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SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

NOVEMBER 2022

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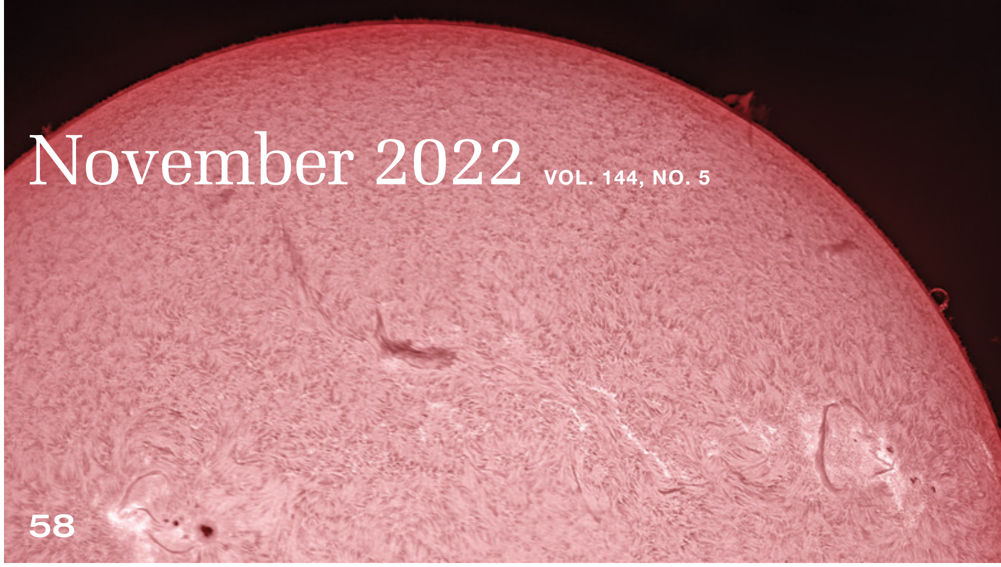

November 2022 VOL. 144, NO. 5

FEATURES

OBSERVING

S&T TEST REPORT

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ON THE COVER

Nearly 1,000 images make this mosaic of Stephan's Quintet.
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Instant Gratification

THE FIRST IMAGES FROM the James Webb Space Telescope released in July were a revelation (see cover and page 12). In a flash, we knew astronomy had just taken the next great leap forward, that this instrument would revolutionize the field. We didn't need to see additional images to convince us that this telescope was all its proponents had cracked it up to be, and more. The first Europeans to lay eyes on the Grand Canyon, having only heard about it from Native Americans, must have had a similar reaction: One can imagine them muttering, with mouths agape, "It's every bit as magnificent as they said it would be."

In ogling those first pictures, one couldn't help but think back on this telescope's long, arduous journey over the past three decades. The technological delays, the cost overruns, the near cancellation. The true nail-biting that began as soon as the telescope left U.S. soil: First the sea voyage to the launch site in French Guiana, then the launch itself and subsequent deployment, with its 344 single points of failure. Even the six months of commissioning. Anywhere along that path, something could have tripped Webb up, and this near-$10-billion tool might have become scrap metal.

▲ August release: the Cartwheel Galaxy and two companions, seen in a Webb composite of near- and mid-infrared imagery

NASA / ESA / CSA / STSCI

But all went swimmingly, and those initial images revealed, in one fell swoop, what a triumph JWST is on so many levels. It's a triumph of ingenuity, perseverance, and collaboration that shows brilliantly what the human mind is capable of. Yet it was not the work of a single individual or team but of an estimated 20,000 people across the globe.

Fittingly, JWST is a telescope for the world, not just for the U.S., European Union, and Canada, the instrument's three principal partners. Any professional astronomer or team can apply for access, and all human beings can marvel at its output online. Every month now, we all can await breathlessly whatever celestial surprises Webb will deliver next. It feels like it's humanity's birthday, and the gifts keep pouring in.

I, for one, can't stop admiring the stars in Webb images, with their signature diffraction spikes. They resemble asterisks (from the Greek *asteriskos*, "little star"), but they serve more like lighthouse beacons. "Here we are," they seem to indicate. "Come explore us and all the wonders you see around us." The spikes are artifacts that arise from the telescope's primary mirror and struts, but in that way, they symbolically attach us to those suns and those scenes.

Is there a more potent example of "greater than the sum of its parts" than JWST? Kudos to all who made it happen. We look forward to savoring its fruits for years to come.

Peter

Editor in Chief

SKY&TELESCOPE
The Essential Guide to Astronomy

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All other countries: $86.05, by expedited delivery
All prices are in U.S. dollars.

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A Stellar Find

After reading Javier Barbuzano's article "The Real Tatooines" (*S&T:* July 2022, p. 34), I found in my collection of astronomical prints a painting entitled "A World with Two Suns" by the Swiss artist Viktor Robert Kiener (1866-1945). The two suns are evidently a red giant and a bluish companion star.

I wish to thank my friend and colleague Eugen Jost for identifying the artist of this print.

Eli Maor
Morton Grove, Illinois

Planet Semantics

I found Christopher Crockett's "The Elusive Planet X" (*S&T:* July 2022, p. 14) very interesting. One irony is if a mini-Neptune is found out in the Kuiper Belt, it may not qualify as a planet due to the current International Astronomical Union definition, which requires that such a world must have effectively cleared out its orbit of debris. This condition probably would be hard to achieve in the busy Kuiper Belt and even more so to verify, since the object would be so far away. It would be strange to have a world bigger than Earth out there that's not a planet because of such a technicality.

Stephen A. Becker
Los Alamos, New Mexico

Saturn in 3D

The article "Saturn's Seeliger Effect" by Thomas A. Dobbins (*S&T:* July 2022, p. 52) contains two Hubble Space Telescope images of Saturn to illustrate the Seeliger effect. These images also yield a spectacular 3D representation of Saturn.

Simply rotate the page 90° and use a separator between the pictures (I use an index card) so that the right eye sees one image and the left sees the other. Relax your gaze, and the images will merge to create a magnificent 3D image of Saturn and its rings.

Frank Ridolfo
Bloomfield, Connecticut

Feline Astronomers

After four decades as an amateur astronomer, using everything from modest binoculars in the beginning to, currently, Go To telescopes with CCD and video cameras, naked-eye phenomena such as the June 24th planetary alignment (*S&T:* June 2022, p. 48) are rewarding. Fortunately, a clear sky allowed me and my wife to see Venus, Mars, Jupiter, Saturn, and the Moon around 6 p.m. local time in a rural area. Even elusive Mercury was clearly visible. I located it first with binoculars and then without optical aid at only 3.5° above the horizon. We were accompanied by our cats (Sirius and Orion), who climbed up a nearby tree, as if they also wanted to observe the alignment. Truly, it was a beautiful experience. Thanks, *S&T*, for informing us about these wonderful spectacles.

Florentino Sánchez
Badajoz, Spain

With Pencil and Paper

Congratulations on Howard Banich's "Drawing in the Dark" (*S&T:* June 2022, p. 58). Even though I'm not much of a visual observer anymore, I have fond memories of sketching at the eyepiece with black paper and white pastel pencils under a red light. As Banich points out, the results may not be masterpieces, but they are great reminders of what I actually saw. And the effort was excellent training for teasing out subtle details in the view.

No quick glances for us sketchers — spending an hour staring at a single field is a real education for the eye and the mind.

Well done!

Robert K. Buchheim
Lost Gold Observatory
Gold Canyon, Arizona

Pushing Glass in Chicago

Jerry Oltion's "Pushing Glass" (*S&T:* July 2022, p. 58) was a refreshing break from the articles about expensive technology. There are hundreds of thousands of small villages in the world whose residents don't have the money to buy a completed mirror. A first glance at a planet in an eyepiece should be part of everyone's education. It completely changes one's perspective.

The mirror-grinding class at Adler Planetarium was so popular when I was in the Chicago Junior Astronomical Society that it was impossible to get in. I completely agree with Oltion that a class or a mentor is "far, far (almost infinitely far) greater than" trying to teach oneself.

Some of the most famous discoveries in astronomy were made with homemade equipment, including lenses. I await an article on that skill.

Terry Herlihy
Chicago, Illinois

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A Pleasant Surprise

Imagine the shock I received as I read the title of David Grinspoon's article "Searching for Intelligence on Earth" (*S&T:* July 2022, p. 12). But it was a good kind of shock!

Kudos to Grinspoon for his Cosmic Relief and telling it like it is. The concern regarding Russia and our space program is a real one.

Earth may not be an infant, but relatively speaking, the human race is. We are still growing into our intelligence, and like any group of children, we all progress at a different rate. When will national leaders learn to play well with others in their own country, as well as with those around the world?

It seems as long as there are people who are only interested in power and money, we'll have such people gaining leadership positions. It is up to those of us who want no part of that to do what we can to make sure as few of them attain those positions as possible.

Leaders come and go, and we'll hold out hope that Russia's current leader (and others like him in countries around the world) will go sooner rather than later, so that well-meaning Russian astronauts and other folk can once again enter into the spirit of worldwide cooperation in space and other areas.

Perhaps we should bring all the world leaders up into space to see firsthand our little blue marble. Do you think that would help?

But take heart, a quick search on NASA's website shows we currently cooperate with many other countries. Russia may be the largest country, but it is after all just one.

I look forward to reading Grinspoon's book *Earth in Human Hands: Shaping Our Planet's Future*.

Terry Robinson
Norway, Maine

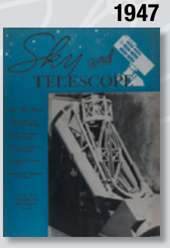
FOR THE RECORD

- The team that applied its own analysis techniques to the LIGO, VIRGO, and KAGRA collaboration data and found 10 new candidates is from the Institute for Advance Study (*S&T:* Sep. 2022, p. 11).
- In "A Lingering Jovian Mystery" (*S&T:* Sep. 2022, p. 52), the observations of Io's flash in 1983 from Mauna Kea matched those from Palomar Mountain.
- In the illustration of Earth on page 74 of the September issue, the continents should have been rotated 23.4° clockwise, aligning Earth's equator with the Celestial equator. A corrected version appears here: **https://is.gd/errata2022**.
- On page 25 in the July issue, the name Little Gem refers to the planetary nebula NGC 6818, not NGC 6445.
- The Hubble Space Telescope captured the top image of Saturn on page 52 of the July issue on July 4, 2020.

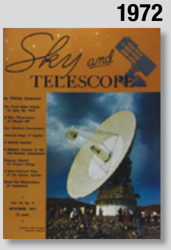
SUBMISSIONS: Write to *Sky & Telescope*, 1374 Massachusetts Ave., 4th Floor, Cambridge, MA 02138, USA, or email: letters@skyandtelescope.org. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

75, 50 & 25 YEARS AGO by Roger W. Sinnott

1947



1972



1997

◖ November 1947

Comet's Outburst "In January, 1946, Dr. G. Van Biesbroeck, Yerkes' comet expert, observed a remarkable brightening of Comet Schwassmann-Wachmann (1925 II). Early in the month the comet had been extremely faint, but on the 25th, Dr. Van Biesbroeck was surprised to see that it had brightened to magnitude 10.2, and by the next day it reached 9.4. The 'outburst' did not last long; by February 8th the comet had faded to the 15th magnitude.

"More than a year later, Dr. Seth B. Nicholson, of Mount Wilson Observatory, pointed out . . . that this remarkable behavior of the comet happened to coincide with the time that the largest sunspot ever photographed (to that time) was on the hemisphere of the sun facing the comet."

Outbursts in comets are not very rare, but the trigger is usually a mystery. They may reflect the sudden release of trapped gases or even landslides on a comet's surface.

◖ November 1972

Big Dish "When western amateur astronomers held a convention in California last August . . . , a highlight of the program was an excursion to the huge 210-foot tracking antenna [of] the Goldstone Deep Space Communications Complex. [It] has been extensively used to support the Mariner unmanned missions to Mars and Venus, ever since it went into operation in 1966 . . .

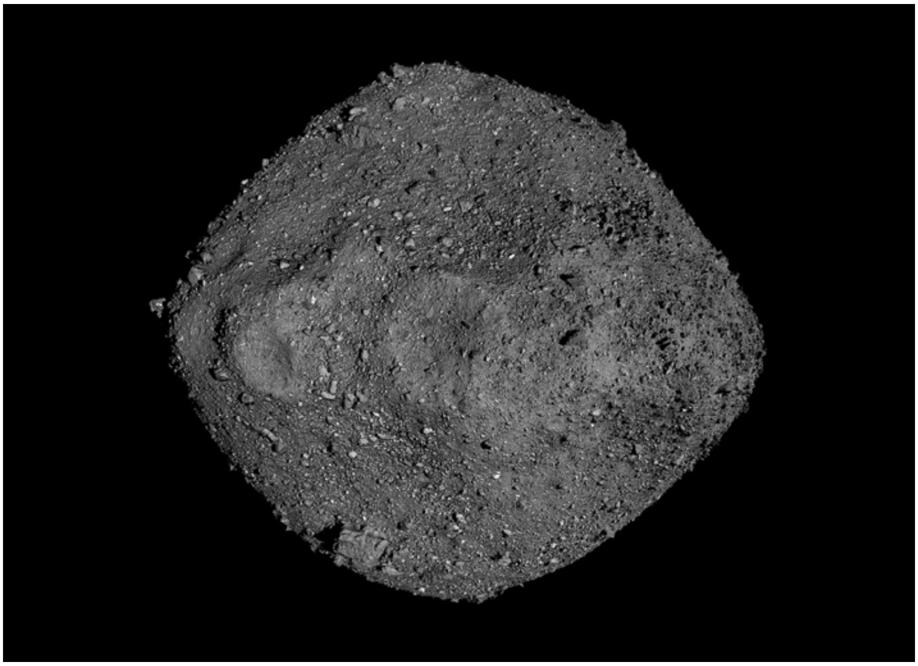
"Currently, one of the tasks of the big dish is support of the Pioneer 10 mission to Jupiter and beyond. In its role as a radar telescope, the 210-foot has been used to measure interplanetary distances with extreme accuracy . . ."

Operated by NASA's Jet Propulsion Laboratory, this venerable workhorse was renovated to 230-foot diameter (70 meters) in 1988. It has played a growing role in the radar mapping of near-Earth asteroids and comets.

◖ November 1997

Antimatter Puzzle "Matter and antimatter were presumably present in equal amounts in the universe's infancy, when space was pervaded with a sizzling soup of particles and photons. Thus equal quantities of matter and antimatter should have completely annihilated each other . . . Our existence, however, shows that matter particles somehow managed to outnumber antimatter . . .

"Andrew G. Cohen [and colleagues] asked themselves what astronomers might see if the universe were made of separate regions of matter and antimatter, each containing its own gases, stars, and galaxies. Such a patchwork cosmos would sidestep the need for physics to always favor one kind of matter over the other. . . . In theory, says Cohen, completely empty zones could have separated matter and antimatter parcels, preventing annihilation. But maps of the microwave sky made by the COBE satellite rule out this contrived hypothesis."



◀ Asteroid 101955 Bennu, as imaged by the OSIRIS-REX spacecraft

SOLAR SYSTEM

Asteroid Bennu Almost Swallowed Spacecraft Whole

WHEN NASA'S OSIRIS-REX took a sample from the asteroid 101955 Bennu on October 20, 2020, it revealed that this little world is more rubble pile than solid rock. New analyses in the July 7th *Science* and *Science Advances* show that when the probe touched down, it punched right through the surface. If the spacecraft hadn't lifted itself back out a few seconds later, the asteroid would have engulfed it.

On sampling day, a 3.35-meter (11-foot) articulated arm attached to the probe unfolded to deploy an aluminum collection head; together, these pieces make up the Touch and Go Sample Acquisition Mechanism (TAGSAM). The probe approached the surface at a slow 10 cm/s (0.2 mph). The plan was then for the TAGSAM head to touch the surface and stay there for 5 seconds while a jet blew nitrogen gas into the surface material, swirling some of it up into the collection head. Lab tests of the sampling procedure "barely made a divot," explains principal investigator Dante Lauretta (University of Arizona).

In practice, the jet blasted out 6,000 kilograms (13,000 pounds) of dust and rock, creating an elliptical crater 9 meters long. "What we saw was a huge wall of debris radiating out from the sample site," Lauretta says. "We were like, 'Holy cow!'"

What's more, TAGSAM didn't stop when it touched the surface. It kept on going, pushing another half-meter down before the spacecraft reversed course. Particles stuck to the spacecraft as well as to the TAGSAM, overflowing the collector, and even jamming the cover until they were carefully shaken out days later.

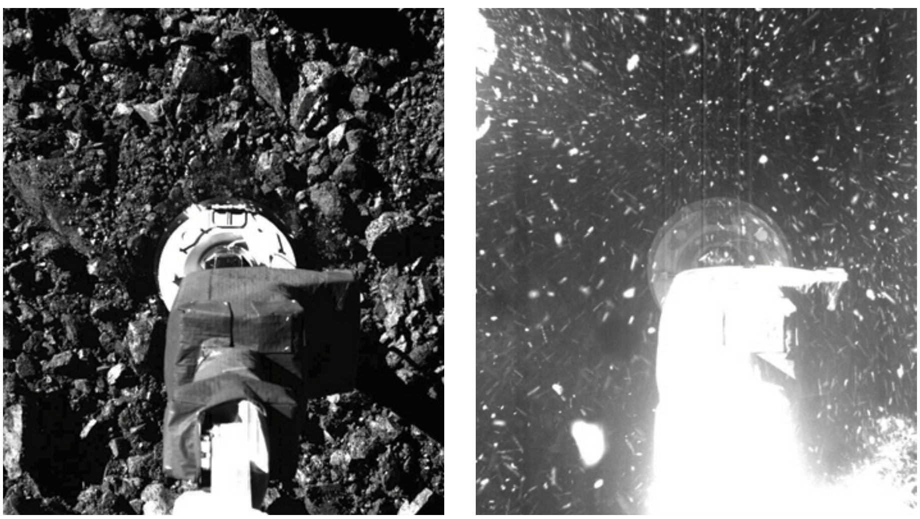
The new analyses show that there's no cohesive force holding together Bennu's outer layers other than the asteroid's feeble gravity. "The particles making up Bennu's exterior are so loosely packed and lightly bound to each other that they act more like a fluid than a solid," Lauretta explains.

Other work, published July 11th in *Nature Astronomy*, explains why Bennu's surface is so rough and boulder-strewn, rather than dust-covered as planetary scientists had expected (*S&T:* July 2019, p. 8). Close examination of other small rubble-pile asteroids, such as 162173 Ryugu, has also shown little dust. Hsiang-Wen Hsu (University of Colorado, Boulder) and colleagues used lab experiments to show that static electricity on these small worlds' surfaces makes dust jump like popcorn, ejecting most small particles from km-size asteroids within a few million years.

Observations of Bennu so far have shown this near-Earth asteroid is a strange world in its own right. Analysis of the 250 grams that OSIRIS-REX is carrying, to be returned to Earth late next year, will reveal further details.

■ **JEFF HECHT**

Watch OSIRIS-REX encounter Bennu at https://is.gd/RubblePile.



◀ The spacecraft extended a robotic arm toward Bennu's surface *(left)*, then stirred up particles for sample collection *(right)*.

MOSAIC OF BENNU: NASA GSFC / UNIVERSITY OF ARIZONA; BEFORE/AFTER IMAGES OF OSIRIS-REX TOUCHDOWN: NASA GSFC

COSMOLOGY

Dark Matter Remains Elusive — for Now

THE FIRST RUN of the most sensitive dark matter detector in the world has come up empty. Sixty days' worth of data-taking by the LUX-ZEPLIN (LZ) experiment failed to show evidence for a type of particle thought to make up dark matter, scientists shared in a July 7th webinar.

Even though dark matter represents 85% of all gravitating matter in the universe, the particles are extremely difficult to catch because they barely interact with "normal" material. One *weakly interacting massive particle (WIMP)* could pass unhindered through 10 million light-years of solid lead before hitting an atomic nucleus, explains LZ spokesperson Hugh Lippincott (University of California, Santa Barbara).

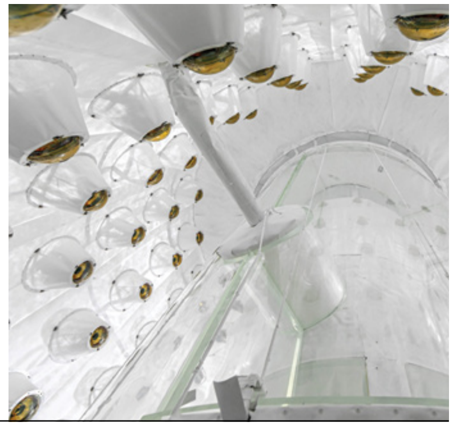
Then again, if these particles are relatively heavyweight then a billion of them should pass through your body every second, so an extremely sensitive detector might succeed in registering rare interactions every now and then.

LZ, located in the Sanford Underground Research Facility (SURF) near Lead, South Dakota, uses seven tons of liquid xenon to look for dark matter. The purified xenon is carefully shielded from all possible sources of background noise, such as cosmic rays and radioactive decay. Almost 500 photomultiplier tubes on the bottom of the inner chamber are on the lookout for the tiny flashes of light that would result should a WIMP crash into a xenon nucleus.

In a paper posted on the LZ website, the collaboration of some 250 researchers from 35 institutes in four countries (U.S., UK, Portugal, and Korea) present their analysis of the first 60-day science run, which commenced late last year. The bottom line: Everything works as expected, but the instrument didn't detect any WIMPs.

Not yet, that is. "We plan to collect about 20 times more data in the coming years," Lippincott said in a press statement, "so we're only getting started. There's a lot of science to do and it's very exciting!"

■ GOVERT SCHILLING



▶ This view looks up into the LZ Outer Detector, which is used to veto radioactivity that can mimic a dark matter signal.

BLACK HOLES

Black Hole Lurks in Nearby Galaxy

ASTRONOMERS HAVE FOUND a dormant stellar-mass black hole around a massive blue star in the Large Magellanic Cloud (LMC), a satellite galaxy of the Milky Way. The black hole seems to have formed without throwing off an accompanying supernova, opening the door to our understanding of *direct collapse* scenarios.

A team led by Tomer Shenar (University of Amsterdam, The Netherlands) trawled through almost 1,000 stars in the LMC's Tarantula Nebula in search of dormant black holes. They found exactly one, known as VFTS 243, by analyzing six years of non-consecutive data from the Very Large Telescope.

Showing that a binary system contains a dormant black hole is notoriously difficult, because the system could contain another dim object (or two) with equivalent mass. In fact, the team behind this discovery is among those known for pouring cold water on the claims of other astronomers (*S&T:* Aug. 2020, p. 8).

The evidence in this case is twofold: First, by measuring the orbital period of the binary pair and the orbital speed of the massive star, Shenar's team concludes that its hidden companion has a mass between 7.2 and 10.1 Suns — black hole territory.

The astronomers also took a spectrum of the system. After carefully removing the light from the massive star, they were left with the spectrum of the star's companion. It shows no features characteristic of ordinary stars, helium stars, or low-mass binaries. Coupled with the object's high mass, the spectrum suggests that this light comes from bits of material falling into a black hole. The results appeared July 18th in *Nature Astronomy.*

There's no sign of the supernova that ought to have accompanied the black hole's birth, though. The near-circular orbit the blue star takes around its invisible companion suggests that when the black hole collapsed, it did so without the "kick" that supernovae typically give collapsed cores.

While most models suggest stars need masses of more than 20 Suns to collapse without a supernova, that scenario remains plausible for this lower-mass black hole.

"If we find more of this type of binary with circular orbits," says Roger Blanford (Stanford University), who was not involved in the research, "then it does suggest that direct collapse is a common way for a heavy star to end its natural life."

■ COLIN STUART

▲ The researchers trawled through nearly 1,000 stars in the Tarantula Nebula, the star-forming region shown here, to find a dormant black hole.

VIEW INSIDE NEW LUX DETECTOR: MATTHEW KAPUST / SANFORD UNDERGROUND RESEARCH FACILITY; TARANTULA NEBULA: ESO / ALMA (ESO / NAOJ / NRAO) / WONG ET AL. / ESO / M.-R. CIONI / VISTA MAGELLANIC CLOUD SURVEY; ACKNOWLEDGMENT: CAMBRIDGE ASTRONOMICAL SURVEY UNIT

BLACK HOLES

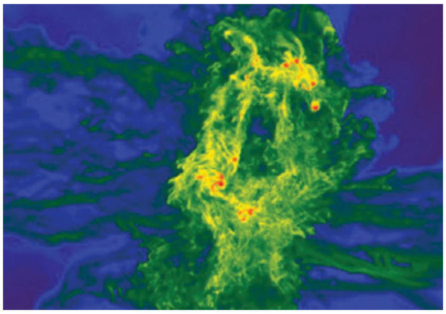
Where Did the First Quasars Come From?

JUST 700 MILLION YEARS after the Big Bang, we already see supermassive black holes with the heft of 1 billion Suns. Now, a team of astronomers is using computer simulations to demonstrate the formation of these dark behemoths.

In their scenario, massive clouds of pristine gas collapse directly into black holes in the early universe. (See page 16 for other options for making "black hole seeds.") The calculations for such massive implosions are delicate, though. What's to prevent the gas cloud from fragmenting and forming smaller stars, as the ones in the modern universe are wont to do?

Previously, astronomers have suggested the ultraviolet emission of nearby newborn stars might have heated the gas, keeping it too warm to fragment. But such specific requirements would have made the process rare.

Now, Muhammad Latif (United Arab Emirates University), Daniel Whalen (University of Portsmouth, UK), and colleagues report in the July 7th *Nature* that intense turbulence might have blocked fragmentation.



▲ Rivers of gas rush into a central, churning sea, in which two massive primordial black holes are forming.

In computer simulations that rebuild the conditions of the universe when it was around 100 million years old, the team followed the growth of a small, frothing sea of matter fed by four torrents of inflowing gas. Within the sea, a clump took shape, and then another. The turbulence of the inrushing gas flows kept the massive clumps from collapsing straightaway into stars. By the end of the simulation's first stage, each clump contained tens of thousands of Suns' worth of mass.

In a separate simulation, the researchers then show that the two clumps would compress into supermassive stars, which would last perhaps 2 million years before collapsing further into black holes of 30,000 and 40,000 solar masses, respectively.

The team estimates that such a confluence of cosmic rivers would have been common enough to explain observations of early quasars.

Priyamvada Natarajan (Yale), who wasn't involved in the study, agrees that the simulation presents a natural pathway for the formation of massive black hole seeds. But she adds that it's not a unique solution; other environments, such as a dense star cluster, could enable direct collapse, too.

■ MONICA YOUNG

DANIEL WHALEN (UNIVERSITY OF PORTSMOUTH, UK)

IN BRIEF

A Burst with a Heartbeat

The discovery of a pulsing fast radio burst (FRB) provides fresh evidence in support of neutron star origins for these brief and mysterious flashes. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope in British Columbia has cataloged several hundred FRBs since it came online, but its most recent FRB sighting, featured in the July 14th *Nature*, is unique. The unusually long flash, which lasted three seconds (much longer than the average burst), contained nine heartbeat-like pulses. The team contends that this strange FRB originates in or around a neutron star. "This signal, with an imprinted periodicity, could be the clue that at least some FRBs are produced by rotating neutron stars," agrees Jens Mahlmann (Princeton), who was not involved in this study. "Their spinning magnetic fields may play an important role for explaining subpopulations of FRBs."

■ ARWEN RIMMER

Booster Impact Found

NASA's Lunar Reconnaissance Orbiter (LRO) has imaged the impact site created by a rocket booster hitting the farside of the Moon on March 4th (*S&T:* June 2022, p. 11). Observers had spotted the object on a Moon-bound trajectory, but the impact itself was of course out of Earth's line of sight. Initial calculations suggested the object was the second stage of the SpaceX Falcon 9 rocket that had launched the Deep Space Climate Observatory mission in 2015. But observers later refined the trajectory and identified the object as a Long March 3C upper stage from China's Chang'e 5 T1 mission, which flew around the Moon in late 2014. To date, China hasn't confirmed the identification. The LRO team found the impact site about 8 kilometers (5 miles) from the JPL predictions, a slight shift that may have been caused by the gentle push of the solar wind. Surprisingly, the image revealed a pair of craters: one to the east 18 meters across superimposed on a 16-meter western crater. Most of the mass from the spent Chang'e 5 T1 booster was expected to be located in the motor end, but the double crater indicates a large mass on both ends. LRO images of Apollo booster impacts show craters of similar sizes, but while some of them are irregular, none are double.

■ DAVID DICKINSON

See the image at https://is.gd/farside.

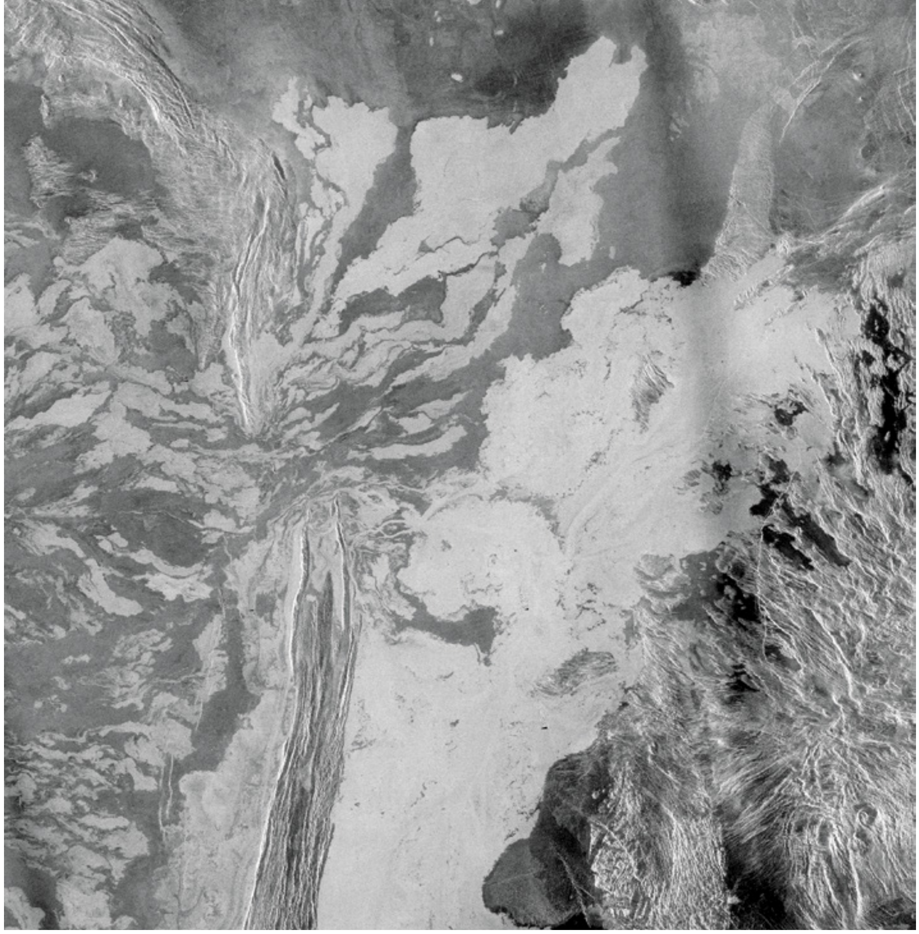
Capstone Cubesat Launches

A NASA CubeSat designed to test a unique lunar orbit is safely in space. The Cislunar Autonomous Positioning System Technology Operations and Navigation Experiment (Capstone) successfully lifted off on a Rocket Lab Electron rocket. Despite an early communications hiccup, the CubeSat was able to separate from the rocket and head toward the Moon on a ballistic lunar transfer orbit. The meandering path has Capstone arriving at the Moon on November 13th, where it will enter a highly inclined and elongated *near-rectilinear halo orbit*. The crewed Lunar Gateway platform of the Artemis mission will eventually use the same orbit: It's stable, requires relatively little fuel for station-keeping, and allows access to the lunar poles for crewed landing missions. Capstone will demonstrate this orbit for six months, passing 1,610 kilometers from the lunar surface over the Moon's north pole, and 70,000 kilometers from the Moon's south pole, once every 6½ days. Capstone will also test autonomous communications with NASA's Lunar Reconnaissance Orbiter. The first launch for the Lunar Gateway is currently scheduled for late 2024.

■ DAVID DICKINSON

Sending Astronauts to Venus

Crazy as it might seem, it's a logical and thrilling prospect.



▲ Imagine astronauts using remote observation to explore Venusian landscapes in real time (here, a Magellan radar image mosaic of the lava-streaked Lada region). It's an electrifying thought.

NASA / JPL

ASTRONAUTS TO VENUS? It sounds like a joke, delusion, or cruel punishment. Yet recently I spent two days at Caltech in a workshop titled "Venus Science Enabled by Human Proximity."

Why would bright and apparently sane people gather to discuss such an outlandish thing? We all know that Venus is an oven, about the last place you'd want to send people. Yet it's the closest planet to Earth, rich with mystery and untapped, priceless knowledge. There are important lessons that we'll never learn about our home planet, and therefore about ourselves, until we deeply explore this neighboring world.

These lessons include the origin and fate of Earth and the uniqueness of our biosphere, as well as the mechanics of climate change on Earth-size, geologically active worlds. We need to know answers not only to satisfy our curiosity but to grow into our role as a planet-changing species.

Comparative planetology of Mars, Earth, and Venus can help. Venus is the least explored of the three, but we now have several robotic spacecraft approved for launch over the next decade that will start to close the gap. We already know that Venus is a complex volcanic world sheathed in variable, chemically rich clouds that could possibly even host some kind of organisms today. Current observations and modeling suggest it's also a vibrantly active planet that for much of its history might have had habitable surface oceans. After the upcoming missions, we will need follow-ons to explore in more depth.

But why would we possibly imagine sending humans? Believe it or not, there are several good reasons.

From orbit we can tell the surface is rich in exotic landscapes, with enticing targets for up-close exploration that would be scientifically important and also captivate the public. With current technology, we can't send rovers; they'd quickly fry. Autonomous aircraft couldn't do the complex, real-time navigation and decision making required. But we could send Remotely Operated Vehicles that float near the surface, escaping to higher altitudes to cool off.

We use ROVs now to investigate Earth's deep oceans, with operators on surface ships using teleoperation. On Venus, ROVs couldn't be driven from Earth; the time delay is too great. But astronauts in orbit or passing through near-Venus space could drive them. These explorers would virtually search through enchanting landscapes while an enthralled public looked over their shoulders, safely wandering Venus with their own VR devices.

Human missions are costly, of course. How could we convince NASA or other agencies to make this a priority? Such a mission actually may fit very well into current plans for a Moon-to-Mars architecture. Many optimal Mars trajectories include a flyby of Venus for a gravitational boost to or from Mars.

Then again, maybe a trip straight to Venus is warranted: There's a lot of concern today about the unknown health risks of multi-year, deep-space travel, and a shorter trip to Venus might be a valuable first step to ensure that we can safely send astronauts to other solar system destinations.

So, don't worry, we're not talking about cooking anyone. In fact, keeping humans alive while engaging in breathtaking exploration and crucial science is very much the point. Some of us are getting quite excited about the possibility of making it happen.

■ **DAVID GRINSPOON** is author of *Venus Revealed: A New Look Below the Clouds of Our Mysterious Twin Planet.*

The first data to come down from the James Webb Space Telescope demonstrate unprecedented capabilities.

Since the idea of the James Webb Space Telescope (JWST) took shape around the turn of this century, the mission has had its share of naysayers. They've had their reasons: years of delays and a ballooning budget, its origami-like design, and even after deployment, an unexpectedly large micrometeoroid strike on one of its mirrors.

But the team has persisted, and now we are reaping the rewards. The testing JWST underwent during its commissioning shows that all has gone to plan, and then some. The optics are better aligned than expected, the stray light less, the images sharper — all of which mean that the telescope can go deeper faster in almost every observation. The observatory has even been fuel-efficient, with enough propellant left for at least 20 years of operations. While the better-than-hoped-for performance became apparent in commissioning, it really shone through when the mission team released the first science images.

A Long Time Ago in a Galaxy Far, Far Away

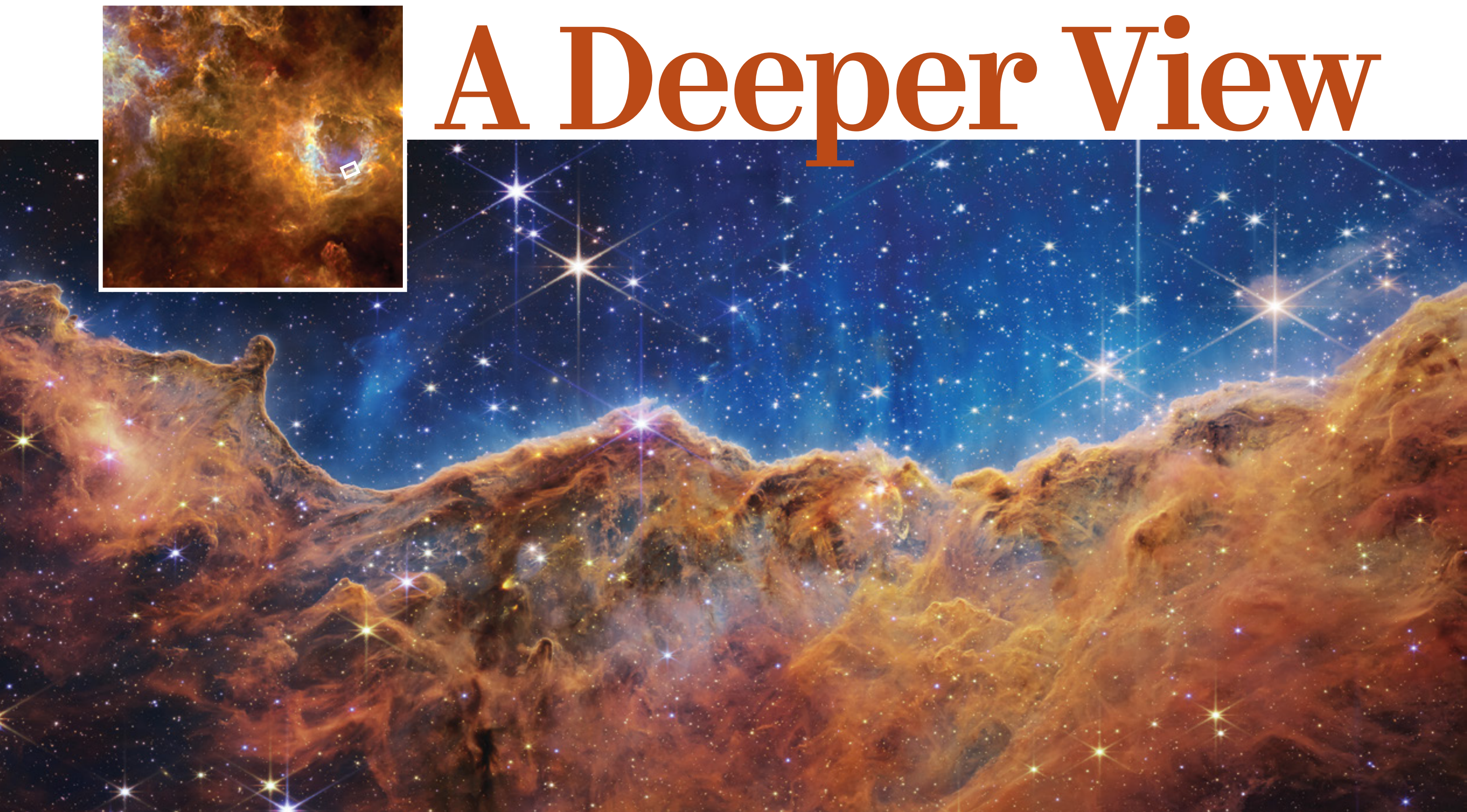
Among its most impressive qualities, JWST is a time machine. The images it takes go deep into space and thus far back in time to the infant universe.

When we look at the Sun (with proper filters), we see it as it was 8 minutes ago — that's how long its light took to travel to Earth. Likewise, light from the Andromeda Galaxy was emitted 2.5 million years ago. As light travels through the expanding universe, its wavelength stretches, too, becoming redder. The Hubble Space Telescope, which explores visible and ultraviolet light, has revealed young galaxies and even a faraway star (*S&T:* Aug. 2022, p. 11), but its reach is limited. With its sharp view at longer, infrared wavelengths, JWST offers us our best hope of seeing the very first galaxies only a couple hundred million years after the Big Bang.

As the observatory kicked off science operations, it was already delivering on that promise. When NASA released its image of the massive galaxy cluster SMACS 0723, the team pointed out several galaxies from up to 13.1 billion years ago — that is, in a universe just 700 million years old.

And these are still early days: Multiple teams are already claiming the independent discovery of even more distant

A Deeper View



COSMIC CLIFFS This image shows the edge of a star-blown bubble (NGC 3324). The newborn stars at top emit intense ultraviolet light and shed particle winds, both of which erode the heights of the surrounding gas-and-dust cloud. The tallest dusty peaks are 7 light-years high, and the white "steam" rising off the range is actually ionized gas. The full bubble is shown for context (inset), as imaged by ESA's Herschel Space Observatory in 2012 at far-infrared wavelengths; the white box in the inset shows the field of view of the JWST image.

