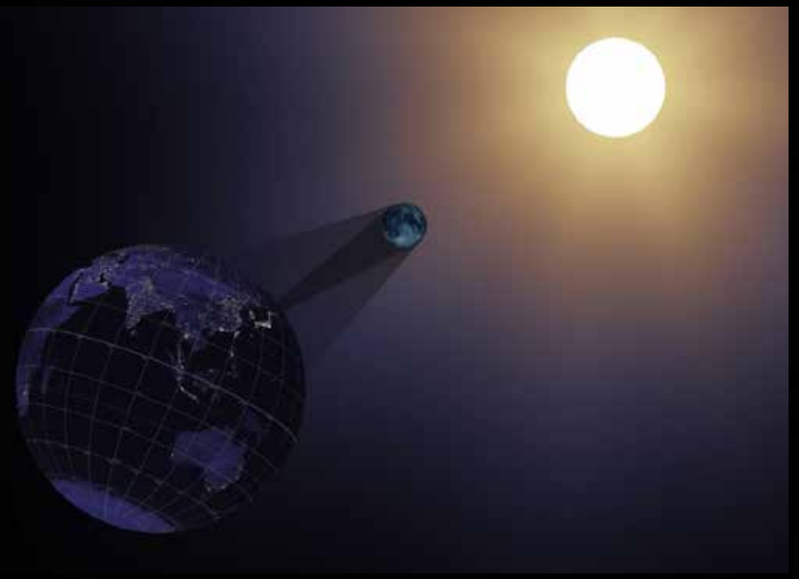
Corona Light

Missed last year's annular eclipse? We've got you covered with some of the best shots out there.

BY JAY PASACHOFF



The Mango Education Group experienced annularity during clear weather from Dehradun, the winter capital and most populous city in the Indian state of Uttarakhand. That fortunate weather allowed them to capture this crisp shot of the thin circle created by the Sun's disk stretching out just beyond the Moon's silhouette. HARINDRA BARAIYA (WILDLIFE INSTITUTE OF INDIA/MANGO ASTRONOMY CLUB); IMAGE FORWARDED BY STEPHEN INBANATHAN (AMERICAN COLLEGE IN MADURAI)

Right: On June 21, the Moon was relatively far from Earth in its elliptical orbit, so its angular size was smaller than usual. Therefore, it couldn't fully block the solar disk when the Sun, Moon, and Earth aligned, or entered syzygy, as shown in this artist's illustration. ERNEST T. WRIGHT, NASA'S GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO

The wild year of 2020 boasted two solar eclipses: an annular eclipse on June 21 and a total solar eclipse on December 14. Travel restrictions prevented North Americans, as well as many others in the Western Hemisphere, from viewing the path of annularity that stretched from Africa through the Middle East to Pakistan, India, mainland China, and Taiwan. Fortunately, local eclipse viewers who managed to get beneath the Moon's shadow captured wonderful images of the breathtaking event.

The following is a smattering of shots from last June's annular eclipse, which I monitored into the wee hours of the morning with the help of email, the web, and livestreams from the Middle East and Asia. My decades-long interest in eclipses, and the resulting expeditions I have taken to view them, have allowed me to meet many fascinating people who I never would have otherwise. And although I don't keep in constant contact with every one of them, when an eclipse passes overhead anywhere in the world, I have a good chance of hearing from some of my old friends who are eager to share their new pictures.

At the time of this writing, the next solar eclipse to be seen from Earth will be total, with its peak occurring near the Argentina/Chile border on December 14, 2020. Be sure to keep an eye out for images of December's total solar eclipse in future issues of *Astronomy*.

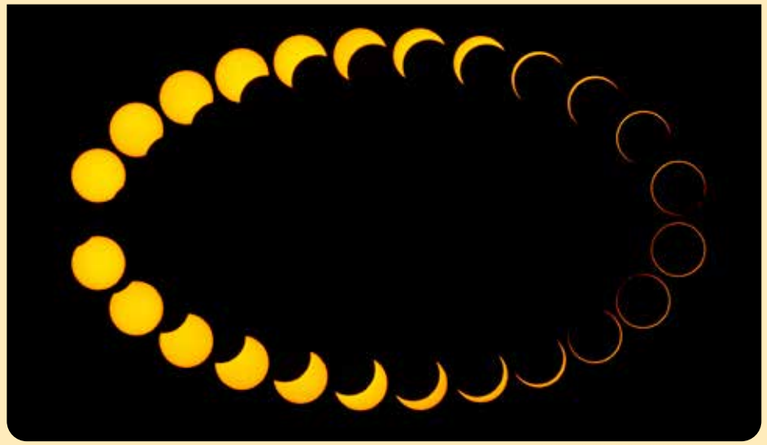
Meanwhile, the next annular eclipse will be on June 10, 2021. Its path will trek from southern Canada over the North Pole and down to the Russian Far East. Observers in the northeastern United States will be happy to learn that partial phases of this annular eclipse will be visible to them in the early morning. So, make sure to get your filtered solar eclipse glasses now, available at MyScienceShop.com.

