Annular Eclipse Training Resources

If you would like an editable PowerPoint (.pptx) version of this presentation, it is available in a Google Drive folder linked below, which also includes resources about using the training that aren't in this PDF. We encourage you to make your own copy of the folder and its contents. The Google Drive folder contains:

- Instructions with information about the resources in the folder and their intended use.
- An editable slide deck with content on eclipse safety, science, and engagement opportunities. (You are welcome to use the presentation as is, adapt it to your needs, or pick and choose content as needed.) The presentation also includes videos and animations that aren't visible in this PDF.
- A Google doc with compiled links to additional resources.
- A Google doc with sample questions to solicit feedback from your participants.
- A Google doc with a link to an eclipse question bank that will help you evaluate your eclipse lessons, and help NASA improve their educational resources.

The link below also includes an optional survey, which Oregon State University, in partnership with the NASA Heliophysics Education Activation Team (NASA HEAT), will use to understand the impact of this training and help guide future development of education and training materials.

To access the Google Drive folder of Annular Eclipse Training Resources and to take the survey, click the following link: https://oregonstate.qualtrics.com/jfe/form/SV_9ubU3t00Sq6yYnQ


ECLIPSE
2023 THROUGH THE EYES OF NASA
National Aeronautics and
Space Administration
NASA
Annular Solar
Eclipse Training
www.nasa.gov

Training Overview

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Part 1:
Welcome

Welcome to NASA's Annular Solar Eclipse Training

Credit: NASA/Bill Ingalls

During an annular solar eclipse the Moon covers the Sun, but because the Moon is farther from Earth than average, it appears smaller it doesn't cover the Sun completely.

On **Saturday, October 14, 2023**, nine U.S. states are in the path of annularity. All 48 contiguous states plus parts of Alaska will experience a partial solar eclipse. This annular solar eclipse will cross North, Central, and South America.

Credit: NASA/Bill Dunford

Welcome to the Annular Solar Eclipse Training

Acknowledgments

NASA Heliophysics Education Activation Team (NASA HEAT) is providing eclipse support.

POC: Dr. Michael S. Kirk, michael.s.kirk@nasa.gov

Find More: solarsystem.nasa.gov/eclipses/2023

This product is supported by the NASA Heliophysics Education Activation Team (NASA HEAT), part of NASA's Science Activation portfolio.

Part 2:
Science, Safety, and Engagement During the 2023 Annular Solar Eclipse

Lessons

Lesson 1: Eclipse Viewing Safety

Lesson 2: Eclipse Basics: What Is an Annular Eclipse?

Lesson 3: NASA's Priorities and Key Messages for the 2023 Eclipse

Lesson 1:
Eclipse Viewing Safety

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

Learning Objectives

By the end of this lesson, you will be able to answer the following questions:

Credit: JAXA/NASA

2023 Annular Solar Eclipse Safety

Observing the annular solar eclipse without eye protection can cause permanent eye damage. You will need to follow safety precautions and use special safety equipment to safely experience the eclipse.

For an annular solar eclipse it is not safe to remove eye protection at any phase, because this type of eclipse does not block the entire view of the Sun like a total eclipse does.

Use only eclipse glasses from reputable manufacturers that are verified to meet the **ISO 12312-2 international standard**.

Before each use, check the front and back of each lens for scratches, pinholes, or separation from the frame. If damaged, cut into small pieces and discard.

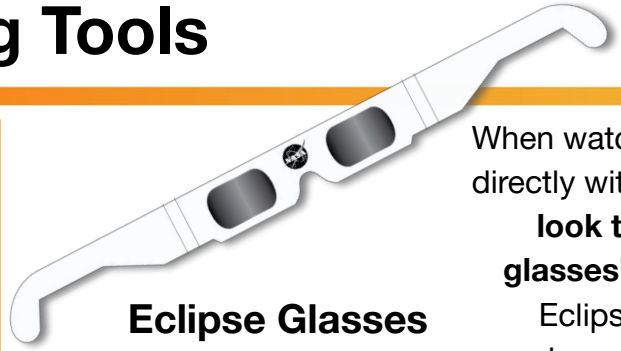
Credit: NASA

Employees and visitors at NASA Headquarters put on eclipse glasses to watch a partial eclipse in Washington, DC.

Eclipse Viewing Tools

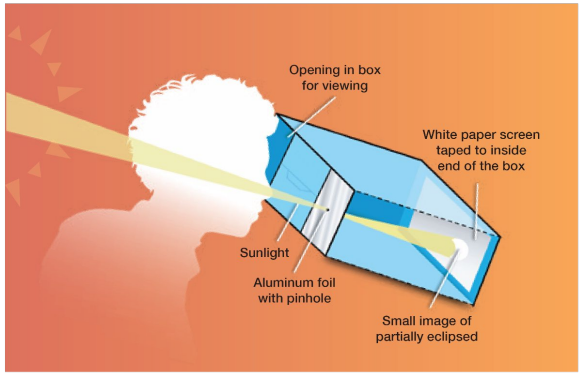
Credit: NASA/Bridget Caswell

A young eclipse viewer experiences the August 21, 2017, total solar eclipse in Cleveland, Ohio, using protective glasses.



Eclipse Glasses

When watching a partial solar eclipse or annular solar eclipse directly without other specialty viewing equipment, **you must look through safe solar viewing glasses ("eclipse glasses") or a safe handheld solar viewer at all times**. Eclipse glasses are NOT regular sunglasses; regular sunglasses, no matter how dark, are not safe for viewing the Sun. Safe solar viewers are thousands of times darker and must comply with the ISO 12312-2 international standard.



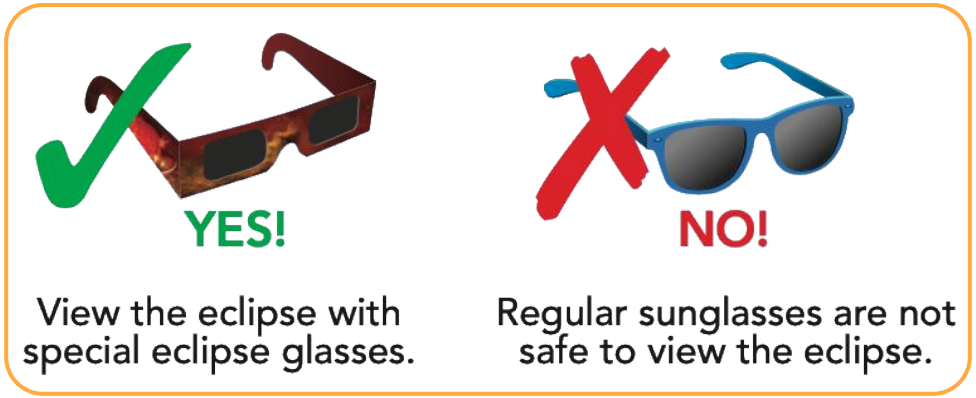
You can make your own eclipse projector with almost any cardboard box, paper, tape, and foil. The longer the distance from the pinhole to screen, the larger the image of the Sun will be.

Indirect Viewing Methods

If you don't have eclipse glasses or a handheld solar viewer, **you can use an indirect method, such as pinhole projection, in which you pass sunlight through a small opening** (for example, a hole punched in an index card) and project an image of the Sun onto a nearby surface. Do NOT look at the Sun through the pinhole!

Eclipse Glasses

- You can look at the Sun and a solar eclipse through safe solar viewing glasses ("eclipse glasses") or other safe solar filter at any time. You can try out your eclipse glasses today!
- NEVER look directly at the uneclipsed or partially eclipsed Sun without appropriate eye protection. Sunglasses are not safe for viewing a solar eclipse or the Sun.
- **Do NOT use eclipse glasses or handheld viewers with cameras, binoculars, or telescopes.** Those require different types of solar filters.



Find More: go.nasa.gov/EclipseEyeSafety

Credit: NASA/Shannon Reed

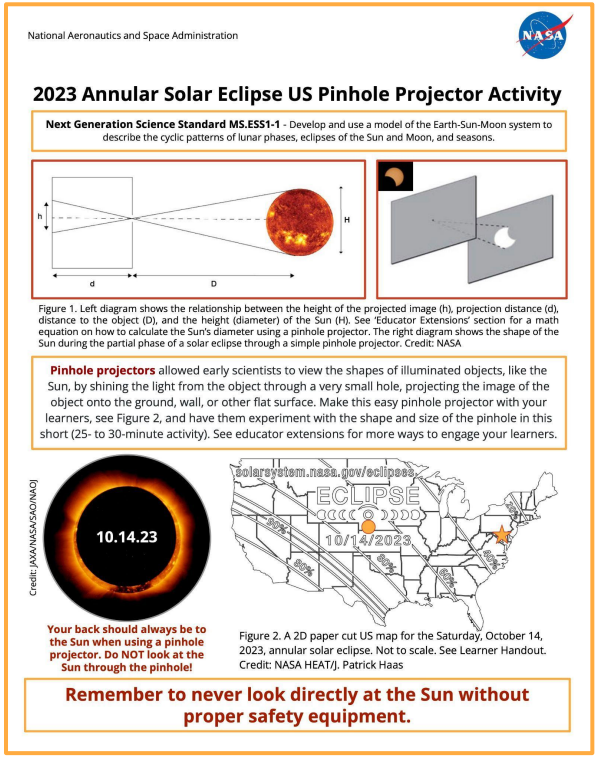
Feel free to decorate your eclipse glasses! This tiara add-on was created using heavy cardstock, scissors, markers, tape, and ribbon.

Safe Indirect Viewing Method

Pinhole projectors allowed early scientists to view the shapes of illuminated objects, like the Sun, by shining the light from the object through a very small hole, projecting the image of the object onto the ground, wall, or other flat surface. A pinhole projector is a great method for safe solar viewing. When using it, make sure the Sun is always behind you.

Credit: NASA HEAT/J. Patrick Haas

You can learn how to make your own pinhole projector like the activity at this link: nasa3d.arc.nasa.gov/detail/usa-eclipse-2023



National Aeronautics and Space Administration

2023 Annular Solar Eclipse US Pinhole Projector Activity

Next Generation Science Standard MS.ESS1-1 - Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.

Figure 1. Left diagram shows the relationship between the height of the projected image (h), projection distance (d), distance to the object (D), and the height (diameter) of the Sun (H). See 'Educator Extensions' section for a math equation on how to calculate the Sun's diameter using a pinhole projector. The right diagram shows the shape of the Sun during the partial phase of a solar eclipse through a simple pinhole projector. Credit: NASA

Pinhole projectors allowed early scientists to view the shapes of illuminated objects, like the Sun, by shining the light from the object through a very small hole, projecting the image of the object onto the ground, wall, or other flat surface. Make this easy pinhole projector with your learners, see Figure 2, and have them experiment with the shape and size of the pinhole in this short (25- to 30-minute activity). See educator extensions for more ways to engage your learners.

Credit: JAXA/NASA/SKO/NAOJ

10.14.23

Your back should always be to the Sun when using a pinhole projector. Do NOT look at the Sun through the pinhole!

solarsystem.nasa.gov/eclipses

ECLIPSE

10/14/2023

Figure 2. A 2D paper cut US map for the Saturday, October 14, 2023, annular solar eclipse. Not to scale. See Learner Handout. Credit: NASA HEAT/J. Patrick Haas

Remember to never look directly at the Sun without proper safety equipment.

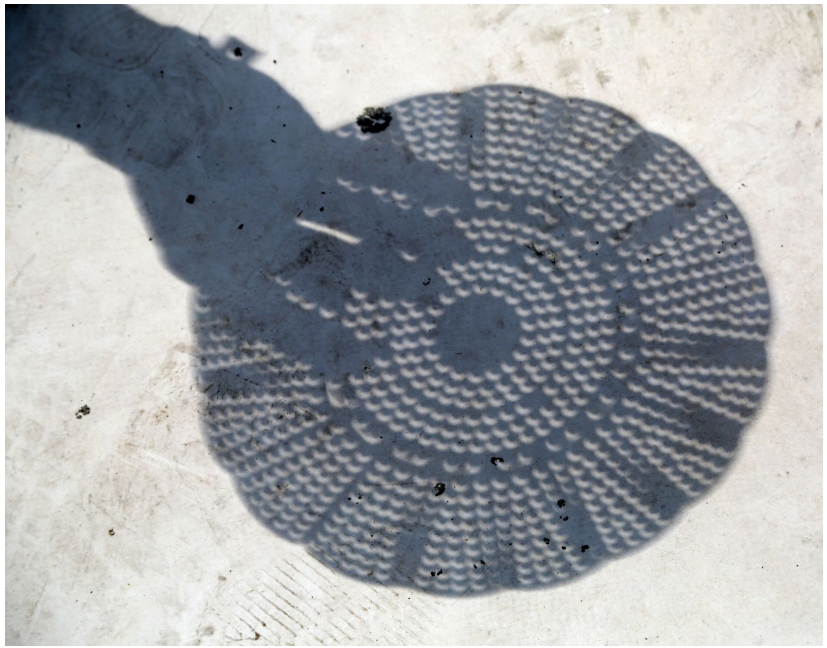
Credit: NASA HEAT/J. Patrick Haas

More Safe Indirect Viewing Methods

Credit: AAS

Project images of the Sun using your hands.

