2017 Solar Eclipse – NASA Media Tool Kit

On Monday, Aug. 21, 2017, the U.S. will be treated to a total eclipse of the sun.

The eclipse will be visible -- weather permitting -- across all of North America. The entire continent will experience a partial eclipse lasting two to three hours. Anyone within a 70-mile-wide path that stretches through 14 states from Oregon to South Carolina will experience a total eclipse. During those brief moments -- when the moon completely blocks the sun's bright face for about two minutes -- day will turn into night, making visible the otherwise hidden solar corona, the sun's outer atmosphere. Bright stars and planets will become visible as well. Birds will fly to their nighttime roosts. Nocturnal insects such as cicadas and crickets will buzz and chirp.

For NASA, the eclipse provides a unique opportunity to study the sun, Earth, moon and their interaction, because of the eclipse's long path over land coast to coast. Eleven NASA and NOAA satellites, the International Space Station, more than 50 high-altitude balloons, and hundreds of ground-based assets will take advantage of this rare event over 90 minutes, sharing the science and the beauty of a total solar eclipse with all.

Via live streams and a NASA TV broadcast, NASA will bring the Aug. 21 eclipse live to viewers everywhere in the world.

For interviews with NASA experts, please contact:

Dwayne Brown / Laurie Cantillo
202-358-1726 / 202-358-1077
dwayne.c.brown@nasa.gov /
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Karen Fox
301-286-6284
karen.c.fox@nasa.gov

For footage, please contact:

Fred Brown
202-358-0713
fred.a.brown@nasa.gov

Key Media Events

AUG 16: Live Shots on eclipse safety

- Live from 6:00am-noon EDT and again in the afternoon.
- Contacts:
    - Michelle Handleman
      Michelle.z.handleman@nasa.gov

301-286-0918

- Clare Skelly
  clare.a.skelly@nasa.gov
  301-286-4994

AUG 21 NASA TV: Four-hour live broadcast from 12 p.m. – 4 p.m. EDT

- NASA experts along the path of totality
- Live feeds from NASA aircraft, balloons, and the International Space Station
- Eclipse views from around the U.S.
    - Contacts for satellite feed information:
        - Fred Brown
          Fred.a.brown@nasa.gov

Resources

Information:

- **eclipse2017.nasa.gov**
    - Comprehensive information on the 2017 eclipse, eclipse science, and interactive maps showing what can be seen where and activities planned
- **eclipse2017.nasa.gov/safety**
    - Key safety information
- **eclipse2017.nasa.gov/espanol**
    - resources in Spanish

Localized information:

- **eclipse2017**.nasa.gov/sites/default/files/interactive_map/index.html
    - Find the times and duration for the 2017 eclipse anywhere in the world
- **eclipse2017.nasa.gov/event-locations**
    - Find eclipse events planned around the world
- **eclipse2017.nasa.gov/nasas-eyes**
    - JPL's "Eyes on the Sky" eclipse app provides local viewers with an animation of what the eclipse will look like from any city in the U.S.

Imagery:

- **svs.gsfc.nasa.gov/eclipse2017**

Real-time NASA videos and live streams on Aug. 21:

- **nasa.gov/eclipselive**
    - NASA TV will air a nationally-broadcast multi-hour show -- *Eclipse Across America: Through the Eyes of NASA.* The program will provide unprecedented live images of the celestial event along with public reaction and activities across the nation in parks, sports stadiums, museums and social media postings.
    - Live streams from more than 50+ high altitude balloons launched from around the country, coordinated by Montana State University.
    - Live streams of NASA-related eclipse events around the nation. Including a 4.5 hour live telecast of the eclipse from Carbondale, Illinois, via NASA EDGE including scientist interviews, high resolution sun imagery in various wavelengths, and a balloon launch.
    - Real time imagery of the sun from NASA's sun-watching space telescope, the Solar Dynamics Observatory. Views will include a lunar transit from 3:27 to 3:55 p.m. EDT on Aug. 21, 2017.

Social Media:

- @NASASun
- Facebook.com/NASASunScience
- snapchat.com/add/NASA
- Instagram.com/NASAGoddard

Eclipse Fast Facts

> *"The hair on the back of your neck is going to stand up and you are going to feel different things as the eclipse reaches totality. It's been described as peaceful, spiritual, exhilarating, shocking. If you're feeling these things, don't worry, you're experiencing the total eclipse of the sun!" – Brian Carlstrom, Deputy Associate Director of the National Park Service Natural Resource Stewardship and Science Directorate*

- On Aug. 21, 2017, all of North America will view – weather permitting -- a partial eclipse, when the moon obscures part of the sun.
- A total eclipse will be viewable throughout a 70-mile-wide path that crosses 14 of the United States from Oregon to South Carolina.
- The umbra (or dark inner shadow) of the moon will be traveling from west to east from almost 3,000 miles per hour (in western Oregon) to 1,500 miles per hour in South Carolina.

- The last total eclipse in the contiguous United States occurred on Feb. 26, 1979. The last total eclipse that crossed the entire continent occurred on June 8, 1918.
- Experiencing a total solar eclipse where you live happens on average about once in 375 years.
- 12.2 million Americans live in the path of the total eclipse. Of course, with visitors, that number will be much higher on Aug. 21!
- About 200 million people (a little less than 2⁄3 the nation's population) live within one day's drive of the path of this total eclipse. In addition, millions of Americans will be able to view a partial eclipse, weather permitting.
- The lunar shadow enters the West Coast at 9:05 a.m. PDT, and Lincoln City, Oregon will be the first place in the continental U.S. to see the total solar eclipse, beginning at 10:15 a.m. PDT.
- Southern Illinois, near Carbondale, will experience the longest eclipse duration, clocking in at two minutes, 40.3 seconds, beginning at 1:20 p.m. CDT.
- Hopkinsville, Kentucky will view the greatest eclipse – that is, where the sun, the moon and Earth line up the most precisely. The eclipse begins there at 1:24 p.m. CDT.
- Charleston, South Carolina will be the last place in the continental U.S. to see the total solar eclipse, ending at 2:48 p.m. EDT.
- The lunar shadow will exit the East Coast of the U.S. at 4:09 p.m. EDT.
- 11 spacecraft, over 50 NASA-funded high-altitude balloons, numerous ground-based observations and citizen scientists will capture a wealth of images and data that will be made available to the public before, during, and after the eclipse.
- Total solar eclipses offer unprecedented opportunities to study Earth under uncommon conditions. The sudden blocking of the sun during an eclipse reduces the sunlight energy that reaches the Earth. Scientists stationed in Columbia, Missouri and Casper, Wyoming will measure the radiant energy in the atmosphere from the ground and in space. Their goal is to improve our understanding of how the sun's radiant energy within the Earth's atmosphere changes when clouds, particles, or the moon block sunlight from reaching the Earth's surface.
- Scientists have made extensive atmospheric radiant energy measurements during eclipses before, but this is the first opportunity to have coordinated data from both the ground and from a spacecraft located 1 million miles (1.6 million kilometers) from Earth that can see the entire sunlit Earth during an eclipse.
- These quick-changing conditions can affect local weather and even animal behavior. For example, orb-weaving spiders were observed dismantling their webs during a 1991 eclipse in Mexico.
- There have been numerous misconceptions about eclipses over the centuries. For more: https://eclipse2017.nasa.gov/eclipse-misconceptions
- For additional eclipse FAQs visit: https://eclipse2017.nasa.gov/faq

Image caption: The lunar shadow first enters the West Coast at 9:05 a.m. PDT. Totality begins in Lincoln City, Oregon, at 10:15 a.m. PDT. Totality ends at 2:48 p.m. EDT in Charleston, South Carolina. The lunar shadow leaves the East Coast at 4:09 p.m. EDT. Credits: NASA/SVS

Safety

https://eclipse2017.nasa.gov/safety

Viewing Safety:

The only safe way to look directly at an uneclipsed or partially eclipsed sun is through special-purpose solar filters, such as eclipse glasses or handheld 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. Looking directly at the sun is unsafe except during the brief total phase of a solar eclipse, called totality, when the moon entirely blocks the sun's bright face. This will happen only within the narrow path of totality.

It is NOT safe to look at the sun through the viewfinder of a camera or an unfiltered telescope, binoculars, or other optical device. You may, however, safely look at the screen of your smart phone or digital camera focused on the eclipse, though you are unlikely to get a good view.

An alternative method for safe viewing of the partially eclipsed sun is pinhole projection. In this method, you don't look directly at the sun, but at a projection on a piece of paper or even the ground. For example, cross the outstretched, slightly open fingers of one hand over the outstretched, slightly open fingers of the other. Standing with your back to the sun, do not look at your hands, but at the shadow of your hands on the ground. The little spaces between your fingers will project a grid of small images, showing the sun as a crescent during the partial phases of the eclipse. See the appendix for ways of making projectors out of readily available materials such as a cereal box.

