

Total Eclipse Training Resources

If you would like editable PowerPoint (.pptx) versions of these presentations, 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.
- A folder containing three editable slide decks with content on eclipse safety, science, and engagement opportunities along with each part's hi-resolution images and videos. (You are welcome to use the presentation as is, adapt it to your needs, or pick and choose content as needed.)
- 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.

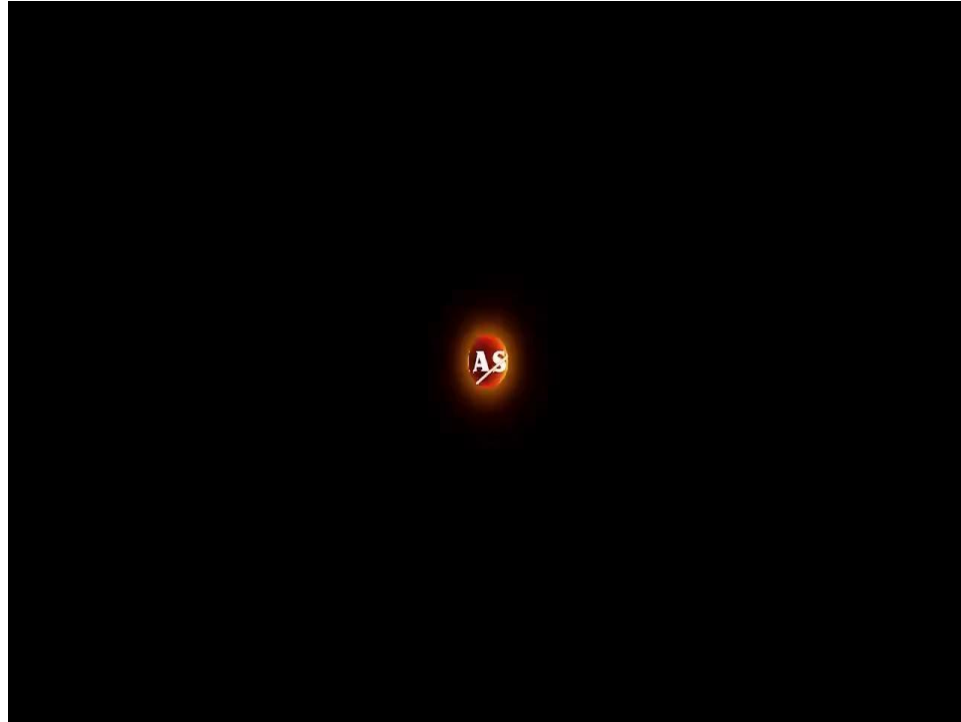
Some imagery and activities offered by NASA contain eclipse imagery.

To access the Google Drive folder of Total Eclipse Training Resources and to take the survey, click the following link:

https://oregonstate.qualtrics.com/jfe/form/SV_6fWGZyawC3IuZPo

**Part 2:
NASA Science
and Eclipses**

Eclipse Science



Part 2 Lessons



Lesson 2.1: Learning from Total Solar Eclipses

Lesson 2.2: Science Investigations During the 2024 Total Solar Eclipse

Lesson 2.3: NASA Missions Explore the Sun



Lesson 2.1:

Learning from Total Solar Eclipses

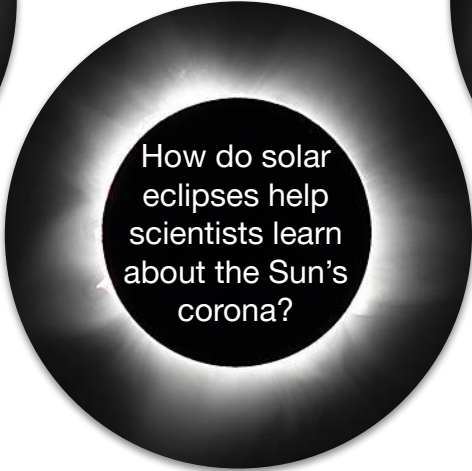
The Moon is seen as it starts passing in front of the Sun during the August 2017 total solar eclipse above Ross Lake, Northern Cascades National Park, Washington.
Credit: NASA/Bill Ingalls

Lesson 2.1 Learning Objectives

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



What did scientists learn from historic observations of total solar eclipses?



How do solar eclipses help scientists learn about the Sun's corona?



Why do scientists study Earth's ionosphere during a solar eclipse?



How do eclipses help scientists find exoplanets?

Credit: Mantarays Ningaloo, Australia/MIT-NASA Eclipse Expedition

Science Discoveries Aided by Eclipses

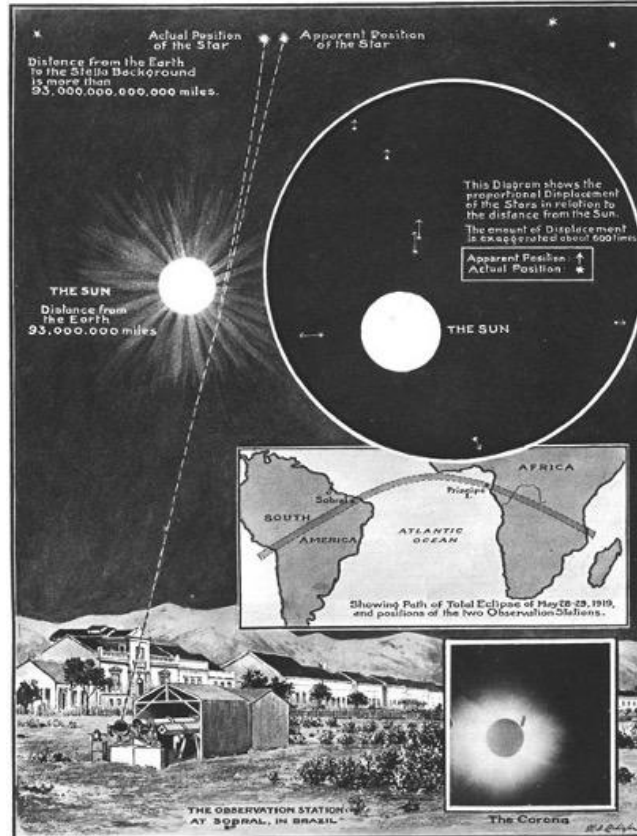


Credit: MinuteEarth

What Have We Learned From Past Total Solar Eclipses?

More accurate measurements of the orbits of Earth and the Moon

Earth's rotation speed has changed over thousands of years

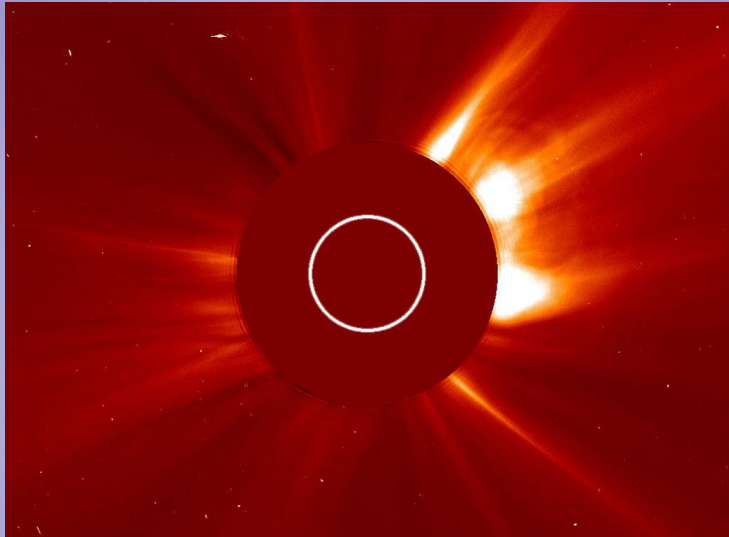


Discovery of helium

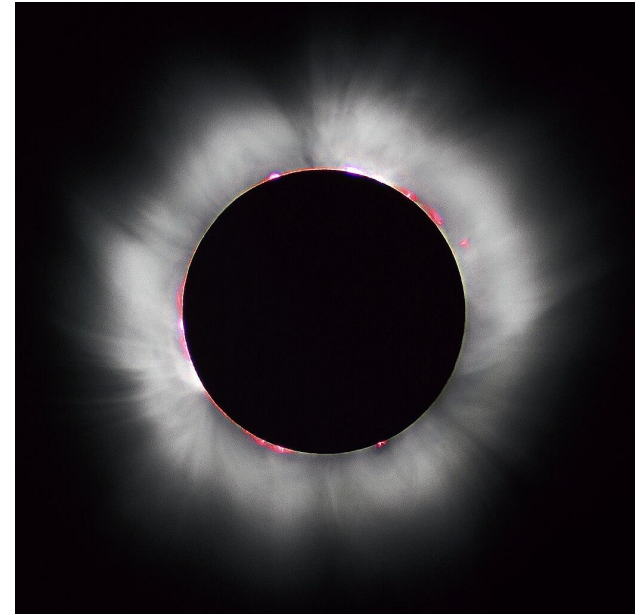
Experimental proof of Einstein's theory of relativity