If you do not have eclipse glasses or a pinhole projector, you can improvise other safe indirect viewing methods.



Credit: NASA/Joy Ng

Pull out a colander from your kitchen, and with the Sun to your back, watch the projections of the eclipse on the ground.

Knowledge Check

1. How can you safely view the annular solar eclipse? Select all that apply.
   a. Eclipse glasses
   b. Sunglasses
   c. Pinhole projector
   d. Solar filter

2. Which of the following is NOT considered a proper safety precaution to take while viewing an annular solar eclipse?
   a. Viewing the eclipse with a pinhole projector
   b. Using a colander to project the eclipse on the sidewalk
   c. Wearing sunglasses or ski goggles to view the eclipse

3. True or false? You should keep your eclipses glasses on during all phases of the annular solar eclipse.

Knowledge Check - Answers

1. How can you safely view the annular solar eclipse?
   - **a. Eclipse glasses**
   - **c. Pinhole projector**
   - **d. Solar filter**

   (Eclipse glasses, pinhole projects, and solar filters can be used to safely view the annular solar eclipse. Eclipse glasses are NOT regular sunglasses; regular sunglasses, no matter how dark, are not safe for viewing the Sun. Safe solar viewers are thousands of times darker and must comply with the ISO 12312-2 international standard.)
2. Which of the following is NOT considered a proper safety precaution to take while viewing an annular solar eclipse?

   c. Wearing sunglasses or ski goggles to view the eclipse

   (Neither of these are considered proper eyewear for viewing the eclipse.)
3. You should keep your eclipses glasses on during all phases of the annular solar eclipse. **TRUE**

   (During an annular solar eclipse the Moon does not completely cover the Sun; thus you must use eye projection during all phases of an annular eclipse. You may remember from 2017 that people observing the eclipse in the path of totality were able to remove eclipse glasses during totality. For an annular solar eclipse it is not safe to remove eclipse glasses at any phase, because this type of eclipse does not completely cover the Sun like a total eclipse does.)

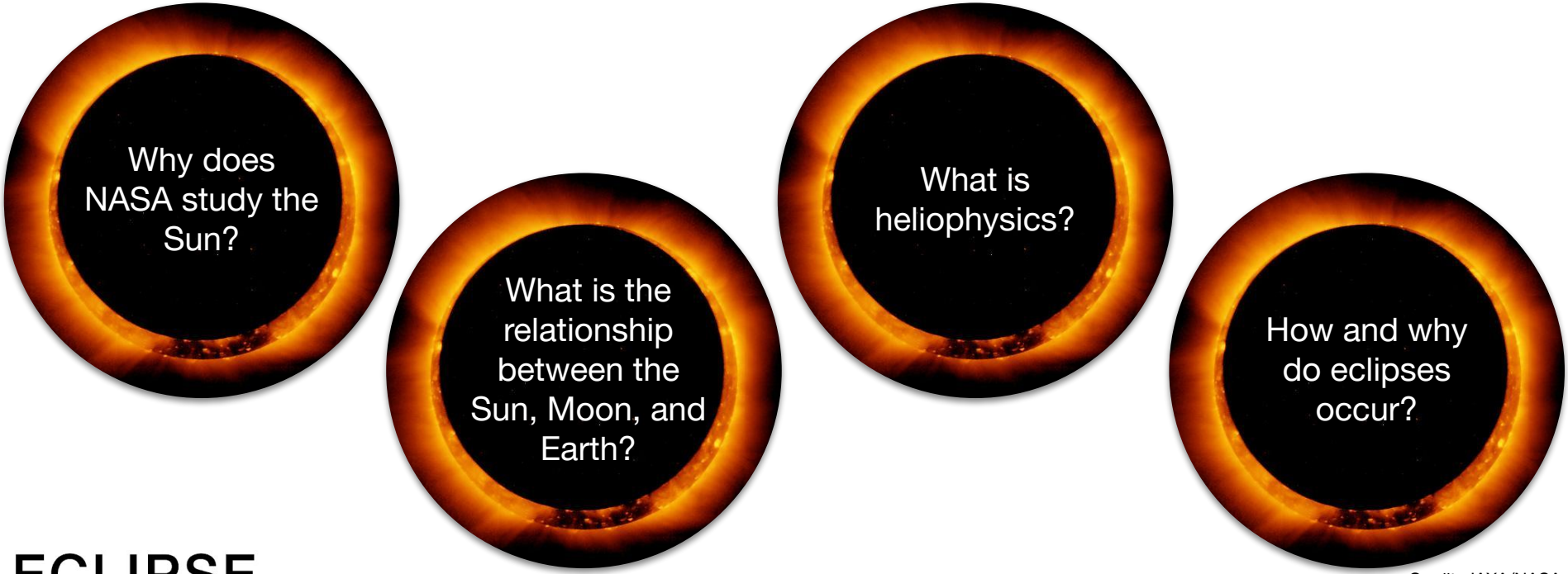
Lesson 2:

Eclipse Basics: What Is an Annular Solar Eclipse?

Photographed view of an annular eclipse.
Credit: NASA/Bill Dunford

Learning Objectives

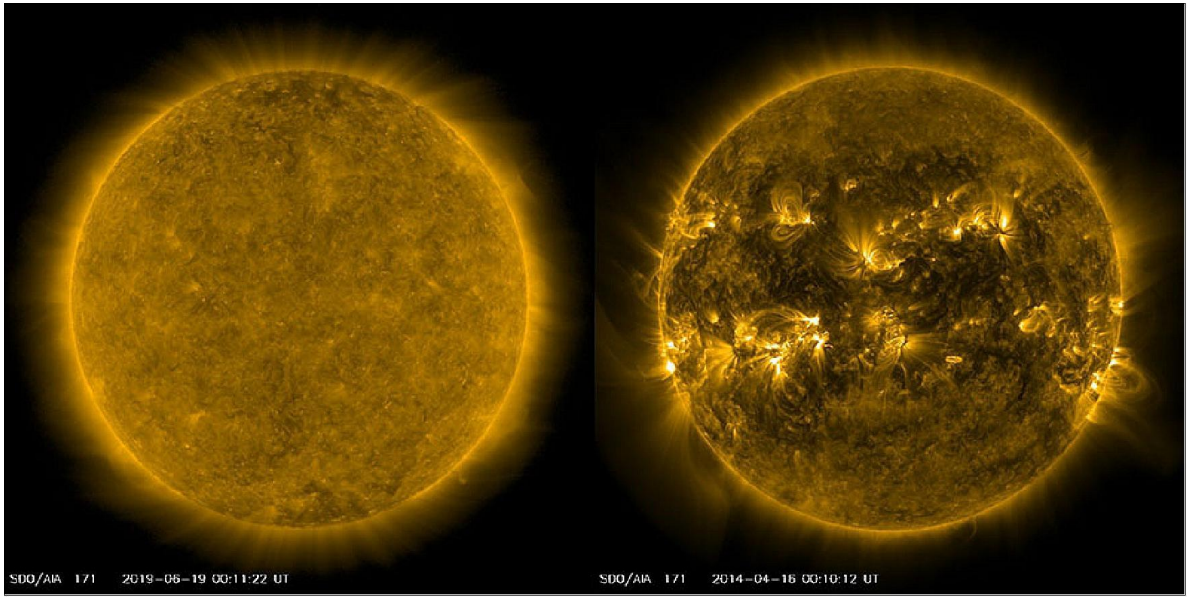
By the end of this lesson, you will be able to address the following:



Credit: JAXA/NASA

What Is the Sun? It's a Star!

Studying the Sun is not only about its distance, size, mass, and amount of light, but it's a dynamic star. "It's alive every second," says Nour Raouafi, Project Scientist for NASA's Parker Solar Probe at Johns Hopkins University Applied Physics Laboratory.



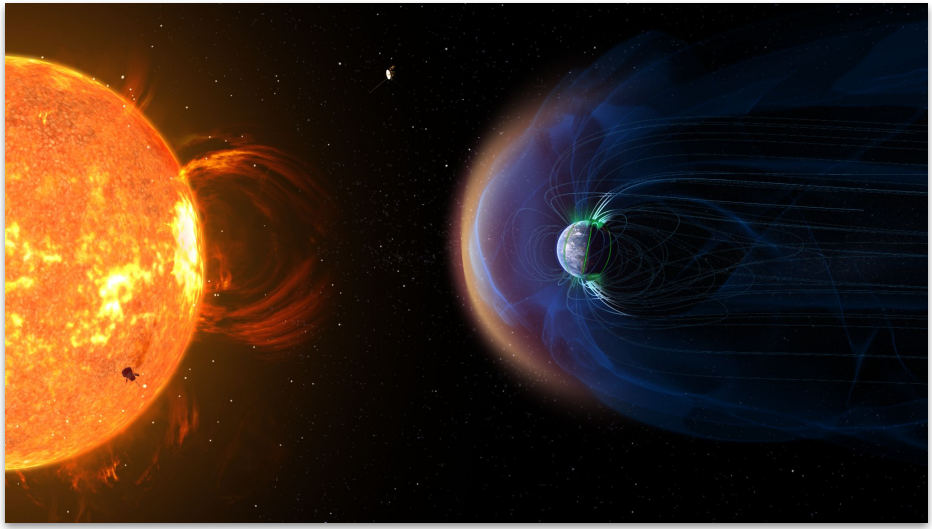
Credit: NASA SDO/AIA

Images from NASA's Solar Dynamics Observatory highlight the appearance of the Sun at solar minimum (left, December 2019) versus solar maximum (right, April 2014).

The Sun goes through cycles. Each cycle lasts approximately 11 years from minimum activity to maximum and back to minimum again. The last solar minimum was in December 2019, and the next solar maximum is forecasted to be in mid-2025.

The Sun-Earth Relationship

Our Sun and Earth have a special relationship. The Sun heats Earth just enough to make it habitable for humans and is the origin of nearly all the energy necessary for life.



Credit: NASA Conceptual Image Lab/NASA HEAT

- Our Sun and Earth: The Sun is responsible for almost all the heat that exists on Earth but does not cause the seasons. Seasons occur because of the tilt of Earth's axis of rotation.
- Our Sun and Space Weather: Space weather and solar storms originate from the corona, the Sun's outer atmosphere, and are deflected by Earth's atmosphere and magnetic field.
- Our Sun and Solar System: The plasma coming from the Sun defines our solar system and affects every planet.

Heliophysics is the study of our star, the Sun [helio], understanding why it behaves the way it does [physics], and how it affects everything in the solar system – especially Earth's atmosphere.

What Is a Solar Eclipse?

Credit: NASA

A solar eclipse occurs when the Moon moves between the Sun and Earth during the New Moon phase, resulting in the Moon casting a shadow onto the surface of the Earth. The Moon will either partially or fully block the light of the Sun.

What Is an Annular Solar Eclipse?

On Saturday, October 14, 2023, many people in the U.S. will be able to see an **annular solar eclipse**.

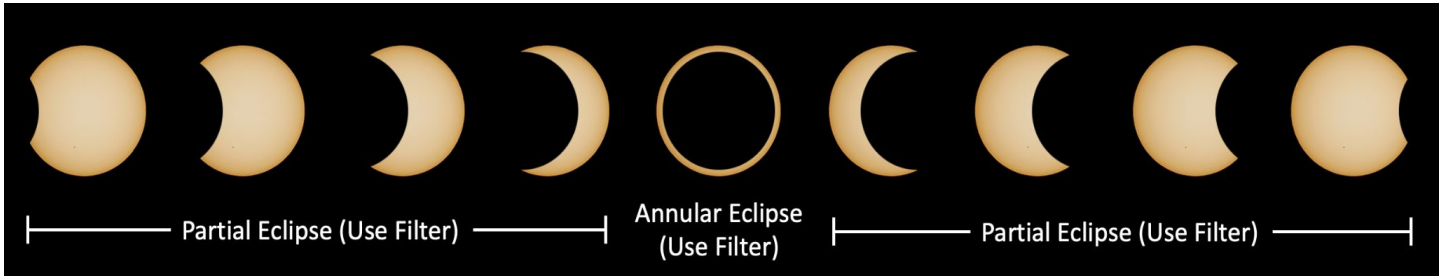
An annular solar eclipse happens when the Moon is farthest from Earth, appears smaller, and does not block the entire view of the Sun – creating a "ring of fire" around the Moon.

Left image: Photographed view of an annular eclipse. Right image: Annular solar eclipse seen by the Hinode spacecraft from orbit in 2022.

Credit: NASA/Bill Dunford

Credit: JAXA/NASA

Annular Solar Eclipse Phases



Credit: AAS

At all times during an annular or partial solar eclipse, or when no eclipse is occurring at all, view the Sun only through special-purpose solar filters that comply with the transmission requirements of the ISO 12312-2 standard.

1st contact - Partial eclipse begins	2nd contact - Full annularity starts	Maximum eclipse	3rd contact - Annularity ends	4th contact - Partial eclipse ends
The Moon touches the Sun and takes its first tiny nibble out of the solar disk.	The ring of fire appears. For a few seconds Baily's Beads, which look like beads of light, may be visible at the edge of the Moon's silhouette.	The Moon covers the central part of the Sun but not the entire solar disk. This lasts a few minutes.	The Moon starts moving away from the disk of the Sun. Once again, Baily's Beads may be visible along the Moon's edge.	The Moon no longer covers any part of the solar surface. The eclipse is officially over.