3-D printable pinhole projectors of each state available at: https://eclipse2017.nasa.gov/3d-printable-pinhole-projectors

Travel Safety

> *"We're encouraging people to put in some extra effort to plan their travel ahead of time, as this isn't your average travel weekend." – U.S. Federal Highway Administration*

The best advice for travelers planning to view the total solar eclipse is to plan well in advance. In fact, for many key viewing locations, it may already be too late to make a lodging or camping reservation. So you may have to get creative and plan to stay with family or friends.

The Federal Highway Administration calls this a "planned special event for which there has been no recent precedent in the United States." There may well be intense traffic both before and after the eclipse along the path of totality. Viewers should attempt to get to their viewing spot well ahead of time – a day or more in advance if possible. Travelers should make sure to bring food and water, and determine how to access a bathroom if they need wait out the traffic when they leave.

For more information and safe driving tips, visit:
https://ops.fhwa.dot.gov/publications/fhwahop16085/index.htm
and
www.fhwa.dot.gov.

Eclipse Terminology

Annular solar eclipse: A solar eclipse that occurs when the apparent size of the moon is not large enough to completely cover the sun. A thin ring of very bright sunlight remains around the black disk of the moon, known as the "ring of fire."

Baily's Beads: The effect seen just before and just after totality when only a few points of sunlight are visible through valleys around the edge of the moon.

Contact: The points when the apparent position of the edges of the sun and the moon (for eclipses) and the sun and a planet (for transits) cross each other.

Corona: The upper atmosphere of the sun. It appears as a halo around the sun during a total solar eclipse.

Diamond ring: During a total solar eclipse, the effect seen in the few seconds just before and after totality when a single point of sunlight brilliantly shines through a valley on the limb of the moon – appearing almost as if it's a giant diamond in the sky.

Eclipse: An alignment of astronomical objects in which a planetary object (for example, the moon) comes between the sun and another planetary object (for example, Earth), resulting in a shadow being cast by the middle planetary object onto the other planetary object.

Lunar eclipse: The passage of the moon into the shadow of Earth, making the moon seem to go completely dark from our viewpoint on the ground. Lunar eclipses can only occur during a full moon, when Earth lies in between the sun and the moon.

Occultation: An astronomical event that occurs when -- from a given viewpoint -- a celestial object passes in front of a smaller object, obscuring it completely.

Partial solar eclipse: When the moon passes in front of the sun, but blocks only part of the photosphere -- the bright, visible surface of the sun.

Penumbra: The moon's faint outer shadow. Observers in the penumbra do not experience the full darkness that occurs during a total eclipse, and they observe a partial solar eclipse in the sky -- because from their perspective the sun is only partially blocked by the moon.

Ring of fire: The sun's visible outer edges during an annular (not total) eclipse. During an annular eclipse, the moon is too far from Earth to obscure the sun completely, leaving the sun's edges exposed, which produces the ring of fire effect.

Shadow bands: Faint ripples of light sometimes seen on flat, light-colored surfaces just before and just after totality.

Solar eclipse: The passage of the moon directly between the sun and Earth, when the moon's shadow is cast upon Earth. The sun appears to be either partially or totally covered by the moon. Solar eclipses only occur during new moons, when the moon lies between the sun and Earth.

Total solar eclipse: When the celestial alignment of the sun, moon and Earth cause the moon to appear -- from a given vantage point on the ground -- to block the entire face of the sun.

Totality: The period during a solar eclipse when the sun's photosphere -- the bright, visible surface of the sun -- is completely covered by the moon. For a lunar eclipse, totality is the period when the moon is in the complete shadow of Earth.

Transit: The phenomenon of at least one celestial body appearing to move across the face of another celestial body, hiding a small part of it, as seen by an observer at a particular vantage point.

Umbra: The moon's dark inner shadow. Observers in the umbra see a total solar eclipse. The path of the umbra across Earth's surface, called the path of totality, is usually about 70 miles (100 kilometers) wide and travels over a path some 10,000 miles (16,000 kilometers) long.

For a complete eclipse glossary, please visit: https://eclipse2017.nasa.gov/eclipse-glossary#for_row11

Spacecraft Viewing the Eclipse

11 NASA and partner spacecraft will observe the 2017 solar eclipse.

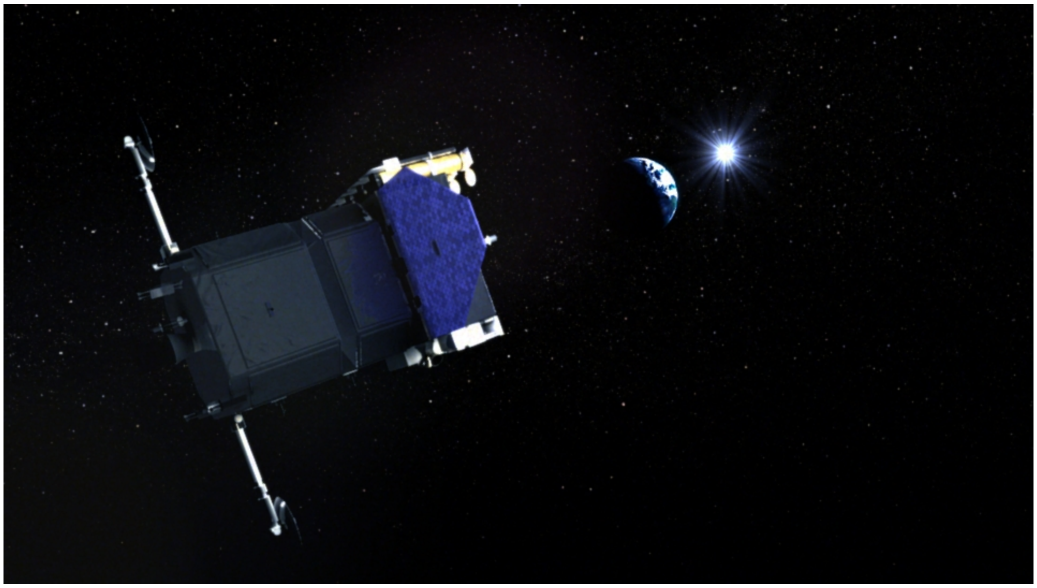

Image caption: An artistic illustration of the Solar Dynamics Observatory, or SDO. Credits: NASA Courtesy: Ryan Zuber

Observing a partial eclipse from space

NASA's Solar Dynamics Observatory

SDO studies what creates solar activity that causes space weather effects near Earth. To do so, SDO is equipped to measure the sun's interior, its magnetic field and the hot plasma of the solar corona.

NASA's Interface Region Imaging Spectrograph

IRIS makes use of high-resolution observations and state-of-the-art computer models to unravel how matter, light, and energy, travel through and heat a little-understood region little-understood region in the sun's lower atmosphere.

JAXA/NASA's Hinode

Hinode explores the magnetic fields of the sun in order to improve understanding of what powers the solar atmosphere and drives solar eruptions. Hinode's Solar Optical Telescope is the first space-borne instrument to measure the strength and direction of the sun's magnetic field on the sun's surface, the photosphere.

Observing the sun and its atmosphere from space

ESA/NASA's Solar Heliospheric Observatory

A joint ESA/NASA mission, SOHO studies the sun from deep inside its core to the outer corona and solar wind. A workhorse of NASA's fleet of solar-watching spacecraft, SOHO has been capturing images of dynamic solar eruptions – such as solar flares and coronal mass ejections -- since 1996.

NASA's Solar Terrestrial Relations Observatory

The STEREO mission employs two nearly identical space-based observatories—to provide the first-ever stereoscopic measurements to study the sun. With this pair of viewpoints, scientists have been able to see the three-dimensional structure and evolution of solar storms as they blast from the sun and travel out through space.

Observing Earth from space

NASA's Lunar Reconnaissance Orbiter

LRO is a robotic mission that set out to map the moon's surface and, after a year of exploration, was extended with a unique set of science objectives. LRO observations have enabled numerous groundbreaking discoveries, creating a new picture of the moon as a dynamic and complex body.

NASA's Terra

Launched on Dec. 18, 1999, Terra was the first satellite to look at Earth system science, collecting multiple types of data dedicated to various areas of Earth science. It joined other satellites designed to monitor specific areas of Earth science and has since been joined by others that all work in concert to collect data that leads to a better understanding of how our planet functions as a whole.

NASA's Aqua

Aqua launched on May 4, 2002. The satellite has six different Earth-observing instruments on board and is named for the large amount of information being obtained about water in the Earth system from its stream of approximately 89 Gigabytes of data a day.

NASA’s Suomi National Polar-orbiting Partnership

> Suomi NPP represents a critical first step in building the next-generation Earth-observing satellite system that will collect data on long-term climate change and short-term weather conditions. NPP is the result of a partnership between NASA, the National Oceanic and Atmospheric Administration, and the Department of Defense.

