Our Place in the Solar System

Sun, Earth, Moon & Eclipses Activity Guide

Image Credit: images.nasa.gov

CREDITS FOR ACTIVITIES AND RESOURCES

This Activity Guide was developed by the Girl Scout Stars team at the SETI Institute, ARIES Scientific, Inc., Girl Scouts of Northern California, Girl Scouts of the USA, University of Arizona , and the Astronomical Society of the Pacific. Louis Mayo and Edna DeVore co-authored this booklet of activities, with significant contributions by Pamela Harman, Larry Lebofsky, Vivian White, Theresa Summer, Jean Fahy, Jessica Henricks, Elspeth Kersh, and Wendy Chin. Further contributions were made by Joanne Berg, Cole Grissom, Amanda Hudson, Don McCarthy, and Wendy Friedman. The team was led by Edna DeVore, Principal Investigator of "Reaching for the Stars: NASA Science for Girl Scouts," which is funded by NASA Cooperative Agreement #NNX16AB90A. Updated Jan 2020 P. Harman / D. Richardson.

ACTIVITY OR RESOURCE	AUTHOR and SOURCES
LIVING IN A BUBBLE—PLAY WITH MAGNETS AND COMPASSES	L. Mayo, and Multiverse—UC Berkeley Space Sciences Lab
SUNBURN—ULTRAVIOLET LIGHT DETECTORS	L. Mayo, E. DeVore
SEEING THE INVISIBLE—INFRARED LIGHT DETECTORS	L. Mayo, NASA Airborne Astronomy Ambassadors
LET'S SEE LIGHT IN A NEW WAY—DIFFRACTION SPECTRA	L. Mayo, E. DeVore
A LIGHT SNACK—COOKIE BOX SPECTROMETERS	L. Mayo, E. DeVore, NASA: The Science of the sun
MAKE SUN S'MORES!	NASA Climate Kids
HOW BIG IS BIG? SOLAR PIZZAS	L. Mayo, NASA sun-Earth Day
EARTH AS A PEPPERCORN—SIZE AND SCALE OF THE SOLAR SYSTEM	Guy Ottwell, The Thousand Yard Model
SUN TRACKING	J. Henricks, P. Allan and D. Schatz, Pacific Science Center
WAXING AND WANING—PHASES OF THE MOON AND ECLIPSES	E. DeVore, L. Mayo
HOW DO ECLIPSES WORK? YARDSTICK ECLIPSE	Astronomical Society of the Pacific
WHEN DAY TURNS TO NIGHT	L. Mayo, P. Harman, E. DeVore
MAKE AN ECLIPSE VIEWER	L. Mayo, J. Henricks E. DeVore
ECLIPSE CHALK ART	J. Henricks, L. Mayo, E. DeVore
NASA ECLIPSE WEBSITE GUIDE	NASA
HOW TO VIEW THE 2017 SOLAR ECLIPSE SAFELY WEBSITE EL EXLIPSE SOLAR DEL 2017 CON SEGURIDAD	American Astronomical Society, American Academy of Opthalmology, NASA, American Academy of Optometry, NSF
NASA ECLIPSE RESOURCES	NASA: https://eclipse2017.nasa.gov
MORE RESOURCES	Astronomical Society of the Pacific, SETI Institute
COMPLETE LIST OF MATERIALS	E. DeVore

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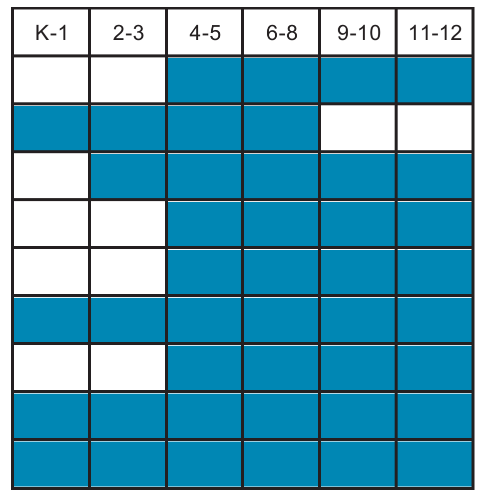

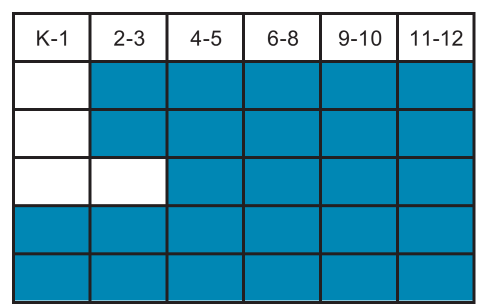

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INTRODUCTION AND HOW TO USE THIS GUIDE

Welcome to the Eclipse Activity Guide!

This guide support activities for learning about the sun, light, our solar system, and eclipses. They draw upon hands-on, safe activities suitable for children as well as adults. While these activities were designed to help people prepare for the total eclipse of the sun in 2017, they can be used beyond the eclipse as part of your outreach programs. And, there is another total eclipse of the sun crossing the U.S. in 2024!

Age Levels: Each activity shows the recommended age levels.

Materials List: Each activity includes a materials list and what you need to obtain to do the activity. Mostly, the materials that you are asked to provide are the basics: paper, pens and pencils, cardboard boxes, aluminum foil, tape, etc. There are also activities that offer people the opportunity to use smartphones and digital cameras as sensors.

2017 Total Eclipse of the Sun: NASA and others have created guides for safely observing the 2017 solar eclipse (pages 36-39.) You are welcome to copy these for distribution. You may also download the original files from: *https://eclipse2017.nasa.gov*. Have fun and keep looking up!

ECLIPSE BASICS

What Are Eclipses?

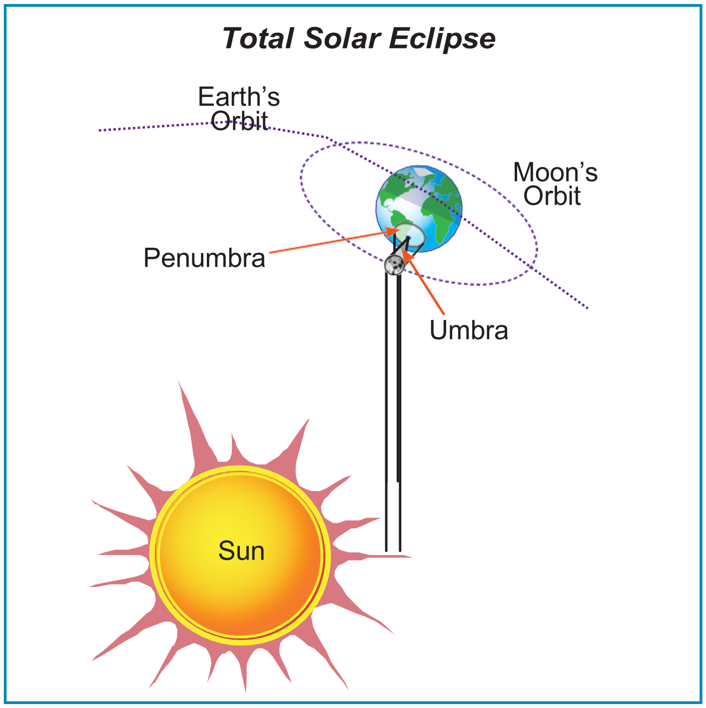
Eclipses are all about shadows. Eclipses occur when one astronomical object moves in front of another, or when an astronomical object moves into the shadow of another object. In the sun-Earth-moon system, eclipses occur when the sun, Earth and moon all line up. In astronomical terms, this is called *syzygy*, a word derived from Ancient Greek that means “yoked together.”

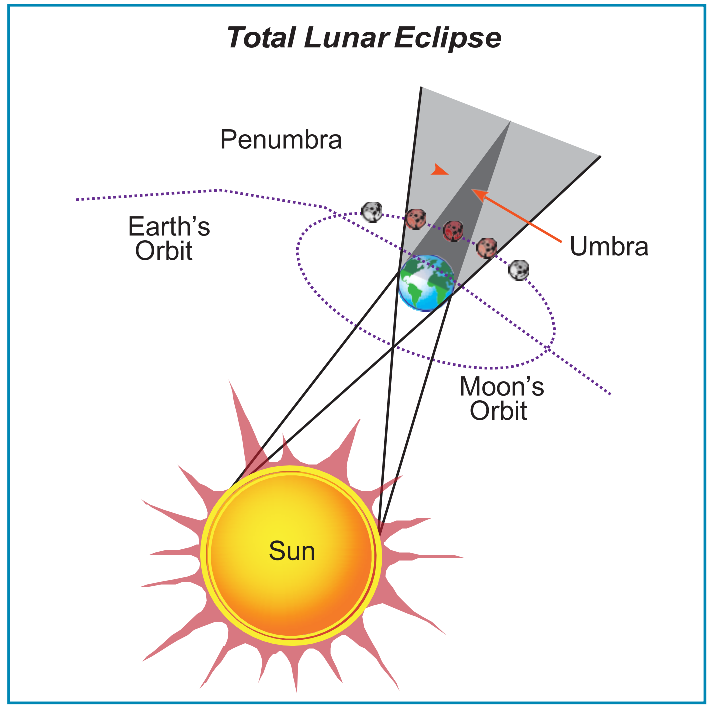
Total Solar Eclipses:

Eclipses of the sun occur when the new moon passes between the Earth and sun. When the moon covers the entire disk of the sun, we see a spectacular total eclipse of the sun with the corona glowing. During the eclipse, the moon’s shadow is cast upon the Earth and travels across the surface at more than 1,000 miles per hour. From start to finish, from when the moon first starts to cover the sun to when the sun is completely uncovered, a solar eclipse takes a couple of hours. During most of that time, the sky is bright because the sun continues to light the Earth. You need eye protection the entire time when only part of the sun is covered by the moon. When the sun is completely covered—during *totality*—darkness descends, and it’s safe to view the sun’s corona without eye protection for a short time. *Totality* lasts only a few minutes. The longest total solar eclipses last over 7 minutes. The total eclipse of the sun on August 21, 2017 lasted up to 2 minutes and 40 seconds, depending on location.

Partial Solar Eclipses:

People inside the shadow’s path see a *partial solar eclipse* if they are in the *penumbra* of the moon’s shadow, and a *total solar eclipse* if inside the *umbra*. (see diagram below.) Only part of the sun is covered during partial eclipse. You need eye protection the entire time during the partial phases of an eclipse.





Credit: E. DeVore, SETI Institute

Annular Eclipses:

The moon's orbit is elliptical. On average, it is about 240,000 miles from Earth, but it can be as far as 251,900 miles (maximum distance), and as close as 225,300 (minimum distance). If the solar eclipse occurs when the moon is far from the Earth (near the maximum distance), the moon will not fully cover the disk of the sun, and an *annular eclipse* occurs. During an annular eclipse, we see a bright ring of sunlight around the moon. Eye protection is required at all times during annular eclipses.

Lunar Eclipses:

Eclipses of the moon occur when the full moon passes through the shadow of the Earth. Everyone on the nighttime side of the Earth can view a lunar eclipse. If the moon passes through the penumbra of the Earth's shadow, it will be slightly dimmer and redder. Penumbral eclipses are hard to detect. When the moon passes through the central part of the Earth's shadow—the umbra—it will dim to a dark red color. Like red skies at Sunset, the Earth's atmosphere bends the redder (longer wavelength) light into the Earth's shadow. (The other colors are scattered by the atmosphere). During lunar eclipses, the moon is illuminated with this red light. Lunar eclipses last for several hours as the moon moves through the Earth's shadow. It is completely safe to view the moon during lunar eclipses because the moon is actually dimmer during the lunar eclipse than when it is full and outside Earth's shadow.

Why Don't Eclipses Happen Every Month?

Eclipses only happen when the sun, moon and Earth all line up, at syzygy. The moon's orbit is tilted about 5 degrees from the plane of the Earth's orbit around the sun. The lunar orbit crosses the plane of Earth's orbit in two places called nodes. Most months, the lunar orbit carries the new moon above or below the sun, and so there is no solar eclipse. The same is true for lunar eclipses: most months, the lunar orbit carries the moon above or below the shadow of the Earth, and there is no lunar eclipse. Solar eclipses happen when the new moon occurs near a node of the lunar orbit. Likewise, lunar eclipses happen when a full moon occurs near a node.

1. LIVING IN A BUBBLE: PLAY WITH MAGNETS AND COMPASSES

What Is This About?

Magnetic fields are all around us! You can't see them or feel them, but they play an important role in supporting life on Earth. Though they are invisible, you can sense magnetic fields with a compass. You can use a compass to measure the direction of the Earth's magnetic field and find north and south. Compasses have been used for hundreds of years to help sailors at sea find their way. The earliest compasses were invented by the Chinese about two thousand years ago. These used lodestones (naturally magnetized iron) made into the shape of a spoon. It pointed north/south when put on a smooth metal plate. Later compasses were made of magnetic needles floating in a bowl of water.

Materials: (you provide)

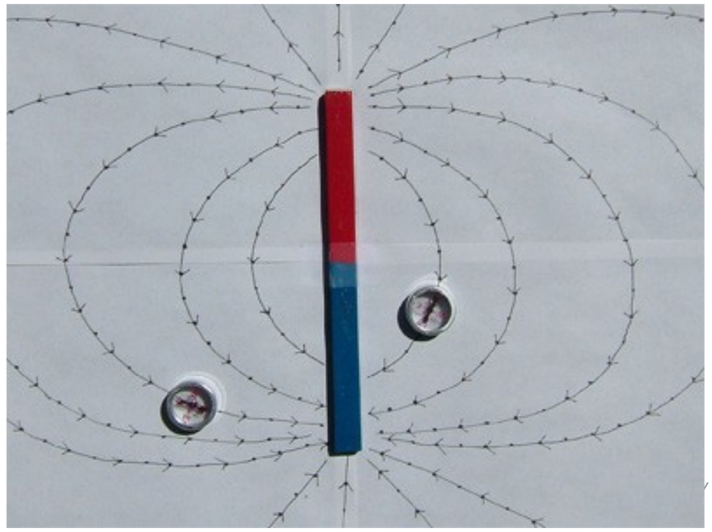
- Small compasses and bar magnets
- Paper, tape, pen or pencil

To Do:

Use a bar magnet to make a model of Earth's magnetic field and sketch the shape of a bar magnet's magnetic field.

- Tape the bar magnet to the middle of a piece of paper.
- Draw a dot somewhere near the magnet and place the center of a compass over the dot.
- Draw another dot at the location of the arrowhead (or tail) of the compass needle.
- Draw a line to connect the 2 dots and add an arrowhead at the north end.
- Move the compass center directly over the second dot, and again draw a dot at the location of the compass needle head or tail.
- Repeat these steps, marking the direction of the needle with dots and connecting them until the line meets the magnet or the edge of the paper. Go back to the first dot and repeat these steps until the other end of the line also meets the magnet or the paper edge.
- When finished with the first line, pick another spot near the magnet and repeat the process to trace more field lines.