What Is the Difference Between an Annular and a Total Solar Eclipse?

On Saturday, October 14, 2023, viewers will experience an **annular solar eclipse**. You may also be familiar with a total solar eclipse. We experienced this in the U.S. in 2017 and will experience this again on Monday, April 8, 2024.*

Credit: NASA/MSFC/Joseph Matus

Credit: NASA/Bill Dunford

Credit: NASA/Bill Ingalls

There is a key difference between these solar eclipses. During an annular solar eclipse, the Moon is farther away. It does not block the entire view of the Sun. During a total solar eclipse, the Moon blocks the entire Sun. **Find More:** solarsystem.nasa.gov/eclipses/2023

From left to right, these images show a total solar eclipse, annular solar eclipse, and partial solar eclipse. A hybrid eclipse appears as either a total or an annular eclipse (the left and middle images), depending on the observer's location.

There are other types of eclipses called lunar eclipses. Find More: moon.nasa.gov/moon-in-motion/eclipses

Credit: NASA/SVS

*An additional training will be held prior to the 2024 total solar eclipse. That training will cover topics specific to the 2024 total solar eclipse.

Explore NASA's Eclipse Map

Credit: NASA

NASA's U.S. Eclipse Map for 2023 & 2024

Credit: Michala Garrison and NASA/SVS, in collaboration with the NASA Heliophysics Activation Team (NASA HEAT), part of NASA's Science Activation portfolio. Eclipse calculations by Ernie Wright, NASA Goddard Space Flight Center.

Find More: svs.gsfc.nasa.gov/5073

Why Isn’t There an Eclipse Every Month?

This animation illustrates how the tilt of the Moon’s orbit often keeps it out of alignment with the Sun and Earth, preventing frequent eclipses. Credit: NASA

Knowledge Check

1. Which three characteristics most accurately describe the Sun? Select all that apply.
    a. The Sun is a star.
    b. The Sun is a planet.
    c. The Sun is responsible for almost all the heat on Earth.
    d. The Sun will likely be more active and dynamic this year than it was last year.
2. What is heliophysics? Select all that apply.
    a. The study of the Sun and how it changes.
    b. The study of the Sun-Earth relationship.
    c. The study of how the Earth's atmosphere is changed by the Sun.
    d. The study of how the Sun affects the solar system.
3. Why isn't there a solar eclipse every month?
    a. The Moon's orbit is tilted.
    b. The Moon is too far away.
    c. The Moon is too small.
    d. Because the eclipse was after sunset.
4. What needs to happen for an annular solar eclipse to occur? Select all that apply.
    a. The Moon passes between the Sun and Earth.
    b. There needs to be a full Moon.
    c. The Moon is at or near its farthest point from Earth.

Knowledge Check - Answers

1. Which three characteristics most accurately describe the Sun? Select all that apply.
    a. **The Sun is a star.**
    c. **The Sun is responsible for almost all the heat on Earth.**
    d. **The Sun will likely be more active and dynamic this year than it was last year.**
2. What is heliophysics? Select all that apply.
    a. **The study of the Sun and how it changes.**
    b. **The study of the Sun-Earth relationship.**
    c. **The study of how the Earth's atmosphere is changed by the Sun.**
    d. **The study of how the Sun affects the solar system.**
2. Why isn't there a solar eclipse every month?
    a. **The Moon's orbit is tilted.**
4. What needs to happen for an annular solar eclipse to occur? Select all that apply.
    b. **The Moon passes between the Sun and Earth.**
    c. **The Moon is at or near its farthest point from Earth.**

Lesson 3:
NASA's Priorities and Key Messages for the 2023 Eclipse

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

Learning Objectives

By the end of this lesson, you will be able to answer the following questions:

Credit: JAXA/NASA

NASA Observes Solar Eclipses

Eclipses aren't just beautiful – they're great for science. In addition to inspiring artists and musicians, eclipses have driven numerous scientific discoveries. **For over a century, solar eclipses have helped scientists decipher the Sun's structure and explosive events, find evidence for the theory of general relativity, and discover the element helium, among other things.**

Credit: NASA/Balloon Program Office

Suborbital sounding rockets and high-altitude scientific balloons are just two ways NASA studies eclipses. They carry instruments to study a variety of phenomena including the Sun's impact on Earth's upper atmosphere. Both will be launched during upcoming eclipses.

NASA Priorities for the 2023 Annular Eclipse

Safety	NASA's #1 core value and the #1 priority during any event
Broadening Participation	Inviting all voices to the conversation
Science	Awareness of missions, research, and new discoveries
Public Engagement	Unique opportunity to participate in a celestial event
Science Activation	Learners experience "doing" science
Citizen Science	Citizens gathering data for scientific analysis

Credit: National Park Service

A crowd uses handheld solar viewers and solar eclipse glasses to safely view a solar eclipse.

NASA Key Messages

1

Observing our star, the Sun, can be safe and inspirational.

2

Experiencing an eclipse is one way that everyone can participate in NASA science.

3

Innovative NASA missions help us learn about our closest star, the Sun, and its interactions with Earth.

NASA Key Messages

1. Observing our star, the Sun, can be safe and inspirational.

Annular Solar Eclipse: **Always wear eclipse glasses or use a solar filter when looking at an uneclipsed, partially eclipsed, or annularly eclipsed Sun**, such as during the annular solar eclipse on October 14, 2023. You can also use an alternative viewing method, such as a pinhole projector. Solar filters can be used at any time to safely view the Sun.

Time to reflect: Did you observe the 2017 total solar eclipse (or another eclipse)? How did you safely observe the eclipse?

- Eclipse glasses
- Pinhole projector
- Other methods
- I have not observed any solar eclipses

Credit: NASA/Josh Krohn

Employees and visitors at NASA's Jet Propulsion Laboratory stopped to watch the solar eclipse on Aug. 21, 2017.

NASA Key Messages

2. Experiencing an eclipse is one way that everyone can participate in NASA science.

a. Eclipses are a unique opportunity to participate in a celestial event.
b. Work together with NASA to make discoveries possible before, during, and after an eclipse.
c. Scientists can use partial or annular solar eclipses to study the Sun-Earth relationship, especially in Earth's atmosphere.
d. You do not have to be in the eclipse path to participate.

For more detailed information, see Part 4 of this training - Engaging the Public in Eclipse Activities

Credit: NASA TV

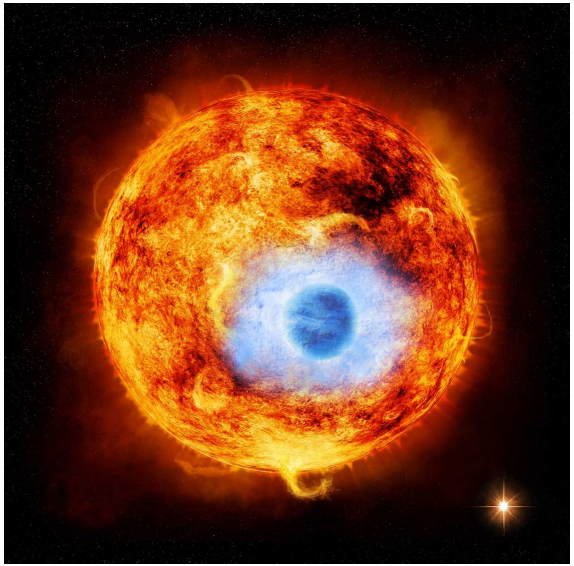
The Sun appears partially eclipsed in this image from 2017.

NASA Key Messages

3. Innovative NASA missions help us learn about our closest star, the Sun, and its interactions with Earth.

a. Ask questions about our closest star to learn how studying our Sun and its interactions with Earth is possible through innovative NASA missions. (See Part 3: NASA Eclipse Science)
b. Transits in other planetary systems help us find exoplanets around other stars; eclipses are a special type of transit found in our solar system.
c. Eclipses occur on Earth when the Sun, the Moon, and Earth line up, either fully or partially, providing exciting celestial events.
d. Advances in technology are allowing us to send spacecraft closer to the Sun than ever before, and even study the outer atmosphere of the Sun, the corona, from within it.
e. Particles and material ejected by the Sun pass through the corona and are accelerated into the solar system, interacting with Earth and the other planets to create space weather.

Artist's impression showing the HD 189733 system, containing a Sun-like star orbited by an exoplanet about the size of Jupiter.



Credit: NASA/CXC/M. Weiss

Knowledge Check

1. Which of the following statements align with NASA's key messages for the 2023 annular solar eclipse? Select one answer.
    a. NASA is studying the eclipse to understand the Sun-Earth relationship.
    b. Safely viewing the eclipse is possible with proper equipment and/or precautions.
    c. The eclipse is a great opportunity for the public to engage in NASA science.
    d. All of the above
2. True or false? The public can only engage in NASA eclipse activities if they are in the eclipse path.
3. True or false? By observing the eclipse on our own planet, NASA scientists can learn how to observe eclipses in other planetary systems.

Knowledge Check - Answers

1. Which of the following statements align with NASA's key messages for the 2023 annular solar eclipse?
   d. - All of the above
2. The public can only engage in NASA eclipse activities if they are in the eclipse path. **FALSE**
   - If you can travel to a location within the narrow path of annularity (from Oregon to Texas to Central America and northern South America) and the weather is good, you will see a "ring of fire" on October 14, 2023. However, everyone in the contiguous 48 states will see a partial eclipse. Find More: solarsystem.nasa.gov/eclipses/2023
3. By observing the eclipse on our own planet, NASA scientists can learn how to observe eclipses in other planetary systems. **TRUE**
   - Eclipses will never happen on Mercury or Venus, as they have no moons. Mars has two moons, but the sizes of those moons are too small for total solar eclipses. Partial eclipses on the Red Planet are still possible and happen frequently. NASA's Perseverance rover captured a video of a solar eclipse on Mars on April 20, 2022.
   - Jupiter, Saturn, Uranus, and Neptune join Earth in being capable of total solar eclipses. They have large enough moons at the correct distances to block the sunlight needed for an eclipse.
   - Transits aren't caused only by planets, exoplanets, asteroids, and moons. During Kepler's mission, the spacecraft has been able to observe transits not only between planets and stars, but also between stars and other stars.
   - Astronomers can also look for transits occurring in distant star systems to reveal information about alien worlds many light-years away.

Part 3:
NASA Eclipse Science

Lessons

Lesson 1: Science Done Using Eclipses

Lesson 2: The Sun-Earth-Moon Relationship and the 2023 Annular Solar Eclipse

Lesson 3: What Do NASA Missions Learn About the Sun?

Lesson 1:
Science Done Using Eclipses

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

What Can We Learn From Eclipses?

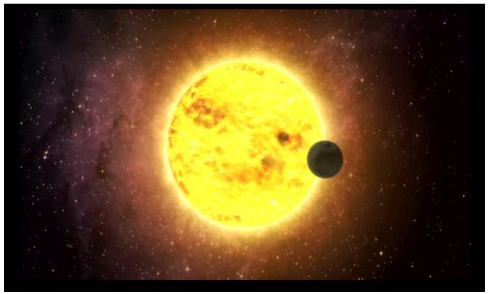
- Solar eclipses provide an opportunity to study Earth’s atmosphere under uncommon conditions.
- Eclipses have historically allowed scientists to experimentally prove Einstein's Theory of Relativity and, more recently, to map continuous solar structures from the Sun’s surface deep into the solar system.
- Eclipses are a special type of transit, where one astronomical object blocks another. NASA uses transits to study the exoplanets orbiting around distant stars.
- Eclipses can help us better understand Earth's ionosphere, which is a very active part of the atmosphere, and it grows and shrinks depending on the energy it absorbs from the Sun. Understanding this region is important because it’s home to many low Earth orbit satellites as well as communications signals, and changes there can have significant impacts on our technology and communication systems.

Credit: NASA/JPL-Caltech/Malin Space Science Systems/Texas A&M Univ.

NASA’s Mars Curiosity rover viewed an eclipse of the Sun by Phobos on Aug. 20, 2013.

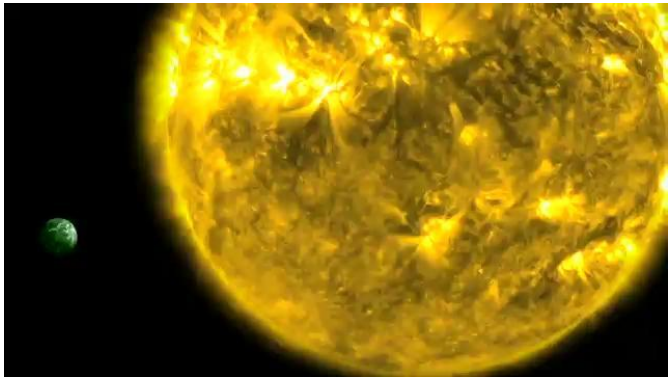
Finding Exoplanets Through Distant Eclipses

Scientists can apply the knowledge gained from our careful observations of brightness changes of the Sun during eclipses to better understand the characteristics of exoplanetary systems.



