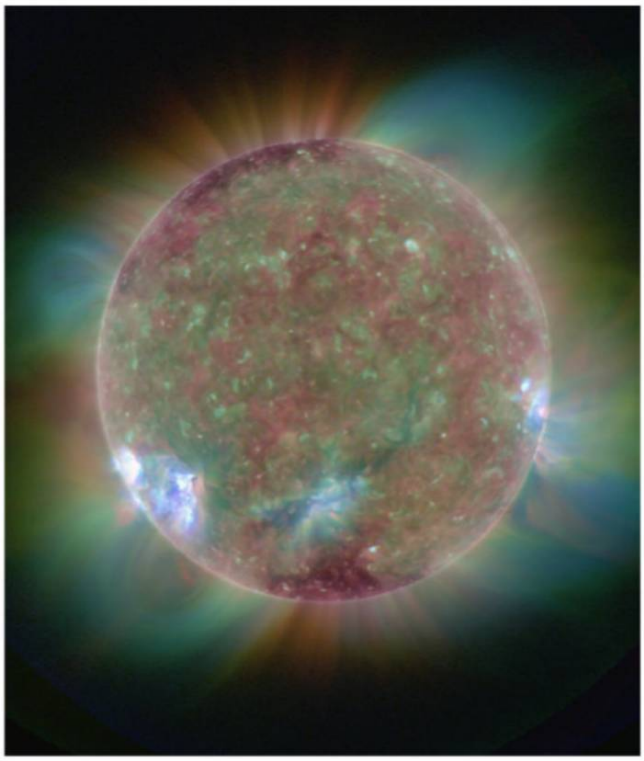
Revealing the 2020 ECLIPSE

Though most were unable to see last year's total solar eclipse in person, local astronomers and websites captured the cosmic event. BY JAY M. PASACHOFF

Anyone who has had the pleasure of viewing a total solar eclipse understands the desire to see another. This makes it easy to fall down the eclipse-chasing rabbit hole. But witnessing cosmic wonder isn't the only draw when you're an eclipse seeker.

Solar eclipses give astronomers a unique opportunity to view objects around the Sun, such as Mercury and nearby stars normally blocked by the Sun's brilliance.

In western Chile, Professor Patricio Rojo went to Gorbea with his wife and children. He captured some interesting views of the corona though the clouds using the 400mm telephoto we had gifted him. PATRICIO ROJO



The National Oceanic and Atmospheric Administration's GOES-16 spacecraft captured this false-color image of the Sun in extreme ultraviolet light — wavelengths shorter than visible light — at eclipse time with its Sun-facing Solar Ultraviolet Imager. The satellite's main cameras face Earth and continuously provide images of terrain and clouds from its geosynchronous vantage point. NOAA/GOES-16, COURTESY OF DANIEL B. SEATON/U COLORADO & NOAA

But it isn't just the objects around the Sun that draw astronomers to view eclipses. Scientists still don't agree how the Sun's corona, the outermost atmosphere of our star, is heated to more than a million degrees Fahrenheit (555,500 degrees Celsius), while the Sun's surface is only 9,940 F (5,500 C). The longest possible duration of an eclipse is 7 minutes 31 seconds, but most are considerably shorter, and total eclipses occur about once every 18 months. So, research opportunities during totality are sporadic at best and astronomers devote months or years of planning to take advantage of those few precious minutes.

Unlike totality during the July 2, 2019, eclipse — which was visible low in the sky along a narrow path through Chile and Argentina shortly before sunset — the December 14, 2020, total eclipse was high in the sky over the Patagonia region in South America.

But that wasn't the only major difference between the two eclipses. Planning for the December 2020 total solar eclipse was especially sporadic due to fluctuating travel restrictions related to the COVID-19 pandemic. My scientific team's original plans involved accompanying a tour group to a viewing site in Argentina, but restrictions led the cancellation of most tours, including our own. However, my team still managed to obtain permission to enter Chile and view from the otherwise-closed Villarrica National Park.