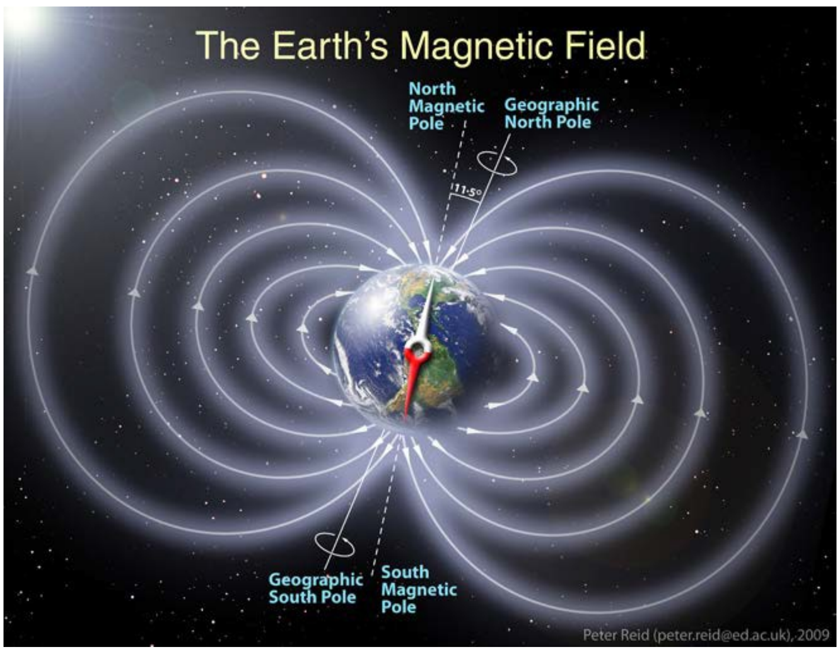
What Do You See?



- What shape is the magnetic field you sketched?
- What happens to the field lines when you get near the north or south pole of the magnet?
- Compare your sketch with other people's sketches. Do they look similar?

For More Fun:

- Add another magnet and sketch the resulting fields of the two magnets.
- Take one of the small compasses and set it in front of you on a table. Notice the direction it points. Can you confirm that the compass is pointing north? Now, slowly bring a magnet near the compass. The compass needle should move. Why? The magnetic field generated by the bar magnet is stronger than the Earth's magnetic field.



Credit: Image used by permission of Peter Reid (peter.reid@ed.ac.uk)

Space Science Tie-In:

We live in a magnetic field bubble around the Earth. The sun, Earth, and all the gas giant planets (Jupiter, Saturn, Uranus, and Neptune) have their own magnetic fields generated by the movement of molten materials around their cores. Planets' magnetic fields look like the field you sketched around the bar magnet. These fields are called "magnetospheres" except for the field around the sun, which is called a "heliosphere." Earth's magnetosphere protects the atmosphere from the solar wind, and helps to protect us from harmful radiation from space.

Activity Credit: Multiverse—University of California at Berkeley

Image Credit: NASA/Hinode/XRT

2 SUNBURN: ULTRAVIOLET LIGHT DETECTORS

What Is This About?

Our sun shines brightly in the daytime, warms our planet, and helps plants grow. But the sunlight we see with our eyes is only a very small part of the light the sun gives off. Most sunlight cannot be seen with just our eyes. One type of this invisible light is called "ultraviolet light," also known as UV. This is the light that gives us suntans and sunburns. Bees see in UV, and it helps them to find flowers. Since we cannot see ultraviolet light with our eyes, we build and use instruments to detect UV.

We have known about UV light for over 200 years. In 1801, a Polish physicist, Johann Wilhelm Ritter discovered a special kind of light just beyond the blue part of the visible spectrum. He called this light "chemical rays" because of its intense interaction with the chemical silver chloride. Later, it was renamed ultraviolet light.

Materials: (you provide)

- UV beads and chenille stems
- Materials that may filter ultraviolet light: Sunscreen, sunglasses, regular glasses, paper, cloth, hats, plastic, window glass, water

To Do:

Make a UV detector with chenille stems and UV beads.

- Begin inside a building away from any sunlight.
- Give each person a chenille stem and 3 to 5 beads to make a bracelet, ring or belt hanger.
- What color are the beads? (White, indoors.)
- Ask participants to explore light sources (lamps, light through window glass) with the UV beads. Any changes?
- Now go outside on a sunny or partly sunny day.
- What happens to the beads?
- What can people say about how sunlight affects their UV beads?

*Note: UV beads react to ultraviolet light from the sun by changing color. They go back to being white out of sunlight after a bit of time.

Before exposure to sunlight

After exposure to sunlight

Credit: E. DeVore, SETI Institute

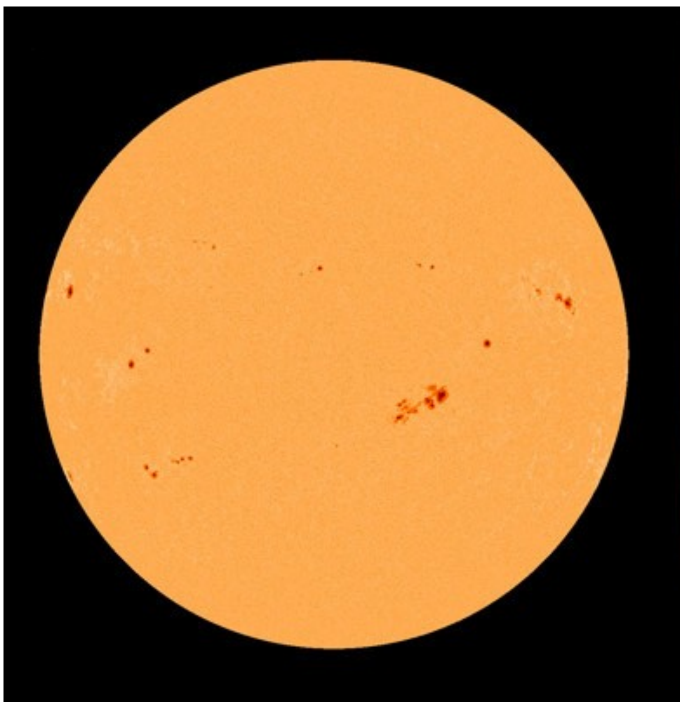
Going Farther: Test for UV Blockers

Participants can test several things to find out what does or does not block UV. Begin the tests inside so that the UV beads are white.

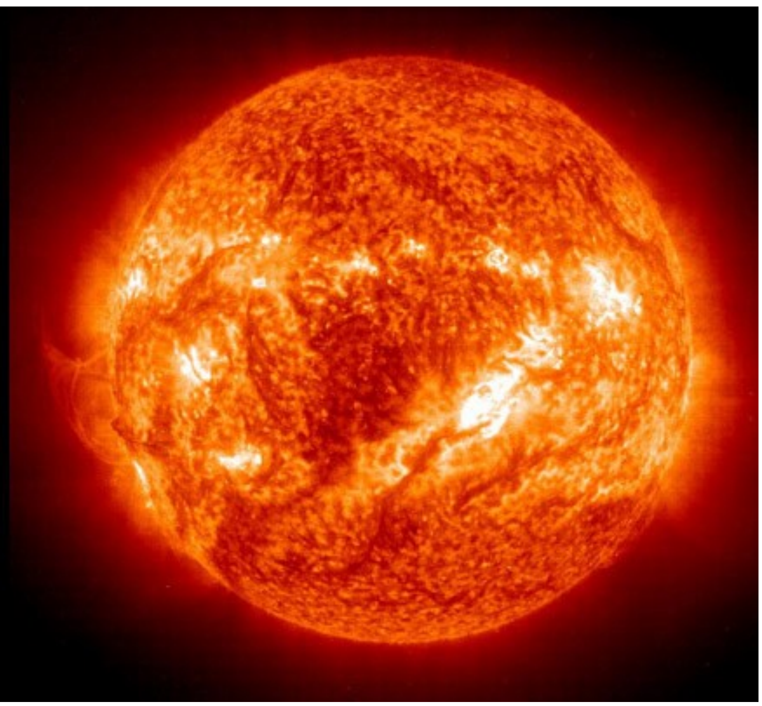
- Sunscreen: Participants can apply sunscreen to their UV beads before going outside, and see how well it works!
- Sunglasses: Participants can use sunglasses to block sunlight from UV beads. Do the glasses work? What about regular eyeglasses?
- Other tests: Participants can test other things that might block UV: paper, cloth, plastic, glass, car windows, brims of caps, water, and differences between mid-day and evening.

Space Science Tie-In:

Although some UV light passes through our atmosphere to the ground, most UV light from the sun is filtered out by our atmosphere and never reaches the surface of Earth. To study UV light from the sun and other stars, scientists use high altitude balloons, suborbital rockets, or spacecraft to get above the atmosphere. All stars emit UV light, some more than others. The UV light emitted by planets tells us about their atmospheres.



The sun photographed in visible light



The sun photographed in UV light

Credit: NASA/European Space Agency: SOHO: Solar and Heliospheric Observatory

3. SEEING THE INVISIBLE: INFRARED LIGHT DETECTORS

What Is This About?

Have you ever wondered how remote controls work? They send signals in a special type of light called “infrared light.” You can’t see infrared light (IR) with just your eyes, but smartphones and digital cameras can.

Infrared light was discovered accidentally in 1800 by British scientist, Sir Frederick William Herschel. In what is now famously known as the Herschel Experiment, he attempted to measure how different colors of light change the temperature of a thermometer by passing sunlight through a prism. He placed one of his thermometers outside the red part of the visible spectrum, where no light appeared to be falling as a control unit. He expected the control thermometer to stay unchanged. To his surprise, the control thermometer got hotter than all the rest! He called this invisible radiation “calorific rays.” Today, it is known as infrared light.

Sir William Herschel and his famous IR light experiment

Credit: NASA/IPAC

Materials: (you provide)

- Smartphones or digital cameras
- TV remote controls

Space Science Tie-In:

Astronomers understand the universe by observing it in many types of light. Infrared light is important in understanding planets, stars, and galaxies because in IR light we can see things that are warm, but not hot enough to shine like stars. Most IR light is filtered out by water vapor in our atmosphere. So, scientists launch infrared telescopes into space or use infrared telescopes in high-altitude airplanes or balloons. They also use large ground-based telescopes on top of tall mountains, such as the Infrared Telescope Facility in Hawaii at 14,000 feet elevation, which can see part of the IR spectrum.

To Do:

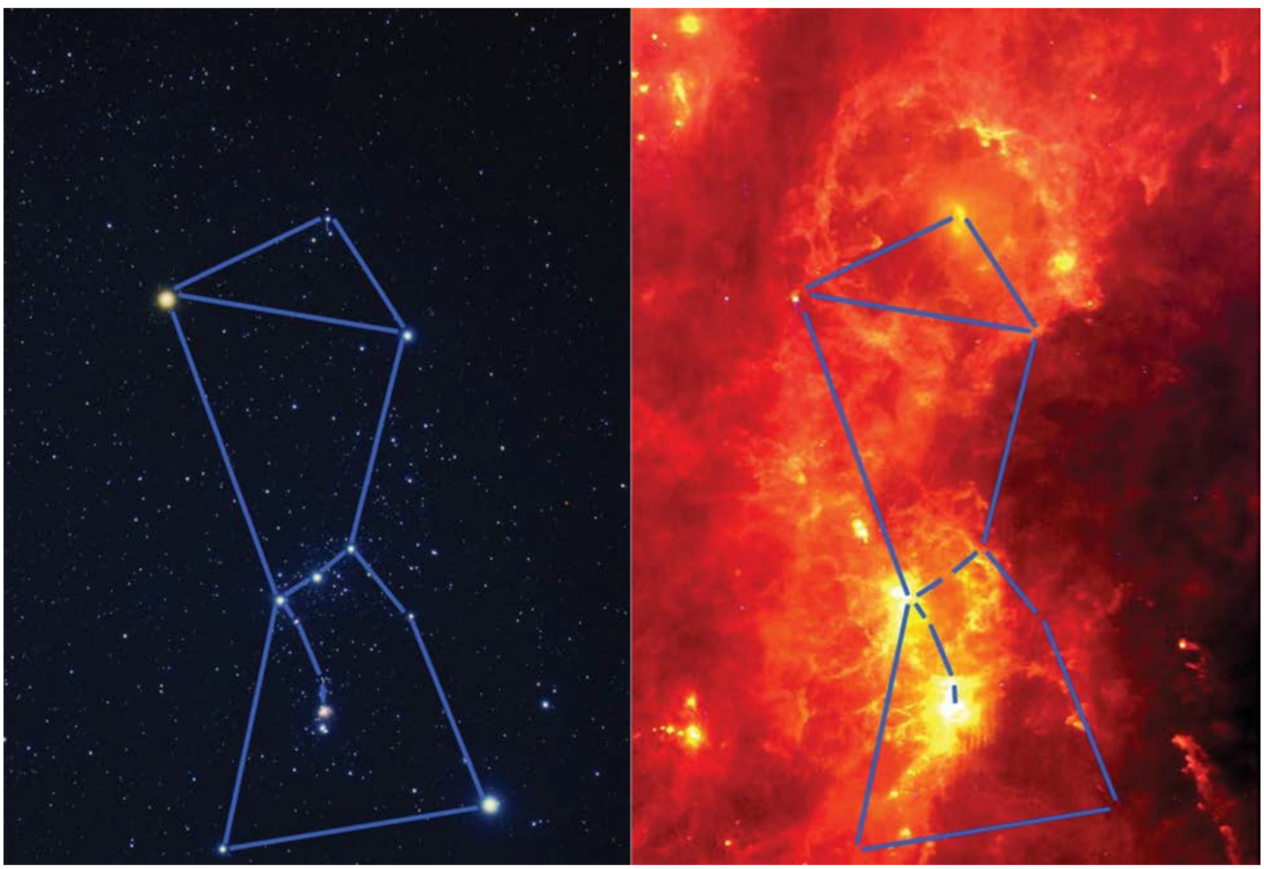
Your smartphone or digital camera takes pictures and videos electronically. They have imaging chips that detect both visible and IR light.

- Take a TV remote control that you know works.
- Look at the end of the remote control that you point toward the TV and press any button.
- Hold the button down. Can you see any light coming from the end of the remote control?
- Now, do the same thing, holding down any button on the remote control, but view the remote control through your smartphone or digital camera.*
- What can you see? If you see a blinking light from your remote control, you have just used an infrared detector to "see" invisible light!

*Hint: With smartphones, switch to the screen-side camera if the other camera does not detect IR. Some digital cameras do not detect IR because they include a filter that blocks IR.

More to Explore:

Does infrared light pass through the same materials as visible light? Use the remote control and your smartphone or digital camera to experiment. Try paper, cellophane, plastic bags of various types, hard plastic, and glass. Does IR pass through Sunglasses or regular eyeglasses?



The constellation Orion in visible light *and in infrared light*

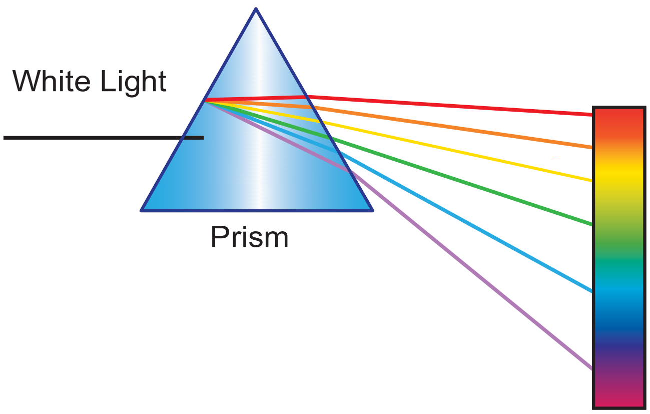
Credits: NASA/SOFIA
Visible light image: Akira Fujii; Infrared image: Infrared Astronomical Satellite

Image Credit: NASA/Hinode/XRT

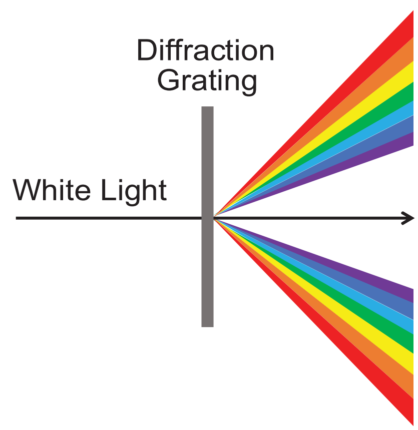
4. LET’S SEE LIGHT IN A NEW WAY: DIFFRACTION SPECTRA

What Is This About?

