Science News Explores

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SPECIAL EDITION

THE ULTIMATE BLACKOUT

A rare total solar eclipse will race across North America on **April 8** — are you ready for it?

By **James R. Riordon**

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MURATART/SHUTTERSTOCK

Solar eclipses are dramatic events as a rule. The moon moves between the Earth and the sun and blocks out our star. The world around you goes eerily dark for a few minutes. But the total eclipse coming on April 8 is going to be more special than usual.

The last total eclipse crossed the United States in 2017. It was a spectacular event witnessed by millions. Maybe even you. But this year's total eclipse will last longer. The sky will fall darker. The sun itself will put on a much livelier show. And even more people will be able to step outside their front doors to see one of the most astounding astronomical events of their lives.

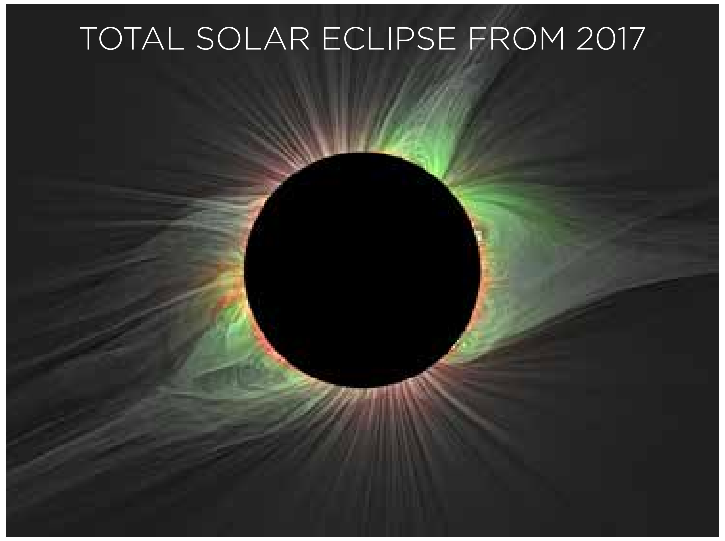
It will also be the last major eclipse to cross North America for 20 years. All of that makes for an especially rare opportunity for casual observers and scientists alike. Here are a few things to know about this spectacular event.

Why will this eclipse last longer?

The moon's orbit isn't a circle. It's closer to the Earth at some times than at others. During the April eclipse, the moon will be at a point in its orbit that's comparatively near to the Earth. That will make the moon appear particularly large. This will mean something special for anyone fortunate enough to make it to the path of totality. That's where the moon completely blocks out the sun's disk. For them, this will be an especially dark eclipse. And it will last for nearly 4.5 minutes. That's almost two minutes longer than the Great American Eclipse of 2017.

What's more, the sun will be close to solar maximum in 2024. That's the peak of its roughly 11-year activity cycle. As a result, lots of bright, petal-like streamers of plasma will extend from the solar corona. This is the sun's outer atmosphere. The increase in solar activity also ups the chances of a coronal mass ejection, or CME. This is a large puff of hot gas trapped in a loop of magnetic field that's blasted away from the sun's surface.

A longer time to observe the eclipse and a more active sun will make a better show. And it will be a boon for scientists. They now have more telescopes, sensors and satellites available to study the sun than ever before. Even non-scientists should be able to see streams of glowing gases flowing from the sun and a CME, if one occurs. (Eclipse glasses are a necessity to safely view the eclipse before and after totality. Your school or local library might give them away for free. Or you can order them online.)



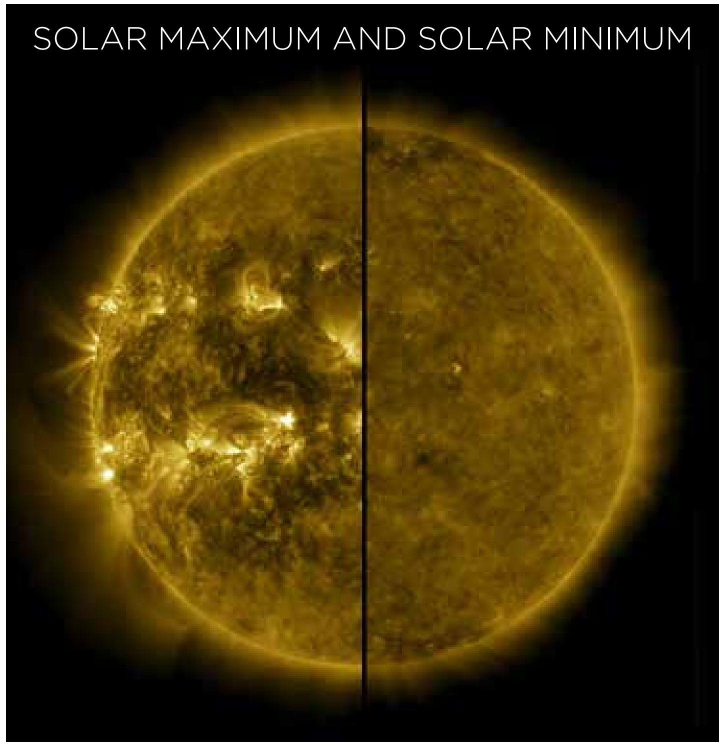
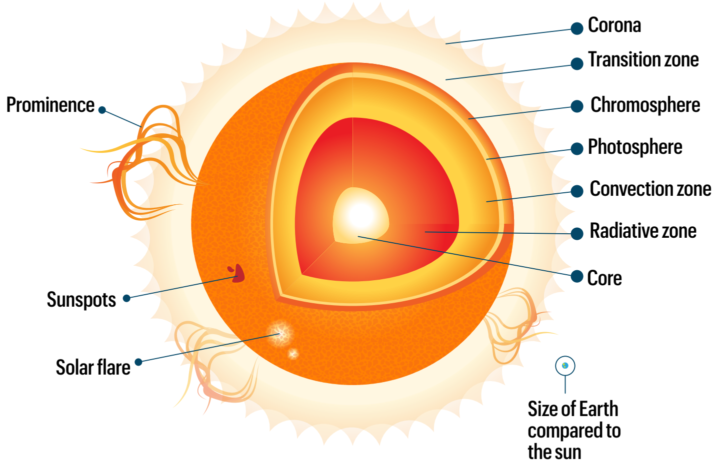