▲ **GALAXIES GALORE** Hold a grain of sand at arm's length: That's the breadth of this tiny sliver of sky, yet it holds thousands of galaxies, many never seen before. The focus of the image is galaxy cluster SMACS 0723, whose primary constituents are the white foreground galaxies. Background galaxies appear red and yellow. The cluster's heft gravitationally lenses the background galaxies, magnifying them and distorting their shapes. The image is a composite of four infrared wavebands, or "colors," represented here as visible colors for us to see.

COSMIC CLIFFS: NASA / ESA / CSA / STSCI; LARGER FIELD OF VIEW FOR CONTEXT: JWST: NASA / ESA / CSA / STSCI; HERSCHEL: ESA / PACS / SPIRE / THOMAS PREIBISCH, UNIVERSITÄTS-STERNWARTE MÜNCHEN, LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN, GERMANY; MATT POVICH (CALIFORNIA POLYTECHNIC STATE UNIVERSITY); GALAXY CLUSTER: NASA / ESA / CSA / STSCI

galaxies in the field, going back as early as 200 million years after the Big Bang. (These studies are on the arXiv preprint server but as of press time haven't yet undergone peer review.) Astronomers didn't necessarily expect early galaxies to be quite as abundant, massive, and bright as they appear to be, so the discoveries may put our theoretical ideas about galaxy formation to the test.

"We're getting as close as many scientists thought the first galaxies are," says Thomas Zurbuchen (NASA). "So, I believe we're going to get awfully close, if not really getting to the first ones."

The Last Gasps of a Dying Star

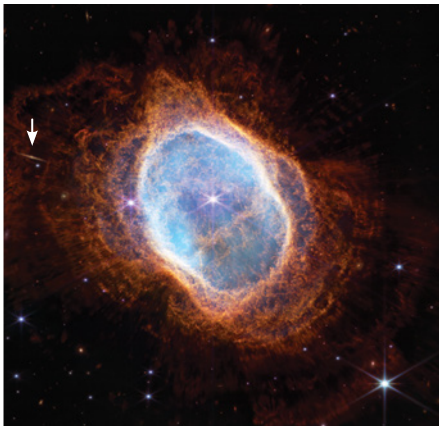
Planetary nebulae, the illuminated clouds blown out by stars collapsing into white dwarfs, have long mystified astronomers with their dazzling variety (*S&T:* Nov. 2014, p. 20). One of these celestial jewels is the Southern Ring Nebula (also called NGC 3132 or the Eight-Burst Nebula) in Vela. It's actually a biconical nebula, its shape like two bowls joined at their bottoms. However, we are viewing the bowls face on, which gives the nebula the appearance of a single ring around the center (which is where the two bowls meet).

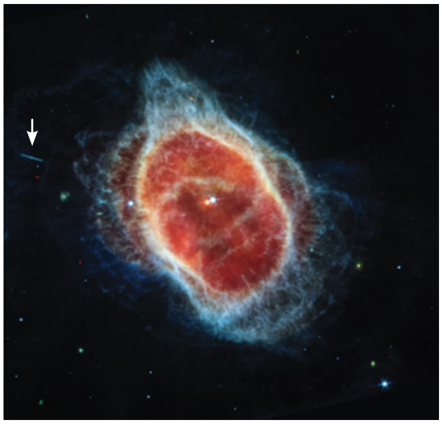
Doppelgängers

A key signature of a JWST image is the six primary diffraction spikes on bright stars, due to the hexagonal-shaped mirrors — Hubble images have only four. Another diffraction pattern, from the struts holding the secondary mirror in place, creates a fainter horizontal bar on bright stars.

Like many such nebulae, the Southern Ring's beauty originates in the pair of stars at its core: a bright star and a dimmer white dwarf. The dwarf emerges at mid-infrared wavelengths because of the dust that still surrounds it. While near-infrared light pierces dust, the grains themselves glow warmly at the longer, mid-infrared wavelengths. Despite its dusty shroud, the hot white dwarf lights up the nebula's center and, together with its stellar companion, stirs up the gases there.

The scene also sheds light on the birth of complex molecules in interstellar space. As the dying star gave in to gravity, it pulsed and sent out layer after layer of gas. The shed plasma cooled as it expanded, enabling grains of dust to form within it. These dusty shells dominate the mid-infrared image.





◀ **LAST GASPS** These near- and mid-infrared (top and bottom, respectively) images reveal different aspects of the Southern Ring Nebula. The central white dwarf (dimmer central star at bottom) has shed its outer envelope in a series of shuddering sighs. An edge-on galaxy (arrow) peeks through the nebula's gaseous shells.

Deep Dive into a Planet's Atmosphere

Perhaps underappreciated among the release of big, beautiful images was the spectrum of WASP-96b. This hot *super-puff* — half Jupiter's mass but still equivalent to Jupiter in size — whips around its star every 3.4 days. JWST's near-infrared *transmission spectrum* shows starlight filtered through the sliver of atmosphere visible when the planet passed in front of its star.

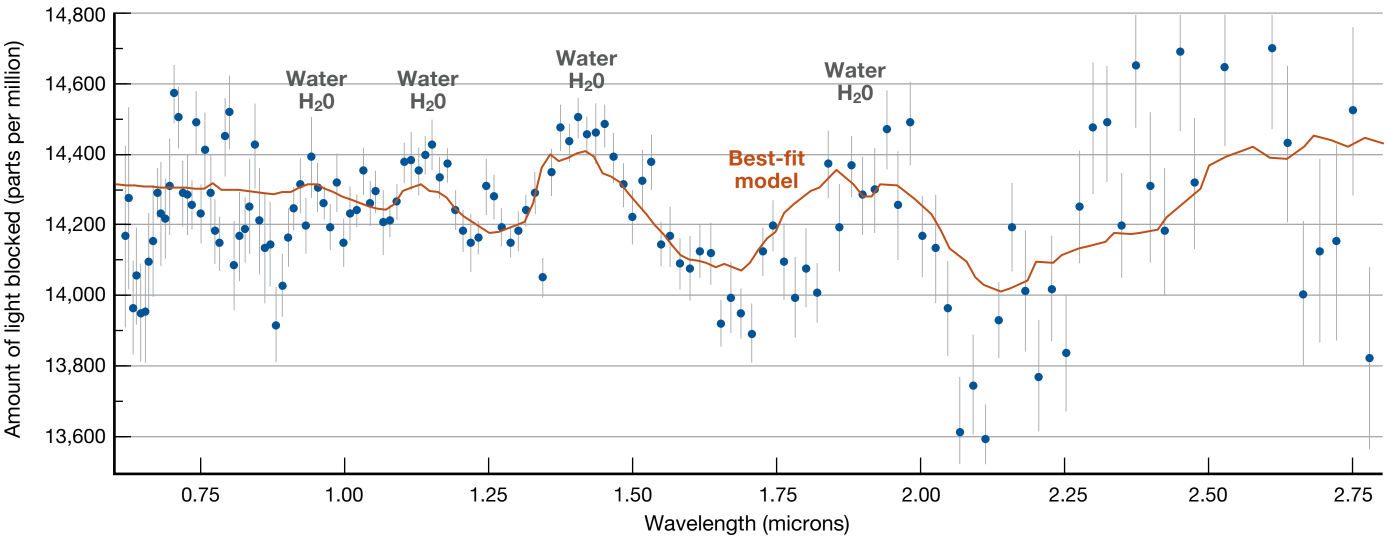
The spectrum acts as an encoded message, with bumps (absorption bands) that translate to elements and molecules present in the atmosphere. And with JWST specifically equipped for exoplanet spectroscopy, it conveys this message with unprecedented detail, as it will for many other worlds. In the case of WASP-96b, the spectrum reveals water vapor on a hot gas giant.

The presence of the molecule isn't actually surprising; astronomers expect to see water vapor in hot planet atmospheres. But while previous studies had concluded that this world is cloudless, JWST's higher-quality spectrum shows it's not: Water vapor features are weaker than expected, indicating that clouds *are* present and hiding some of the vapor-filled atmosphere from view. The slight downward slope toward shorter wavelengths could come from haze, too; firm conclusions await a full analysis.

Cosmic Cliffs

JWST's sharp infrared view also has pierced dense dust to reveal protostars in the cloud surrounding the stellar nursery NGC 3324, 7,600 light-years away in Carina.

Newborn stars populate the top of the image, their radiation and wind blowing out a bubble within their natal cloud.



▲ **HOT WATER** This spectrum captures absorption from water vapor in the atmosphere of the "hot Saturn" WASP-96b. Spanning red light (600 nm) to infrared light (2800 nm) in such a spectrum has never been done before in a single shot. The *y*-axis appears reversed (with absorption bands shown as peaks) because the star's spectrum must be subtracted from the combined spectrum to see the light that the planet has blocked. In effect, as the planet crosses its star, it appears larger in those wavelengths at which molecules in its atmosphere are absorbing the host star's light.

SOUTHERN RING: NASA / ESA / CSA / STSCI (2); EXOPLANET SPECTRUM: GREGG DINDERMAN / S&T; SOURCE: K. PONTOPPIDAN ET AL. / NASA / ESA / CSA / STSCI

STEPHAN'S QUINTET Four of these five galaxies in Pegasus are close enough to interact gravitationally; the leftmost galaxy is actually in the foreground. Infrared wavelengths showcase these interactions, which have pulled out sweeps of gas, dust, and stars (white). The central galaxy's infall has even raised a giant shock wave of hot hydrogen gas (red and gold). Barely visible diffraction spikes emanate from the brilliant center of the topmost galaxy, NGC 7319, indicating activity around the black hole in its core.

That push instigates a new round of star formation in the dusty clouds along the bubble's edges, where stars are still in the process of coming together. At the same time, as the cloud disintegrates, star formation is coming to a halt. The image thus captures a delicate balancing act.

The youngest of the forming stars, still hosting planet-forming disks, appear as red dots in the darkest parts of the image. (In fact, JWST is finding that some of these that were thought to be singletons are actually multiples.) Look closely, and you may spot the golden signatures of the jets emitted from some of these nascent stars.

Stephan's Quintet

Of all the images JWST released in July, this one's target was the most familiar to amateur astronomers. With an infrared view, though, details never seen before become visible.

Four galaxies in this group are swiping and clashing with one another, gravitationally speaking. The infrared image shows the dust, gas, and stars flung out in these interactions as sweeping white arches. Shock waves, too, are visible as the central galaxy, NGC 7318B, crashes through the group. (The galaxy at left, 250 million light-years closer to Earth, remains unaffected by the drama.)

Galactic side-swipes and mergers can trigger bursts of star formation as well as send gas spiraling in to feed supermassive black holes at galactic centers, so that the stars and the dark core grow together. The topmost galaxy, NGC 7319, hosts such a feeding black hole, as revealed by JWST's *integral field units*, combined camera-spectrographs that take images and spectra simultaneously.

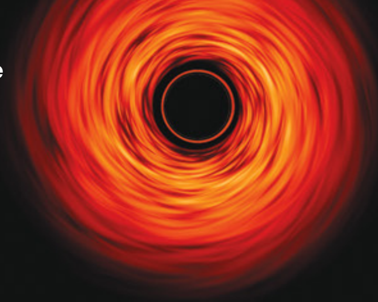
The Future Now

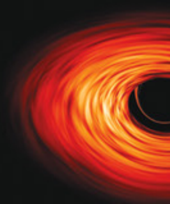
As this article goes to press, JWST has already taken additional stunning galaxy images and exoplanet spectra. It can do in hours what Hubble does in weeks, and we'll be hard-pressed to keep up! The infrared revolution is only beginning.

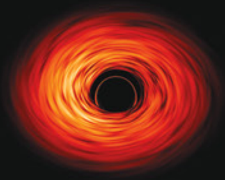
■ MONICA YOUNG is *Sky & Telescope*'s news editor.

NASA / ESA / CSA / STSCI

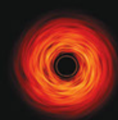
THE DARK HUNT by Jenny Greene







The Search for Middleweight Black



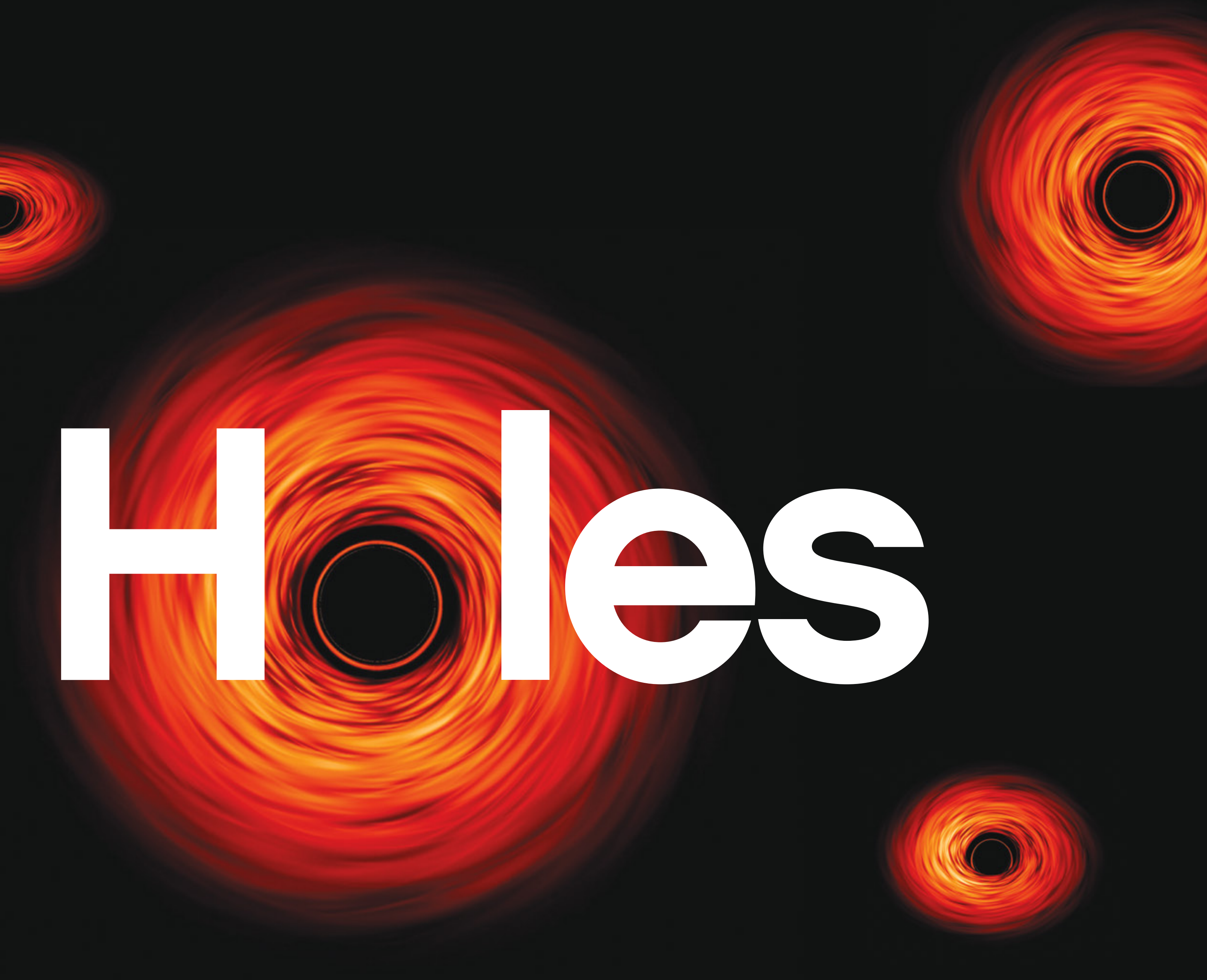
Elusive intermediate-mass black holes hold the key to understanding their supermassive siblings.

I became an astronomer because of black holes.

Over almost all of history, astronomers have gathered information about the universe from light. Yet black holes are objects so dense that not even light can escape their gravitational pull. They come in a wide variety of sizes, each one packing a mind-boggling amount of mass into an extremely tight space: If our Sun were shrunk down to become a black hole, for example, it would have the same width as Manhattan.

You would think, if light cannot escape a black hole, that black holes might remain nothing more than thought

NASA GODDARD SPACE FLIGHT CENTER / JEREMY SCHNITTMAN



Holes

experiments. Yet astronomers keep finding clever ways to uncover their existence. I wanted to be clever like that, too, so I became a black hole hunter.

By following both the orbits of stars and the glow of hot gas swirling around invisible objects, we have found evidence of two families of black holes. On the "small" end we have *stellar-mass* black holes, the collapsed cores of massive stars that went supernova; these hold within themselves the equivalent of a few to even a few dozen Suns' worth of mass. On the large end, we have *supermassive* black holes, monsters of millions to billions of Suns that are found in the centers of galaxies. While we don't know yet how these monsters formed, we have some ideas.

The mystery that captivates me is whether there are any black holes between the stellar-mass and the supermassive ones — the realm of the *intermediate-mass* black hole. These middleweights are really defined by our ignorance: Everything between stellar-mass and supermassive black holes qualifies as an intermediate-mass black hole, a range that spans hundreds to hundreds of thousands of Suns. After decades of hunting, we are only just starting to find black holes to fill this huge gulf in our knowledge. We're also just starting to ask the exciting questions about how midweight black holes form and evolve.

This search is inspired by more than just idle curiosity. The thing is, black holes with billions of solar masses did not pop into existence fully grown: They must have formed from smaller black holes, and the relics of their formation should still be out there today. Finding these "seeds," measuring their masses, and seeing where they live, will give us important clues about the formation of the largest black holes in the cosmos.

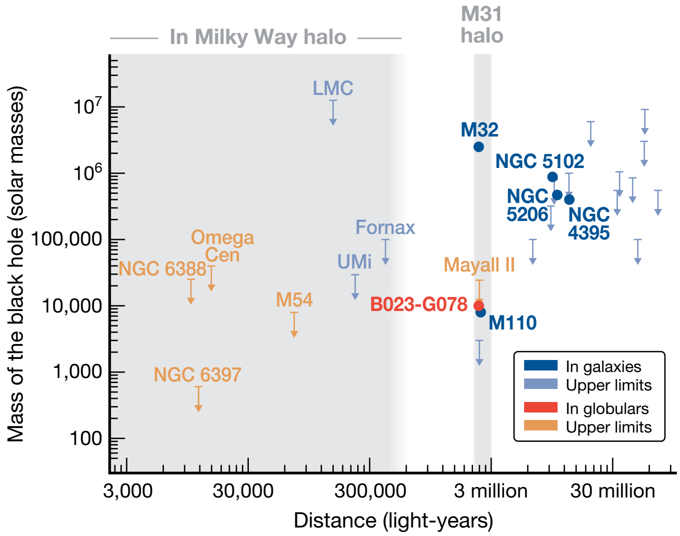
The Search So Far

Compared with supermassive black holes, intermediate-mass black holes are much harder to find. The reason why comes down to gravity.

Take our best-studied supermassive black hole, the one at the center of the Milky Way. We can see individual stars whipping around a nearly invisible object at thousands of kilometers per second, and we know that there has to be something really dense right at the center of the galaxy that is causing the stars to move so fast. Now imagine moving that black hole and all its neighboring stars 500 times farther away from us, a distance that encompasses many nearby galaxies. We wouldn't be able to see the individual stars anymore; all their motions blur into averages. But using those blurred motions, we could still find the black hole.

If, however, we replace that black hole with one that's a tenth the heft of the Milky Way's (in other words, at the top end of the middleweight range), then its influence on the stars extends to a much smaller region of the galaxy. For the nearest low-mass galaxies, that region is just a few tenths of an arcsecond across from our vantage point — the full Moon is several thousand times wider in the sky. We need to peer all the way into the very center of the galaxy to measure the black hole's gravitational impact.

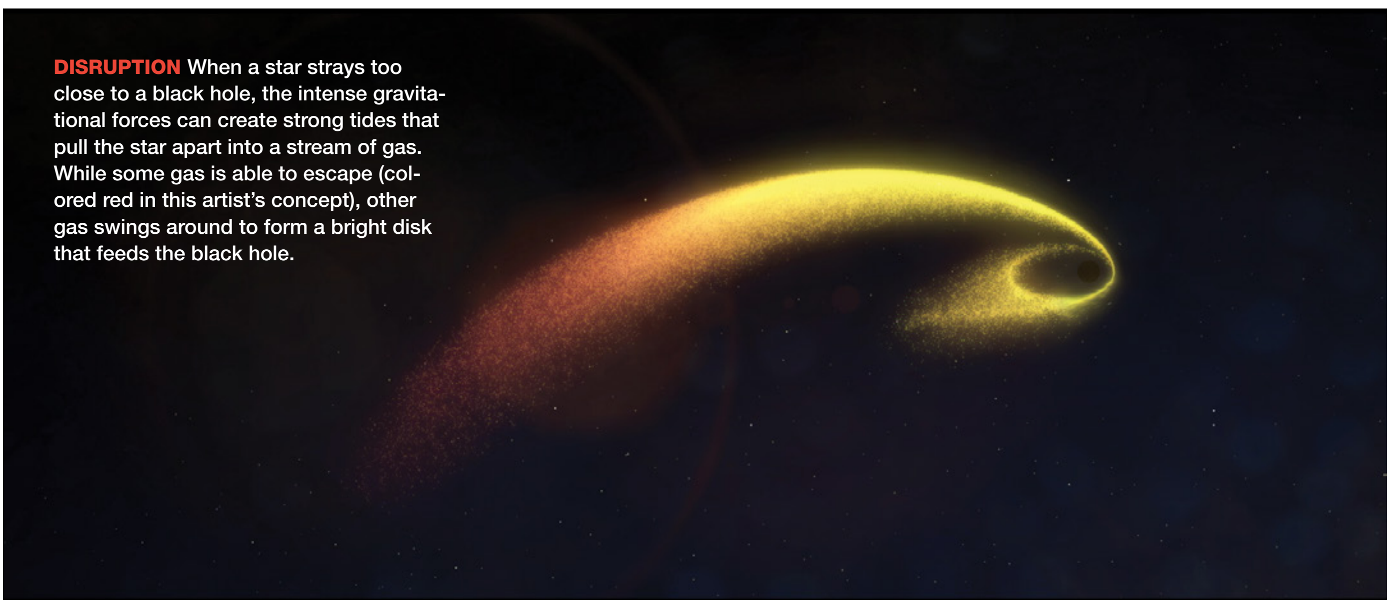
Still, our best information comes from using stars (or gas) in orbit around black holes, as in the Milky Way. Because we need to see with such sharp focus, astronomers have only been able to peer into the centers of 10 nearby low-mass galaxies to make out the blurred motions of material whizzing around the black hole. The observers came up with five black holes, each of at least 100,000 Suns. Thus, at least half of these little galaxies contain black holes, and black holes of these sizes are probably pretty common. One of the most exciting prospects for the coming decade is to point extremely large ground-based telescopes at the centers of even smaller galaxies, to see if we can find and "weigh" their black holes in the same way.



▲ **MASS FROM MOTIONS** By measuring the gas or stars circling in the centers of galaxies (blue) or globular clusters (orange), astronomers have measured or found limits for several intermediate-mass black holes.

Another way we can search for black holes is by looking for the glow of gas around them. Most black holes are not "active," in the sense that they have no nearby gas clouds to snack on. But when they *are* active, we can identify the black hole by the light coming from gas as it falls in and heats up. Finding this glow is harder for intermediate-mass black holes, because they can't hold on to as much gas as bigger ones can, and the signature glow is thus not as luminous.

Nevertheless, we have found hundreds of active intermediate-mass black hole candidates eating gas in the centers of dwarf galaxies, which have 1% to 10% as much mass as the Milky Way. We suspect these active black holes contain hundreds of thousands of Suns' worth of mass. The smallest



DISRUPTION When a star strays too close to a black hole, the intense gravitational forces can create strong tides that pull the star apart into a stream of gas. While some gas is able to escape (colored red in this artist's concept), other gas swings around to form a bright disk that feeds the black hole.

GRAPH: J. GREENE; TIDAL DISRUPTION EVENT: NASA GODDARD SPACE FLIGHT CENTER / CHRIS SMITH (USRA / GESTAR) found so far using this technique is the object in the galaxy RGG 118. It holds only 50,000 Suns.

Middleweight black holes can also turn up outside galactic centers. Supermassive black holes sink quickly to a galaxy's core, because they build up a wake of stars behind them that drags them in; intermediate-mass black holes, on the other hand, are so light that they might never make it all the way in. Their galaxy might even be eaten by a bigger galaxy, and as the little galaxy is torn apart and its contents spread throughout the big galaxy's halo, the black hole could be left to wander far out in the halo forever.

It can be hard to find gas to munch on in a galaxy's far-flung reaches, so black holes in the outskirts are faint and hard to find. It can also be tricky to be sure that we have found a black hole associated with the galaxy, and not a much more massive and distant black hole peeking through the galaxy's outskirts. We have some tantalizing evidence for active intermediate-mass black holes snacking outside of galactic centers, and work is ongoing to verify these exciting potential wanderers.

Another way a black hole can be fed is if a star comes too close and is ripped apart in a *tidal disruption event.* In that case, a previously quiet black hole suddenly brightens over weeks or months. There are a handful of possible midweight black holes discovered via likely TDEs, including some outside of galactic centers. Astronomers still debate the nature of these signals, though, and we don't yet have robust ways to estimate the mass of a black hole lit up by a TDE.

One final type of object that astronomers once suspected was the signpost of feeding middleweight black holes are *ultra-luminous X-ray sources* (ULXs). They're called ultra-luminous because they produce more X-rays than we thought possible for neutron stars or stellar-mass black holes. ULXs are common in star-forming galaxies, where vigorous star formation creates the conditions for as many as a few ULXs per galaxy. That may not sound like much, but if all of those ULXs were middleweight black holes, that would be many more than we have found through any other means.

We have now realized, however, that most ULXs are likely powered by neutron stars, because at least some ULXs pulse the way spinning neutron stars do. The extreme emission we see may come from a narrow region that's pointing towards us, making these neutron stars appear more powerful than they truly are.

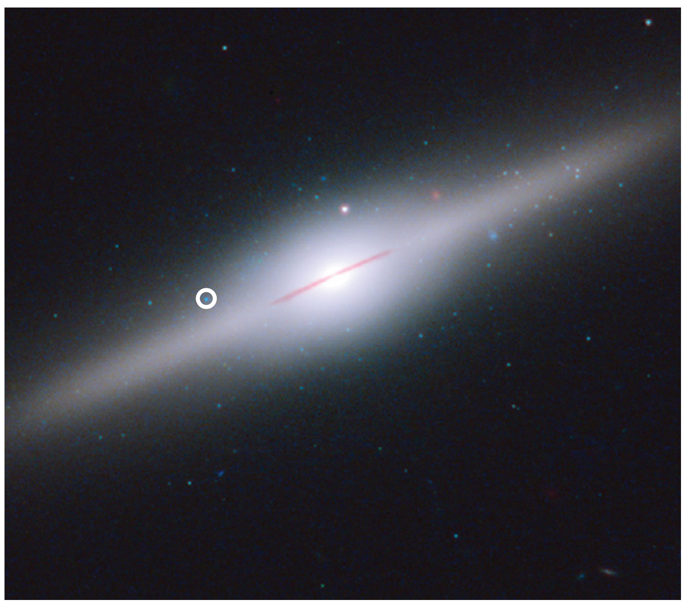
There is one important exception, an object that's even more powerful than most ULXs: the *hyper*luminous X-ray source number 1, or HLX1. HLX1 resides outside the center of an edge-on disk galaxy called ESO 243–49, and it presents probably the best evidence for an intermediate-mass black hole candidate. Signatures in the energy distribution of the source's X-rays suggest that they're escaping from the gravity of a 20,000-solar-mass black hole. It's still a mystery why we haven't yet found other sources like HLX1.

For much smaller black holes, of hundreds or thousands of solar masses, studying the light of stars and hot gas hasn't turned up any definite objects. But even quiet, middling-

▼ **GAS-GUZZLING MIDDLEWEIGHT** A three-color Hubble composite shows the dwarf galaxy RGG 118, 340 million light-years away in Serpens. At its core is the smallest black hole known to reside in a galactic center; it has the heft of 50,000 Suns. Evidence for the black hole's existence comes from the gas swirling around it. The gas heats up and emits tell-tale visible signatures and X-rays before falling into the maw.

▼ **ULTRALUMINOUS** An edge-on galaxy is home to a 20,000-solar-mass black hole drifting above the galactic plane, known as HLX1 (circled). This is the best intermediate-mass black hole candidate among ultraluminous X-ray sources. The black hole, the gas around it, and the star cluster around it may all once have been part of a smaller galaxy that was devoured by the larger one.

RGG 118: NASA / ESA / BALDASSARE ET AL. / *ASTROPHYSICAL JOURNAL* 2017; HLX1: NASA / ESA / S. FARRELL (UNIVERSITY OF SYDNEY, AUSTRALIA AND UNIVERSITY OF LEICESTER, UK)



mass black holes may reveal themselves when they collide and release gravitational waves. The event GW190521, for example, most likely was the merger of black holes with 85 and 66 solar masses, respectively, creating a behemoth among stellar-mass black holes. Our stellar-evolution theories said that these two objects shouldn't exist, because we expected that stars couldn't create black holes between 50 and 120 Suns. But gravitational-wave observations have turned up a handful of black holes in this "mass gap." They might have formed in the mergers of a previous generation of smaller objects (*S&T:* June 2022, p. 12).

In summary, we are confident that black holes extend down to 100,000 solar masses, and that such objects are common in small galaxies. We are also just starting to find black holes with masses of hundreds of Suns. But while at least one 20,000-Sun black hole has been found in HLX1, we have no knowledge yet of black holes of thousands of Suns. What's more, while it's now clear that black holes do inhabit the intermediate-mass range, we don't yet understand the formation paths of all the ones we've found.

We are entering an era of unprecedented access to black holes across the cosmos.

Supermassive Origins

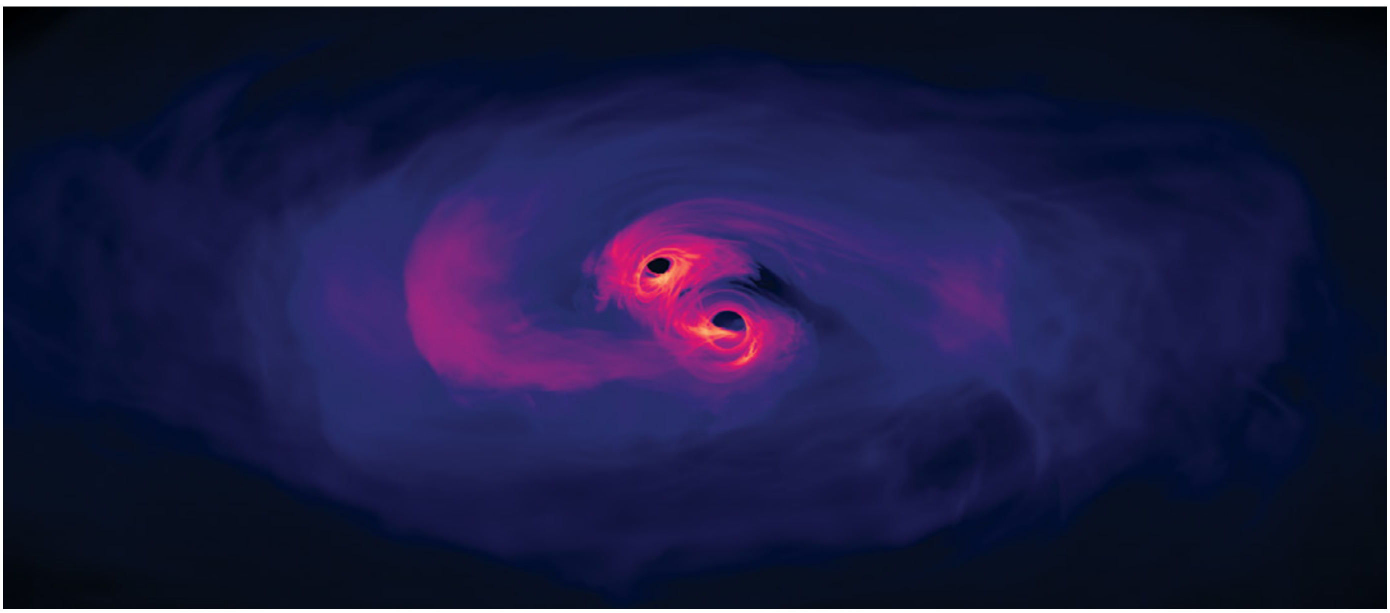
Being a black hole hunter means more than just tallying up discoveries. We want to understand how black holes form and when. We search for midweight objects in the universe today, hoping that they will give us a sneak peek into the conditions in the early universe. That's when, somehow or other, the heavyweights of today were bulking up.

Our discoveries so far suggest that the seeds of today's gigantic black holes formed at masses of less than 100,000 Suns — and probably lower than 20,000 Suns, given the existence of HLX1. Seeds of roughly 100 solar masses could have come from the collapsed cores of the universe's first stars. These stars were humongous by modern standards, and only they would have been large enough to make seeds of this heft. For slightly larger seeds, under the right conditions a cascade of collisions between smaller black holes in the center of dense star clusters could have made 1,000-solar-mass seeds. Both of these kinds of seeds would need to grow fast to become the black holes containing billions of solar masses that we see only 650 million years after the Big Bang.

A third option is that gas clouds could have collapsed directly into more massive black holes of 10,000 to 1 million Suns, without forming a star first. The process requires goldilocks conditions, though; the gas has to be not too hot and not too cold (*S&T:* Jan 2017, p. 24). Such heavy seeds, forming only early in the universe, would likely be pretty rare.

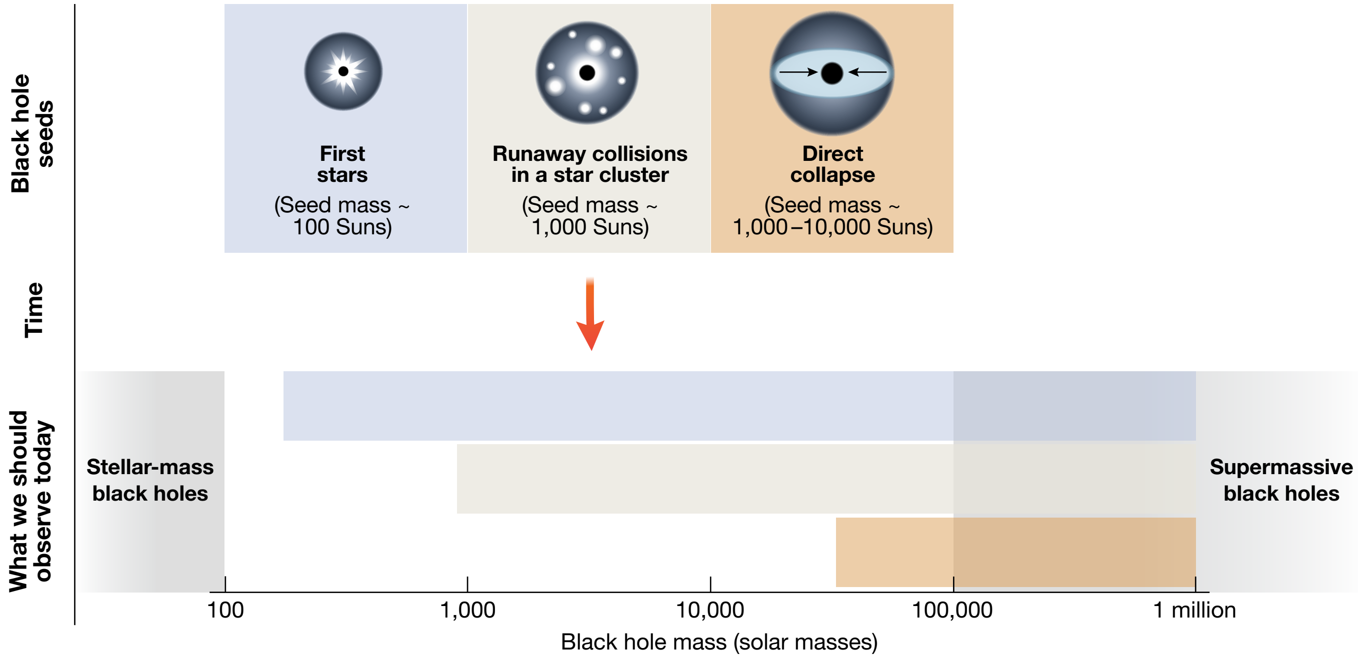
If runaway collisions happen, then we should be able to observe such mergers in the modern universe. At the end of 2022, gravitational-wave detectors will once again be scanning the sky for black hole mergers, this time with even greater sensitivity, and we may find more massive black holes on the start of a runaway trip to supermassive status.

But gravitational-wave detections like GW190521 add an interesting wrinkle: We don't know how these pairs of black holes came together in the first place, or whether they inhabit



NASA GODDARD SPACE FLIGHT CENTER

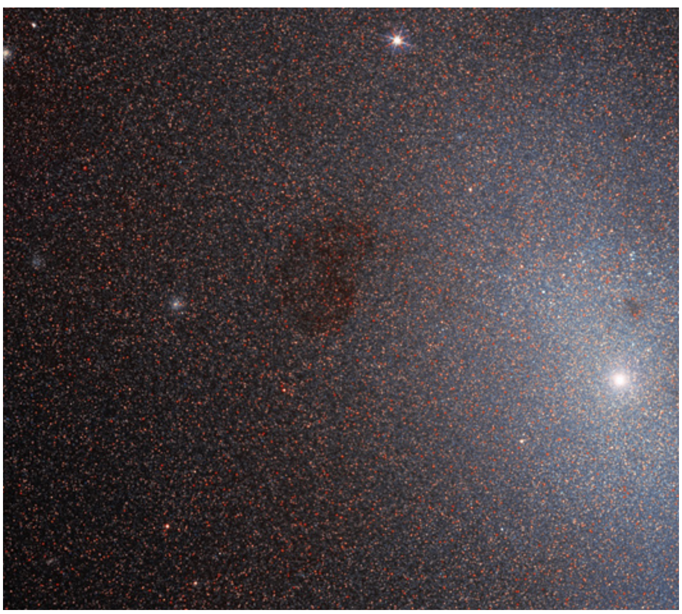
▲ **GRAVITATIONAL CHIRP** Massive black holes reveal themselves when they merge and release gravitational waves in the process. While most such mergers have involved stellar-mass black holes, a few have resulted in an object of more than 100 Suns, making the smallest of the intermediate-mass black holes.



▲ **BLACK HOLE SEEDS** The masses of intermediate-mass black holes we see in the universe today depend on their origin stories. It's possible all scenarios are in play; searches for the lower end of the intermediate-mass range will help decide which scenario dominates.

environments in which they could keep merging and growing. Are they budding supermassive black holes, or will they top out at around 100 solar masses?

Another way to look at runaway collisions is by finding more black holes in star clusters. Tidal disruption events in these clusters — and outside of galactic nuclei — should pop up when the Legacy Survey of Space and Time begins at the Vera C. Rubin Observatory in the coming years.



▲ **DARK CENTER** Stars and gas whirling in the center of M110, a dwarf satellite of the Andromeda Galaxy, revealed a black hole of less than 100,000 Suns. Future telescopes will measure even smaller black holes.

The other two scenarios are harder to observe, since they would've happened soon after the Big Bang. One way to distinguish between them is by trying to find more smaller-mass objects like HLX1 and RGG 118. If directly collapsing gas clouds made black hole seeds, then we don't expect to find many black holes smaller than HLX1. If seeds formed from the death of massive stars, however, we expect to find many. Next-generation "extremely large" telescopes will be perfect for this search, measuring orbits to weigh galactic centers.

Maybe the intermediate-mass range is populated in many ways, both by relics of the supermassive seeding process and by the upper end of stellar-mass mergers. Or maybe these processes are inextricably linked in ways we don't yet understand. We need new kinds of data to address these questions: Instead of focusing on the relics of seed black holes in the universe today, we need to detect these seeds as they form.

Luckily, we are entering an era of unprecedented access to black holes across the cosmos. With the successful start of the James Webb Space Telescope operations (see page 12), we may be on the brink of taking direct baby pictures of growing supermassive black holes just hundreds of millions of years after the Big Bang. And in a decade, the space-based Laser Interferometer Space Antenna will start listening for the gravitational waves ringing from black holes of thousands to millions of solar masses as they merge throughout the universe. Then we will know exactly how massive the seeds of the first leviathans were, and when and how they formed.

■ **JENNY GREENE** is a professor of astrophysical sciences at Princeton University and faculty director of the Princeton Prison Teaching Initiative.

Cosmic Cataclysm in South America

Evidence of an ancient aerial explosion points to an ongoing danger.

One of the driest places on Earth, the Atacama Desert in northern Chile, preserves evidence of an ancient catastrophe. More than a decade ago, geologist Nicolás Blanco (National Geology and Mining Service, Chile) and his colleagues were mapping the geology of a vast desert plateau nestled between the foothills of the Andes to the east and the Chilean Coastal Range to the west when they came across six areas littered with dark green and black glass. The glass formed chunks of folded and twisted material, as well as flat slabs measuring up to tens of centimeters in width.