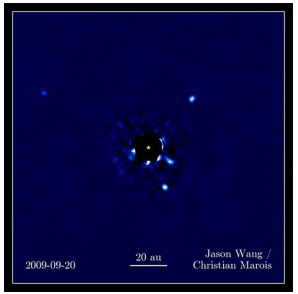
Credit: NASA GSFC

Transits of planets around distant stars are one way astronomers can detect these extrasolar planets.



Credit: NASA

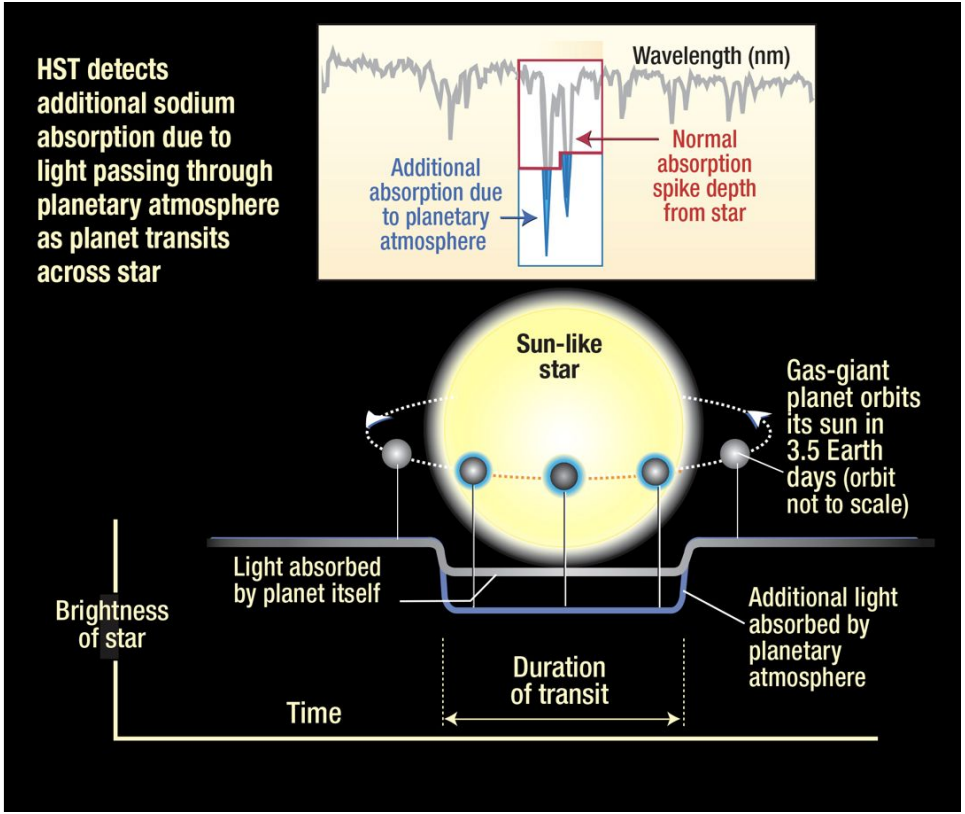
When a planet crosses directly between us and its star, we see the star dim slightly because the planet is blocking out a portion of the light. We can make a plot called a light curve with the brightness of the star versus time. Using this plot, we can see what percentage of the star's light the planet blocks and how long it takes the planet to cross the disk of the star. Larger planets block out more light.



Credit: Jason Wang (UC Berkeley) & Christian Marois (NRC Canada), NExSS (NASA)

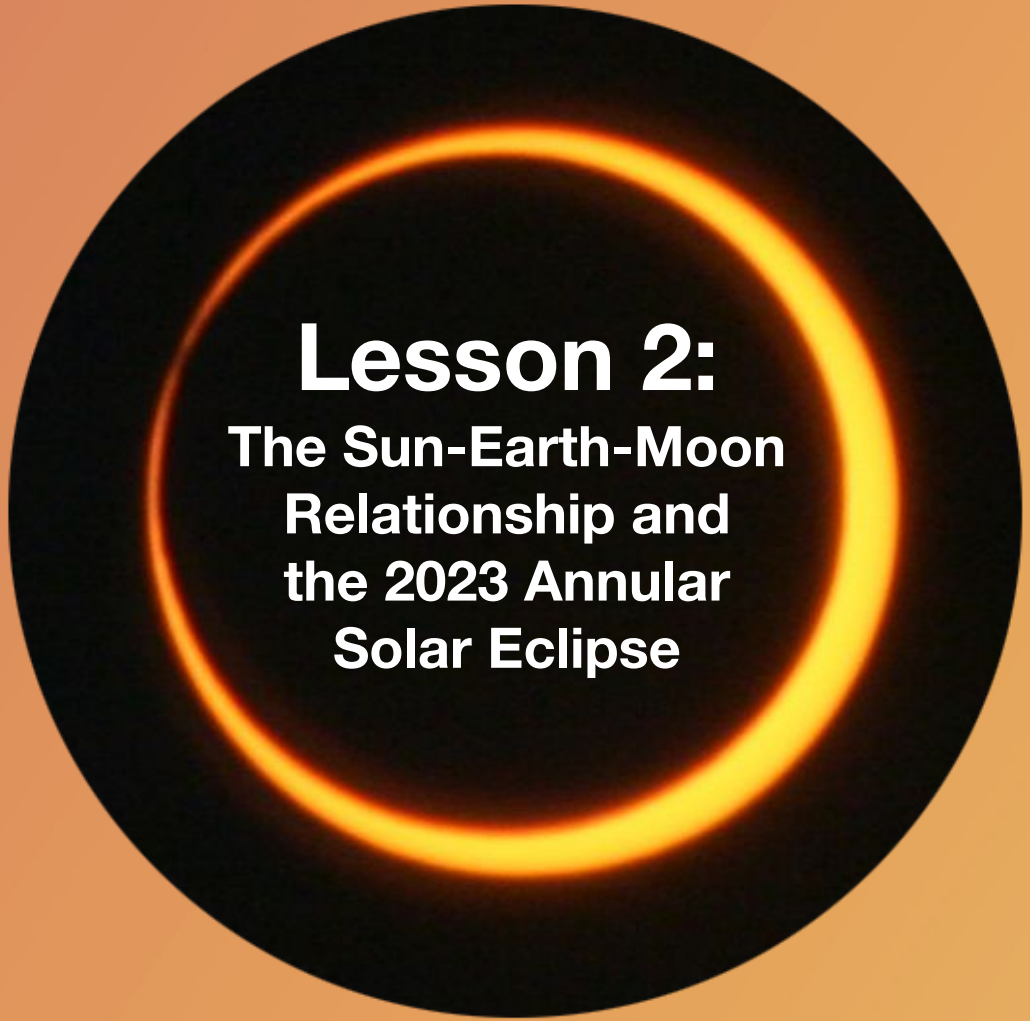
Four planets orbit the star HR 8799.

Understanding Exoplanets Through Eclipses



Credit: Space Telescope Science Institute/Ann Feild

In addition to transits of stars, planets can be studied by detecting gases through absorbed light in their much cooler atmospheres. Here sodium is detected in the atmosphere of a planet from Hubble Space Telescope (HST) spectral observations. This observation of HD 209458 (150 light-years away) in the constellation of Pegasus was the first direct detection of a planetary atmosphere outside our solar system.



Photograph of an annular eclipse
Credit: NASA/Bill Dunford

NASA Science for the 2023 Annular Solar Eclipse

During the annular solar eclipse various science experiments may be done to increase our understanding of the Sun-Earth-Moon relationship. It is a chance to observe the effects of what happens when the Sun is temporarily blocked, when viewed from a small area of Earth.

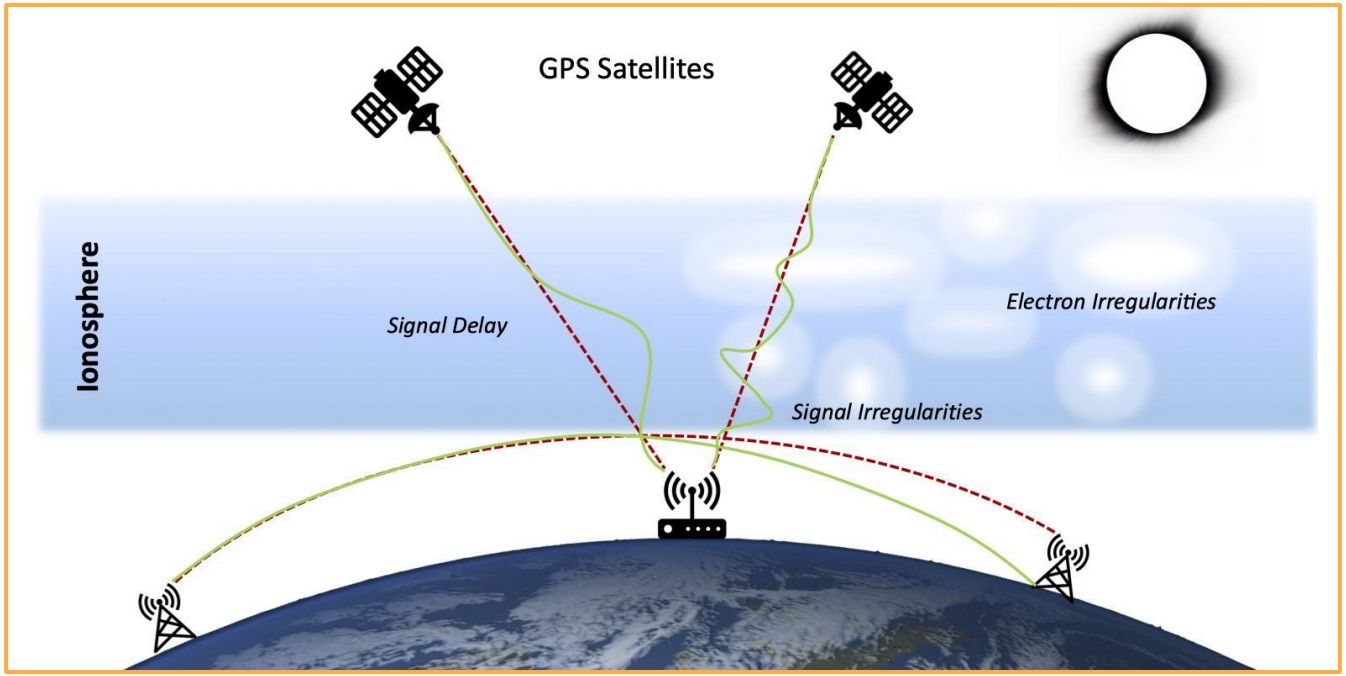
Credit: NASA/NOAA

During an annular solar eclipse, NASA is interested in:

- Testing the design and function of new hardware in the unique eclipse conditions;
- Studying the ionosphere, thermosphere, and mesosphere as the eclipse passes over a location;
- Monitoring eclipse-induced changes in the atmosphere under the shadow of the Moon;
- Using satellites, suborbital rockets, high-altitude balloons, and other NASA assets to observe the eclipse and its effects.

Eclipses and the Ionosphere

Eclipses change the way the ionosphere passes signals between space and the ground. During an eclipse, the ionosphere experiences a rapid cooling effect, which causes the ionized gases to recombine, becoming less conductive. As a result, the way radio waves pass through the ionosphere changes, affecting the propagation of signals between space and the ground. This change can cause disruptions in communication systems, such as those used in GPS and satellite communication.

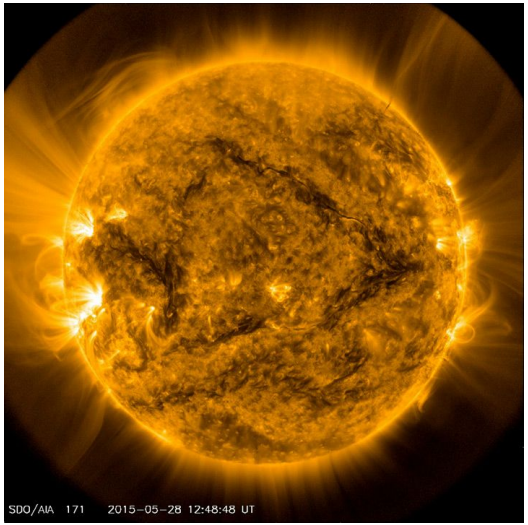


Credit: Adapted from: Linty, Nicola et al. IEEE Transactions on Aerospace and Electronic Systems 55 (2019): 303-317

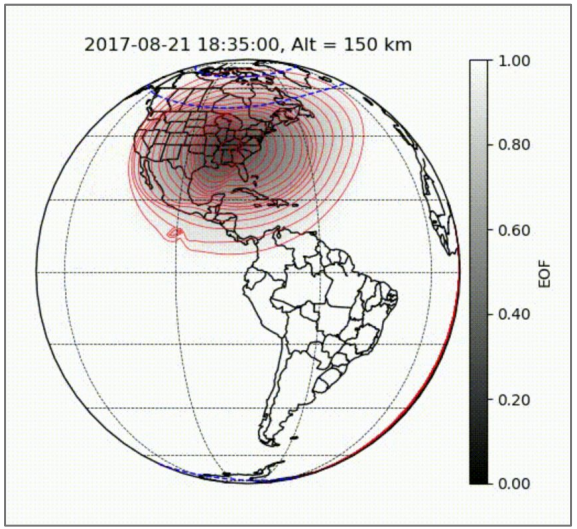
Eclipses and Ultraviolet Light

Extreme ultraviolet light from the Sun is blocked during an eclipse.