And don't forget: Share what you see!

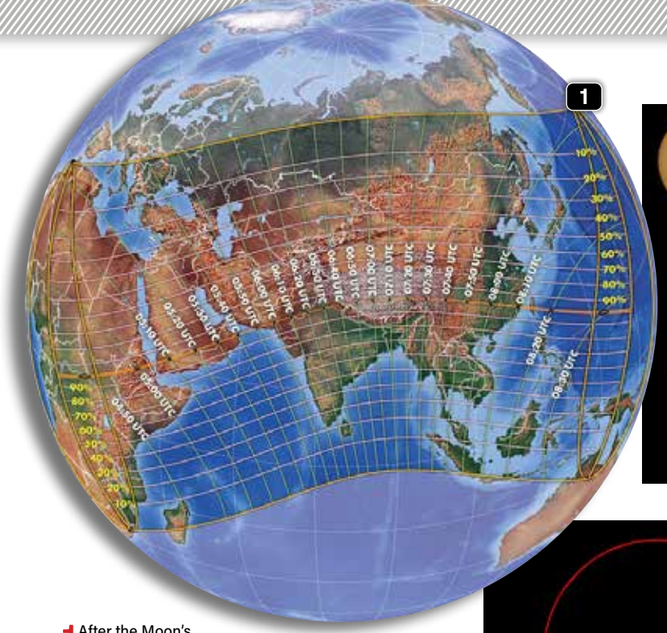
A RINGED ECLIPSE

The word annular comes from annulus, which means "ring." So, when the Moon is just far enough away from Earth that it leaves the outer perimeter of the Sun's disk unobscured, the result is often referred to as a "ring-of-fire" eclipse. At maximum coverage, this outer band of sunlight is up to a few percent of the solar disk's diameter. So, technically, it could be called a "ring-of-photosphere" or a "ring-of-sunlight" eclipse.

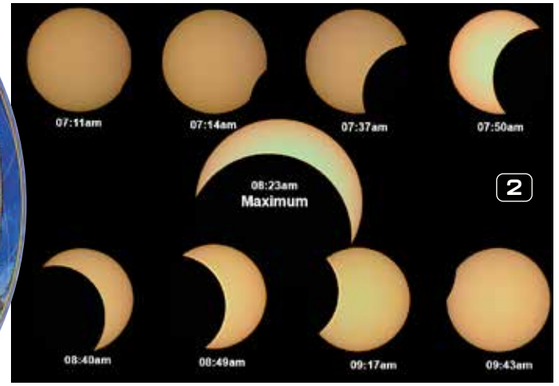
The term "ring-of-fire" has murky origins dating back at least 150 years, but its current usage in reference to annular eclipses dates has been around for at least a few decades, when it started popping up various publications. However, "ring-of-fire" is somewhat misleading terminology, and it is disliked by many professional and amateur astronomers, or so-called umbraphiles (an umbra is the dark part of a shadow). Contrary to common conception, there is no chemical fire on the Sun. Rather, we owe the warmth and light we receive from the Sun to the clean thermonuclear fusion of hydrogen gas safely occurring some 93 million miles (150 million kilometers) away.



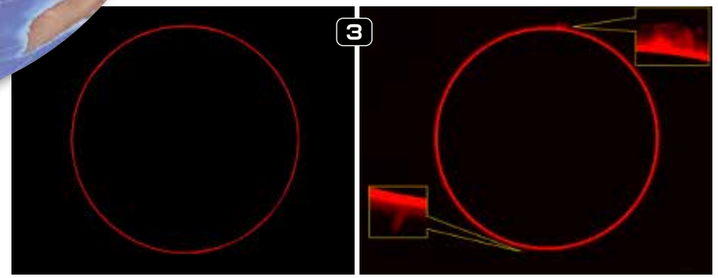
IMAGES: JAY PASACHOFF; COMPOSITE: MUZHOU LU



1 After the Moon's shadow first touched the Republic of Congo during the June 21 annular eclipse, it departed Africa, went through the Middle East, then passed through southern Pakistan, northern India, mainland China, and Taiwan before vanishing southeast of Guam. The annular eclipse path, which stretched 9,058 miles (14,578 km) was just 13 miles (21 km) wide and maximum eclipse (99 percent) lasted about 38 seconds. MICHAEL ZEILER