A Unique Opportunity to See the Corona

The light from the corona, the outer atmosphere of the Sun, is over one million times fainter than the light from the photosphere, the visible surface layer of the Sun. So it is impossible to see the corona unless you blot out the light from the Sun.



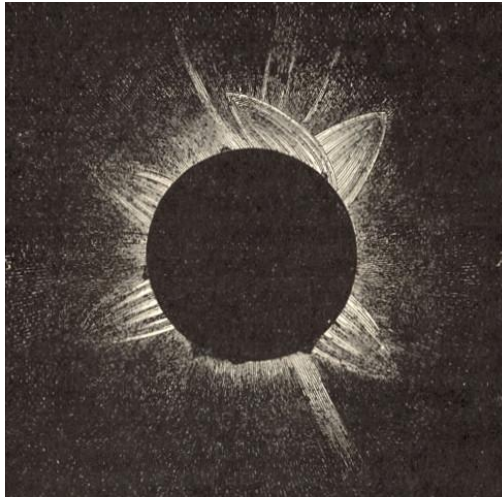
Today, NASA satellites can stage artificial eclipses using a coronagraph, but they are limited because the lower part of the corona is blocked. During a total solar eclipse, details in the entire corona can be studied. Credit: NASA/SOHO



Total solar eclipse, 1999, in France
Credit: Luc Viator

Historic Observations of the Corona

Drawings and photographs are our best unbiased representations of the corona during total solar eclipses. These drawings and photographs show many details of the corona's typical appearance including streamers, prominences, and even coronal mass ejections.



A March 25, 1857, sketch from Mexico shows helmet streamers and jets. Credit: Emmanuel Liais

Archeologists have identified a smattering of ancient renditions of total solar eclipses from rock art and from oblique references in texts made prior to the 1800s, when careful drawings and photographs became routine.

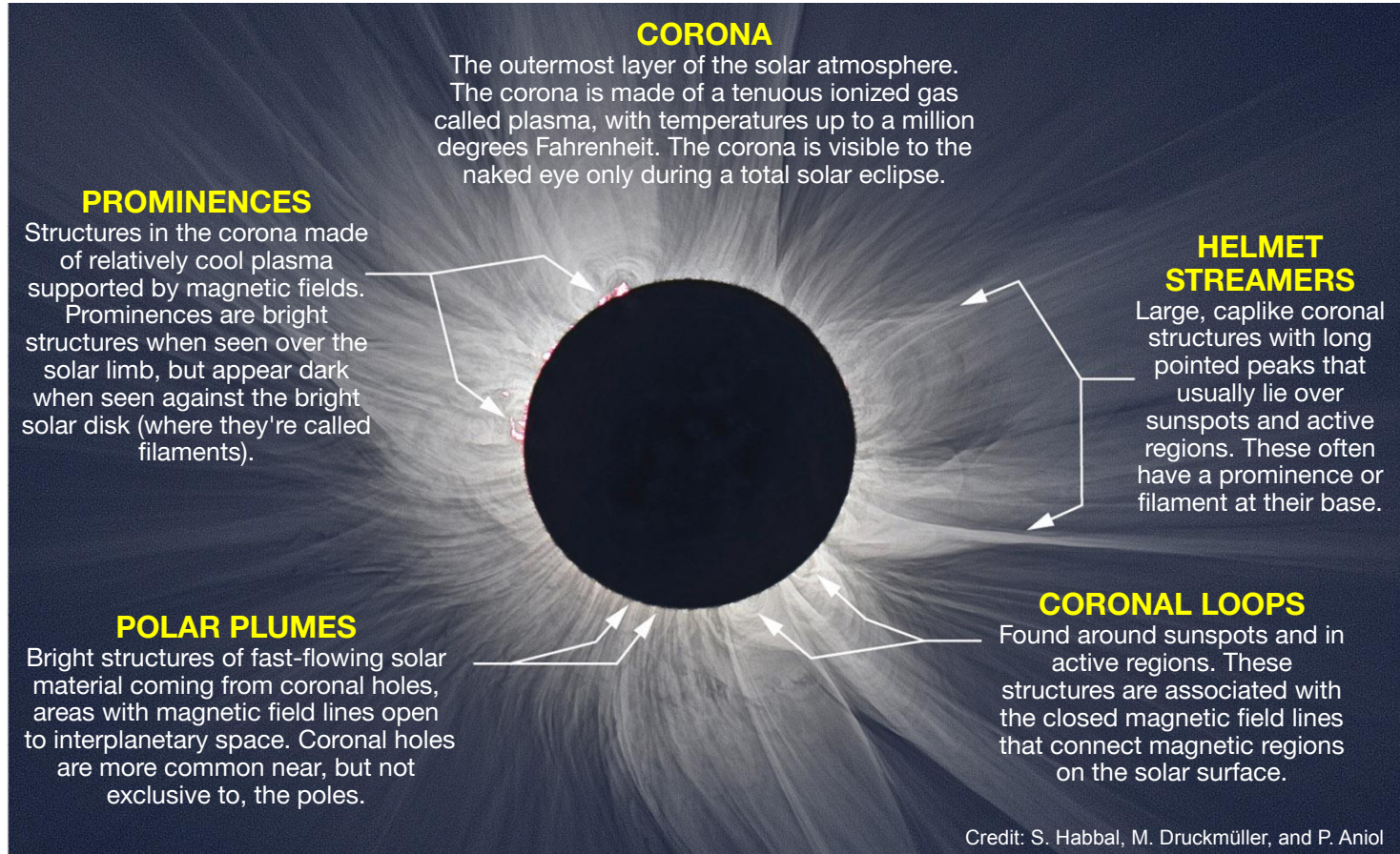


Rock art in Aspeberget, Sweden, shows a possible total solar eclipse from 1229 BCE, with coronal streamers.