- Solar X-ray and extreme ultraviolet (EUV) radiation is almost completely absorbed within the thermosphere.
- During a total or partial solar eclipse, it is possible to map the contributions of specific active regions on the Sun to the overall heating and ionization of the thermosphere.
- Observations of solar EUV contributions help scientists to develop accurate satellite drag forecasts.



Credit: SDO/AIA



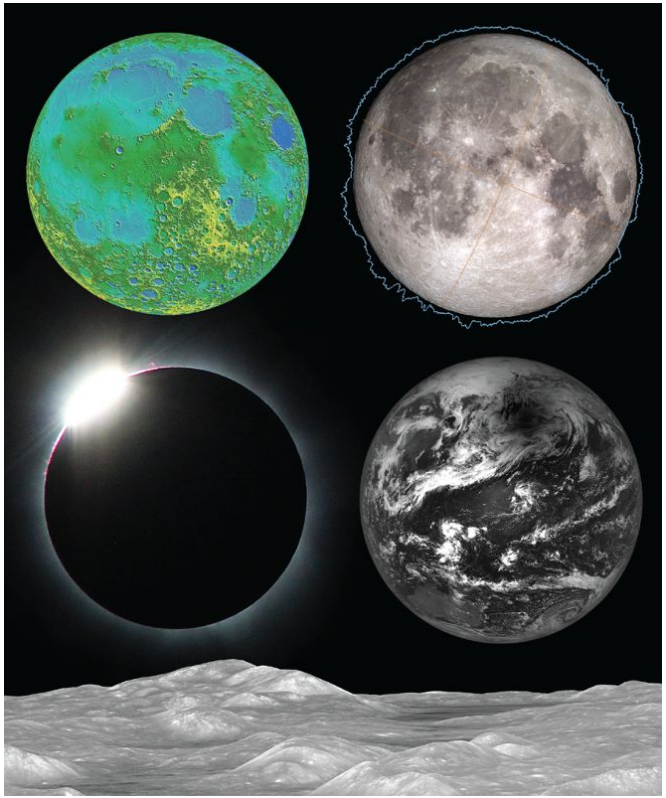
Credit: Sebastijan Mrak - pyEclipse; National Science Foundation grant AGS-13019141 and NASA grant 13018916.

Studying the Moon During the Eclipse

NASA's Lunar Reconnaissance Orbiter (LRO) studies the Moon and will point its cameras at Earth to observe the Moon's shadow during the eclipse.

Top left: In this topographic map of the Moon, cool colors (blues) represent the lowest elevation and warm colors (yellow) represent the highest elevation Credit: NASA/GSFC/LRO/LOLA

Bottom left: When sunlight peaks through the low points in the jagged lunar limb during a total solar eclipse, one can see phenomena known as Baily's Beads and the diamond ring effect. Credit: Rick Fienberg/TravelQuest International/Wilderness Travel



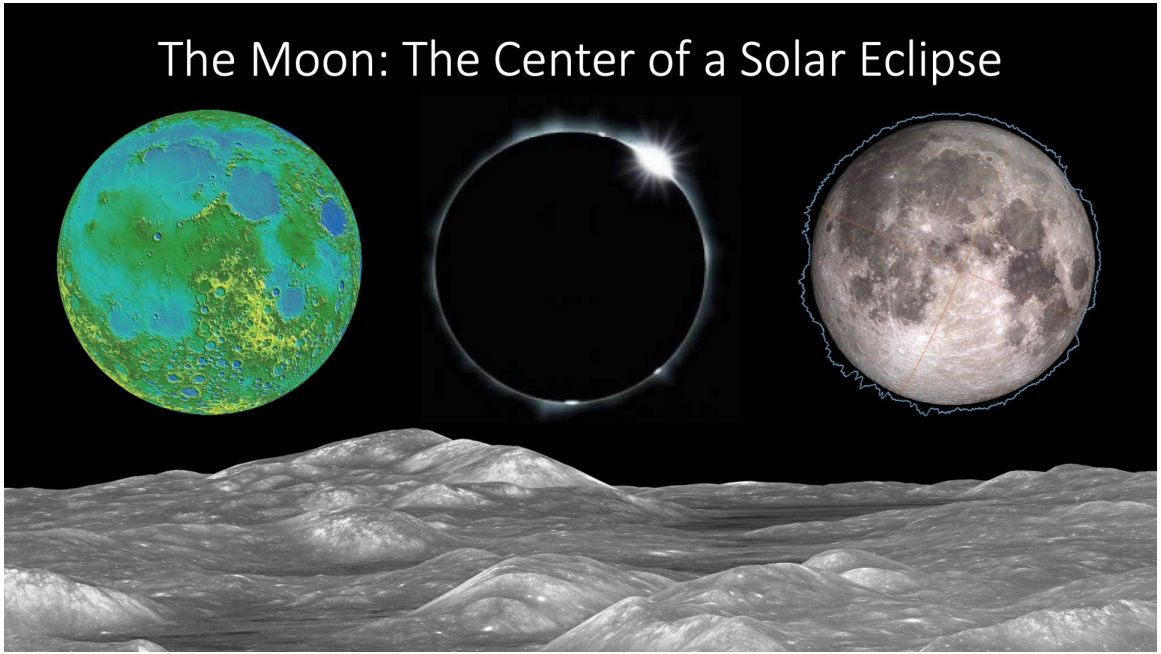
Top right: The blue line surrounding the Moon shows the outline of the Moon's topographic profile, exaggerated 20 times. Credit: NASA/SVS

Bottom right: Using LRO's topography data, scientists can more precisely and accurately predict the location and duration of these phenomena, and the shape of the Moon's shadow on Earth. Credit: NASA/GSFC/ASU

Studying the Moon During the Eclipse

Thanks to the laser altimeter and high-resolution cameras onboard NASA's Lunar Reconnaissance Orbiter (LRO), we know the shape of the Moon better than any other Moon or planet in the solar system – including Earth.

At any given time and location, only a single, very small valley or saddle point on the limb is needed to create the diamond ring effect.



Baily's Beads are visible not only during a total solar eclipse but may also be visible during an annular eclipse, depending on the Moon's topography.

Credit: NASA/GSFC/ASU

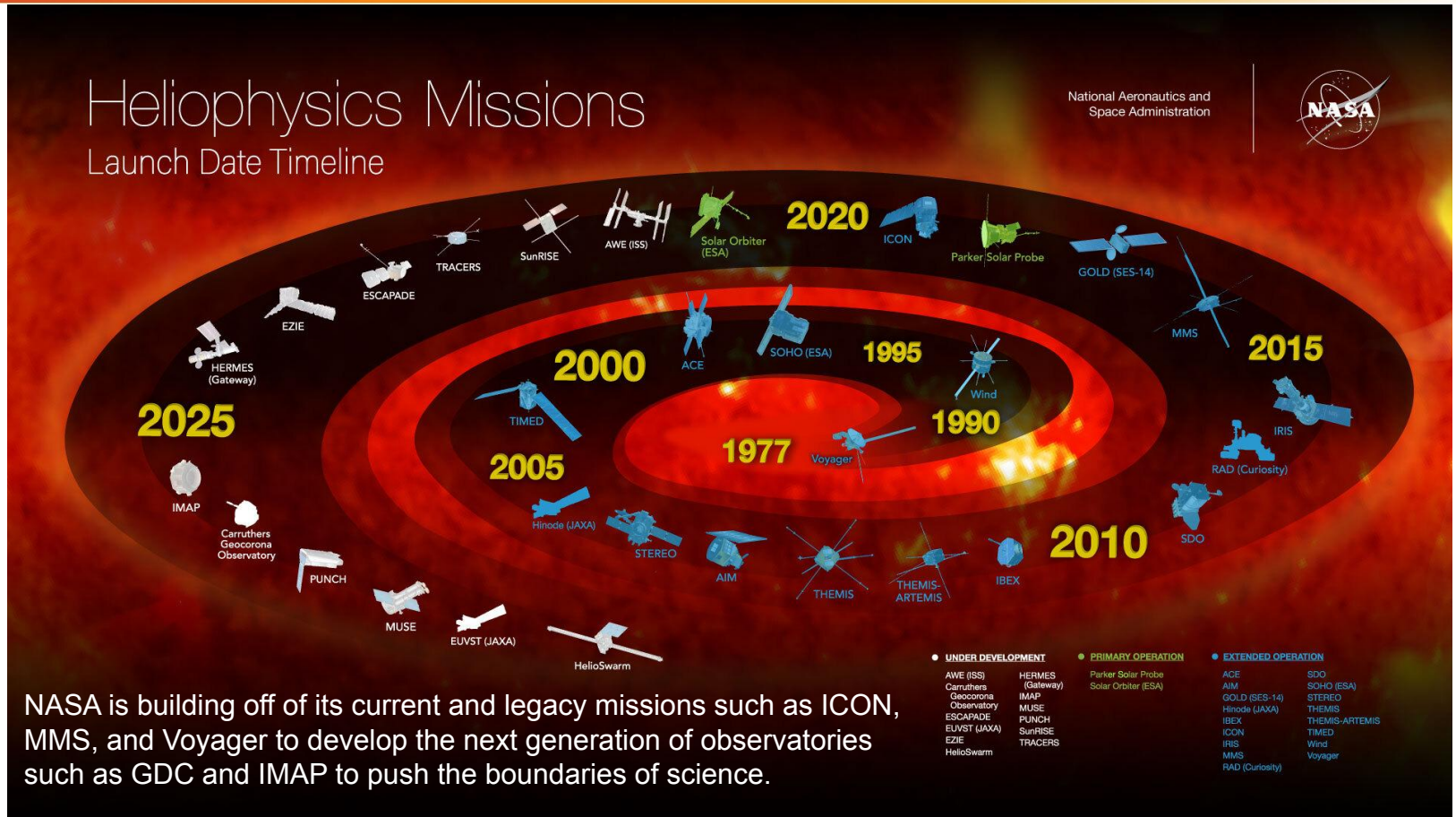
The bottom image shows an oblique view of the Orientale basin: an example of the rough topography found on the Moon.

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

Heliophysics System Observatory

The Heliophysics flight missions form a fleet of solar, heliospheric, geospace, and planetary spacecraft that operate simultaneously to understand the dynamics of the solar system. This fleet can be thought of as a single observatory, the **Heliophysics System Observatory (HSO)**.

Heliophysics Mission Launch Timeline



NASA is building off of its current and legacy missions such as ICON, MMS, and Voyager to develop the next generation of observatories such as GDC and IMAP to push the boundaries of science.

Parker Solar Probe

Launched on Aug. 12, 2018, Parker Solar Probe is providing new data on solar activity and solar wind, and making critical contributions to our ability to forecast major space weather events that impact life on Earth.

Parker Solar Probe is touching the Sun. It is swooping within four million miles of the Sun's surface, facing heat and radiation like no spacecraft before it.

Credit: NASA GSFC/CIL/Brian Monroe

SDO: Solar Dynamics Observatory

SDO studies how solar activity is created and how space weather comes from that activity.

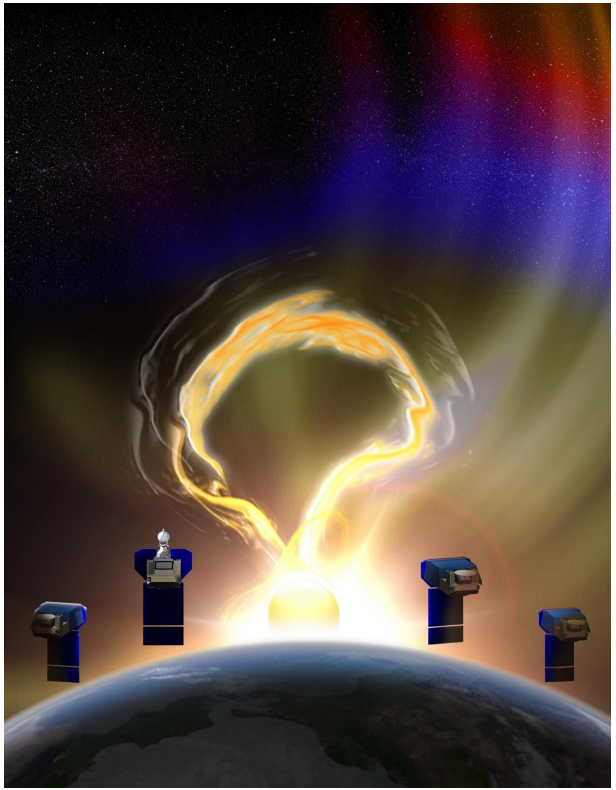
Credit: SDO/AIA

Since its launch in 2010, SDO has continuously made measurements of the interior of the Sun, the Sun's magnetic field, the hot plasma of the solar corona, and the irradiance that creates the ionospheres of the planets.