FAST FACT

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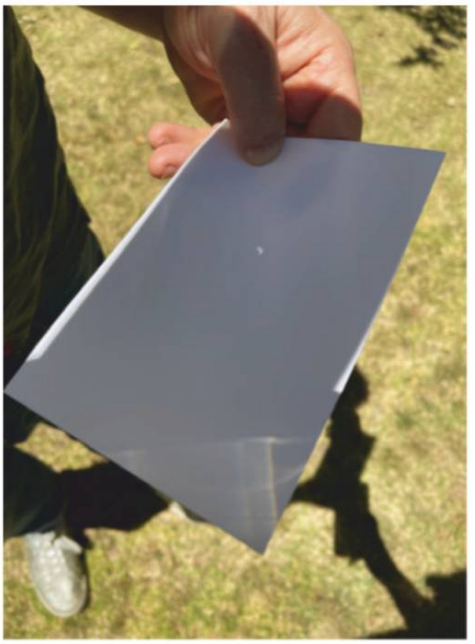
As eclipse day approached, I was hopeful that COVID would retreat, making it safer to navigate through airports to our restricted-access site for viewing the eclipse. Instrument specialists Alan Sliski of Lincoln, Massachusetts, and David Sliski of the University of Pennsylvania planned to join me as well.

A week before the eclipse, I decided to cancel my trip because of the increase in COVID-19 cases. Though I've already seen 35 totalities, it was a difficult decision to make. Instead, I took in the views from behind a computer screen miles away. Thankfully, local amateur and professional astronomers were able to share the experience with the world and give us scientific data to study.

Capturing an eclipse

Leading up to the eclipse, a research group from Predictive Science Inc. continued their streak of predicting what



Elizabeth Isaman, our contact at the American Embassy in Santiago, helped us gain permission to enter Chile despite travel restrictions. She had clear weather to view the partial phases as seen from Santiago. ELIZABETH ISAMAN

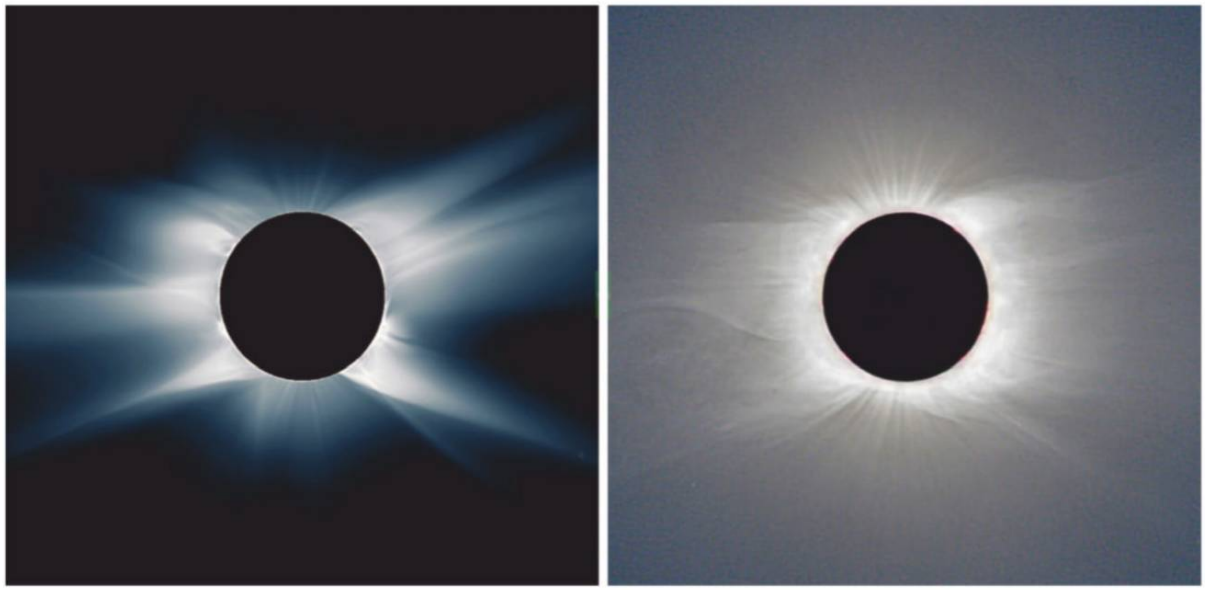
Verónica Espino captured these prominences near Las Grutas, Argentina. VERONICA ESPINO