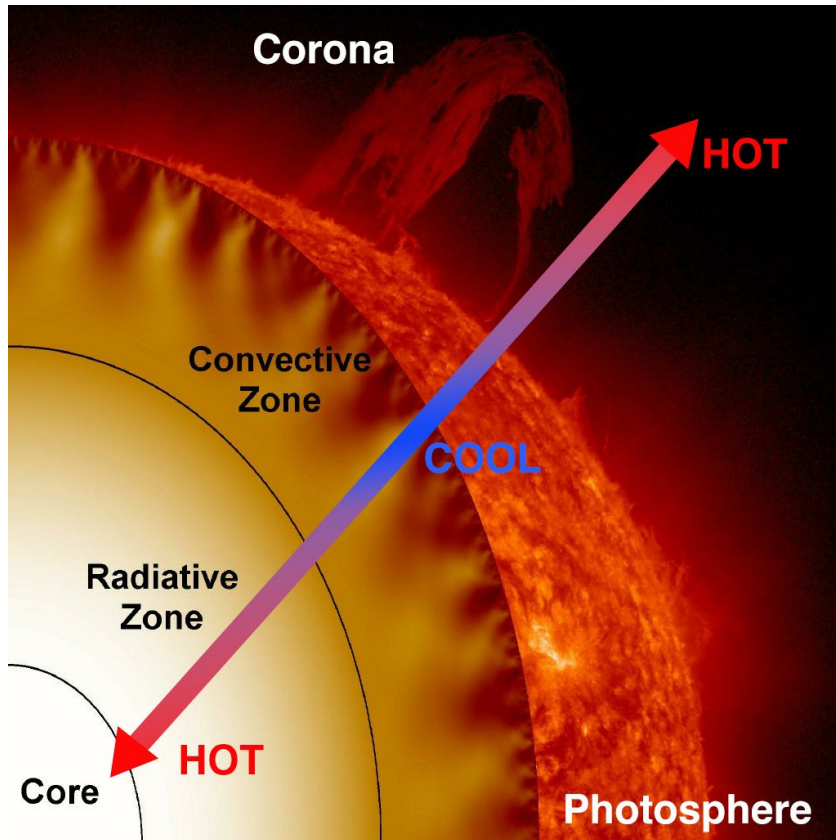
Credit: Sven Rosborn, CC BY 3.0

<<https://creativecommons.org/licenses/by/3.0>>, via Wikimedia Commons

Modern Observations of the Corona



The Mystery of the Corona

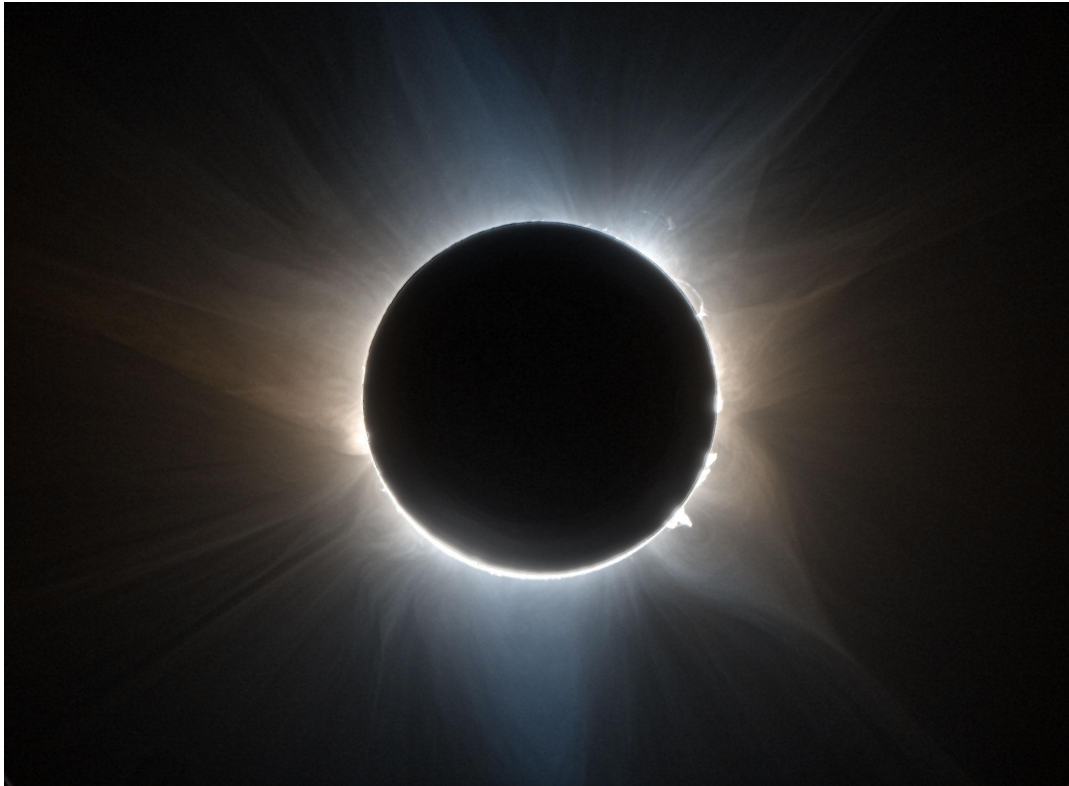


Credit: NASA

The Sun's energy is created in the core and travels outward through the radiative zone and convection zone to the Sun's surface (the photosphere), then radiated through the Sun's atmosphere (the corona) out into space.

As energy moves outward in this process, the layers of the Sun gets cooler. But something strange happens in the inner corona, which scientists are still trying to figure out: **The Sun's corona is actually hotter than the surface of the Sun.** Careful studies of the coronal plasma, through missions like Parker Solar Probe, will help scientists understand where this heat energy comes from.

Recent Discoveries From Solar Eclipses



Credit: SwRI/Citizen CATE 2024/Dan Seaton

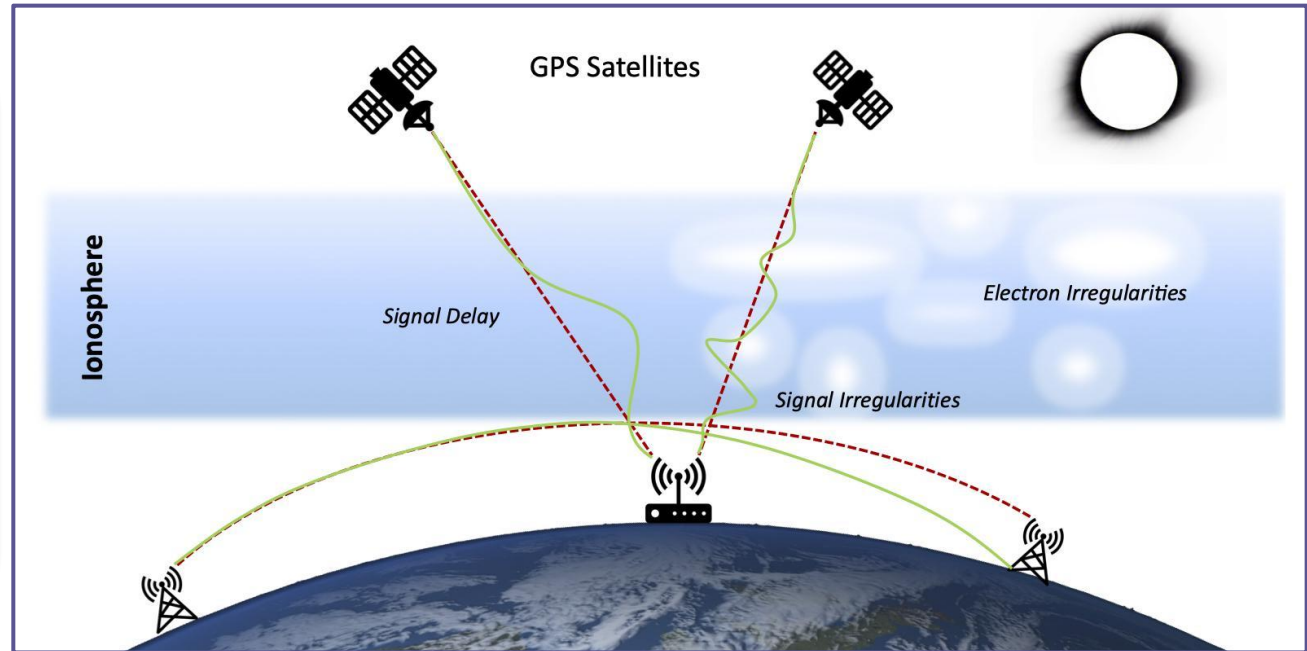
The corona maintains a fairly constant temperature. In 2021, scientists published findings made with over a decade of eclipse observations. The team found that the corona maintains a fairly constant temperature, despite undergoing changes that occur over 11 years known as the solar cycle.

Most of what scientists learn about the cosmos comes from studying light. Current studies investigate the polarization of the light from the corona.

