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SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

JUNE 2026

ASTRO-IMAGING

Put the Deep Sky in Context

Page 60

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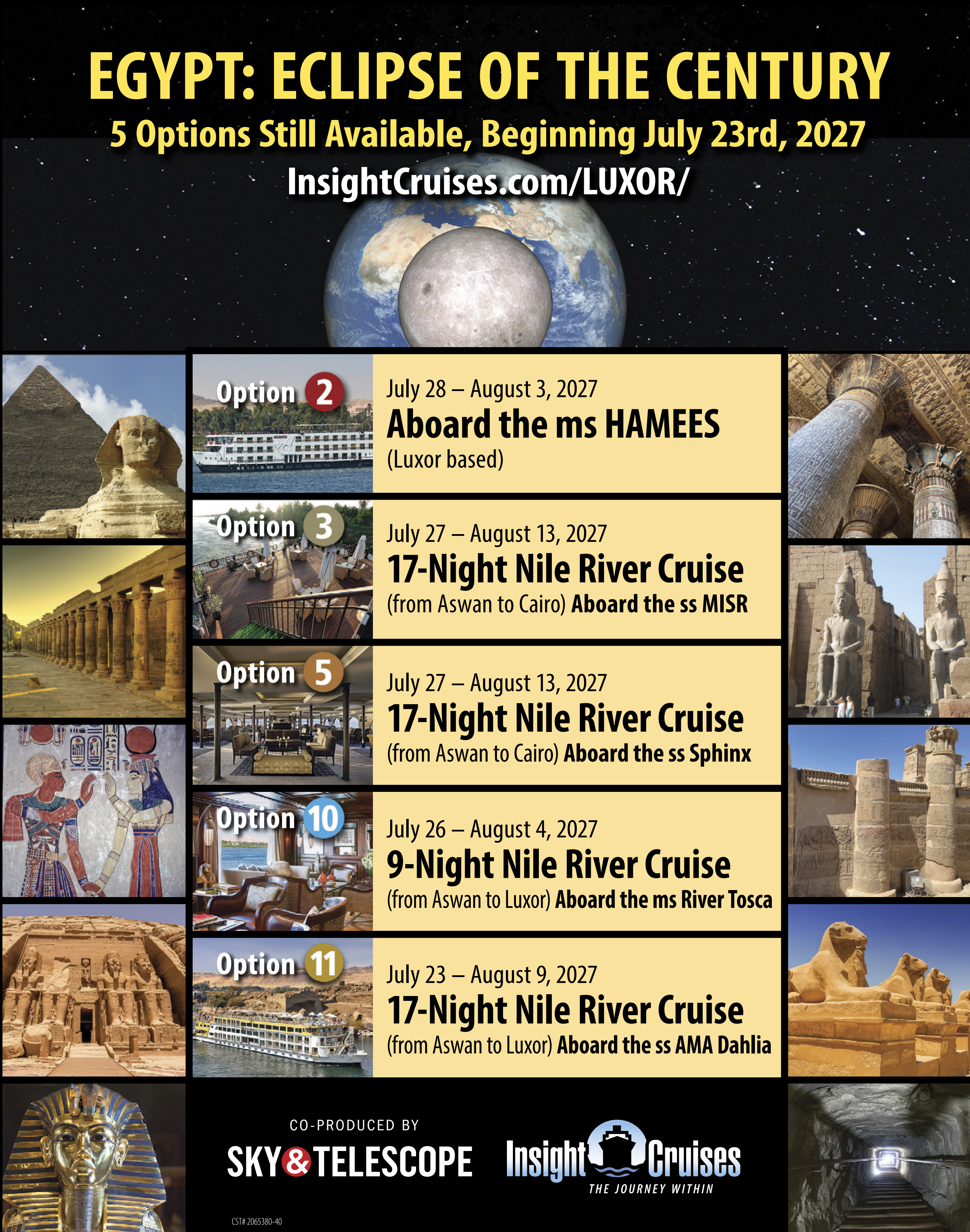
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SKY&TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

June 2026 VOL. 151, NO. 6


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Supernova remnant CTB-1 in Cassiopeia, near Beta Cas

PHOTO: CHRIS SCHUR

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Follow the Stars

I REMEMBER HOW EXCITED I was as a kid when I learned about stellar patterns in the night sky — constellations, asterisms, and how they all fit together. Even more thrilling was learning how those stars and patterns could help me navigate the celestial vault and find other exciting things to see. "Arc to Arcturus, spike to Spica" is one mantra that many an eager skygazer might remember.