Confined to a 75-kilometer-long swath roughly aligned in a north-south direction near the little town of Pica, these fields of glass posed a real puzzle. There are no nearby volcanoes or traces of industrial activity in this arid wasteland. Nor are there well-defined craters in the region.

Blanco, his associate Andrew Tomlinson, and others suggested in a 2012 paper that the fields of glass might be the result of the intense heat generated when a bolide exploded close to the surface. By 2016, a geology student from Santiago named Sebastián Perroud and his advisor, meteorite researcher Millarca Valenzuela (at that time at the Pontifical Catholic University of Chile), had performed additional field-

▲ **ANCIENT REMAINS** This aerial view of one of the field sites shows several clusters of glasses strewn across the treeless surface, with the Andes Mountains in the distance. Two people (arrows) provide a sense of scale.

◀ **EVIDENCE OF A CALAMITY** Slabs and twisted masses of glass lie scattered over the Atacama Desert in northern Chile. Intense heat and winds generated by an incoming bolide instantly fused the desert soil. The largest piece (center) is about 40 cm (16 inches) across.

AERIAL VIEW OF THE PICA GLASSES: R. SCOTT HARRIS, P. H. SCHULTZ ET AL. / *GEOLOGY* 2021; GROUND VIEW OF GLASSES: P. H. SCHULTZ work with the help of two French researchers. Although they did not find evidence for an airburst, some of them thought that this remained a possible explanation.

One year later, however, the French investigators and their colleagues concluded that the glasses must have formed by another process. Their laboratory studies failed to detect chemical traces of meteoritic material or evidence of shock metamorphism, the distinctive transformation of rocks compressed by hypervelocity impacts. In addition, radiocarbon dating of organic material in the soils near and under the glasses, as well as variations in the orientation and intensity of the terrestrial magnetic field imprinted in the glass when it cooled, suggested that there were multiple episodes of heating at different times. They proposed that the glasses were instead formed by intense fires, fed by ancient grasses and organic-rich soils during extreme dry spells. To support this hypothesis, they cited a paper published during the 1960s that described glass that had formed under 325 tons of burning hay bales. Ranging in thickness from millimeters to a few centimeters, the fused mixtures of hay and glass looked like hairy pads.

Grassfires had also once been proposed to account for glasses buried at different levels in Argentina's Pampas region — glasses that work by me and my colleagues showed are in fact the result of at least eight different impacts during the last 10 million years. Due to our expertise in impacts, the Chilean geologists invited me and one of my former students, Scott Harris (Fernbank Science Center), to come to Chile and work with them to see what we could together make of the glasses. This is the story of that journey of discovery.

Boots on the Ground

Sebastián Perroud took us to places so remote and desolate that it was easy to imagine that we had landed on Mars. Cyclic wet periods had fed streams from the Andes that deposited silts on the parched desert pavement, covering its thick gypsum dust. At one point the wheels of our truck sank into the soft sediment, and we had to wedge slabs of the very glass we'd come to study under the tires (with a pang of regret!) in order to extricate ourselves. Without them we would have been stuck for a long time, since there wasn't another soul for many kilometers and no cellphone service.

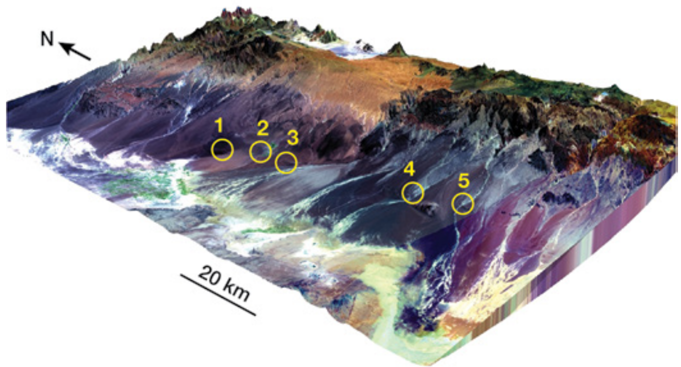
We were struck by the sheer amount of glass. Many slabs with shiny upper surfaces appeared to have formed and cooled in place. But there were other glassy masses, weighing over a kilogram and measuring more than a meter across, that had been violently tossed around while they were still molten. Twisted, sheared, or folded, they looked like kneaded dough, sometimes with soil trapped between the folds. When these semi-molten blobs slammed into the ground, whatever was on the surface made impressions in the glass like a seal in hot wax. In a few instances these impressions included casts of grass and twigs.

This was clearly not the work of grassfires. The environment could not have supported the required volume of grass to create such large clumps of glass, nor would a fire have forcefully thrown material around. We *did* find well-preserved mats of ancient grass beneath some of the deposits, but in most areas they were either separated from the glass by unaltered layers of silt or completely unrelated.

Tell-Tale Signs

Back in the United States, we began to carefully examine more than 300 samples we had collected from the chunks and slabs of glass. Polished sections revealed beautiful green swirls welded to packets of unmelted or partially melted soils.

Scott studied scores of thin sections of glass using the



P. H. SCHULTZ ET AL. / *GEOLOGY* 2021

▶ **WIDESPREAD** Glass litters several sites (five shown in image above right) along a stretch of some 75 km, running in a north-south direction. The sites are remote, far from volcanic or industrial activity. The small town of Pica lies between sites 1 and 2.

Fernbank Science Center's scanning electron microscope. Many contained packets of zirconium oxide and silicon dioxide, created when intense heat decomposed grains of the hardy mineral zircon (zirconium silicate). This chemical transformation requires temperatures exceeding 1,670°C (3,040°F), much hotter than any grass-fire. Some of the zircon particles had been completely converted, yet they still retained their original outlines within the glass. This indicated that the zircons scattered in the soils were not only exposed to extremely high temperatures but also cooled very rapidly, thereby preventing mixing within the molten material.

Then Scott made an even more surprising discovery. Samples of glass collected all along the 75-km corridor are riddled with unmelted meteoritic particles. Many of the smaller particles are composed of exotic minerals (including serpentinite clasts with troilite, a rare iron sulfide mineral) that were altered by exposure to water at low temperatures. Laboratory experiments constrain the conditions of formation and survival of some of these minerals to the low temperatures found in primitive, water-rich bodies from the outer solar system. Samples from Comet Wild 2, returned to Earth by NASA's Stardust spacecraft, also found these "alien" minerals. For these and other reasons, we think the Pica bolide was likely a comet. The French team may have failed to detect the meteoritic traces because the bulk-chemical-analysis method

◀ **GREEN GLASS** Thin-section view of folded glass showing the typical green color, bubbles, and density variations. The large bubble at top is roughly 200 microns wide.

they employed wasn't sensitive enough to pick up the tiny contribution from microscopic particles amid all the glass.

The long corridor containing the glass fields, combined with the fact that samples containing the same meteoritic inclusions were collected at sites tens of kilometers apart, suggests two possible scenarios. In the first scenario, the object arrived as a single body that entered the atmosphere at a low grazing angle and fragmented as it passed through the atmosphere, producing a series of airbursts. Alternatively, the object may have broken up prior to entering the atmosphere and arrived as a swarm at a steeper angle of 30° to 45° relative to Earth's surface. Comets and their rubble-pile kin among the asteroids are fragile bodies, but comets in particular easily split into clusters of large fragments while traversing the inner solar system.

Radiocarbon dating of organic matter in soils directly beneath and in contact with the glasses gives ages ranging from 11,500 to 12,300 years ago. To be clear, these results only provide the age for the sediments, not for the glasses. Prior work in this region has demonstrated that there are surfaces side by side that could have an age difference of 1,000 years, explaining why the French researchers concluded that there was a range of ages for the glasses.

GREEN GLASS: P. H. SCHULTZ ET AL. / *GEOLOGY* 2021; IMAGES OF GLASS: P. H. SCHULTZ (4); FUSION: P. H. SCHULTZ ET AL. / *GEOLOGY* 2021

1 **TWO-FACED** Some Pica glasses were still partially molten when they were tossed onto grassy matts. This example shows both the glossy upper surface that quenched in air and the side that landed on the grass, creating imprints of grass.

2 **TWISTED** The melting process was complex. This example reveals numerous small, elongated blebs of glass that fused together. The entire assemblage was twisted after slamming into the surface before cooling completely.

3 **FUSION** The fused soils resulted in glassy bombs with embedded pieces of twigs and grass. Because the grasses have a high-silica content, they actually turned into glass as well.

4 **KNEADED** Many glasses show evidence of being folded into much larger masses before fully cooling. As a result, the overlapping glasses look like kneaded dough.

5 **FLOWING** This close-up shows once-molten glass overlapping and wrapping around other, less mobile packets. This pattern reveals that the molten glass not only flowed after being heated but also cooled suddenly, freezing this texture in place.

1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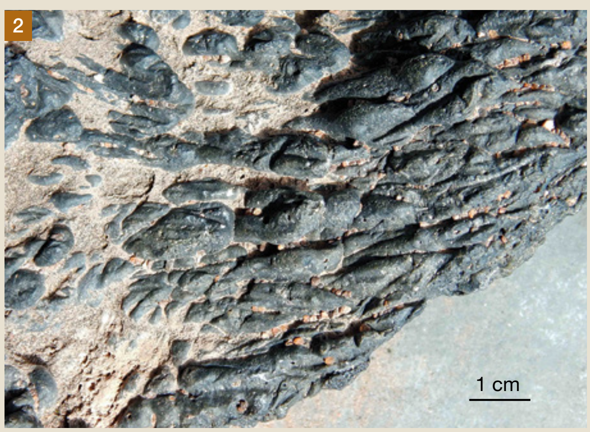

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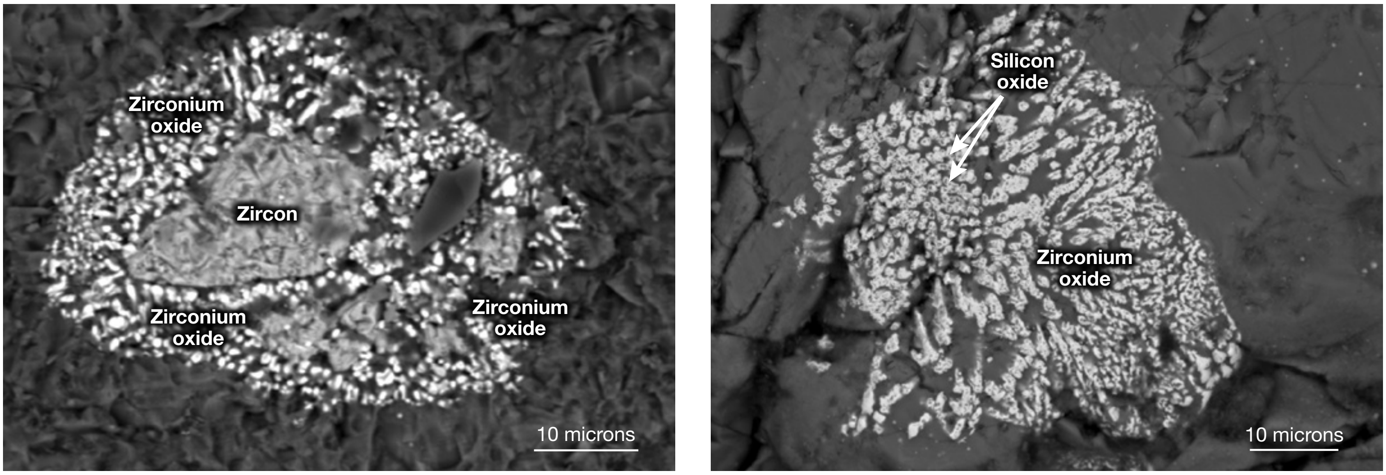


▲ **ZIRCON CLUES** Microscopic images reveal zircon grains that have been partially *(left)* or completely *(right)* decomposed into zirconium oxide and silica. Such thermal decomposition requires temperatures greater than 1670°C and rapid cooling.

The Pica event might even have reached beyond this region. Intriguingly, there is a layer of material at a site 250 kilometers south of the Pica glass fields that appears to have formed roughly when the Pica deposits did. This layer (dated to 11,500 years ago) contains magnetic particles with similar compositions to some of the Pica grains, at levels that not only are almost 100 times greater than the concentrations in soil layers above and below but also exceed concentrations in layers of similar age elsewhere. Further study is required to determine whether these are connected to the Pica glasses.

According to archaeologists, humans had already arrived in the Atacama 12,000 years ago, so there may have been witnesses to this terrifying spectacle.

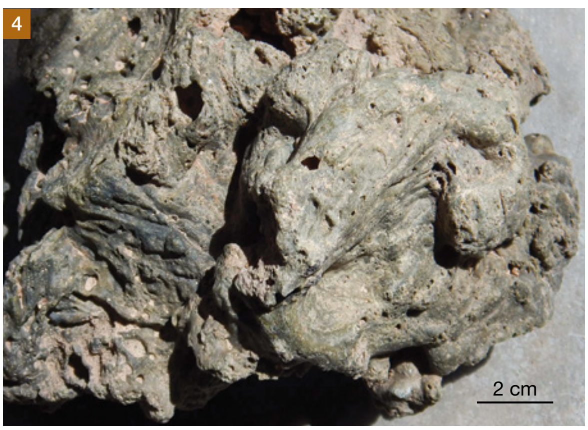
Armageddon

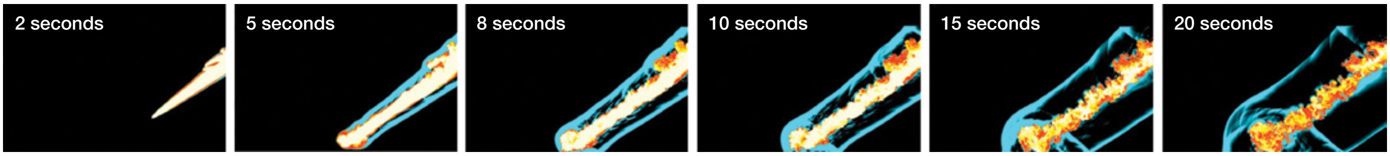
Our onsite observations and later sample analysis indicate that the creation of the Pica glasses was a special event, involving more than the brief pulses of intense radiant heat and shock waves generated by two recent cosmic encounters: the Tunguska and Chelyabinsk events. Both of these events produced large, high-altitude airbursts. The Tunguska Event that felled 80 million trees in a remote Siberian wilderness in 1908 was the result of a stony meteoroid 50 to 60 m in diameter exploding with an estimated energy of 5 to 30 megatons of TNT, at an altitude of between 8 and 15 km. The 2013 Chelyabinsk meteoroid was also a stony object but smaller, with an estimated diameter of 20 m, and it exploded at a higher altitude of 30 km, creating shock waves that collapsed walls and shattered countless windows in the city below.

Even at close range, the pulse of intense heat that radiates from an exploding bolide isn't capable of producing glass slabs thicker than about 2 cm (0.8 in). The brief duration of the fireball, combined with soil's poor ability to transport heat, limits the depth of melting to only 1 or 2 cm. How can so many masses of the Pica glass be dozens of times thicker?

In 2008, physicists Mark Boslough and David Crawford (then both at Sandia National Laboratories) published computer simulations of low-altitude airbursts on Earth, incorporating insights gleaned from observations of Comet Shoemaker-Levy 9's collision with Jupiter in 1994. They determined that if an incoming body traveling at least 20 km/s (roughly 50 times the speed of sound in air) vaporizes at a sufficiently low altitude, the debris from the explosion will continue downward through the atmosphere as a hot, rapidly

MICROSCOPIC IMAGES: P. H. SCHULTZ ET AL. / *GEOLOGY* 2021 (2)





▲ **AIRBURST BLAST** An incoming object that vaporizes above the surface in an airburst will continue downward as a churning jet of hot gas. When this jet hits the surface, it blasts and melts surface soils, creating complex glass deposits.

expanding jet of meteoritic vapor and melt. When this fireball collides with the surface, it has far more profound effects than just the shock wave or thermal radiation from an object exploding at high altitude — one of which is the creation of surface glasses.

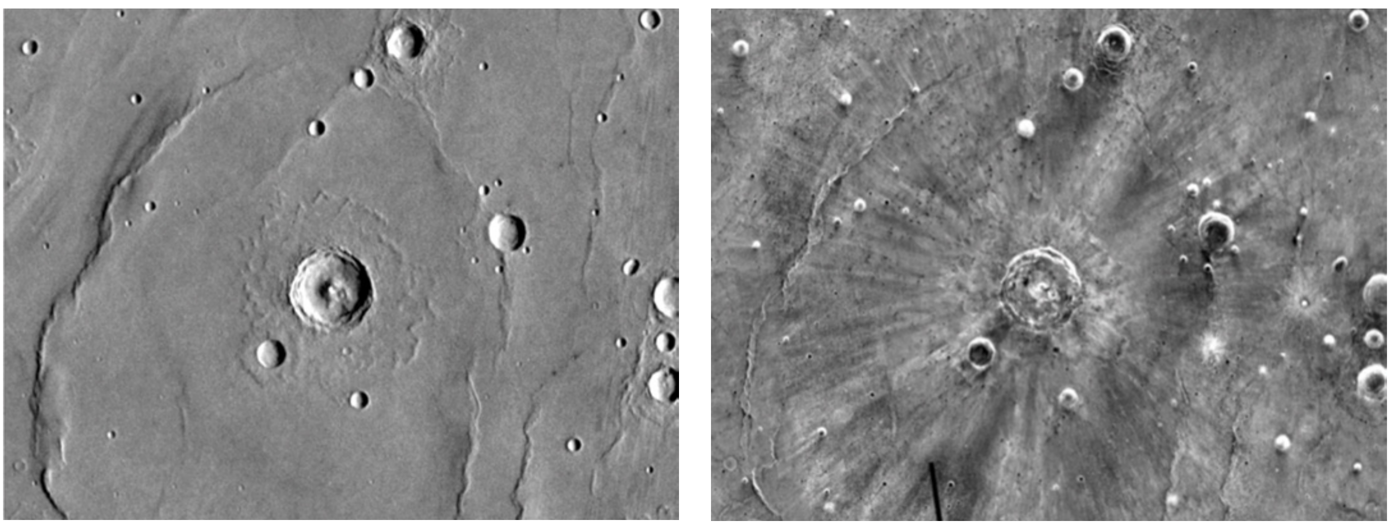
We've actually seen effects of hypersonic fireballs reaching the surface — not on Earth, but on Venus. During the early 1990s, NASA's Magellan spacecraft used radar to see through the planet's opaque canopy of clouds and map its surface. These observations revealed that the dense atmosphere has shielded the surface from impacts that would gouge craters smaller than about 5 km wide. Instead of small craters, there are hundreds of diffuse, radar-bright "splotches" of various shapes, overprinted by central, radar-dark areas. Scientists inferred these features are the scars of airburst shock waves, created by objects that didn't make it to the surface.

The splotches have a peculiar appearance. At that time, researchers thought that an entering body would flatten like a pancake before suddenly exploding, but such behavior wouldn't make marks like these. While trying to understand these scars, I attempted to replicate airbursts using the hypervelocity Vertical Gun Range at NASA's Ames Research Center in California. The results revealed that rather than flattening into a pancake, the disrupted projectile morphs into a needle shape, enabling the swarm of fragments to penetrate deep into the atmosphere and reach the surface. Small fragments of the projectile literally surf the trailing shock wave.

When these hot clouds of gas and trailing debris collided with the surface of Venus, they scoured it with intense winds, sweeping away radar-dark particles that were both delivered to and dislodged near "ground zero." They were carried long distances, until they were blocked by ridges and collected in crevasses. I could see this effect when I studied Magellan's radar images closely.

In Chile, we think that similar jets of incandescent gas and supersonic winds combined to make masses of glass much larger than a short-lived pulse of thermal radiation alone could generate. Rather than simply forming a thin, uniform layer of glass, the violent winds and shock-driven turbulence created a chaotic mess. Loose soil and silt were lofted, flash-melted, and fused into larger masses, giving the chunks and slabs their telltale contorted shapes. Large pebbles and rocks that couldn't be lofted were only singed by brief exposure to the intense heat. Meteoritic dust shed during entry arrived in trailing vortices to salt the mixture, thereby explaining the presence of certain thermally unstable minerals. The entire cataclysm probably lasted only tens of seconds.

Preliminary calculations based on previous work suggest that each of the six glass fields might have required fragments 50 to 100 meters in diameter that vaporized only 1 to 2 km above the surface, with energies exceeding 3 megatons. The parent body might have been as large as 1 km in diameter. Although scientists estimate a similar size and larger energy for the Tunguska object than for each of the Pica fragments,



▲ **COMET BLAST** The 20-km-wide crater Santa Fe in Mars's Chryse Planitia looks normal enough in visible light *(left)*. But a nighttime infrared image from the Mars Odyssey Orbiter's THEMIS instrument *(right)* reveals twin streaks extending from old crater rims (upper and lower left). These streaks are interpreted as coarse surface materials exposed when Santa Fe's impact-generated vapor plume interacted with pre-existing obstacles.

JET SIMULATION: MARK BOSLOUGH / SANDIA NATIONAL LABORATORIES; MARTIAN CRATER: NASA / JPL-CALTECH / ARIZONA STATE UNIVERSITY (2) the stony Tunguska body probably didn't vaporize the way Pica's pieces did, and it exploded far too high for its fireball to reach the ground. (It bears emphasizing that the estimates for these events' details involve considerable uncertainty.)

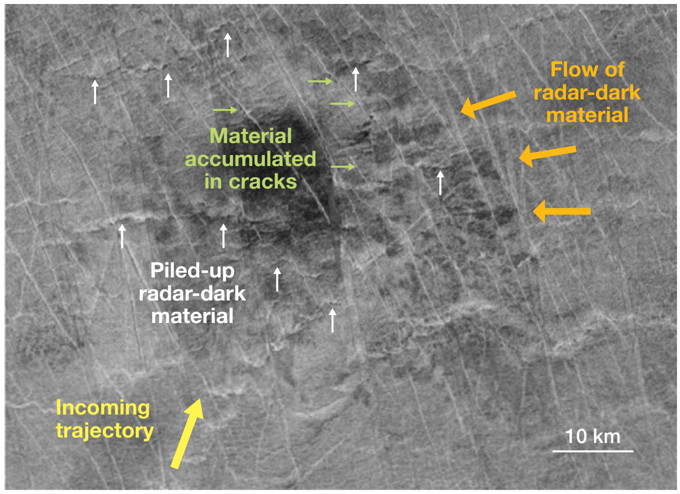
The physics of low-altitude airbursts also explains findings by the French investigators that seemed inconsistent with a cosmic collision. When the jet of gas from a low-altitude airburst strikes the surface, it doesn't generate the same ultrahigh pressures produced by the impact of a solid object traveling at tens of kilometers per second. This explains the absence of the shocked metamorphic rocks in the Pica glasses that are the distinctive signature of ordinary impacts. And because both the jet of white-hot gas and surrounding heated air are highly ionized, it alters the intensity and orientation of the terrestrial magnetic field preserved in the glass when it rapidly cools, a process that accounts for the observed magnetic variations in the samples.

The Next One?

Finds like the Pica glasses, as well as at least eight different impact-glass layers with shock features laid down in Argentina over the last 10 million years, suggest that we may be underestimating the current flux of objects that damage Earth's surface. Our estimates depend to a large extent on atmospheric entry models, and many models fail to capture the process. For example, according to most models, a stony meteoroid less than 10 meters across can't survive atmospheric entry to slam into the ground at hypersonic velocities. But that's exactly what happened at Carancas, Peru, in 2007. That body must have been a shape-changing rubble pile that survived atmospheric passage all the way to the surface, at speeds high enough to produce a 20-meter-wide crater with melt and shock features.

The frequency of near-surface airbursts is also uncertain. In some environments, glasses may not have formed or their traces were simply erased. The Pica glasses are preserved in nearly pristine condition because the Atacama Desert has been one of the driest places on Earth for millennia. Even greater uncertainty surrounds the number and size distribution of cometary objects, the role of comet swarms arriving from the outer solar system like the Kreutz sungrazers, and the ability of old comets to masquerade as asteroids.

In fact, a recent study of 12 well-preserved craters on Mars suggests that comets may pose an unexpected level of danger. These unusual craters are surrounded by radiating wind streaks that are only visible in nighttime infrared images. Unrelated to either impact ejecta or local wind patterns, the streaks extend from pre-existing topographic features that deflected the impact-generated winds. After performing numerous computer simulations and lab experiments, Stephanie Quintana Bouchey (then at Brown University) and I concluded that those craters with extensive wind streaks were formed by rare cometary impacts: When the icy body smashed into the surface (which would happen at higher speeds than a typical asteroid would achieve), the crash



▲ **VENUS SPLOTCH** Radar images like this one from NASA's Magellan mission revealed surprising marks on Venus's surface that appear to be scars made by bolides exploding above the surface that left no crater. The dark areas correspond to either less dense material or particles smaller than about 1 cm. Hot supersonic gas generated strong surface winds that transported these materials (including meteoritic debris), explaining why they piled up along ridges facing the splotch's center and got trapped in cracks. The pattern here suggests an oblique collision.

NASA / JPL

vaporized the ices, generating an outward rush of intense and prolonged winds.

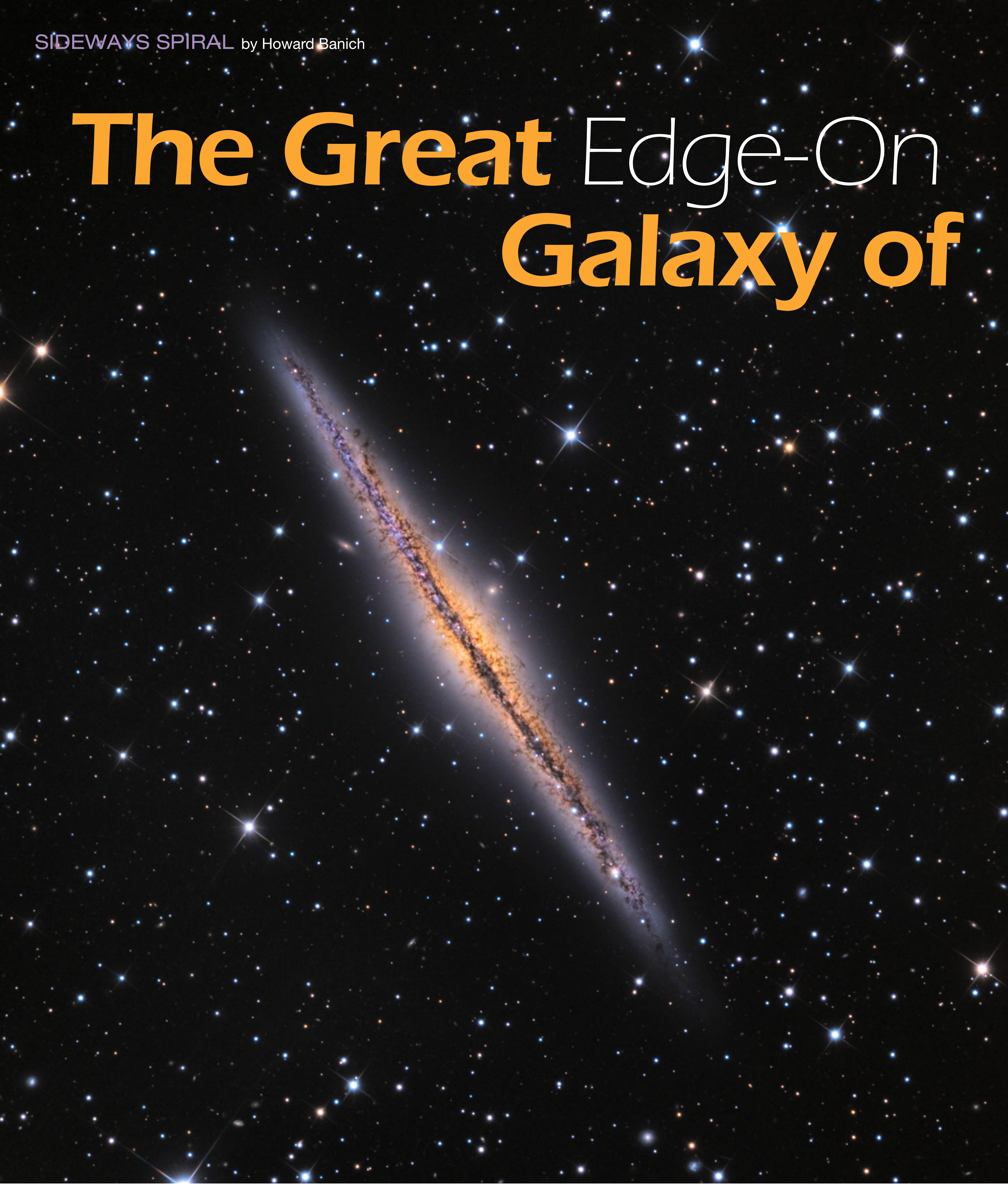
The number of these anomalous craters, compared with the total number of craters of similar age, and taking into account the estimated cometary impact rate on Earth relative to Mars, suggests that the percentage of cometary bodies larger than 3 km hitting our planet may comprise about 16% of all impactors. This estimate is considerably higher than most previous ones, and it raises the possibility that even smaller objects could be more common as well.

Planetary-defense efforts generally emphasize the threat near-Earth asteroids pose, and we're used to thinking of our atmosphere as a shield that protects us from cosmic shrapnel. However, deep dives by small, fragile objects like comets have devastating effects over a much wider area than the impact of a solid space rock of the same mass because more energy is transferred to the atmosphere rather than to the ground. The well-preserved Pica glasses might offer a rare glimpse of dangers that we are only beginning to recognize.

■ **PETER SCHULTZ** (Professor Emeritus, Brown University) has spent 50 years exploring processes that shape planetary surfaces (including Earth's), especially those involving impacts. He's published a book (*Moon Morphology*) and more than 180 papers as well as participated in various NASA missions, including Magellan, Deep Impact, EPOXI, Stardust-NExT, and LCROSS. *S&T* Contributing Editor **THOMAS DOBBINS** became fast friends with Peter Schultz when they shared a podium at the Stellafane Lunar Morphology Workshop in 2010.

FURTHER READING See the 2021 *Geology* paper this article is based on at **https://is.gd/Picabolide**.

The Great Edge-On Galaxy of



NGC 891 is a splendid object upon which to feast your eyes. Spend some time in the area and explore its neighbors, too.

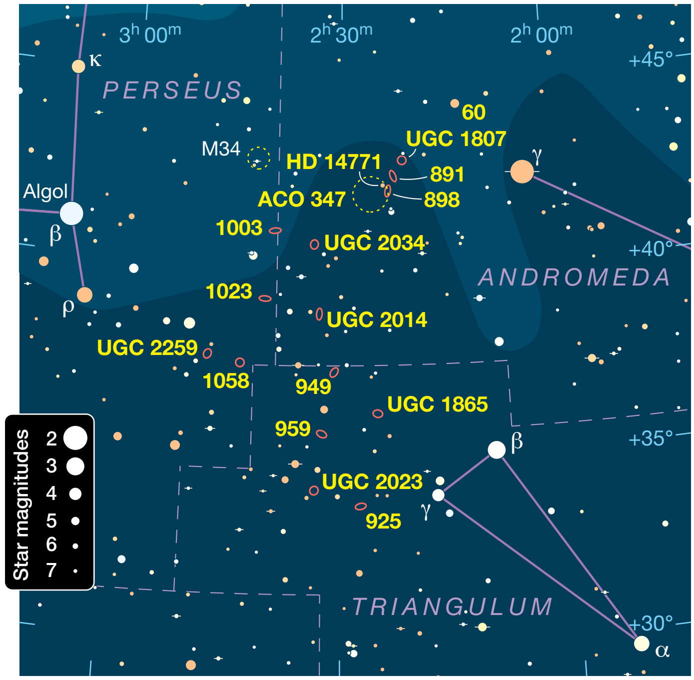
Autumn

The symmetry of an edge-on spiral galaxy is a delight, but only if you can see your target well. **NGC 891** has a reputation for being difficult to nab visually because of its low surface brightness, but a good view is so memorable that you'll likely never forget it. Part of the magic is that NGC 891 looks similar to how we'd perceive our own galaxy from a great distance. If we were in NGC 891 itself, we'd see its arms and dust lanes arcing across the sky, just like the naked-eye sight of the Milky Way from the Southern Hemisphere when the galactic center is near the zenith.

For many boomers, another aspect of NGC 891's appeal is that the 1960s sci-fi TV series *The Outer Limits* featured a photo of the galaxy in the closing credits. To those who followed the program, that presence gave NGC 891 an undeserved eeriness that still boosts its allure. For those who never watched the TV show, consider this a minor bit of trivia. But if you ever come across the term "Outer Limits Galaxy," this is why.

More to the point, NGC 891 not only looks a lot like the outside view of our Milky Way galaxy, but it's also actually rather similar in other important ways, too. At about 30 million light-years away, astronomers consider it to be the closest analog of the Milky Way. NGC 891 is about the same size as our galaxy and shares similar chemical and structural features, including a potential central bar. It's also looped by stellar streams from former dwarf galaxies that have merged, or are in the process of merging, with it.

◀ **NGC 891 IN ALL ITS GLORY** This magnificent galaxy is seen edge-on from nearly 30 million light-years away and is considered a near twin of our Milky Way Galaxy. North is up in all images unless otherwise noted.



How To Find NGC 891

I like to star-hop, and even though NGC 891 might seem easy to find I always have trouble spotting it on my first attempt. Located about 3° east of the 2.2-magnitude star Almach, or Gamma (γ) Andromedae, in far eastern Andromeda, NGC 891 forms a nearly equilateral triangle with it and 4.8-magnitude 60 Andromedae. Heck, there's even a 6.6-magnitude star, HD 14771, about a ¼° southeast of NGC 891. Piece of cake.

But not for me — I usually need at least two attempts to find NGC 891. I've had better luck recently by drawing an imaginary line from Gamma to Algol, and visualizing NGC 891 about one-third of the way to Algol and just a tad north of the line connecting the two stars. (Or, you could just use the Go To system on your scope.)

NGC 891 and Companions

Object	Surface Brightness	Mag(v)	Size/Sep	Distance (M l-y)	RA	Dec.
NGC 891*	13.6	9.9	11.7′ × 1.6′	30	02^h 22.6^m	+42° 21′
UGC 1807*	16.6	15.9	1.5′ × 1.5′	32	02^h 21.2^m	+42° 46′
ACO 347	—	—	56′	217 – 252	02^h 25.8^m	+41° 52′
NGC 898	12.9	13.7	1.8′ × 0.4′	252	02^h 23.3^m	+41° 57′

The asterisk indicates object is a member of the NGC 1023 Group. Angular sizes are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

NGC 891: ADAM BLOCK

NGC 891 is too dim to show up in my 80-mm finderscope, but what's immediately evident is that there are many foreground stars in this part of the sky — the band of the Milky Way isn't that far away. These stars vie with the galaxy for attention and are so obviously in front of it that they impart a faraway, distant look to NGC 891, reinforcing its subtlety. Perhaps this has helped the Outer Limits Galaxy nickname stick.

NGC 891 has a listed magnitude of 9.9, but it appears significantly fainter than that because of its low surface brightness of 13.6, which is only partially caused by intervening dust in our galaxy. But once you have it in the eyepiece of your telescope, this somewhat ethereal object illustrates how insubstantial some galaxies are — and makes me wonder how delicate it would appear if we viewed it from a face-on perspective.

The following selection of observations are (mostly) in chronological order. This not only gives an idea of why I've come to think of NGC 891 as the great edge-on galaxy of autumn, but it also shows how observing conditions affect the sight through the eyepiece — and that sometimes the biggest scope doesn't offer the most pleasing view.

Firsts and Lasts

The first time I saw NGC 891 through a telescope was at the 1991 Oregon Star Party. This was the last time the event was held on the slopes of Steens Mountain in southeastern Oregon and was my first-ever star party. It was also the first time I observed at a truly dark, high-altitude site, and was the last time I used my 12.5-inch f/7.8 telescope — because my brand new 20-inch Obsession arrived a week later. Whew!

On the final night of the star party, the clouds that had plagued the sky for the first half of the night cleared off and a group of observers was generating a buzz of excitement by loudly exclaiming how amazing whatever they were observing looked. After they treated me to a knock-my-socks-off view of M33, I followed their enthusiastic approval of NGC 891 by pointing my 12.5-inch f/7.8 Dobsonian at what to me was a brand-new object:

> *Again, shouts from across the field grabbed my interest. Again, yow! This is an edge-on spiral with a dark lane bisecting it down its full length. This is a beauty and it's magical at 260×. The field is strewn with zillions of foreground stars really giving 891 the look of being way outside the Milky Way. I'm coming back here again. (1991)*

This was likely the finest observation it was possible to get of NGC 891 with a 12.5-inch scope.

Only a short while after that awesome view I set up my new 20-inch in my light-polluted, suburban backyard and pointed it at the galaxy. The sight that greeted me was less than inspiring:

> *Very faint, almost missed it, but at 127× it showed up as a faint streak of light. Hard to tell if there was a dark lane or not. (1991)*

The view through the 12.5-inch at Steens Mountain was far better than this. However, a year later under a dark and exceptionally transparent sky what I saw with the 20-inch Dob was remarkable:

> *Super view of this edge-on galaxy. Even though it has a low surface brightness it's very distinct and its bisecting dark lane cuts it almost perfectly in half. Lots of foreground stars – best at 182× and 242×. (1992)*

These last two log entries show that even a big scope needs a great sky to shine.

Fine Views

After replacing the 20-inch scope with my homemade 28-inch in 2004, NGC 891 was one of my first targets. My first view of it through the larger instrument was spectacular:

SPIRIT OF NGC 891 This is a rare sketch from my observing notebook because I took the time to refine it into a finished drawing. I think it captures the spirit of the galaxy as I saw it with the 28-inch scope on a good night from a dark observing site. Note how the dark lane doesn't completely bisect the galaxy. I used magnifications of 253× and 408× while sketching.

HOWARD BANICH

Wow! This was without a doubt the finest view I've had of this edge-on galaxy. It was far more distinct for both the bright areas and the dark lane, but I can't really say I saw more detail. 297× gave the best view but 467× was pretty darn good too. (2004)

Seventeen years later, this was my first look from my semi-dark backyard:

Now I'm impressed! [NGC] *891 was right there with direct vision, dark lane and all. ACO 347* [of which more later] *showed 8 galaxies with a casual sweep, which is even more impressive. 253×, 20.36 SQM* [Sky Quality Meter]. *(2021)*

The bisecting dust lane has never appeared to run from end to end of NGC 891 in the 20-inch or 28-inch scopes, which is surprising given my view through the 12.5-inch Dob. Perhaps the smaller instrument couldn't reveal the full extent of the side-on spiral arms, so the dust lane only seemed to stretch to both ends. Just as likely, it could be that the 12.5-inch view from a pristine site really is the best I've had among these three scopes.

My observation with visual observer extraordinaire Jimi Lowrey's 48-inch scope was as much about the two faint galaxies I saw on either side of NGC 891 as it was about the galaxy itself:

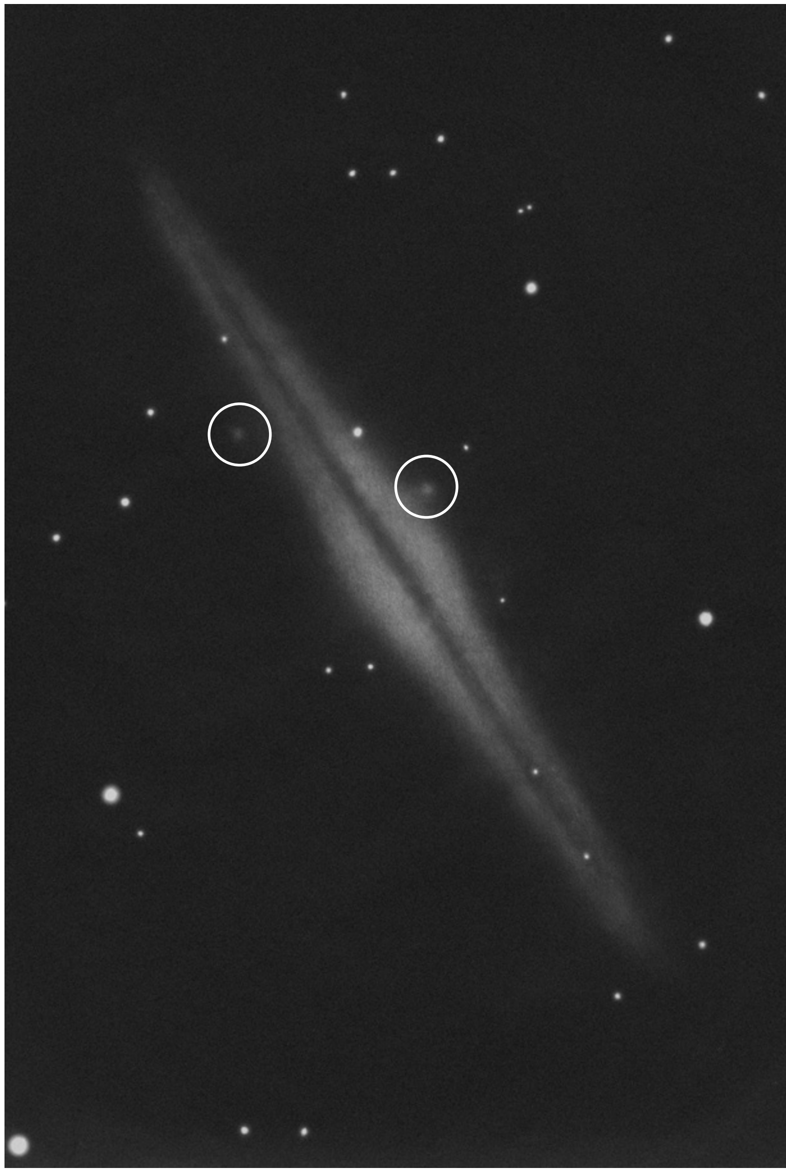
Excellent! A small galaxy right next to the core along with another, fainter galaxy of the opposite side of [891] *— and* [NGC 891] *itself — Longer and brighter than I've seen it before. The seeing comes and goes, but the view at 488× is fantastic — I need to draw this! 21.46 SQM. (2013)*

NGC 891 looked absolutely magnificent in Jimi's scope. I should note that although the view was much brighter than with my 28-inch, there wasn't much more detail except for the two small galaxies on either side — and the bisecting dust lane appeared longer, nearly stretching from one end of the galaxy to the other. I had hoped to see some of the fine dark vertical spikes that extend perpendicularly to the main dark lane, but they weren't visible, at least not on this night. The sky wasn't at its best, so it's likely there's more yet to see.