Studying the Ionosphere During Solar Eclipses

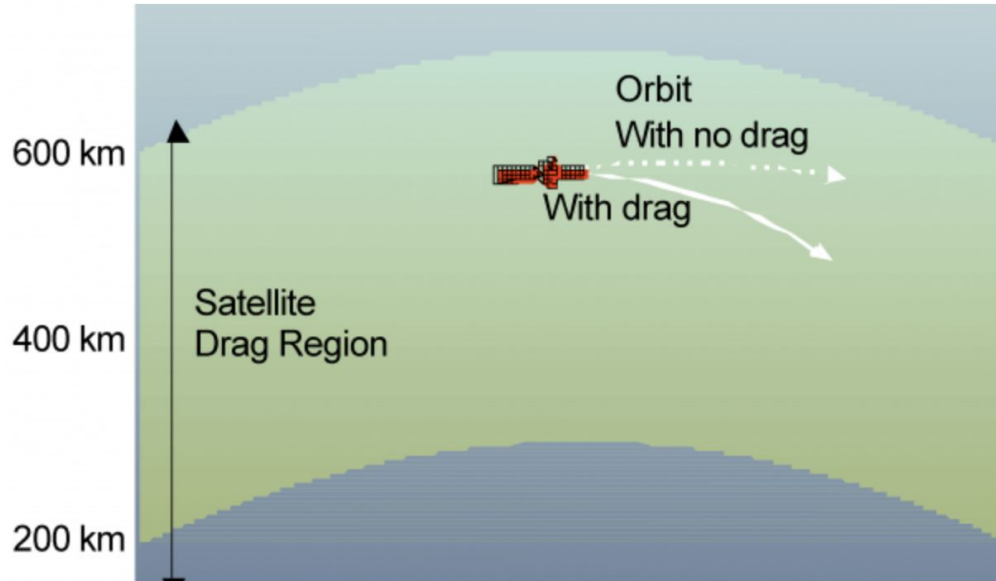
Conditions during solar eclipses change the way the ionosphere, Earth's upper atmosphere, passes signals between space and the ground.

Scientists study Earth's ionosphere during solar eclipses to learn more about how the Sun's energy affects the atmosphere. Changes in the ionosphere can disrupt communications and navigation signals, so understanding how it responds to the Sun's energy is a key part of safeguarding our technology.



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

Studying Ultraviolet Light During Solar Eclipses



Credit: NOAA

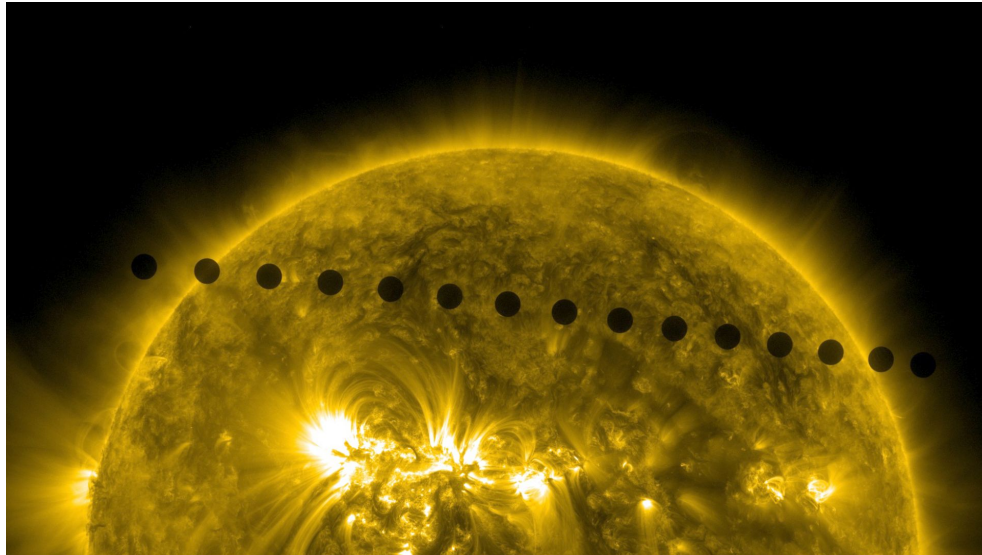
Under normal conditions, X-ray and extreme ultraviolet (EUV) radiation from the Sun is almost completely absorbed by the ionosphere.

But during solar eclipses, X-ray and EUV light is blocked. This allows scientists to map the impacts of specific regions that are active on the Sun to the overall heating of the upper atmosphere.

These observations help scientists to develop accurate satellite drag forecasts. Understanding satellite drag is critical to launching any new satellite and protecting current assets in space.

An Eclipse Is a Type of Transit

A **transit** occurs when one astronomical object blocks another. From Earth, we can observe solar transits by Mercury and Venus, and of course the Moon during a solar eclipse. Mercury and Venus are too far away to even come close to blocking out the entire Sun, like a total solar eclipse.



Images taken in sequence and composited together show the path of Venus across the Sun in 2012.

Credit: NASA/SDO

Would you like to see an eclipse on another planet? NASA's Mars Curiosity rover took these images of a solar eclipse by Phobos.



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

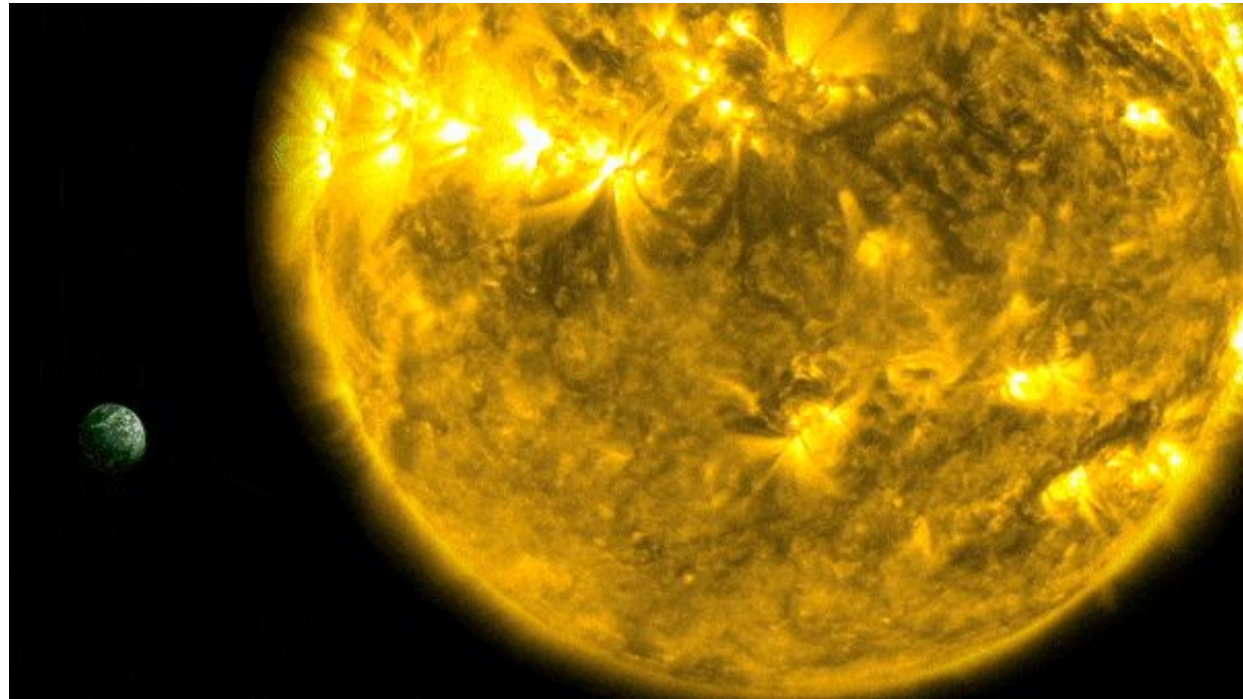


Finding Exoplanets by Observing Transits

NASA uses transits, or distant eclipses, to discover exoplanets. Exoplanets are planets outside of the solar system, orbiting distant stars. NASA can find these exoplanets by analyzing the light from the stars they orbit.