PUNCH: Polarimeter to UNify the Corona and Heliosphere

PUNCH is a NASA Small Explorer (SMEX) mission that will be ready to launch in 2025 to better understand how the mass and energy of the Sun's corona become the solar wind that fills the solar system.

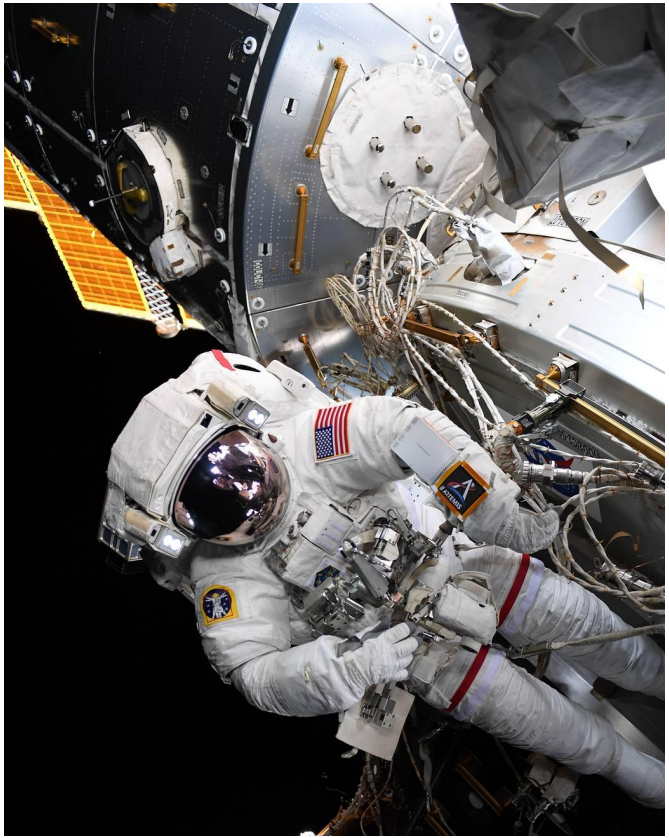
Four suitcase-sized satellites will work together to produce images of the entire inner solar system around the clock.



Credit: SWRI/PUNCH

PUNCH satellites in orbit around Earth

Artemis



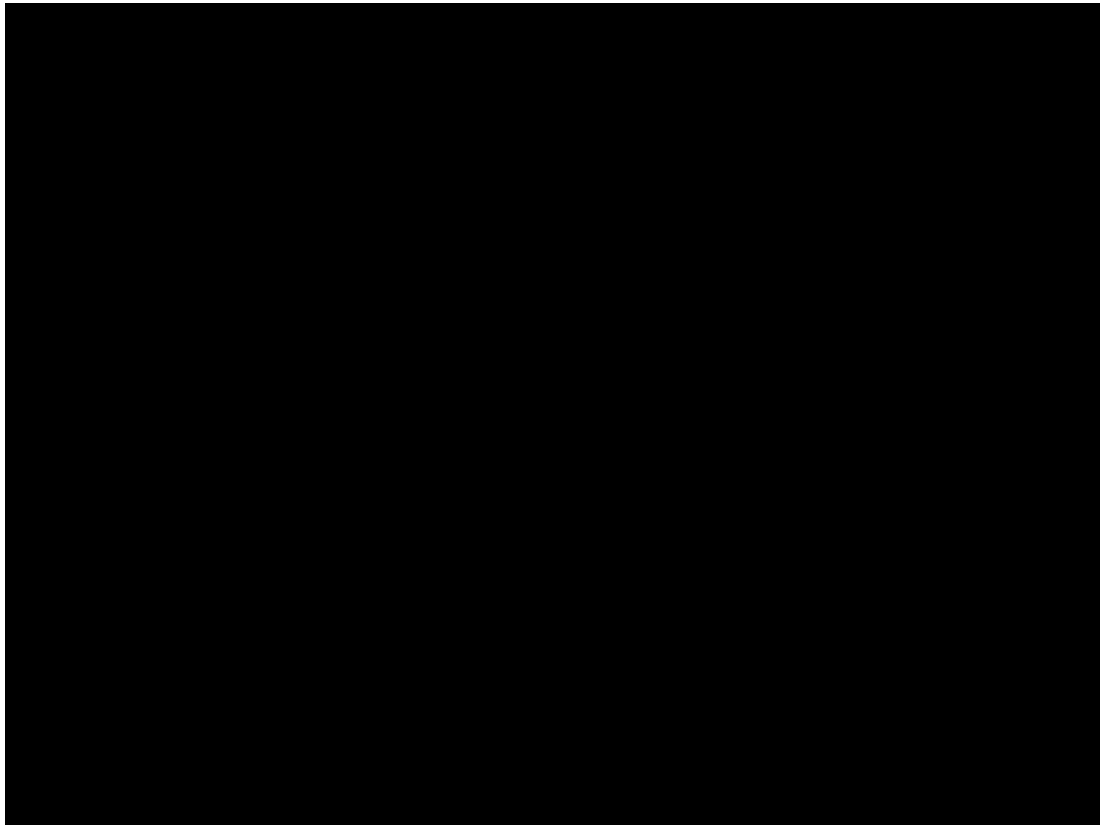
Credit: NASA

Returning humans to the Moon and continuing on to Mars is a NASA priority.

As part of the Artemis program, the Moon to Mars Space Weather Analysis Office was established to provide accurate predictions of space weather events, which can pose a risk to astronauts during their journeys and while on the surface of the Moon or Mars.

Eclipse Sounding Rocket Campaign

NASA is launching a suborbital sounding rocket from White Sands Missile Range in October 2023 to observe and understand the effects of the annular eclipse on the Earth's atmosphere. This campaign will follow up with another launch from Wallops Flight Facility in April 2024 to observe the effects of the total eclipse.



Credit: NASA SVS

Part 4:
Engaging the Public in Eclipse Activities

Lessons

Lesson 1: NASA's Eclipse Engagement Initiatives

Lesson 2: Get involved!

Lesson 3: Additional Resources

Lesson 1:
NASA's Eclipse Engagement Initiatives

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

NASA Initiatives Supporting the Annular Solar Eclipse

NASA Science Activation

- NASA HEAT
- Eclipse Ambassadors
- Nationwide Eclipse Ballooning Project
- Earth to Sky

Office of STEM Engagement

INSPIRE ENGAGE EDUCATE EMPLOY
The Next Generation of Explorers

- Next Gen STEM
- NASA CONNECTS

Office of Communications

- NASA Eclipse Website
- NASA Heliophysics Social Media

HELIOPHYSICS BIG YEAR

NASA Heliophysics Division: Heliophysics Big Year

NASA's Science Activation (SciAct) Program

- NASA's Science Activation (SciAct) Program builds partnerships between science experts and the public to help learners of all ages "do" science to activate minds and promote deeper understanding of our world and beyond.
- The Science Activation Portfolio includes 48 active teams.
- Several teams focus specifically on the solar eclipses in three areas:
  - Engaging learners for the upcoming 2023 annular eclipse and 2024 total solar eclipse over North America;
  - Integrating data into science learning;
  - Enabling the nation's learners to be active participants in the scientific process.

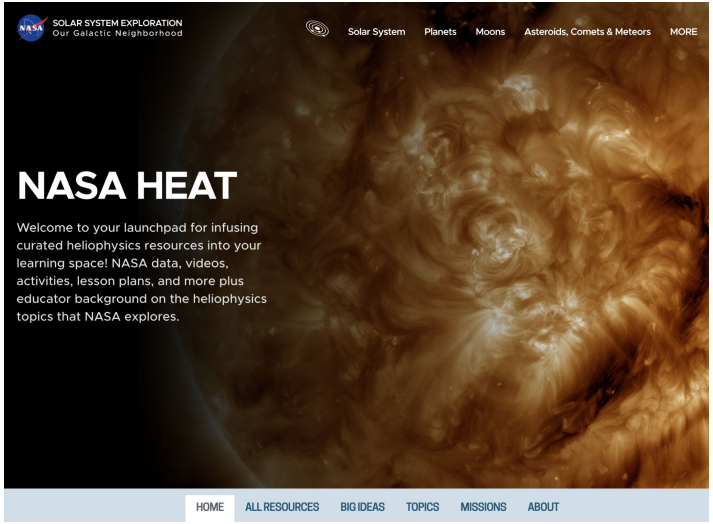
Find More: https://science.nasa.gov/learners

NASA HEAT - NASA Goddard Space Flight Center

NASA Heliophysics Education Activation Team (NASA HEAT) is laying a foundation for the next generation of STEM educators to build upon. We are bringing NASA from the laboratory to learning spaces to inspire future scientists and spark breakthroughs in heliophysics. Part of the Science Activation program, NASA HEAT is working to educate learners of all ages about heliophysics.

NASA HEAT is supporting the broader NASA eclipse efforts through:

- Educational Activities – e.g., 2D/3D Pinhole Projector Activity
- Public Engagement Materials – e.g., NASA eclipse map co-created with NASA's Scientific Visualization Studio (SVS)
- Digital Eclipse Lessons – e.g., Eclipse Lesson Plans with MyNASAData



Find More: [NASA HEAT's website for heliophysics resources] and [NASA's eclipse website]

Eclipse Ambassadors

Eclipse Ambassadors Off the Paths will prepare 500 communities off the central paths of the back-to-back solar eclipses in 2023 and 2024. Engagement events will prepare community members to enjoy the science and wonder of this natural phenomenon.

ECLIPSE AMBASSADORS

Did you know that there are many undergraduates or amateur astronomers looking for partners to participate?

Eclipse Ambassadors will bring outreach programs to underserved audiences in local libraries, colleges, schools, and other community organizations. Training, partnerships, and resources are provided. Undergraduates will also receive a stipend, plus opportunities to further their involvement in NASA programs.

Credit: Eclipse Ambassadors

A NASA Science Activation project managed by the Astronomical Society of the Pacific, the program is pairing undergraduate students with amatuer astronomers to engage their local communities before and between the two solar eclipses.

Apply today! www.eclipseambassadors.org

Nationwide Eclipse Ballooning Project (NEBP)

The Nationwide Eclipse Ballooning Project (NEBP) is sponsored by NASA Space Grant College and Fellowship Program, NASA Science Mission Directorate's Science Activation Program, and the NASA Balloon Program Office.

Credit: NEBP

NEBP will engage 53 student teams from across the country to learn and take part in stratospheric ballooning campaigns during the eclipses. Teams participate on one of two tracks: atmospheric science or engineering.

- Engineering teams will fly one balloon during each eclipse. The payloads, built by the students, will include live-streaming cameras, precision GPS for catching gravity waves, and individual experiments designed by each team.
- Atmospheric science teams will fly radiosondes every hour for 24 hours prior to and 6 hours after the eclipses. Teams will examine the data for atmospheric changes driven by the eclipse shadow.

Credit: NEBP

The project has a goal of 50% of students involved in NEBP who are historically underrepresented or underserved in STEM.

Find More: eclipse.montana.edu

Earth to Sky

The Earth to Sky Partnership nurtures and supports a growing community of interpreters, educators, and scientists learning and sharing science and communication techniques.

Find More: earthtosky.org

For the 2023 and 2024 solar eclipses, Earth to Sky connects frontline interpreters and informal educators with NASA science and eclipse resources by:

- Offering mini-webinars on solar, lunar, and Earth science related to the eclipse, interpretive connections to the eclipse, resources available to assist efforts, and citizen science opportunities before/during/after the eclipse (webinar series began January 30th);
- Maintaining an email list for interpreters to follow updates on eclipse efforts throughout NASA;
- Assisting one site for each of the eclipses with their outreach efforts.

Next Gen STEM

Engaging K-12 Students to Build the Future STEM Workforce

NASA is universally known for its exciting mission and technical excellence. Children are drawn to the wonders of science, flight, and space. NASA employees were drawn to the agency by that excitement and are a force for inspiring and equipping the next generation.

INSPIRE ENGAGE EDUCATE EMPLOY
The Next Generation of Explorers

For the 2023-2024 academic year, NASA's Office of STEM Engagement's Next Gen STEM (NGS) program will promote the solar eclipses with priority in formal and informal learning environments (grades K-12).

- In partnership with NASA's Science Mission Directorate, the NGS team will develop evidence-based, mission focused, national standards-based solar eclipse toolkits for K-12 that will incorporate existing and new resources.
- The NGS Team will serve as points of contact across field centers for formal and informal education institutions seeking partnerships with NASA in eclipse engagement.
- NGS will provide educator professional development that is online or in person at conferences and events and will create an Eclipse Collection in its online Community of Practice where NASA and educators collaborate.
- NASA's Office of STEM Engagement will share evaluation data and lessons learned.