NOAA’s Geostationary Operational Environmental Satellite-16

> GOES-16 is the first of NOAA’s next generation of geostationary weather satellites. It provides continuous imagery and atmospheric measurements of Earth’s Western Hemisphere, total lightning data, and space weather monitoring to provide critical atmospheric, hydrologic, oceanic, climatic, solar and space data.

NOAA’s Deep Space Climate Observatory, or DSCOVR

> The Deep Space Climate Observatory, or DSCOVR, will maintain the nation's real-time solar wind monitoring capabilities which are critical to the accuracy and lead time of NOAA's space weather alerts and forecasts.

Celestial Geometry

A total solar eclipse happens when the sun, moon and Earth are perfectly aligned, so that the moon blocks all the sun’s light to part of Earth’s surface.

Total solar eclipses are only possible on Earth because of a celestial coincidence: The moon and the sun both appear to be about the same size from our vantage point on the ground. The sun is about 400 times wider than the moon, but it is also about 400 times farther away. That geometry means that when they line up just right, the moon blocks the sun’s entire surface, creating a total solar eclipse.

Image caption: The moon's shadow cones during a total solar eclipse. Observers on Earth within the smaller, central shadow, or umbra, see a total eclipse. Within the larger shadow, the penumbra, observers see a partial eclipse. Credit: NASA

During an eclipse, the moon's shadow is cast onto Earth's surface. This shadow, formed from concentric cones, can be divided into two parts:

- The *penumbra* is the moon's faint outer shadow. Observers in the penumbra experience a partial solar eclipse, because the sun is only partially blocked by the moon from their perspective.
- The *umbra* is the moon's dark inner shadow. Observers in the umbra see a total solar eclipse. The path of the umbra across Earth's surface, called the path of totality, usually stretches for about 10,000 miles (16,000 kilometers), though it is only about 70 miles (113 kilometers) wide.

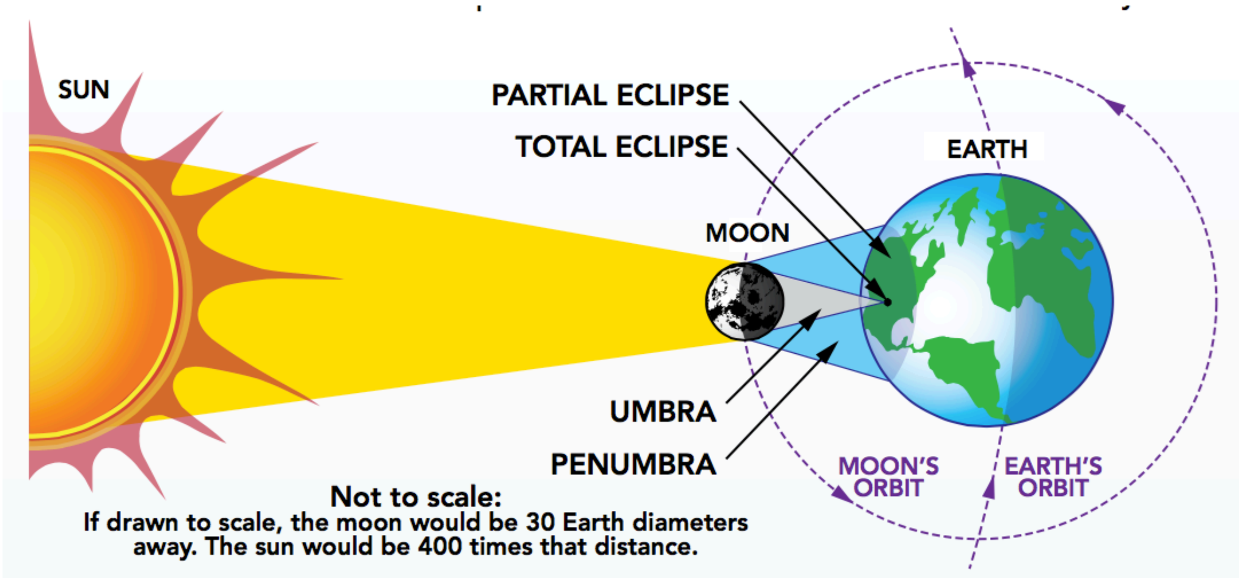

Image caption: *This illustration depicts the alignment of the sun, the moon and Earth – which only perfectly occurs about once every 18 months, on average. The umbra and penumbra are shown. Credit: NASA*

Total solar eclipses happen exclusively during new moon phases, when the moon passes directly between Earth and the sun, and its dark side faces Earth. New moons occur once a month, but we don't see eclipses every month because of the path along which each body orbits. The moon's orbit is tilted by about five degrees with respect to the sun and Earth, so it's only about once every 18 months that the three bodies line up perfectly.

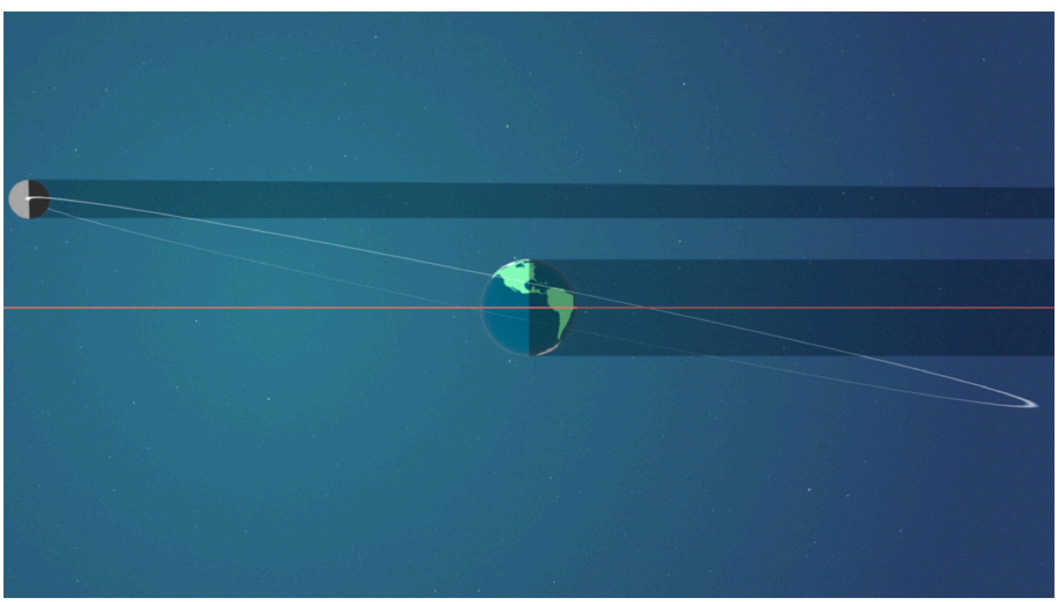

Image caption: While the moon comes between Earth and the sun once a month, the moon's shadow often lies above or below Earth, so we do not see an eclipse every month, making it more of a rare celestial treat.
Credit: NASA

NASA Eclipse Science – Overview

"This is the first eclipse in almost 100 years that's covering the entire country and that's going to be a game changer for eclipse science – both for studying the sun and what's happening here on Earth. Sports-viewing was essentially revolutionized by having cameras that could follow a player from start to finish. That's a little like what scientists can do during this eclipse. We can't send a camera in real time to follow the eclipse shadow – it travels at 1,500 miles an hour -- but we can line up cameras or sensors or, in this case, balloons. We then turn those many observations into one giant observation that lasts for roughly an hour and a half."
– Alex Young, Solar Scientist, NASA's Goddard Space Flight Center

The path of the total eclipse will provide a unique opportunity for NASA and other scientists to study the sun, moon, Earth, and their interaction. Weather permitting, other planets and astronomical phenomena will be visible. With its long path over land, this total eclipse provides unprecedented research opportunities: NASA funds balloons, ground measurements, and planes that "chase" the eclipse. Scientists can take continuous measurements of the sun and the eclipse's effects on Earth for relatively long periods of time.

Several NASA missions in space will observe the event. This includes astronauts aboard the International Space Station; NASA's Lunar Reconnaissance Orbiter, which will turn its instruments to face Earth and attempt to track the shadow of the moon on our planet; a host of Earth-observing spacecraft, which can both observe the shadow of the moon and measure how the dip in sunlight affects plants and the heating of the planet; and a fleet of solar observing spacecraft observing a partial eclipse.

The Sun

> *"During an eclipse, we're able to view the lower parts of the solar corona, the sun's atmosphere. This is a region where some of the biggest solar action happens, the action that drives space weather, both here on Earth and through the solar system."*
> *– Alex Young, Solar Scientist, NASA's Goddard Space Flight Center*

Understanding the sun has always been a top priority for space scientists. Studying how the sun affects space and the space environment of planets is a field known as heliophysics.

