- Scissors
- Retractable pen or mechanical pencil
- Cardboard tube
- Tape

Instructions:

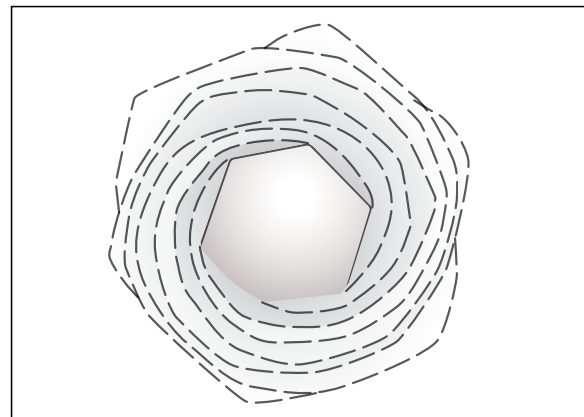
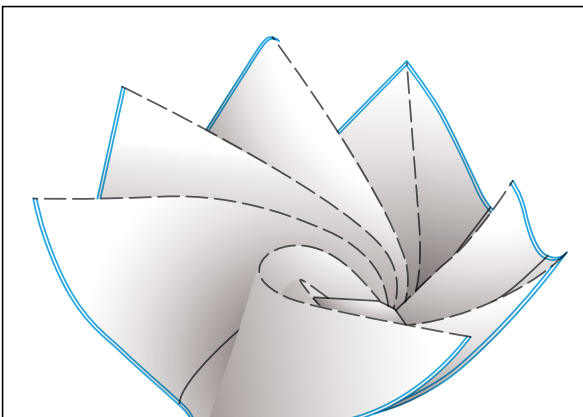
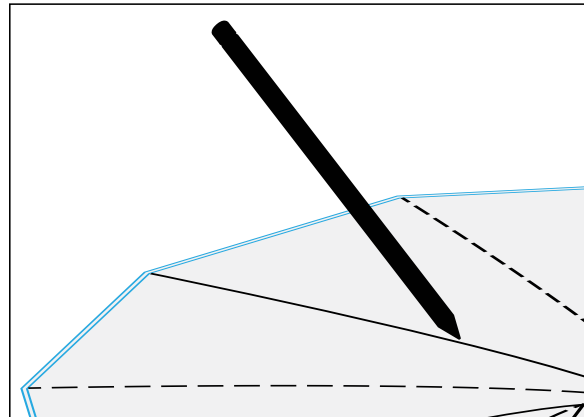
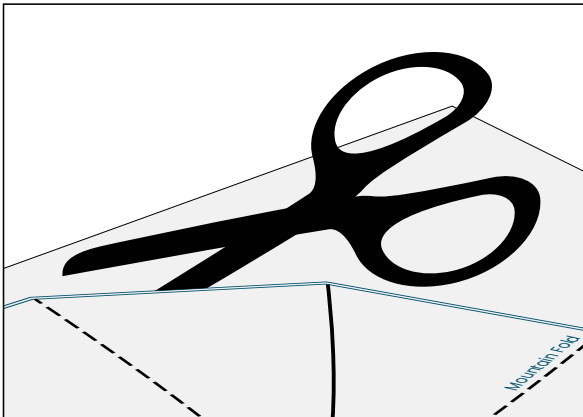
1. Cut around the outside edge of the Starshade template.
2. Once the shape of the Starshade is free from the rest of the page, use the edge of a retracted pen or mechanical pencil to score lightly along the crease lines for easier folding.
3. Carefully crease each line. The mountain lines fold up and valley lines down or away.
4. Slowly fold each line, starting at the center and working outward toward the edge. Use the center hexagon to hold and rotate the shade in place as the folds spiral around the outside.





5. To prepare the shade for launch, you will need a cylindrical sheath to hold the folded shade closed. From the left-over template scraps, cut a strip of paper long enough to fit loosely around the wrapped shade. With one hand holding the strip in place around the shade, use your other hand to tape the ends of the strip together, making sure the tape does not touch the shade itself.