IMAGE PRODUCED BY M. DRUCKMULLER AND PUBLISHED IN HABBAL ET AL. 2021; SDO/NASA

SUN CROSS SECTION



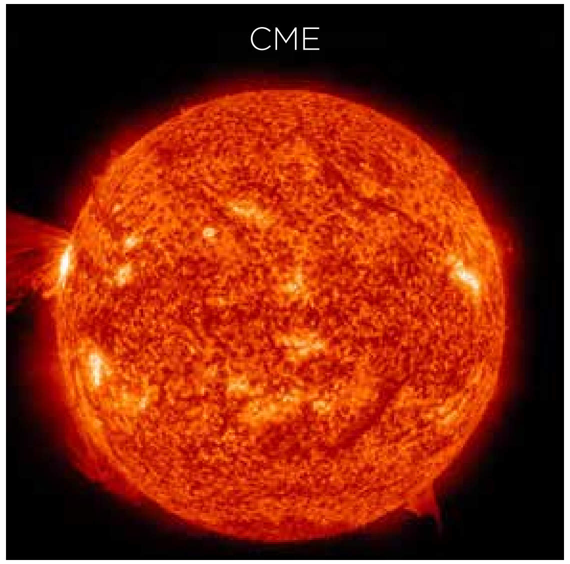
What's different about this eclipse's path?

"Next April," says Michael Zeiler, "there's nearly 32 million people [who will be] inside the path [of totality]." That's about 2.5 times as many as during the 2017 eclipse. And "the major East Coast metros from Baltimore [Md.] to Boston [Mass.] are all about 200 miles [320 kilometers] from the path of totality."

That means that the path of totality is going be very accessible to the bulk of the U.S. population, says Zeiler. He's a cartographer and founder of the website GreatAmericanEclipse.com. The eclipse will be visible to some degree in every U.S. state. And people in portions of northwestern Mexico and southeastern Canada will also be able to see it.

VECTORMINE/SHUTTERSTOCK; SDO/GODDARD SPACE FLIGHT CENTER/NASA

The total solar eclipse in 2017 (left, top, photographed by scientists with a special filter) was spectacular, but this year's eclipse is expected to be better. That's in part because it will occur during solar maximum (left, bottom), when the sun's activity peaks. More sun activity makes it more likely scientists could study a coronal mass ejection (right, shooting off the left side of the sun) during the eclipse.



The 2024 eclipse path will also be helpful for researchers who use radar to study charged particles high in the atmosphere. That's according to space scientist Bharat Kunduri of Virginia Tech in Blacksburg. This eclipse's path passes within the observing range of three radars in the worldwide Super Dual Auroral Radar Network. That wasn't true for the last two North American eclipses.

Those radars monitor a gaslike plasma of positively charged atoms and negatively charged electrons in the Earth's atmosphere. The sun's rays kick electrons off atoms to create this plasma. The plasma makes up a layer around our planet called the ionosphere. It can act like a mirror for radio signals. And it causes those signals to bounce from terrestrial transmitters back down to receivers, instead of letting the signals head out to space. That extends the range that transmitters can reach. The ionosphere also alters the transmission of signals down to Earth from GPS satellites. Taking that effect into account is crucial for ensuring that GPS systems are accurate.

During a solar eclipse, as at nighttime, all the radiation from the sun goes away. The atmosphere becomes a little less dense and less ionized. "And radio waves can behave differently," Kunduri says. Using the instruments in the radar network during an eclipse can help scientists better understand how the sun generates the ionosphere. It can also help them learn how the plasma layer affects transmissions from satellites and radios.

An eclipse "gives you an excellent opportunity to study what happens when there is a sudden change in the upper atmosphere," he says.

What's unique about this chance to spot a CME?

Two satellites will be looking at the sun from the side while the eclipse is happening. These are the European Space Agency's Solar Orbiter and NASA's Parker Solar Probe. Because of the sun's elevated activity this time, the chances are very high that eclipse observers on the ground and those satellites could study a CME at the same time.