During a total eclipse, the lower parts of the sun's atmosphere, or corona, can be seen in a way that cannot completely be replicated by current human-made instruments. The lower part of the corona is key to understanding why the sun's atmosphere is so much hotter than its surface as well as the process by which the sun sends out a constant stream of solar material and radiation, which can cause changes in the nature of space and impact spacecraft, communications systems, and orbiting astronauts.

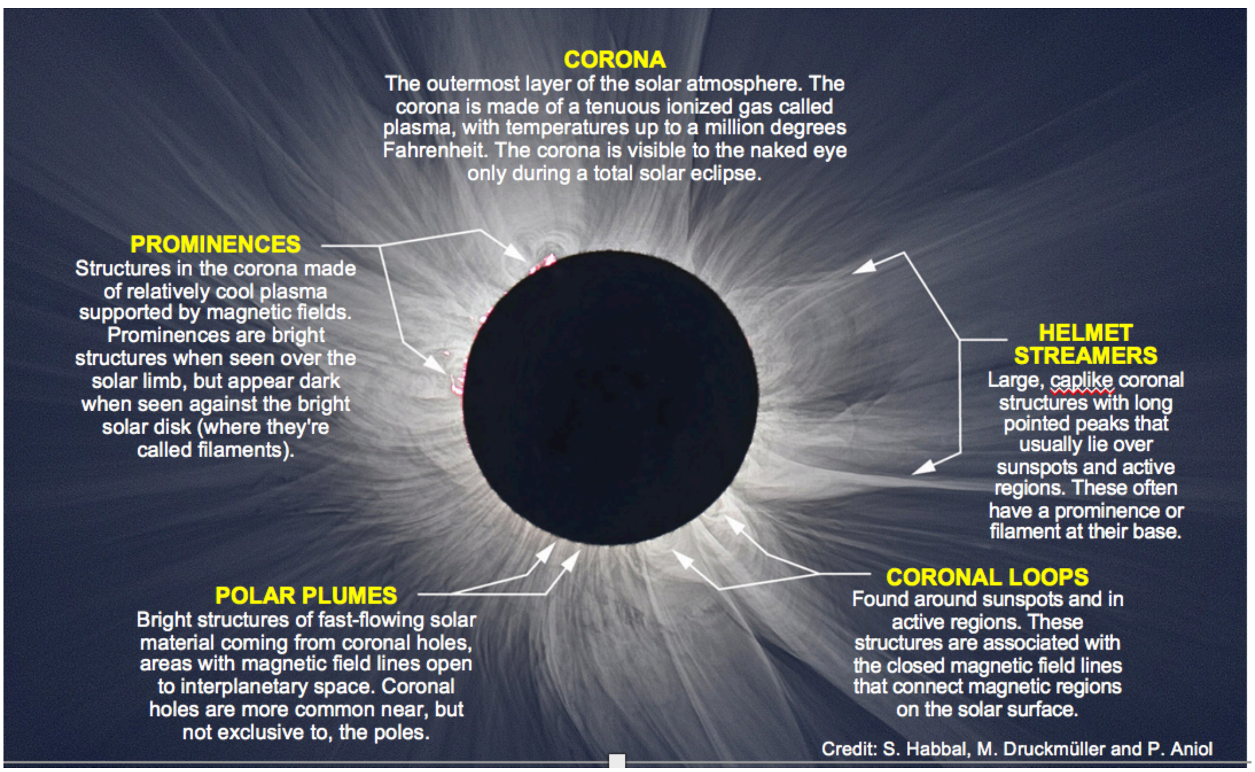

Image caption: During a total eclipse, detailed structures in the sun's atmosphere, the corona, can clearly be seen. Such structures are too dim to be seen next to the bright light of the sun's surface. Credits: NASA/S. Habbal, M. Druckmuller, P. Aniol

To further studies into the sun's constant outpouring of radiation, a new NASA mission, Parker Solar Probe, will launch in 2018 and will fly directly into the solar atmosphere that we can see with the naked eye during a total solar eclipse. The mission will provide first-of-its kind data on the star we live with, to help inform why the corona is so much hotter that the surface of the sun and how the solar wind is accelerated. This also helps provide key situational awareness of its effects on the space we travel through as we explore the solar system and beyond.

Real Time NASA Heliophysics Research

- NASA's Solar Dynamics Observatory and Interface Region Imaging Spectrograph, and the joint JAXA/NASA Hinode will all observe the sun during the eclipse.
- Two NASA WB-57 planes will take measurements of the solar corona in visible and infrared light in order to better understand how energy moves throughout the sun's atmosphere.
- Building on the work of Citizen CATE, in which citizen scientists can help gather imagery of the eclipse from wherever they are, scientists will gather additional imagery of the eclipse from two sites -- Tetonia, Idaho and Carbondale, Illinois. The experiment will map the two-dimensional electron distribution in the inner solar corona, providing new input for models that address the question of why the sun's atmosphere, the corona, is so much hotter than its surface.
- Two experiments from a mountaintop near Casper, Wyoming, scientists will gather images of the eclipse in a wide range of light wavelengths to map the magnetic field in the sun's corona, which can help improve models that show when the sun might erupt with a solar flare or coronal mass ejection.
- In Madras, Oregon, scientists will test a telescope that can see polarized light from the corona.
- A team of scientists spread across four states during the total solar eclipse will use spectrometers, which analyze the light emitted from different ionized elements in the corona, as well as specialized filters to probe the physics of the sun's outer atmosphere.

The Moon

It takes three bodies to create a total solar eclipse: Earth, the sun, and the moon. NASA currently has a robotic explorer at the moon. The Lunar Reconnaissance Orbiter, or LRO -- which launched in 2009 with a suite of seven instruments -- is helping us see the moon in a new light, as a complex and diverse body. For example, LRO recently found new evidence of frost on the moon's surface.
Thanks to 3-D mapping of the moon's surface by LRO, we know more than ever about the shadow that will be cast on Earth during the eclipse.

The incredible resolution provided by LRO makes it possible to predict the shape of the moon's horizon – providing information on just how light rays stream through lunar valleys. During totality, sunlight peeks through valleys and around mountains, creating jagged edges on the moon's inner shadow, the umbra. These edges warp even more as they pass over Earth's own mountain ranges.

Visualizers used data from LRO, coupled with NASA topographical data of Earth, [to precisely map the upcoming eclipse](#) in unprecedented detail. This shows how the umbra's shape varies with time; it is not simply an ellipse, but an irregular polygon with slightly curved edges.

Image caption: This map shows a detailed visualization of the moon's umbral shadow as it passes over the United States during the Aug. 21, 2017, total solar eclipse.
Credits: NASA/Goddard/SVS/Ernie Wright

Real Time NASA Lunar Research

The LRO spacecraft will turn around and take pictures of the moon's shadow on Earth during the Aug. 21 eclipse. The time of the eclipse across the U.S. is about 1.5 hours while the LRO orbit period is about two hours --117 minutes to be precise. Since a total eclipse observation is complex and anything but routine for LRO, the mission team will attempt to capture an image of the moon's shadow on Earth, consistent with the health and safety of the spacecraft. LRO has a solid track record of capturing previous eclipses, such as those shown here: http://lroc.sese.asu.edu/posts/513.

The mission team anticipates it will take images of the eclipse on one orbit and then will transmit them to Earth on a subsequent orbit.

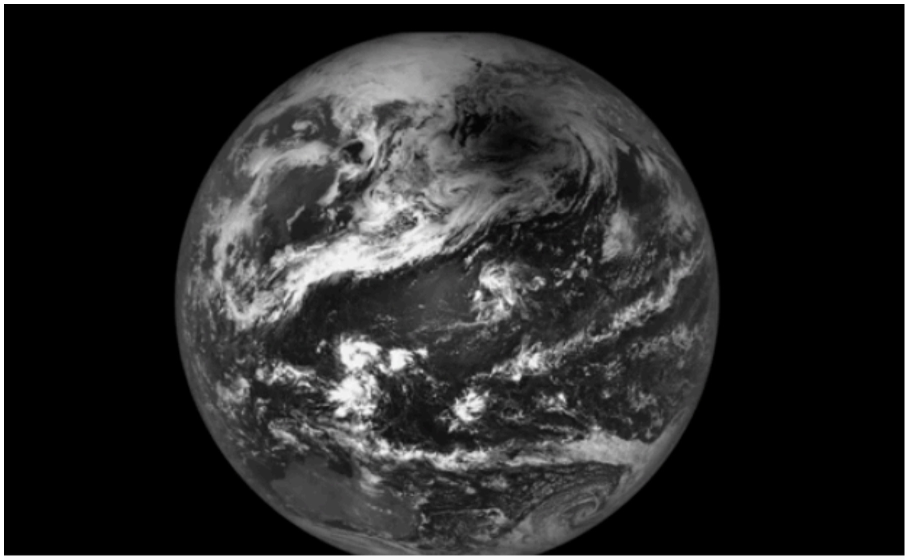

Image caption: NASA's Lunar Reconnaissance Orbiter, or LRO, captured an image of the moon's shadow on Earth during the annular solar eclipse of May 2012. On Aug. 21, 2017, LRO will once again capture images of the moon's shadow on Earth's surface. Credits: NASA/LRO