Most of us take our sight for granted. We see the world around us in reflected light from the sun or artificial light sources. Today, we understand that light can be composed of many colors or “wavelengths.” Our eyes and brain work together to blend these wavelengths into a single color. Isaac Newton first used the word “spectrum” to describe these individual colors that can be seen when passing light through a prism. These are the familiar colors of rainbows.



Credit: NASA Space Place



Credit: E. DeVore, SETI Institute

In this activity, you will explore various light sources using a “spectroscope.” The spectroscope is made with a transparent plastic film that has thousands of lines etched in it. When light passes through the etched film, it bends relative to its color or wavelength like it does through a prism. The diffraction grating spreads out the visible light, making it easy to see all the colors. For more information on the spectrum, see pages 14-15.

Materials: (you provide)

- 10 spectroscopes that participants can share
- Light sources (see next page)
- White paper to reflect sunlight

Credit: E. DeVore, SETI Institute

WARNING: DO NOT LOOK DIRECTLY AT THE SUN.
DOING SO CAN DAMAGE YOUR EYES.

To Do:

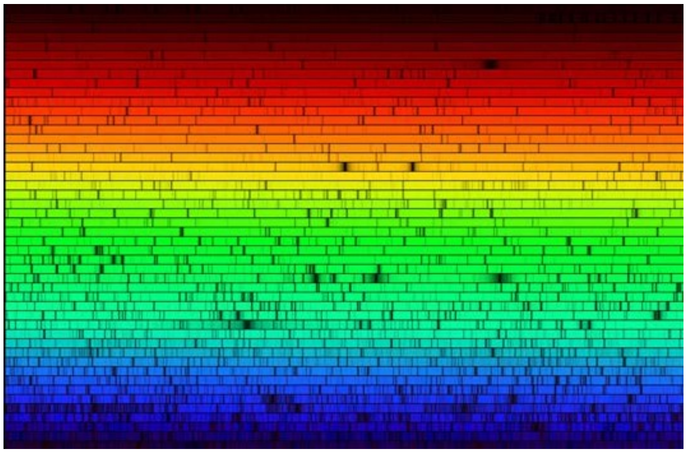
- Look at your spectroscope. Read the safety label. **DO NOT LOOK DIRECTLY AT THE SUN.**
- Look at the ends of the spectroscope.
- One end has a slit—that's the front end that you point at light sources. The other end has a small opening with a transparent piece of diffraction grating mounted in it. See page 16.
- Be careful not to touch the diffraction grating. Your fingerprints will make it work poorly.
- Look through the spectroscope at a lamp or ceiling light. What do you see?

Are All Sources of Light the Same? Check These Out!

- Incandescent (old fashioned) lamp
- Compact fluorescent lamp (CFL)
- Fluorescent lights (in the ceiling)
- A white piece of paper on the ground in sunlight. **DO NOT LOOK DIRECTLY AT THE SUN.**
- Brightly colored cars or flowers
- Neon signs
- Television and computer screens
- Stoplights
- LED lamps, flashlights, and holiday lights
- Bug lights
- Floodlights
- The moon

Space Science Tie-In:

Today, scientists build sensitive instruments called spectrometers to study the light from distant objects: stars, galaxies, planets, dust and gas in space. Like people, each atom and molecule shows its own unique set of fingerprints—lines in the spectrum. By studying these fingerprints—the spectrum of an object—astronomers can tell what a star or planet is made of. The spectrum can also tell us about the temperature and pressure, motion, and ultimately, the formation and evolution of celestial objects.



The spectrum of the sun

Credit: N. Sharp, NOAO/AURA/NSF

5. A LIGHT SNACK: COOKIE BOX SPECTROMETERS

What Is This About?

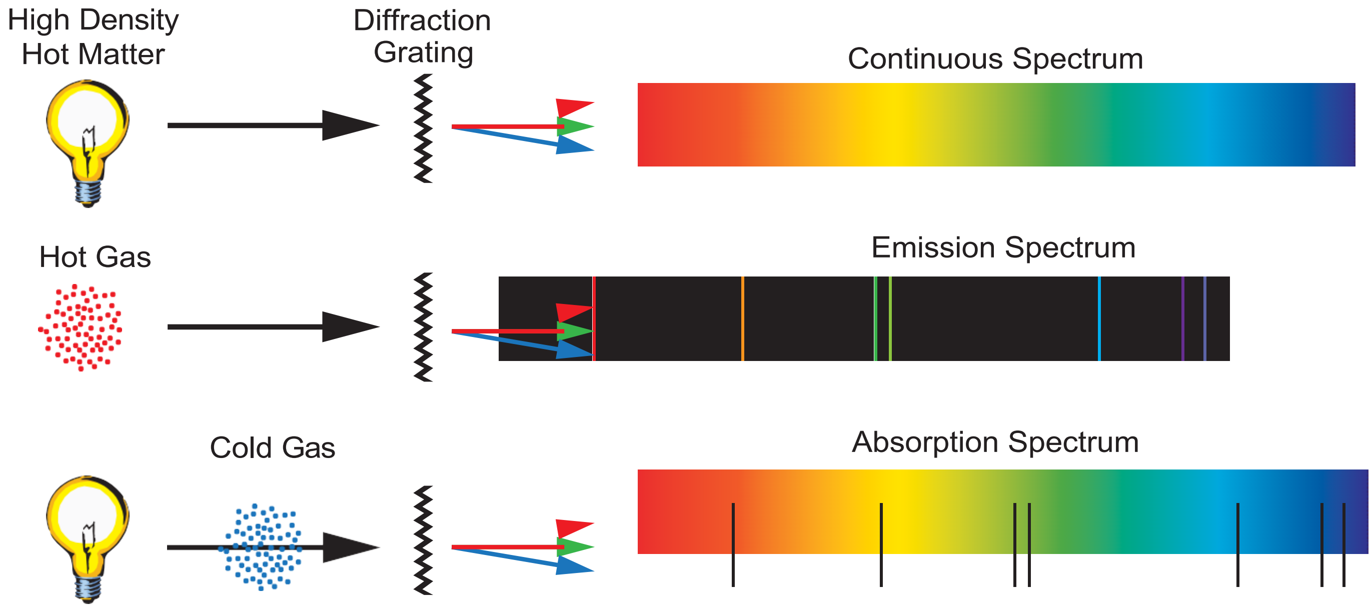
When you look at a rainbow, you are seeing the spectrum of white light from the sun. Tiny spherical raindrops refract (bend) and spread out white light into its component colors. In this activity, you will go deeper to explore the science and engineering of spectroscopy—the study of the spectrum and what it tells us about our world and the universe.

In 1665, Isaac Newton demonstrated that a prism can break light into its component colors and that a second prism can re-assemble them back again into white light. He was the first to call this the “spectrum.” In 1814, Joseph Fraunhofer invented the spectroscope to study light, and discovered absorption lines in the spectrum of the sun. Helium was first discovered in the spectrum of the sun!

What Is Going On With Light?

When atoms of different materials are excited by an electric current or another source of energy, they produce a unique spectrum. Atoms of different elements have different colors in their spectra. Each atom or molecule’s spectrum is unique to that element or compound, just as fingerprints are unique for every person.

Dive deeper into spectra with NASA: https://science.nasa.gov/ems



Credit: Mark Tiele Westra

The Computers:

The first spectra of stars were made with a telescope, a prism and a photographic glass plate. Beginning in 1870s, women were hired as “computers” at Harvard College Observatory to classify these stellar spectra.

Harvard computers at work circa 1890:

Henrietta Swan Leavitt seated, third from the left, with magnifying glass, Annie Jump Cannon in center also with magnifying glass, and Williamina Fleming standing, in the center, and Antonia Maury, far right.

Credit: Harvard Astronomical Plate Collection

Annie Jump Cannon studied the spectra of more than 225,000 stars as a “computer” at Harvard Observatory. She perfected the classification system we use today. She compiled the largest accumulation of astronomical information ever assembled by a single individual—the nine volume Henry Draper Catalog. She won many honors and awards in the United States and Europe during her lifetime. Today, the Annie Jump Cannon Award is presented each year by the American Astronomical Society to a North American female astronomer in the first five years after her doctorate.

Henrietta Swan Leavitt worked alongside of Cannon as a “computer.” Leavitt studied variable stars—stars that dim and brighten repeatedly. She discovered the “Cepheid Variables” that allow astronomers to accurately measure distances in our galaxy, and to other galaxies. Her discovery helped other astronomers discover that the universe is expanding. Leavitt was deaf most of her career. Lauren Gunderson’s play “Silent Sky” portrays these women at the dawn of modern astronomy.

Space Science Tie-In:

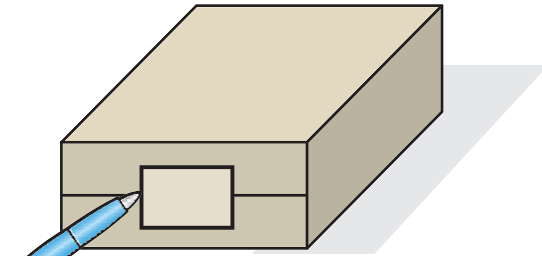
Astronomers study light of all types—the electromagnetic spectrum—to understand the universe and everything in it. From the spectrum of a star, we can discover its composition, temperature, motion through space and deduce its size, mass and age. All from just light. This is true for planets, comets, moons, asteroids, gas clouds, star clusters, galaxies—everything in the universe.

Astronomers build spectrometers to launch into space or to use with ground-based telescopes to observe the spectrum of distant objects. Launching a spectrometer above the atmosphere allows us to observe high energy light sources in UV, x-rays, or gamma rays that would normally be filtered out by our atmosphere. It also allows astronomers to inspect the full infrared spectrum, much of which is filtered out by atmospheric water vapor.

MAKING YOUR

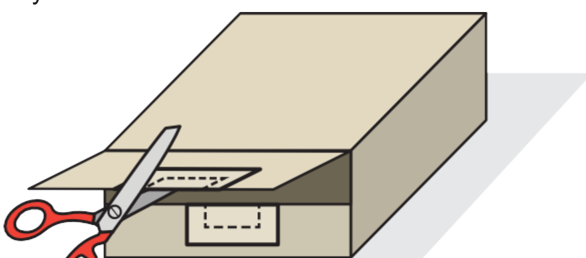
CEREAL BOX SPECTROSCOPE

1. Select one end of the cereal box, and close the flaps. Place a diffraction grating on this end and outline it with a sharpie. This will be referred to as the front of your "Spectroscope".



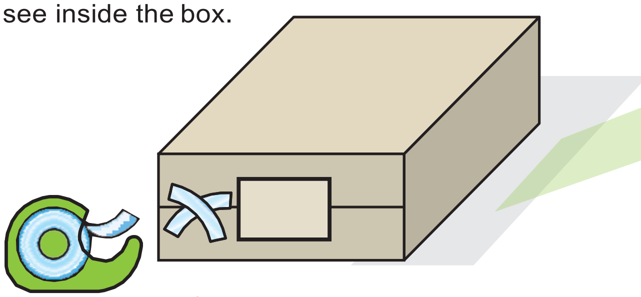
Cereal Box Front

2. Open the flaps and cut a hole smaller than the size of your outline in the cereal box.



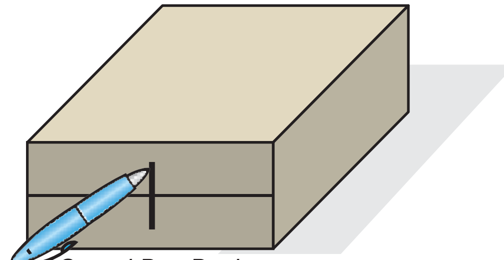
Cereal Box Front

3. Tape the cereal box flaps closed. Arrange your diffraction grating right side up (so you can read the label), then tape it over the hole you just cut. Make sure you can look through the grating and see inside the box.



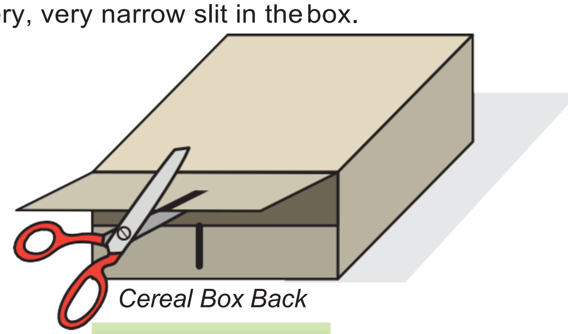
Cereal Box Front

4. Rotate the box around so you are now looking at the opposite end. (This will be the back of your "Spectroscope"). Close the two flaps and draw a line down the center (top to bottom, not side to side). The line should be directly opposite the diffraction grating, and centered.



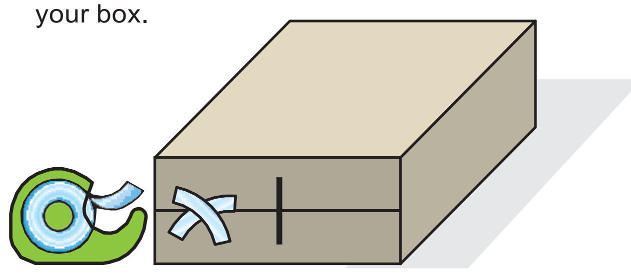
Cereal Box Back

5. Cut along the mark you just made, making a very, very narrow slit in the box.



Cereal Box Back

6. Close and tape the flaps on the back of your box.



Cereal Box Back

You're done!!

Look through the grating in your spectroscope to see the light spectrum!

Credit: NASA — The Science of the Sun—Solar Dynamics Observatory Education Unit https://sdo.gsfc.nasa.gov/assets/docs/UnitPlanSecondary.pdf

Materials: (you provide)

Cookie box spectrometer

Credit: E. DeVore, SETI Institute

- Cereal or cookie boxes, one per spectroscope
- Tape
- Scissors
- Sharpie or other pen
- Diffraction gratings, one per spectroscope*
- Black electrical tape (optional)

*Diffraction gratings are readily available.
Search online for “Diffraction Grating Slides.”
Look for “single axis” or “linear” gratings with 500 to 1,000 lines per inch.
They cost about $1.00 each.

Scope Out the Light—Use Your Spectroscope:

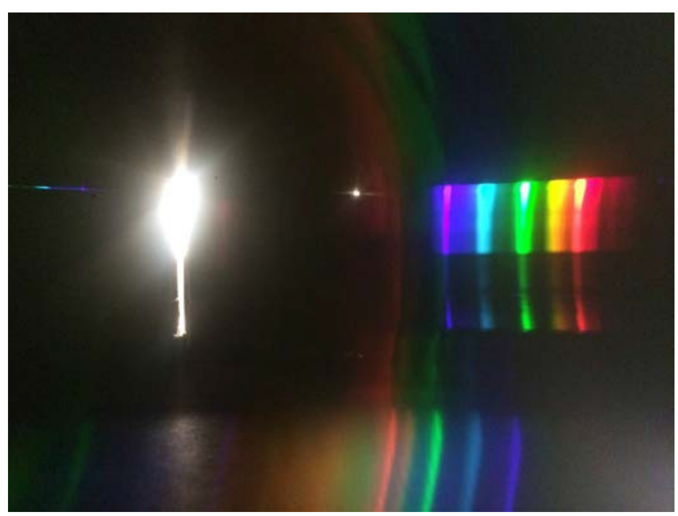
- You may need to troubleshoot your spectroscope.
- If you don’t see a broadband of colors, try rotating the diffraction grating 90° (1/4 turn).
- If the slit is too wide, use pieces of black electrical tape to make it narrower and crisper.

**WARNING: DO NOT LOOK DIRECTLY AT THE SUN.
DOING SO CAN DAMAGE YOUR EYES.**

Are All Sources of Light the Same? Check These Out!