As a planet passes in front of its star, missions like the Transiting Exoplanet Survey Satellite (TESS) and the James Webb Space Telescope can detect exoplanets by studying the brightness of the star over time.

By analyzing the amount of dimming of the star's light, astronomers can determine the size of the planet, its mass and orbital radius, as well as other characteristics.






Lesson 2.2:

Science Investigations During the 2024 Total Solar Eclipse

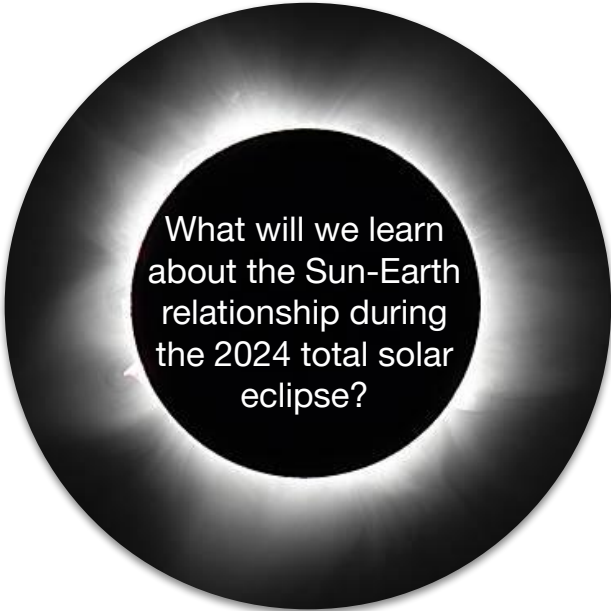
The Moon is seen as it starts passing in front of the Sun during the August 2017 total solar eclipse above Ross Lake, Northern Cascades National Park, Washington.
Credit: NASA/Bill Ingalls

Lesson 2.2 Learning Objectives

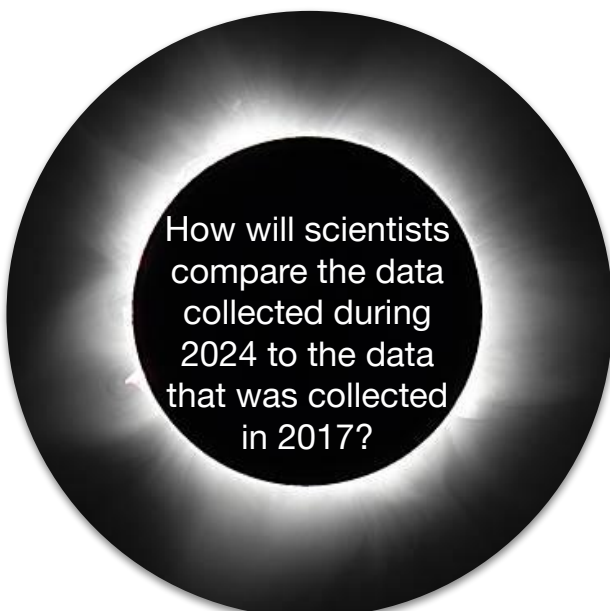
By the end of this lesson, you will be able to answer the following questions:



What science investigations will NASA fund for the 2024 total solar eclipse?



What will we learn about the Sun-Earth relationship during the 2024 total solar eclipse?



How will scientists compare the data collected during 2024 to the data that was collected in 2017?

NASA Science for the 2024 Total Solar Eclipse



Credit: NASA/NOAA

During the total solar eclipse, various science experiments will be done to increase our understanding of the Sun-Earth 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.

During a total solar eclipse, NASA is interested in:

- Learning more about solar science such as the connections between the lower and middle corona.
- Learning more about atmospheric science through the observation of 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.
- Testing the design and function of new hardware in the unique eclipse conditions.



Funded NASA Eclipse Science

1. Chasing the Eclipse with NASA's High-Altitude Research Planes [Southwest Research Institute]
2. Airborne Imaging and Spectroscopic Observations of the Corona [University of Hawaii]
3. "Contest" for Amateur Radio Operators [University of Scranton]
4. The Effects of Solar Radiation on Earth's Upper Atmosphere Layers [Virginia Tech]
5. Bringing the Sun's Magnetic "Hot Spots" Into Sharper Focus [JPL/GAVRT]
6. Eclipse Sounding Rocket Campaign [Embry-Riddle Aeronautical University]



Credit: NASA

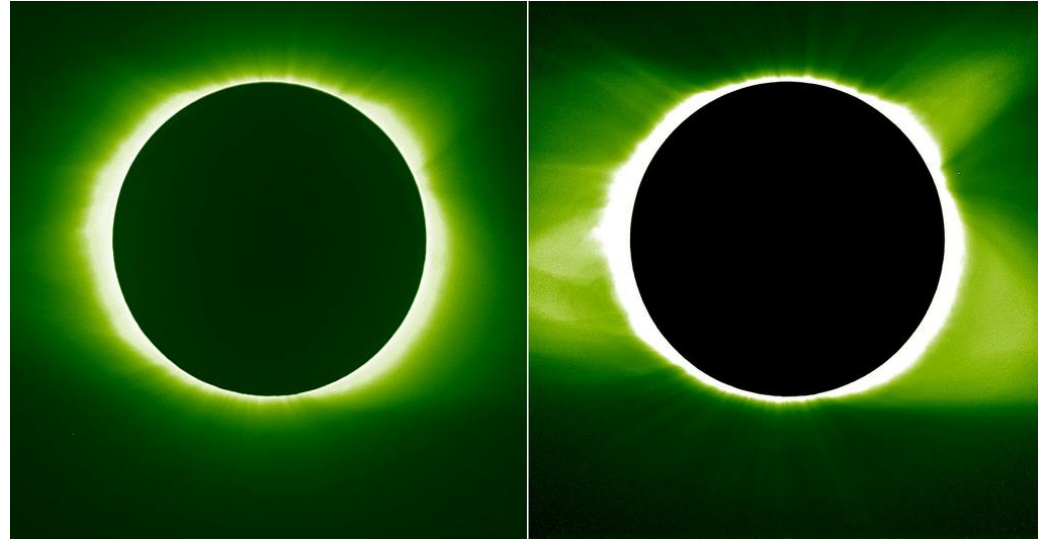
“ —
Seven years after the last American total solar eclipse, we're thrilled to announce the selection of ... new projects that will study the 2024 eclipse. We're excited to see what these new experiments will uncover about our Sun and its impact on Earth. — ”

- Peg Luce, Deputy Director of the Heliophysics Division in the Science Mission Directorate at NASA Headquarters

1. Chasing the Eclipse with NASA's High-Altitude Research Planes

Using NASA's WB-57 high-altitude research aircraft, one project will capture images of the eclipse from an altitude of 50,000 feet above Earth's surface. By taking these images in Earth's upper atmosphere, the team hopes to be able to see new details of structures in the middle and lower corona. The observations, taken with a camera that images in infrared and visible light at high resolution and high speed, could also help study a dust ring around the Sun and search for asteroids that might orbit near the Sun.

The project, led by the Southwest Research Institute in Boulder, builds on a [successful 2017 project](#) with a new camera suite. Images from the 2017 eclipse are shown on the right.



Visible-light data was gathered during the August 21, 2017, eclipse by a telescope aboard NASA's WB-57 jet. Raw data is on the left, and processed data is on the right.

Credit: NASA/SwRI/Amir Caspi/Dan Seaton

2. Airborne Imaging and Spectroscopic Observations of the Corona



A WB-57F jet is readied for a test run at NASA's Johnson Space Center in Houston.

Credit: NASA's Johnson Space Center/Norah Moran

NASA's WB-57 airplanes will also fly cameras and spectrometers (which study the composition of light) to learn more about the temperature and chemical composition of the corona and coronal mass ejections, or large bursts of solar material. By flying along the eclipse path, they also hope to extend their time in the Moon's shadow by over two minutes. The team hopes these observations will provide new insights into structures in the corona and the sources of the constant stream of particles emitted by the Sun, the solar wind. The team is led by the University of Hawaii.