2 The path of annularity during the June 21 eclipse grazed Saudi Arabia, resulting in a partial eclipse for many. Abouazza Elhamdi of the Astronomy and Physics Department of King Saud University captured this sequence of partial phases in the early morning from Riyadh, Saudi Arabia. I am working with Abouazza and colleagues from Saudi Arabia, atmospheric physicist Marcos Peñaloza-Murillo of Venezuela, and Michael Roman of England to analyze how eclipse darkening impacts the local temperature and humidity in that desert climate. ABOUAZZA ELMHAMDI



3 **LEFT:** Unlike central Saudi Arabia, Izki, Oman, did see annularity. Alaa Ibrahim and Zach Ioannou of the Astronomy Group at Sultan Qaboos University captured a series of images with the aid of a hydrogen alpha filter, including the single short exposure seen here. A. IBRAHIM/Z. IOANNOU

RIGHT: The view of the annular eclipse at right was created by stacking 210 images, which revealed some notable solar prominences, or bright tendrils of plasma anchored to the Sun's surface (photosphere) that extend into the corona. The observers also tracked the ambient temperature and humidity of their site throughout the event. Before the eclipse, they reported it was 113 degrees Fahrenheit (45 Celsius), which

AN UNFILTERED VIEW LEADS TO A REVISION

The June 21 annular eclipse also traced a path through Pakistan, where the cloud-cover forecast was not as favorable as in the lower Arabian Peninsula. Fortunately, it turned out to be very clear.

From Sukkur — a city in the Pakistani province of Sindh — Talha Moon Zia, who is a research astronomer at Pakistan's National Center for Big Data and Cloud Computing/NED University of Engineering & Technology, obtained these wonderful unfiltered views of the annular eclipse. The shots above were created by stacking several short-exposure images and were taken under the guidance of Michael Kentrianakis, the former project manager of the American Astronomical Society's 2017 U.S. eclipse efforts and a member of our International Astronomical Union's (IAU) Working Group on Solar Eclipses.

Our IAU group focuses on being a central resource for anyone looking to find out more about past or upcoming solar eclipses. To do this, we maintain a website at the easiest possible address to remember: eclipses.info. The working group also acts as a clearing house for professionals pursuing international eclipse expeditions, coordinating such matters as visas, customs, and the shipping of equipment.

For the above image, Zia and Kentrianakis forwent filters in order to capture detailed views of Baily's beads, which occur when sunlight peeks through valleys along the lunar limb. This allowed them to successfully detect the solar chromosphere, and even the inner solar corona.

Prior imaging of Baily's beads taken during previous total solar eclipses led to discussions between me, Xavier Jubier, and Ernest T. Wright of NASA's Scientific Visualization Studio. We concluded that the IAU's nominal solar diameter — the defined size of the Sun's photosphere, which is used for predicting the length of eclipse totalities down to a fraction of a second — needed a minor revision. By comparing our observations to simulations from Jubier's website of the expected Baily's beads for this eclipse, which were based on high-resolution 3D mapping of the lunar surface obtained by NASA's Lunar Reconnaissance Orbiter and the Japanese Kaguya mission, our suspicions were confirmed.

The true size of the Sun's photosphere is a slightly larger than previously thought.

BOTH IMAGES: NCBC-NEDUET

4 Rafay Kazmi, a student at Williams College in Williamstown, Massachusetts, observed a partial eclipse from his home in Islamabad, Pakistan. Here, he and his sister are seen viewing the eclipse through special solar filters, one of thousands left over from the 2017 Great American Eclipse and available through Astronomers Without Borders. RAFAY KAZMI

5 Clouds only served to add mystique to this view of the eclipse from the city of Sirsa in the northern Indian state of Haryana, taken by Neelam and Ajay Talwar.
NEELAM & AJAY TALWAR

6 This series of images, showing the partial eclipse as seen from Coimbatore, a city in the south Indian state of Tamil Nadu, was captured by members of the Mango Astronomy Club. OBULI CHANDRAN

7 The Talwar team also captured this series of images tracking the progress of the annular eclipse over Sirsa. Even through the clouds, one can identify Baily's beads, the solar chromosphere, and, perhaps, even glimpse the solar corona.
NEELAM & AJAY TALWAR

ECLIPSE RESOURCES

Many observers who were unable to personally see the annular eclipse dim the skies during the daytime instead opted to monitor images and livestreams of the event aired during the middle of their local night — an option not available to eclipse enthusiasts just a few decades ago.