A white piece of paper on the ground in sunlight. **DO NOT LOOK DIRECTLY AT THE SUN.**

- Incandescent (old fashioned) lamp
- Compact fluorescent lamp (CFL)
- Fluorescent lights (in the ceiling)
- Brightly colored cars or flowers
- Neon signs
- Television and computer screens
- Stoplights
- LED lamps, flashlights, and holiday lights
- Bug lights
- Flood lights
- The moon



Fluorescent ceiling lamp seen through cookie box spectrometer

Credit: E. DeVore, SETI Institute

6. MAKE SUN S'MORES!

A Bit of History

For more than 2000 years, people have converted sunlight into different or more concentrated forms to stay warm and to cook. Many ancient cultures built their houses to have the most energy efficient sun exposures, facing their buildings towards the southern sky to get the most sun. Ancient Egyptians lined pools with black tiles that absorbed the sun's energy during the day. The warmed pool water was then piped into palaces as a heating source. In this activity, you will build a solar oven that collects the sun's rays to cook food.

Materials: (you provide)

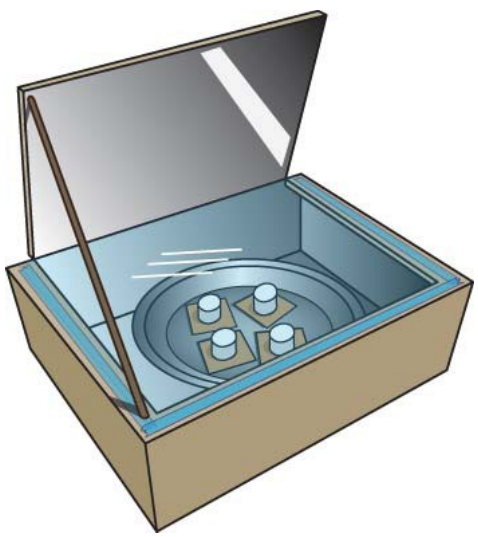
- Oven thermometer
- Cardboard pizza box (or similar box with an attached lid that has flaps so that the box can be closed tightly. Box should be about 3 inches deep.)
- Box knife or scissors (with adult help, please!)
- Aluminum foil
- Tape
- Glue stick
- Plastic wrap
- Ruler or straight edge
- Stick or ruler—about 1 foot long to prop the lid

Space Science Tie-In:

NASA uses solar energy to provide power for spacecraft in the solar system. Solar cells on Earth orbiting and deep space flyby missions, orbiters, and landers power spacecraft and their instruments. The most distant spacecraft to use solar cells is the JUNO mission, now orbiting Jupiter.

S'Mores Supplies: (you provide)

- Graham crackers
- Large marshmallows
- Plain chocolate bars (thin)
- Aluminum pie pan
- Napkins



Completed solar oven in action

To Do:

HAVE AN ADULT CUT THE BOX!

#1 — Using the straight edge of the ruler as a guide, cut a three-sided flap in the top of the box, leaving at least a 1-inch border around the three sides.

#2 — Cover the inside of the flap with aluminum foil, spreading a coat of glue from the glue stick onto the cardboard first and making the foil as smooth as possible. Line the inside of the box with aluminum foil, again gluing it down and making it as smooth as possible.

#3 — Tape two layers of plastic wrap across the opening you cut in the lid—one layer on the top and one layer on the bottom side of the opening in the lid.

Test the stick you will use to prop the lid up. You may have to use tape or figure another way to make the stick stay put.

Make Sun S'mores in Your Solar Oven

Set the oven in the direct sunlight with oven thermometer inside in view. Close the oven lid (the part with the plastic wrap on it) tightly, and prop up the flap to reflect sunlight into the box. You may need to tape the prop in place.

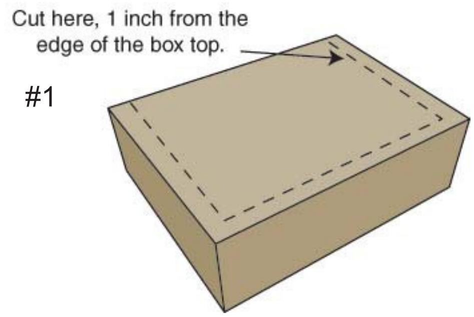
Preheat the oven for at least 30 minutes and check the thermometer. It should be at least 125°.

Break graham crackers into squares. Place four squares in the pie pan with a marshmallow on each. Place the pan in the preheated solar oven.

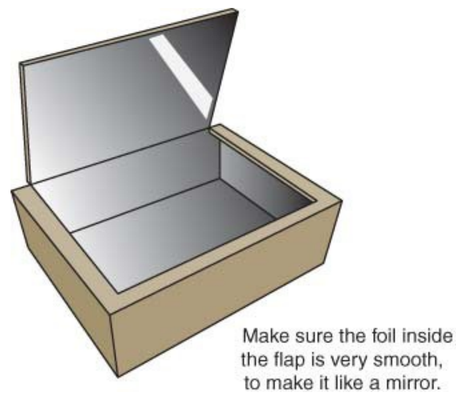
IMPORTANT! Unlike most recipes, our s'mores have the marshmallow UNDER the chocolate. That's because it takes the marshmallow longer to melt than the chocolate in the solar oven.

Depending on how hot the day is, and how directly sunlight shines on the oven, the marshmallows will take 30 to 60 minutes to get soft.

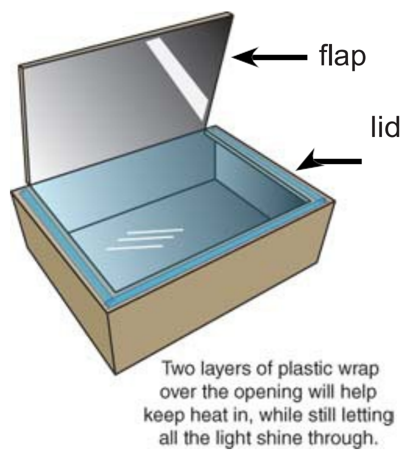
#1



#2



#3



Once the marshmallows are soft, open the oven lid and place a piece of chocolate (about half the size of the graham cracker square) on top of each marsh-mallow.

Place another graham cracker square on top of the chocolate and press down gently to squash the marshmallow.

Close the lid of the solar oven and let the sun heat it up for a few minutes to melt the chocolate.

ENJOY!

Credit including illustrations NASA Climate Kids: http://climatekids.nasa.gov

Image Credit: NASA/Hinode/XRT

7. HOW BIG IS BIG? SOLAR PIZZAS

What Is This About?

How big is the Earth? The sun? How far away is the sun? These questions puzzled people for a long time. Eventually they were answered using a little geometry and careful observations. This activity is about the relative size of the sun and Earth and the distance between them, which is called the “Astronomical Unit.”

Materials: (you provide)

- Solar pizza
- 100-foot (or shorter) measuring tape

To Do: Model the Earth and Sun

How big is the sun in comparison to Earth?

- Go outside.
- Have one person hold the cardboard sun—the solar pizza.
- Hold it up high so everyone can see it.
- If the sun were as big as the solar pizza (about 8-inches across), how big would the Earth be?
- Everyone can show their guesses using their fingers, hands, or arms.
- Turn the solar pizza over and show everyone the Earth, which is scaled to the size of the sun.
- Were the participants’ guesses close to the actual scaled size? Surprises?
- Fun Fact: The sun is 109 times the diameter of Earth.

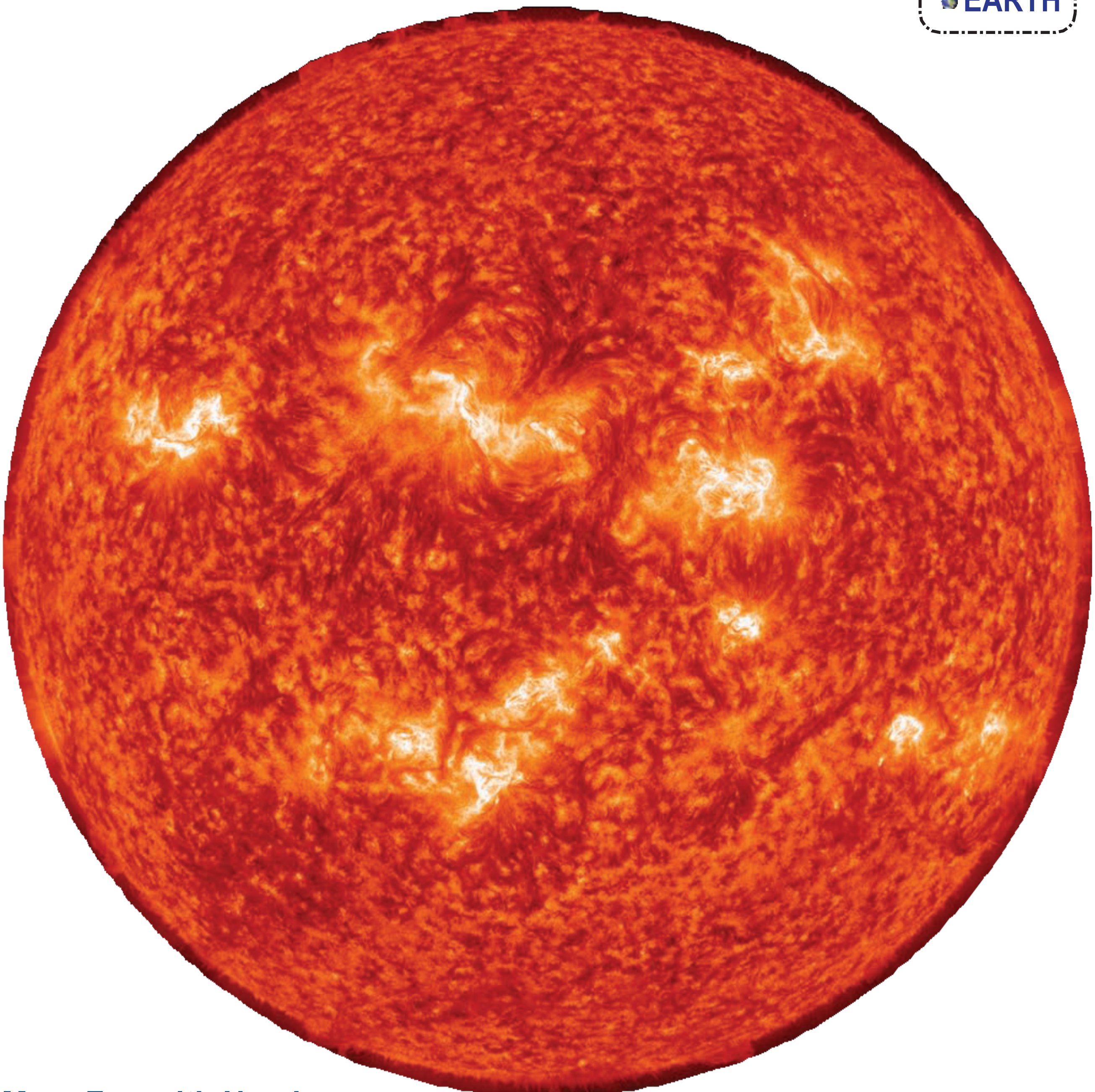
How far apart are the sun and Earth?

- Have one person hold the cardboard sun — the “solar pizza.”
- Pull out the Earth tab on the back of the solar pizza and hand it to another person.
- Have the Earth and sun stand together.
- Ask “If the sun is the size of this picture, how far away is the Earth?”
- Ask the person holding the Earth to slowly walk away from the sun.
- Each person says “STOP” when she thinks it is the right distance.
- The Earth keeps walking until everyone has had a vote.
- Look on the back of the solar pizza for the correct answer. Measure that distance and have the Earth stand at that distance from the sun.
- This distance is the “Astronomical Unit.”

Solar Pizza —

- Cut out the images of the sun and Earth.
- At this scale, the sun and Earth are separated by about 65 feet (about 20 meters). The actual distance between the sun and Earth is about 93 million miles (150 million kilometers).

This image is scaled to the correct size in relation to the image of the sun.



For More Fun with Numbers:

Sun and Earth Facts:

Diameter of sun: about 863,000 miles (1,490,000 km)

Diameter of Earth: about 8,000 miles (13,000 km)

You can fit 109 Earths across the sun's diameter!

The distance from Earth to the sun is called the "Astronomical Unit." How long would it take you to travel the distance to the sun in a car? In a jet airplane? The distance to the nearest star, Proxima Centauri, is about 25,000,000,000,000 miles. How long would it take you to go there in a car? An airplane? A spaceship?

Credit: NASA
https://Sunearthday.nasa.gov

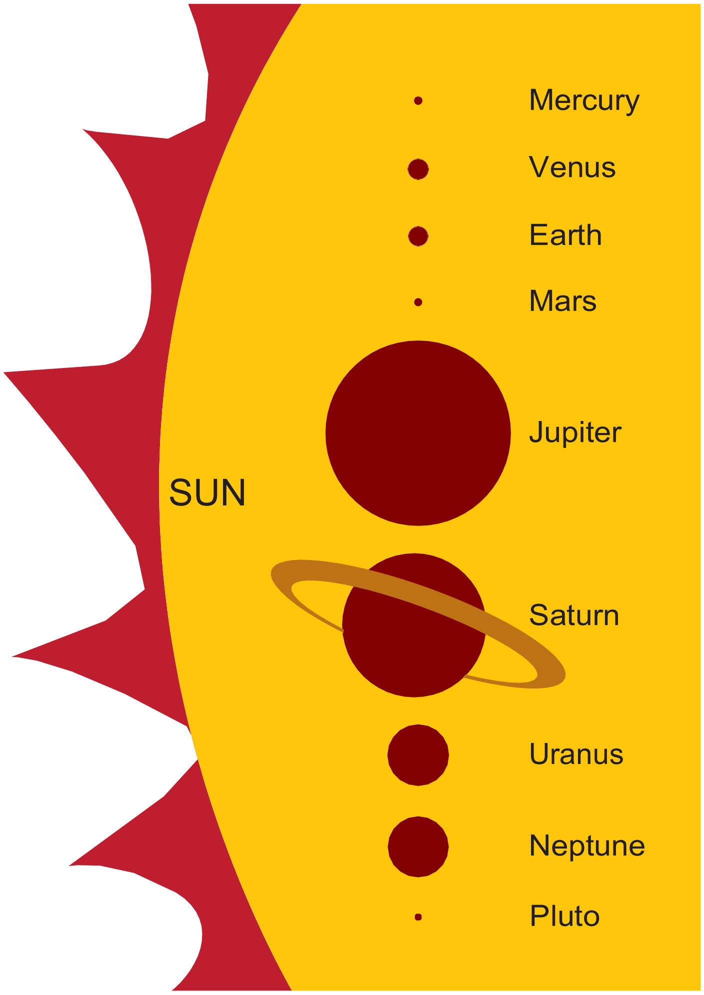
8. EARTH AS A PEPPERCORN: SIZE AND SCALE OF THE SOLAR SYSTEM

What Is This About?

Can you picture how big the solar system is? It's really hard because the solar system is really big! You may have seen a picture of the solar system in a book or on the web. To get all the planets into the picture, they were all scrunched together. Or, you may have seen a picture of their orbits, and the planets were so tiny they were hard to find. In this activity, the sizes and distances use the same scale.

Materials: (you provide)

- 9 index cards
- Marker
- Outdoor area up 6/10th mile in length
- Sun—any ball, diameter = 8 inches
- Mercury—a pinhead, diameter = 0.03 inch
- Venus—a peppercorn, diameter = 0.08 inch
- Earth—a peppercorn, diameter = 0.08 inch
- Mars—a pinhead, diameter = 0.03 inch
- Jupiter—a chestnut or a pecan diameter = 0.90 inch
- Saturn—a hazelnut or an acorn diameter = 0.70 inch
- Uranus—a peanut or coffee bean diameter = 0.30 inch
- Neptune—a peanut or coffee bean diameter = 0.30 inch
- To include the dwarf planet, Pluto—a pinhead (or smaller, since Pluto is a dwarf planet.)