Ground-based observers would be able to watch a CME traveling out from the sun. Meanwhile, the satellites would see the event head on, if they happen to lie in the path of an ejection. They might even be able to take samples as the solar material goes blasting past. It's the only time in the lifetimes of the two satellites that they'll be aligned like this during an eclipse at solar maximum.

Two NASA WB-57F jets (one shown) will fly along the path of the eclipse. This will let them collect data for longer than people on the ground and ensure clouds don't obstruct the view.

NASA

"If we would be so lucky to have one," says Nour Raouafi, and it's "propagating toward the spacecraft … it will be fascinating to see it during a total solar eclipse." Raouafi is an astrophysicist at Johns Hopkins Applied Physics Laboratory in Laurel, Md.

Scientists want to know more about CMEs because the solar eruptions, when aimed at Earth, can disrupt communications and power grids. They can also threaten satellites or astronauts in orbit around the Earth.

In addition to observing any ejection, the satellites' observations could help confirm the source of very speedy solar winds. These seem to be accelerated by kinks that develop in magnetic fields near the surface of the sun.

Insights into the solar wind, in turn, provide further insights into how CMEs can affect Earth. That's because the ejections, Raouafi says, pile up material in the solar wind. This "will affect the arrival time of these events to Earth. So, knowing the conditions of the solar wind before the [ejections] is extremely important to predict when they are arriving or how important they will be."

How will scientists study this eclipse?

Several experiments planned for 2024 are repeats from past eclipses. Some feature updated instrumentation. Others will benefit from observations gathered while the sun is near its solar maximum. This will let scientists make comparisons to the quieter phase that the sun was in during the 2017 eclipse. All the 2024 experiments should benefit from the increased data quality and quantity that comes with the longer viewing time.

Take the WB-57F jet planes that carried instruments to observe the 2017 eclipse while flying along its path of totality. They will be in the air again in April, says Amir Caspi. He is a physicist at the Southwest Research Institute in Boulder, Colo. "It's a big improvement because we're flying new instruments [that provide] better information. The fact that it's solar maximum will give us a lot more things to look at."

Improved cameras and spectrometers, for example, will offer detailed views of the corona close to the sun's surface. The corona is the outer, bright layer of the sun's atmosphere. It's the only part of the sun that's visible during totality.

"This eclipse is also twice as long as the last one. On the ground, it's 4.5 minutes," Caspi says. "In the air, we're going to get 6.5 minutes per airplane." Planes can't travel fast enough to keep up with the moon's shadow during an eclipse. But they can travel fast enough to extend the time they spend in totality.

If all goes well, he says, they could also discover some asteroids thought to exist within the orbit of Mercury. Those asteroids are difficult to detect without the moon blocking the sun's glare.

Shadia Habbal is an astronomer at the University of Hawaii in Honolulu. She is leading a team that will fly updated cameras and spectrometers on the jets as well. She's also setting up ground-based observations at sites in Mexico, Texas and Arkansas.

Habbal is even planning to send a spectrometer 4 kilometers (2.5 miles) aloft on a kite from a location near Kerrville, Texas. The kite will get above any clouds that might block the view of the sun. The spectrometer collects light from the sun to determine the composition of material in the corona. "There are changes in the corona that occur on time scales of seconds to minutes to hours," she says. "So the longer duration [of the eclipse] also enables us to capture [more] time-variable events and their impact on the corona and solar wind."

Other repeat experiments include weather balloons that will measure waves of pressure in the atmosphere that ripple away from the passing shadow of the eclipse. And a newly redesigned spectrometer will ride aboard a Gulfstream jet chasing the eclipse over Texas.