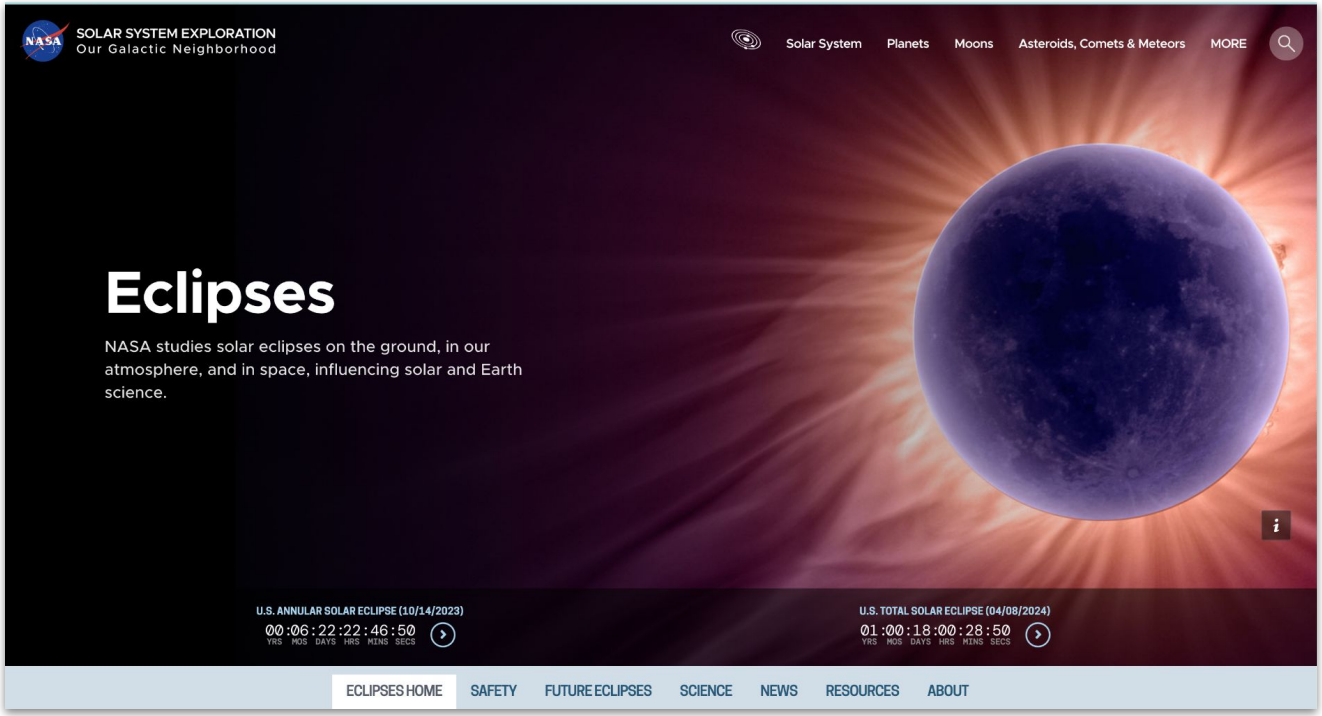
Find More: nasa.gov/stem/nextgenstem

NASA CONNECTS

NASA CONNECTS (Connecting Our NASA Network of Educators for Collaborating Together in STEM) is an online, professional learning community for educators to collaborate with each other and NASA.

NASA Eclipse Website

You can access more exciting information about these eclipses, including downloadable activities, information about our Sun, and alternative ways to view the eclipse at solarsystem.nasa.gov/eclipses.



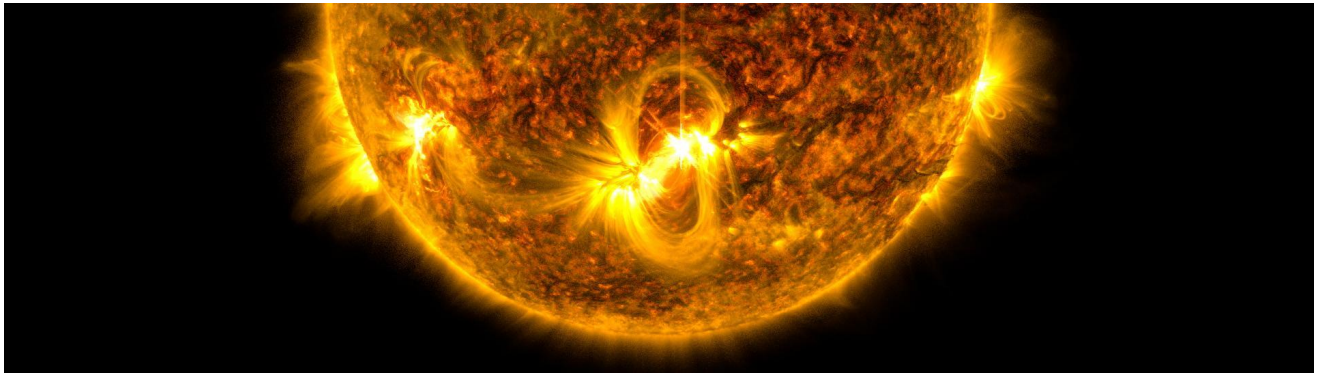
NASA Heliophysics Social Media

Follow us on Twitter, Facebook, and Instagram as we journey closer to our star!

@NASASun

@NASASunScience

@NASASolarSystem



Credit: NASA/SDO

NASA Heliophysics Big Year

The Heliophysics Big Year is a global celebration of solar science and the Sun's influence on Earth and the entire solar system. **Join us October 2023 to December 2024!**

Find out how you can participate with event-planning activities, outreach, and funding around citizen science projects, contests, and more.
Email hq-heliobigyear@mail.nasa.gov

HELIOPHYSICS
BIG YEAR

We want you to **bring your joy and curiosity to this opportunity of a lifetime** to participate with NASA Heliophysics! Learn more at go.nasa.gov/HelioBigYear

Photograph of an annular eclipse
Credit: NASA/Bill Dunford

Get Involved!

How can you get involved in eclipse events and how can you engage your family and community?

- Watch the NASA broadcast or a livestream.
- Facilitate eclipse engagement activities with your family or community groups.
- Participate in a citizen science project.

We need your help to spread the word about eclipse excitement and safety!

Credit: NASA/Shannon Reed

Exploratorium

The Exploratorium will produce four different livestreams to allow you to have the media you need for a successful eclipse event.

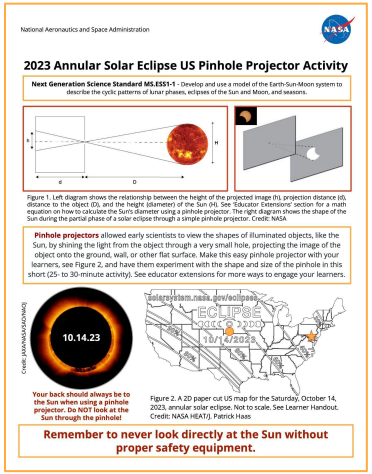
Credit: Exploratorium

All streams will also be available on the Exploratorium's Total Solar Eclipse app for iOS and Android: great for outdoor viewers!

Find the app and livestream information at exploratorium.edu/eclipse

Engagement Activities

Pinhole Projector Activity


National Aeronautics and Space Administration

2023 Annular Solar Eclipse US Pinhole Projector Activity

Next Generation Science Standard MS.ESS1-1 - Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.

Figure 1. Left diagram shows the relationship between the height of the projected image (h), projection distance (d), distance to the object (D), and the height (diameter) of the Sun (H). See 'Educator Extensions' section for a math equation on how to calculate the Sun's diameter using a pinhole projector. The right diagram shows the shape of the Sun during the partial phase of a solar eclipse through a simple pinhole projector. Credit: NASA

Pinhole projectors allowed early scientists to view the shapes of illuminated objects, like the Sun, by shining the light from the object through a very small hole, projecting the image of the object onto the ground, wall, or other flat surface. Make this easy pinhole projector with your learners, see Figure 2, and have them experiment with the shape and size of the pinhole in this short (25- to 30-minute activity). See educator extensions for more ways to engage your learners.

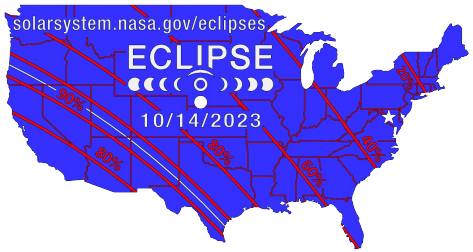
10.14.23

Your back should always be to the Sun when using a pinhole projector. Do NOT look at the Sun through the pinhole!

Figure 2. A 2D paper cut US map for the Saturday, October 14, 2023, annular solar eclipse. Not to scale. See Learner Handout. Credit: NASA HEAT/J. Patrick Haas

Remember to never look directly at the Sun without proper safety equipment.

Explore the 2D paper cut and 3D printed versions of the annular solar eclipse pinhole projectors and activity.



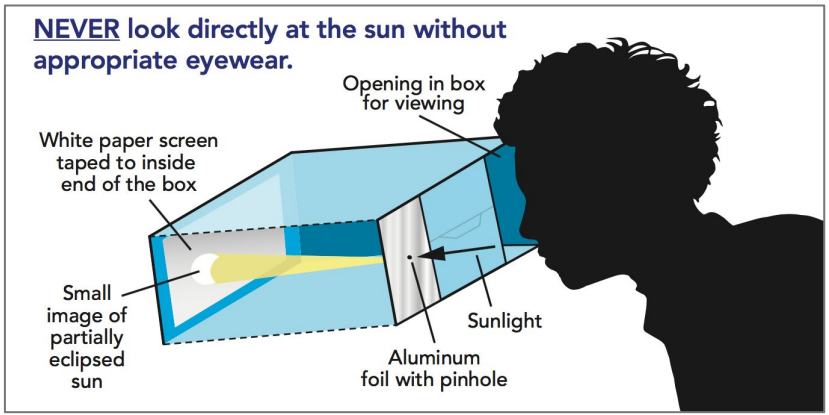
Pinhole projectors allowed early scientists to view the shapes of illuminated objects, like the Sun, by shining the light from the object through a very small hole, projecting the image of the object onto the ground, wall, or other flat surface. These are a great method for safe solar viewing. Be sure that when using a pinhole projector, the Sun is always behind you.

Find More: 2023 Annular Solar Eclipse Pinhole Projector Activity

Eclipse Box Projector Activity

You can make your own eclipse projector using a cardboard box, a white sheet of paper, tape, scissors, and aluminum foil. With the Sun behind you, sunlight will stream through a pinhole punched into aluminum foil taped over a hole in one side of the box. During the partial phases of a solar eclipse, this will project a crescent Sun onto a white sheet of paper taped to the inside of the box. Look into the box through another hole cut into the box to see the projected image.

Find More: svs.gsfc.nasa.gov/12638



Credit: NASA GSFC/NASA HEAT

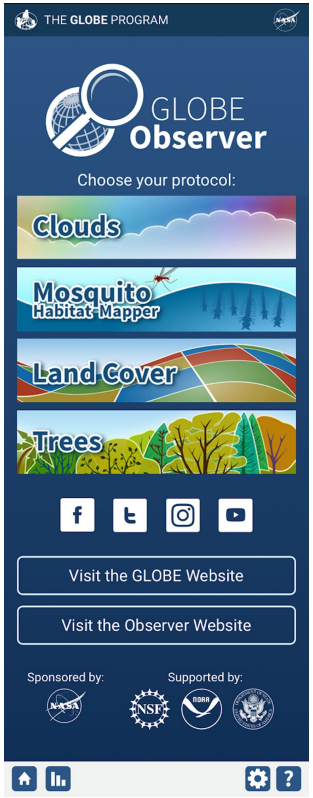
NASA Citizen Science

NASA defines citizen science as “a form of open collaboration in which individuals or organizations participate voluntarily in the scientific process in various ways.”

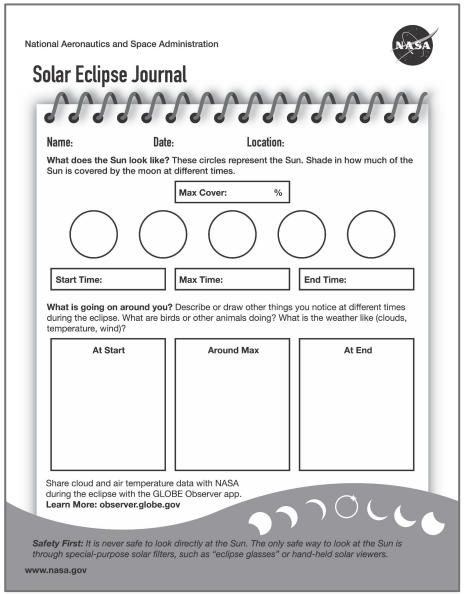
Low to Medium Tech (Phone/Laptop)	Medium to High Tech (Additional Software/Equipment)
●GLOBE Observer ●Solar Jet Hunter ●Planet Hunters Transiting Exoplanet Survey Satellite (TESS)	●Eclipse Soundscapes ●HamSCI ●Radio JOVE ●Sungrazer Project

These projects all relate to the dynamic science possible by studying the Sun’s corona and the effects of the Moon’s shadow on Earth’s upper atmosphere.

GLOBE Observer



GLOBE needs your help to collect data!
GLOBE Observer is an international network of citizen scientists and scientists working together to learn more about our shared environment and changing climate.



THE GLOBE PROGRAM

Visit the GLOBE Observer Eclipse page for more details about equipment needed, how to take observations, and answers to frequently asked questions.

The program collects data to understand how the eclipse changes atmospheric conditions. The app allows volunteers to contribute observations of cloud and sky conditions, air temperature, and surface temperature.