Scaled sun and planets

Credit: E. DeVore, SETI Institute

To Do:

In this activity, you will make a scale model of the solar system and hike to the planets. The sizes and distances will be much smaller than they are in real life, but both will be to the same scale. What does this mean?

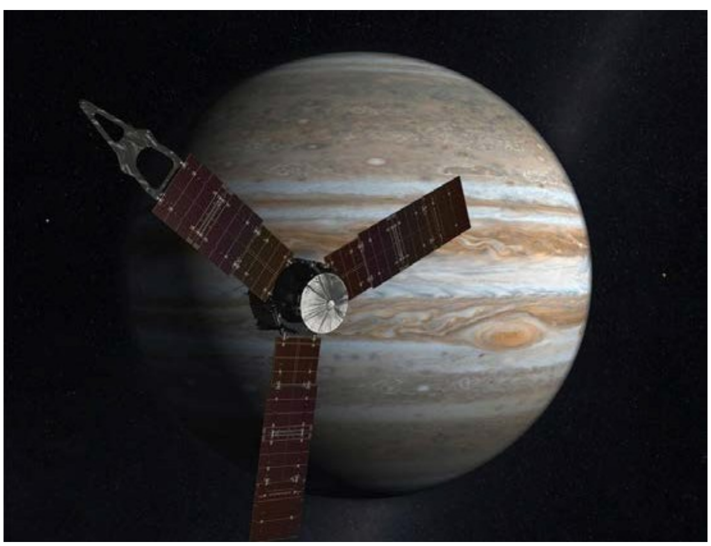
Let's start with the sun, which is 800,000 miles in diameter. An 8-inch diameter ball represents the sun. So, in our model, one inch represents one hundred thousand miles in reality. Our planet, Earth, is almost 8,000 miles in diameter. That's about 1/100th the diameter of the sun. In our scale model, that means Earth is the size of a peppercorn, about 0.08 inches across.

The Planets: The list of materials has suggestions for objects to use, but you make substitutes. Or you can draw a dots or dots on the cards to represent the planets. It's a good idea to glue or tape the objects to cards and write the name of the planet on the card.

First Step: There are 8 planets plus the dwarf planet, Pluto. Set them out on a table, and compare them with the sun.

Second Step: How much space do we need to make our solar system? To arrive at the answer, we need to return to our scale. One inch equals 100,000 miles. This means that one yard (36 inches) represents 3,600,000 miles. It's 93,000,000 miles from the sun to the Earth. That's 26 yards.

So, it's time to take a hike! Give the sun and planets to participants. You will need to find a place where you can hike about one thousand yards in something like a straight line. It's good to be able to turn back and see the sun and other planets, but not essential.



Juno at Jupiter

Credit: NASA/JPL

Pick a route that will make a good story afterwards like "All the way from the flagpole to the Japanese garden!"

Place the sun where you can see it from a distance, and begin the hike. The participants can count out the yard-long paces.

Fun Fact: At each planet, look back at the sun. It will appear the actual size that you would see from each planet. Can you still see the sun from Neptune?

OBJECT	PACES	TOTAL PACES FROM THE SUN	AVERAGE DISTANCE (MILLIONS OF MILES)
Sun	0	0	0
Mercury	10	10	36
Venus	9	19	67
Earth	7	26	93
Mars	14	40	142
Jupiter	95	135	484
Saturn	112	247	887
Uranus	249	496	1,784
Neptune	281	777	2,794
Pluto	242	1,019	3,675

You have marched more than half a mile! The distance in the model adds up to 1,019 1-yard paces. A mile is 1,760 yards.

Look back toward the sun ball. Can you see it? Look at the pinhead representing Pluto. The solar system is REALLY BIG!

On this scale, the nearest star, Proxima Centauri is about 4,000 miles away! How far is that? It's the distance between Miami, Florida and Anchorage, Alaska!

Space Science Tie-In:

Today, we can measure accurate distances to the planets by bouncing radio waves off their surfaces. Space scientists use these measurements along with observations of the motion of the planets and a knowledge of physics to accurately target planetary space probes like Cassini, Curiosity, Dawn, Juno, New Horizons and many others.

Credit: Adapted from "The Thousand Yard Model" Guy Ottwell

9. SUN TRACKING

What Is This About?

Long before humans kept track of time with mechanical clocks, atomic radiation, or computer chips, they used the sun to tell time. As the Earth spins around like a top, the sun appears to move across our sky. This movement causes shadows to move and change over the course of a sunny day.

The simplest sun tracker is called a gnomon, pronounced “no min.” A gnomon casts a shadow, and can be as simple as a vertical pole. It can be used to track time on its own, or to measure time in hours and minutes as part of a sundial.

Materials: (you provide)

- Vertical pole, stick (straight branch, stake, pencil)
- Open location on a sunny day
- Rocks or other markers, 3 or more

To Do:

If you are installing your own stick as a temporary gnomon:

- Find a clear, sunny space with soft dirt
- Press the stick straight down into the ground until it stands up on its own
- Find your gnomon’s shadow and mark the shadow’s end with a rock
- Decide when you can return to your gnomon, at least 30 minutes later
- Estimate where the gnomon’s shadow will be at this future time
- Place a second rock at the location of your guess.
- Groups can make multiple guesses with more rocks
- Return to your gnomon after the planned amount of time

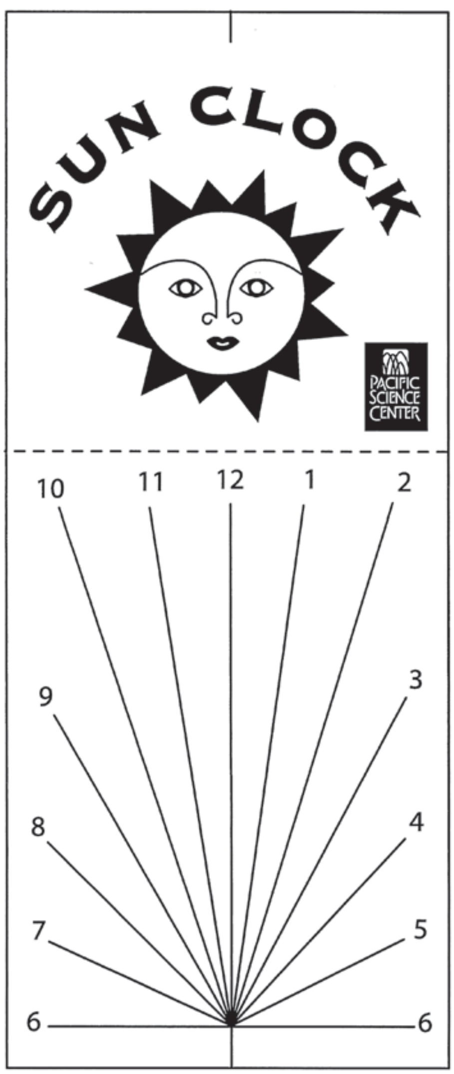
Check your guess. Is the rock close to the shadow? Did the shadow move more, less, or differently than you expected? Based on this movement, where do you hypothesize the shadow might be if you waited the same amount of time again? If you have time, guess again and check back a second time. Did the shadow move as you expected?

Make a Pocket Sun Clock:

Make a simple pocket sun clock. Pick the pattern for your location, and print on heavy paper or glue onto cardstock. Cut out the sun clock, and carefully cut the short notch at each end. Fold along the dotted line, with the print on the inside. Take about 7 inches (20 centimeters) of string, and place the ends through the notches. Tape one end to the back of the clock. Make the string tight when the two parts of the clock are at a 90 degree angle. Tape the second end of the string to the back of the clock.

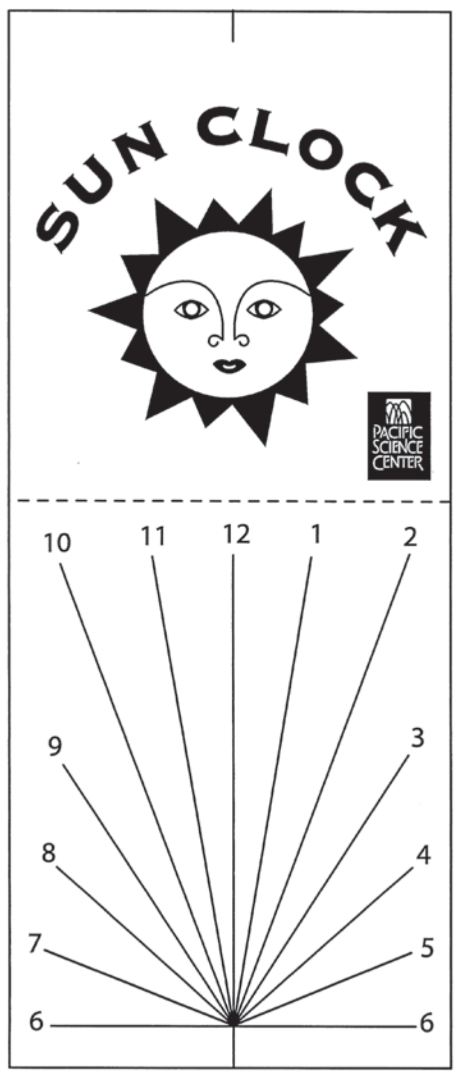
Take the pocket sun clocks outside on a sunny day. Ask the participants to place the clocks on a flat surface and experiment with them until they tell the right time. Which way are the clocks facing? Is there only one correct position? If possible, mark the position on the ground, and return about an hour later to experiment again. Any changes?

CLOCK 1



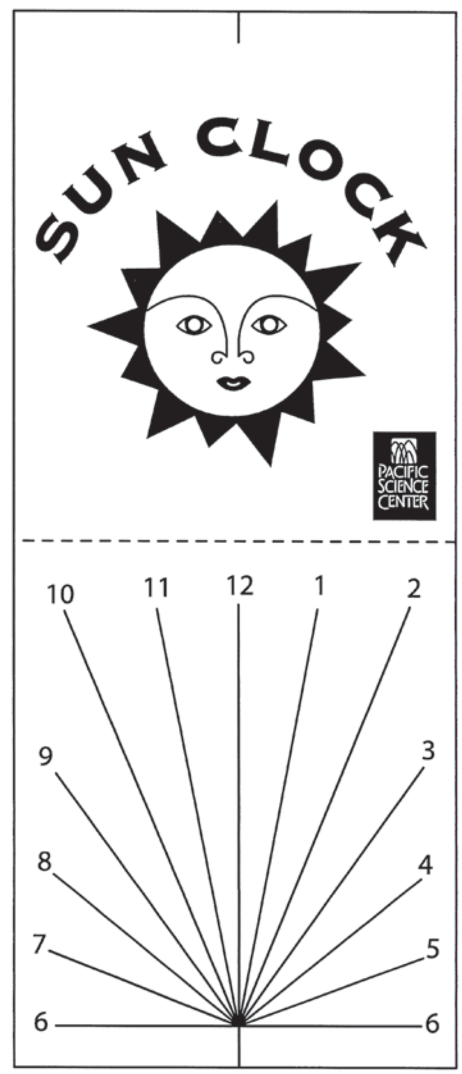
Use this sun clock if you live in: So. CA, So. NV, AZ, NM, A, TX, AL, LA, TN, MS, AL, GA, FL, NC or SC

CLOCK 2



Use this sun clock if you live in: No. CA, No. NV, UT, CO, So. WY, NE, KS, IA, MO, IL, IN, OH, KY, VA, WV, MD, DE, NJ, PA, So. NY, MA, CT, or RI

CLOCK 3



Use this sun clock if you live in: WA, OR, ID, MT, ND, SD, No. WY, MN, WI, MI, No. NY, VT, NH, ME, So. Canada

Credit: Paul Allen and Dennis Schatz, AstroAdventures, Sun Watching, Lesson 4: Making a Sun Clock, © Pacific Science Center

10. WAXING AND WANING: PHASES OF THE MOON AND ECLIPSES

A Bit of History:

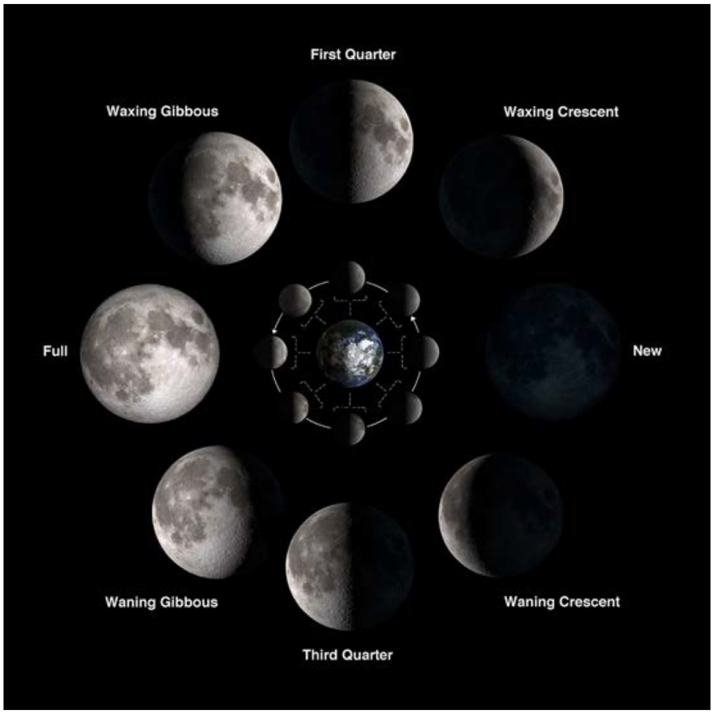
People have watched the moon go through its predictable phases from full to new and back again for tens of thousands of years. We don't know who first understood and described the reasons for the phases of the moon. We do have evidence that people followed and recorded the phases of the moon as much as 30,000 years ago through lunar calendars where notches and holes were carved into sticks, reindeer bones and mammoth tusks. In this activity, you will create a model of the sun—Earth—moon system and demonstrate the changing phases of the moon.

Materials: (you provide)

- 20 moon balls
- 20 pencils, skewers or other short sticks
- The sun as a single light bulb in a lamp without a shade (or a bright flashlight)
- Darkened room
- Masking or duct tape to tape down the lamp cord (safety)

Get Ready:

- Set up the lamp in the middle of the room. This is the sun. Tape the cord to the floor to avoid tripping hazard. Alternative: One person holds a flashlight, and is the sun.
- Give each person a moon ball, and pencil, skewer or stick. Mount the ball on the pencil, and form a circle around the lamp.
- Each person's head is the Earth, and each person holds up the moon ball at arm's-length.



Phases of the moon

Credit: NASA/Bill Dunford
http://solarsystem.nasa.gov/galleries/phases-of-the-moon

To Do: Phases of the Moon

- Always hold the moon ball at arm's-length in front of you as you do this activity.
- First, hold the moon in the direction of the light source. Where is the light on the ball? Since the light is shining on the other side of the moon, you (the Earth) should see a dark moon in front of you. This is the new moon.
- Turn to the left and watch the moon. What's happening? When you see a little of the moon illuminated, it's called a waxing crescent.
- When you've turned one-quarter of the way around the circle, how much of the moon is lit up? This is called a first quarter moon.
- Keep turning, and you will see more of the moon illuminated as it becomes a waxing gibbous moon.
- Next, turn so that your back is to the sun. Make sure to hold the moon high enough that your head does not block the light from the sun. What do you see now? How much of the moon is illuminated? This is the full moon.
- Keep turning, and you will notice that less of the moon is illuminated. This is the waning gibbous moon.
- Continue until half of the side facing you is illuminated. This is the third or last quarter moon.
- Finally, turn back through the waning crescent moon to the new moon.
- The full cycle of lunar phases from new moon to new moon takes 29.5 days.
- Waxing and waning: As the moon goes from new moon to full moon, we say that the moon is "waxing." And, when the moon goes from full moon to new moon, we say it is "waning."