Information about whether or not the two small galaxies are companions to NGC 891 is hard to come by. The galaxy near the western side of the core is 2MASS J02223046+4221370, and the one on the northeastern edge is 2MASS J02224186+4222417 (circled in the sketch at right). The NASA/IPAC Extragalactic Database lists both galaxies as infrared sources and doesn't provide a redshift for either, but to my eye they have the look of being far in the background.

Going Small

I've done only one observation of NGC 891 with an 8-inch scope, but according to my notes, that's enough aperture for a satisfying view:



HOWARD BANICH

▲ **THROUGH THE BIG SCOPE** This sketch shows NGC 891 as I saw it with Jimi Lowrey's 48-inch telescope. The view was stunning, to put it mildly, and the two most obvious additional details I noted were the small galaxies on either side, as well as the bisecting dust lane that nearly stretched from end to end of NGC 891.The brighter of the two small galaxies is just west (at right in the sketch; 2MASS J02223046+4221370) of the core, and the slightly fainter one is east (at left in the sketch; 2MASS J02224186+4222417) of the northern end of NGC 891. I used a magnification of 488× for these observations. Compare this drawing with the image on page 28 to spot the small galaxies.

In the 8-inch, 891 looks much like nearby NGC 898 does in the 28-inch, only broader – and [I can] *possibly detect the dark lane, which I'm not 100% positive I can see. 127×, 21.47 SQM.*

Although it was a pretty good observation, I'll bet that under even darker and more transparent skies I'd be able to see the dust lane more easily. Even if it's no surprise that I've had fantastic views of NGC 891 with the big telescopes, my experiences with the 12.5-inch and 8-inch apertures show that this almost perfectly edge-on galaxy can be seen well in more modest apertures.

Something I enjoy thinking about when observing NGC 891 is that any of its astronomically minded residents would have a similar view of our Milky Way — but wouldn't see our galaxy quite as edge-on. Look at NGC 891's position on a star chart and you'll see that it's less than 20° from the galactic equator — this means that the Milky Way would appear approximately 20° from being exactly edge-on as seen from NGC 891. Cool stuff to ponder while at the eyepiece.

A Galaxy Group

Like most galaxies, NGC 891 isn't alone in the void. It's part of the **NGC 1023 Group**, which includes a dozen other galaxies (six of which are NGC targets). On average, they're about 20 million light-years away, which puts NGC 891 on the far side of this collection. You can spend a lovely evening observing just the brighter targets in this collection.

A member of the group, the 15th-magnitude, gas-rich satellite galaxy **UGC 1807**, lies about ½° northwest of NGC 891. It seems to be a good candidate for the interacting object creating the stellar streams that loop around NGC 891, but its stellar population makes it a poor fit. We'll need to wait for future research to settle this.

A Galaxy Cluster

On the other hand, the galaxy cluster **ACO 347** has no physical relationship to NGC 891 and is merely along the line of sight. It's a real treat of a cluster as it's loaded with nine galaxies with NGC numbers. Its brightest member, **NGC 898**, is less than ½° southeast of NGC 891. At a distance of 252 million light-years, NGC 898 is more than eight times farther away than NGC 891. If you can see both galaxies in the same field of view, you'll have a depth of field that's hard to match anywhere in the sky.

Even better, consider the Milky Way field stars you're seeing all this through. They range from a few hundred to a little more than a thousand light-years away, making the depth of field even more pronounced — the universe can click into startling 3D if you think about all this while peering through the eyepiece of your telescope. Wow!

At magnitude 13.7, NGC 898 is a well-defined but small edge-on galaxy that's bright enough to detect without giant optics:

> *I can just see it in the 8-inch with averted vision as a faint smudge, slightly elongated. 127×, 21.47 SQM.*

But it's much more interesting through a 28-inch:

> *This is the brightest galaxy in ACO 347 and is surprisingly long.* [It has] *a bright but not quite stellar core, and there appears to be a small, faint background galaxy nearby (PGC 212965). 408×, 21.47 SQM.*

Making this distant object even more intriguing, NGC 898 likely sports a nifty bisecting dust lane just like NGC 891 does. I couldn't see this feature with the 28-inch, but just knowing it's there is cool, especially when both galaxies are in the same field of view.

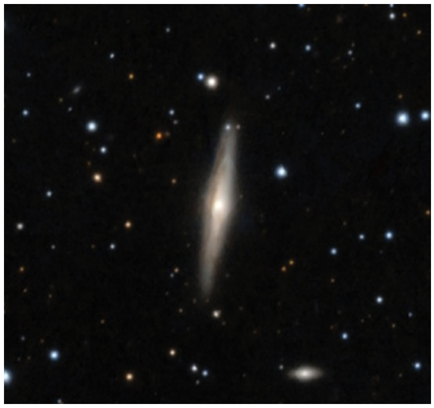
There's more to ACO 347 than NGC 898, though. The rest of the cluster is full of accessible NGC galaxies, some of which are nestled among foreground Milky Way stars. I first observed the brighter members of the galaxy group without initially knowing where they all were, and then, armed with

Other Members of the NGC 1023 Group

Object	Constellation	Surface Brightness	Mag(v)	Size/Sep	RA	Dec.
NGC 1023	Perseus	12.8	10.4	7.4′ × 2.5′	$02^h\ 40.4^m$	+39° 04′
NGC 925	Triangulum	14.4	10.1	10.5′ × 5.9′	$02^h\ 27.3^m$	+33° 35′
NGC 949	Triangulum	12.9	11.8	3.0′ × 1.6′	$02^h\ 30.8^m$	+37° 08′
NGC 959	Triangulum	13.6	12.4	2.3′ × 1.4′	$02^h\ 32.4^m$	+35° 30′
NGC 1003	Perseus	13.8	11.5	4.3′ × 1.3′	$02^h\ 39.3^m$	+40° 52′
NGC 1058	Perseus	13.4	11.2	2.5′ × 2.5′	$02^h\ 43.5^m$	+37° 20′
UGC 1865	Triangulum	15.9	13.8	3.2′ × 2.6′	$02^h\ 25.0^m$	+36° 02′
UGC 2014	Andromeda	15.8	15.3	1.9′ × 0.9′	$02^h\ 32.9^m$	+38° 41′
UGC 2023	Triangulum	15.3	13.3	2.8′ × 2.6′	$02^h\ 33.3^m$	+33° 29′
UGC 2034	Andromeda	14.8	13.2	2.5′ × 1.9′	$02^h\ 33.7^m$	+40° 32′
UGC 2259	Perseus	14.8	13.2	2.6′ × 2.0′	$02^h\ 47.9^m$	+37° 32′

Angular sizes are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

▶ **GALACTIC TWINS?** I like to imagine the edge-on galaxy NGC 898's bisecting dust lane, so similar to NGC 891's, even if I can't see it in my telescopes. The Pan-STARRS image at right shows a tantalizing hint of the dark lane. The small lenticular galaxy at bottom right of NGC 898 is PGC 212965.



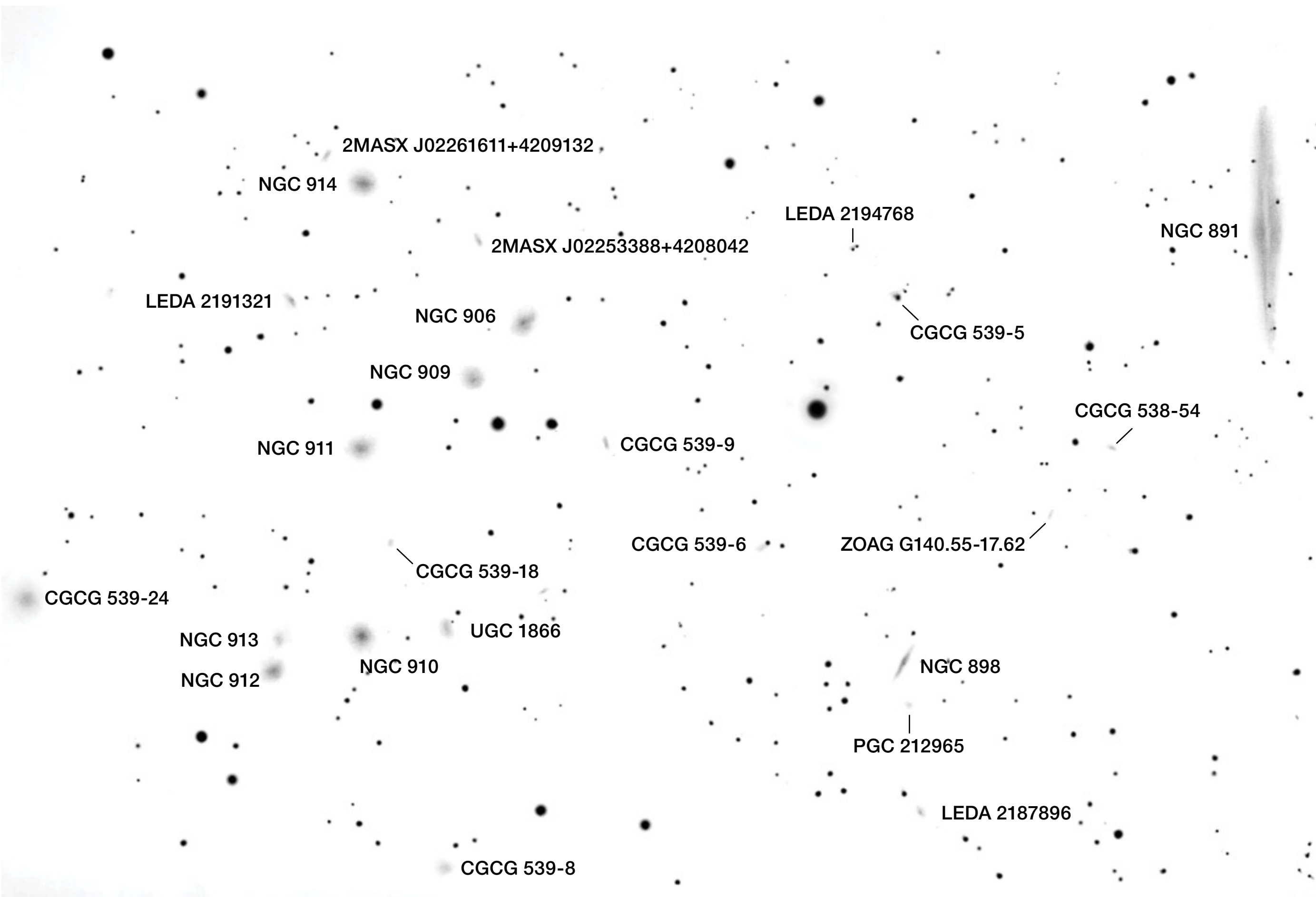
a finder chart, found the more challenging objects on subsequent nights. This is a rewarding collection, and if you're observing in bright skies don't give up if you don't see any of its galaxies at first. Remember, a night with excellent transparency can make up for a less than perfectly dark sky.

Transparency is important for NGC 891, too. You may find yourself thinking that Banich guy must be bonkers to suggest you can see it in an 8-inch scope. But if you observe on the most transparent nights there's a good chance you'll snag a fine view of this beautiful edge-on galaxy.

Unfortunately, great transparency is about as rare as really steady seeing conditions. It happens, but usually when you don't expect it. I've yet to see an online astronomy weather forecast accurately predict great transparency and seeing, so the only thing to do is to keep plugging away whenever the sky looks promising.

As the great edge-on galaxy of autumn, NGC 891 is worth the extra effort and patience it takes to get a memorable view. It's not as flashy as NGC 4565, the great edge-on galaxy of spring, but it's every bit as fascinating. Besides, what's not to like about a beautiful edge-on galaxy beyond the outer limits?

■ Contributing Editor **HOWARD BANICH** can't decide whether he enjoys observing NGC 891 or NGC 4565 the most. In the meantime, you can reach him at **hbanich@gmail.com**.



▲ **INTO THE CLUSTER** This labeled version of my sketch of NGC 891 and the background galaxy cluster ACO 347 shows what I could see through my 28-inch scope. I drew all but one of the NGC galaxies of the cluster — NGC 923 is just off the left edge of the sketch. There are more than 20 galaxies in this sketch, which is about 1 degree wide. You can use this as a finder chart to locate the cluster's galaxies. I used magnifications from 155× to 408×. North is to the upper right.

 by Anthony Mallama

Understanding Lunar Eclipses

Celestial geometry and Earth's atmosphere combine to create one of the night sky's most spectacular sights.

UMBRAL DELIGHT This composite photo shows the November 19, 2021, near-miss partial lunar eclipse. During this event, 97% of the Moon was immersed in Earth's dark, umbral shadow at maximum eclipse. This circumstance presented a rare opportunity to capture a series of images that neatly show the umbra.

The total lunar eclipse on November 8th will be an eye-catching astronomical display. The basics of the event are easy to understand: Earth blocks light from the Sun, and the Moon grows faint. Other aspects are less obvious, such as how our planet's shadow causes the Moon to turn red. And one phenomenon in particular has been an enigma for centuries: Observations show that the size of Earth's umbral shadow is larger than simple geometry indicates it ought to be. How is that possible?

Lunar Eclipses 101

Normally when the Moon is opposite the Sun's position in the sky, we simply get a full Moon — something that occurs every 29½ days. However, when the full Moon passes through the plane of Earth's orbit, it traverses our planet's long shadow, and we get to see a lunar eclipse. In fact, Earth's shadow has two parts — a relatively light *penumbra* and a darker *umbra*. It's the Sun's apparent diameter that produces the distinction between the two shadow components. Solar illumination in the penumbra shades from full intensity at its outer edge to deep shadow at the umbral boundary. From the perspective of an astronaut on the lunar surface, only a portion of the Sun is eclipsed by Earth during the penumbral phase. When Earth completely covers the Sun, our astronaut would be standing in the umbral shadow.

There are three main phases to a total lunar eclipse. First, in the *penumbral phase*, some or all of the Moon is in the penumbra, but no portion is in the umbra. Second, in the *partial phase*, part of the Moon is in the umbra and a slice remains in the penumbra. Finally, in the *total phase*, the entire Moon is immersed in the umbra. A *total eclipse* includes all three phases, while a *partial eclipse* has partial and penumbral phases, and a *penumbral eclipse* only has the penumbral phase. Of the three, a total eclipse, like the one occurring this month (see page 48), is by far the most visually compelling.

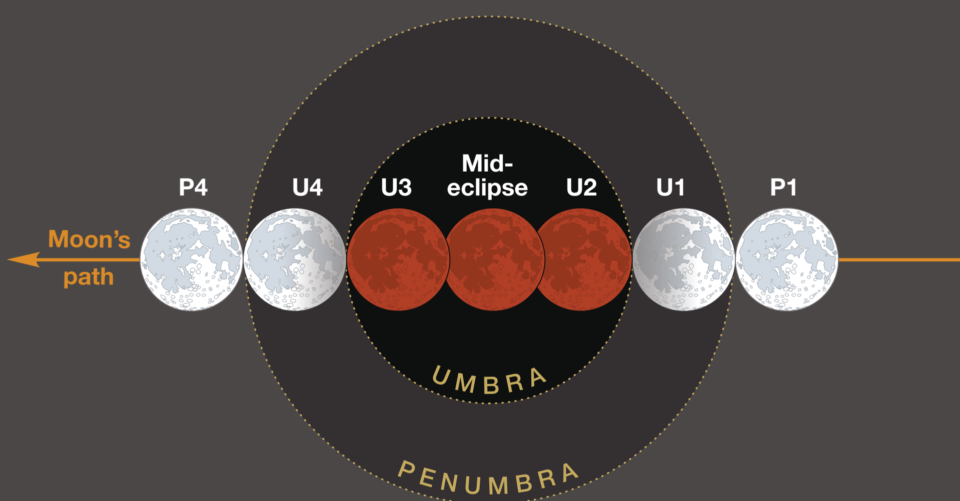
The sizes and separations of the Sun and Earth determine the diameters of the umbral and penumbral shadow regions at the distance of the Moon. As the diagram below shows, the penumbral annulus is approximately equal to the width of the Moon, while fewer than three lunar widths span the umbra. Observers can readily detect the four umbral contacts (U1 to U4), but the moment when the lunar disk enters or completely exits the penumbra (P1 and P4) are too subtle for the eye to distinguish.

It might seem that predicting the duration of an eclipse should be a straightforward matter of geometry. But if we only take into account the factors described so far, we end up predicting eclipses that are too short when compared with observations. To compensate, most almanacs base their timings on a hypothetical umbra that is about 2% larger than its geometrical size. This apparent enlargement was first reported in 1687 by the French astronomer Philippe de la Hire. Some scientists postulated that a physical "absorbing layer" high in Earth's atmosphere could account for the effect. However, atmospheric specialists have never detected any such feature even with sensitive meteorological instruments. To solve the mystery of the enlarged umbra, we need to understand the behavior of sunlight as it travels through Earth's atmosphere.

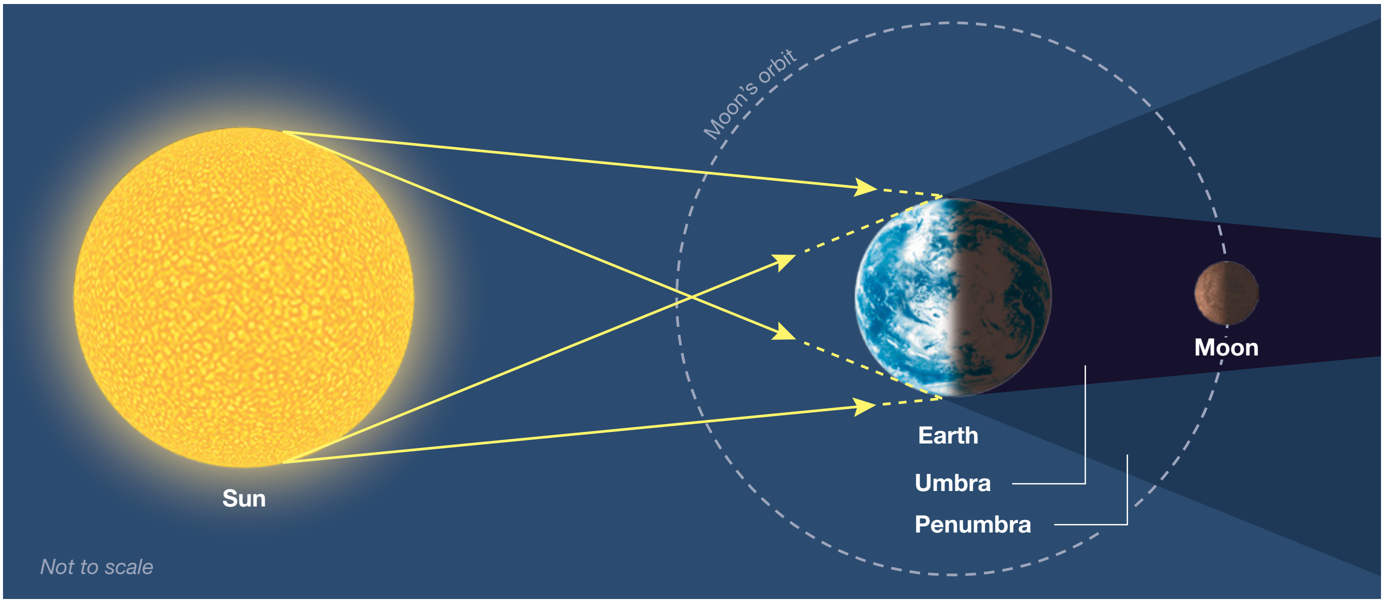
A Trick of the Light

If Earth were an airless world, the Moon would be completely invisible during the total phase of an eclipse. However, as anyone who has witnessed a lunar eclipse knows, the Moon is visible even when it's fully immersed in the umbral shadow. That's because our planet's atmosphere refracts sunlight into the shadow region, similar to how a lens bends light. This refraction accounts for solar illumination reaching the center of the shadow, allowing us to see the Moon even during totality.

ECLIPSE SCHEMATIC
This diagram shows the relative sizes of the umbra and penumbra and the lunar disk. The times when the leading and trailing limbs of the Moon contact the umbra are labeled U1 for first contact and U2 for second contact. U1 and U4 indicate the beginning and end of the partial phase, while totality lasts from U2 until U3. The labels P1 and P4 mark the first and last penumbral contacts.



ECLIPSE SEQUENCE PHOTOS: ZOLTAN LEVAY; ECLIPSE SEQUENCE DIAGRAM: GREGG DINDERMAN / S&T

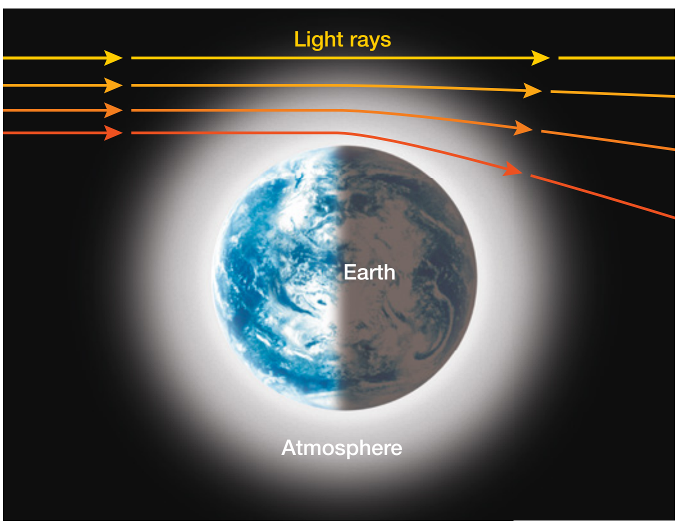


▲ **ALL LINED UP** For a lunar eclipse to occur, two things have to happen at the same time: The Moon must be opposite the Sun's position in our sky and pass through the plane of Earth's orbit. When a total lunar eclipse occurs, the entire lunar disk is immersed in the shadow's dark, inner portion, called the umbra. It's the sizes and separations of the Sun, Earth, and Moon that determine the dimensions of the umbra and penumbra. The duration of the eclipse depends mainly on how close the center of the Moon passes to the center of the umbral shadow.

If the Moon were a lot closer to Earth, it would pass through a portion of the shadow inside the cone produced by refracted rays. In this fictional circumstance, the Moon *would* completely disappear from view for the same reason artificial satellites vanish when they traverse Earth's shadow.

Surprisingly, refraction around Earth's limb is nearly independent of color. That might seem odd when we think of optical prisms, which disperse white light into the familiar rainbow of colors. However, two different scales of refraction are in play. With *differential refraction* (as the effect is called in atmospheric physics), the rising or setting Sun is displaced by about 35 arcminutes above its actual position, but there's practically no prismatic color separation. On the other hand, *atmospheric absorption* of sunlight is strongly color-dependent, and it introduces the reddish hues we see during a lunar eclipse. Specifically, *Rayleigh scattering* due to molecular absorption is why the daytime sky is blue, and why the rising or setting Sun is tinted red. These colors occur because blue light is scattered more than red. During a lunar eclipse, light rays refracted around Earth's limb into the umbra experience very high levels of atmospheric absorption and give the totally eclipsed Moon a deep-red color.

▼ **BENDING LIGHT** Refraction in the atmosphere increases progressively with depth. As a result, light that bends into the shadow is diluted in strength. The intensity depends on the degree of refraction a light ray has experienced on its way to the Moon.



Modeling an Eclipse

Most lunar eclipse predictions only consider the effects of geometry to construct the familiar timing tables published for a specific event. But, if we also take into account the effects of Earth's atmosphere, we can create a computer model that more accurately predicts the duration of the eclipse as well as the brightness and color of the eclipsed Moon. My model first computes the refraction and absorption of light passing close to Earth's limb. Next, it calculates the shadow's brightness from the center out to the edge of the penumbra by factoring in the apparent size of the solar disk. Finally, it determines the total apparent brightness of the Moon by combining a Moon-size disk with the computed distribution of sunlight in the shadow.

The graph on page 38, derived from my computer modelling, shows the change in brightness from the outer boundary of the penumbra to the center of the umbra. The magnitude scale on the vertical axis indicates the amount of

GREGG DINDERMAN / S&T (2)

brightness lost in the shadow. Bear in mind that, as with the stars at night, a difference of 5 magnitudes corresponds to a factor of 100 in intensity. Going rightward on the graph toward the shadow center, brightness declines slowly at first. Then, about a third of the way in, a very rapid fading occurs, accompanied by the light separating into three color-dependent branches. This sudden change corresponds to the transition from penumbra to umbra.

Blue light fades most rapidly and red light most slowly, as a result of color-dependent absorption in Earth's atmosphere. As the graph shows, the intensity of blue light in the center of the umbra has fallen by 22 magnitudes — an intensity that's almost a billion times less than when the Moon lies outside Earth's shadow. Red light is also attenuated, but to a much smaller degree. It's diminished by 11 magnitudes, or about 25,000 times. The separation of the red and blue curves is what accounts for the strong red coloration of the Moon when it's in the umbra.

My model indicates that a visual observer should initially see only a modest fading as the Moon goes from magnitude –12.7 before the eclipse to –12.0 when fully immersed in the penumbra. A steeper decline to magnitude –10.0 occurs as the center of the Moon crosses the umbral boundary. Dramatic dimming follows as more and more of the lunar disk enters the umbra, until the Moon drops to magnitude –3.5 at the onset of totality. During eclipses when the center of the Moon reaches the center of the umbral shadow, the lunar disk fades even more to magnitude +1.4. The brightness ratio between magnitudes –12.7 and +1.4 is nearly half a million!

The table at right lists predicted visual magnitudes for upcoming eclipses. The color index gives the Moon's redness, with values ranging from 1 for a neutral hue up to about 6

Brightness and Color of Upcoming Lunar Eclipses

Date (UT)	Type*	Mag.	Color Index**
Nov. 8, 2022	T	–0.5	4
May 5, 2023	N	–12.0	1
Oct. 28, 2023	P	–11.5	1
Mar. 25, 2024	N	–12.0	1
Sep. 18, 2024	P	–11.5	1
Mar. 14, 2025	T	–2.0	3
Sep. 7, 2025	T	–0.5	4
Mar. 3, 2026	T	–2.0	3
Aug. 28, 2026	P	–4.0	1.5
Feb. 20, 2027	N	–12.0	1
Jul. 18, 2027	N	–12.5	1
Aug. 17, 2027	N	–12.5	1
Jan. 12, 2028	P	–11.5	1
Jul. 6, 2028	P	–10.5	1
Dec. 31, 2028	T	–1.5	3
Jun. 26, 2029	T	+1.5	5.5
Dec. 20, 2029	T	–2.5	3
Jun. 15, 2030	P	–10.0	1
Dec. 9, 2030	N	–12.0	1
May 7, 2031	N	–12.0	1
Jun. 5, 2031	N	–12.5	1
Oct. 30, 2031	N	–12.5	1
Apr. 25, 2032	T	–2	3
Oct. 18, 2032	T	–2.5	3
Apr. 14, 2033	T	–2.5	3
Oct. 8, 2033	T	–1	3.5

*T = total, P = partial, and N = penumbral
**Color Index indicates the redness of the eclipsed Moon, with values ranging from 1 for a neutral hue up to about 6 for extreme coloration.

GARY SERONIK / S&T

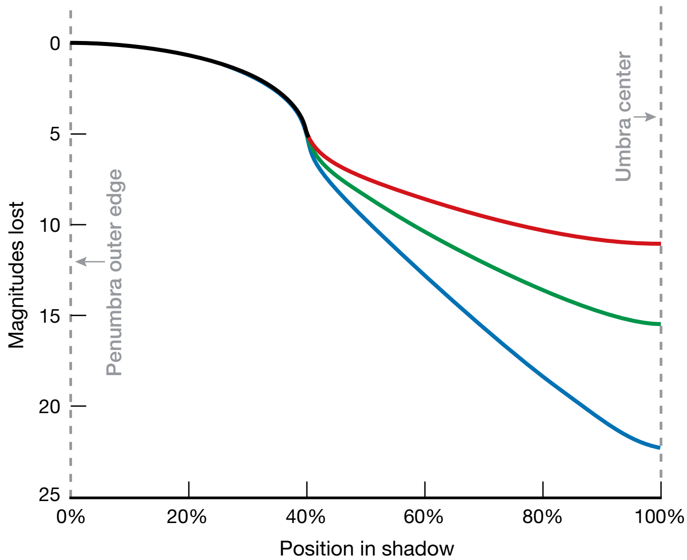
▼ **MAKING CONTACT** This sequence of photos from the January 2019 lunar eclipse shows three key moments leading up to totality. At U1 (left photo), the leading edge of the Moon first contacts the umbral shadow. Roughly 30 minutes later, the lunar disk is half immersed in the umbra (middle). Finally, at U2 (right), the trailing edge of the Moon slips into darkness.

for extreme coloration. My model predicts the November 8th event will have lunar magnitude reaching –0.5 at mid-eclipse, and a color index value of 4, indicating a deep-red tint.

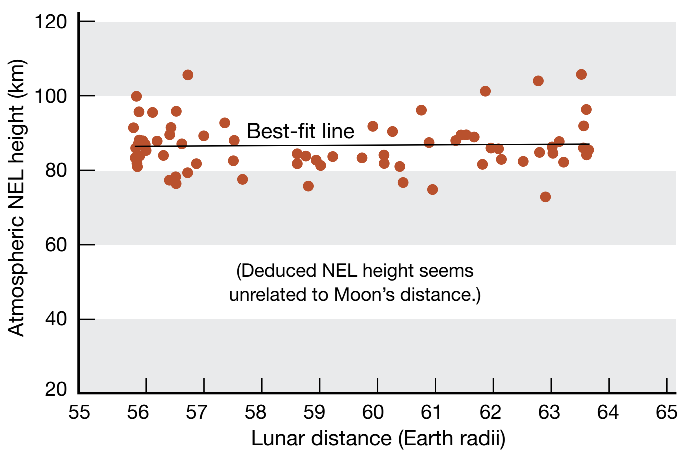
There are circumstances in which the lunar disk can be substantially fainter than my model predicts. These dark eclipses often follow major volcanic eruptions that inject huge quantities of aerosols into Earth's stratosphere. These particles absorb light that would usually be refracted into the umbra under clear atmospheric conditions. For this reason, the values in the table indicate an approximate upper limit to the Moon's brightness during totality.

Forecasts for last May's lunar eclipse suggested that the Hunga Tonga–Hunga Ha'apai eruption in the South Pacific, which occurred earlier this year, might dim the Moon. My model predicted a brightness of magnitude –0.5 — a team of Brazilian amateur observers measured a magnitude of –0.8 with an uncertainty of ±0.3 magnitude. The close agreement of the predicted and observed brightness indicates to me that there was no substantial dimming due to aerosol absorption.

However, unusually dark eclipses certainly do occur. Older readers may remember the eclipse of December 30, 1963, which occurred after the devastating eruption of Mount Agung in Bali, Indonesia. That was the first lunar eclipse that I ever witnessed, and I assumed it was normal for the Moon to practically disappear during totality. Later eclipses proved to be far brighter, and, personally, I have never seen anything to equal that 1963 event.



▲ **SHADOW EDGE** The brightness distribution of sunlight inside Earth's shadow is plotted from the outer edge of the penumbra to the center of the umbra. The colors overlap in the penumbra but separate in the umbra, where red light is 25,000 times brighter than blue at the center of the umbral shadow.



▲ **DRAWING A LINE** This graph plots crater timing data, which indicate that on average the atmospheric add-on to Earth's radius (the Notional Eclipse-forming Layer, NEL) amounts to 87 km (54 mi). Each dot represents the average of timings for a single eclipse.

A Question of Timing

Having described the factors influencing the brightness and color of a lunar eclipse, there remains one additional important phenomenon to consider: the perceived enlargement of Earth's umbral shadow. *Sky & Telescope* readers have monitored the size of the umbra for the past several decades, beginning with a program introduced in 1956 by *S&T*'s Joseph Ashbrook, who later served as editor in chief. Other individuals and organizations have recorded data for even longer.

The method used is quite simple. Telescopic observers note the times when specific lunar craters are covered and uncovered by the umbra's edge (see the table at right). German astronomer Johann Friedrich Julius Schmidt recorded more than 1,000 such timings at Athens Observatory between 1842 and 1879. The late Byron Soulsby of Canberra, Australia, also collected an extensive data set. Recently, David Herald of Murrumbateman, Australia, and *Sky & Telescope* Senior Contributing Editor Roger Sinnott assembled and analyzed more than 22,000 crater timings obtained between 1842 and 2011. They determined that an addition to Earth's radius — what they called "the notional eclipse-forming layer" — amounted to a mean enlargement of 87 kilometers (54 miles). They published their findings in the *Journal of the British Astronomical Association* in 2014 and in this magazine a year later (*S&T:* June 2015, p. 28). One of the graphs from the *S&T* article is presented at left.

We can understand the umbral shadow's increased size by examining brightness as a function of position within Earth's shadow. That relationship is graphed on page 40. Without refraction, the light curve would plummet to infinite magnitude (zero brightness) at the geometric boundary. However, refraction actually begins to reduce the slope of the line higher up. My data show that the rate of brightness change is steepest 211 km outside the geometric boundary. So, although my eclipse model does indicate shadow enlargement, the predicted amount is greater than the 87 km average value reported by observers. What accounts for the difference?

The precise extent of umbral enlargement depends on the state of the atmosphere. The model's 211 km result is

UMBRA GRAPH: GREGG DINDERMAN / S&T, SOURCE: ANTHONY MALLAMA; SHADOW EDGE GRAPH: GREGG DINDERMAN / S&T, SOURCE: ROGER SINNOTT

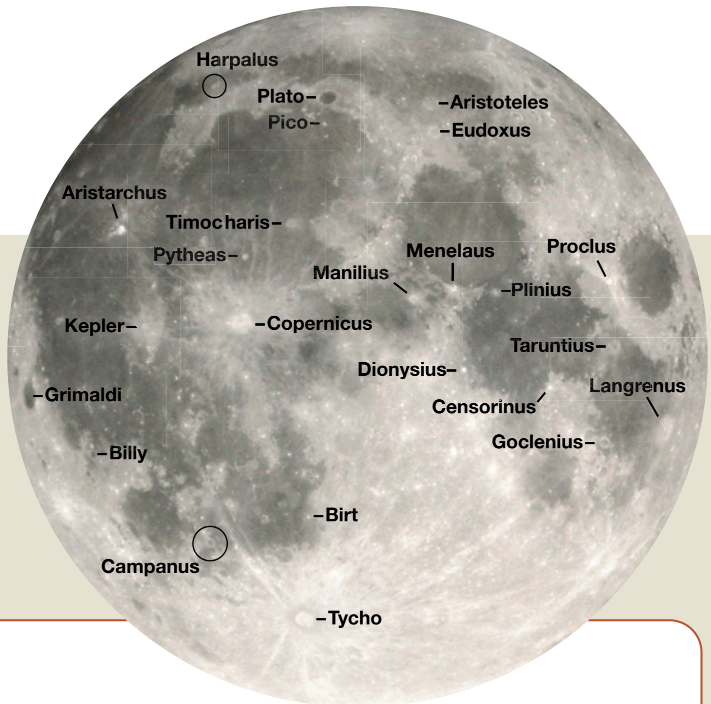
Crater Timing Predictions

ENTRANCES		EXITS	
Feature	**UT**	**Feature**	**UT**
Grimaldi	9:10	Harpalus	11:47
Billy	9:14	Aristarchus	11:49
Kepler	9:20	Grimaldi	11:50
Aristarchus	9:21	Kepler	11:55
Campanus	9:24	Plato	11:55
Copernicus	9:29	Billy	11:57
Pytheas	9:31	Pico	11:57
Birt	9:32	Pytheas	11:59
Tycho	9:33	Timocharis	12:01
Harpalus	9:37	Copernicus	12:02
Timocharis	9:37	Aristoteles	12:04
Pico	9:45	Eudoxus	12:06
Manilius	9:46	Campanus	12:09
Plato	9:47	Manilius	12:15
Dionysius	9:48	Birt	12:16
Menelaus	9:50	Menelaus	12:18
Plinius	9:54	Tycho	12:19
Eudoxus	9:55	Plinius	12:21
Censorinus	9:56	Dionysius	12:23
Aristoteles	9:57	Censorinus	12:31
Goclenius	10:00	Proclus	12:31
Taruntius	10:03	Taruntius	12:35
Proclus	10:05	Goclenius	12:38
Langrenus	10:07	Langrenus	12:44

▶ **CRATER TIMING** Surface features that stand out well during a lunar eclipse are identified here. Approximate times when the umbra's edge will cross them are listed in the table above.

for a perfectly clear atmosphere — any extra attenuation will reduce it. For example, my model doesn't consider some absorbers in the atmosphere. One of these is the ozone layer, which produces the *Chappuis absorption band*, where light transmission is reduced in the visible part of the spectrum. Clouds and high mountains will also block sunlight along Earth's limb, where it's most strongly refracted. Absorption and obstruction counteract the effect of refraction, which is what enlarges the umbra in the first place. Consequently, these added impediments to sunlight make the umbra appear less enlarged and help explain the difference between the model and observations.

Another factor that can account for some of the 124-km difference is that the human eye is not a linear photometric sensor. So, the perceived umbral boundary is not necessarily the same as the steepest brightness gradient. Observers are instructed to record the time the umbra's "edge" reaches the center of a crater — consequently, they could very reasonably take the shadow boundary to be towards the darker side of the steepest part of the slope shown in the graph on page 40. In other words, the computer model and the visual observ-



MOON PHOTO: GARY SERONIK / S&T

Crater Timings Sought!

Researchers are still investigating why the size of Earth's umbra varies slightly from one eclipse to the next. You can measure the extent of the umbral shadow by carefully timing when the edge of the umbra crosses a lunar marking during an eclipse. All you need is a small telescope (using fairly high magnification), an accurate clock, and a notepad or voice recorder.

Simply note when the umbra's edge — where the shadow appears to change brightness most abruptly — crosses a feature's center. Record the time to at least the nearest 5 seconds.

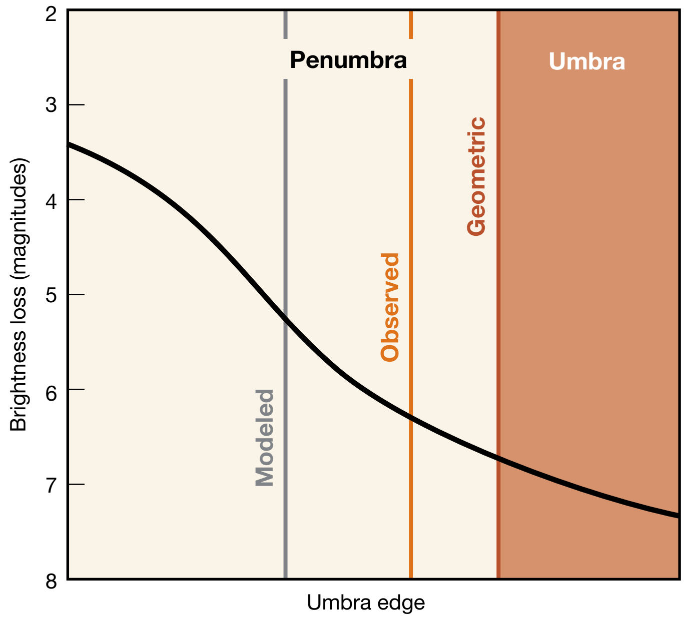
Please report your eclipse timings to Roger Sinnott at **roger.sinnott@verizon.net**.

ers are effectively measuring two different aspects of shadow enlargement. The model provides a quantitative measure of brightness relative to the geometric umbra boundary, while crater timings indicate where the edge of the umbra appears to be located based on human perception.

When the lunar eclipse takes place on the morning of November 8th, Earth's atmosphere will refract sunlight into the umbral shadow and absorb much of the blue light. These factors will dim the eclipsed Moon and give it its characteristic red hue. The eclipse will last slightly longer than expected because the umbra appears to be enlarged — a phenomenon we now understand is a result of atmospheric refraction and absorption.

As you enjoy watching the eclipse, contemplate the nature of this remarkable spectacle with your mind's eye.