Our team's meteorological station, set up and ready to go. JAY RACELA AND MARCOS PEÑALOZA-MURILLO (WILLIAMS COLLEGE)

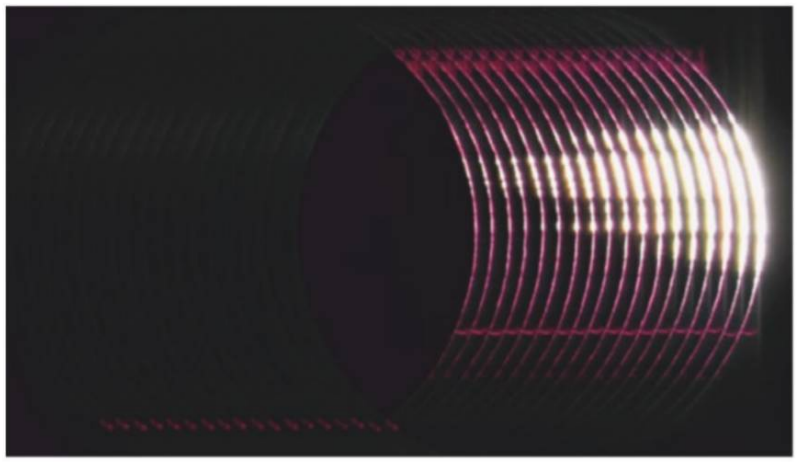
This image shows the predicted appearance of the eclipse at totality, based on observations from NASA's Solar Dynamics Observatory. PREDICTIVE SCIENCE INC.

the Sun's corona would look like. These computations were based on observations from NASA's Solar Dynamics Observatory of the solar magnetic field in the months leading up to the eclipse. Because the Sun's activity cycles from low to high and back to low about every 11 years, and the latest cycle began at the end of 2019, the researchers predicted that observers would see increased activity, such as forked streamers near the equator on either side of the Sun as well as plumes emanating from the poles. After the eclipse, some of the earliest images we received showed such prominences arcing up from the surface of the Sun.

The members of my team who had made the trip were forced to improvise when their views turned cloudy. Instead of capturing a view from Villarrica, they traveled east to the border with Argentina in an attempt to catch a glimpse of the event. The clouds remained, however, and due to



This set of images compares the predicted appearance of the eclipse (left) with its actual appearance (right). LEFT: PREDICTIVE SCIENCE INC., RIGHT: JAY PASACHOFF, ANDREAS MÖLLER, PATRICIO ROJO, VERÓNICA ESPINO, ET AL./WILLIAMS COLLEGE EXPEDITION (CHRISTIAN LOCKWOOD, DAVID SLISKI, ALAN SLISKI, THEO BORIS, XAVIER JUBIER, THIERRY LEGAULT)/NSF AGS/COMPUTER COMPOSITE BY WENDY CARLOS WITH IMAGES FROM CHILE AND ARGENTINA



This progression shows the evolution of Baily's beads as totality begins. ANDRÉS VATTUONE

COVID-19 restrictions, they were unable to cross into Argentina to find a new observing site. Instead, the team returned to the hotel and crewed a meteorological station in partnership with Marcos Peñaloza-Murillo of the Universidad de los Andes in Mérida, Venezuela. Using these measurements, we are now studying the effect of the abrupt eclipse darkening on terrestrial atmospheric parameters and potential gravity waves emanating from the path of totality. The equipment measured: temperatures at three heights, the pressure, the wind speed, and the amount of solar energy reaching a given area of Earth's surface every 20 seconds throughout the duration of the eclipse. We had already collected comparison data from the days before and took more in the days following.