To Do: Eclipses of the Sun and Moon

- Eclipses are all about shadows.
- Cover up the sun with your moon ball. What is the phase of the moon? (new moon)
- This is a solar eclipse. Look at a friend's face—you will see the shadow of the moon on her face. To see a total eclipse of the sun, you have to be inside the central part of the moon's shadow, called the umbra. If you are on the daytime side of the Earth, but outside the umbra, you may see a partial eclipse in the part of the moon's shadow called the penumbra.
- To make a lunar eclipse, turn around with the moon held out at arm's-length until it goes into the shadow of the Earth (your head). What is the phase of the moon? (full) Everyone on the dark side of the Earth can see a lunar eclipse.
- Eclipses only happen when the sun, Earth and moon all line up.

Try This:

Go outside at the same time on 3-5 successive days—daytime or nighttime—when you can see the moon. Each time, note the location of the moon and its phase. Draw the image of the moon you see on a sheet of paper. What do you see happening? Is it like the model you created?


Image Credit: NASA/Hinode/XRT

11. HOW DO ECLIPSES WORK? THE YARDSTICK ECLIPSE

What Is This About?

The moon and sun each appear to be about 1/2 degree across the sky. That is about the width of your pinky finger when held at arm's-length. Earth is unique in all the solar system having a moon that appears to be almost exactly the same size as the sun.

How is this possible when our moon is only 1/400th the size of the sun? It is because the moon is also 400 times closer! This wonderful coincidence coupled with the fact that the moon orbits in about the same plane as the Earth allows us to see total solar eclipses every year or two. But how, exactly do eclipses work?

Materials: (you provide)

- Folding yardsticks
- Binder clips
- 1-inch balls
- 1/4-inch beads
- Long wooden toothpicks
- Index cards (optional)

Get Ready:

Space Science Tie-In:

Total solar eclipses are more than just beautiful natural displays. They also help astronomers who study the sun (called heliophysicists) learn about the sun's extended atmosphere called the corona. Many spacecraft that observe the sun create an artificial eclipse by putting a mask over the bright solar surface (the photosphere) to study the much dimmer corona. These masks usually cover more than just the photosphere of the sun, so the spacecraft only observe the outer part of the corona. A natural solar eclipse allows astronomers to study the lower corona, much closer to the surface of the sun. (See diagram of the sun on page 35).

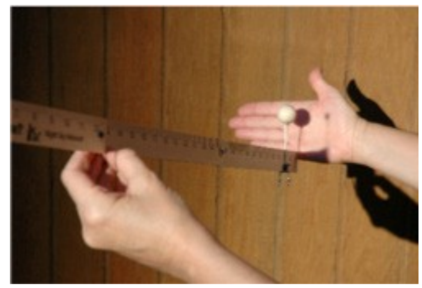
For More Eclipse Information and Images:

American Astronomical Society — https://eclipse.aas.org
NASA — https://eclipse2017.nasa.gov

You are making a model of the Earth, moon, and sun to demonstrate how they align to produce eclipses. What is a model? It's a simulation that shows how the real Earth, moon, and sun line up, but at a scale you can play with.

- Unfold the yardstick so that it is straight.
- Put the Earth ball on the end of a long toothpick. Clamp the other end of the toothpick to the yard stick near one end (at the 2 or 3-inch mark). How large is the real Earth? It's almost 8,000 miles in diameter. The Earth ball is one inch in diameter. That means that one inch = 8,000 miles in our model.
- How large is the real moon? It's just over 2,000 miles in diameter, about 1/4 the diameter of Earth. So, the moon is the 1/4-inch bead in our model. Attach the 1/4-inch bead moon bead to the end of another toothpick.
- How far away is the moon? The actual moon is about 240,000 miles away from Earth. That's 30 Earth diameters away. So, in our model, each inch on the yardstick represents one Earth diameter. Clamp the moon toothpick to the yardstick, 30 Earth diameters away from the Earth ball. You now have a scale model of the Earth—moon system.

Assembled yardstick model



Moon bead casting shadow on Earth ball

To Do:

- We need the sun* to make our model work! On a sunny day, take the eclipse yardstick model outside with another person
- Turn your back to the sun—you are using the real sun in this model—to play with the shadows of Earth and moon.
- Hold the yardstick model up with the Earth ball closest to you (but out of your shadow).
- Have the other person hold her hand or an index card behind the moon so that you can find the shadow of the moon as a tiny dot.
- Can you make an eclipse of the moon? Move the yardstick model until the moon bead is covered by the shadow of the Earth ball. That's a *lunar eclipse*!
- Can you make an eclipse of the sun? That happens when the moon is between the sun and Earth, and the moon casts its shadow on the Earth.
- Turn the yardstick model around so the moon bead is closest to you. Slowly adjust the position of the moon until its shadow falls on the Earth ball. You have just created a *total solar eclipse*!
- Trade places with your partner and let her make eclipses.

*A bright flashlight in a darkened room can substitute for doing this outside with the real sun.

Credit: Yardstick Model: Astronomical Society of the Pacific

12. WHEN DAY TURNS TO NIGHT: MEASURING LIGHT LEVELS AND TEMPERATURE

What Is This About?

One of the eeriest sensations you will experience during a total solar eclipse is the rapid drop in light levels around you. Though the sky has been getting slowly darker for a while, the jump from a sliver of partiality to total produces a huge drop in brightness. As darkness falls during totality, both animals and plants prepare for actual night time. Crickets chirp, birds and squirrels will nest, cows start to return to their barns, and roosters crow. It has even been reported that fish are more likely to bite. Animals that are normally active at night come out to prowl or hunt. In this activity, you will measure this drop in sky brightness.

Solar Eclipse at Your Location:

Everyone on the continental United States was able to see the August 2017 eclipse. Most people will see a partial eclipse where the moon covers only a part of the sun. To see the total eclipse, you need to be along the central path of the moon's shadow. NASA provides maps and tools to help you find out about the eclipse for you.

NASA Eyes: an interactive animation of the eclipse you can set for your location.
https://eclipse2017.nasa.gov/nasas-eyes

Eclipse Maps: U.S. maps for the path of totality
https://eclipse2017.nasa.gov/maps-cartography

Materials: (you provide)

- Smartphone
- Google Science Journal Application (free download) or other light-level app for smartphones
- Digital thermometer
- Tape and string to make a hanger for the digital thermometer
- Paper or notebook and pencil or pen
- Outdoor location

Get Ready: Before the Day of the Eclipse

- Download an application: you may need an adult's help or permission to download a smartphone application that measures light levels.
- For Android smartphones:
search for "Google Science Journal".
- For IOS smartphones:
search for "light meter" select an application.

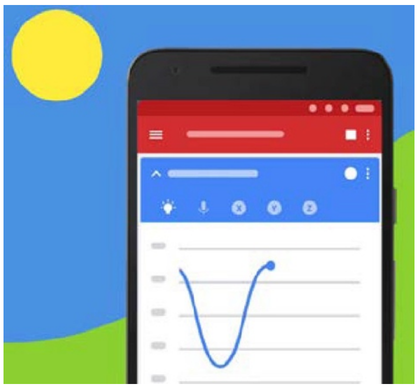
Space Science Tie-In:

Total solar eclipses are more than just beautiful natural displays. They also help astronomers who study the sun (called heliophysicists) learn about the sun's extended atmosphere called the corona. Many spacecraft that observe the sun create an artificial eclipse by putting an mask over the bright solar surface (the photosphere) to study the much dimmer corona. These masks usually cover more than just the photosphere of the sun, so the spacecraft only observe the outer part of the corona. A natural solar eclipse allows astronomers to study the lower corona, much closer to the surface of the sun.

To Do:

Figure out how to access and use the light level or light meter app on your smartphone. Your smartphone camera is used to measure light levels. Try putting your hand over your phone or pointing your phone at a bright light. Can you see the graph or meter go up and down as the light levels change?

When you are comfortable with recording light levels, you will be ready to record the drop in light levels from the eclipse of the sun. The closer you are to the path of totality, the more dramatic the change in light levels will be. Farther off the path and you may not register any change, but try it! Right on the path, where the eclipse is total for a short time, the change should be dramatic! If you are using the Science Journal, you can record the light level changes with your smartphone through the eclipse! You can add photos and voice recordings as the light levels are being recorded.



Credit: Google Science Journal

Measuring light levels with Google Science Journal

Make a hanger for the digital thermometer

Credit: P. Harman, SETI Institute

Be a Scientist: Sample Light Levels

- Start taking 10 second samples of the ambient light an hour before the eclipse. Repeat every 10 minutes until maximum eclipse has occurred. For each 10 second reading, record the lowest and highest reading value.
- On the path of totality: As the total eclipse time approaches, begin a continuous recording. Start one minute before totality and stop recording one minute after totality ends. Your total record will be about 4 to 5 minutes.
- Off the path of totality: Do the same experiment. You may or may not detect changes in light level. It depends on how much of the sun is eclipsed.

Be a Scientist: Sample Temperatures

- Hang your digital thermometer from a tree limb or other object out of direct sunlight.
- Don't touch the thermometer during the experiment as your body's heat will change the temperature being measured.
- Record the temperature at 10 minute intervals starting an hour before maximum eclipse to an hour after. Be sure to get at least one measurement during totality! More is better!
- Graph the Results: time vs. temperature.

Analyze Your Data:

- Review your results with other people.
- Did you all record the same readings?
- Were there differences? Why?
- How dramatic were the changing light levels?
- How did the temperature change?
- Did you notice the drop with just your eyes?

Going Farther:

We all enjoy the beauty of sunrise and sunset. You can also be a scientist at these times of the day by measuring the change in light levels and temperatures at sunrise or sunset, using the same sampling method as for eclipses. Start an hour before sunset, or just as the sun rises. It's a good way to practice if you are going to record data during the eclipse!

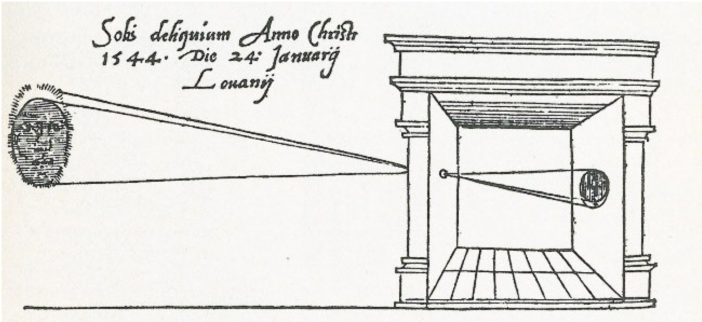
Image Credit: NASA/Hinode/XRT

13. MAKE AN ECLIPSE VIEWER

What Is This About?

It is not safe to look directly at the sun without taking precautions to protect your eyes. The sun is far too bright to view directly. But you can build a simple pinhole projector to help you see an image of the sun, safely.

“Pinhole cameras” were originally called “Camera Obscura.” This drawing by Leonardo da Vinci of a “Camera Obscura” shows the sun projected through a pinhole onto a wall. This is just like the projector you will make.



Credit: Gemma Frisius, De Radio Astronomica et Geometrica, 1545.

Materials: (you provide)

- Cardboard box: carton, cereal box, shoe box. The longer the box, the larger the image of the sun.
- Scissors or box knife
- Masking or transparent tape
- 1 piece of white paper
- Pin
- Duct (opaque) tape, as needed.

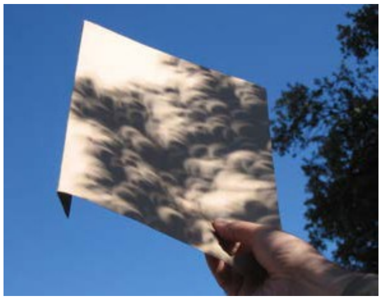
Space Science Tie-In:

Astronomers have observed the sun with ground based observatories for about 400 years. Galileo proved that the sun rotated by observing the motion of sunspots on its surface. Today, we observe the sun in many wavelengths from large ground-based observatories like the National Solar Observatory and from spacecraft: Solar and Heliospheric Observatory, Solar Terrestrial Relations Observatory and the Solar Dynamics Observatory.

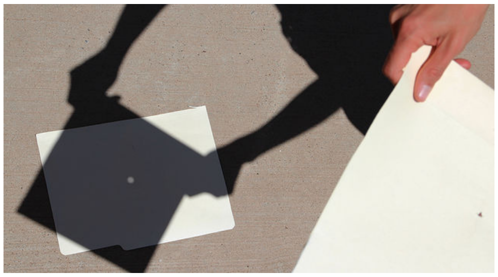
Try These:

During an eclipse of the sun, any small hole will make an image of the sun. Here’s some other fun ways to project images of the sun during partial eclipses.

Colander



Leaves



Pinhole Projection

Credit: Public domain (top) and jpl.nasa.gov (bottom)

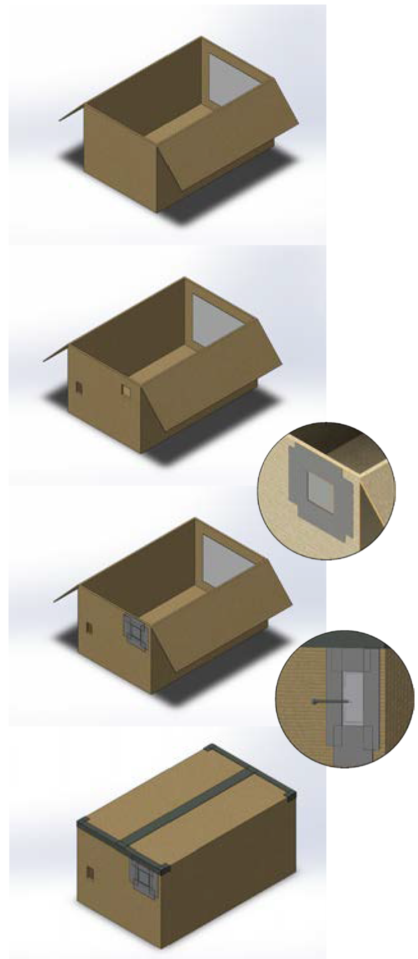
Build the Box Projector:

Any box will work. The longer the box, the larger the image of the sun. These instructions are for a cardboard box. If using a box with open seams, seal up the box with opaque tape to make the inside dark. Only the pinhole in the foil should let in light when you are looking through the viewing opening.

CAUTION:
Never look at the sun without eye protection.

It is safe to project the sun through small holes, and look at the projected image.

Never look directly at the sun through pinholes in paper or foil.



Tape white paper inside on one end of box.

Cut or poke eye and sun holes.

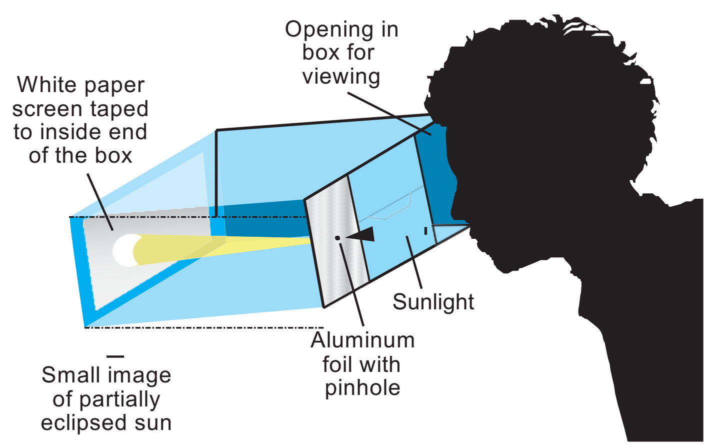
Tape aluminum foil over sun hole.

Poke hole in foil with pin.

Tape box shut to block light leaks.

To Do:

- Stand with the sun behind you.
- Point the pinhole end of the box toward the sun. Move around until, looking through the viewing opening, you see an image of the sun projected inside the box.
- An easy way to align with the sun is to make the shadow of the box and your head as small as possible.
- Your pinhole projector will show a small image of the sun that is useful during a partial eclipse to see the "bite" the moon takes out of the sun.
- The longer the box is, the larger the image of the sun will be.