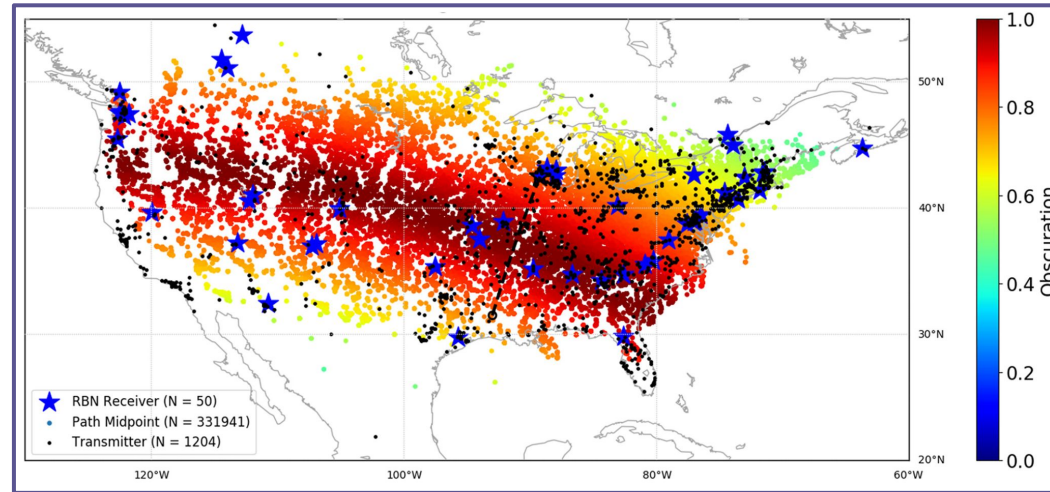
3. “Contest” for Amateur Radio Operators

During the total solar eclipse on April 8, 2024, the worldwide amateur (ham) radio community will collect data for space physics research. Through a series of friendly ham radio competitions and researcher-led experiments, the ham radio community will collect data by transmitting, receiving, and recording signals across the high-frequency radio spectrum before during, and after the eclipse. This project is lead by the University of Scranton and is trying to answer these questions:

How does the ionosphere couple with the neutral atmosphere and with space?

How do solar eclipses impact ionospheric structure and dynamics?

Reverse Beacon Network (RBN) Solar Eclipse QSO Party Observations During the August 21, 2017, Total Solar Eclipse



RBN observations were made during the total solar eclipse in 2017. Midpoints between transmitter and RBN receiver are color coded by their maximum obscuration.

Credit: [Frissell et al. \(2018\) in Geophysical Research Letters](#)

4. The Effects of Solar Radiation on Earth's Upper Atmosphere

The darkest part of the 2024 total eclipse's shadow passes across several locations equipped with Super Dual Auroral Radar Network (SuperDARN) radars. SuperDARN monitors space weather conditions in the upper layers of Earth's atmosphere, so the eclipse offers a unique opportunity to study the impact of solar radiation on this part of the atmosphere during the eclipse.

A project led by Virginia Tech will use three SuperDARN radars to study the ionosphere during the eclipse. The team will compare the measurements to predictions from computer models to answer questions about how the ionosphere reacts to a solar eclipse.



The SuperDARN Dome C North (DCN) radar is located at Franco-Italian base, Concordia, in Antarctica.

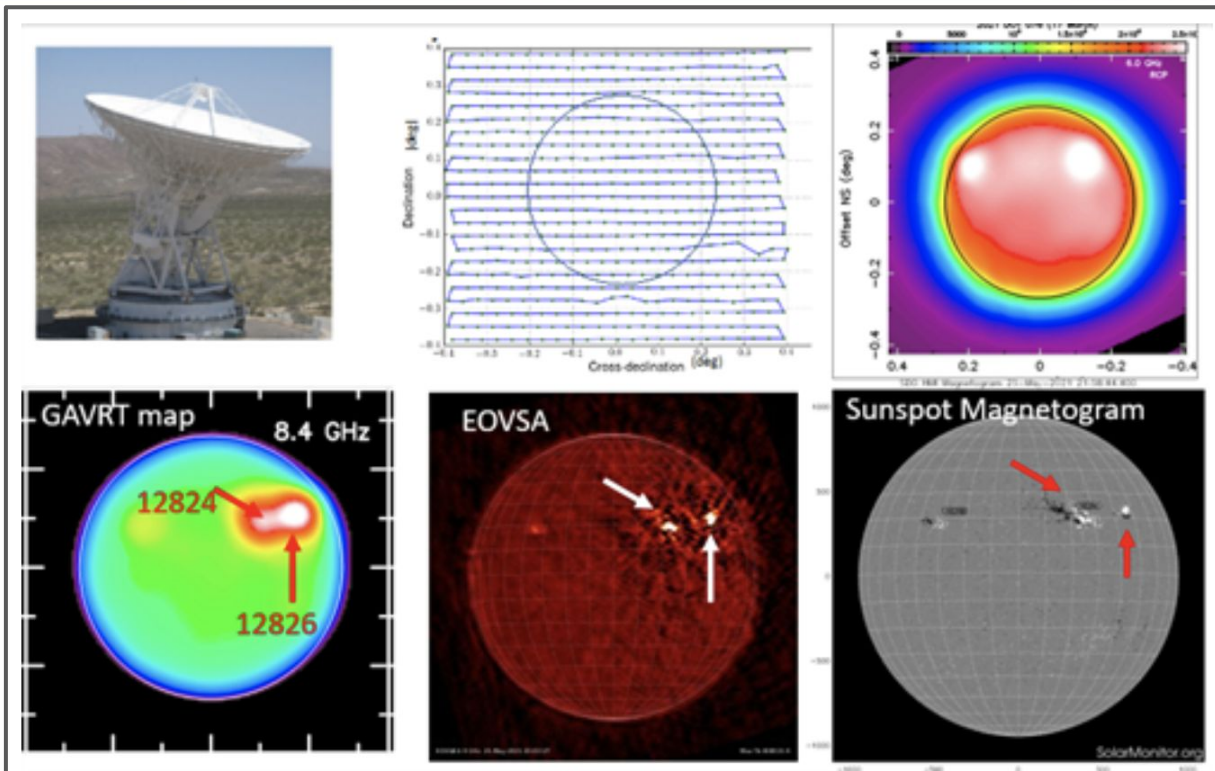
Credit: INAF (Italy) and CNR (France)

5. Bringing the Sun's Magnetic “Hot Spots” Into Sharper Focus



During the eclipse, NASA's Jet Propulsion Laboratory, educators at the Lewis Center for Education Research in Southern California, and participants in the center's [Solar Patrol citizen science program](#) will observe solar “active regions” – the magnetically complex regions that are often associated with sunspots – as the Moon moves over them.

The Moon's gradual passage across the Sun blocks different portions of the active region at different times, allowing scientists to distinguish small-scale coronal features in radio wavelengths for the first time.



A GAVRT antenna produces radio images of the Sun that cannot be seen with the naked eye.

Credit: Goldstone Apple Valley Radio Telescope

6. Eclipse Sounding Rocket Campaign

NASA is launching suborbital sounding rockets from Wallops Flight Facility in April 2024 to observe and understand the effects of the total eclipse on Earth's atmosphere. This is a continuation of an experiment that also flew during the October 2023 annular solar eclipse out of White Sands. This project is led by Embry–Riddle Aeronautical University.

Objectives

- Explore how the eclipse shadow promotes irregularities in the ionosphere
- Understand how the ionosphere responds to local changes in density, temperature, and conductivity
- Assess how lower atmosphere cooling due to the eclipse impacts ionospheric dynamics

Launch Sequence

- Rocket 1: launching ~35 minutes before peak eclipse
- Rocket 2: launching at peak eclipse
- Rocket 3: launching ~35 minutes after peak eclipse



Credit: NASA SVS



Lesson 2.3:

NASA Missions Explore the Sun


The Moon is seen as it starts passing in front of the Sun during the August 2017 total solar eclipse above Ross Lake, Northern Cascades National Park, Washington.
Credit: NASA/Bill Ingalls

Lesson 2.3 Learning Objectives


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



How do all missions in NASA's science fleet work together to learn more about the universe?