Download the app here:
observer.globe.gov/about/get-the-app

Credit: GLOBE Observer

Eclipse Soundscapes

The Eclipse Soundscapes (ES) Project is studying how the October 14, 2023, annular solar eclipse and the April 8, 2024, total solar eclipse affect life on Earth. Participants can join us in this scientific exploration by learning about eclipses on the website, observing and submitting multisensory observations online, collecting audio data during eclipse week, or analyzing sound data after the upcoming solar eclipse! Learn more at www.EclipseSoundscapes.org

Eclipse Soundscapes Participant Roles

Apprentice

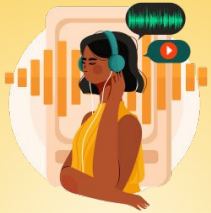
Learn about solar eclipses via free online learning and earn a certificate of completion.

Observer

During the upcoming eclipses along or near the 2023 annular eclipse path or the 2024 total eclipse path, go outside and observe with all of the senses available to you. Then share these observations with the ES team!

Data Collector

Collect data using an AudioMoth Recorder along or near the 2023 annular eclipse path or the 2024 total eclipse path. Then share the data with the ES team!



Data Analyst

Analyze sound data in 2024 and 2025 alongside scientists using your computer or mobile device.

Eclipse Soundscapes is supported by NASA award No. 80NSSC21M0008

Ham Radio Citizen Science Investigation

Concurrent with the October 14, 2023, and April 8, 2024, annular and total eclipses, the worldwide amateur (ham) radio community will be creating data for space physics research. They will do so by transmitting, receiving, and recording signals across the high-frequency (HF) radio spectrum. The operating format will be a series of friendly ham radio competitions and researcher-led experiments.

Credit: HamSCI

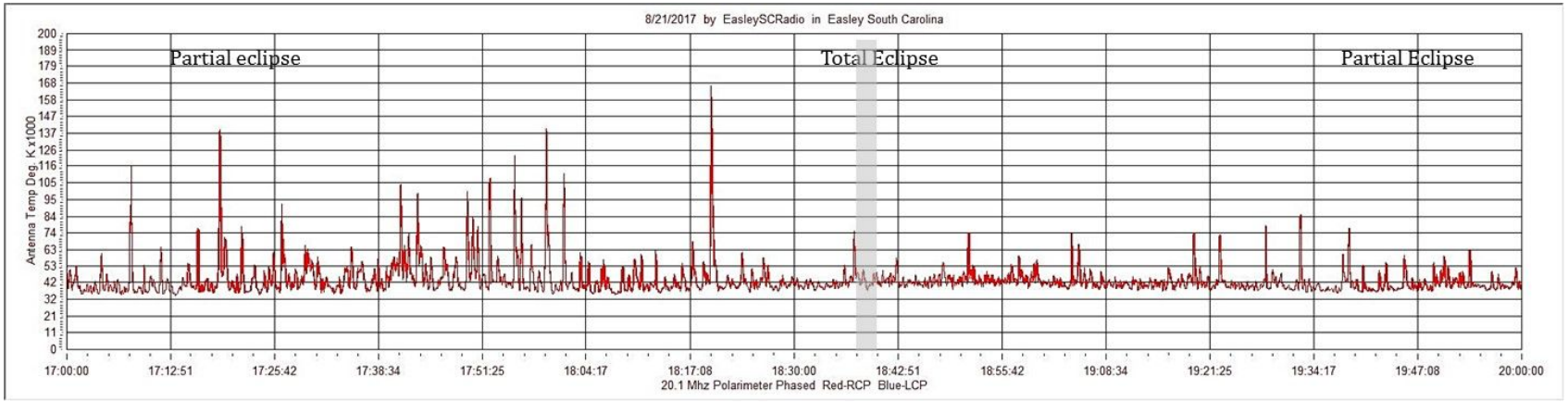
The HamSCI Festivals of Eclipse Ionospheric Science will consist of multiple events, each with a goal of increasing our understanding of Sun-ionosphere-Earth relationships. Participants will include volunteer amateur radio operators, short-wave listeners, and science researchers from multiple U.S. universities.

Details on how to participate can be found here: hamsci.org/eclipse

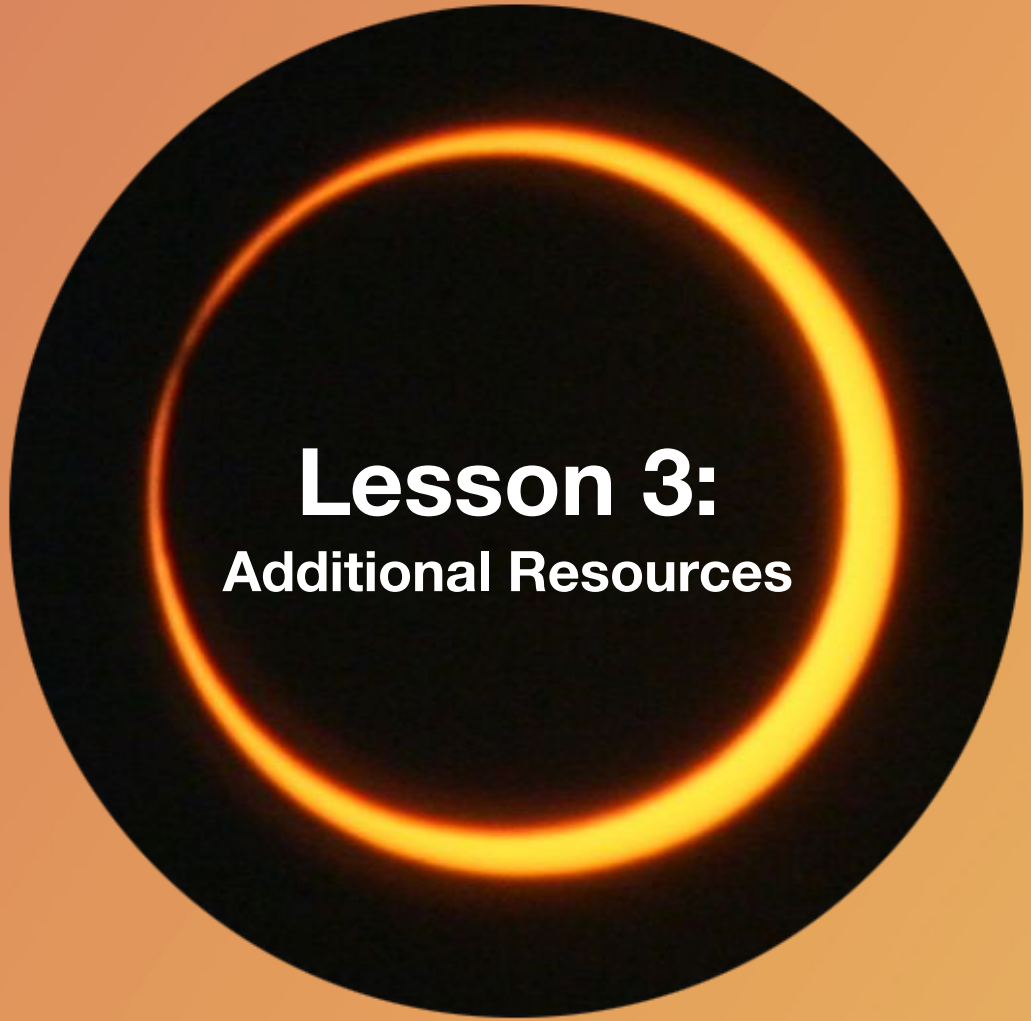
The Radio JOVE Project

Radio JOVE students and amateur scientists from around the world observe and analyze natural radio emissions from Jupiter, the Sun, and our galaxy using their own easy-to-construct radio telescopes. **Find More:** radiojove.gsfc.nasa.gov

Solar Radio Emissions During the 2017 Total Solar Eclipse



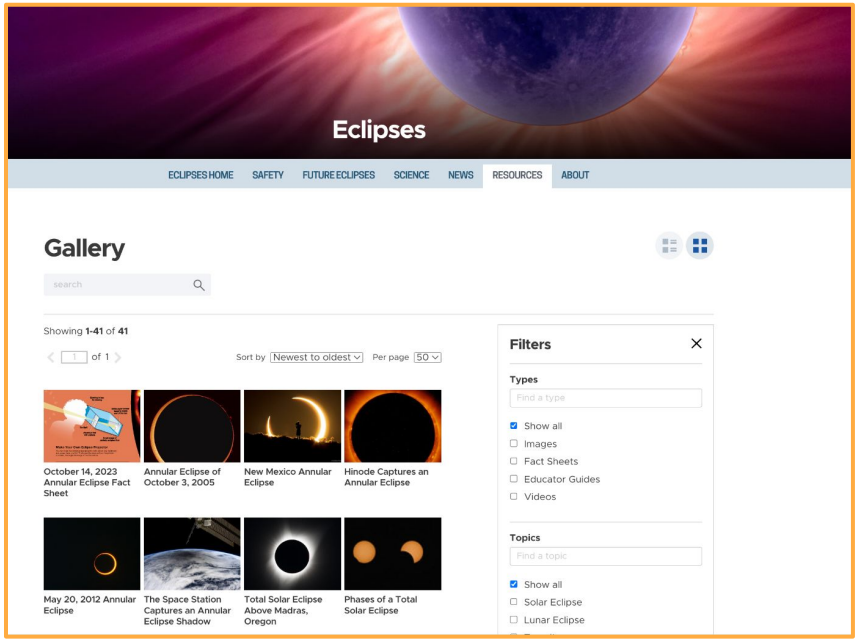
Smoothed Radio JOVE data was collected from Easley, South Carolina, from 17:00 – 20:00 UT. Totality occurred from 17:37-17:39 UT and is colored in gray. Radio JOVE collects and analyzes the data to determine whether the presence of the Moon occulted the radio-emitting regions near the Sun, and whether Earth's ionosphere was significantly affected by the umbral shadow of the Moon. Credit: Radio JOVE/John Cox

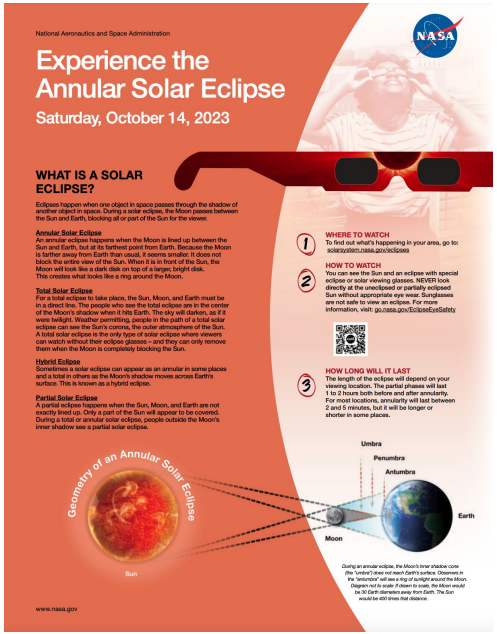


Photograph of an annular eclipse
Credit: NASA/Bill Dunford

Eclipse Resources

Visit the NASA 2023 annular solar eclipse website for updates on NASA's involvement in the Saturday, October 14, 2023, annular solar eclipse. You will find safe viewing information, a fact sheet, a NASA map showing eclipse paths, and more.



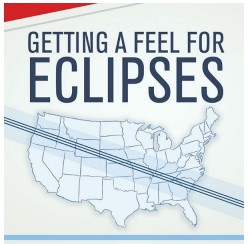


Credit: NASA

Find More: solarsystem.nasa.gov/eclipses/resources

Accessible Eclipse STEM Resources

Tactile Eclipse Books



A tactile eclipse book in braille and English is provided by NASA's Solar System Exploration Research Virtual Institute. An updated version includes the 2017, 2023, and 2024 eclipse paths.

Find this and other braille books for Earth and space sciences at sservi.nasa.gov.

Eclipse Soundscapes

Credit: Eclipse Soundscapes

The Eclipse Soundscapes Mobile Application makes solar eclipses accessible to everyone, with a special focus on users who are blind or have low vision. The bilingual (English and Spanish) app includes illustrative audio descriptions of annular and total eclipses, as well as an interactive "rumble map" that allows users to conceptualize an eclipse through touch and sound.

Find More: eclipsesoundscapes.org/mobile-app/

Eclipse Resources to Reach a Multilingual Population

To meet the needs of an increasingly diverse learner population, NASA has the following multilingual messages and resources:

- Eclipse fact sheet in English and Spanish
- Eclipse eye safety flyer in English and Spanish - a joint effort with the American Astronomical Society
- Eclipse glossary in English, Spanish, Chinese, and French
- Cómo observar un eclipse anular de forma segura - Eclipse Safety information in Spanish
- NASA Space Place in English and Spanish - Videos, games, activities, and more for engaging younger students in a variety of space science topics.
- Indigenous Eclipse Teachings - 13-minute video featuring Navajo, Cherokee, and Northern Arapaho traditional knowledge of solar eclipses.
- Eclipse words in Navajo - Coming Soon!

NASA Eclipse Newsletter

Want to receive periodic updates about NASA's eclipse activities? Sign up for the NASA eclipse newsletter.

Find More: go.nasa.gov/3oObEDI

Thank you!

Find More: solarsystem.nasa.gov/eclipses/2023