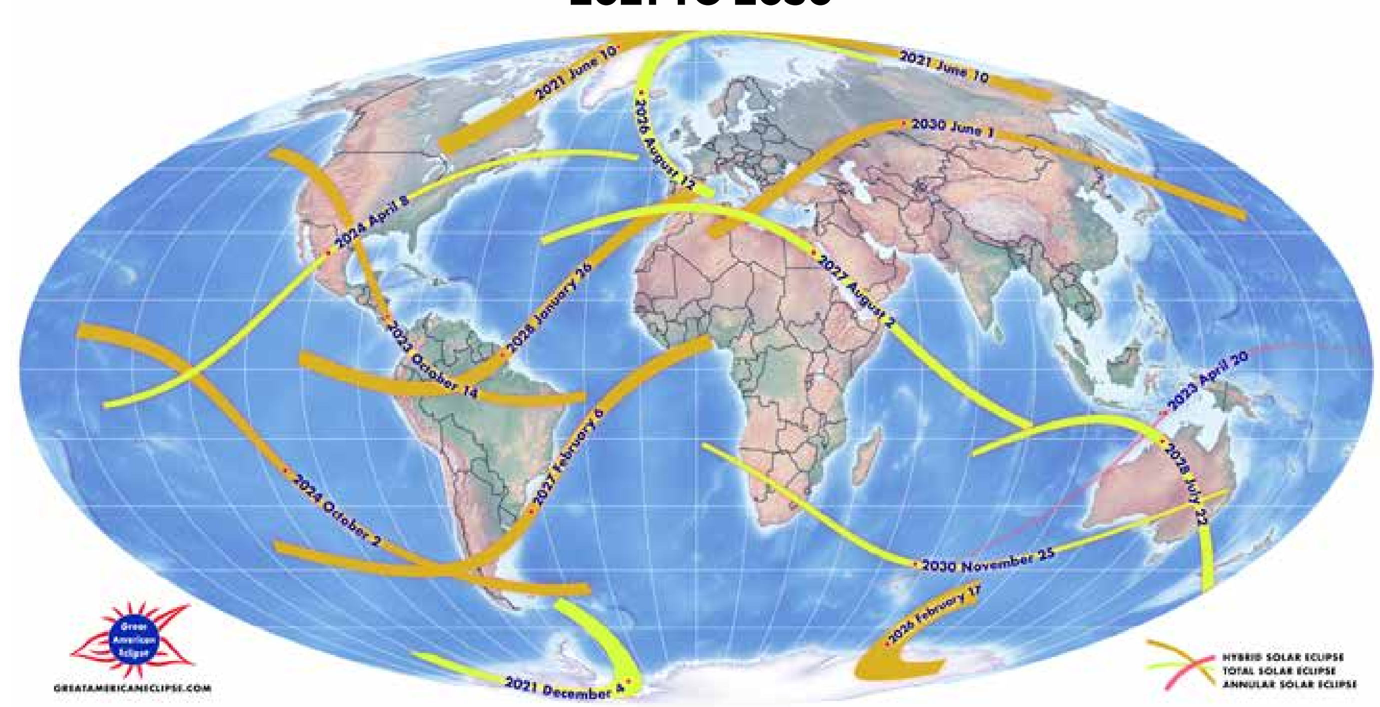
Looking forward

Alaska has the worst seat in the house, as far as U.S. states go. Only a sliver of the state lies in the range that will see a portion of the sun covered up during the eclipse. And none of it is in totality. But the state will get an exclusive viewing when another total eclipse crosses the western side of Alaska in the spring of 2033. That's it for North America until a total eclipse passes primarily over Canada in 2044. Then another will cross the United States and eastern South America in 2045.

The astronomical event on April 8 will be both livelier and longer than many eclipses. But Habbal says that it doesn't diminish the importance of studying other eclipses. "Every total solar eclipse yields new discoveries."

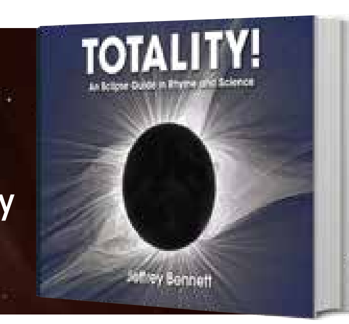
This one, though, is probably an astronomical event you won't want to miss.

TOTAL AND ANNULAR SOLAR ECLIPSES
2021 TO 2030



Earth will experience six total solar eclipses, seven annular eclipses and one hybrid eclipse from 2021 to 2030. See page 26 for the difference between a total solar eclipse and an annular eclipse. The hybrid eclipse in 2023 started as an annular eclipse, turned into a total solar eclipse and then back into an annular eclipse.

GREAT AMERICAN ECLIPSE; BIG KID SCIENCE



YOUR GUIDE TO THE APRIL 8, 2024 SOLAR ECLIPSE

HOW MUCH OF THE ECLIPSE WILL YOU BE ABLE TO SEE?

Many cities and towns lie in the path of totality for the April 8 eclipse. People outside that zone should be able to see a partial eclipse on that day.

ALEXMX/SHUTTERSTOCK; GREAT AMERICAN ECLIPSE

WHAT TO EXPECT

If you're in the path of totality
Over an hour before totality, the moon will begin to move in front of the sun. At first, it will look like someone has bitten a chunk out of the sun. Then it will turn into a smaller and smaller crescent. Make sure you're wearing your eclipse glasses if you want to see this.

As more and more of the sun is covered, the sky will get darker and darker. But it's a different, and somewhat creepier, darkness than sunset. Then, totality. The sun's bright corona is visible and perhaps the chromosphere (the sun's lower atmosphere), with the sun's disk entirely covered by the moon. For several minutes, you'll be able to remove your glasses and look directly at the eclipse. You might spot stars or other celestial objects in the sky.

Keep an eye on the clock, though. Before totality ends, you'll need to put your glasses back on as the partial eclipse returns, revealing more and more of the sun until the moon entirely separates from the orb.

If you're outside the path of totality
How much of the eclipse you'll be able to see will depend on how far you are from the path of totality. But even a partial eclipse is still amazing to witness. Just make sure you keep your eyes protected the whole time.

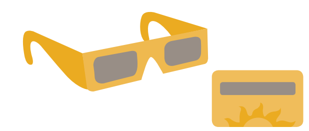
HOW TO BE SAFE

What's the danger?
Looking directly into the sun, even when it's partially covered by the moon, can damage your eyes and lead to a permanent blind spot in your vision.

How do I protect my eyes?
You'll need glasses certified to meet the ISO 12312-2 international standard. They block out 100 percent of harmful ultraviolet light and 99.999 percent of visible light. Your school or local library may give them away for free. They can also be purchased online (check eclipse.aas.org for sources).