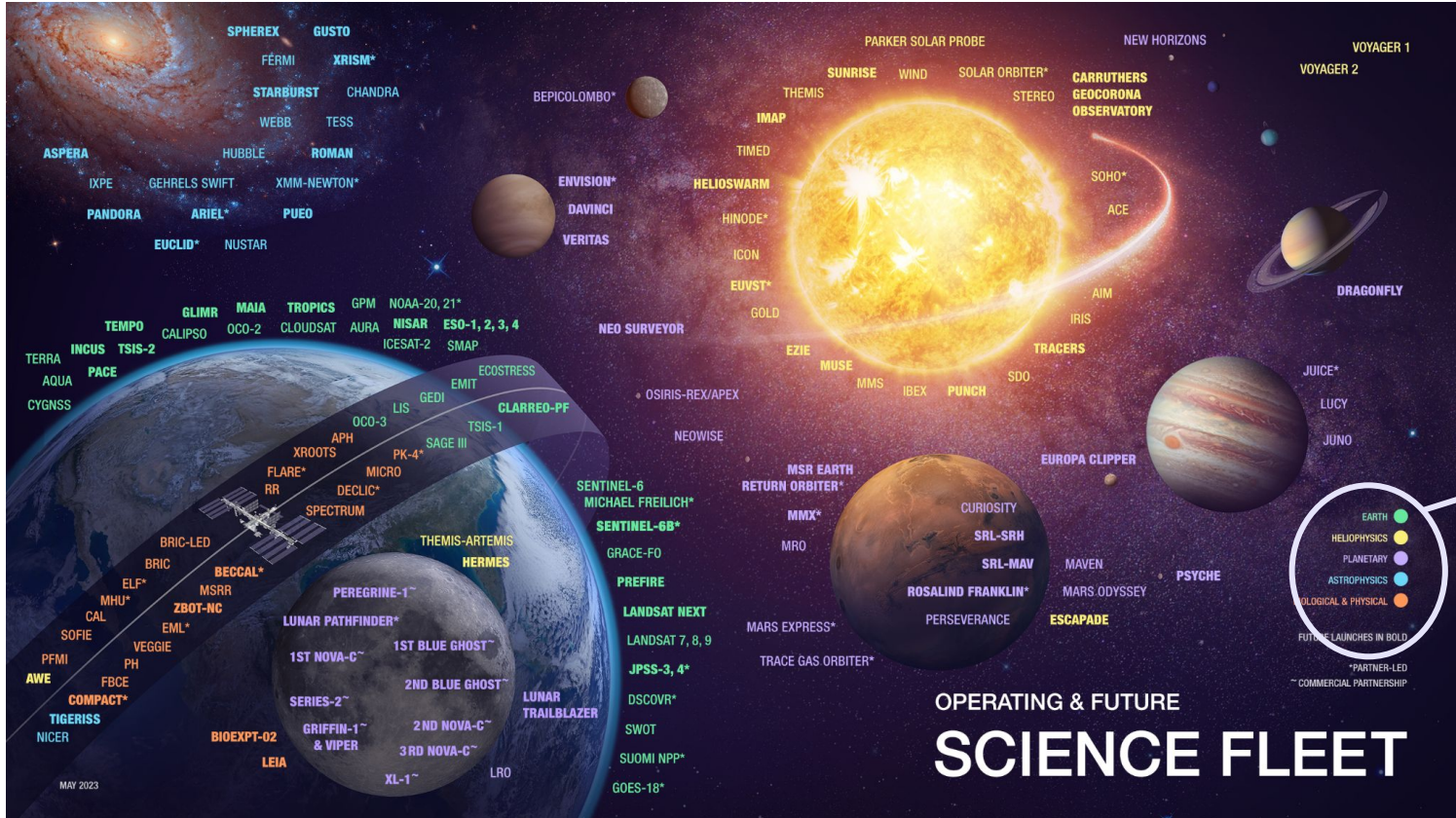


How do other types of missions contribute to heliophysics?



Why is heliophysics important to human space flight?

NASA Science Fleet



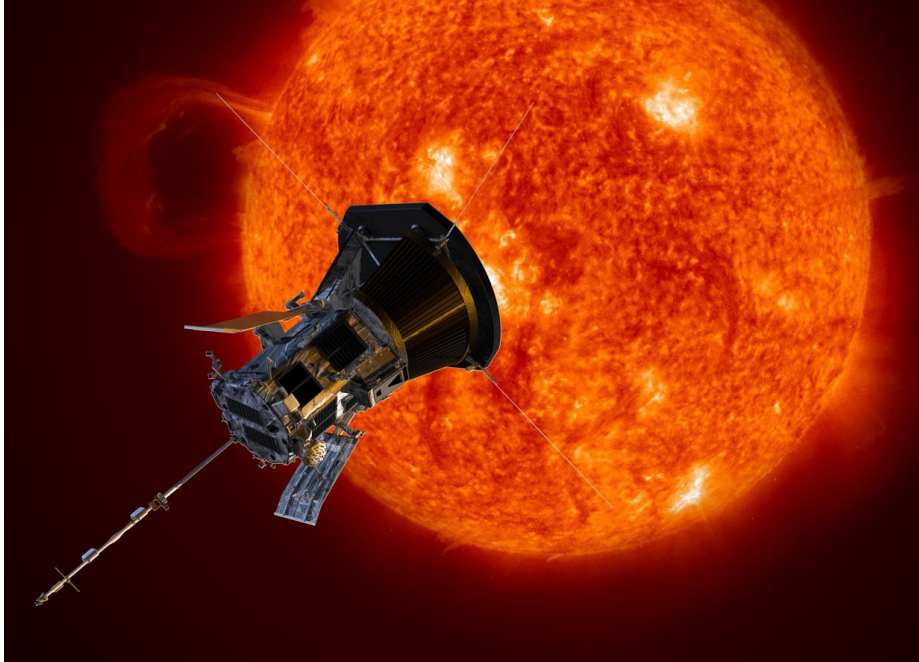
- EARTH (Green circle)
- HELIOPHYSICS (Yellow circle)
- PLANETARY (Purple circle)
- ASTROPHYSICS (Cyan circle)
- BIOLOGICAL & PHYSICAL (Orange circle)

*PARTNER-LED
 **COMMERCIAL PARTNERSHIP

Image not to scale.