Graphics: Credit: Jessica Henricks, Girl Scouts of Northern California; Conor McQuaid

14. ECLIPSE CHALK ART

What Is This About?

Observing a total solar eclipse can be an exciting, once in a lifetime experience! Long before there were cameras or telescopes, eclipse watchers recorded what they saw in the sky in words, drawings, and paintings. You can have fun creating your own picture of a solar eclipse with chalk and paper!

Materials: (you provide)

- Paper, dark blue or black. Smooth cardstock paper works best (not construction paper).
- White, non-toxic chalk
- Pencil
- Scissors
- Masking tape
- Circle templates cut from cardstock, file folders or cereal boxes
- OPTIONAL: Brightly colored construction paper or foam sheets for cut-out horizon detail.

To Do:

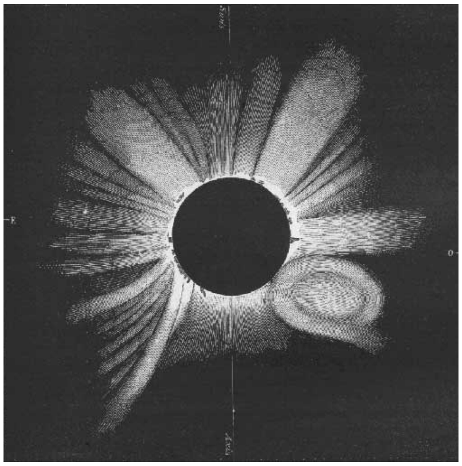
Credit: J. Henricks, Girl Scouts of Northern California

- Make circle templates on stiff paper. Trace around the masking tape roll with a pencil, and cut out the template. Make several for group activities.
- Place the template on a piece of dark paper. Secure with a loop of masking tape or simply hold down with one hand.
- Draw a thick circle of chalk around the template. Go around 2 or 3 times. It does not need to be neat.
- Holding the template in place, smudge the chalk away from the center of the circle using a finger to create the corona of the sun.
- When you are done smudging, remove the circle template.
- Add words, pictures, or fun designs.
- You've made total solar eclipse art!

Space Science Tie-In:

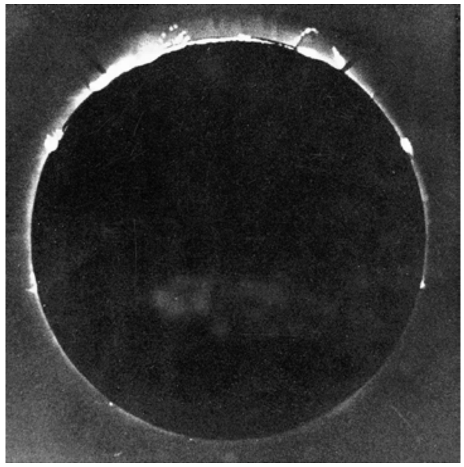
Until the advent of sophisticated and highly specialized ground and space-based solar telescopes, the only opportunity anyone had to observe the sun's corona was during a total solar eclipse.

Eclipse photography was not use until about 1860. Before that, astronomers would sketch what they saw at the eyepiece of their telescopes.



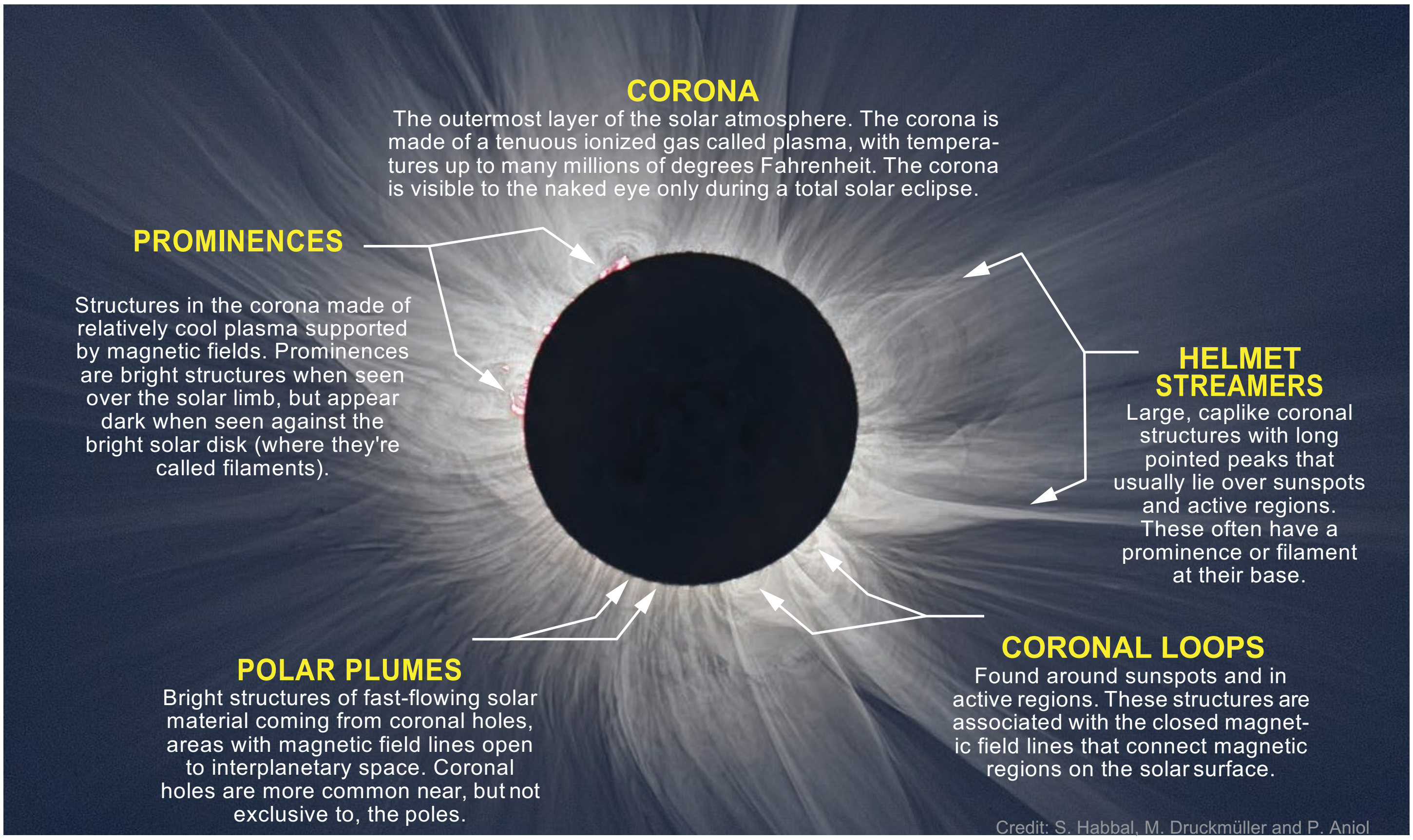
Sketch of 1860 total solar eclipse by G. Temple showing a coronal mass ejection

Credit: G. Temple



First photograph of a solar eclipse by Charles A. Young, July 18, 1860

Credit: C. Young



Credit: NASA

For More Eclipse Information and Images:

American Astronomical Society: https://eclipse.aas.org
NASA: https://eclipse2017.nasa.gov

NASA ECLIPSE GUIDE


Credit: Marla Hladiuk

WHAT IS A SOLAR ECLIPSE?

A solar eclipse happens when the moon casts a shadow on Earth, fully or partially blocking the sun's light in some areas.

Observers within the path of totality will be able to see the sun's corona (weather permitting), like in the images above and left. Observers outside this path will see a partial eclipse.

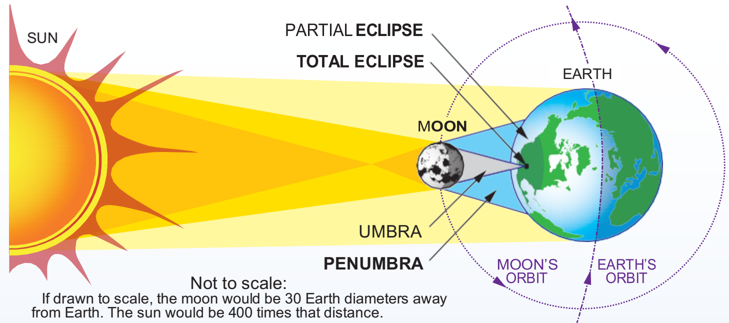
THE NEXT ECLIPSE

After the 2017 solar eclipse, the next total solar eclipse visible over the continental United States will be on **April 8, 2024**.


Credit: International Space Station

This photo taken from the International Space Station shows the moon's umbral, or inner, shadow during the total solar eclipse of March 29, 2006.

Total or Partial Solar Eclipse?



Not to scale:
If drawn to scale, the moon would be 30 Earth diameters away from Earth. The sun would be 400 times that distance.


Credit: Rick Fienberg, TravelQuest International and Wilderness Travel

In this series of stills from 2013, the eclipse sequence runs from right to left. The center image shows totality; on either side are the 2nd contact (right) and 3rd contact (left) diamond rings that mark the beginning and end of totality respectively.

WHERE TO WATCH

Find a nice, clear spot with a good view of the sky.

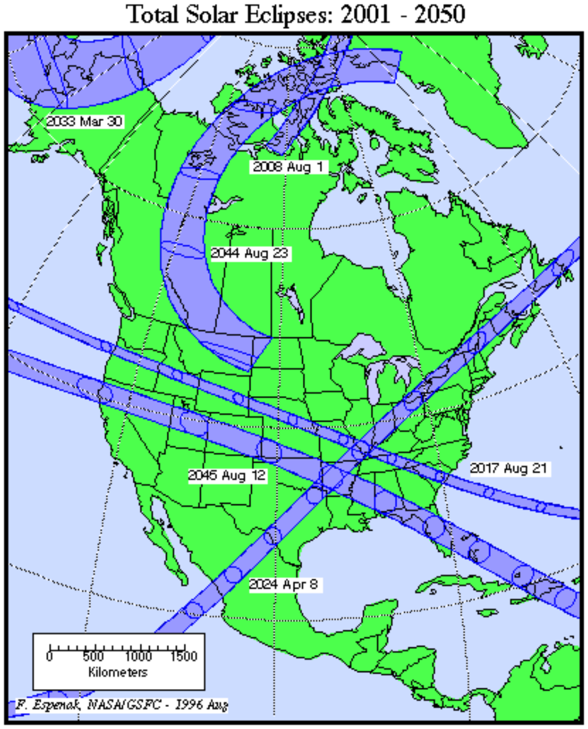
HOW TO **WATCH**

You can see the sun and the eclipse with special eclipse glasses. NEVER look directly at the sun without appropriate eyewear. Regular sunglasses are not safe to view the eclipse. More: *http://eclipse2017.nasa.gov/safety*

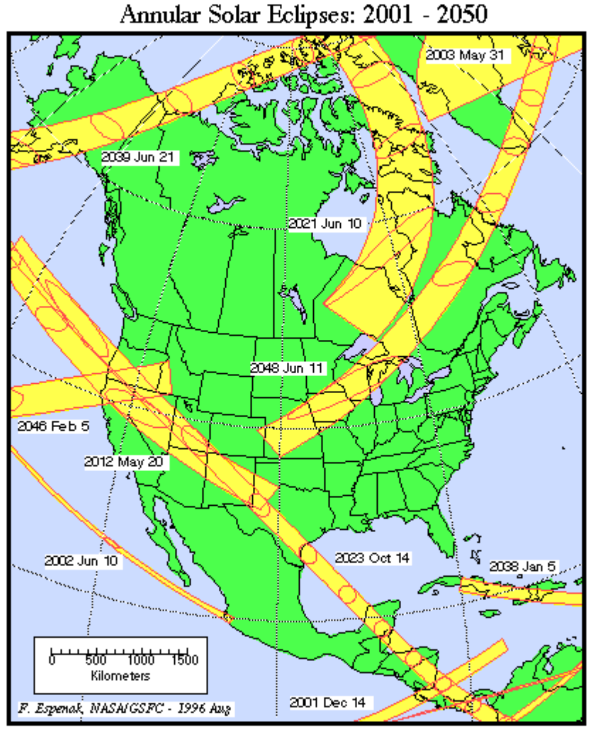
HOW LONG WILL IT LAST

The total eclipse, when the sun is completely blocked by the moon, will last up to 2 minutes and 40 seconds, depending on your location.

Total Solar Eclipses: 2001 - 2050



Annular Solar Eclipses: 2001 - 2050



SAFELY observing THE SUN

WARNING! Never look directly at the sun without proper eye protection. You can ***seriously*** injure your eyes.

Check with local science museums, schools and astronomy clubs for eclipse glasses—or purchase an ISO 12312-2 compliant pair of these special shades!

View the eclipse with special eclipse glasses.

Regular sunglasses are not safe to view the eclipse.

SUN FUNNEL

Inexpensive and easy to build, the sun funnel is a device that completely encloses the light coming from a telescope and projects a magnified image of the sun, large enough for many people to view at once.

http://eclipse2017.nasa.gov/make-sun-funnel

STRANGE SHADOWS!

Copyright © Elisa J. Israel

Sunlig[illegible]clipse funnels through tree leaves to project images of crescents on the ground.

ECLIPSE DETAILS FOR CITIES IN THE PATH OF TOTALITY

	Eclipse Begins	Totality Begins	Totality Ends	Eclipse Ends	
Madras, OR	09:06:43	10:19:36	10:21:38	11:41:06	PDT
Idaho Falls, ID	10:15:10	11:33:04	11:34:48	12:58:05	MDT
Casper, WY	10:22:21	11:42:44	11:45:09	01:09:30	MDT
Lincoln, NE	11:37:16	01:02:40	01:03:48	02:29:46	CDT
Jefferson City, MO	11:46:07	01:13:07	01:15:38	02:41:05	CDT
Carbondale, IL	11:52:25	01:20:06	01:22:41	02:47:25	CDT
Paducah, KY	11:54:03	01:22:16	01:24:38	02:49:32	CDT
Nashville, TN	11:58:31	01:27:25	01:29:23	02:54:02	CDT
Clayton, GA	01:06:59	02:35:49	02:38:23	04:01:27	EDT
Columbia, SC	01:13:08	02:41:51	02:44:21	04:06:21	EDT

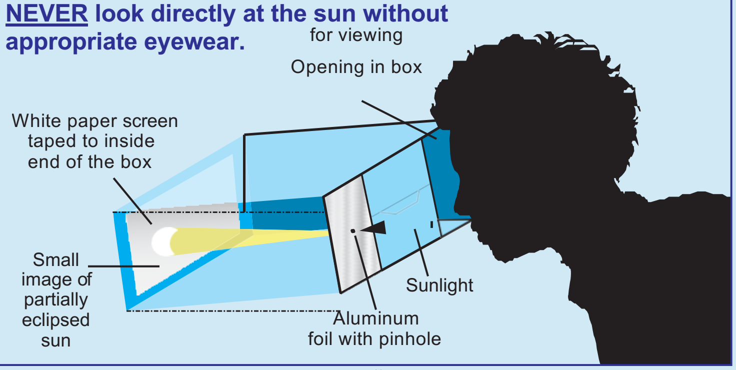
Seconds may vary depending on your location. View the interactive map for more information: *https://eclipse2017.nasa.gov/sites/default/files/interactive_map/index.html*

MAKE YOUR OWN ECLIPSE PROJECTOR

You can make this simple eclipse projector with almost any cardboard box, paper, tape and foil.

The longer the distance from the pinhole to screen, the larger the image of the sun will be.