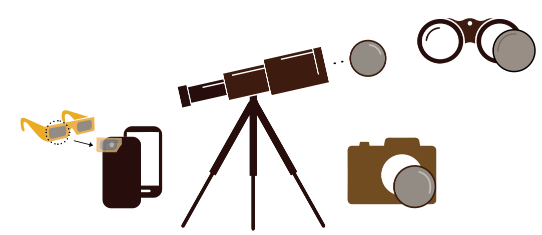
Can I ever look directly at the sun?
Yes, but only in the brief moments of totality during a total solar eclipse when the moon fully blocks out the sun's disk. (Check with an adult before you take off your glasses.)

SAFE Use specially designed solar eclipse glasses and viewers to block the sun's harmful rays.

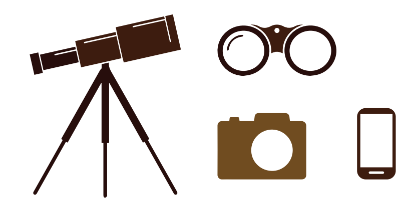


NOT SAFE Ordinary sunglasses are not strong enough to protect your eyes.

SAFE Use only specially designed filters for lenses.



NOT SAFE Wearing solar eclipse glasses to look through a camera, binoculars or a telescope will not protect your eyes.



AMERICAN ACADEMY OF OPHTHALMOLOGY AND THE AMERICAN ASTRONOMICAL SOCIETY; JOY NG/NASA

TRY THIS

During the partial eclipse, take an object with lots of tiny holes, such as a colander or a cracker, and hold it in front of a piece of paper with the sun behind you. You'll be able to see the eclipse in the object's shadow!

This space physicist uses radios to study eclipses

Nathaniel Frissell works with amateur radio operators to learn more about our atmosphere

Next month, Nathaniel Frissell will lead a worldwide effort to collect data during the solar eclipse. Frissell is a space physicist at the University of Scranton in Pennsylvania. He'll be teaming up with amateur radio, or ham radio, operators to collect data through the organization Ham Radio Science Citizen Investigation, or HamSCI, to study the ionosphere.

Ham radio operators are located around the world. They might use their radios to talk to people in their town or in another country. Some help during emergencies. Others participate in science. During the solar eclipse, they'll help Frissell study how the eclipse affects a layer of the atmosphere called the ionosphere. Electrically charged particles in this layer reflect radio waves. During a solar eclipse, less sunlight reaches the ionosphere. This can lead to fewer electrically charged particles and, in turn, disrupt radio signals.

Frissell has been lucky to turn his childhood hobby, amateur radio, into a career. In this interview, he shares his experience and advice with *Science News Explores*. (This interview has been edited for content and readability.) — *Aaron Tremper*

Q What inspired you to pursue your career?

A In middle school, I went on a Boy Scout trip where I met a ham radio operator. He was talking to people all over the world using just a radio setup and a wire. I became fascinated with radios and how the signals get from one place to another. I kept following that passion until I got my Ph.D. in electrical engineering at Virginia Tech in Blacksburg.

Q How did you get to where you are today?

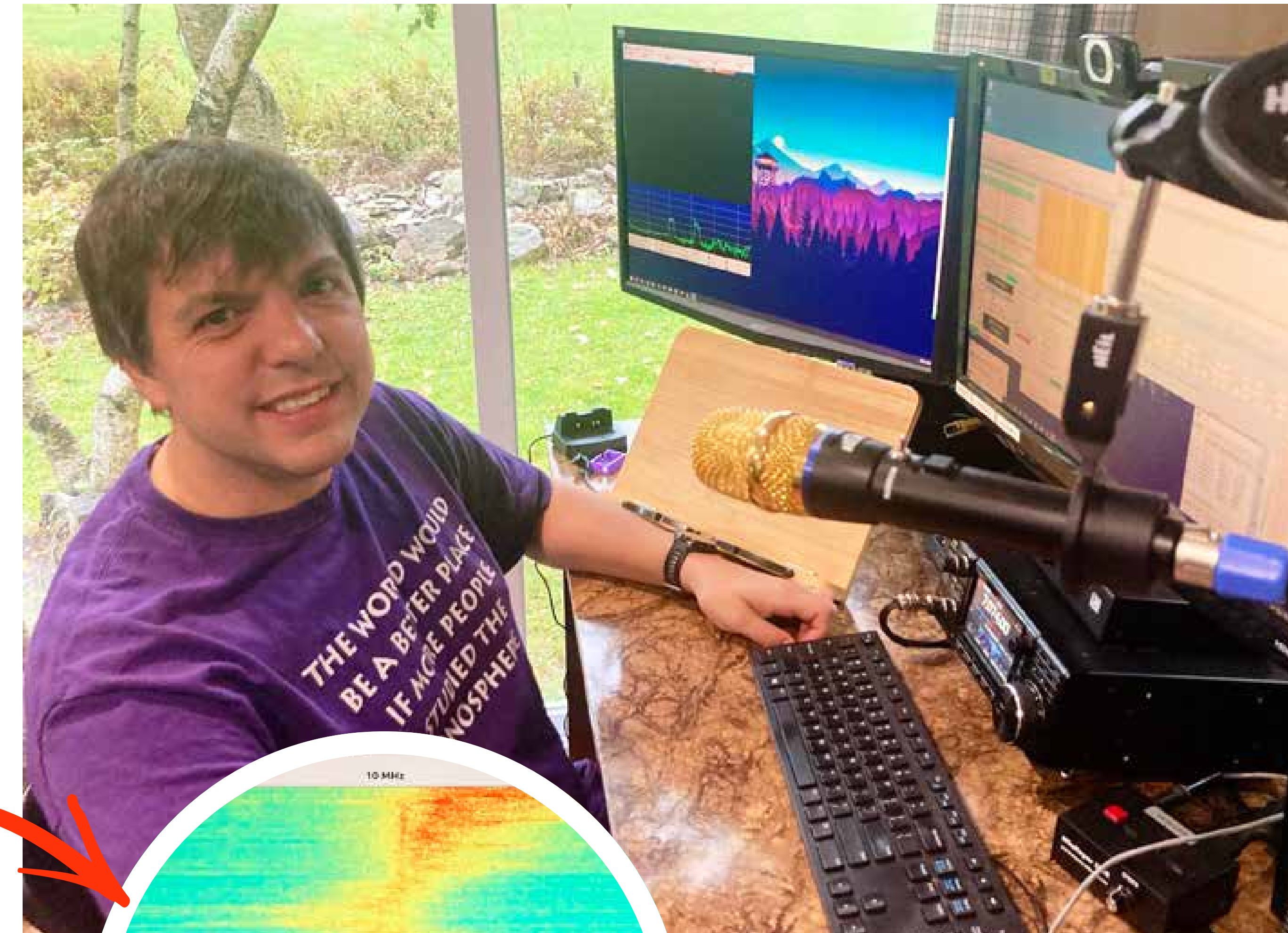
A Virginia Tech had a ham radio club. I started looking for ways to join the ham radio community and the professional community together. I met some people who wanted to study the ionosphere during the 2017 solar eclipse. These eclipses basically serve as controlled experiments that let us study the upper atmosphere in the absence of the sun's light. I suggested that we could do that with ham radio data, too. It was during that project when we developed HamSCI.