Credit: NASA's Goddard Space Flight Center

The Rhythm of the Sun and Heliophysics



Credit: NASA/Parker Solar Probe

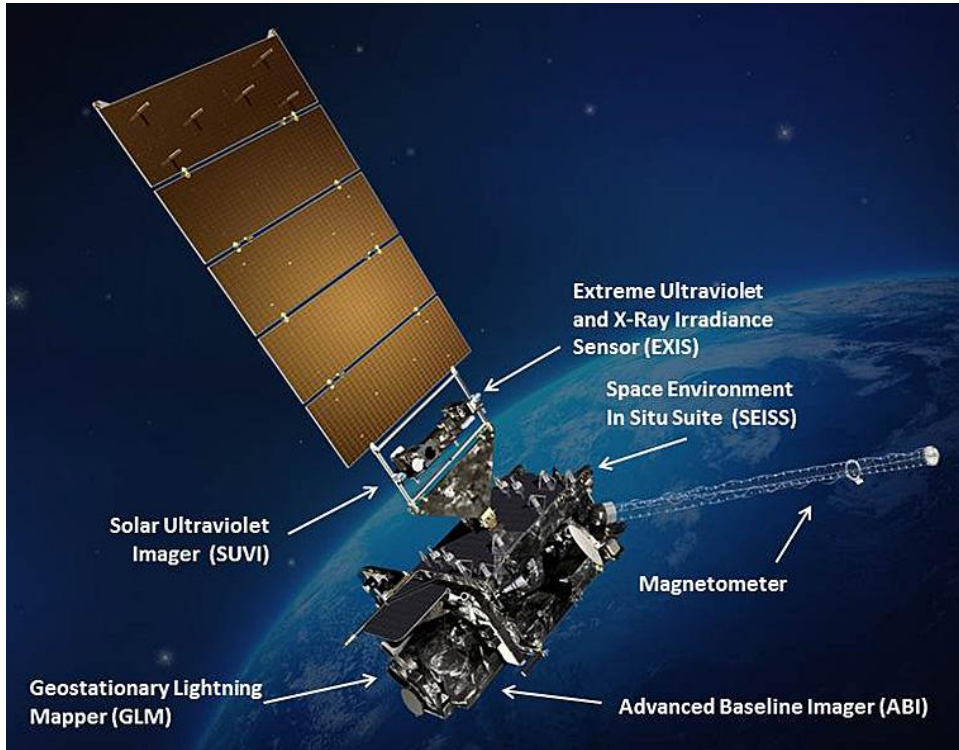
The **Parker Solar Probe** mission is only one of many dedicated heliophysics missions whose goals are to study the Sun across the electromagnetic spectrum.

Parker Solar Probe helps us learn more about...

Space Weather: The data collected by Parker, combined with NASA's best theoretical models of how our Sun produces space weather, help us predict "solar storms," which can endanger humans and our technology.

Solar Wind: The origin of the solar wind is the Sun's corona. Parker will fly within 3.8 million miles of the Sun, collecting unprecedented data from the Sun's corona.

The Rhythm of the Sun and Earth Science



Credit: GOES, NASA/NOAA

The **Geostationary Operational Environmental Satellites (GOES) R-series** mission includes multiple satellites that monitor weather on Earth.

The GOES R-series satellites help us learn more about...

Space Weather: These satellites carry a number of sensors to monitor our Sun in support of space weather modeling and forecasting.

The Space Environment In-Situ Suite (SEISS) instrument detects solar radiation storm events and monitors spacecraft charging – which are harmful to satellites and humans operating in space.

Solar Flares: The Extreme Ultraviolet and X-ray Irradiance Sensors (EXIS) keep track of solar flares that could affect radio communications on Earth.

The Rhythm of the Sun and Astrophysics



Credit: NASA

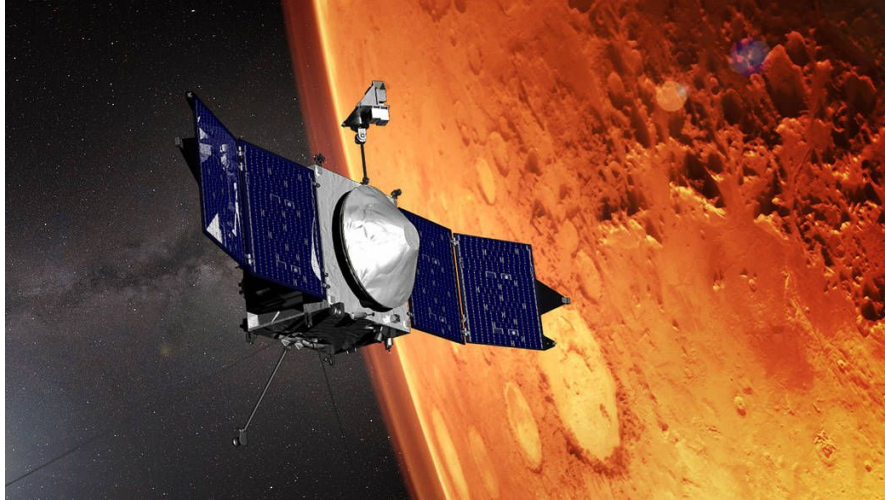
The **Imaging X-Ray Polarimetry Explorer (IXPE)** mission traces the story of where X-rays come from, including the geometry and inner workings of X-ray sources where matter is under extreme conditions – violent collisions, enormous explosions, 10-million-degree temperatures, and strong magnetic fields.

IXPE helps us learn more about...

Solar Flares: Solar flares produce bursts of intense, million-degree X-ray light.

Magnetic Reconnection: IXPE observes distant magnetic reconnection, a process that occurs both in the solar and Earth environment. Reconnection also occurs in remote astrophysical systems such as the disks of swirling plasma surrounding black holes.

The Rhythm of the Sun and Planetary Science



This artist concept shows the MAVEN spacecraft and the limb of Mars.

Credit: NASA

The **Mars Atmosphere and Volatile Evolution (MAVEN)** mission explores the Red Planet's upper atmosphere, ionosphere, and interactions with the Sun and solar wind.

MAVEN helps us learn more about...

Solar Wind: The Martian atmosphere has been steadily eroded by the solar wind over the last 3 billion years. MAVEN is measuring how rapidly this is occurring and what atmospheric molecules are involved.

Space Weather: MAVEN continuously monitors atmospheric escape as Mars is affected by coronal mass ejections and bursts of solar wind particles.

The Rhythm of the Sun and Biological and Physical Sciences (BPS)



Credit: NASA

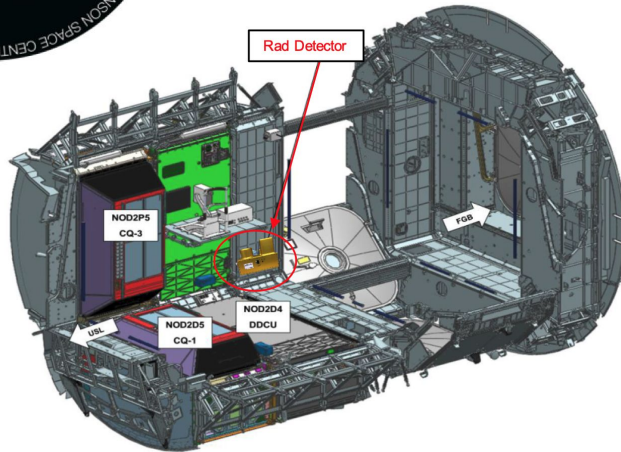
A majority of BPS missions are aboard the International Space Station. The **3D Tissue Chips** mission and Microphysiological Systems (MPS) replicate human organs using organ-specific cells – such as heart, liver, or pancreatic cells – on small devices, roughly the size of a USB drive. Researchers and clinicians use these tissue chips to test and observe how cells respond to various environmental factors (such as radiation and microgravity) and devise treatments for long-term human spaceflight.

The 3D Tissue Chips mission helps us learn more about...

Radiation Effects of the Sun on Human Tissue: 3D Tissue Chips will help determine individual sensitivity for each astronaut, allowing NASA to tailor countermeasures for personalized medical kits for long-duration missions.

Effective Medical Treatments on Earth: 3D Tissue Chips provide insight into disease models, drug development, clinical trial design, and chemical/environmental exposures and countermeasures.

The Rhythm of the Sun and Human Spaceflight



Location of ISS-RAD on the space station
Credit: NASA

The **International Space Station Radiation Assessment Detector (ISS-RAD)** detects high-energy particles from the Sun produced during solar flares and coronal mass ejections. It is an essential instrument for monitoring astronaut radiation exposure.

ISS-RAD helps us learn more about...

Solar Flares: ISS-RAD identifies the energy spectrum of the particles arriving at the International Space Station.

Coronal Mass Ejections: Scientists can compare the recorded events from ISS-RAD with solar phenomena that may have caused them, such as coronal mass ejections.

One Universe, One NASA



To study the entire heliosphere requires enormous amounts of data spanning timescales from seconds to decades and distances from meters to billions of kilometers.

With only a handful of spacecraft armed with the right sensors, investigations in each science division have to leverage the data from the entire armada of NASA spacecraft to build their physics-based models and to advance the collective human knowledge of the universe.

An artist's illustration depicts an astronaut working on the lunar surface.
Credit: NASA