Citizens Do Eclipse Science

CITIZEN SCIENTISTS, AMATEUR ASTRONOMERS, AND PROFESSIONALS WILL BE WATCHING AUGUST'S ECLIPSE FOR A RARE PEEK INTO THE SUN'S CORONA.

By Monica Bobra • On the day of the eclipse, people all over the U.S. will line up to eke out their small stake on the 70-mile-wide strip of totality that sweeps from the Pacific Northwest to the Carolinas. Scientists, amateurs, and the public alike will take this opportunity to study the Sun through citizen-science projects, do-it-yourself experiments, and scientific endeavors.

Here's a rundown of some of the solar eclipse science happening this August 21st.

Citizen Science

During those fleeting few minutes when the Moon completely blocks the Sun's disk, we're left with an astounding view of the *corona*. The Sun's thin, wispy atmosphere might look static during totality, but in fact it's changing all the time.

The problem is that one person at one location can only see the eclipse for a couple of minutes, and the changes happening in the corona occur on timescales of 5 to 15 minutes.

But what if lots of us stationed ourselves all along the eclipse path? As the Moon's shadow blitzes across the United States, we could all take images in succession. Then, for the first time in history, we would observe the Sun's atmosphere for 90 straight minutes.

That's the plan. Here are some ways it's going to happen — and ways that you can participate.

Above: Students and their mentors conduct a practice launch in Rexburg, Ohio. On August 21st, 57 teams of high school and university students around the country will participate in high-altitude balloon launches to film and livestream the total solar eclipse.

MONTANA STATE UNIVERSITY

Eclipse Megamovie Project

About 10 million people live directly within the total eclipse path, and about 200 million more live within a day's drive. So as the celestial spectacle unfolds overhead, it's safe to say that millions of people will be taking photos. The team behind the Eclipse Megamovie Project hopes you'll share them.

You can send the team your images of the eclipse, along with your location on the eclipse path, using a smartphone app available at **https://eclipsemega.movie**. The team will then string everyone's images together to make a movie. In fact, they'll make two: One movie will use photos taken from phones, and the other will use images from higher-quality, GPS-calibrated cameras fitted with filters and a zoom lens. Anyone can participate in either group. The resulting movies, along with the images, will be available to everyone.

Hugh Hudson (University of California, Berkeley), who developed the idea, says the project will provide raw data to study the Sun's corona. It will also help measure the size of the Sun. Although it might seem like we know that already, current measurements of the solar radius are only accurate to about 300 miles or so (or 1 part in 3,000).

To measure the Sun, we can use the Moon. By 2011 NASA's Lunar Reconnaissance Orbiter and other spacecraft had mapped the lunar surface in high resolution, so we know its exact shape — down to the last crater. During an eclipse, these craters allow light from the solar surface to reach Earth, like beads on a ring, creating a visual effect called Baily's Beads (see page 22). The duration of this effect, as reported by people using the smartphone app, combined with the speed of the Moon in its orbit around Earth, will enable the Eclipse Megamovie team to calculate the distance across the Sun.