Q How do you get your best ideas?

A I'm very collaborative and good at connecting people with others who share interests. For instance, a couple months ago, the Lackawanna Blind Association here in Scranton wanted someone to talk to them about ham radio. Later, I was at a NASA science conference. There, I found copies of a Braille book called *Getting a Feel for Eclipses* that explains how solar eclipses work. It had these embossed infographics of solar eclipses that were absolutely gorgeous. I'm going to bring copies of the book to the Lackawanna Blind Association. I'd like to put together a program or talk on eclipses. We have all this data from the annular solar eclipse that we just took this past October. We can convert that data into audio so that people can hear it.

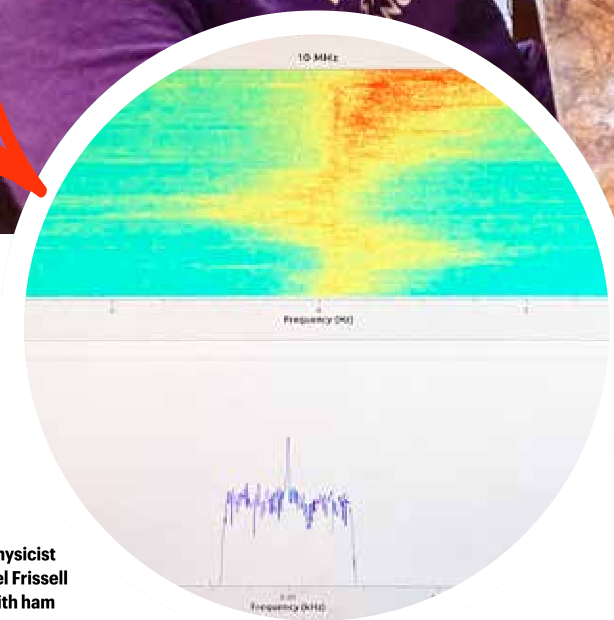
Q What was one of your biggest failures and how did you get past that?

A I think I come across lots of little failures every day. It's an important message to have people not get discouraged. My projects don't always work out the way I planned. But I'll learn something different from that work instead. When you come across challenges, try to just stay calm and don't give up.



Space physicist Nathaniel Frissell works with ham radio operators to study how eclipses affect a layer of the atmosphere called the ionosphere. Here, he sits in front of his personal ham radio setup during last year's annular eclipse.

ANN MARIE ROGALCHECK-FRISSELL



During an eclipse, Frissell and his team try to communicate with as many radio operators as possible. Signals from these communications can help pinpoint where an eclipse is affecting radio waves.

Gather valuable data during the solar eclipse

Amateur scientists have many chances to assist in research during the U.S. eclipse

During the total solar eclipse on April 8, sky watchers across North America will see the moon pass in front of the sun. This will not only offer a uniquely spectacular view of our star — it will be a prime opportunity for solar science! Here are a couple of ways that amateur scientists like you can gather valuable data during the solar eclipse.

SUNSKETCHER

People in the path of totality — where the moon completely masks the sun from view — can use smartphone cameras and the SunSketcher app to time the appearance of "Baily's beads." These are bright spots that appear when sunlight shines through valleys on the moon. They appear just before and after the moon fully eclipses the sun.