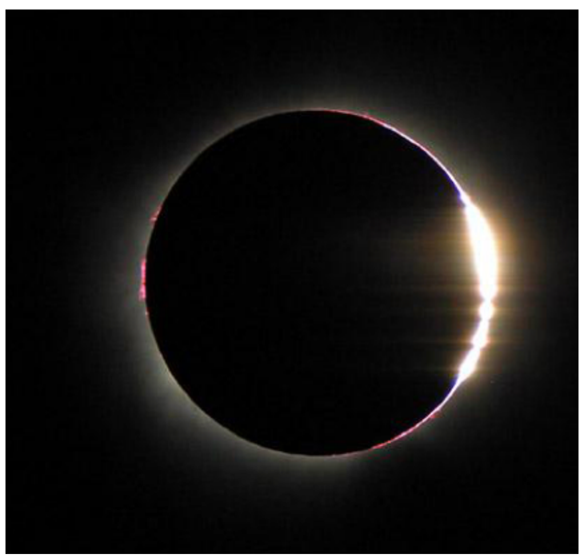

Image caption: Sunlight peeks through the low points on the moon's jagged edge during the 2002 total solar eclipse, creating a phenomenon known as Baily's Beads. Credit: Arne Danielson

Earth

During a total solar eclipse, the normal rhythms of Earth are briefly disrupted. The sudden blocking of the sun makes the day appear to be night in more ways than just the loss of light. The temperature drops and plants and animals react as if it is dusk – birds can be seen flying home to settle in for sleep in the middle of the day.

The eclipse also provides a unique opportunity for scientists to study the atmosphere of our solar-powered planet. NASA researchers want to improve our understanding of how solar energy is absorbed and reflected in Earth's atmosphere, known as Earth's Radiation Budget. Scientists have made extensive atmospheric measurements during eclipses before, but this is the first opportunity to collect coordinated data from the ground and from a spacecraft located approximately one million miles (1.6 million kilometers) away to observe the entire sunlit Earth during an eclipse. These data will better explain a more ordinary phenomenon— the effect of cloud cover. Scientists call this study a 3-D closure experiment.

Scientists will be on the ground in Casper, Wyoming and Columbia, Missouri for this experiment. They will compare ground measurements with those observed by NASA's Earth Polychromatic Imaging Camera, or EPIC, aboard the National Oceanic and Atmospheric Administration's Deep Space Climate Observatory, or DSCOVR. DSCOVR is located on Earth's first Lagrange point, known as L1 for short, about one million miles (1.6 million kilometers) from Earth.

NASA uses the vantage point of space to understand and explore our home planet to improve lives and safeguard our future. For more than 30 years, NASA has measured the solar energy hitting the top of Earth's atmosphere, the amount of the sun's energy reflected back to space, and the amount of thermal energy Earth emits to space. Later this year, NASA will continue to monitor the sun-Earth relationship by launching the Total and Spectral Solar Irradiance Sensor, or TSIS-1, to the International Space Station and the sixth Clouds and the Earth's Radiant Energy System, or CERES, instrument to orbit.

NASA and GLOBE invite eclipse watchers to become Citizen Scientists
The public will have an opportunity to help NASA with their science experiment by collecting cloud and temperature data from their phones. NASA's Global Learning and Observations to Benefit the Environment, or GLOBE, is a citizen science project that allows users to record observations with a free app. On Aug. 21, the program will feature a special eclipse observation. With the app, citizen scientists can help observe how the eclipse changes atmospheric conditions near them, and contribute to a database used by students and scientists worldwide in order to study the effects of the eclipse on the atmosphere. Even

observers in areas with a partial eclipse or outside the path of totality can still provide useful comparison data.

This year, NASA also will be recruiting private pilots at the Experimental Aircraft Association AirVenture Annual Conference to help us collect data regarding how changes in air temperatures can impact flying. These private airplane pilots will be flying into small rural airports around the country to view the eclipse and capturing key measurements with NASA GLOBE.

Learn more at: observer.globe.gov.

Download the app (available for both iOS and Android devices) here: https://observer.globe.gov/about/get-the-app

Citizen scientists may observe atmospheric changes during the total solar eclipse using an app called GLOBE Observer. Credits: NASA/GLOBE

Real Time Spacecraft Observations of Earth

Three of NASA's Earth-watching missions – Terra, Aqua and EPIC on board DSCOVR, will observe the Earth during the total solar eclipse. NASA's Lunar Reconnaissance Orbiter and the International Space Station will attempt to capture images of the moon's shadow on Earth.

Two NASA and NOAA missions also will capture the eclipse shadow, Suomi National Polar-orbiting Partnership and Geostationary Environmental Satellite.

Image caption: An image from EPIC of the moon's shadow on Earth in the March 2016 Total Solar Eclipse. Credits: DSCOVR/EPIC images NASA Goddard

ISS Eclipse Observations

The International Space Station orbits Earth every 92 minutes. During a total solar eclipse in 2006, ISS astronauts were treated to a view out their window of the moon's dark shadow. The fast-moving shadow was in a nearly perfect path relative to the ISS orbit pass so that, from an altitude of about 250 miles (400 kilometers), the lunar shadow seemed like a big "black hole" that had opened up as the ISS sped past it in a matter of a few seconds.

Image caption: ISS images of lunar shadow
Credits: NASA/ISS

A previous opportunity to observe a total solar eclipse from a manned spacecraft occurred in 1999 for Cosmonauts in the MIR space station shown here.

Image caption: ISS images of lunar shadow
Credits: NASA/ISS

It is anticipated that for the Aug. 21, 2017 total solar eclipse at least some part of the eclipse will be visible by the ISS astronauts. In fact, the ISS should see both a partial eclipse and the shadow of the moon on the ground.

Imagery from the ISS will be available following the eclipse; astronauts also will be speaking during the final hour of the NASA TV live broadcast.

More ISS images of previous eclipses may be found at https://www.nasa.gov/content/solar-eclipse-from-the-international-space-station

Balloon Observations

“This eclipse comes at a time when we have new tools that allow us to view the eclipse in ways that nobody has tried before. This is the first time that aerial footage of a total solar eclipse will be live-streamed from high-altitude balloons. Low-cost and lightweight computers, radio modems, cameras and other technologies such as 3-D printing are allowing our teams of college and high-school students across the country to interact with this awe-inspiring eclipse in a unique way.”
-- Angela Des Jardins, principal investigator of the Eclipse Ballooning Project at Montana State University, Bozeman

Real Time NASA High Altitude Research

NASA uses high-altitude balloons to launch sensitive scientific payloads that observe the universe. These balloons make observations above most of Earth’s obscuring atmosphere, making research into the full breadth of spectral wavelengths possible. For the 2017 eclipse, a number of balloon borne experiments will observe the sun and the moon’s umbral shadow on the Earth. Students will conduct high-altitude balloon flights from more than 50 locations across the 2017 total eclipse path, from Oregon to South Carolina, providing live videos and images from near space.

Image caption: *The BOREALIS flight team prepares to launch its high-altitude balloon during its T-minus one year test flight from Dubois, Idaho. Credits: Shane Mayer-Gawlik, Montana Space Grant*

Q & A with the Eclipse Ballooning Project

What is the purpose of the balloons?

The primary goal of the Eclipse Ballooning Project is to live-stream aerial footage of the eclipse from the edge of space to NASA's website for a worldwide audience. In addition to live streaming footage, the balloons will collect observations for scientific experiments on atmospheric waves, the last beads of sunlight prior to totality, and resilient bacteria.

Who is doing this?

The Eclipse Ballooning Project was initiated by Montana Space Grant Consortium at Montana State University in 2014. The project is sponsored by the NASA Science Mission Directorate and NASA's Space Grant program, a national network that includes over 900 affiliates from universities, colleges, industry, museums, science centers, and state and local agencies belonging to one of 52 consortia in all 50 states, the District of Columbia and the Commonwealth of Puerto Rico. The more than 50 teams participating in the project include students and organizers from universities and colleges, high schools and ballooning groups. A list of teams can be found at http://eclipse.montana.edu/programs-of-the-eclipse-ballooning-project/.

How many balloons are there, and where will they be?