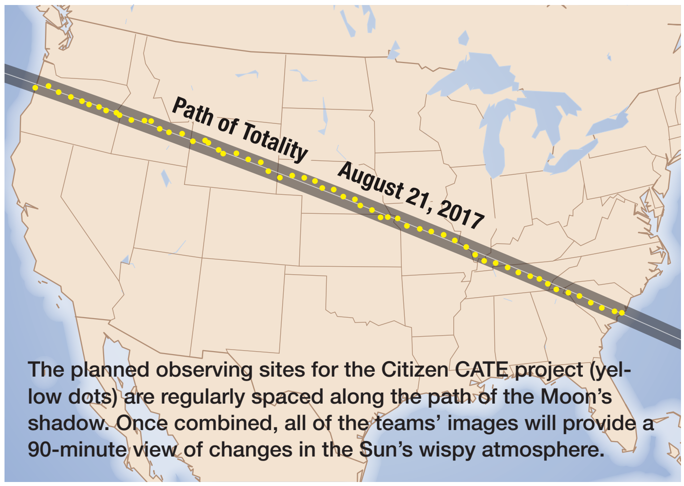
Citizen CATE

During an eclipse, the Sun's dim corona stretches out to at least four times the diameter of the solar disk. To capture this vast yet faint atmosphere, the Citizen Continental-America Telescopic Eclipse Experiment (Citizen CATE) team will image the eclipse through 60 identical telescopes equally spaced along the path. As the Sun slides out of totality at one location, it will slide into totality at the next. By the time the news airs on television that night, CATE's organizers will debut their resulting movie: the first uninterrupted view of the entire solar atmosphere throughout a transcontinental eclipse.

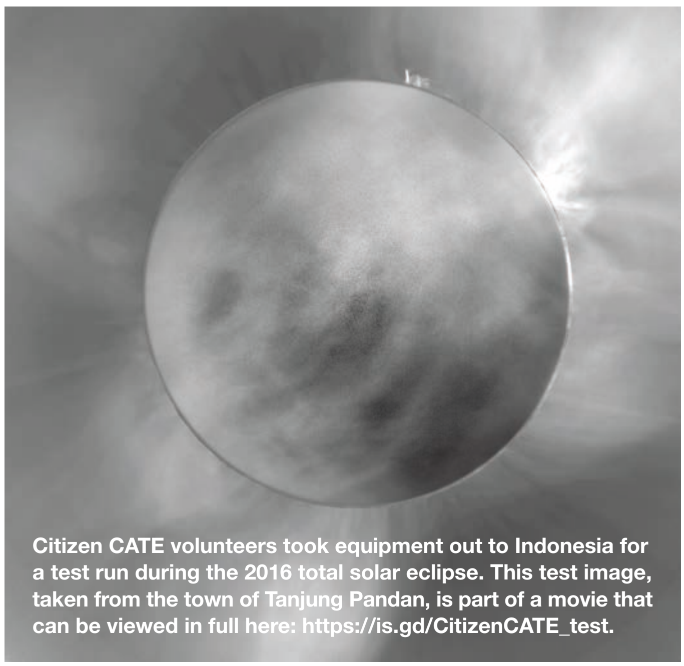
This movie will show how the solar atmosphere changes over time. The team will use it to investigate million-degree plumes of gas that spurt like geysers from the Sun every 10 minutes, jetting outward at 250,000 miles per hour. Scientists will study the video to learn how hot and cool gases mix together to set off powerful explosions like solar flares. And they'll also use it to figure out how loops of gas oscillate back and forth, like the vibrating strings on a banjo.

The head of the project, Matt Penn (National Solar Observatory), says that the general public is welcome to show up at one

A visual effect known as Baily's Beads occurs when sunlight filters between crater walls along the Moon's limb just as the Moon covers and uncovers the Sun. By measuring the duration of this effect, viewers can help scientists better estimate the Sun's size.



The planned observing sites for the Citizen CATE project (yellow dots) are regularly spaced along the path of the Moon's shadow. Once combined, all of the teams' images will provide a 90-minute view of changes in the Sun's wispy atmosphere.



Citizen CATE volunteers took equipment out to Indonesia for a test run during the 2016 total solar eclipse. This test image, taken from the town of Tanjung Pandan, is part of a movie that can be viewed in full here: https://is.gd/CitizenCATE_test.

TOP: FRED ESPENAK; MIDDLE: GREGG DINDERMAN / *S&T*; SOURCE: NATIONAL SOLAR OBSERVATORY; BOTTOM: LASCO / SOHO CONSORTIUM / NRL / ESA / NASA

of the CATE sites and watch the teams — a mix of middle and high school students paired with amateur astronomers — in action. To contact one of the CATE site coordinators or sign up for updates, go to **https://is.gd/CitizenCATE**. And after the eclipse is over, the teams get to keep their instruments for use in future citizen-science projects.