Astronomers can use the timing of Baily's beads to clock exactly how long it takes the moon to pass in front of the sun. They can use that information to calculate how wide the sun is. Scientists want to know the exact shape of the sun because that shape affects the sun's gravitational tug on planets.

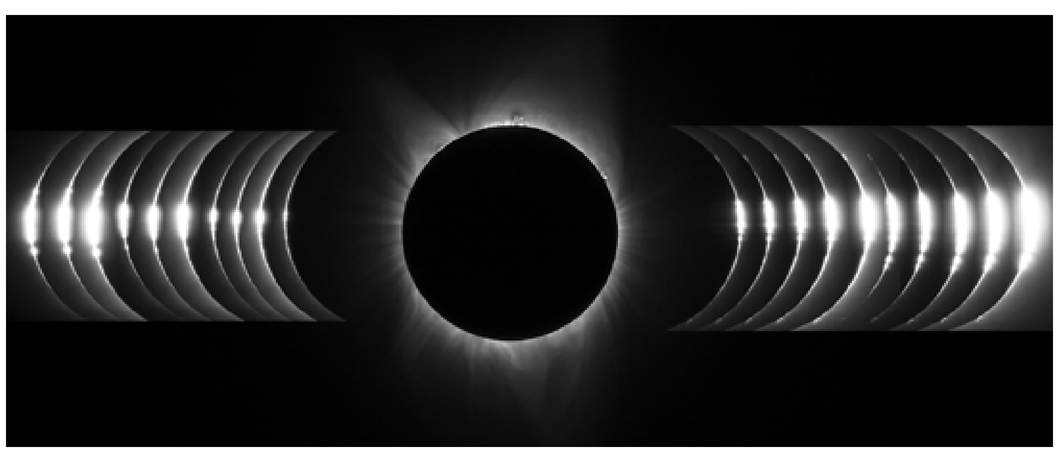
SunSketcher.org

ECLIPSE SOUNDSCAPES

Amateur scientists both in and out of the path of totality can contribute to the Eclipse Soundscapes project. The goal is to record audio during the eclipse that may reveal how this rare, dramatic event affects wildlife on Earth. For instance, sound recordings may capture birds falling quiet or crickets starting to chirp as the moon dims the midday sun.

The Eclipse Soundscapes website (eclipsesoundscapes.org) has instructions to build equipment to record sounds. You can also simply observe the impacts of the eclipse on your local environment. Volunteers will analyze data uploaded to the project's website.

eclipsesoundscapes.org



This composite image collects 10 pictures of Baily's beads taken before and after the total solar eclipse of 2017 (center).

JAMES WEST/FLICKR

Crossword

If you're having trouble figuring out the answers to the clues below, make sure you read all the stories in this section. Check your work by following the QR code at the bottom of the page.

ACROSS

3. This happens when a planet passes in front of its star
5. Spacecraft threatened by coronal mass ejections
6. The moon does this around Earth, and Earth does it around the sun
9. The lunar phase when solar eclipses can happen
11. The only part of the sun visible during totality
12. A kite carrying this tool could study the sun's corona
13. The phase of the solar cycle when our star is most active
15. The upcoming solar eclipse could reveal asteroids around this planet
16. A solar eclipse where the moon completely masks the sun
18. A solar eclipse featuring a "ring of fire"

DOWN

1. These animals may start to chirp during a solar eclipse
2. A solar eclipse where the moon partly masks the sun
4. Citizen scientists can use this app to help measure the sun's shape
7. This layer of plasma surrounds Earth
8. Many people on this continent will see a solar eclipse on April 8
10. This happens when three celestial bodies line up in space
14. This U.S. state will see a solar eclipse in 2033
17. Tools that make it safe for you to view a solar eclipse

Eclipses come in many forms

Awesome things can happen when one celestial body gets in front of another

To eclipse something means to overshadow it. That's exactly what happens during a solar or lunar eclipse. These celestial events take place when the sun, moon and Earth briefly make a straight (or nearly straight) line in space. Then one of them will be fully or partially shrouded by another's shadow. Similar events occur when other stars, planets and moons line up in much the same way.

Scientists have a good handle on how planets and moons move through the sky. So eclipses are very predictable. If the weather cooperates, such events easily can be seen with the unaided eye or simple instruments. (But be careful! It's not safe to look at the sun during a solar eclipse without proper eye protection.) Eclipses and related phenomena are fun to watch. They also provide scientists with rare opportunities to make important observations. — *Sid Perkins*