■ In 1963 **ANTHONY MALLAMA** cofounded the Chagrin Valley Astronomical Society in Ohio. He later worked as an astronomer on the Hubble Space Telescope and other spacecraft missions at NASA's Goddard Space Flight Center. A technical paper explaining his lunar eclipse model is available at **https://arxiv.org/abs/2112.08966.**



▲ **SHADOW BORDER** The umbral enlargement perceived by visual observers occurs between the steepest brightness gradient calculated by the eclipse model and the purely geometric boundary.

BIG RED MOON This shot of the totally eclipsed Moon was captured during the January 2019 event, during which the Moon passed north of the center of Earth's umbral shadow. The upcoming November 8th eclipse will be similar, but this time the southern edge of the Moon will graze the center of the umbra.

UMBRAL EDGE GRAPH: GREGG DINDERMAN / S&T, SOURCE: ANTHONY MALLAMA; TOTALLY ECLIPSED MOON: GARY SERONIK / S&T

November 2022

1 **DUSK:** Look toward the south to see the first-quarter Moon hanging 4½° below Saturn. Turn to page 46 for more on this and other events listed here.

4 **EVENING:** The waxing gibbous Moon is about 3° below left of Jupiter. Face southeast to take in this sight.

6 **DAYLIGHT-SAVING TIME ENDS** at 2 a.m. for most of the U.S. and Canada.

8 **MORNING:** A total lunar eclipse is visible in the Americas, the Pacific, Asia, and Australia. Viewers in western and northwestern North America could witness the total event provided skies are clear, while those in the middle and eastern side of the continent will catch the partial phases. Go to page 48.

9 **MORNING:** Look to the west to see the Moon, one day past full, around 3° from the Pleiades. You'll want binoculars, though, to enjoy the cluster's stars.

11 **MORNING:** The delightful sight of the waning gibbous Moon nestling up to Mars between the horns of Taurus, the Bull, greets early risers. You'll find the pair high in the west with less than 2½° separating them.

12 **EVENING:** Mars rises in the east-northeast bracketed by the Bull's "horn tips." The Moon follows the trio a bit more than an hour later.

13 **EVENING:** The Moon, Castor, and Pollux form a line above the east-northeastern horizon. The tidiness of the line depends on your viewing location.

16 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:36 p.m. PST (see page 50).

17 **MORNING:** High in the southeast, the Moon, one day past last quarter, sits some 6° left of Regulus in Leo.

18 **MORNING:** The Leonid meteor shower peaks. The waning crescent Moon rises about two hours after the radiant and may hamper viewing somewhat (turn to page 50).

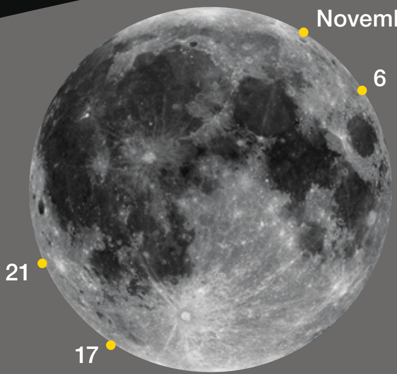
19 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:25 p.m. EST (7:25 p.m. PST).

21 **MORNING:** The thin waning crescent rises in the east-southeast, trailing Virgo's lucida, Spica, by a bit more than 4°.

28 **EVENING:** Low above the southwestern horizon the waxing crescent Moon is around 6° below Saturn. Catch this sight before the pair sink out of view.
— DIANA HANNIKAINEN

Large swaths of the globe, including North America, will witness an eclipse of the Moon on the morning of November 8th. This photo, taken during the lunar eclipse of July 2019, features the Dolomites of northern Italy in the foreground. GIORGIA HOFER

NOVEMBER 2022 OBSERVING
Lunar Almanac
Northern Hemisphere Sky Chart



Yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration.
NASA / LRO

MOON PHASES

SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

FIRST QUARTER
November 1
06:37 UT

FULL MOON
November 8
11:02 UT

LAST QUARTER
November 16
13:27 UT

NEW MOON
November 23
22:57 UT

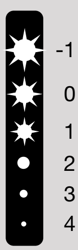
FIRST QUARTER
November 30
14:37 UT

DISTANCES

Apogee 404,921 km	November 14, 07^h UT Diameter 29′ 31″
Perigee 362,826 km	November 26, 02^h UT Diameter 32′ 56″

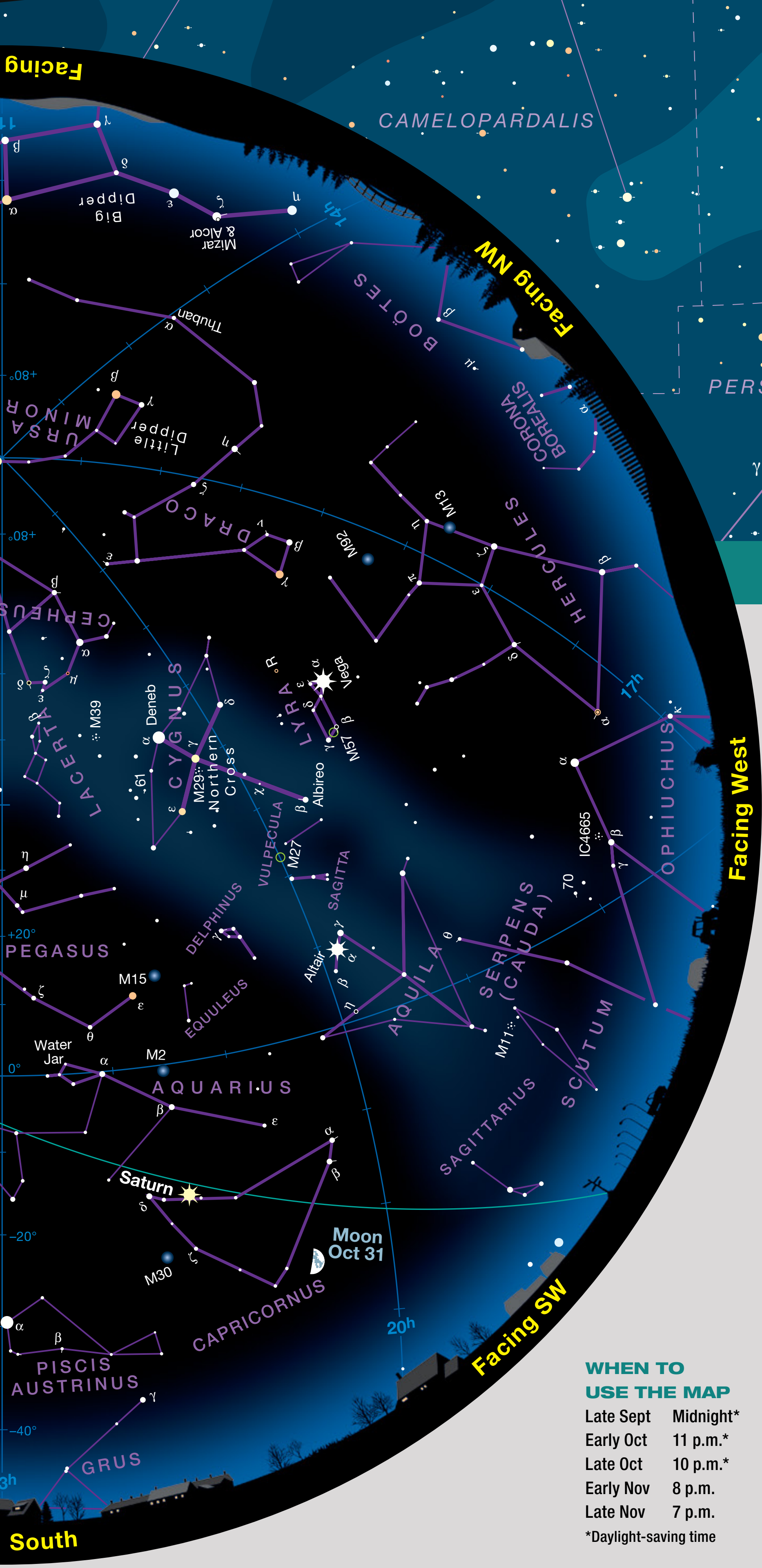
FAVORABLE LIBRATIONS

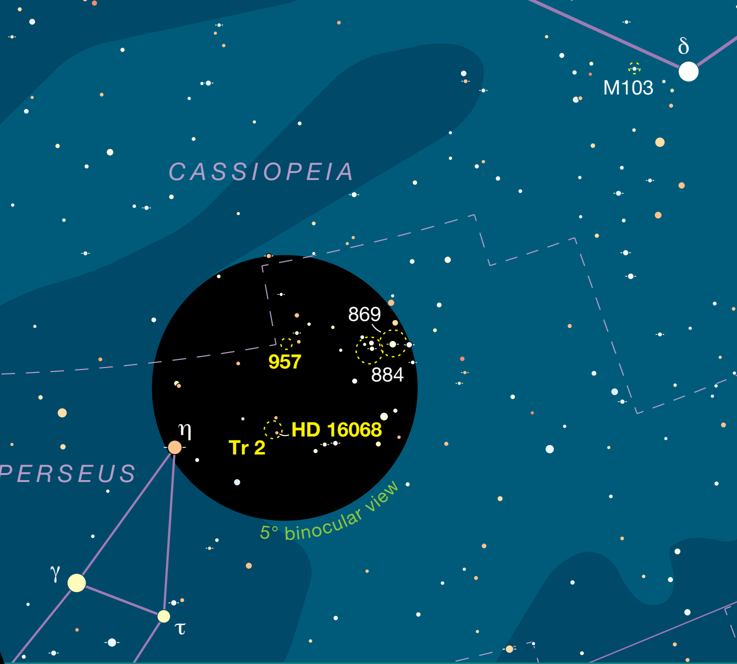
- Mare Humboldtianum — November 3
- Mare Marginis — November 6
- Pingre S Crater — November 17
- Vallis Inghirami — November 21



Planet location shown for mid-month

USING THE NORTHERN HEMISPHERE MAP
Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing. Exact for latitude 40°N.





Binocular Highlight by Mathew Wedel

Roadside Attractions

How many times have I traced the line from Delta (δ) Cassiopeiae to Eta (η) Persei, connecting the Queen and Hero, looking to find the Double Cluster (NGC 869 and NGC 884) floating between them? Hundreds of times at least, and I've only been stargazing for 15 years.

But how many times have I stopped to take in the other celestial wonders along that same route? Shamefully, many times fewer. Let's fix that! Our main target this month is the open cluster **Trumpler 2**, located just a little south of the line between the Double Cluster and Eta Persei. At magnitude 5.9 it's nice and bright, and even detectable with the naked eye under sufficiently dark skies. Trumpler 2 is also more than just a fuzzy blob — in my 10×50 binoculars the brighter stars of the cluster form an arc or sickle shape whose horns point to the Double Cluster and Eta Persei, as if it were a hammock slung between them. With very keen eyes you might spot 7th-magnitude **HD 16068**, a red giant star at the center of the cluster, though I need binoculars to snag it.

Another open cluster, **NGC 957**, sits less than 2° north-northwest of the HD star, making a sort of squashed parallelogram with Trumpler 2, the Double Cluster, and Eta Persei. At magnitude 7.6, NGC 957 is much less bright than Trumpler 2, and it might require darker skies or bigger binos to pull it out of the rich Milky Way background. At roughly 6,000 light-years distant, NGC 957 is about three times farther from us than Trumpler 2. Fittingly, both clusters reside in our galaxy's Perseus Arm, and they help define its grand sweep across the autumn sky. If you follow that starry road, take time to check out all its wonders, not merely the most famous.

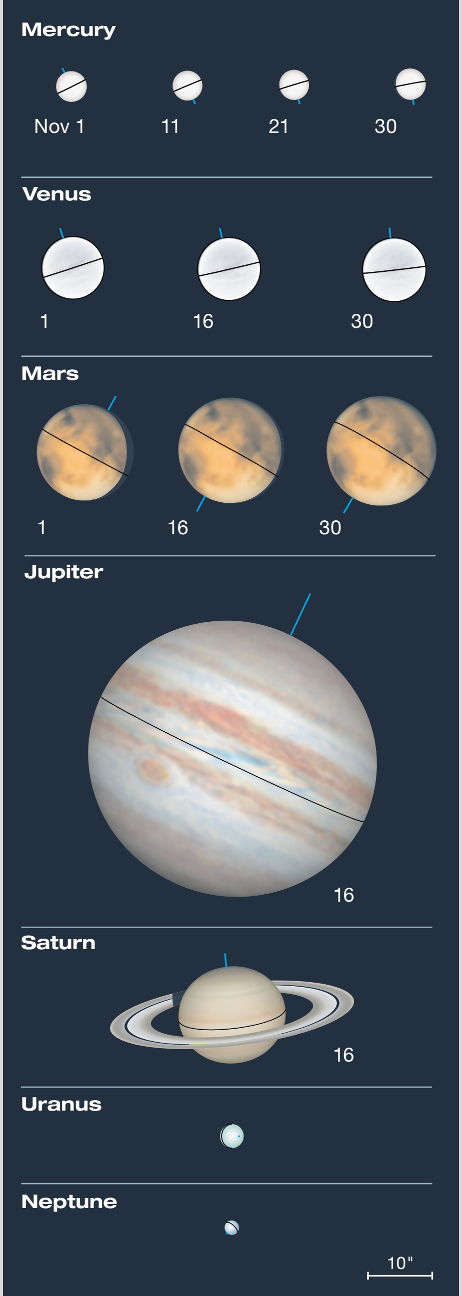
■ MATT WEDEL is always up for a road trip, especially if all he has to pack are his favorite binoculars.

WHEN TO USE THE MAP

Late Sept	Midnight*
Early Oct	11 p.m.*
Late Oct	10 p.m.*
Early Nov	8 p.m.
Late Nov	7 p.m.

*Daylight-saving time

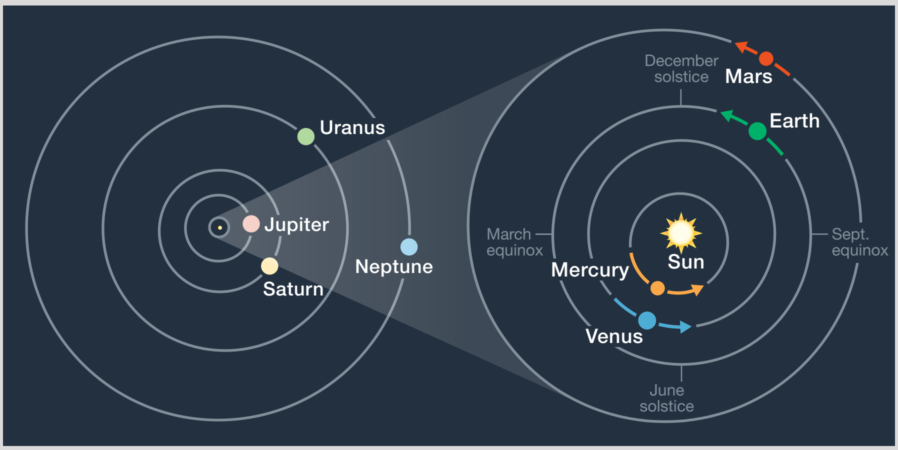
PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** is lost in the Sun's glare all month • **Venus** visible at dusk starting on the 27th • **Mars** rises in the evening and is visible to dawn • **Jupiter** visible at dusk and sets before dawn • **Saturn** transits in the evening and sets before midnight.



November Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$14^h 23.4^m$	–14° 15′	—	–26.8	32′ 13″	—	0.993
	30	$16^h 22.5^m$	–21° 33′	—	–26.8	32′ 26″	—	0.986
Mercury	1	$14^h 05.8^m$	–11° 45′	5° Mo	–1.2	4.8″	99%	1.399
	11	$15^h 08.6^m$	–17° 48′	1° Ev	–1.4	4.7″	100%	1.445
	21	$16^h 12.8^m$	–22° 24′	7° Ev	–0.8	4.7″	98%	1.430
	30	$17^h 12.4^m$	–24° 57′	12° Ev	–0.6	4.9″	95%	1.369
Venus	1	$14^h 33.6^m$	–14° 15′	2° Ev	–4.0	9.7″	100%	1.714
	11	$15^h 23.2^m$	–18° 08′	5° Ev	–3.9	9.8″	100%	1.707
	21	$16^h 15.0^m$	–21° 13′	7° Ev	–3.9	9.8″	99%	1.695
	30	$17^h 03.1^m$	–23° 08′	10° Ev	–3.9	9.9″	99%	1.681
Mars	1	$5^h 39.4^m$	+23° 52′	133° Mo	–1.2	15.1″	94%	0.620
	16	$5^h 30.7^m$	+24° 31′	150° Mo	–1.6	16.6″	97%	0.566
	30	$5^h 11.1^m$	+24° 55′	168° Mo	–1.8	17.2″	100%	0.545
Jupiter	1	$0^h 00.2^m$	–1° 41′	141° Ev	–2.8	47.6″	100%	4.141
	30	$23^h 56.9^m$	–1° 54′	111° Ev	–2.6	43.7″	99%	4.510
Saturn	1	$21^h 24.8^m$	–16° 33′	100° Ev	+0.7	17.3″	100%	9.628
	30	$21^h 29.2^m$	–16° 11′	72° Ev	+0.8	16.5″	100%	10.103
Uranus	16	$2^h 55.8^m$	+16° 22′	173° Ev	+5.6	3.8″	100%	18.695
Neptune	16	$23^h 34.1^m$	–4° 07′	119° Ev	+7.9	2.3″	100%	29.420

The table above gives each object's right ascension and declination (equinox 2000.0) at 0^h Universal Time on selected dates, and its elongation from the Sun in the morning (Mo) or evening (Ev) sky. Next are the visual magnitude and equatorial diameter. (Saturn's ring extent is 2.27 times its equatorial diameter.) Last are the percentage of a planet's disk illuminated by the Sun and the distance from Earth in astronomical units. (Based on the mean Earth–Sun distance, 1 a.u. equals 149,597,871 kilometers, or 92,955,807 international miles.) For other timely information about the planets, visit **skyandtelescope.org**.

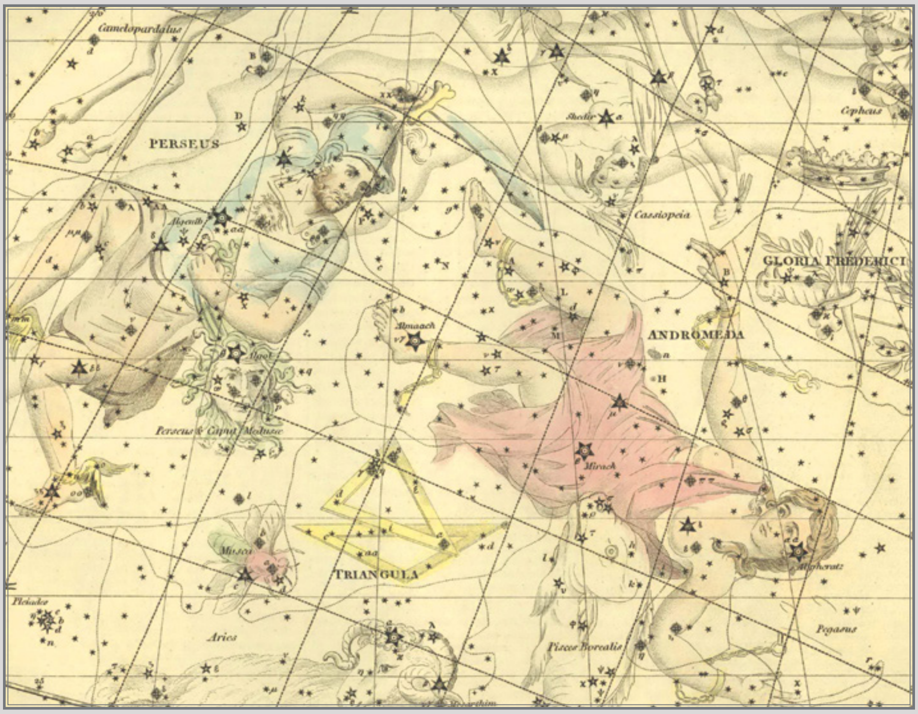


▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

▶ **ORBITS OF THE PLANETS** The curved arrows show each planet's movement during November. The outer planets don't change position enough in a month to notice at this scale.

The Hero and the Demon Star

Algol is much more than the star of a mythical tall tale.



▲ **MYTHICAL MISSION** Sword-wielding Perseus is depicted here holding the severed head of Medusa while Andromeda lies to his left, awaiting rescue. This fanciful illustration is from Alexander Jamieson's 19th-century *Celestial Atlas*.

On November evenings we can fully appreciate an ancient Greek myth that involves no less than six constellations that together occupy roughly a quarter of the sky. The story's cast of colorful characters includes Cassiopeia the Queen, Cepheus the King, Pegasus the Winged Horse, and Cetus the Whale (or Sea-Monster). But the central figures in this particular tale are Andromeda (daughter of Cepheus and Cassiopeia) and mainly Perseus, the hero.

Use our Northern Hemisphere map on pages 42 and 43 as your guide to our dramatis personae as they tread the celestial stage. Facing northeast, you'll find Perseus about halfway between the horizon and the zenith, his form a remarkable collection of moderately bright stars split into two main branches. The long line of stars representing Andromeda points towards Perseus, while the bright zigzag of Cassiopeia lies northward along the Milky Way. Pegasus and Andromeda share a 2nd-magnitude star called Alpheratz. It does double duty as Alpha (α) Andromedae and as the northeast corner of the Great Square of Pegasus. Lastly, surfacing above the evening sky's southeast horizon, is the large but relatively inconspicuous constellation, Cetus.

The most famous star in Perseus is Beta (β) Persei, better known as Algol, and sometimes as the Demon Star. Of all the variable stars in the sky, Algol is perhaps the easiest to follow without optical aid. It usually shines at magnitude 2.1, but every few days it dims dramatically to 3.4. The plunge to minimum brightness takes about 5 hours and the return to maximum the same. The exact period between minima is 2 days, 20 hours, 48 minutes, and 56 seconds.

Algol was the first identified *eclipsing binary* — a stellar system in which a dimmer star regularly eclipses a brighter one. In the case of Algol, something less than 80% of the primary star gets covered, so the eclipse is always partial.

If you want to watch the Demon Star blink, it's best to plan ahead by consulting the table and chart on page 50. Although Algol reaches minimum many times each month, you have to work around daylight (obviously), the weather, and the times when the star is high enough above the horizon during an eclipse. You'll likely have a crack at fewer than half of the 10 November minima listed in the table.

Let's return now to our multi-constellation story. Algol isn't actually a part of the stick figure of Perseus, but rather represents the severed head of Medusa. Medusa was one of the three Gorgon sisters having snakes for hair and faces that were literally petrifying — so dreadful that anyone who gazed at one of them was turned to stone. Perseus managed to safely decapitate Medusa with his sword and deposit her head in a bag, guided by a distorted image of her visage reflected in his bronze shield. Later, he used this grisly trophy to rescue Andromeda, who was chained to a rock and about to be sacrificed to Cetus. Revealing Medusa's head successfully turned the sea monster to stone, allowing Perseus to rescue (and later, wed) Andromeda.

Despite Algol's important role in mythology, there are surprisingly no records of its variability being noted by the ancient Greeks or medieval Arabs (the latter's name for Algol means "the ghoul"). It wasn't until 1667 when the Italian astronomer Geminiano Montanari first recognized Algol's brightness changes. And it wasn't until 1782 that the English observer John Goodricke first established the regularity of the star's period.

■ **FRED SCHAAF** finds that, thanks to computer games, more of his college students today have heard of Medusa than of Perseus and Andromeda.

To find out what's visible in the sky from your location, go to skyandtelescope.org.

The Moon Greets Spica at Dawn

Planets, stars, and even a cluster are on the lunar agenda this month.

TUESDAY, NOVEMBER 1

For those who enjoy keeping up with the brightest members of the solar system, the November evening sky is chock-full of excitement as two planets are in their post-opposition primes, while another one is only a month away from reaching that milestone. And the waxing **Moon** visits all three, starting tonight with **Saturn**. The Ringed Planet was at opposition back in August and now reaches the *meridian* (the imaginary line that joins north to south and passes directly overhead) before any of the other planets. Indeed, as November gets underway, +0.7-magnitude Saturn is due south (and highest) a little after 7:30 p.m. local daylight-saving time. On the evening of the 1st, the Moon is just 4½° away for a fine naked-eye pairing.

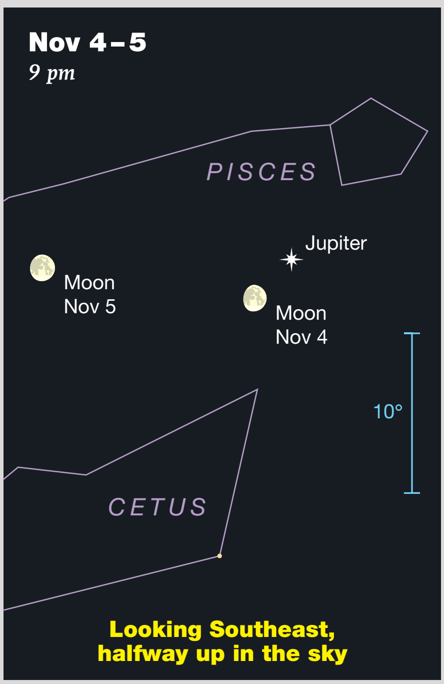
FRIDAY, NOVEMBER 4

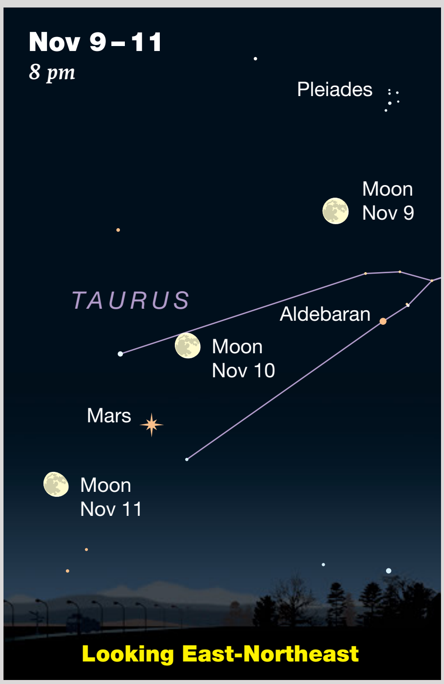
Three nights after its encounter with Saturn, the **Moon** is positioned a little less than 3° from **Jupiter**. This get-together is considerably more striking than the one with Saturn, both because Big Jove is so much brighter and because the Moon approaches quite a bit closer — three Moon diameters closer, as a matter of fact. At magnitude –2.8, Jupiter is by far the brightest planet visible in the sky this evening. It's 25 times brighter than Saturn and outshines Mars by 4 times.

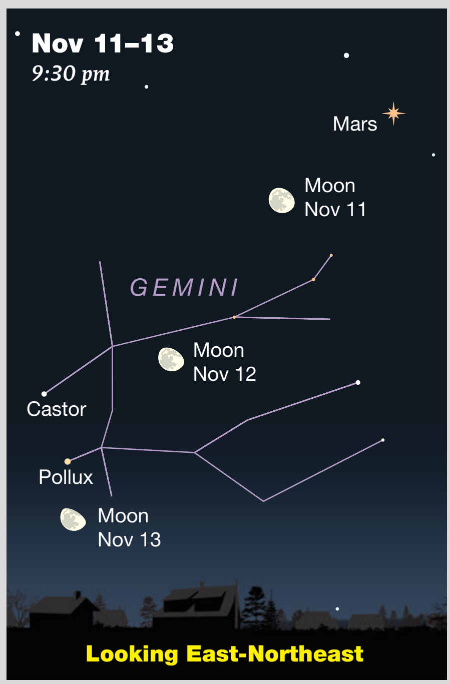
Mind you, that "brightest planet" title is temporary and falls to Jupiter only because brilliant Venus remains hidden in the Sun's glare, having had its solar conjunction on October 22nd. Jupiter's dominance will end when Venus reappears at dusk towards the end of November to reign once again as the Evening Star.

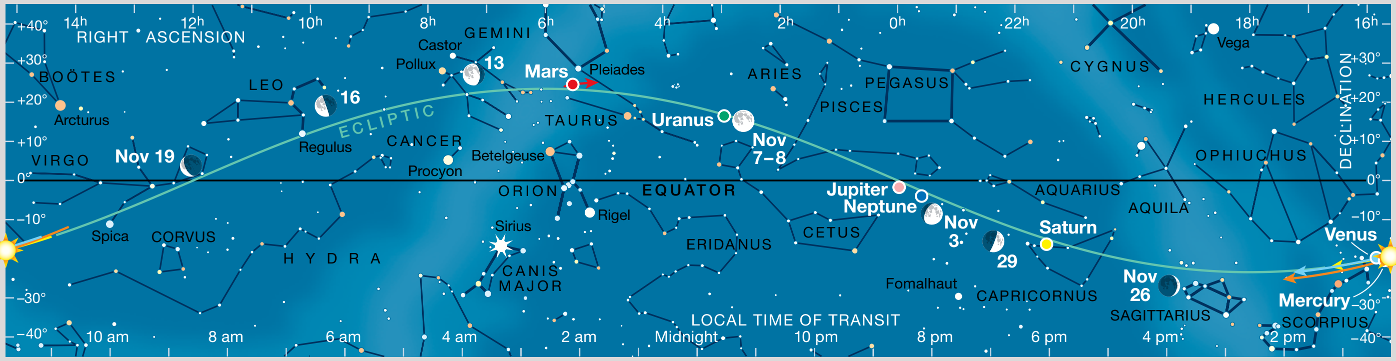
FRIDAY, NOVEMBER 11

Jupiter's main rival this month is **Mars**. At dawn today, the waning gibbous **Moon** pulls up alongside the Red Planet for the closest Moon-and-planet encounter in November. The two objects are situated between the stars marking the tips of Taurus's horns and are less than 2½° apart as morning twilight begins. Although Mars glows brightly at magnitude –1.5, I'd suggest using your binoculars anyway. The planet's rich, orange hue is even more apparent with an optical boost — especially when boldly contrasted with the neutral gray of the lunar disk. It's a striking effect. This is a fine conjunction and definitely worth rising early







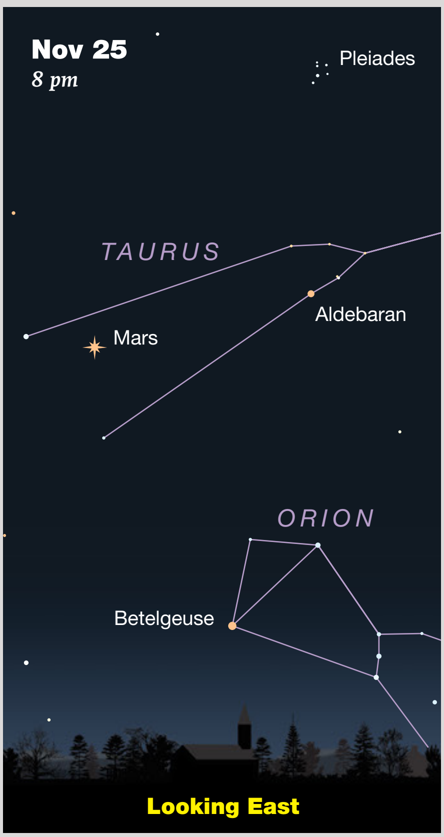


▲ The Sun and planets are positioned for mid-November; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st, and an hour earlier at month's end.

to see, but the best is yet to come. In a little less than a month, Mars will be at its brightest as it meets up with the full Moon. For observers in North America and Europe, the Moon not only gets very close to the planet, it actually eclipses Mars. Much more about that in our December issue!

SUNDAY, NOVEMBER 13

Not every lunar conjunction includes a planet. This evening, cast your gaze toward the east-northeast around 9:30 p.m. (local standard time) to watch the waning gibbous **Moon** rising with not one but *two* bright stars. The luminaries in question are Gemini's **Castor** and **Pollux**. The latter is the brighter of the pair (magnitude 1.2), while at magnitude 1.6 Castor is noticeably fainter. This evening's three-in-a-row arrangement is a bit imperfect, however. For one thing, the Moon is quite a bit closer to Pollux than Pollux is to Castor. And depending on where you are, the alignment might be a bit off-kilter. Skywatchers across most of the eastern half of North America get the most satisfyingly vertical straight line. For observers on the West Coast, the Moon's steady eastward drift will have carried it far enough along that the line is conspicuously bent, though the spacing between elements will be much more even.



MONDAY, NOVEMBER 14

The **Moon** passes near a few open clusters on its monthly journey along the ecliptic. Late this evening it's positioned about 3½° from the **Beehive Cluster** (M44) in Cancer. This will be a binocular-only sight, however. Partly that's because the cluster simply doesn't pack the kind of luster you find in the Hyades or the Pleiades, for example. The other factor is the brightness of the gibbous Moon. It showers the scene with enough light that the Beehive's stars struggle to pierce the background skyglow. That said, things get worse before they get better. For the next several months, the Moon grows even fatter and brighter at each Beehive encounter. It won't be until springtime that the situation improves.

◀ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west). European observers should move each Moon symbol a quarter of the way toward the one for the previous date; in the Far East, move the Moon halfway. For clarity, the Moon is shown three times its actual apparent size.

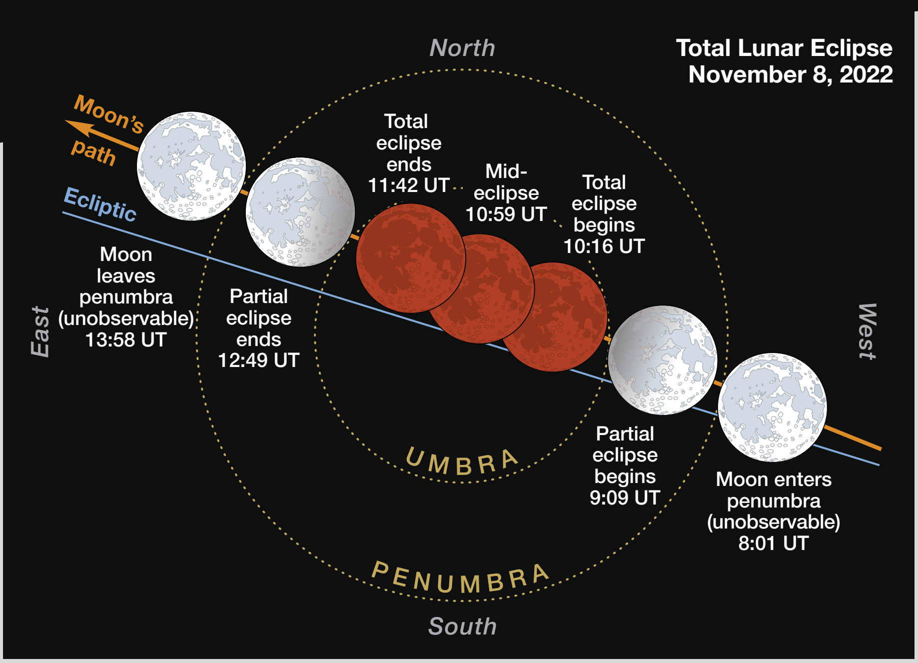
MONDAY, NOVEMBER 21

At dawn today, a thin, waning crescent **Moon** sits 4½° below left of **Spica**, also known as Alpha (α) Virginis. This meeting has been a long time coming — it's the first viewable one since the beginning of August, when the Moon passed within 3° of the first-magnitude star at dusk. Since then, Spica has been lost in the Sun's glare. This morning's event kicks off a new series during which the Moon draws a little nearer to Spica at each passage. However, it won't always be the case that they're closest when they're visible from where you live — some encounters occur during daylight hours or when the star is below the horizon. The best of the upcoming bunch (before Spica again succumbs to twilight late next summer) occurs on July 24, 2023. On that evening the waxing lunar crescent will be half as far from Spica than it is this morning.

■ Consulting Editor **GARY SERONIK** has been keeping an eye on the Moon and planets since childhood.

2022's Final Eclipse

November's total lunar eclipse will be widely visible across the Americas.



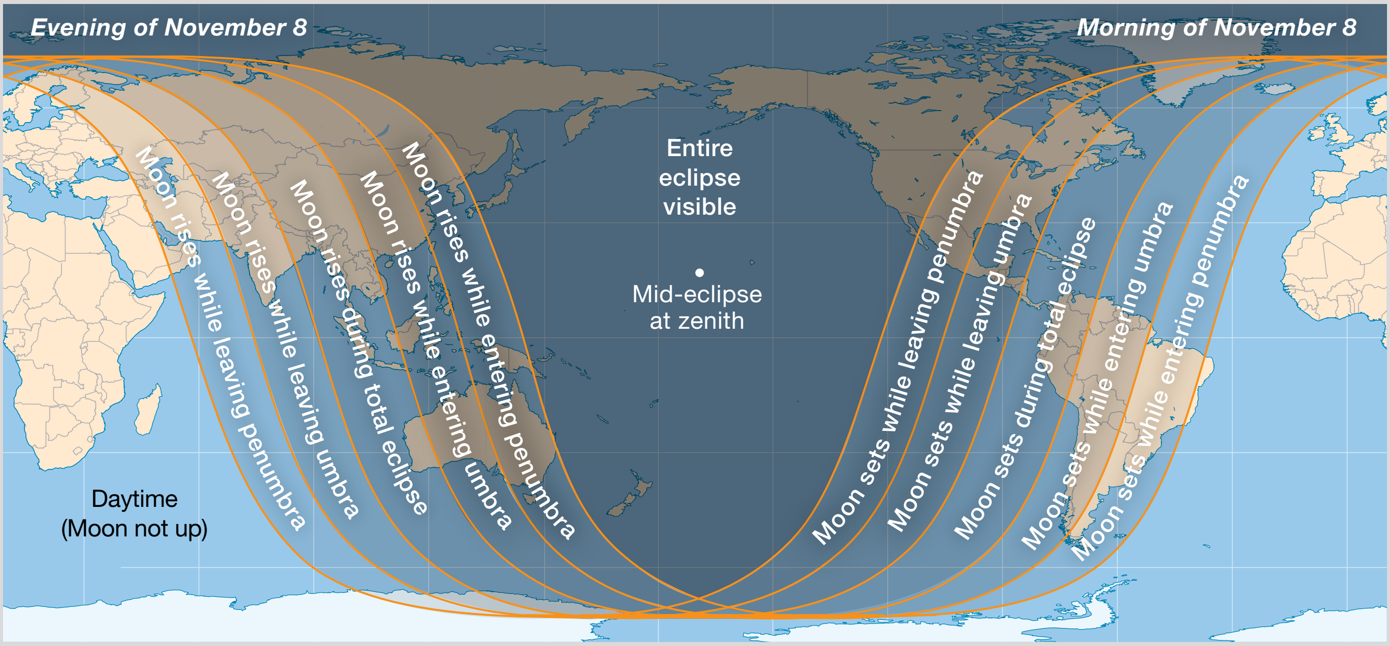
Back in May I stood along the edge of a pond in the company of spring peepers, the most vocal of our local frogs, and watched the Moon slide silently into Earth's shadow. Having recently emerged from hibernation, the males peeped loudly and persistently in search of mates. Six months later, they and their progeny hibernate beneath mud and duff near the same pond, now covered in ice.

A similar seasonal cycle is reflected in this year's pair of total lunar eclipses. During the May event, a perigean Moon traversed the southern half of Earth's umbral shadow. This month's eclipse in the morning hours of November 8th finds the Moon crossing the umbra's northern half, just six days before apogee. Consequently, the diameter of the lunar disk appears 7% smaller than it did in May.

In May the maria-rich northern half of the Moon passed closest to umbral center and appeared strikingly faint to the eye, while the more reflective southern highlands lay closer to the shadow's edge and glowed ruddy orange. This time, the inky interior of Earth's shadow will obscure the Moon's bright highlands, while the maria will be closer to the umbra's edge. I suspect this may have the effect of giving the Moon a homogenous tone during totality.

As the map below shows, some or all of the eclipse will be visible across much of the Americas, the Pacific, Asia, New Zealand, and Australia. For observers in North America, it's an early-morning event with the Moon shining high in the southwestern sky in Aries. The partial phase begins at 9:09 UT (4:09 a.m. EST), though attentive observers will notice the much gentler bite of the penumbra across the eastern half of the Moon well before this.

Totality gets underway at 10:16 UT and lasts 86 minutes until the partial phase resumes at 11:42 UT. From the East Coast, the Moon sets in bright twilight during totality, while Midwest-



LEAH TISCIONE / S&T, SOURCE: USNO (2)

erners will witness all of totality and most of the final partial phases as morning twilight swells. For the western mountain states the Moon sets halfway through its penumbral exit, and farther west the entirety of the eclipse will be visible.