Eclipse Ballooning Project

Instead of watching the spectacle from the ground, members of the Eclipse Ballooning Project will be sending equipment to the stratosphere for a unique view. All along the eclipse path, 57 teams of high school and college students will launch about 65 unpiloted balloons to altitudes between 60,000 and 80,000 feet (that's between 11 and 15 miles above Earth) to record and stream live video of the eclipse. NASA will broadcast the feed directly on its homepage, **nasa.gov**, and on NASA TV; up to 1 billion viewers from all over the world are expected to watch.

Nobody has ever live-streamed an eclipse from a balloon, let alone from 100 of them. However, during the 2012 total eclipse, a Romanian-Australian team recorded video from high altitude by placing a GoPro camera on a balloon. The result (**https://is.gd/ballooneclipse2012**) is stunning not only for its view of the Sun but also for its view of the Moon's shadow on Earth. Live streaming to such a large audience wasn't even possible until a couple of years ago.

The Eclipse Ballooning Project, spearheaded by Angela Des Jardins (Montana State University), isn't stopping there. Each balloon will also carry a secondary payload: a scientific instrument of the team's choice. In addition, teams will launch roughly 100 radiosonde balloons to relatively low altitudes before, during, and after the event, so they can study how Earth's atmosphere changes in response to a solar eclipse.

Most of the balloons are launching from public locations — find them on the project's website, **http://streameclipse.live** — and anyone is free to show up and watch. Probably the most publicized balloon will launch from the top of Saluki Stadium at Southern Illinois University in Carbondale, Illinois, near which totality will last for the longest duration of anywhere on the eclipse path: 2 minutes 42 seconds. From its vantage point in the stratosphere, the balloon will see almost 200 miles in every direction.

Do-It-Yourself Relativity

This summer's eclipse also offers a chance to relive history. When Albert Einstein developed his theory of general relativity in 1915, he also proposed a way to check it: Carefully record the

Some 65 high-altitude balloons will launch on August 21st to provide streamed video of the solar eclipse from a unique perspective. A practice run produced this clear image of the Beartooth Mountains in Montana and Wyoming — the view extends out to 180 miles.

MONTANA SPACE GRANT BOREALIS BALLOONING TEAM positions of stars in a patch of sky at night, then observe the same ones during a total solar eclipse. According to general relativity, the mass of the Sun should warp spacetime and bend starlight, which would shift the stars' apparent positions on the sky by a tiny amount.

In May 1919 British astronomer Arthur Eddington set out to the island of Príncipe, off the west coast of Africa, to perform this experiment (see page 50). As the sky darkened, he imaged stars twinkling near the eclipsed Sun. Then he compared their positions to ones he'd measured for the same stars at night. He found that the stars did, in fact, shift from one image to another. General relativity had passed a crucial observational test, and Einstein became famous almost overnight.

Now, an amateur astronomer is trying the same experiment. Donald Bruns has developed an experiment to measure the deflection of starlight by the tiniest of angles — about 1/2,057 of 1°. This is the shift you'd observe by moving your outstretched hand by the width of a human hair. To make such an accurate measurement, you need a good telescope, camera, and observing conditions. Bruns will be observing from Wyoming, where it's not likely to rain. He'll take 25 images, each with a 1-second exposure, and average them together after the eclipse. Then he'll compare his measurements against star positions in the same patch of sky recorded by the European Space Agency's Gaia satellite.

Want to try it yourself? Check out his instructions here: **https://is.gd/DIY_Relativity_Test**.