On Aug. 21, about 55 Eclipse Ballooning Project teams will launch balloons from locations across the eclipse's path of totality. Some teams will launch multiple balloons. An estimated 70 balloons will be launched. Local winds will carry the balloons as they rise through the atmosphere. The balloons could travel many miles from the launch location, but are expected to remain in the path of totality.

What equipment will the balloons carry?

The primary payloads carried by each balloon consists of three things: a tracking system, a video system and a still-image system. These hang below the balloon along a line of string nylon cord that is roughly 20 feet long. The tracking system consists of a lightweight modem that communicates with a network of satellites, allowing our teams, as well as air-traffic controllers and others, to see the location and altitude of all of the balloons in real-time. The video system consists of ring of eight small video cameras hooked to a lightweight computer and radio transmitter. The teams can select which camera to transmit in order to have the most desired view. The still-image system consists of single camera hooked to a lightweight computer and radio transmitter. Some of the balloons carry additional equipment according to experiments that are being conducted.

How big are the balloons?

The balloons are roughly eight feet tall when they are filled with helium at the launch sites. They are taller than they are round. After launch, as the balloons rise through the atmosphere, they grow as the atmospheric pressure drops, causing the fixed volume of helium gas to expand.

How high will the balloons go?

The balloons are designed to attain an altitude of roughly 85,000 feet. During test flights the balloons have reached altitudes exceeding 110,000 feet. This is the edge of outer space. The view from this altitude shows the blackness of space and the curvature of the Earth.

How long will the balloons be in the air, and during which times?

Each team will launch their balloon(s) roughly 80 minutes prior to the time of eclipse totality at the team's location. This is done so that the balloons achieve the targeted altitude shortly before totality occurs. Shortly after totality, the balloons will pop because of the low atmospheric pressure, or the balloon's payload will be cut down using a remotely controlled mechanical system, releasing the balloon, which will rise rapidly and pop.

What are the experiments that are part of the balloon project?

Each balloon carries common payloads to stream live footage to the NASA website. Higher resolution footage will also be stored on the payload computers and will be shared after the eclipse. In combination with data collected by other weather balloons, interesting atmospheric science can be done by examining the clouds in the footage. In addition, we are partnering with researchers at NASA's Ames Research Center to fly a special type of resilient bacteria on several balloons. The temperature and pressure conditions at 85,000 feet in Earth atmosphere are similar to those on the surface of Mars. Flying the bacteria to the edge of space provides a unique opportunity to examine how bacteria are able to survive in harsh Martian conditions. Finally, each student team is flying an experiment of their own design. More information about those experiments can be found at http://streameclipse.live.

Who will be looking at the data?

Several research and education entities will look at the data that is retrieved from the balloon payloads including but not limited to NASA, National Science Foundation, and National Oceanographic and Atmospheric Administration scientists, the teams' institutions' faculty members and students, and the general public.

What do you hope to learn from the balloon project?

We hope to gain valuable insight in science, technology, and education arenas. Some of the questions we hope to learn about include: How does our atmosphere react to the sharp shadow of the eclipse speeding across the continent at over 1,500 miles per hour? What does the exact surface of the sun look like? What happens to resilient bacteria when exposed to a Mars-like environment? How do we transmit live video with inexpensive equipment from space-like conditions and over long distances? What happens on the Internet when hundreds of millions of people are watching live streams from the same source at the same time? What can students gain by working together on a massive scientific collaboration? How do we communicate science to the public in a meaningful way?

What does the ground support look like?

Each team will use ground-based antennas (it looks similar to a residential satellite TV dish) to receive the video and photo transmission from its balloon. The antennas are connected to a computer, which has an Internet connection. Specially designed software immediately “pushes” the footage from the computer to the Web. Each team will also retrieve the payload(s) once they parachute back to Earth.

How do you get the balloons to come back down?

The balloons pop and return to Earth separately from the payloads. The balloons are made of a lightweight biodegradable latex and are not re-usable.

Is it possible to lose a balloon?

Because the balloon payload includes a tracking system, the project teams can know the exact location of the payload at any time. The location data are also used by air traffic controllers and others to track the balloons.

Tell us more about the bacteria that will be flown to the edge of space.

This will be basically a stripped-down version of our most recent E-MIST experiment. We must be lightweight and passive in order to make our science easy to fly. So we will be sending each team two test “coupons” with known concentrations of harmless bacteria. One coupon will fly to the stratosphere and back; one coupon will remain on the ground. We will then take a look at how the bacteria survived the journey and any genomic consequences of the exposure to Mars-like conditions. The bacteria are common in nature, though this particular strain seems especially resistant to environmental stress. We are using it as a model organism for inferring how terrestrial bacteria might respond to Mars-like conditions. This will help NASA Astrobiology better understand the environmental limits for terrestrial life, in order to inform our search for life on other worlds.

Why does NASA Astrobiology use analog environments for research?

Understanding the limits of life in one of Earth's most extreme environments – the upper atmosphere – is directly aligned with the research topic of habitability. Insight into the type of microorganisms capable of surviving in the stratosphere and underlying protection or repair mechanisms can guide the search for life beyond Earth.

Past astrobiology research has used environments in Antarctica to study Mars by analogy. But there are significant limitations to these environments. Rarefied atmosphere and high radiation, alongside other conditions in the stratosphere including severe dryness and coldness, make it substantially more Mars-like.

What's so special about balloons?

Unlike orbital spaceflight, it is much faster and cheaper to conduct biology research with balloons, sending specimens to the near space environment of Earth's stratosphere. Samples can be loaded the day of a launch and sometimes returned to the laboratory within 24 hours after flying. A payload in the middle portion of the stratosphere (about 22,000 miles or 35,000 kilometers above sea level) will be exposed to an environment similar to the surface of Mars: freezing temperatures, thin atmospheric pressure, low relative humidity levels, plus a harsh illumination of ultraviolet and cosmic radiation levels that can be found nowhere else on the surface of the Earth

Why does this experiment need to occur during the solar eclipse?

The solar eclipse over the continental USA gives us a rare opportunity to study the stratosphere when it is even more Mars-like. Normally, stratospheric UVA & UVB are slightly higher than the surface of Mars. With the full solar eclipse on Aug. 21 and about 55 teams flying balloon payloads across 33 states at various points along the path of totality, we expect to obtain a modulated sunlight gradient in the upper atmosphere, more closely resembling Mars UVA & UVB levels. This will provide a high-fidelity analog environment, only available for a few hours, for studying microbial responses to Mars conditions.

Moreover, it is almost inconceivable to perform a standardized, coordinated astrobiology experiment across 33 states simultaneously. The eclipse project offers a special opportunity for high statistical fidelity and extremely broad spatial coverage in the stratosphere.

The Solar System

Depending on conditions, several planets will be observable during the total eclipse. Mercury and Mars will appear close to the eclipse (with Mercury to the east and Mars to the west.) Venus will be much brighter, appearing further to the west. Jupiter also will appear brighter to the east for some observers; for locations in the western U.S., Jupiter will not have risen yet.