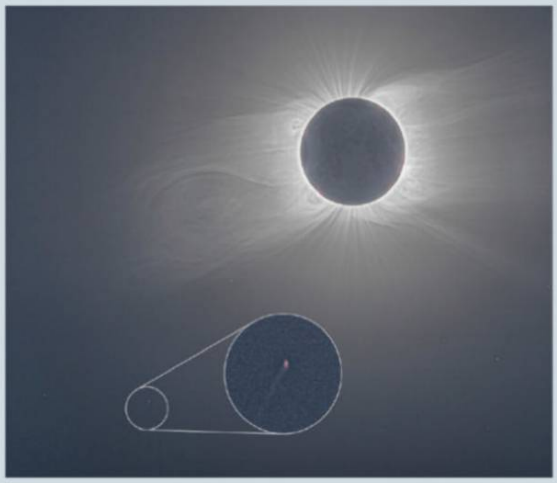
Filmmakers Matthew and Michelle Taylor accompanied my team in the hopes of capturing Baily's beads at the beginning and end of totality. Unfortunately, the cloudy skies made it impossible to get a clear enough image of the eclipse to do so.

The first notification I received of coronal observations through reasonably clear skies came from Andreas Möller of Germany, who had gone to Argentina with the U.K. Astro-Trails tour — one of the few tours that had not been canceled — to a site at Piedra del Águila. Back in New York City, my longtime colleague, computer-adept composer Wendy Carlos, created a composite of Möller's images by choosing the best exposed part of each. She sent the result to Joy Ng and Lina Tran of NASA's Goddard Space Flight Center, who compared the photos with predictions generated by Predictive Science Inc. The resulting press release not only shows a fade from their prediction to our actual image of the event, but also provides a slider that allows readers to compare the two images in detail.

Eclipse enthusiasts John Beattie and Tim Todd chartered two Cessna Citations to carry 11 eclipse observers from La Araucanía International Airport to 33,000 feet (10,058 meters) above the Pacific before the eclipse reached South America. Michael Gill, who runs the Solar Eclipse Mailing List, and Patrick Poitevin, who ran the first Solar Eclipse Conferences, were among those on board the second plane, along with Beattie, Craig Small, Jordan Sutton, and Ken Schwartz.

Looking forward

What's next? We have plenty of observations to keep us busy, but that doesn't



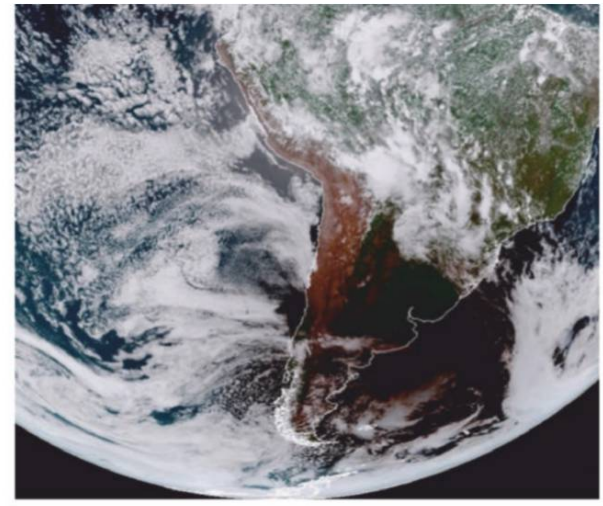
This composite image combines 65 frames and shows Comet C/2020 X3 (SOHO) during the eclipse. ANDREAS MÖLLER, PROCESSED BY JAY PASACHOFF AND ROMAN VANUR