Scientific Endeavors

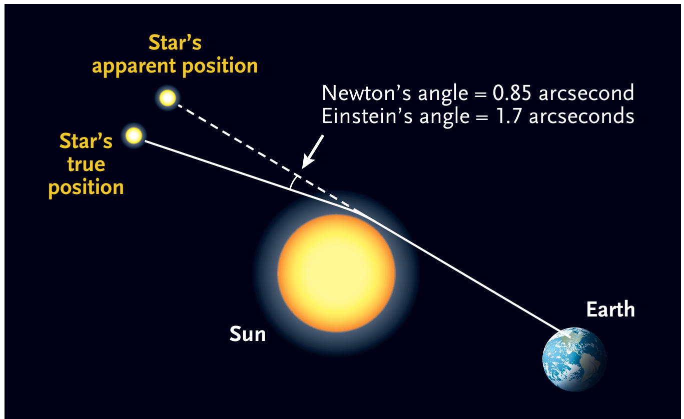
Professional astronomers from all over the world will also gather on the eclipse path to make detailed measurements of the Sun's atmosphere.

In visible light, the Sun's disk is a million times brighter than its corona. Like a spotlight, the Sun swamps any images and makes the corona difficult to observe. Ground-based telescopes can artificially block out the solar disk, but sunlight that scatters through Earth's atmosphere still limits how close to the Sun astronomers can observe. Even in space, where there's no atmosphere to scatter sunlight, spacecraft wobble so much that the artificial blockade needs to be about four times larger than the Sun itself — otherwise the telescopes might fry their cameras.

That's why an eclipse, which naturally blocks the solar disk, is the best time for astronomers to see the faint solar atmosphere. Across the country, solar physicists will observe totality with instruments that separate visible light into different colors and record the infrared part of the spectrum. With this information, they hope to learn how the Sun's corona changes in temperature, shape, speed, and composition — ultimately, to understand its nature and how it arises from the Sun's expanse.

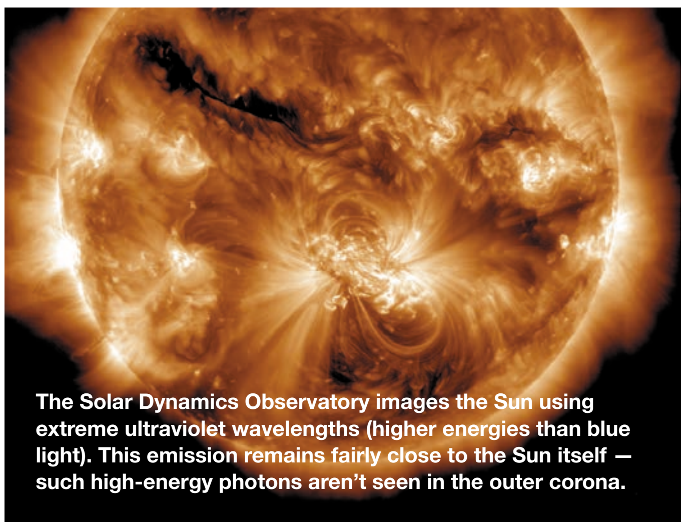
Together, everyone — citizens, amateurs, and scientists — can help paint a whole picture of our nearest star.

Monica Bobra is a research scientist studying the Sun and space weather at Stanford University.



The Sun's gravity shifts the apparent position of stars near its edge, an effect that can be tested during a total solar eclipse. Einstein's theory of general relativity correctly predicts this shift, which Eddington observed in 1919. (Diagram not shown to scale.)

The Moon's disk reveals the Sun's feathery corona during the total solar eclipse of August 1, 2008. The composite, which combines 55 individual images, also shows more than 450 stars, including the Beehive Cluster (upper right of the Sun).



The Solar Dynamics Observatory images the Sun using extreme ultraviolet wavelengths (higher energies than blue light). This emission remains fairly close to the Sun itself — such high-energy photons aren't seen in the outer corona.

LEAH TISCIONE / S&T; SOURCE: DONALD BRUNS; MIDDLE: © 2008 MILOSLAV DRUCKMÜLLER, PETER ANIOL & VOJTECH RUŠIN; BOTTOM: SDO / AIA