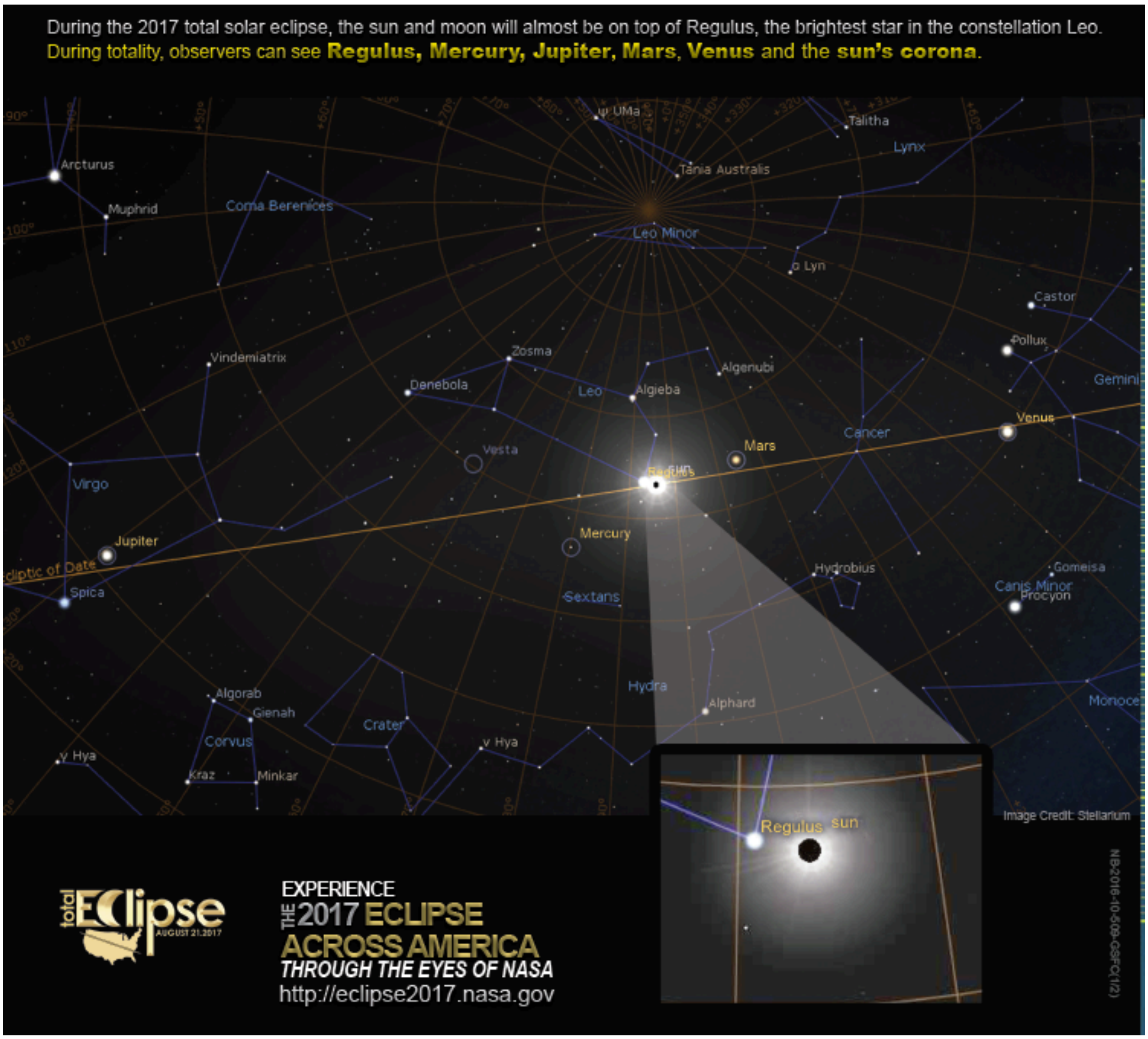

Image Caption: During totality, viewers may be able to see Mercury and Mars closer to the eclipse, with Venus to the west and Jupiter to the east (for observers in much of the U.S. except for western states.) Credits: Stellarium/NASA

Transits and Occultations

Eclipses are a special kind of transit, which is when one astronomical body passes in front of another.

Solar System Transits

Occasionally, an inner planet – Mercury or Venus – will transit the sun. These transits are rare, with Mercury passing in front of the sun about 10 times a century, and transits of Venus happening twice, eight years apart, over a period ranging from 105 to 121 years.

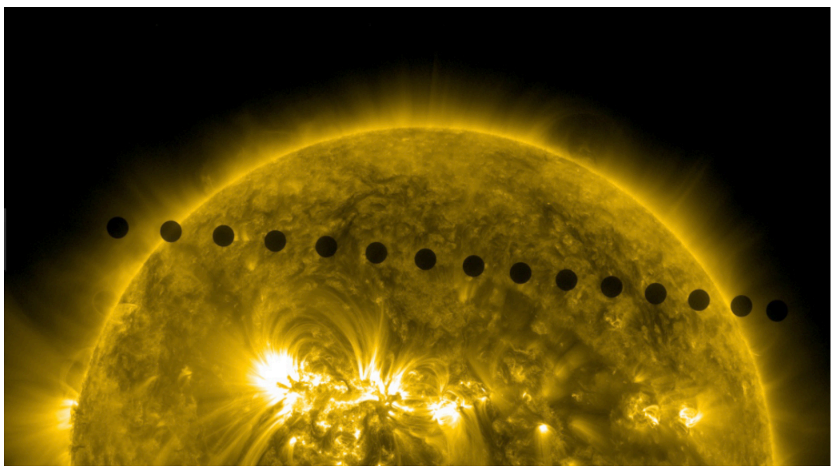

Image caption: These images from NASA's Solar Dynamics Observatory show Venus' path across the sun during the transit of 2012. Credits: NASA/SDO

For centuries, scientists used transits of the inner planets to derive distances between the sun and planets by combining the length of the transit with images of the transiting planet from different places on Earth. This method was also used to make the first estimates of distances to nearby stars.

Occultation – when an object passes in front of another object with a much smaller apparent size, like the moon passing in front of a distant star – can provide valuable information about the size, shape and atmospheric properties of planets and other worlds. In 1977, the rings of Uranus were discovered by NASA's Kuiper Airborne Observatory when the planet occulted a star.

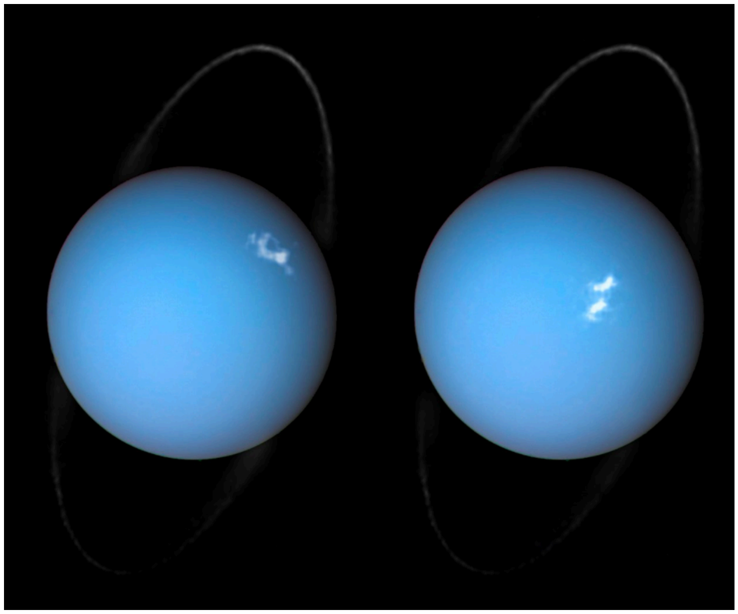

Image caption: Uranus' faint ring system was discovered when the planet passed in front of a distant star in 1977. [Credits: ESA/Hubble & NASA, L. Lamy / Observatoire de Paris]

NASA's New Horizons plans to explore Kuiper Belt Object 2014 MU69 – an object more than 4 billion miles (6.5 billion kilometers) from Earth -- in a flyby on New Year's Day 2019. To learn more about it ahead of time New Horizons scientists are making use of occultations: On June 3, July 10 and 17, 2017, this object passes in front of and occults three different stars. The main goal of these observations is to search for hazards; the secondary objective is to catch a glimpse of the object itself, to learn its precise size. Scientists will be flying on SOFIA, which has a 100-inch infra-red telescope installed on the side a Boeing 747SP aircraft to observe this object. SOFIA can fly nearly anywhere in the world to catch shadows of solar system objects as they pass in front of background stars. In 2015, SOFIA was able to make a key measurement of Pluto's atmosphere by studying its occultation.

In October 2017, Neptune's largest moon, Triton, passes in front of a distant star, offering SOFIA and other mission scientists valuable information about the moon's thin atmosphere.

Transits were used to calculate the Astronomical Unit, or AU, which is the mean distance between the earth and the sun. Jeremiah Horrocks is the first person we know of to estimate an AU by observing the 1639 transit of Venus. Edmond Halley proposed a way to get a more accurate estimate of the distance between Earth and the sun, although he died before the next pair of transits in 1761 and 1769.

If scientists measured the transit from different points on Earth and combined their data using a parallax formula, they could make a more accurate measurement of AU. Captain James Cook was one of the explorers who sailed to faraway places to measure a transit, capturing the 1769 transit of Venus from Tahiti. Based on these 1769 measurements an AU was estimated at about 95 million miles (153 million kilometers). The modern AU measurement is just under 93 million miles (149 million kilometers). The modern measurement is different because in the 18th century, they didn't take into consideration the effects of the then-unknown atmosphere of Venus.

The Search for Exoplanets

> *"We have discovered most of the new planets known outside our solar system by using telescopes to see eclipses, or transits, of other stars by the planets that orbit them, and using measurements of the dips in the stars' light to determine how big the extrasolar planets are." -- Paul Hertz, NASA Astrophysics Division Director at Headquarters, Washington.*

While there are a handful of strategies astronomers use to find planets orbiting other stars, transit detections have been responsible for discovering most of the exoplanets we know about today.

When searching for exoplanets via transits, astronomers look for the regular dimming of a star's light as one of its planets moves in front of the star. This method requires that the planet orbits the star in our plane of view. It also favors large planets orbiting close to their stars, as this configuration causes the largest and most noticeable drops in light.