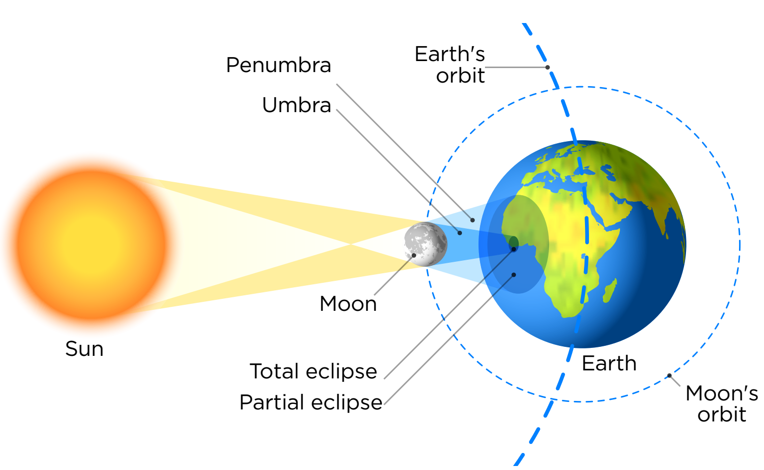
Solar eclipses

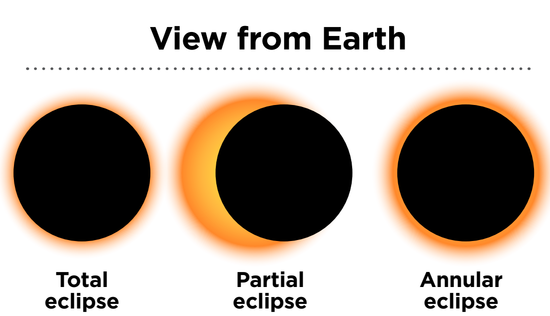
Our moon is, on average, about 3,476 kilometers (2,160 miles) wide. The sun is a whopping 400 times as wide. But because the sun is also about 400 times farther from Earth than the moon is, both the sun and moon appear to be about the same size in the sky. So at some points in its orbit, the moon can entirely block the sun's light from reaching Earth. This is a **total solar eclipse**.

This can happen only during a new moon (see page 3). This is the phase in the moon's orbit where it appears fully dark to us on Earth. A new moon happens about once per month. But the moon's path is slightly tilted compared to Earth's. Most new moons trace a path through the sky that passes near — but not over — the sun.

Some new moons eclipse only part of the sun. This is a partial eclipse. People who are close to but outside the path of the moon's shadow during a total solar eclipse can also see a **partial solar eclipse**.

When the moon is at its farthest point from Earth, it's not quite big enough to block out the entire sun. Instead, a ring of light, called an annulus, surrounds the moon. Scientists call these events **annular eclipses**.

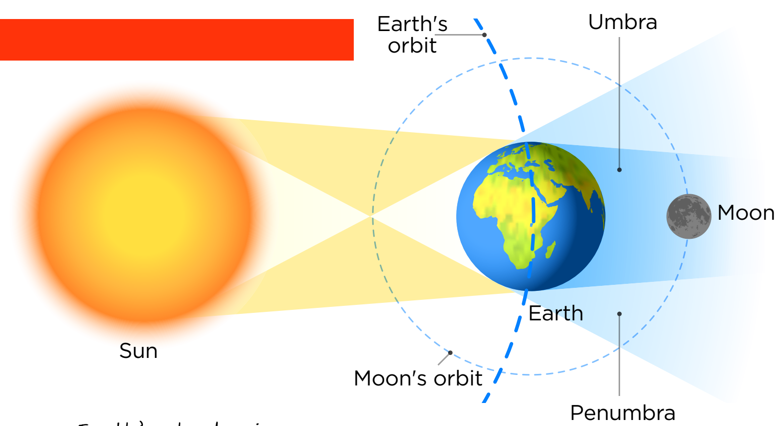




ALHOVIK/SHUTTERSTOCK

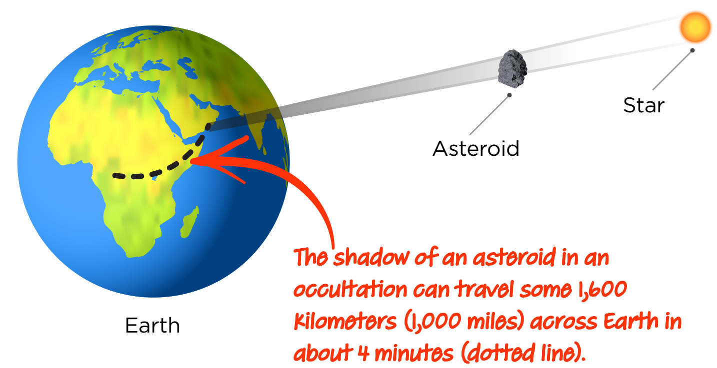
Lunar eclipses

Sometimes the moon falls into Earth's shadow. Such lunar eclipses happen only at full moon, the phase when the moon is opposite the sun in our sky and appears as a completely lit disk. Although total solar eclipses temporarily black out only a narrow path on Earth's surface, a **total lunar eclipse** can be seen from the entire nighttime half of the planet. And because Earth's shadow is so wide, a total lunar eclipse can last up to 107 minutes. Unlike the sun during a total solar eclipse, the moon during a total lunar eclipse remains visible. Sunlight travels through Earth's atmosphere during the whole event, illuminating the moon in a reddish hue.



Occultations

Like an eclipse, an **occultation** occurs when three celestial bodies line up in space. But during occultations, an object that looks large to an observer (usually the moon) moves in front of one that appears much smaller (such as a distant star).



Transits

A **transit** happens when a small object moves in front of a more distant object that appears much larger. In our solar system, for instance, the planets Mercury and Venus sometimes transit across the sun from Earth's viewpoint. Some asteroids and comets, too, can transit the sun from our point of view.

Scientists have long been interested in transits. In 1639, for instance, astronomers used observations of a transit of Venus — and simple geometry — to come up with their best estimate at that time of the distance between the Earth and the sun.