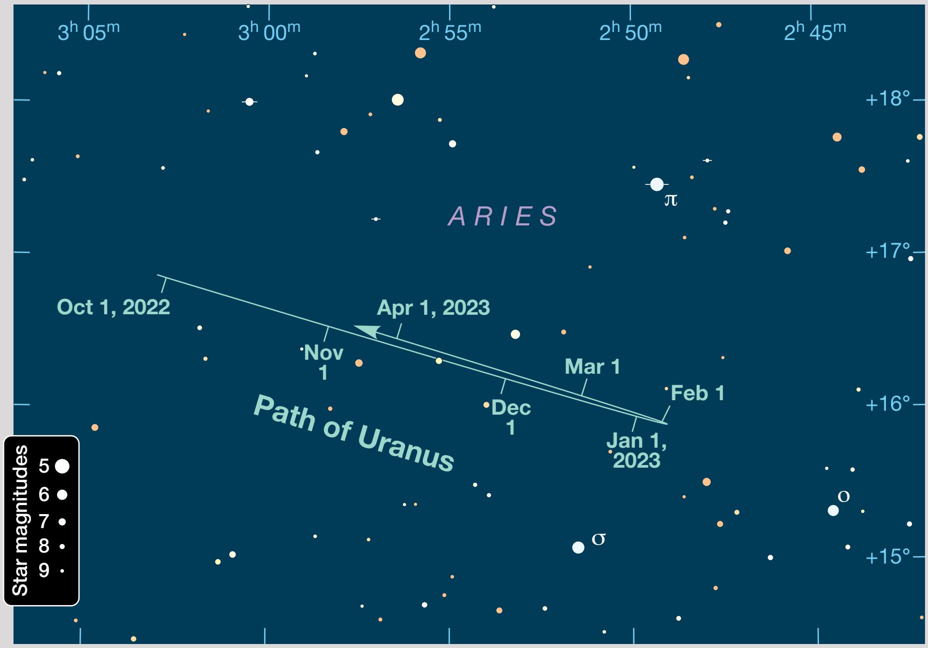
During totality the Moon's leading edge will occult a number of stars. The brightest one is 8.1-magnitude HD 17795, at around 11:30 UT. That's not all — Uranus will also be nearby. The farther west you live, the closer the Moon approaches the 5.6-magnitude planet. Skywatchers in Seattle, Washington, will see the post-eclipse Moon pass approximately 3′ to its north at dawn, while in Anchorage, Alaska, the Moon occults Uranus at about 4:27 a.m. AKST. (For more details, visit: **https://is.gd/UranusNov2022**.)

This November eclipse should be a bit brighter than the one last May since the Moon won't penetrate as deeply into the umbra this time around. *Umbral magnitude* is the fraction of the lunar disk's diameter covered by Earth's umbra and is equal to 1 or greater when the eclipse is total — the larger the number, the more centrally the Moon passes through Earth's umbra. May's value was 1.41, while this month's it's only 1.36.

As noted on page 39, during the partial phases, observers can contribute to a better understanding of how atmospheric changes can alter the size of Earth's shadow by timing when craters enter and exit the umbra.

Of course, you could choose to just relax and savor the scene — and quite a scene it is. The reddened, eclipsed Moon shares the sky with another ruddy luminary, the planet Mars. It's exactly one month before its opposition date, and during the eclipse it beams from Taurus at magnitude –1.4. Also, remember to take a few minutes during totality to examine the sight in a pair of binoculars and appreciate the strangeness of seeing the full Moon surrounded by stars — something that's impossible except during a total lunar eclipse.

Uranus at Opposition

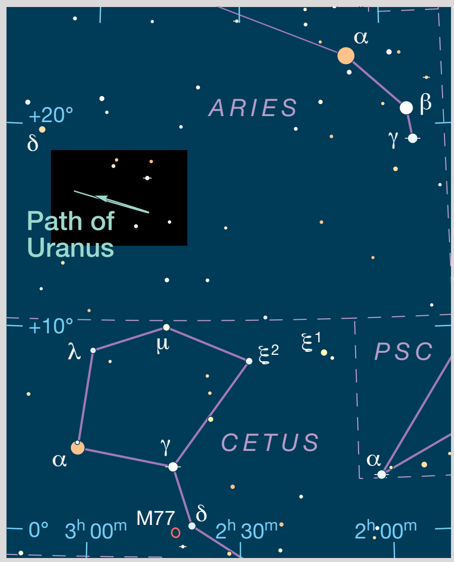


WHEN ARIES' CROOKED FINGER rises in the east and frost stiffens the grass, it's time to seek the seventh planet. Uranus comes to opposition on November 9th in southeastern Aries, moving westward in retrograde motion about 7° northeast of 4.3-magnitude Mu (μ) Ceti, the northernmost star in the head of Cetus, the celestial whale.

Although Uranus glows feebly at magnitude 5.6, its northerly declination this season makes it easier to spot without optical aid under a dark, moonless sky. Bring binoculars and use the maps presented here to track down the planet.

Uranus has a 3.8″-diameter disk that's indistinguishable from a star except through telescopes magnifying around 100× or more. Methane in its atmosphere absorbs sunlight's warmer hues and reflects blue light, coloring the planet a pale turquoise hue.

If you're up for a Uranus challenge, try finding its two brightest moons, Titania (magnitude 13.9) and Oberon (magnitude 14.1). An 8-inch and magnification of 200× to 250× should suffice to dig them out from the planet's glare. To know where and when to look, use visit the Tools page of **skyandtelescope.org** for our handy "Moons of Uranus" interactive observing aid.



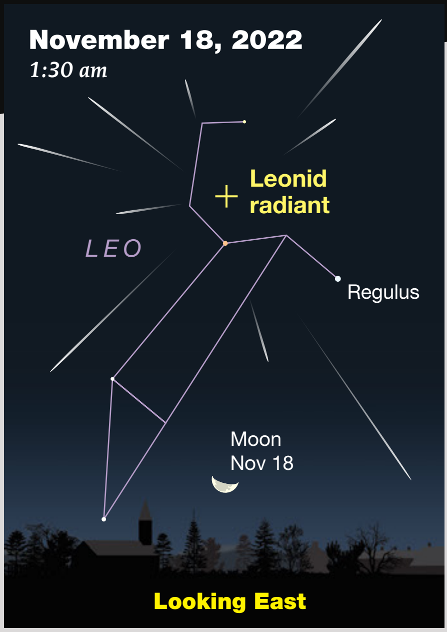
The name "Uranus" wasn't universally in use until 1850 when Her Majesty's Nautical Almanac Office in Britain finally switched from calling it Georgium Sidus, or George's Star. Its discoverer, William Herschel, named it for his patron, King George III. Unsurprisingly, the name didn't gain traction outside of England. German astronomer Johann Bode proposed Uranus, the father of Saturn, which ultimately proved a better fit.

A Triple Leonid Outburst?

THE LEONID METEOR SHOWER is normally a modest affair with 10 to 15 swift meteors per hour visible on the night of November 17-18. But this year's display may be spiced up with multiple outbursts. According to the International Meteor Organization, Earth will cross dust trails laid down by the shower's parent comet, 55P/Tempel-Tuttle, in 1600, 1733, and 1800. The first surge, originating from the 1600 trail, is expected around 7:00 UT (2 a.m. EST) on November 18th, with 5 additional meteors per hour expected.

Anticipation rises when Earth dashes through the wake of cometary particles ejected in 1733. While forecasting shower rates is an inexact science, meteor dynamicist Mikhail Maslov believes a strong outburst from this trail is possible. He predicts a zenithal hourly rate (ZHR) that could reach 250 to 300 with many brighter-than-usual meteors, starting at 6:00 UT on the 19th. That's excellent timing for viewers in eastern North America. The 1800 debris trail provides the final fireworks, with an enhancement of 5 to 10 meteors per hour, expected around 15:00 UT on the 21st. That timing favors Pacific Ocean locations (including Hawai'i) and the Eastern Hemisphere.

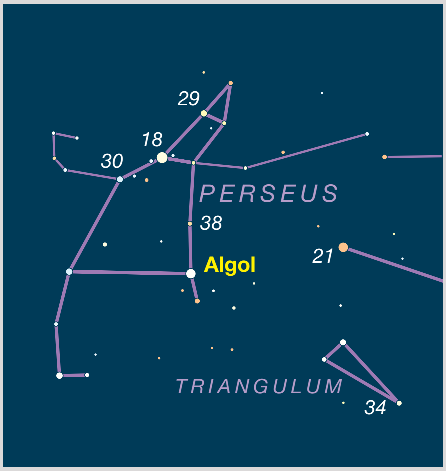
Whichever version(s) of the Leonids we end up with, all you need to enjoy the display are warm clothes and a comfortable reclining chair.



Minima of Algol

Oct.	UT	Nov.	UT
2	9:34	2	22:31
5	6:23	5	19:20
8	3:12	8	16:09
11	0:00	11	12:58
13	20:49	14	9:47
16	17:38	17	6:36
19	14:27	20	3:25
22	11:16	23	0:14
25	8:04	25	21:03
28	4:53	28	17:52
31	1:42		

These geocentric predictions are from the recent heliocentric elements Min. = JD 2457360.307 + 2.867351E, where E is any integer. They were derived by Roger W. Sinnott from 15 photoelectric series in the AAVSO database acquired during 2015–2020 by Wolfgang Vollmann, Gerard Samolyk, and Ivan Sergey. For a comparison-star chart and more info, see **skyandtelescope.org/algol**.



▲ Perseus approaches the zenith after midnight in November. Every 2.7 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Use this chart to estimate its brightness in respect to comparison stars of magnitude 2.1 (Gamma Andromedae) and 3.4 (Alpha Trianguli).

Action at Jupiter

AS NOVEMBER BEGINS, Jupiter is nicely placed for evening telescopic observing. The planet reaches the meridian shortly after 9 p.m., local standard time, where it reaches an altitude of some 48° for those at mid-northern latitudes. On the 1st, Jupiter presents a disk nearly 48″ across and shines brightly at magnitude –2.8 from its perch in southwestern Pisces. The planet doesn't set until after 3 a.m., but it'll cease to be a rewarding high-magnification target a couple of hours before then as its altitude decreases and the chances of steady atmospheric seeing conditions diminish.

Any telescope reveals the four big Galilean moons, and binoculars usually show at least two or three. The moons orbit Jupiter at different rates, changing positions along an almost straight line from our point of view on Earth. Use the diagram on the facing page to identify them by their relative positions on any given date and time. All the observable interactions between Jupiter and its satellites and their shadows are tabulated on the facing page. Find events timed for when Jupiter is at its highest.

Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours.)

October 1: 4:03, 13:59, 23:55; **2**: 9:50, 19:46; **3**: 5:41, 15:37; **4**: 1:32, 11:28, 21:24; **5**: 7:19, 17:15; **6**: 3:10, 13:06, 23:02; **7**: 8:57, 18:53; **8**: 4:48, 14:44; **9**: 0:40, 10:35, 20:31; **10**: 6:26, 16:22; **11**: 2:18, 12:13, 22:09; **12**: 8:05, 18:00; **13**: 3:56, 13:51, 23:47; **14**: 9:43, 19:38; **15**: 5:34, 15:30; **16**: 1:25, 11:21, 21:16; **17**: 7:12, 17:08; **18**: 3:03, 12:59, 22:55; **19**: 8:50, 18:46; **20**: 4:41, 14:37; **21**: 0:33, 10:28, 20:24; **22**: 6:20, 16:15; **23**: 2:11, 12:07, 22:02; **24**: 7:58, 17:53; **25**: 3:49, 13:45, 23:40; **26**: 9:36, 19:32; **27**: 5:27, 15:23; **28**: 1:19, 11:14, 21:10; **29**: 7:06, 17:01; **30**: 2:57, 12:53, 22:48; **31**: 8:44, 18:40

November 1: 4:40, 14:36; **2**: 0:32, 10:27, 20:23; **3**: 6:19, 16:14; **4**: 2:10, 12:06, 22:01; **5**: 7:57, 17:53; **6**: 3:48, 13:44, 23:40; **7**: 9:35, 19:31; **8**: 5:27, 15:22; **9**: 1:18, 11:14, 21:09; **10**: 7:05, 17:01; **11**: 2:57, 12:52, 22:48; **12**: 8:44, 18:39; **13**: 4:35, 14:31; **14**: 0:26, 10:22, 20:18; **15**: 6:14, 16:09; **16**: 2:05, 12:01, 21:56; **17**: 7:52, 17:48; **18**: 3:44, 13:39, 23:35; **19**: 9:31, 19:26; **20**: 5:22, 15:18; **21**: 1:14, 11:09, 21:05; **22**: 7:01, 16:56; **23**: 2:52, 12:48, 22:44; **24**: 8:39, 18:35; **25**: 4:31, 14:27; **26**: 0:22, 10:18, 20:14; **27**: 6:10, 16:05; **28**: 2:01, 11:57, 21:52; **29**: 7:48, 17:44; **30**: 3:40, 13:35, 23:31

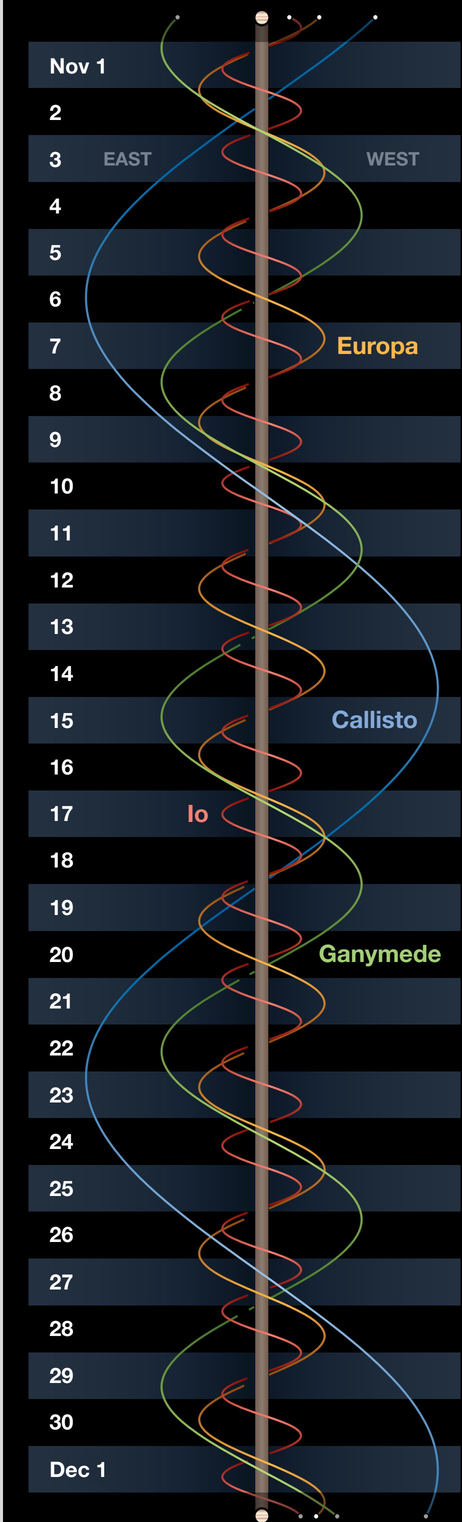
These times assume that the spot will be centered at System II longitude 28° on November 1st. If the Red Spot has moved elsewhere, it will transit 1²/₃ minutes earlier for each degree less than 28° and 1²/₃ minutes later for each degree more than 28°.

Phenomena of Jupiter's Moons, November 2022

Nov. 1	2:09	II.Oc.D
	2:24	I.Oc.D
	5:28	I.Ec.R
	6:26	II.Ec.R
	23:37	I.Tr.I
Nov. 2	0:30	I.Sh.I
	1:50	I.Tr.E
	2:43	I.Sh.E
	20:45	III.Tr.I
	20:45	II.Tr.I
	20:51	I.Oc.D
	22:30	II.Sh.I
	23:15	II.Tr.E
	23:31	III.Tr.E
	23:56	I.Ec.R
Nov. 3	0:22	III.Sh.I
	1:00	II.Sh.E
	3:08	III.Sh.E
	18:04	I.Tr.I
	18:58	I.Sh.I
	20:17	I.Tr.E
	21:12	I.Sh.E
Nov. 4	15:17	I.Oc.D
	15:20	II.Oc.D
	18:25	I.Ec.R
	19:46	II.Ec.R
Nov. 5	12:31	I.Tr.I
	13:28	I.Sh.I
	14:44	I.Tr.E
	15:41	I.Sh.E
Nov. 6	9:44	I.Oc.D
	9:55	II.Tr.I
	10:22	III.Oc.D
	11:48	II.Sh.I
	12:25	II.Tr.E
	12:54	I.Ec.R
	13:11	III.Oc.R
	14:15	III.Ec.D
	14:18	II.Sh.E
	17:01	III.Ec.R
Nov. 7	6:58	I.Tr.I
	7:56	I.Sh.I
	9:11	I.Tr.E
	10:09	I.Sh.E
Nov. 8	4:11	I.Oc.D
	4:31	II.Oc.D
	7:23	I.Ec.R
	9:05	II.Ec.R
Nov. 9	1:25	I.Tr.I
	2:25	I.Sh.I
	3:39	I.Tr.E
	4:38	I.Sh.E
	22:38	I.Oc.D
	23:06	II.Tr.I
Nov. 10	0:15	III.Tr.I
	1:06	II.Sh.I
	1:36	II.Tr.E
	1:51	I.Ec.R
	3:04	III.Tr.E
	3:35	II.Sh.E
	4:25	III.Sh.I
	7:09	III.Sh.E
	19:53	I.Tr.I
	20:54	I.Sh.I
	22:06	I.Tr.E
	23:07	I.Sh.E
Nov. 11	17:05	I.Oc.D
	17:43	II.Oc.D
	20:20	I.Ec.R
	22:24	II.Ec.R
Nov. 12	14:20	I.Tr.I
	15:23	I.Sh.I
	16:33	I.Tr.E
	17:36	I.Sh.E
Nov. 13	11:32	I.Oc.D
	12:17	II.Tr.I
	13:55	III.Oc.D
	14:24	II.Sh.I
	14:48	II.Tr.E
	14:49	I.Ec.R
	16:47	III.Oc.R
	16:53	II.Sh.E
	18:18	III.Ec.D
	21:03	III.Ec.R
Nov. 14	8:47	I.Tr.I
	9:52	I.Sh.I
	11:00	I.Tr.E
	12:05	I.Sh.E
Nov. 15	6:00	I.Oc.D
	6:56	II.Oc.D
	9:18	I.Ec.R
	11:43	II.Ec.R
Nov. 16	3:15	I.Tr.I
	4:21	I.Sh.I
	5:28	I.Tr.E
	6:34	I.Sh.E
Nov. 17	0:27	I.Oc.D
	1:29	II.Tr.I
	3:42	II.Sh.I
	3:47	I.Ec.R
	3:50	III.Tr.I
	4:00	II.Tr.E
	6:11	II.Sh.E
	6:41	III.Tr.E
	8:28	III.Sh.I
	11:10	III.Sh.E
	21:42	I.Tr.I
	22:50	I.Sh.I
	23:55	I.Tr.E
Nov. 18	1:03	I.Sh.E
	18:54	I.Oc.D
	20:10	II.Oc.D
	22:15	I.Ec.R
Nov. 19	1:03	II.Ec.R
	16:10	I.Tr.I
	17:19	I.Sh.I
	18:23	I.Tr.E
	19:32	I.Sh.E
Nov. 20	13:22	I.Oc.D
	14:42	II.Tr.I
	16:44	I.Ec.R
	17:00	II.Sh.I
	17:12	II.Tr.E
	17:33	III.Oc.D
	19:29	II.Sh.E
	20:26	III.Oc.R
	22:20	III.Ec.D
Nov. 21	1:04	III.Ec.R
	10:38	I.Tr.I
	11:48	I.Sh.I
	12:51	I.Tr.E
	14:01	I.Sh.E
Nov. 22	7:49	I.Oc.D
	9:23	II.Oc.D
	11:13	I.Ec.R
	14:22	II.Ec.R
Nov. 23	5:06	I.Tr.I
	6:17	I.Sh.I
	7:19	I.Tr.E
	8:30	I.Sh.E
Nov. 24	2:17	I.Oc.D
	3:55	II.Tr.I
	5:42	I.Ec.R
	6:18	II.Sh.I
	6:26	II.Tr.E
	7:31	III.Tr.I
	8:46	II.Sh.E
	10:23	III.Tr.E
	12:31	III.Sh.I
	15:12	III.Sh.E
	23:33	I.Tr.I
Nov. 25	0:46	I.Sh.I
	1:46	I.Tr.E
	2:59	I.Sh.E
	20:45	I.Oc.D
	22:38	II.Oc.D
Nov. 26	0:11	I.Ec.R
	3:41	II.Ec.R
	18:01	I.Tr.I
	19:15	I.Sh.I
	20:14	I.Tr.E
	21:28	I.Sh.E
Nov. 27	15:13	I.Oc.D
	17:08	II.Tr.I
	18:40	I.Ec.R
	19:36	II.Sh.I
	19:40	II.Tr.E
	21:15	III.Oc.D
	22:04	II.Sh.E
Nov. 28	0:10	III.Oc.R
	2:23	III.Ec.D
	5:05	III.Ec.R
	12:29	I.Tr.I
	13:44	I.Sh.I
	14:42	I.Tr.E
	15:57	I.Sh.E
Nov. 29	9:40	I.Oc.D
	11:53	II.Oc.D
	13:08	I.Ec.R
	14:28	II.Oc.R
	14:29	II.Ec.D
	17:00	II.Ec.R
Nov. 30	6:57	I.Tr.I
	8:13	I.Sh.I
	9:11	I.Tr.E
	10:26	I.Sh.E

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

Jupiter's Moons



The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites' positions east or west of Jupiter.

Seeing the True Colors of Mars

A lesson for astronomers from a chemist

Like the Moon, Mars displays a distinctive pattern of light and dark areas that early astronomers designated as *terrae* (lands) and *maria* (seas). The notion that the dark areas were actual bodies of water was abandoned late in the 19th century in favor of the belief that they were tracts of vegetation. Unlike their lunar counterparts, the Martian maria exhibit seasonal changes in intensity and seasonal changes in outline suggestive of the growth and decay of vegetation like we experience here on Earth. But the major underpinning of the vegetation theory stemmed from the fact that many observers perceive the color of the dark areas on Mars as distinctly bluish-green.

The palette of reported colors includes grass green, moss green, olive, teal, and even robin's-egg blue. These eyepiece impressions are so common that a popular 1953 book about the possibility of life on Mars, written by physiologist and space-medicine pioneer Hubertus Strughold, bore the title *The Green and Red Planet*. Yet all these vivid hues are literally in the eye of the beholder — the products of an optical illusion discovered early in the previous century by a French chemist.

Michel-Eugène Chevreul (1786-1889) was a towering figure of chemistry in the 19th century. In 1823 he embarked on an exhaustive study of natural dyes and was soon appointed Director of Dyeing at the Manufacture des Gobelins, France's national tapestry workshop, where he was tasked with improving color fastness and intensity in woolen goods.

As part of his rigorous approach to the technology of dyeing, Chevreul also investigated color perception. He discovered that the perceived color of an object depends on the color and brightness of its surroundings, which he called "the law of simultaneous contrast of colors." He wrote: "In the case when the eye sees at the same time two contiguous colors, they will appear as dissimilar as possible, both in their optical composition and in the height of their tone."

Simultaneous contrast causes colored highlights to impart their complementary hue to any adjacent low-luminosity features. For Mars observers, the implications should have been obvious — a dark neutral marking viewed against a bright reddish background will take on a bluish-green cast. In his 1833 work *A Treatise on Astronomy*, the British astronomer (and accomplished chemist) Sir John Herschel dismissed the greenish color of the Martian maria as a contrast illusion arising from "a general law in optics." Indeed, many impressionist painters made great use of simultaneous contrast, yet only a handful of astronomers seemed to be aware of it. By the dawn of the 20th century, leading Mars observers like Eugène Antoniadi and Percival Lowell seemed oblivious to the illusion.

Gerard Kuiper made a very painstaking attempt to determine the true colors of Mars during the planet's 1954 apparition. Widely regarded as the father of modern planetary science, Kuiper used

▲ This color composite of Mars captured by the European Space Agency's Rosetta spacecraft attempts to accurately depict the planet's true hues.

ESA & MPS FOR OSIRIS TEAM MPS / UPD / LAM / IAA / RSSD / INTA / UPM / DASP / IDA the 82-inch Cassegrain reflector at the University of Texas's McDonald Observatory, employing a binocular viewer (a rare accessory at the time) and a pair of eyepieces that yielded a magnification of 900×. At this generous image scale, the Martian disc appeared a whopping 6° in diameter — 12 times the diameter of the Moon seen with the unaided eye.

Kuiper placed a chart issued by the Glidden Paint Company containing 180 rectangular swatches of various color shades at arm's length just below the eyepiece and illuminated it with a lamp that was a close spectral match for sunlight. The intensity of the lamp was carefully adjusted to match the apparent surface brightness of the chart's color patches with the telescopic image of Mars.

To Kuiper's surprise, the apparent color of the planet's dark markings seemed to depend greatly on the quality of the seeing. He noted that Mare Acidalium had a greenish hue in poor or average seeing, but when the seeing improved, it lost nearly all green color, and whenever the seeing was truly excellent, it had the same ochre color as its surroundings. These visual impressions were repeated on several nights.

Kuiper resumed his color observations in 1956. Once again, he found that with rare exceptions "the dark areas are, to a first approximation, *neutral*, having the same color as the rest of the planet, only darker."

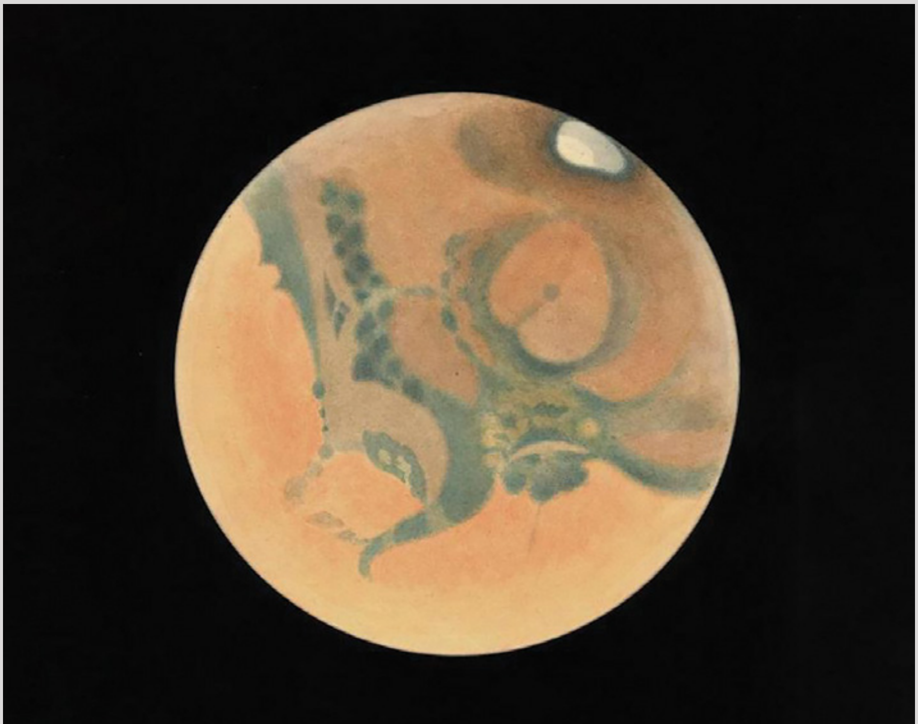
> *The dark regions look somewhat greenish at first, but this color disappears when one looks straight at the area in question. The initial color impression seems to be due to contrast with the ocher desert regions. If one looks straight at the dark areas, there is no apparent correlation between seeing and color, as was reported in my 1954 observations. Apparently, this correlation was due to the circumstance that, with poor seeing, the eye tends to wander over the planet while, with good seeing, it fixes on the area being studied.*

Kuiper's account points to a phenomenon that perceptual psychologists call negative afterimages. We perceive color using our retina's cone cells. There are three types of cone cells, each containing a different photopigment that responds to light of long wavelengths (orange-red), medium wavelengths (yellow-green), or short wavelengths (blue-violet). When these photoreceptors are overstimulated, their photopigments are depleted and they lose sensitivity. Normally, images on the retina are moved to fresh photoreceptors by tiny, random, involuntary eye movements. But if you stare at a brightly illuminated red object for 20 to 30 seconds, then shift your gaze to a white or grey surface, you will briefly see a ghostly afterimage with a cyan (blue-green) complementary color.

William K. Hartmann, who received his doctorate in astronomy as a student of Kuiper at the University of Arizona, is a talented artist whose paintings of planetary landscapes are among the most realistic. In 1988, Hartmann observed Mars with a 24-inch Cassegrain reflector from the summit of Mauna Kea. Although the dark markings looked "bluish-grey" at the eyepiece, he found that in "a textbook display of simultaneous contrast" they could be very realistically depicted in an acrylic painting using only pigments on the warm (reddish brown) side of neutral.

According to the renowned space artist Don Davis, the appearance of the dusty soil covering Mars is a drab, ruddy brown that's a dead ringer for cumin spice powder. The dark, feldspar-rich basalt rocks that comprise the planet's dusky features are generally neutral grey, with thin, ephemeral coatings of dust deposited and swept away according to the whims of Martian winds.

When you observe Mars during this apparition, bear in mind the phenomenon of simultaneous contrast and how it influences your eyepiece impressions. Perhaps you'll see the planet in a whole new light.



Eugène Antoniadi depicted the colors of Martian markings in shades of green in this beautiful 1909 watercolor. Even the most gifted observers can be deceived by the effects of simultaneous contrast. South is up.

COURTESY RICHARD MCKIM

■ A chemist by profession, Contributing Editor **TOM DOBBINS** has often observed simultaneous contrast while studying Mars at the eyepiece.

Off the Beaten Track in Perseus

Two open clusters in southern Perseus are modest but worthy targets.

Mid-November, nightfall. No clouds. I quickly spot Perseus already halfway up the northeastern sky. Keeping track of the curvy star pattern as it climbs higher becomes a neck-craning exercise. Viewed from my suburban home near the 49th parallel, the constellation stands directly overhead by midnight. Best to observe it early.

There's lots of deep-sky treasure here. Because the Milky Way runs through Perseus, it's home to almost two dozen open clusters, including the famous Double Cluster and splashy M34. However, tonight I'm interested in a couple of modest specimens located in the constellation's southern region. I can find them easily via the star-hop method, using my 4¼-inch (108-mm) f/6 Newtonian reflector.

To help the hop, I need to aim the scope at a suitable celestial landmark. My choice is 3rd-magnitude **Epsilon (ε) Persei**. Epsilon is a worthy target in its own right, as it's a strongly unbalanced double. The 2.9- and 8.9-magnitude components, 8.8″ apart, resolve nicely in the 4¼-inch at 93×. It's a good start to the evening's work.

Dragon Cluster

The first cluster on my list, 7.0-magnitude **NGC 1582**, lies a little more than 7° northeast of Epsilon Persei. The 6×30 finderscope on my compact Newtonian is adequate but not exactly deluxe for star-hopping. Happily, the route to NGC 1582 isn't difficult — though it pays to study the chart on the facing page before going outside.

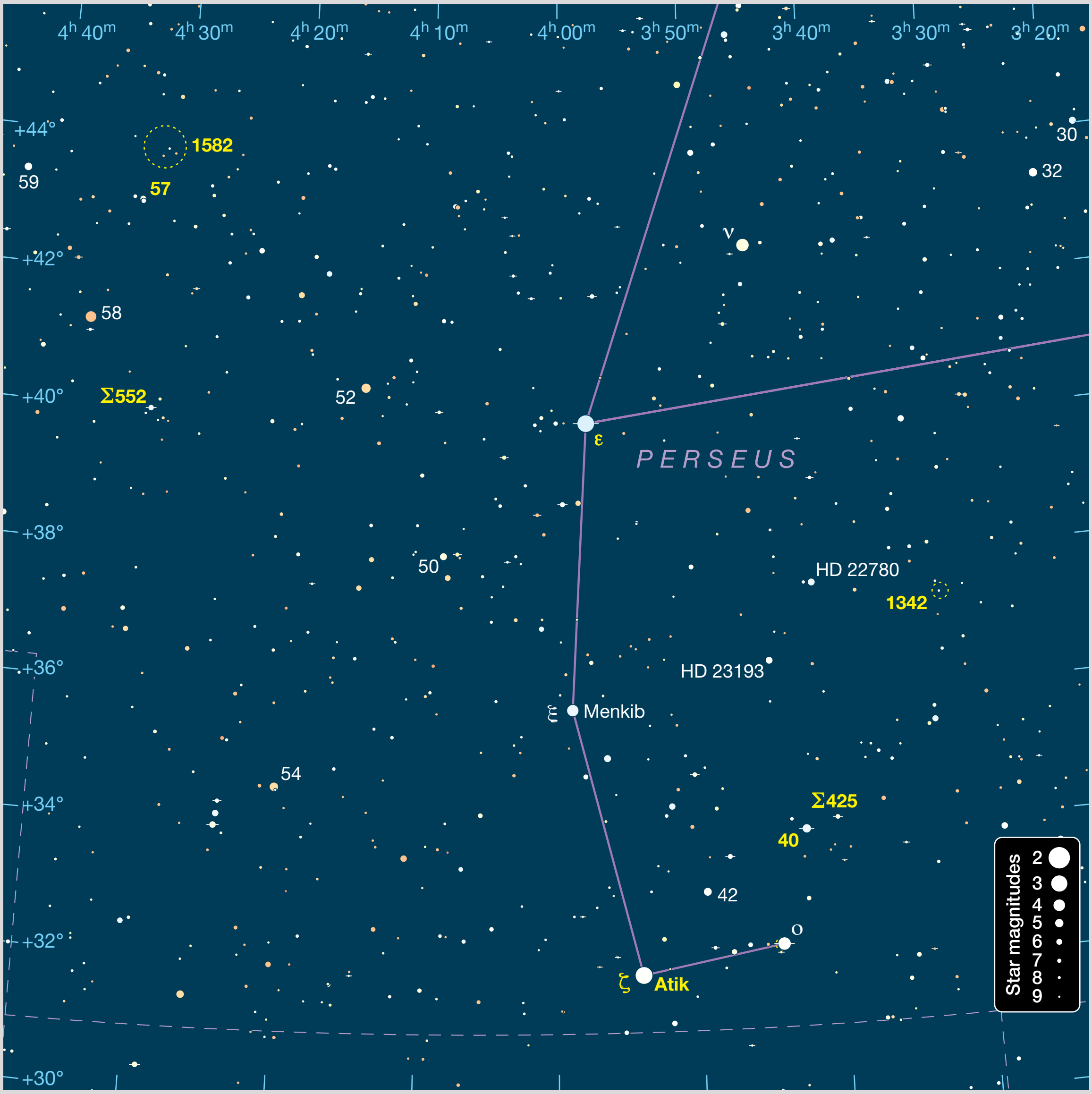
From Epsilon, I head eastward about 3¼° to 4.7-magnitude 52 Persei, then go a little more than 4° in the same direction to 4.3-magnitude 58 Persei and turn north-northwestward for 2° to **57 Persei**. The latter is a finder-friendly double dot comprising eye-catching 6.1- and 6.8-magnitude stars 2′ apart. A line extended from 58 Persei through 57 reaches NGC 1582, less than a degree north of the double. The cluster doesn't show in my 6× finder, but it's plainly visible in the main scope at 27×.

NGC 1582 is sparsely populated. However, the 24′-wide cluster presents an unusual shape to small, city-based optics. My little reflector at 27× picks up a sinuous pattern, oriented broadly east-west and dominated by three 9th-magnitude stars — two of them orange, the third blue-white. In total, I count about 14 stars down to 11th magnitude. The western end of the serpentine star cluster is headed by a quadrilateral reminiscent of the head of Draco, the Dragon. Upping the magnification to 54× confirms that the southern corner of the quadrilateral is established by an attractive pairing of 10.7- and 10.9-magnitude stars 45″ apart.

At approximately the midpoint of my Dragon Cluster are three dim stars delineating a bent line 48″ in length. The trio is indistinct at 54× but obvious at 93×. This moderately high magnifi-

◀ **SERPENTINE SYSTEM** The open star cluster NGC 1582 is a loose collection of just 20 stars, but the sinuous pattern it forms is pleasing to the eye. Its similarity to the constellation Draco has inspired the author to dub it the Dragon Cluster.

JIM THOMMES



OFF-ROADING IN PERSEUS The author's tour area in southern Perseus covers a fair amount of sky. The first cluster on his list, NGC 1582, lies almost halfway from Epsilon Persei to zero-magnitude Capella in neighboring Auriga.

cation pulls in numerous other faint stars, most of them pooled around the mini-Draco's strongly curled tail. In the tail itself, one star of magnitude 9.8 isn't quite tack-sharp; adding a 2× Barlow to the eyepiece reveals a weak attendant. Curiously, this pair isn't listed in the reputable and exhaustive *Washington Double Star Catalog*.

After NGC 1582, I return to orangey 58 Persei, then veer southwest for 1½° to a clump of a half-dozen 8th- and 9th-magnitude stars loosely bundled around one prominent star. That hub star is a binary called **Struve (Σ) 552**. Its 6.8- and 7.2-magnitude components, 9″ apart, resolve at 38×. Lovely sight!

Admiring Σ552 leads to a bonus: A 6½° sweep of the scope directly westward returns me to my landmark star — Epsilon Persei.

Zigzag Cluster

The second cluster on my list, 6.7-magnitude **NGC 1342**, lies a bit less than 6° west-southwest of Epsilon. Like NGC 1582, this pale puddle of stars is beyond the range of my modest finderscope. It's important to visualize the cluster's location by referring to our chart. NGC 1342 forms the vertex of a isosceles triangle made with Epsilon and 4th-magnitude Xi (ξ) Persei.

Four star-hops get me to the destination. The first one is a slam-dunk: I simply shift 4¼° southward from Epsilon to Xi. Then I head 3° west-northwestward to 5.6-magnitude HD 23193, veer northwestward for 1⅓° to similarly bright HD 22780, and hop due west nearly 1° to my quarry — invisible in the finder but readily apparent in the main scope.

NGC 1342 is 17′ wide and, like NGC 1582, seems thinly populated. It shares another similarity with my Dragon Cluster in that its lucida is magnitude 8.7. In my reflector at 27×, NGC 1342 displays a 15′-long zigzag of at least eight 9th- to 11th-magnitude stars, lined up roughly east-west. A pair of 8.4- and 9.2-magnitude stars, 2.5′ apart, are on the cluster's northeastern edge. Another tandem of 8.9- and 9.2-magnitude stars, 1.3′ apart, lie approximately 20′ west of the cluster's center. The main zigzag plus the two extras span some 40′ of sky — a comfy fit in any low-power field.

Upping to 93× produces another four or five points in the zigzag. Images of the cluster show its core stars glowing orange, blue, and white. Unlike with NGC 1582, though, the pleasing colors in NGC 1342 don't materialize in my suburban scope. Colorful or not, the ragged pattern stands out wonderfully against the muted Milky Way, thanks to our pervasive local light pollution (I can't believe I just said that).

NGC 1342 has a wee bit more to offer. Patient staring at 93× rewards me with a sprinkling of faint cluster members between the zigzag and the seemingly isolated star pair to the northeast. A magnification of 93× also reveals an intriguingly fuzzy pinpoint above the zigzag. This time the *Washington Double Star Catalog* clarifies my find — the tiny blur is an obscure binary named **ALI 516**. Its 10.4- and 11.2-magnitude components, 13.2″ apart, are barely resolved at 93× (hence the fuzziness), but the dim duo looks much better at 186×.

▲ **LOW-DENSITY NEIGHBORHOOD** Open cluster NGC 1342 is a thinly populated collection of stars whose 99 members are mostly too faint for small, city-based telescopes to detect. But the zigzag at its core stands out nicely. The star labelled ALI 516 is a tight double.

JIM THOMMES

Doubling Down

NGC 1342 isn't my final stop in southern Perseus. Sweeping 4° south-southeastward nets **40 Persei**, a lopsided double featuring 5.0- and 10.0-magnitude stars 19.9″ apart. The reasonable separation is deceiving — this dramatically uneven binary is surprisingly tough to resolve. The glare of the primary star is so strong, I usually need more than 100× to positively detect the companion.

Nudging ½° west-northwest of 40 Persei captures an even more difficult binary called **Σ425**. The 7.5- and 7.6-magnitude near-twins of Σ425 are currently separated by a scant 1.7″. I require the 186× combo (a 7-mm eyepiece plus 2× Barlow) to resolve it (barely) in steady seeing conditions. I get a more satisfying resolution with a 2.5× Barlow, which results in 232×. I really enjoy cracking this tough nut!

My Perseus off-road journey terminates 3¾° farther southeastward, at 3rd-magnitude **Zeta (ζ) Persei**. Zeta is a quadruple system. The primary star is magnitude 2.9, while the secondary sun, 12.8″ away, is magnitude 9.2. The uneven binary resolves at 93×. A pair of 10th-magnitude stars 2′ southward are visible as well.

Even though the Double Cluster and M34 get most of the Perseus traffic, I hope these lesser sights have convinced you that a little off-roading can be worth the effort.

■ Long-time deep-sky hunter **KEN HEWITT-WHITE** has yet to observe every cluster in Perseus.