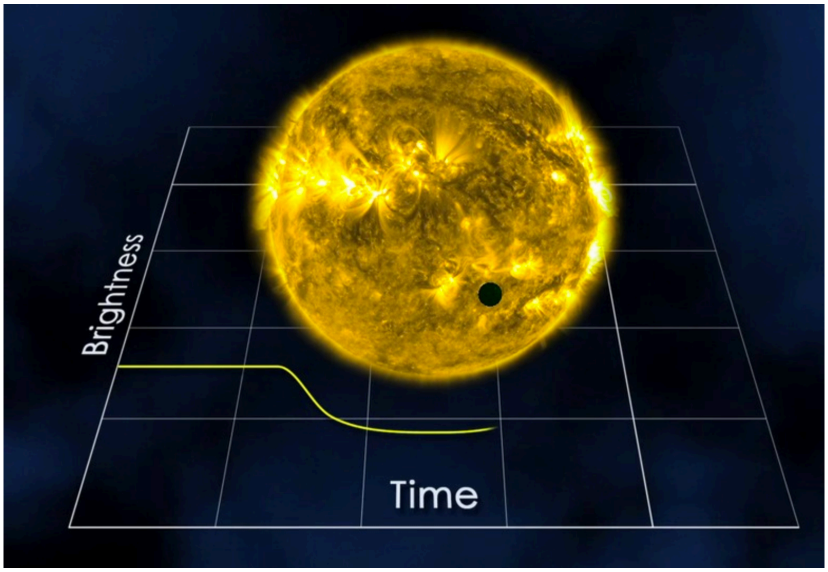

Image caption: We can find exoplanets by detecting the dips in light they create as they pass in front of their home star. [Credit: NASA]

Using both spacecraft and ground-based observations, NASA plays a key role in detecting planets around other stars. NASA's Kepler Space Telescope has been searching for exoplanets since its launch in 2009. It has confirmed the existence of more than 2,300 exoplanets, with more than 30 of which are approximately Earth-sized and orbit within the habitable zone, the distance from the host star where liquid water could exist on a planet's surface.

Kepler's data produces light curves, which show the level of light we can see from a star over time. From these curves, we can detect an exoplanet's orbital period, orbital inclination, and size. Combining this information with spectral observations and other data helps scientists understand the exoplanet's structure, atmosphere, and evolution, as well as its potential for supporting life.

NASA's Spitzer Space Telescope recently discovered seven Earth-size planets around the nearby TRAPPIST-1 star 40 light-years away by combining transit data with other observations from ground-based telescopes. Scientists were able to determine the size, mass, and distance from the star for most of these planets, and were able to show that three of them are firmly in the habitable zone.

Transiting Exoplanet Survey Satellite (TESS), launching in 2018, will find new planets the same way Kepler does, but closer to our solar system while covering 400 times the sky area. It plans to monitor 200,000 bright, nearby stars for planets.

Hubble and the James Webb Space Telescope are capable of finding planets via transits, and can also look for chemical fingerprints and what could be signs of life in the planet atmospheres, such as oxygen, methane and water.

Expected to launch in the mid-2020s, the Wide Field Infrared Survey Telescope, or WFIRST, will look for exoplanets through microlensing, the deflection of light by massive objects. WFIRST will be the first space-based observatory to use a high-performance coronagraph, which will use an artificial eclipse to help blot out the light of a star and directly image nearby exoplanets.

More information on new exoplanet discoveries can be found at nasa.gov/exoplanets.

Eclipse History

Total eclipses throughout history have paved the way for major scientific findings. It was during eclipses that people first described the structure of the sun, when they realized the corona surrounded the sun and not the moon. Prominences, structures where solar flares and coronal mass ejections originate, were also first discovered during a solar eclipse and are still actively studied today.

Other solar science discoveries in history:

- *Discovery of coronal mass ejections, or CMEs*: In the 19th century, astronomers observed a solar eclipse from different locations across Europe. Many reported an arc-like structure propagating out from the sun. Angelo Secchi, a Jesuit priest and celebrated astronomer, dismissed these reports. But this could have been the first report of a coronal mass ejection. Today, NASA's Solar Terrestrial Relations Observatory, or STEREO, mission has a suite of instruments onboard called SECCHI, which examines CME propagation.

- *Coronal heating problem*: During the solar eclipse of Aug. 7, 1869, scientists thought they spotted light streaming from an unknown, new element, which they dubbed coronium, since it appeared in the sun's corona. We now know this to be iron, which can only form at very high temperatures – thus providing information on how incredibly hot the sun's corona is. Scientists are still not sure which heating mechanism is responsible for heating the corona to hundreds or thousands of times the temperature of the sun's surface. NASA research efforts will likely focus their attention on this problem during the August 2017 eclipse.

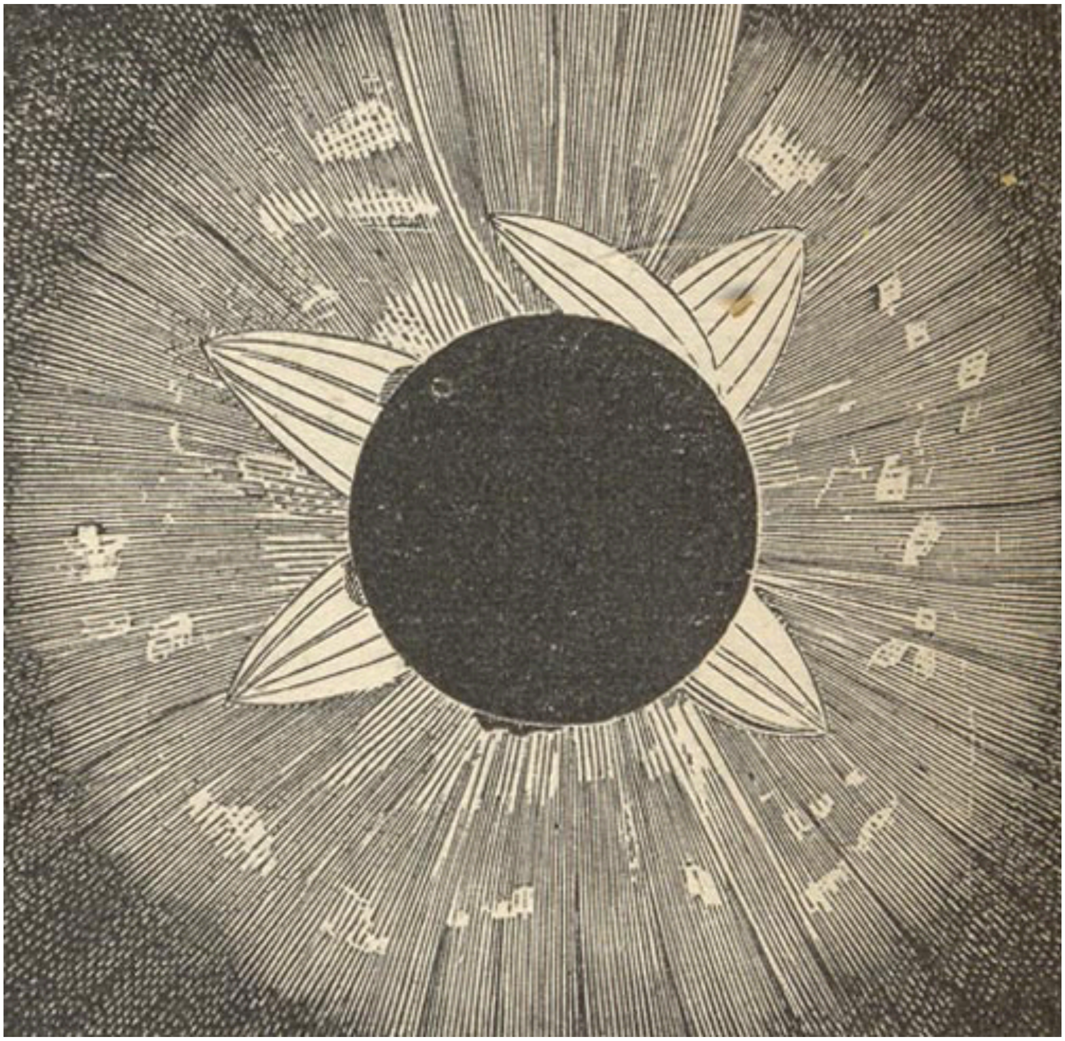

Image caption: An 1873 hand-drawn illustration of a coronal mass ejection, observed during a total eclipse. Credits: Eclipse drawing from Fourteen Weeks in Descriptive Astronomy by J. Dorman Steele, 1873 (Barnes and Co., NY)

Eclipses have historically presented opportunities for a wide range of scientific studies – not just heliophysics. Other findings in eclipse science include:

- *Discovery of helium*: The second most abundant element was first discovered in the sun's atmosphere during a solar eclipse in 1868. Many NASA solar satellites have a helium filter to observe the solar chromosphere.

***Confirmation of general relativity*: In 1919, Arthur Eddington noted the apparent change in location of background stars during a solar eclipse, confirming the curvature of space predicted by Einstein's theory of general relativity.**