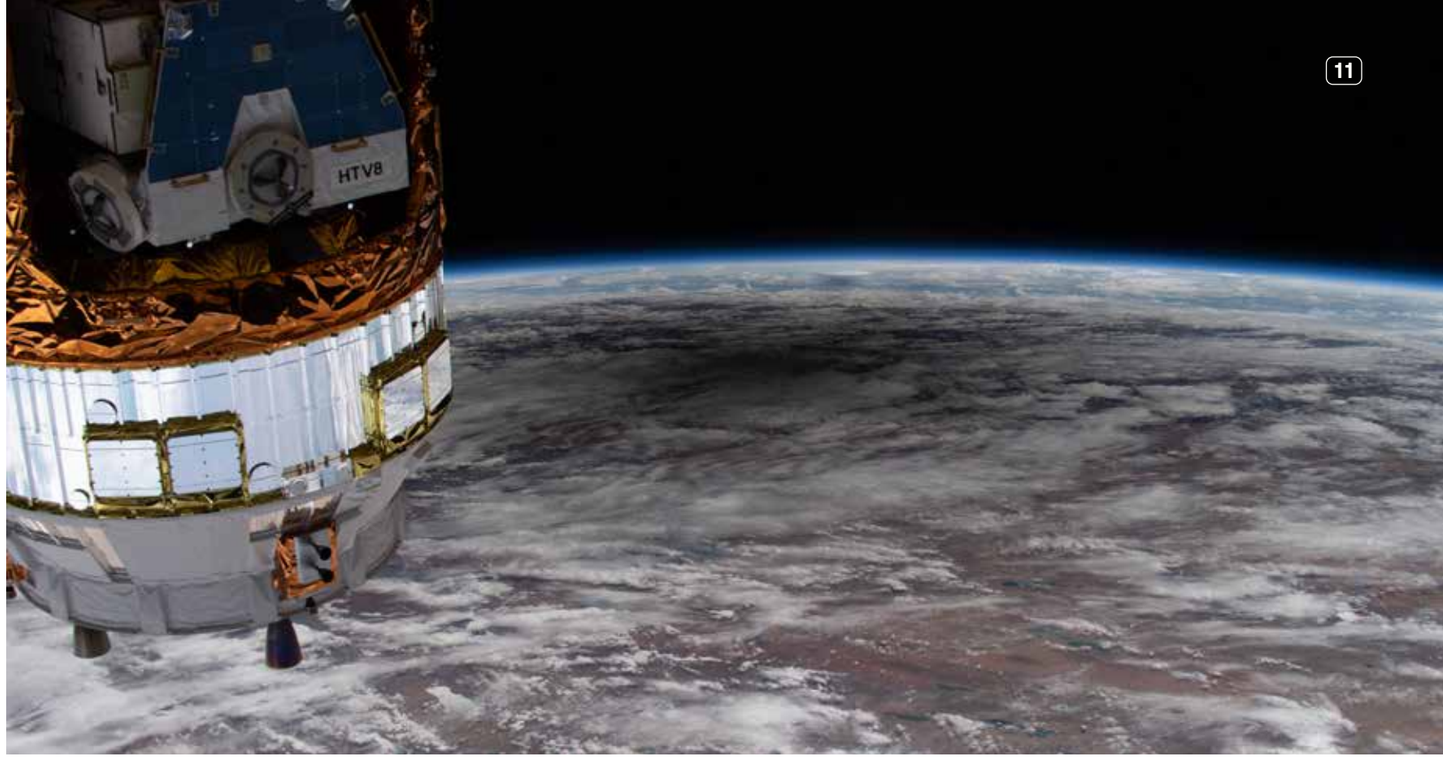
Now, worldwide communication and online eclipse-mapping tools, like those from Xavier Jubier of France (http://xjubier.free.fr/ase2020map) and retired astrophysicist Fred Espenak (EclipseWise.com), provide detailed eclipse data for any location on Earth. Additionally, cartographer Michael Zeiler of New Mexico has meticulously created high-quality eclipse maps, while cloudiness statistics over the decades have been gleaned and put into context by Jay Anderson of Canada. (Anderson and I jointly authored the Peterson Field Guide to Weather, which is being published in summer 2021.)