Southern Perseus Off-Road Finds

Object	Type	Mag(v)	Size/Sep/Per.	RA	Dec.
Epsilon Per	Double star	2.9, 8.9	8.8″	03^h 57.9^m	+40° 01′
NGC 1582	Open cluster	7.0	24′	04^h 31.7^m	+43° 44′
57 Per	Double star	6.1, 6.8	121.4″	04^h 33.4^m	+43° 04′
Σ552	Double star	6.8, 7.2	9.0″	04^h 31.4^m	+40° 01′
NGC 1342	Open cluster	6.7	17′	03^h 31.6^m	+37° 23′
ALI 516	Double star	10.4, 11.2	13.2″	03^h 31.1^m	+37° 23′
40 Per	Double star	5.0, 10.0	19.9″	03^h 42.4^m	+33° 58′
Σ425	Double star	7.5, 7.6	1.7″	03^h 40.1^m	+34° 07′
Zeta Per	Double star	2.9, 9.2	12.8″	03^h 54.1^m	+31° 53′

Angular sizes and separations are from recent catalogs. Visually, an object's size is often smaller than the cataloged value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

Deep-Sky Hunter

Get inspired by a prolific observer who's made a career of collaborations with pros.

If the name Patchick rings a bell, that might be because you may have come across it in the pages of this magazine. Dana Patchick works at the California Veterans Home in West Los Angeles, but he's also an avid amateur astronomer. His first submission to *Sky & Telescope* was a series of photos of Earth's shadow for the Observer's Page column back in December 1974. Most recently, Howard Banich's Cygnus Loop article in the September 2021 issue mentions Patchick 27, a planetary nebula that Dana discovered (see image below).

In between, a lot has happened.

Patchick's path. As for so many of us, the night sky inspired Dana from a young age. His first view of a five-day-old Moon through a 3-inch refractor sparked a lifelong passion for astronomy. He founded his junior high school's astronomy club, and by the time he was a young teenager, he became a member of the Los Angeles Astronomical Society.

After 1974 Dana's name appeared regularly in the magazine. He found supernovae — e.g., the May 1988 issue mentions his discovery of SN 1987L in NGC 2336 in Camelopardalis — and identified asterisms and star clusters. Sue French, in her Deep-Sky Wonders column, frequently observed Dana's objects and noted their delightful monikers, such as the Cosmic Question Mark asterism or the Squiggle Cluster.

Planetary nebulae kindled Dana's imagination after he saw the Ring Nebula (M57) through a 4½-inch reflector. During the 1980s, with the advent of readily available nebula filters and armed with his 17½-inch f/4.5 Dob, he ramped up his observations of planetary nebulae, and he has continued ever since.

Publish like Patchick. One of the features of the early internet was the proliferation of online chat groups in which people could exchange information. Amateur astronomy was no exception — a pioneer group flourished as the site of lively discussions on all things observing. Professional astronomers, such as Brian Skiff of Lowell Observatory, would chime in from time to time. Inspired by reports of the discoveries of new objects in that early forum, accomplished Brazilian amateur Bruno Alessi established a venue dedicated to such endeavors. And so, in 2003, the Deepskyhunters came into being — with Dana as one of the founding members.

Dana and his colleagues scoured online data sources, such as the Digitized Sky Survey, in order to locate hitherto unknown objects. In 2003 Dana stumbled upon an uncataloged object. Unable to identify it using the DSS data alone, he turned to Adam Block of Kitt Peak National Observatory, who then pointed a 20-inch telescope at the area in question. Their investigation revealed that the target had the classic ring-shaped structure of a planetary nebula — this object garnered the name Patchick's Planetary. It was the first discovery of a planetary nebula by an amateur astronomer since 1894! (Block is another name readers will recognize well — one of his images is actually on page 28 of this issue.)

Spurred on by new discoveries, the Deepskyhunters started to publish their findings. Their first journal paper (on open cluster candidates) appeared in *Astronomy & Astrophysics* in 2006, with long-time members and prolific amateurs Matthias Kronberger and Philipp Teutsch leading that project.

The Deepskyhunters also attracted the interest of professional astronomers. In 2010, the group teamed up with George Jacoby (also of Lowell Observatory) and focused its efforts on planetary nebulae. Through Jacoby, members had access to several telescopes, including the Nicholas U. Mayall 4-meter Telescope at KPNO. To date, the Deepskyhunters have identified more than 200 candidate and confirmed planetary nebulae.

Most recently, the group published an article on the discovery of 12 galactic globular cluster candidates, with lead authors Elisa Garro and Dante Minniti (Universidad Andres Bello, Santiago, Chile). Besides Dana, Alessi and Kronberger are also listed as coauthors.

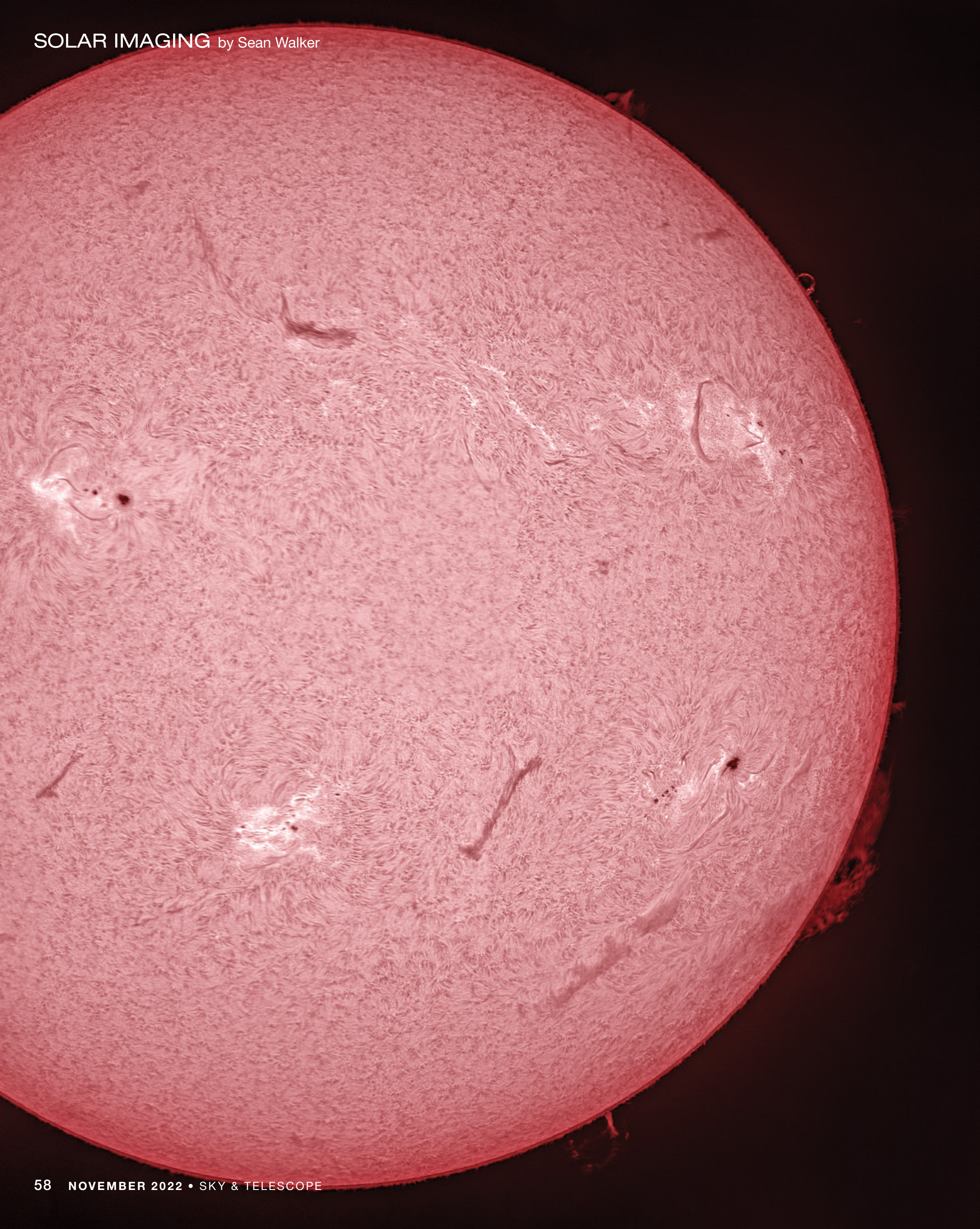
If you're interested in following Dana's example, The Deepskyhunters has an online forum at **https://is.gd/DSHunters**. Or visit **https://is.gd/plan_neb_fr/**, a French-led forum with material in English.

Happy hunting!

■ Observing Editor **DIANA HANNIKAINEN** remembers well the thrill of publishing research.

MIKE KEITH

▲ **PATCHICK 27** This image shows the planetary nebula that Dana discovered (arrowed) north of the Cygnus Loop, as well as wisps of the supernova remnant's nebulosity.



Catching the Sun

As the solar cycle ramps up, it's a great time to photograph this captivating target.

As the nearest star, the Sun is the most dynamic object you can observe in the sky. A nearly perfect sphere of incandescent plasma, it's loaded with fascinating details that change by the minute. And at long last, solar activity is on the rise. Solar Cycle 25 is already on track to produce lots of active regions, sunspots, and flares. Here's how you can get in on the imaging action.

Areas of Interest

The Sun is close enough to reveal its churning atmosphere in a properly equipped telescope of any size. By happy coincidence, it appears around a half degree in diameter — the same apparent size as the Moon. This is one reason we get total solar eclipses, which allow for brief, unfiltered views of the Sun's outer atmosphere, the *corona* (*S&T:* Mar. 2020, p. 30). The rest of the time, pointing any optic at the Sun requires the use of a safe solar filter in order to reduce its intense brightness to a safe level.

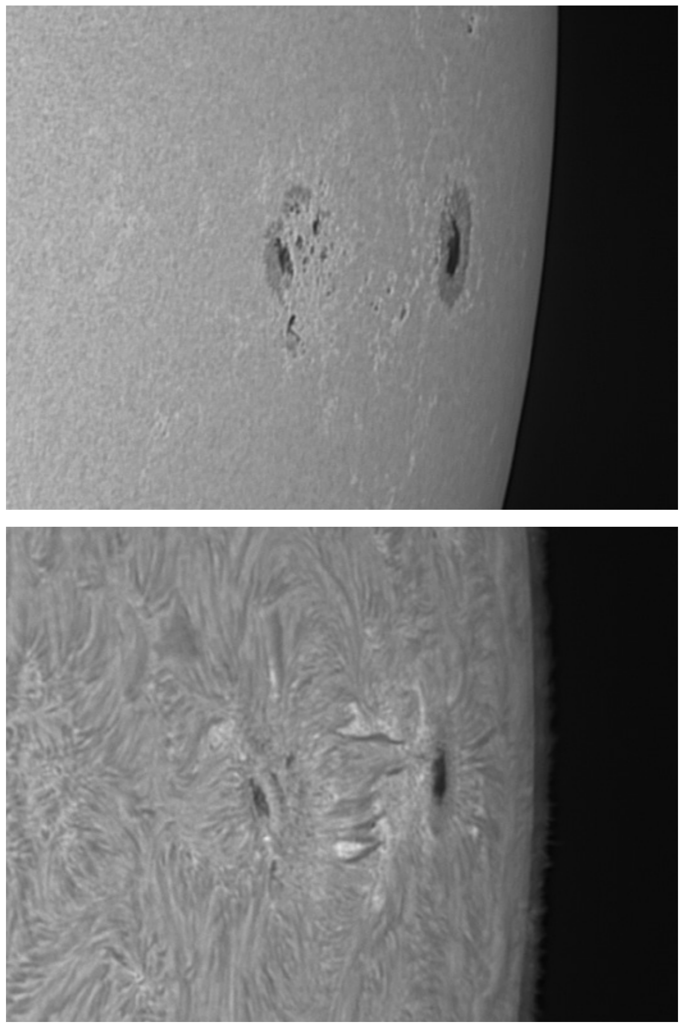
With the appropriate solar filter, the Sun is observable in many wavelengths, though Earth's atmosphere blocks some of the more interesting ones (particularly at ultraviolent wavelengths).

Besides the corona, two additional layers of the solar atmosphere are of interest to amateurs: the *photosphere* and the *chromosphere*. The photosphere is made up of bright granules of plasma that rise and sink over the course of about 10 minutes and is the deepest layer of the Sun that we can directly observe. Additionally, dark sunspots appear in the photosphere, where magnetic fields break through the surface. The photosphere is visible through simple "white-light" solar filters and until fairly recently was the primary region that amateurs could view.

The other visible layer of the solar atmosphere is the chromosphere, residing about 3,000 to 5,000 kilometers above the photosphere. Meaning *sphere of color*, the chromosphere is arguably the most dynamic layer. It comprises primarily reddish, low-density plasma visible along the solar limb during total eclipses. The chromosphere is where much of the excitement happens on the Sun: Gigantic prominences shimmer along the limb, dark filaments snake across the disk, and coronal loops, plage, and occasional bright flares come and go on timescales that can last from minutes to weeks.

Although the chromosphere is briefly visible during a total eclipse, it's best seen through a specialized filter that only passes a narrow region of the spectrum where this activity is visible. The most popular are hydrogen-alpha (Hα) filters, which pass less than one angstrom of light at 656.28 nanometers and reject everything else. These filters are much

◀ **HEATING UP** Solar Cycle 25 is roaring to life, making this a great time to experience the excitement of solar imaging. This mosaic of the Sun was captured by the author on July 15, 2022, with an Astro-Physics 92-mm Stowaway refractor equipped with a Daystar Quark Chromosphere solar filter. Sixteen, 15-second videos were recorded using the Player One Mars-M video camera reviewed in the February issue. The results were stacked in *Autostakkert!3*, then assembled in *Adobe Photoshop*.



▼ **ATMOSPHERIC LAYERS** *Top:* Sunspot group AR 3038 appears surrounded by small areas of bright plage when recorded in white light. *Bottom:* The same group shows spicules and small filaments in the chromosphere when imaged through a Daystar Quark Chromosphere filter.

ALL IMAGES COURTESY OF AUTHOR

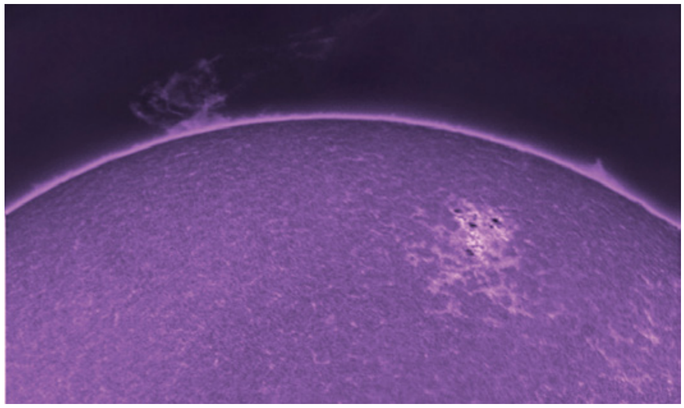
more complex (and therefore more expensive) than white-light filters and are not the same as deep-sky filters used to image the night sky. The hydrogen-alpha wavelength reveals an amazing show unlike any other in the sky.

The chromosphere is also visible in a bluer region of the spectrum centered at 393.4 nm where calcium is ionized in the solar atmosphere, known as the calcium-K line (Ca-K). Such filters display a violet image of the Sun similar to, but higher contrast than, the white-light view showing sunspots, granulation, supergranulation, faculae, and extended plage regions where strong magnetic fields are present. Prominences are also visible through a Ca-K filter, though they appear much fainter than in Hα. Because the Ca-K line is at the violet end of the visible spectrum, older observers often have a hard time seeing through these filters, and in general they're better suited to imaging rather than visual use.

Manufacturers including Baader Planetarium (**baader-planetarium.com**), Daystar Filters (**daystarfilters.com**), Lunt Solar Systems (**luntsolarsystems.com**), Meade (**meade.com**), and Solarscope (**solarscope.co.uk**) all offer filter systems you can connect to your own telescope, as well as several dedicated solar telescopes with built-in Hα or Ca-K filters. Regardless of the wavelengths you choose, the process of creating images through them is identical.

Solar Considerations

There are several things you need for solar imaging besides your telescope, filter, and camera. Because you'll be out under the blazing Sun, don't forget to apply sunscreen to avoid sunburn while at the telescope. In addition, any computer you bring out to operate your camera and equipment will need some means of shading it so that you can see its screen in order to focus and monitor your progress. A folding table with a large cardboard box works well and is preferable to the clip-on screens I've seen online. A box will keep your entire computer out of the Sun and reduce the chances of it over-heating. Adding a towel also helps so that you can block the sky from reflecting off the computer screen.

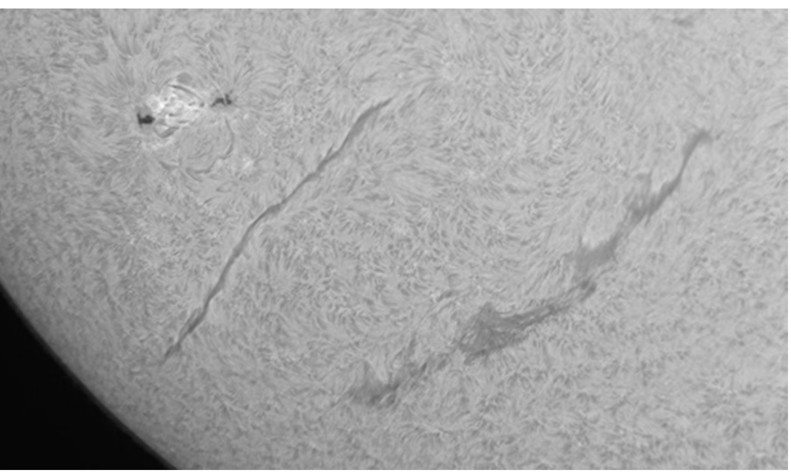


▲ **VIOLET PROMINENCE** A calcium-K filter highlights magnetic fields and supergranulation in the chromosphere. Prominences can also be captured through this filter, as this colorized result shows.

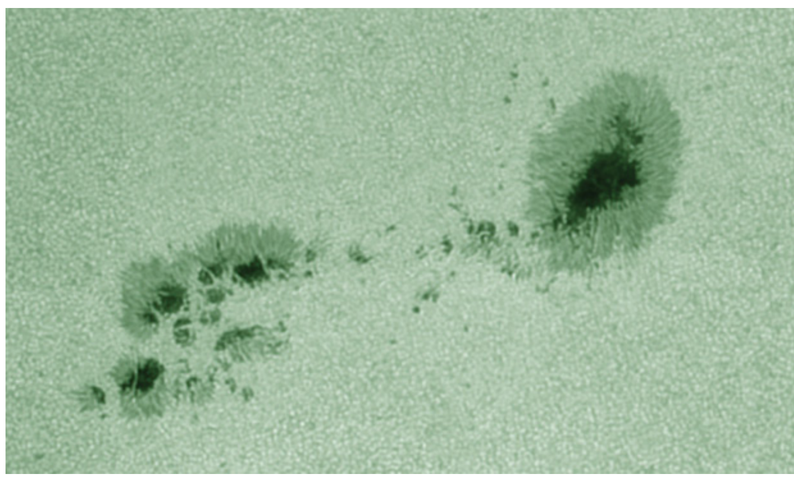
The next piece of equipment to consider is your camera. You can shoot the filtered Sun with any camera, but the quality of your images may vary depending on your choice. For instance, the view through any solar filter, be it white-light, Hα, or Ca-K, is essentially monochrome, so shooting with a color camera such as a DSLR or Mirrorless camera, while doable, isn't quite as easy as when using a monochrome camera designed to fit in a telescope focuser. But if that's what you have to work with, be sure to record many frames to stack and sharpen later.

Imaging our star with a camera having a large sensor with tons of small pixels has a few benefits. First, it's easy to fit the entire Sun on the detector with enough resolution to show all the interesting features visible. In some cases, you don't even need to use a tracking mount — you can simply record images

▼ **SNAKING PLASMA** Huge filaments, which are simply prominences seen against the solar sphere, can dance for hours, days, and even weeks before suddenly lifting off into space.



▼ **CHURNING CAULDRON** Solar granulation, the small light-and-dark cells that make up the photosphere, are best seen under the steady seeing conditions often found in the morning hours. This closeup of AR 3055 was recorded through a 102-mm achromat equipped with a Baader Herschel Wedge and solar continuum filter centered at 540 nanometers (in the green region of the spectrum).



as the Sun drifts across the detector and stack the results later. For example, I often record white-light images using a small refractor with a focal length of 600 millimeters and a Nikon APS-C format DSLR. It's easy to snap several dozen exposures on a sturdy tripod before the Sun drifts too much.

With smaller detectors, it's desirable (but still not entirely necessary) to track the Sun while imaging. However, your best results will come when using a tracking mount, since it allows you to use high magnification and focus your efforts on smaller features.

I prefer to shoot the Sun with a high-speed monochrome video camera because it offers the best signal at any wavelength and allows you to record at extremely fast frame rates, which is important because daytime seeing is often poorer than at night. This is why it's best to image in the morning hours, before buildings, trees, or other objects in your vicinity begin to radiate heat.

Capture Strategy

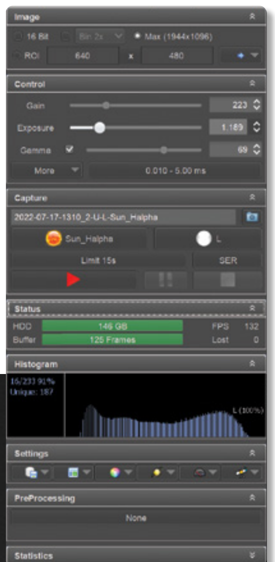
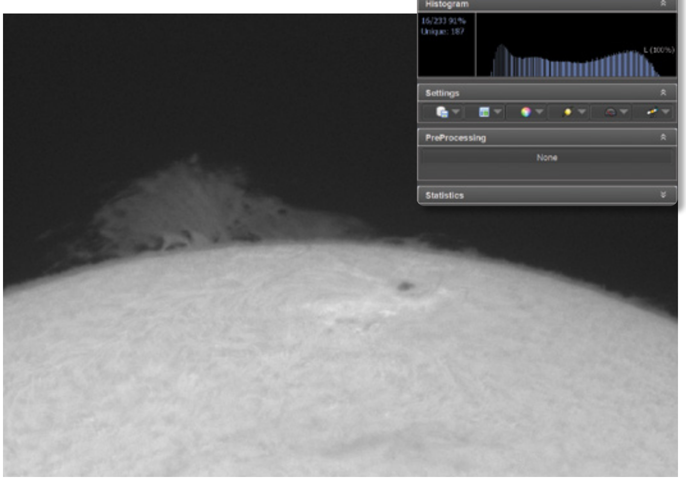
Once you're set up and ready to image, there are a few things to consider before firing off your shots. First, choose a small, high-contrast feature to use as a focus target. It's relatively easy to focus on sunspots in white light, or small filaments in active regions when shooting through Ca-K and Hα filters. Take your time to ensure you've really nailed focus and recheck frequently. Remember, your scope is in direct sunlight and is heating up, which means parts expand and focus changes. I've seen the focus shift in as little as 5 minutes while shooting a full-disk mosaic, making last images notably softer than the first ones.

Next, establish your exposure level. You don't want to overexpose the brighter areas of the solar disk, but you do want to keep noise levels as low as possible. The Sun is the brightest thing in the sky, so you don't need to record it with high ISO or high-gain settings. Keep the gain low and increase the image brightness using the exposure control. A good trick I use is to place the center of the Sun in the middle of the camera's field and set the exposure so that the maximum value on the capture program's histogram is about 90% of maximum. (Most DSLR and Mirrorless cameras allow you to check the histogram of an exposure after it's taken.) That way, the only time anything becomes overexposed is when a flare unexpectedly occurs, typically in Hα.

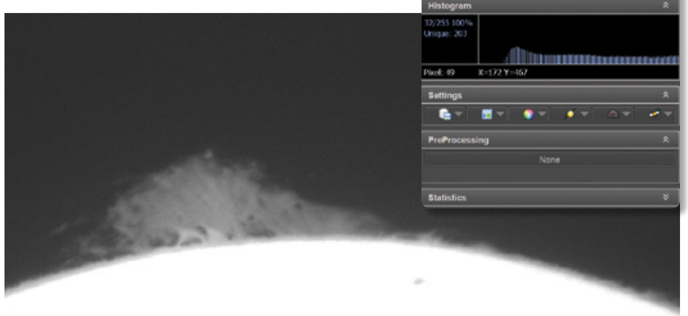
Now you're ready to record. Remember that even in white light, solar features can change appearance quickly. Granules brighten as they rise to the surface, then darken and sink back into the photosphere within about 5 minutes. And with thousands of them appearing in each shot, two images taken less than a minute apart will show "scintillation" of these dark and light granules. Combining still images taken within 30 seconds or so should produce a fine image. I usually record videos lasting between 15 and 30 seconds, depending on the frame rate of the camera. Experiment with these settings to find a combination that works best for your particular setup.

If you're shooting a high-resolution mosaic of the solar disk, you may need to record flat-field calibration frames in order to eliminate sensor dust specks appearing in your images, or to compensate for uneven transmission across the field of view in your filter system. Flat-field calibrated images stitch together effortlessly.

Shooting solar flats can be tricky. I usually get away with skipping them in full-disk images by ensuring my detector is clean and free of dust. Smaller fields, however,

▼ **PEAK EXPOSURE** To record detail on the solar disk, monitor the histogram in your capture program (such as *Firecapture* seen at right) and make sure its peak value is roughly 90%.

▼ **LOW GAIN** Increase your exposure length, rather than the gain setting, in order to record very faint prominences along the solar limb at the expense of disk detail. This produces a smooth, bright image of the prominence that stacking software can easily lock on to.

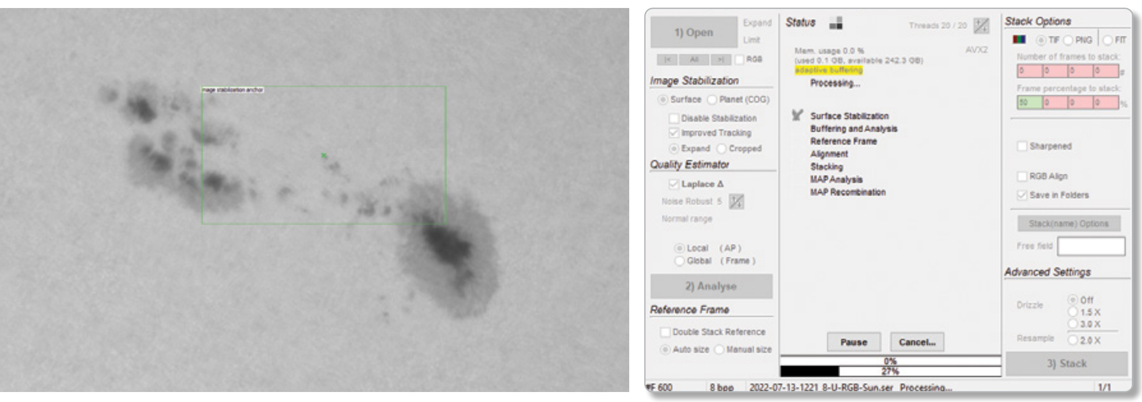
require more attention. Daystar Filters sells a device called a Flat-Cap that diffuses the sunlight coming through your telescope to produce a good flat-field image. I've also found that significantly defocusing the telescope while pointed at a relatively blank area near the middle of the solar disk works well, too. I set the camera's exposure so the histogram is peaking at about 50% and record a short 300-frame video that I later stack and save in *AutoStakkert!3*. I also shoot a new flat if I rotate the camera during a session.

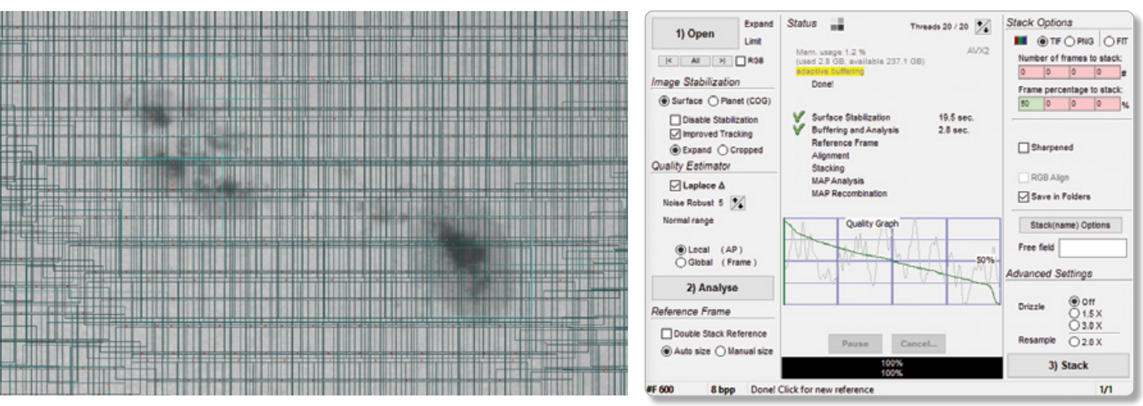
Finally, plan your coverage strategy when shooting solar mosaics. It's no fun putting together a full-disk mosaic only to discover you missed an area! I tend to align my camera square to the RA and declination so that I can systematically sweep across the *entire* solar disk quickly.

Stacking and Sharpening

Once you have all your images recorded, sharpening solar images is easy — any program with sharpening tools can improve your pictures. Stacking the results requires one of several programs, such as *AutoStakkert!3* (**autostakkert.com**) or *RegiStax 6* (**astronomie.be/registax**) for PC computers, or *PlanetarySystemStacker* (**https://is.gd/planetaryss**) for Macintosh users. I actually employ three programs when processing my images. First, I stack all my still frames or videos using *Autostakkert!3*, then sharpen them with wavelets in *RegiStax 6*, and finally stitch together any mosaics and colorize the result with *Photoshop CS*.

▼ **EASY STACKING** *Below: Autostakkert!3* makes it simple to stack dozens of solar videos. First, select a small, high-contrast spot to estimate the quality of the individual frames and click Analyse. *Bottom:* Once the step is complete, clicking Place AP grid automatically generates hundreds of alignment points to track and stack. Enter the number of frames to stack, and click 3) Stack then the program will set off stacking all your videos one at a time.





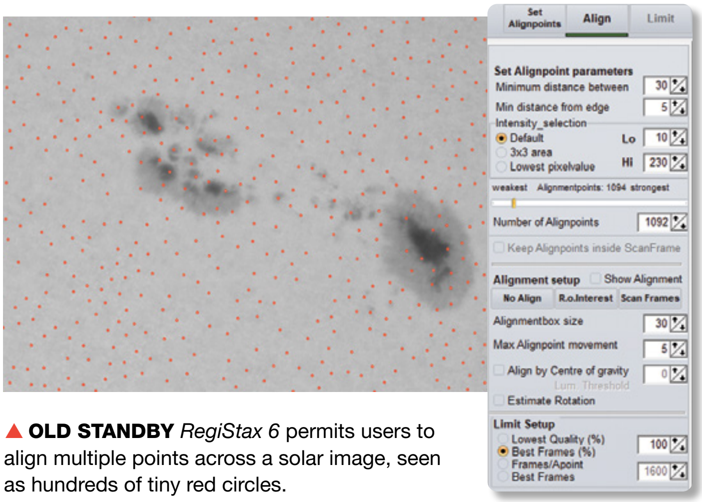
Stacking in *Autostakkert!3* is easy. The program handles still image formats such as TIF, FIT, JPG, or PNG, and takes AVI, MPG, or SER videos. If you've shot a flat-field calibration video, open that first and select ***Image Calibration > Create Master Frame***. In a moment, the video is stacked into a smooth calibration frame that you then save. Next, choose ***Image Calibration > Load Master Flat***, select your flat-field frame, and that calibration image will be applied to all your videos. Select all the images you'd like to stack and drop them into the open program window. In the command window, choose ***Surface*** in the Image Stabilization section and hold the Ctrl button while clicking a contrasty feature to track on, such as a sunspot. Next, click the ***2) Analyse*** button, and the program quickly evaluates all the frames and reorders them so that the best frames are first.

When that step is done, select the alignment point size (I start with 104) and check the ***Multi-Scale*** option at the bottom left of the screen. Now click ***Place AP grid***, and the program will quickly select hundreds of alignment points. Before commencing the stack operation, go to the right side of the control window and select the file format you'd like the final stacked image to be saved as (TIF, PNF, or FIT), then enter the number or percentage of frames to stack. You can do both, and up to four values of each option, which is helpful if you imaged in shaky seeing. Check the ***Save in Folders*** option, then hit the ***3) Stack*** button, and the program will assemble your stacked result.

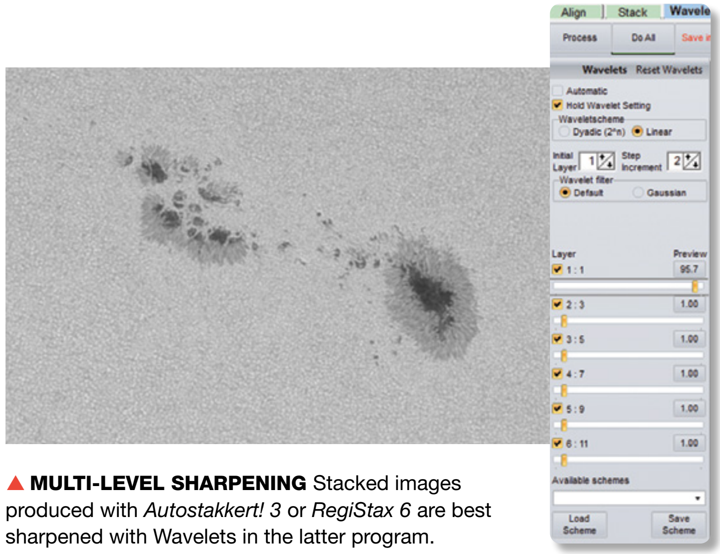
AutoStakkert!3 will batch process many videos, so you don't have to do each one individually. But if you're stacking still frames, you need to concentrate on one group of images at a time.

Once the stacks are completed, I take the results one at a time into *RegiStax 6* and apply mild wavelets. *RegiStax 6* also performs multipoint registration just as well as *AutoStakkert!3* but is more time-consuming because it can only work on one video or image group at a time, and because the program runs far slower than *AutoStakkert!3*.

Simply open the program and drag and drop a stacked



▲ **OLD STANDBY** *RegiStax 6* permits users to align multiple points across a solar image, seen as hundreds of tiny red circles.



▲ **MULTI-LEVEL SHARPENING** Stacked images produced with *Autostakkert! 3* or *RegiStax 6* are best sharpened with Wavelets in the latter program.

image into it. In a moment, *RegiStax 6* proceeds to the sharpening window, with six wavelet sliders displayed along the left side of the screen. Solar images don't require very much sharpening, so I tend to only move the top two sliders until I'm satisfied with the result and then click ***Save image***. Be sure to retitle the result so it doesn't overwrite the raw stacked file.

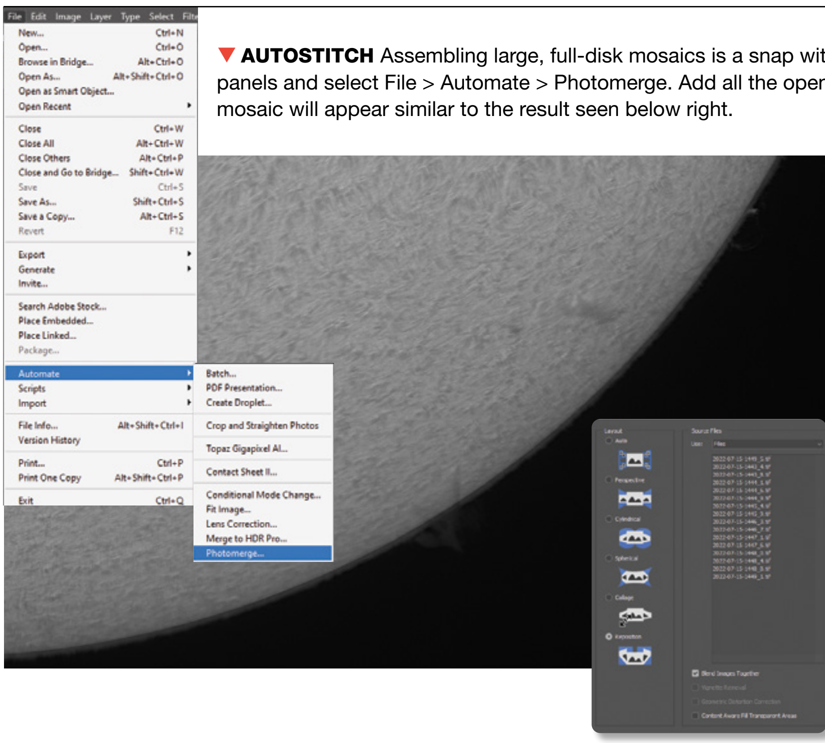
Quick Mosaics

At this point, I open the sharpened results in *Adobe Photoshop* to colorize the result and share it with my friends. If I've recorded a set of images for a mosaic of the solar disk, *Photoshop* makes it easy to quickly assemble the pieces. Simply open all your sharpened images, then select ***File > Automate > Photomerge*** from the pulldown menu. The Photomerge window opens, where you should click the ***Add Open Files*** button, and click OK. In a few moments, your assembled mosaic appears on the screen. Voila!

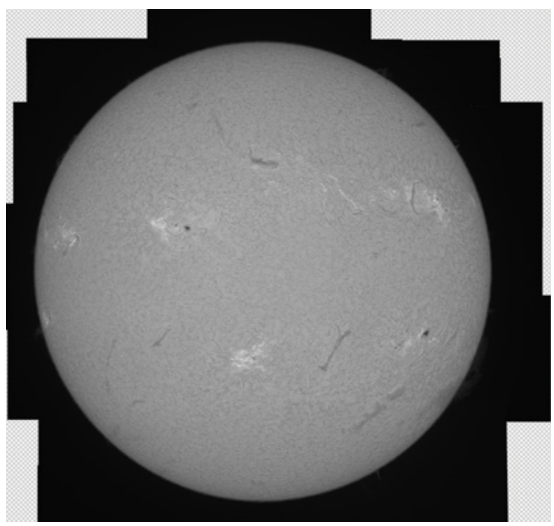
All that's left to do is colorize the result using ***Image > Adjustment > Color Balance***. You might also want to boost the brightness of any prominences along the limb in your Hα or Ca-K pictures; I find the Shadows/Highlights tool does a fine job (***Image > Adjustments > Shadows/Highlights***). Some imagers also invert the disk image using ***Image > Adjustment > Invert***, then layer that image with a positive image of the prominences, in order to make plage and active regions more apparent. It's all up to you at this point.

With the right equipment, solar imaging is easy and enjoyable. You can also make time-lapse videos of flares, prominences, and other rapid changes on the Sun happening every day. And the best part is you won't lose any sleep while solar imaging — it all occurs while the Sun is up!

■ Associate Editor **SEAN WALKER** has been cooking up solar images since he reviewed the Coronado P.S.T. in 2004.



▼ **AUTOSTITCH** Assembling large, full-disk mosaics is a snap with *Adobe Photoshop CS*. Simply open all your sharpened panels and select File > Automate > Photomerge. Add all the open files, then click OK. In a minute or two, your assembled mosaic will appear similar to the result seen below right.



◀ Celestron's Smart DewHeater and Power Controller 4X (seen below the tube) and Aluminum Dew Shield kept the author's C8 corrector plate free of moisture despite the scope dripping with dew halfway through the night.

Celestron's Dew-zapping Power Controller

This smart control center offers more than just dew management for Celestron scopes.

Smart DewHeater and Power Controller 4X

U.S. Price: $439.95
celestron.com

What We Like

Heater rings directly contact corrector plate

Ability to monitor temperature, humidity, and dew point

What We Don't Like

Only 4 heater ports

Works exclusively with Celestron telescopes and recent mounts.

WHAT IS THE BIGGEST impediment to observing with a telescope? Clouds? Light pollution? For many of us, it's dew. In many locations, you will have to deal with the wet stuff. If you use a telescope with a large, exposed optical element, like a Schmidt-Cassegrain Telescope (SCT) corrector plate, there will be many nights when dew quickly ends your observing session.

So, what to do about dew? The first step is a dew shield, an extension that attaches to the front end of the telescope tube. On humid nights, the corrector plate quickly falls below the dew-point temperature, encouraging moisture to form on the glass. A dew shield's job is to slow down the cooling of the corrector by creating a pocket of air between it and the heat-sucking sky, allowing you to observe longer.

As nice as a dew shield is, in high-humidity areas it won't keep the corrector clear for long. A heating element — usually resistive wire enclosed in a cloth band wrapped around the corrector end of the telescope's tube — is a better solution. It applies gentle heat to the corrector — just enough to keep it above dew-point temperature, but not enough to distort the lens's optical figure.

Celestron recognizes these problems and recently released three products designed to keep your optics free from dew: the Dew Heater Ring, Smart DewHeater and Power Controller 4X, and the Aluminum Dew Shield with Cover Cap, each available separately. Prices vary for the heater rings and dew shield based on the size of the scope they are matched to. I tested the suite under the clear but damp skies in southern Alabama with my trusty C8.