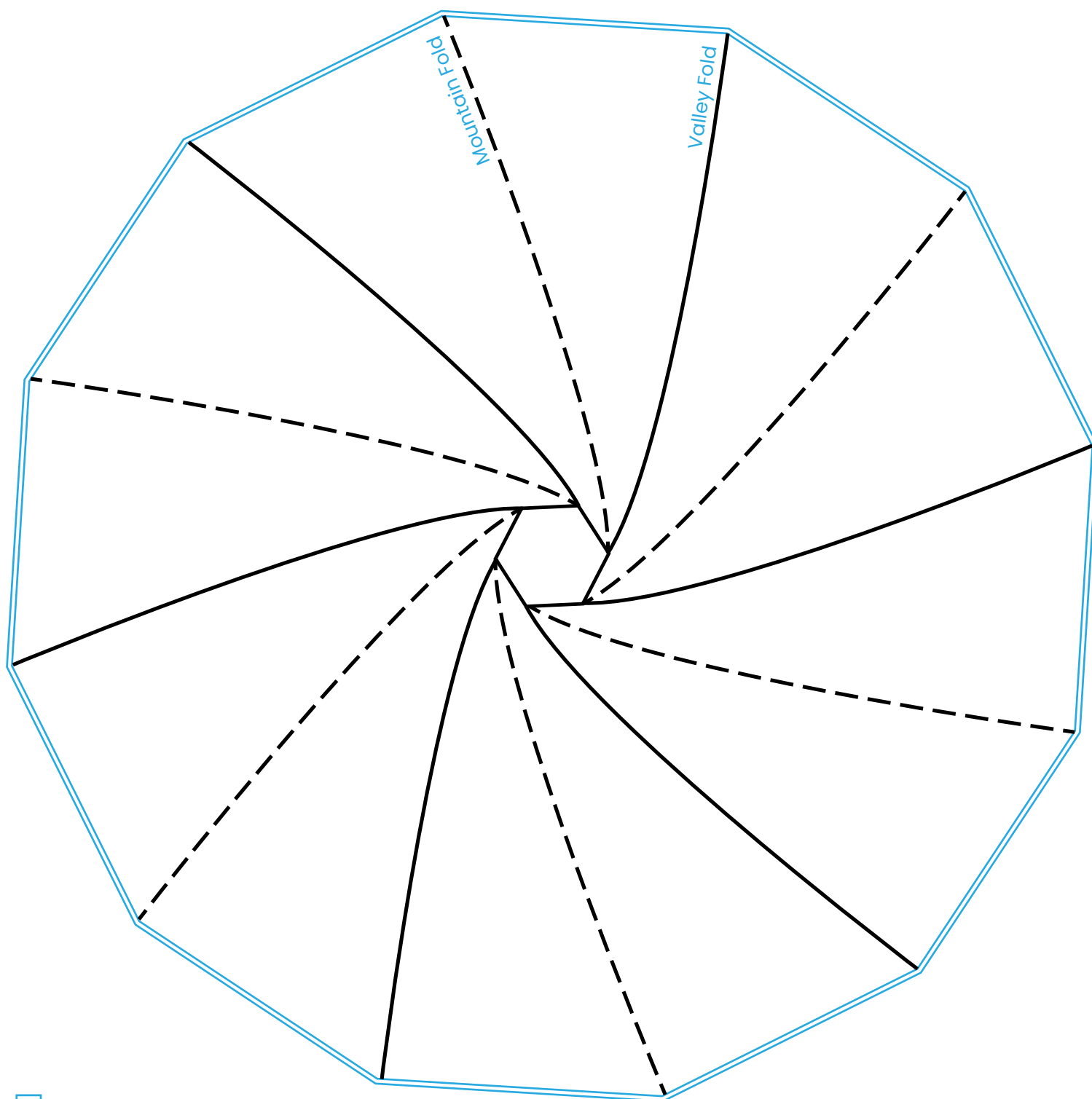
6. Evaluate the shade's effectiveness, using a cardboard tube or straw as a makeshift space telescope, "launch" the telescope and deploy the star shade. Simulate space by holding your launch in a dark room, with one bright light source, like a flashlight or bare lightbulb. Look through the tube in the direction of the light source, with the shade unwrapped in front of the telescope. Notice what you can see, with and without the shade, near the light source. NASA's Starshade will block the blinding light of a star system's star so the craft's telescope can take direct images of the surrounding planets.





Starshade Template

Cut along the double solid lines around the outside of the shape. Dashed lines are folded up (mountain fold), single solid lines are folded down (valley fold).





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Origami Starshade

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