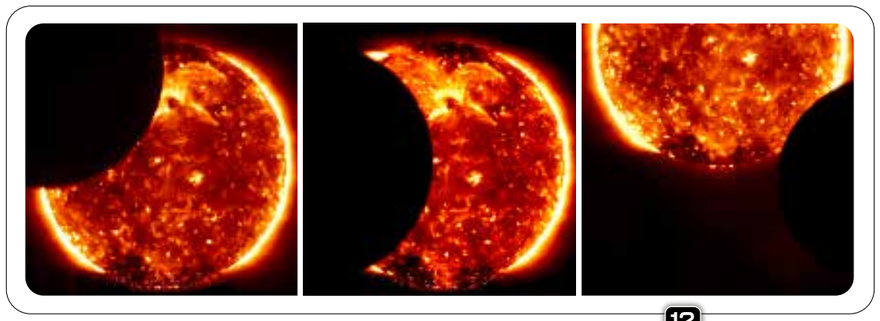
All of these resources are linked on the website for the International Astronomical Union's Working Group on Solar Eclipses (http://eclipses.info), which I chair. Additionally, observations of the 75 or so solar eclipses I worked on in the past are posted to the Williams College Eclipse Expeditions website (https://sites.williams.edu/eclipse).

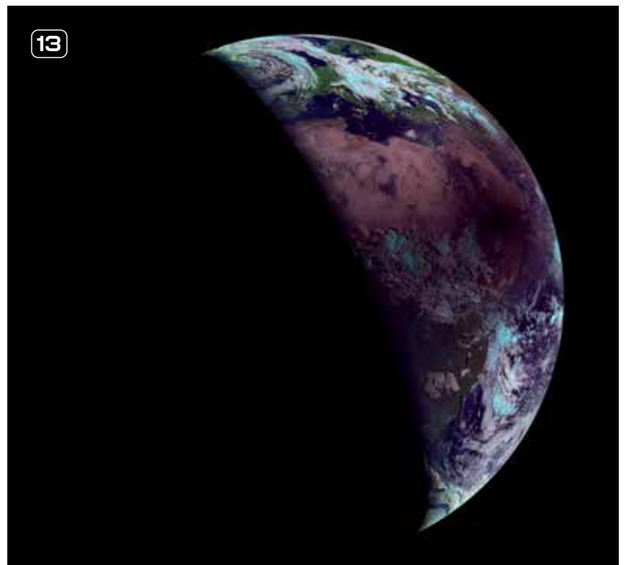
8 Amateur astronomer Zhou Guanhuai (left), who had previously corresponded with the author about earlier eclipses, sent an image (right) of the partial eclipse as seen from Jinan, Shandong province, China. Here, the partial eclipse reached its greatest coverage at 15:55 local time with a magnitude of 0.67. CREDIT: ZHOU GUANHUAI

9 Near the end of the path of annularity in Guam, the eclipse was visible with 97 percent coverage, as seen in this eerie photo taken by Dean Patrick Servito. The path of annularity continued about 50 miles (80 km) out to sea – briefly tempting me to fly to the U.S. territory for a quarantined glimpse from a boat. DEAN PATRICK SERVITO

10 Due to travel restrictions related to the COVID-19 pandemic, I was unable also to venture to Europe. These images came from Thessoliniki, Greece. They were captured by Aris Voulgaris, with whom I closely work on total solar eclipses. ARIS VOULGARIS







Jay Pasachoff *is Field Memorial Professor of Astronomy at Williams College in Williamstown, Massachusetts, and chair of the International Astronomical Union's Working Group on Solar Eclipses. He has worked on 75 solar eclipses and written about the Sun for* Astronomy *since its very first issue.*

11 A camera mounted to the outside of the International Space Station captured this shot of the Moon's shadow racing across Earth (near the border of Kazakhstan and China) during the June 21 annular eclipse. A Japanese cargo spacecraft is visible in the foreground. NASA/ISS EXPEDITION 63

12 The X-ray telescope on the Japanese Hinode spacecraft captured this series of shots, of the Sun's disk being blocked out by the Moon during the June 2020 eclipse, which have been rescaled and colored. Astronomer Taro Sakao of the Japan Aerospace Exploration Agency (JAXA) took advantage of Hinode's vantage point to observe how plasma moves in the high-speed solar wind stream, using the lunar silhouette for calibration of stray light. JAXA/HINODE (THANKS TO ALPHONSE STERLING OF NASA'S MARSHALL SPACE FLIGHT CENTER, AND KATHY REEVES AND LUCAS GULIANO OF THE HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS.)

13 The passage of the Moon's shadow across Earth's surface was tracked by the European Meteosat-8 and the Japanese Himawari-8 spacecraft. Here we see a Meteosat view of Moon's shadow over northeast Africa, the Red Sea, and the Arabian Peninsula. The antumbral shadow (the lighter part) first touched Earth in Congo. COPYRIGHT 2020 EUMETSAT