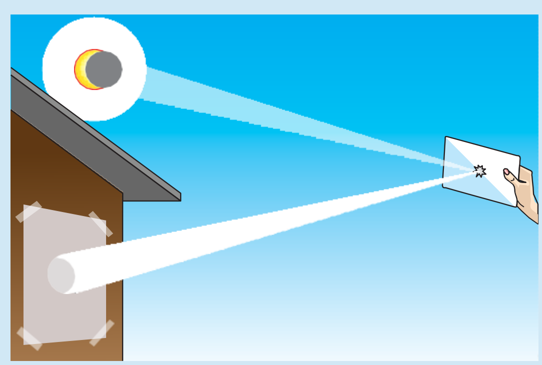
<u>NEVER</u> look directly at the sun without appropriate eyewear.



MIRROR IN AN ENVELOPE

S de a m rror nto an enve ope w th a ragged ho e about 5 8 nch (1 5 cm) cut nto the front. Point the mirror toward the sun so that an image is reflected onto a screen about 15 feet (5 meters) away. The longer the distance, the larger the image.

DO NOT LOOK AT THE MIRROR, ONLY AT THE SCREEN.



More on eclipses | *http://eclipse2017.nasa.gov* *http://www.nasa.gov/eclipse*

More on safe viewing of eclipses | *http://eclipse2017.nasa.gov/safety* *http://go.nasa.gov/2evRZBG*

FS-2016-10-508-GSFC (Rev 5/17)

AMERICAN ASTRONOMICAL SOCIETY | AMERICAN ACADEMY OF OPHTHALMOLOGY | NATIONAL AERONAUTICS AND SPACE ADMINISTRATION | AMERICAN ACADEMY OF OPTOMETRY | AMERICAN OPTOMETRIC ASSOCIATION | NATIONAL SCIENCE FOUNDATION

How to Safely View A Solar Eclipse

Credit: Rick Fienberg, TravelQuest International and Wilderness Travel

Looking directly at the sun is unsafe except during the brief total phase of a solar eclipse ("totality"), when the moon entirely blocks the sun's bright face, which will happen only within the narrow path of totality (https://go.nasa.gov/2pC0lhe).

The only safe way to look directly at the uneclipsed or partially eclipsed sun is through special-purpose solar filters, such as "eclipse glasses" (example shown at left) or hand-held solar viewers. Homemade filters or ordinary sunglasses, even very dark ones, are not safe for looking at the sun; they transmit thousands of times too much sunlight. Refer to the American Astronomical Society (AAS) Reputable Vendors of Solar Filters & Viewers page for a list of manufacturers and authorized dealers of eclipse glasses and handheld solar viewers verified to be compliant with the ISO 12312-2 international safety standard for such products.

- Always inspect your solar filter before use; if scratched or damaged, discard it. Read and follow any instructions printed on or packaged with the filter.
- Always supervise children using solar filters.
- Stand still and cover your eyes with your eclipse glasses or solar viewer before looking up at the bright sun. After looking at the sun, turn away and remove your filter — do not remove it while looking at the sun.
- Do not look at the uneclipsed or partially eclipsed sun through an unfiltered camera, telescope, binoculars, or other optical device.
- Similarly, do not look at the sun through a camera, a telescope, binoculars, or any other optical device while using your eclipse glasses or hand-held solar viewer — the concentrated solar rays will damage the filter and enter your eye(s), causing serious injury.
- Seek expert advice from an astronomer before using a solar filter with a camera, a telescope, binoculars, or any other optical device. Note that solar filters must be attached to the front of any telescope, binoculars, camera lens, or other optics.
- If you are within the path of totality (https://go.nasa.gov/2pC0lhe), remove your solar filter only when the moon completely covers the sun's bright face and it suddenly gets quite dark. Experience totality, then, as soon as the bright sun begins to reappear, replace your solar viewer to look at the remaining partial phases.
- Outside the path of totality, you must always use a safe solar filter to view the sun directly.
- If you normally wear eyeglasses, keep them on. Put your eclipse glasses on over them, or hold your handheld viewer in front of them.

Note: If your eclipse glasses or viewers are compliant with the ISO 12312-2 safety standard, you may look at the uneclipsed or partially eclipsed Sun through them for as long as you wish. Furthermore, if the filters aren't scratched, punctured, or torn, you may reuse them indefinitely. Some glasses/viewers are printed with warnings stating that you shouldn't look through them for more than 3 minutes at a time and that you should discard them if they are more than 3 years old. Such warnings are outdated and do not apply to eclipse viewers compliant with the ISO 12312-2 standard adopted in 2015. To make sure you get (or got) your eclipse glasses/viewers from a supplier of ISO-compliant products, see the American Astronomical Society (AAS) Reputable Vendors of Solar Filters & Viewers page.

An alternative method for safe viewing of the partially eclipsed sun is pinhole projection. For example, cross the outstretched, slightly open fingers of one hand over the outstretched, slightly open fingers of the other, creating a waffle pattern. With your back to the sun, look at your hands' shadow on the ground. The little spaces between your fingers will project a grid of small images on the ground, showing the sun as a crescent during the partial phases of the eclipse. Or just look at the shadow of a leafy tree during the partial eclipse; you'll see the ground dappled with crescent Suns projected by the tiny spaces between the leaves.

A solar eclipse is one of nature's grandest spectacles. By following these simple rules, you can safely enjoy the view and be rewarded with memories to last a lifetime. More information:

eclipse.aas.org **eclipse2017.nasa.gov**

This document does not constitute medical advice. Readers with questions should contact a qualified eye-care professional. v.170702

National Aeronautics and Space Administration

Safety Tips for Viewing a Solar Eclipse

Extreme heat safety
http://bit.ly/28LXx6e

Camping health and safety
http://bit.ly/2eg3dNl

Car safety **(Fact Sheet for State and Local Departments of Transportation)**
http://bit.ly/2eZZstP

Food and drink safety
http://bit.ly/1gh22Bu

Protection against distracted driving
http://bit.ly/2eBRdp0

Preparing for hazards
http://bit.ly/1K9LC2u

Safeguard against biological hazards
http://bit.ly/2eg2lYQ

Crowd safety
http://bit.ly/2eZXOZa

Stay safe in the sun
http://bit.ly/1hz2dsF

Tips for hikers
http://bit.ly/2eg14Bf

MORE RESOURCES

Eye Safety:

It is never safe to look directly at the sun without a special purpose filter. The only exception is during a total solar eclipse, and then only for a few minutes when the moon completely blocks the sun. Safe solar filters can be purchased from more than one vendor, but care must be taken to be sure that the filters meet the ISO 12312-2 international standard. Eclipse glasses manufactured in the United States meet these standards, and can be found via the internet by searching on "eclipse glass manufacturers."

Eclipse Resource Guide:

A *Resource Guide to Exploring Eclipses in General and the August 21, 2017 Total Eclipse of the Sun* by Andrew Frak- noi, Astronomical Society of the Pacific. The *Eclipse Resource Guide* provides an extensive list of resources that in- cludes books, articles about the sun, eclipses and the 2017 eclipse, useful websites, sources of safe eclipse glass- es, interdisciplinary sites, and websites specifically about the 2017 eclipse. This is a treasure trove of information. Search for Eclipses at https://www.astrosociety.org

Night Sky Network:

The Night Sky Network is national network of more than 400 amateur astronomy clubs that conduct outreach activities for the public. Night Sky Network is sponsored by NASA and supported the Astronomical Society of the Pacific. You can find out about star parties, club meetings and other astronomy-related events in your region online. There are search tools that use your zip code to find contact information, and display event calendars at the Night Sky Network website. https://nightsky.jpl.nasa.gov/

American Astronomical Society:

The American Astronomical Society (AAS) is the professional organization of astronomers in the United States and be- yond. For the upcoming eclipse, the AAS has a special website to prepare all Americans for the upcoming eclipse. There are many resources available to help you prepare to view the eclipse from any location in the U.S. https://eclipse.aas.org/

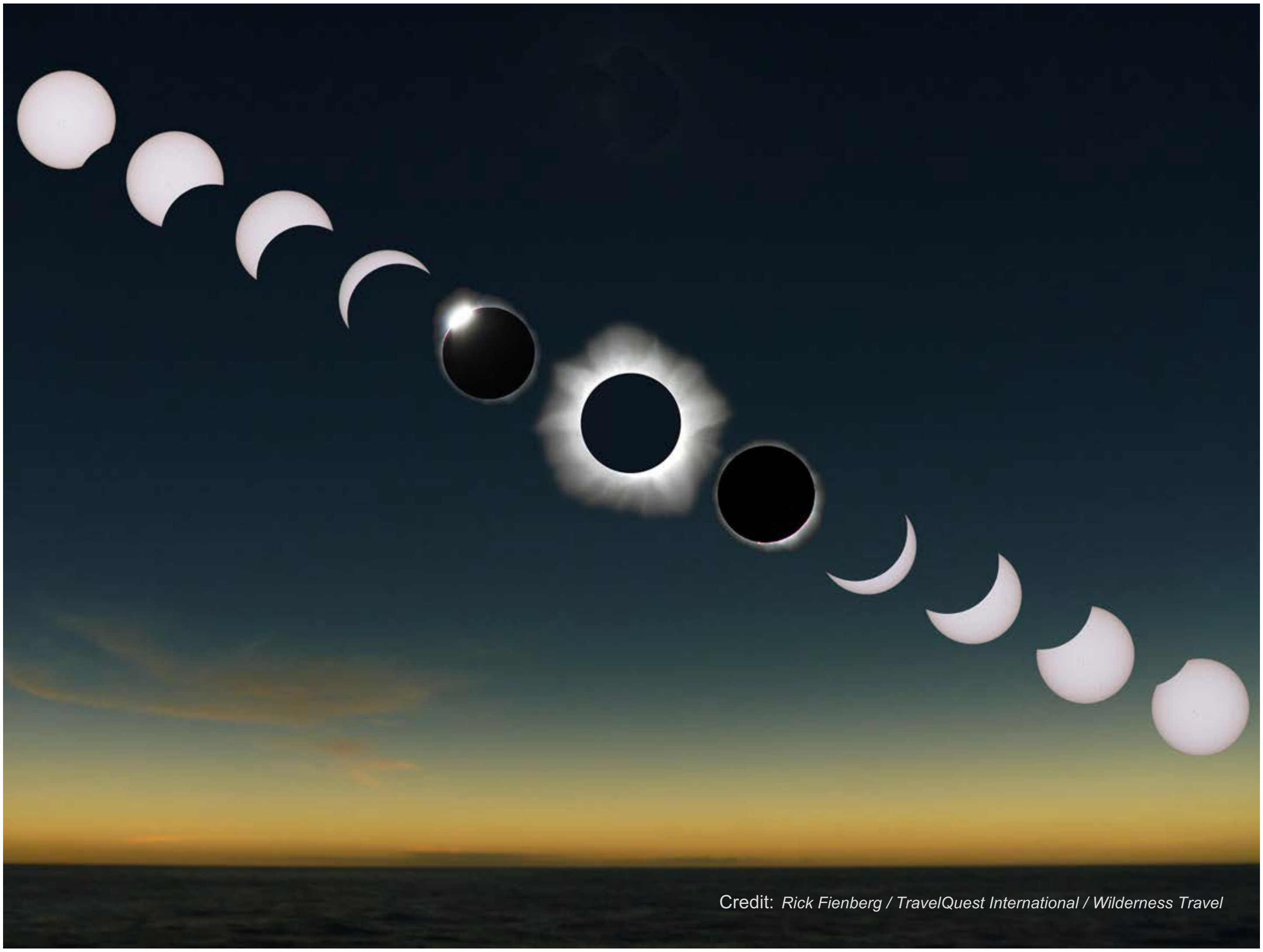
All-American Total Solar Eclipse:

Download this 8-page observing guide ideal for sharing with middle-school students and their families as well as with community leaders. It is adapted from the book *Solar Science: Exploring Sunspots, Seasons, Eclipses, and More* written by award-winning science educators Dennis Schatz and Andrew Fraknoi and published by the National Science Teachers Association. The guide summarizes where and when to see the eclipse across North America, how to observe it safely, and how to understand and explain what causes it. https://eclipse.aas.org/resources/downloads

COMPLETE LIST OF MATERIALS

ACTIVITY OR RESOURCE	PAGES	REUSABLE MATERIALS	MATERIALS YOU PROVIDE
1. LIVING IN A BUBBLE: PLAY WITH MAGNETS AND COMPASSES	6-7	Magnets and compasses	Paper, tape, pens or pencils
2. SUNBURN: ULTRAVIOLET LIGHT DETECTORS	8-9	500 UV beads and 100 chenille stems (These will need to be restocked in the box.)	Sunscreen, sunglasses, regular glasses, paper, cloth, hats, plastic, window glass water
3. SEEING THE INVISIBLE: INFRARED LIGHT DETECTORS	10-11	NASA Lithograph: Infrared Astronomy: More Than Our Eyes Can See.	Smartphones, digital cameras, remote controls for TV and other devices
4. LET'S SEE LIGHT IN A NEW WAY: DIFFRACTION SPECTRA	12-13	10 spectroscopes	White paper, and various light sources
5. A LIGHT SNACK: COOKIE BOX SPECTROMETERS	14-17	None	Boxes (cookie, cereal, shoe boxes), scissors, tape pens, black electrical tape (optional), and diffraction grating slides, light sources
6. MAKE SUN S'MORES!	18-19	12 oven thermometers	Boxes with closable lids, box knives or scissors, aluminum foil, clear plastic wrap, ruler or straight edge, glue stick, tape, Sunny location, pie tin, large marshmal-lows, plain chocolate bars (thin) napkins
7. HOW BIG IS BIG? SOLAR PIZZAS	20-21	Solar pizza—cardboard sun and tiny Earth	Measuring tape to measure up to 65 feet
8. EARTH AS A PEPPERCORN: SIZE AND SCALE OF THE SOLAR SYSTEM	22-23	Index cards	Objects to represent planets
9. SUN TRACKING	24-25	None	Pole or stick, sunny day outdoors, rocks or other markers. sun clocks: scissors, string and print copies of sun clocks on cardstock
10. WAXING AND WANING: PHASES OF THE MOON AND ECLIPSES	26-27	20 moon balls, 1.5" in diameter	20 pencils or skewers or short sticks (handles for moon balls), darkened room, single light bulb (clear and 40-60 Watts), tape to safely tape lamp cord to floor.
11. HOW DO ECLIPSES WORK? YARDSTICK ECLIPSE	28-29	5 folding yardsticks, 20 small binder clips, 5 - 1" balls (Earths), 5 - 1/4" beads (moons), 10 large toothpicks	Index cards (as screens). Hands or other paper works too.
12. WHEN DAY TURNS TO NIGHT: MEASURING LIGHT LEVELS AND TEMPERATURE	30-31	Digital thermometers	Smartphones with downloaded apps to measure light levels, string and tape to make a holder for the thermometers, pa-per or notebook, pencils or pens, outdoor location
13. MAKE AN ECLIPSE VIEWER	32-33	None	Cardboard boxes, opaque tape, aluminum foil, pin, white paper, scissors or box knife, outdoor location
14. ECLIPSE CHALK ART	34-35	None	Smooth cardstock paper (dark color—blue or black), white chalk, pencil, scissors masking tape, file folders or cereal boxes to cut up for templates, construction paper or foam sheets for cut-out horizon details

NOTES



Credit: *Rick Fienberg / TravelQuest International / Wilderness Travel*

Multiple images combined show the progress of the total solar eclipse of November 14, 2012, as seen from aboard a cruise ship in the South Pacific. The lower right image of the sun was taken first and the upper left image was taken last. During the partial phases before and after totality, the camera lens was covered by a safe solar filter. No filter was used during totality, which is about as bright as the full moon and just as safe to look at. The background is an unfiltered view of the ocean and sky during totality, showing sunrise/sunset colors along the horizon.

SOLAR ECLIPSE
ACROSS
AMERICA

Annular:
Sat, Oct 14, 2023

Total:
Mon, Apr 8, 2024

Credit: Evan Zucker / eclipse.aas.org