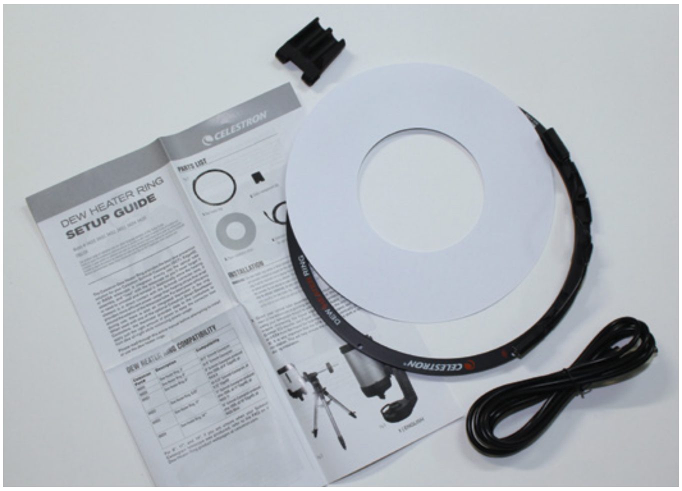
Heating Rings

I've always wondered why telescope makers don't build dew heaters into SCTs. Now, Celestron releases the next best thing. Its Dew Heater Ring ($53.95 for the 8-inch model) installs on the company's SCTs with its heating element in direct contact with the

▼▶ The Smart DewHeater and Power Controller 4X has ports on all four sides. *1:* The front end includes the "bridge" with status indicator lights and power switch. *2:* The left side contains 3 auxiliary connection ports, a USB-B port to connect a PC, and a 3-port USB 3.0 hub. *3:* Power output ports for accessories and the main telescope mount are found on the controller's back end. *4:* Its all-important heater and temperature sensor receptacles along with input power connectors are located in the unit's right side.

1

ALL PHOTOS BY THE AUTHOR



▲ *Left:* The Dew Heater Ring kit comes with a paper installation shield, a cable-management clip, and a 1.8-meter (6-foot) power extension cable. *Right:* The Smart DewHeater and Power Controller 4X includes a temperature sensor extension cable, a Celestron Aux cable, a mount power cord, a strap to attach the controller to a tripod leg, and a battery power cable for the unit.

corrector. The rings are available to fit all Celestron SCTs manufactured since 2006, including Edge HD and RASA models. In the package with the ring is a paper shield to protect the telescope's lens during installation, an extension cord for the power connector, and a cable management clip.

I was anxious to try the Dew Heater Ring, but it would first have to be installed on my 8-inch Edge SCT. The heater completely replaces the plastic, corrector-plate retaining ring. That gave me pause. Even after many years of using SCTs, I'm wary of working around the big, thin front lens. Luckily, Celestron's instructions are well written and easy to follow, though the small black-and-white illustrations could be clearer.

Installation was quick and easy. The instructions advise you to point the telescope tube up toward the zenith before beginning to ensure that the corrector can't fall out once the retaining ring is removed. Damaging the surface of the corrector isn't a worry thanks to the included paper installation shield that slips over the corrector to protect it. The ring's two short cable leads for power and a thermistor temperature sensor need to be unclipped from the ring and secured to the telescope OTA with the cable-management clip.

The Brains of the Operation

Of course, a dew-prevention system needs more than just a heater ring. This is where the controller comes in.

Celestron's Smart DewHeater and Power Controller 4X (hereafter the Smart Dew Controller) has both temperature and a humidity sensors for better environmental monitoring. Other features include four power outputs for accessories, a three-port USB 3.2 hub, and the ability to monitor the device with Celestron's NexStar telescope hand controller or its *CPWI* mount-control software for Windows. The controller ships with a power cord terminated with a cigarette-lighter-style plug, a Celestron auxiliary cable, a cord to connect to the thermistor sensor on the Dew Heater Ring, and a cable for powering your Celestron mount. The company also offers a smaller, 2-port Smart DewHeater Controller 2X unit without the USB or power hubs for $259.95.

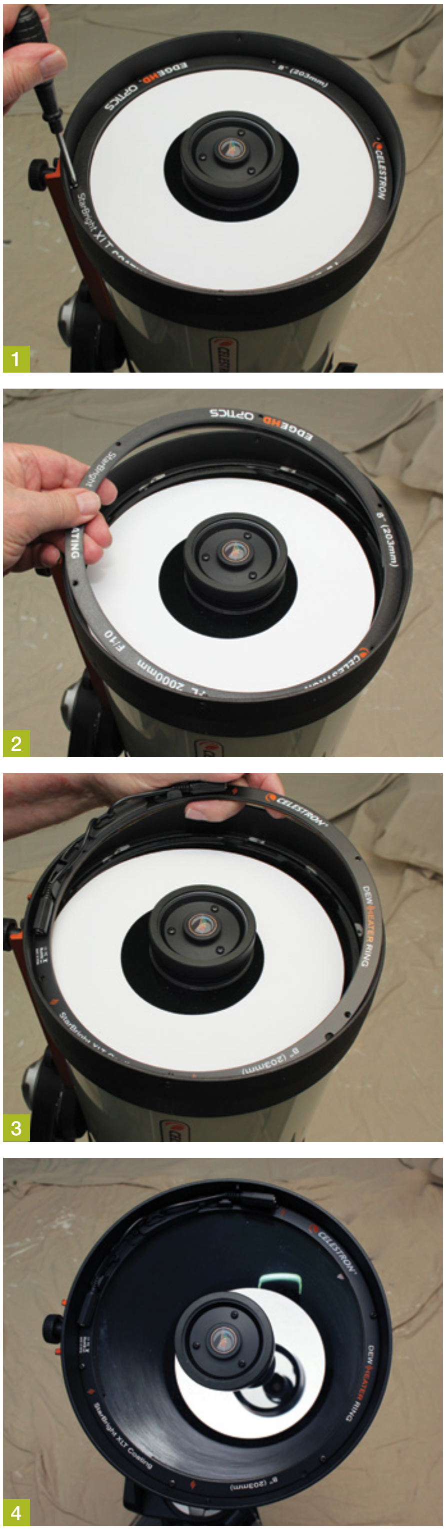
The most distinctive feature of the Smart Dew Controller is its handle, which Celestron refers to as "the bridge." This is where the environmental sensors are located in order to isolate them from the heat-generating power hub. It also sports three LEDs to indicate an over-current condition, power-on, and a low-voltage condition.

One side of the device is devoted to Celestron's Aux ports to connect the unit to Celestron mounts and other accessories, a USB-B connection for attaching a PC, and three powered USB A ports.

2

3

4



▲ Installing the Dew Heater Ring should be done indoors. Start by pointing the telescope straight up and placing the installation shield over the corrector plate, then unscrew the six screws securing the corrector plate retaining ring (1). Remove the retaining ring (2) and replace it with the Dew Heater Ring (3). Reinstall the screws, and installation is complete (4).

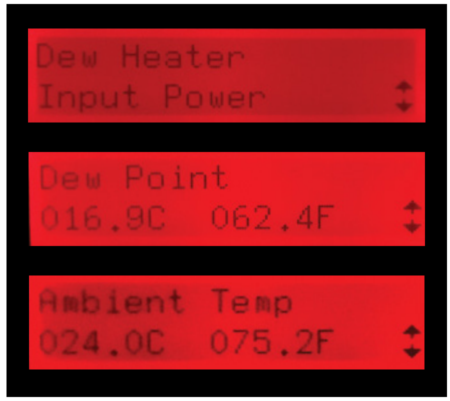
The back of the controller features four accessory DC power ports, three of which provide 12 volts at 7 amps. The fourth can be adjusted from 3 volts to 12 volts. The current capacity of the variable port depends on voltage, but the maximum is 7.5 amps at 8 volts. This variable output would be useful for powering devices like cameras that require less than 12 volts. The voltage can be adjusted with either a Celestron hand controller or the *CPWI* software.

On the other side of the controller are four dew heater ports (RCA phono-style female connectors) and four 2.5-mm audio jack ports for connecting the thermistor temperature sensors. The Smart Dew Controller accepts third-party dew heating straps, and these can also be automated with the addition of another thermistor (at $14.95 each) to monitor its temperature and adjust power accordingly. They can also be operated without a sensor. In that case, power is applied to the port as a percentage of time, 50%, for example, adjustable through the hand controller or software. This side is also where the unit's power input connectors are found — a 12-volt, 10-amp, threaded-barrel type and a 12-volt, 20-amp XT-60 dual-pin connector that's compatible with the cables on Celestron battery packs.

Setting Up and Action

After spending some time reading the controller's 16-page instruction manual, I was ready to test the system under the stars. My scope of choice would be my Celestron Edge 800 SCT riding on a Celestron Advanced VX German equatorial mount. A firmware upgrade to the hand controller was necessary to incorporate the new device into the hand paddle, but that went smoothly.

The first task was installing Celestron's Aluminum Dew Shield with Cover Cap ($169.95). This thin yet sturdy dew shield is lined with dew-absorbing material and didn't add much weight to the front of the scope. It's held in place by two plastic clips that slide over the corrector assembly. Before doing that, it's necessary to unclip the two connectors on the Dew Ring and



▲ The additional menus added to the NexStar hand paddle let you monitor the input power (top), dew point (middle), and ambient temperature (bottom).

position them so they pass through an opening on the dew shield. (The cable management clip provided with the Dew Heater Ring isn't used with the Dew Shield.) Be careful not to pinch the cables in the process of getting the dew shield snapped into place.

The Smart Dew Controller can be mounted either on a tripod leg with an included Velcro strap, or on the telescope's Losmandy-D-style dovetail mounting bar with the controller's built-in clamps. I chose the latter, sliding the unit onto the forward end of the telescope's dovetail and tightening one of the controller's two clamp knobs to secure it. My 8-inch telescope's relatively short dovetail and the presence of the mount's declination motor housing meant only one knob could be tightened, but it was adequate.

I next attached all the cables, beginning with the power supply (I used Celestron's optional 5-amp power supply), a USB cable to my control laptop, the Dew Heater Ring power and sensor cords, a third-party heater strap for the finderscope, and the Aux cable to connect to the Advanced VX mount. I followed Celestron's advice and ran the cords under the bridge to help with cable management, but if I owned the system, I'd also bundle cables together to help prevent snagging.

The mount was powered through one of the controller's accessory ports via the included mount power cable. After getting it all set up, it was time to look

▲ *Left:* The Smart Dew Controller installed on the telescope's dovetail bar. *Right:* The controller is also mountable elsewhere on the scope, such as the tripod leg using the supplied Velcro strap.

at the new dew controller menu on the mount's hand control. The dew-heater menu allowed me to view its power consumption along with the ambient temperature, humidity, and dew point.

Users can also monitor the status of the dew system with a Windows computer running the *CPWI* telescope control software, downloadable from Celestron's website. When using the program, the hand controller is disabled.

With my mount connected to *CPWI*, I could view the dew controller's information more easily than by squinting at the small, red hand-controller display. I was impressed by a graphic displaying the power consumption, temperature, humidity, dew point, and heater status. This screen is also where you can adjust third-party heater strips that lack thermistor sensors. A setting of 50% usually works as a starting point, but additional adjustments may be required over the course of an evening. As the night grew older and cooler, heavy dew began to fall, soon coating the scope's tube, but its corrector remained completely dry during the six hours of my longest observing run.

I found Celestron's dew-prevention system to be considerably more effective than just a set of heater strips. Having the Dew Heater Ring in direct contact with the corrector plate and the ability of the controller to sense and adjust to changing conditions ensured dew-free results. I also appreciated that it operated without me having to adjust the temperature control of the heater ring — the Smart Dew Controller did all the work.

The Aluminum Dew Shield works as well as any other quality dew shield and is designed for use with the Dew Heater Ring. The Smart Dew Controller? It would be nice if Celestron came up with software (or an app) to allow users without Celestron mounts to take advantage of this excellent system. Without a Celestron mount, the Dew Heater Ring will work, but you won't be able to view system status or adjust third-party heaters lacking thermistor sensors — they will default to maximum power draw and will be on continuously.

How do you improve on something as simple as a dew heater? The devices have been around for more than four decades and work well. The Celestron system, however, convinced me you can indeed improve on the idea. The combination of the Dew Heater Ring and the Smart DewHeater and Power Controller 4X is just *better*. If you live where dew can shut down your observing before it's barely begun, you should seriously consider Celestron's dew-fighting tools.

■ Contributing Editor **ROD MOLLISE** lives under the often-damp skies near the Gulf of Mexico.

▲ *Left:* Before attaching the Aluminum Dew Shield, be sure the Dew Heater Ring power and thermistor connectors are unclipped and positioned outside of the tube, then guide the cords so they come through the marked space in the dew shield (right).

▲ SOLAR IMAGER

Player One Astronomy announces a specialized camera geared toward solar imaging at long focal lengths. Its Apollo-M MAX ($599) camera is built around the high-sensitivity Sony IMX432 monochrome sensor. This 1.7-megapixel detector has 9-micron pixels in a 1,608 × 1,104 array measuring 14.5 × 9.9 mm. These large pixels are well-suited for imaging at long focal lengths, particularly when paired with a telescope fitted with a Daystar Quark solar filter. Each USB 3.0 camera can record 126 full-resolution frames per second, and even more when using on-chip ROI cropping. Additionally, the camera includes 256 MB DDR cache memory to ensure no frames are lost when operating with slower computers. The Apollo-M MAX also features easy-access sensor-tilt adjustments to perfectly square the sensor to the optical system. The camera can also issue guiding commands to your telescope mount via an ST-4-style guiding port. Each purchase includes a 2-meter USB 3.0 cable, and 1¼-inch nosepiece.

Player One Astronomy
168 Yuxin Road, Bldg. 1, Rm. 1, Suzhou, China
player-one-astronomy.com

▲ 6-INCH GO TO

Sky-Watcher USA adds Go To slewing and tracking to its 6-inch tabletop reflector telescope. The Virtuoso GTi 150P ($470) is a collapsible f/5 Newtonian reflector paired with the Virtuoso GTi tabletop Dobsonian Go To mount. Together they weigh 8.7 kilograms (19 pounds). Its helical focuser, secondary mirror, and included red-dot finder are mounted on an extendable ring with built-in light shield that slides into the main tube for convenient transportation and storage. The Virtuoso GTi connects to your smartphone or tablet with its built-in Wi-Fi and is controlled with Sky-Watcher's free *SynScan Pro* app containing a database of more than 10,000 objects, including the complete Messier, NGC, IC, and Caldwell deep-sky catalogs (available for Android and Apple devices). The OTA connects to the mount with a V-style dovetail bar. The Virtuoso GTi 150P is powered by eight AA batteries or accepts an optional external 12-volt power supply. Each purchase includes 10-mm and 25-mm eyepieces and a dust cap.

Sky-Watcher USA
475 Alaska Ave., Torrance, CA 90503
310-803-5953; skywatcherusa.com

◀ MINI GUIDESCOPE

Orion Telescopes & Binoculars now offers a compact guidescope for astrophotographers. The Orion StarShoot 32mm Mini Guide Scope ($129.99) is a 32-mm f/3.8 achromat designed to fit into most removable finderscope dovetail saddles. It weighs just 255 grams (9 ounces), complete with its six-point adjustable ring bracket. The objective is focused by unthreading the cell and then locking it down with a threaded collar. The guidescope comes with a 1¼-inch visual back with compression locking ring and built-in T-threads, and an additional C-mount visual back that ensures the unit will come to focus with most autoguiding cameras.

Orion Telescopes & Binoculars
89 Hangar Way, Watsonville, CA 95076
831-763-7000; telescope.com

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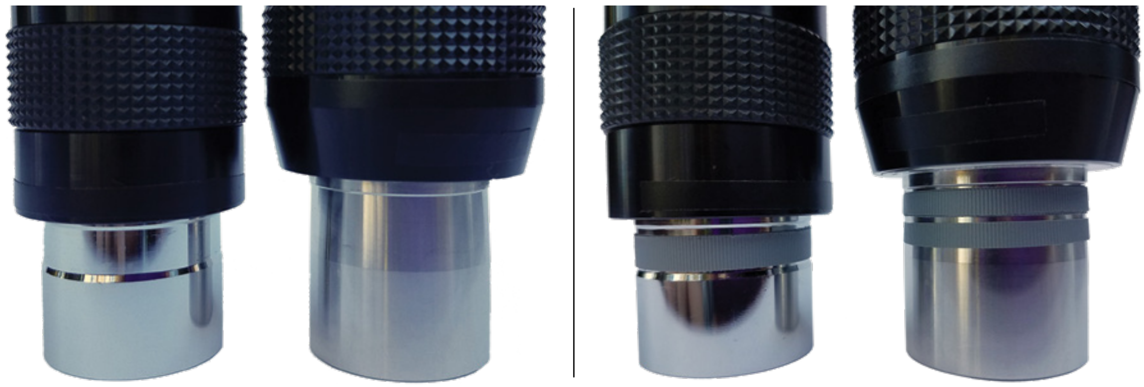
Cut Out the Undercuts

Once a good idea, this safety feature is now just a pain.



◀ *Far left:* Undercuts are the buggy whips of astronomy: once useful, now pointless. *Near left:* Undercuts can be filled with tape. Use tape with glue that won't migrate. Tapered undercuts will require multiple strips of differing thickness.

LOOK AT PRACTICALLY ANY eyepiece in your collection. Chances are it has an undercut on the barrel, a shallow groove milled into it just below the main body. That groove is designed to catch the set screw and prevent the eyepiece from falling out when it's pointed down at the ground, even if the set screw loosens.

Huh? Set screw? Eyepiece pointed at the ground? What am I talking about?

Precisely. Set screws are how we used to clamp eyepieces in focusers, but those have been largely supplanted by compression rings that grip the eyepiece across a much wider area. And the only time your eyepiece is going to point at the ground is when you're using a Newtonian on an equatorial mount, which happens about zero percent of the time anymore. (Except for "hobby killers," see *S&T:* Dec. 2019, p. 36.)

Okay, straight-through refractors still point at the ground, but how many people use refractors without a diagonal? (Hi Drew Sorenson! *S&T:* May 2020, p. 72.)

But eyepieces still have undercuts, and those aren't just a benign holdover from the past. They're a seriously annoying obstacle to modern usage. They catch on the compression ring when you insert or remove the eyepiece, often knocking the scope off target in the process. The undercut literally undercuts the action of the compression ring, which has very little actual metal to push against because most of the contact area has been shaved away. And on eyepieces where the undercut extends all the way to the top — or even on ones where it doesn't if you don't get the eyepiece seated all the way — the sideways pressure of a compression ring (or a set screw) pushes the eyepiece sideways, messing up your collimation.

Binocular-scope users uniformly hate undercuts. Just try to get the images to merge when you're pushing a pair of undercut eyepieces sideways from two different directions.

Most of us who dislike undercuts enough to do something about it fill the channels with tape. That works well enough on flat-bottomed undercuts, provided you use a tape with glue that won't migrate out over time. (Hint: This is not a job for duct tape, nor electrician's tape, nor even masking tape. Use a thick vinyl tape, or gaffer's tape, or even adhesive copper strips like those used for making stained glass windows.)

Filling an undercut becomes much more difficult with the tapered undercuts that some eyepiece manufacturers use. The taper is designed to help prevent catching on the way out of the focuser, so it's a slight improvement in that regard, but it complicates the tape job because to fill that uneven groove you need to add a varying thickness of tape across the width of the undercut. Some people have even resorted to filling the groove with J-B Weld. It's a fussy, painstaking job.

▲ The vast majority of modern focusers use compression rings, not set screws, rendering undercuts worse than useless.

ALL IMAGES COURTESY OF THE AUTHOR

Okay, tape works. But come on now, should end-users have to "repair" a brand-new eyepiece in order to get it to function properly in modern equipment? No, we shouldn't.

Eyepiece manufacturers, I call on you to eliminate the undercut! It's a relic of the past that serves no useful purpose today and causes considerable difficulty for your customers. Give us smooth barrels that won't catch on the way in or out, won't tip sideways (as much, anyway), and still won't fall out of the focuser if the clamping system loosens up because practically nobody's focuser points at the ground anymore.

And while you're at it, telescope manufacturers, please make your dovetail finder mounts load into their brackets from the top, not from the bottom. Dovetail brackets still use set screws, and those still do loosen with use, and a finder that loads from the bottom will fall to the ground and bust the eyepiece. I have the broken finder to prove it. If the finder loads from the top, it won't fall out even if the set screw loosens.

It's not rocket science, folks. Let's get this stuff right.

■ Contributing Editor **JERRY OLTION** has repaired literally dozens of new eyepieces, and several finders.

▲ Finder mounts that slide into their dovetail saddles from the bottom are just accidents waiting to happen.

What Is an Equatorial Mount?

▲ **SIMPLE ACCESS** An alt-azimuth mount, such as the open fork on this Celestron CPC Deluxe 8-inch Schmidt-Cassegrain telescope, permits movement along two axes to point to any location in the sky.

CELESTRON (2)

I REMEMBER DREAMING about owning my first telescope and planning on what I'd look at when I got it and what each object would look like. When my parents finally bought one for me, I was ecstatic! It was a 4½-inch Newtonian reflector, which seemed even more impressive to me than the long, skinny refractors I'd favored. But what was that weird mount it was on? I'd never considered the mount before, only the views I'd get through the scope. It took me a bit of time before I learned what an equatorial mount was and how to use it.

Telescopes come on all kinds of mounts, with fancy names like German equatorial, center-balanced, open fork, English yoke, and one that sounds rather intimidating but really is the most basic of them all, the alt-azimuth mount. So what are these things, and why are they important?

Telescope mounts are necessary for two reasons. First, you can't hand-hold even a small telescope and look through it. Its magnification also amplifies your less-than-steady hands as they shake, rendering the view unusable. Second, the sky moves (actually, it's the Earth we stand upon that's rotating), so in order to study a planet, for example, you have to be able to follow its motion as it arcs across the sky from east to west.

Two Mounts, One Job

There are really only two types of telescope mounts: alt-azimuth and equatorial. And they really aren't that much different from each other when you take a close look at them.

As mentioned earlier, the simplest is the *alt-azimuth* mount. These devices are made to move in two axes: **altitude** (up and down), and **azimuth** (side to side). Having these two motions allows you to point a telescope in any direction. Any mount with a simple up/down, side-to-side motion is an alt-azimuth mount. If you've ever used a camera tripod, you've used an alt-azimuth mount. Dobsonian mounts are also alt-azimuth mounts. Same with the fork mount you might see holding a short telescope like a Schmidt-Cassegrain.

So that's about all you need, right? If you're like most telescope users, then the answer is probably yes. It isn't too difficult to follow an object even at a fairly high magnification of 100× or so by placing it on one side of the eyepiece field and watching it as it drifts across. When it does, just re-aim a little and repeat the process. It all becomes second nature very quickly.

However, the one problem with an alt-azimuth mount is that stars and planets don't move straight up and

▲ **EASY TRACKING** Equatorial mounts are meant to counteract the rotation of Earth, making everything in the night sky appear to stand still in the telescope eyepiece. Any alt-azimuth mount becomes an equatorial when its azimuth axis is aimed at the celestial pole, in this case by adding a polar wedge to the Celestron fork mount to accomplish the task. This action renames the azimuth axis the *polar axis*, and the altitude axis becomes the *declination axis*. The precise amount of tipping depends on your location.

down, or side to side; they tend to move in large arcs sweeping across the sky as Earth rotates. Not a big deal, but that means you usually need to move the telescope in two directions simultaneously to follow your target. Worse, when the cluster or galaxy you're looking at is near the zenith (straight up), it enters a zone where it's hard to track objects at all. Unfortunately, it's that zone where things look their best.

This is where an equatorial mount comes in. This "weird"-looking contraption is designed to permit you to follow objects in the sky by only moving in one direction. In fact, a really simple way to understand an equatorial mount is to imagine that it's the same thing as an alt-azimuth but with its azimuth axis tipped slightly and aimed at the celestial pole (thereby changing its name to *polar axis*). When a mount is configured this way, observers can follow objects across the sky simply by pushing the scope from east to west. Coincidentally, doing so aligns the mount's azimuth axis with the celestial equator (hence *equatorial* mount). Its up-and-down motion is now parallel north to south and renamed the *declination axis*. This configuration also permits the addition of a handy accessory called a *clock drive*. It automatically moves your scope at the speed of Earth's rotation, keeping objects stationary in the eyepiece for as long as you'd like. That fork mount holding the SCT seen at far left instantly becomes an equatorial mount when a polar wedge is added to aim its altitude axis at the celestial pole (near left).

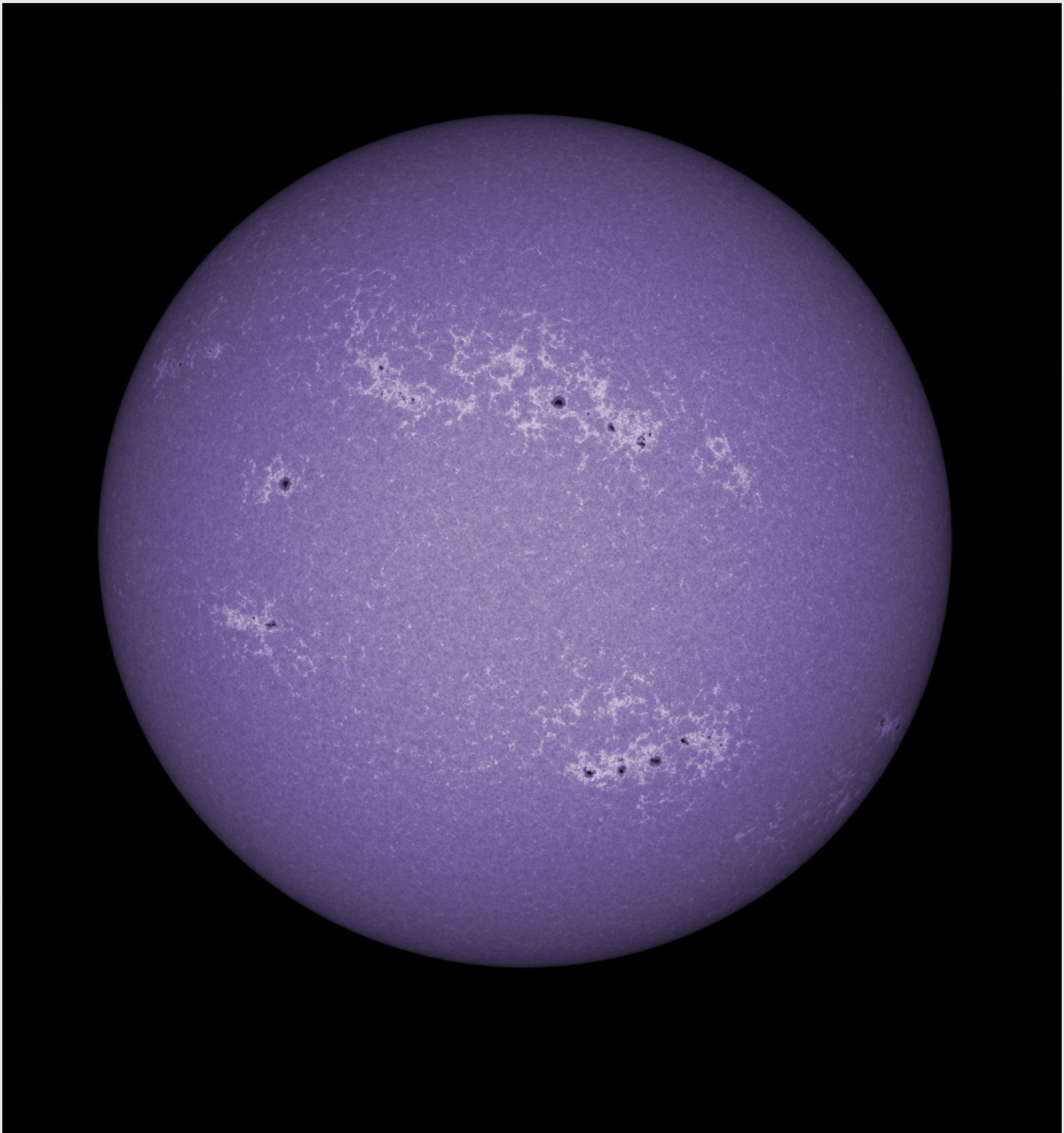
As noted earlier, equatorial mounts come in many different configurations with different names. The one thing they all have in common is that one axis is aimed at the pole.

Which Is Better?

Now that you know the difference between an alt-azimuth and equatorial mount, which is better for you? That really depends on what you want to do.

If you prefer looking through your telescope, you really don't need anything more than an alt-azimuth mount. Tracking is a nice convenience but not strictly necessary. And many decent beginner telescopes these days come on computerized alt-azimuth mounts that provide motorized tracking — in many ways offering the best of both worlds. A good scope and Go To mount combination can take you to thousands of targets and effortlessly track them (a topic for a future column).

Equatorial mounts are really most useful if you're interested in astrophotography, as they allow you to track objects precisely to accumulate long exposures of faint targets. But even that thinking is changing due to technological advancements in cameras and computing. Regardless of its design, the best mount is the one that holds your telescope steadiest and allows you to enjoy what you're doing. ■



VIOLET LIGHT

Arne Danielsen

After several years of low activity, the Sun awoke with a start this summer. Numerous dark sunspots surrounded by webs of bright plage decorate the chromosphere in this sharp image taken on May 16th.

DETAILS: *FLO StellaMira 80-mm refractor and ZWO ASI183MM Pro camera. Stack of multiple frames recorded through a Lunt Calcium K Module.*

◁ WARPED SPIRAL

Ralph MacDonald

Spiral galaxy M106 in Canes Venatici has a particularly active supermassive black hole at its center. Its feasting violently churns matter in the galaxy's bright center, creating red wisps of gas that sprout from either side. The smaller galaxy seen at bottom right is NGC 4248.

DETAILS: *Celestron C11 Schmidt-Cassegrain and ZWO ASI294MC Pro camera. Total exposure: 120 seconds through Optolong filters.*

▽ SUMMER VISITOR

Gerald Rhemann

Despite being nearly 2 a.u. from Earth beyond the orbit of Mars, Comet PanSTARRS (C/2017 K2) sported two tails as it passed in front of faint emission nebulosity in Ophiuchus on the evening of July 26th.

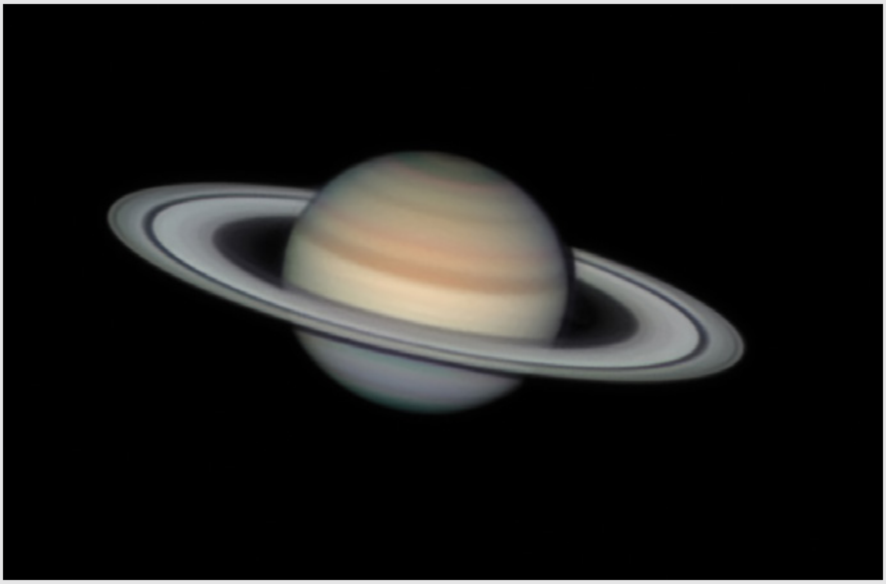
DETAILS: *AstroSysteme Austria 12N-AAF3 astrograph and ZWO ASI6200MM Pro camera. Total exposure: 33 minutes through LRGB filters.*

CELESTIAL SPIDER

Kfir Simon

Located in the Large Magellanic Cloud, 30 Doradus (top left) is the largest and most luminous known stellar nursery in the local universe. Its central star cluster, NGC 2070, brims with massive, young stars with strong stellar winds that are carving deep, intricate cavities into the surrounding gas cloud. North is to the right.

DETAILS: *Celestron 14-inch Rowe-Ackermann Schmidt astrograph and QHY600PRO CMOS camera. Total exposure: 1½ hours through LRGB and Hα filters.*



△ RING TOSS

Damian Peach

Saturn's subtle, pastel-hued belts and zones are well displayed in this image taken on July 11th, just one month from opposition. Although the rings are slowly narrowing due to our changing perspective, the thin Encke Gap along either side of the outer edge is visible, as are several dark regions within the B Ring.

DETAILS: *Celestron C14 Schmidt-Cassegrain and Player One Saturn-M SQR camera. Stack of multiple video frames recorded through RGB filters.*

△ TWIRLING AROUND

Joel Short

Sometimes known as the Helix Galaxy, NGC 2685 in Ursa Major is a Seyfert Type 2 galaxy surrounded by rings of stars, gas, and dust orbiting perpendicular to its galactic plane.

DETAILS: *AG Optical Systems 12.5-inch Dall-Kirkham telescope and QHY11-M CCD camera. Total exposure: 20½ hours through LRGB filters.*

▷ SINKING ECLIPSE

César Briceño

The partially eclipsed Sun sets into the Pacific Ocean as seen from La Serena, Chile, on the evening of April 30.

DETAILS: *Canon EOS RP Mirrorless camera with Tamron 150-to-600-mm zoom lens. Total exposure: 1⁄1600 second at f/8, ISO 800.*

▽ STELLAR CHRYSALIS

Jared Bowens

IC 5146 in Cygnus, also known as the Cocoon Nebula, contains a newborn cluster of stars at its center. These hot, young suns excite the surrounding hydrogen gas, creating a soft, reddish glow.

DETAILS: *Orion 8-inch Newtonian astrograph and Canon EOS 60D camera. Total exposure: 7.4 hours.*

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THE HORSE AND THE SCORPION

Arman Mohammadi

Mount Damavand in Iran appears to wedge itself between the dark nebulae in Ophiuchus (left) and Scorpius (right). The dark nebula is informally known as The Dark Horse. A meandering trail of dust leads from its lifted hoof to the colorful Rho Ophiuchi nebula complex at right.

DETAILS: *Canon Ra camera and Sigma 50-mm lens. Total exposure: 120 seconds at f/2, ISO 3200.*

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Event Calendar

Here's the info you'll need to "save the date" for some of the top astronomical events in the coming months.

September 22–25
BOOTLEG FALL STAR PARTY
Harmon, IL
bootlegastronomy.com

September 22–25
GREAT LAKES STAR GAZE
Gladwin, MI
greatlakesstargaze.com

September 22–25
ILLINOIS DARK SKIES STAR PARTY
Chandlerville, IL
sas-sky.org

September 23–24
IDAHO STAR PARTY
Bruneau Dunes State Park, ID
boiseastro.org/isp.html

September 23–25
BLACK FOREST STAR PARTY
Cherry Springs State Park, PA
bfsp.org

September 23–25
CONNECTICUT STAR PARTY
Goshen, CT
asnh.org

September 23–25
HIDDEN HOLLOW ASTRONOMY CONFERENCE
Bellville, OH
wro.org/hidden-hollow-star-party

September 23–October 1
OKIE-TEX STAR PARTY
Kenton, OK
okie-tex.com

September 24
NOVAC STAR GAZE
C.M. Crockett Park, VA
https://is.gd/NOVACStarGaze22

October 1
INTERNATIONAL OBSERVE THE MOON NIGHT
Everywhere
facebook.com/observethemoon

October 14–23
JASPER DARK SKY FESTIVAL
Jasper National Park, AB
jasperdarksky.travel

October 21–22
DEATH VALLEY STAR PARTY
Furnace Creek Resort, CA
https://is.gd/DeathValley2022

October 23–30
PEACH STATE STAR GAZE
Deerlick Astronomy Village, GA
atlantaastronomy.org/PSSGO

October 24–29
ELDORADO STAR PARTY
Eldorado, TX
eldoradostarparty.org

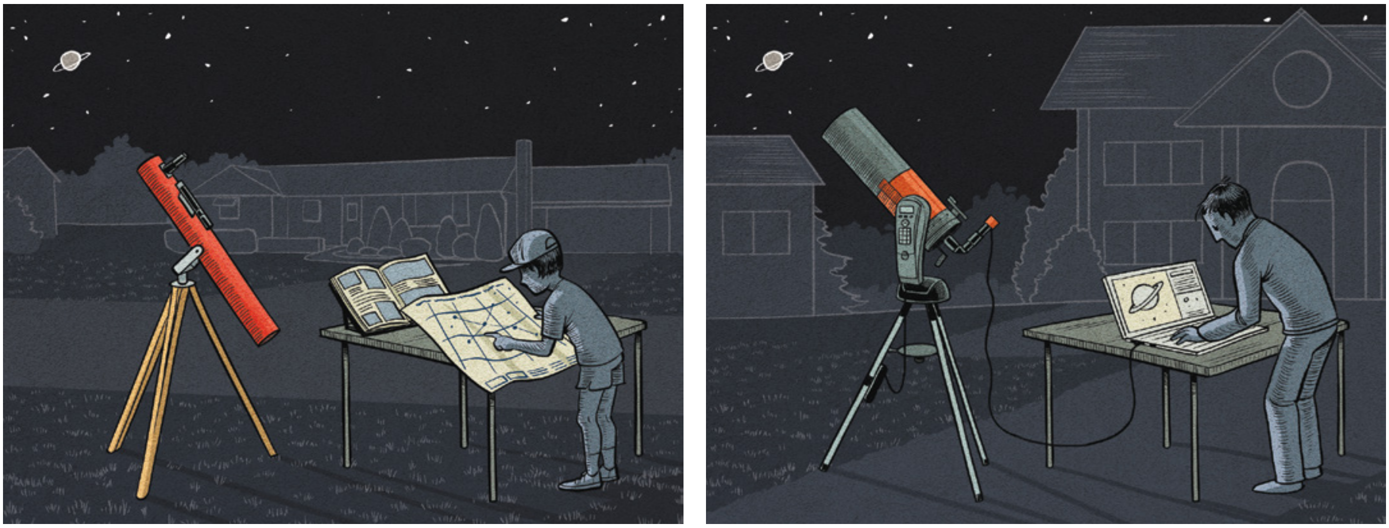
October 25–30
DEEP SOUTH STAR GAZE
Sandy Hook, MS
stargazing.net/DSRSG

October 27–30
SJAC FALL STAR PARTY
Belleplain State Forest, NJ
sjac.us/star-party

• For a more complete listing, visit https://is.gd/star_parties.

A Telescope for the Times

After 40 years, a new scope reconnects the author with the heavens — and with people on Earth.



A LOT CAN CHANGE in four decades. I got my first telescope in 1980 at age 12. My Edmund Scientific 3-inch reflector wasn't much — just a red tube, two mirrors, an eyepiece, and a wooden tripod. But I was blown away when I pointed that tube at Saturn and saw its rings floating so vividly against the black backdrop of space.

When I mentioned this weeks later at a family party, one of my uncles confessed to me, "I haven't seen Saturn in 20 years!" I was stunned, not only to learn he was an amateur astronomer, but also to imagine that anyone would let two decades pass without viewing those fantastic rings. I silently vowed not to let that happen to me.

At 13, I acquired a used 6-inch reflector, a scope with more aperture but less mobility. The skies became a treasure house of wonders, full of hope and promise. Unsurprisingly, though, life in general also ramped up. I started logging Messier objects when I entered high school, which is just when the battle for my limited free time began. Little did I know how long that battle would last!

As the years raced by, I used my scopes periodically, mostly just maintaining but not growing my hobby. The night skies calmly beckoned, with unwavering patience. In the end, it took a global pandemic in 2020 and more time at home to reinvigorate my idled interest. My wife informed me that my Father's Day gift should be a new telescope, one of my own choosing. I heartily agreed.

What a difference 40 years makes!

Tremendous advances took place while I essentially wasn't looking. Setting circles and printed star charts have given way to computer-controlled mounts, automatic sky alignment, digital cameras, and sophisticated software. All of it exceeds anything I ever imagined as a teenager. The Go To mount alone makes my old star-hopping habit a thing of the past. Now I just level the mount, align the scope, fire up the computer, and *voila!* — the heavens are at my fingertips.

Scouring the skies for elusive galaxies, nebulae, and star clusters has never been easier. Setting up and searching takes much less time, leaving more precious hours for actual observing. Today, pretty much anyone can image the planets and use cameras to reveal deep-space objects in ways that were either technologically impossible or absurdly unaffordable in my youth.

The way we share the night sky with others has also changed. I entered our hobby before cellphones, laptops, or Wi-Fi existed, but now we live in a world with social media. We can spread our enthusiasm for astronomy broadly and quickly. Everyone I've come to know over those 40 years can now instantly see the photos I post online. Who knew that so many of them would agree that space is cool?

The rings of Saturn dazzle even more in the new telescope than they did in the old, and the developments in these instruments and related tools in the past four decades are equally impressive. We live in terrific times for amateur astronomy. Take my word for it: No one should wait 20 years to see Saturn, and no one should wait 40 years to get a new telescope.

■ **JOHN WOLFRAM** lives in Louisville, KY, and frequently shares his passion for astronomy and space on social media tagged with **#spaceiscool**.

LEAH TISCIONE / *S&T*