COMET LIGHT, COMET BRIGHT

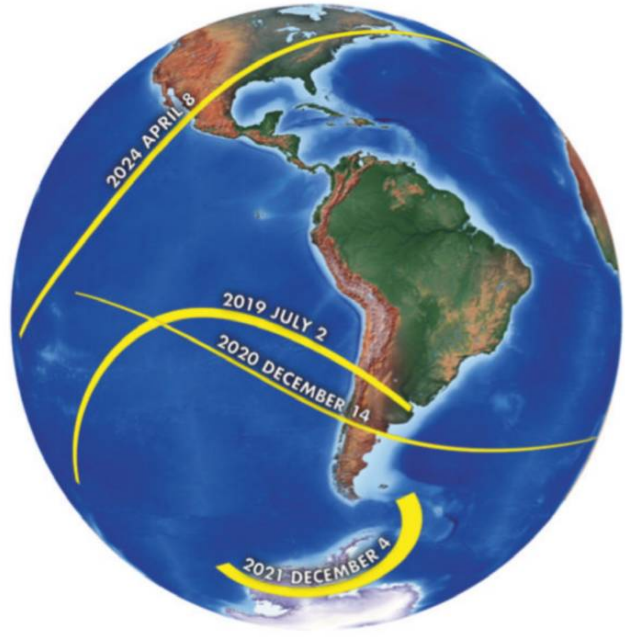
Looking through satellite data from the NASA-funded citizen science Sungrazer Project, Thai amateur astronomer Worachate Boonplod spotted a new comet speeding by the Sun on December 13, a day before the eclipse. Sungrazer encourages citizens scientists to scour images from the joint European Space Agency and NASA Solar and Heliospheric Observatory (SOHO) to find new comets. Astronomers were eager to see if the little speck would be visible in eclipse photographs.

Hopeful it would appear in ground-based observations, I sent a full set of Andreas Möller's raw eclipse images to my colleagues Vojtech Rusin and Roman Vanur in Slovakia. Lo and behold, Vanur's resulting composite, made from five dozen of Möller's images, indeed shows the comet.

Considering about 2,000 SOHO comets are still unnumbered, I reached out to the U.S. Naval Research Laboratory, encouraging them to number this new comet. It soon became SOHO-4108. Later, the International Astronomical Union Minor Planet Center at the Smithsonian Astrophysical Observatory released the comet's new name — C/2020 X3 (SOHO). Additional observations showed it to be a Kreutz sungrazer, a family of comets stemming from a parent comet that broke up well over a thousand years ago. — *J.P.*



ABOVE: The GOES-16 spacecraft captured the path of totality across Patagonia. BELOW: Past and future eclipse paths and dates are mapped on the globe.
ABOVE: TIM J. SCHMIT, NOAA/NESDIS CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR).
BELOW: MICHAEL ZEILER, GREATAMERICANECLIPSE.COM



mean we aren't already planning to collect more in the future, as the Sun continues through its sunspot cycle. This year's annular eclipse over Canada, northwestern Greenland, the North Pole, and Siberia on June 10, 2021, will have partial phases visible in the northeastern U.S. Unfortunately the same can't be said for the Antarctica eclipse on December 4, 2021. Predictions made by Jay Anderson at http://eclipsophile.com indicate clouds will impact the viewing.

With neither a total solar eclipse nor an annular eclipse, 2022 will be an unusual year. So, eclipsophiles are preparing plans for the "hybrid" annular/total eclipse that will clip a peninsula at the extreme western end of Australia in 2023 before going on to East Timor and western Papua. The October 14, 2023, annular eclipse that crosses the U.S., Mexico, Central, and South America will also have partial phases visible throughout the U.S.

But those annular eclipses are child's play compared to what's coming in 2024: The next Great American Eclipse. Totality during this much-anticipated event will cross from Mexico through Texas and on through the upper Midwest to northern New England and the Canadian Maritimes. And, if one can bear to wait a few more decades, the May 1, 2079, total solar eclipse will cross over both New York and Boston.

Regardless of which eclipse you may see, you certainly won't be disappointed — whether you're an astronomer or simply an eclipse enthusiast.

Jay Pasachoff *is a professor of astronomy at Williams College and a veteran of 35 total solar eclipses. His research is sponsored by the National Science Foundation's Division of Atmospheric and Geospace Sciences.*