But for me, surpassing all those experiences was learning that star-hopping could have a practical purpose. I couldn't wait to show off to my friends how to find north without a compass by using the Pointer Stars of the Big Dipper. (Needless to say, some were more impressed than others.) Starting my observing sessions by locating Polaris is still one of my favorite things to do, as it brings back fond memories.

▲ Harriet Tubman helped deliver nearly 900 formerly enslaved people to freedom.

LIBRARY OF CONGRESS

For a bunch of modern-day kids exploring the stars above them, Polaris is a novelty. But for enslaved people in the 1800s in the United States, the North Star was a vital "beacon of freedom." Turn to Joe Barry's moving story starting on page 28 on how modest Polaris guided scores of people from cruel torment to a more hopeful life.

Animals, too, turn to the sky to find their way. Our July 1969 cover story was on how indigo buntings use celestial navigation for their migrations. I think that's the only time in our nearly 85-year history that we've featured an actual bird on the cover. (Coincidentally, that's the month Apollo 11 successfully touched down on the Moon, which we wouldn't have known for sure at press time — but perhaps it's only fitting that we featured a much smaller celestial navigator in that issue.) Research into animals' wayfinding capabilities has come a long way since then, expanding to mammals and insects. Contributing Editor Javier Barbuzano's enlightening article beginning on page 20 showcases the astonishing variety of animals that use the night sky to navigate.

Taken in isolation, these can all appeal to the curious mind: star-hopping to find a celestial target, animals using the sky for their seasonal migrations. But it's when they're placed into the bigger picture, into *context* — people in search of freedom, the survival of a species — that they truly take on meaning. And astrophotographers put things into context, too. Starting on page 60, Chris Schur takes us on a delightfully eye-catching journey on how to capture images that show a deep-sky object within its surroundings — in other words, in context, so as to create a more meaningful visual narrative.

When you next look at the sky, don't just see star patterns or spot Polaris — bear in mind the bigger context that they represent.

Editor in Chief

SKY&TELESCOPE
The Essential Guide to Astronomy

Founded in 1941 by Charles A. Federer, Jr. and Helen Spence Federer

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▲ Anthony Federer (first row, center) poses with his sister Barbara Federer (now Meredith) to his right and their parents, Charles and Helen Federer, on either side at the convention of the Northeast Region of the Astronomical League in Springfield, Massachusetts, in April 1951.

S&T ARCHIVE

A Family Affair

A few nights ago, I, somewhat belatedly, started reading the January issue. My first sentence was in "Shoot for the Moon" by Diana Hannikainen: "somewhere along the line, something or someone inspired you to delve into astronomy" (*S&T:* Jan. 2026, p. 4). And there, an inch to the right, were the names of the people who inspired me: my parents and *S&T*'s founders, Charles A. Federer, Jr., and Helen Spence Federer!

After more than 20 years of star-hopping to distant galaxies with my Orion Skyquest XT8 Plus Dobsonian, I have been inspired by Richard Wright's "Rise of the Smart Telescopes" (*S&T:* Nov. 2025, p. 60) to dip my toe into astrophotography and am now anxiously expecting a DwarfLab DWARF 3 smart telescope to arrive in a few days.

It is great to know that *S&T* probably will outlive me. Are my sister and I the only people remaining who have been with it from the beginning?

Tony Federer
Falmouth, Maine

What A Beautiful Universe

I was extremely excited to read in the January 2026 issue that you've restarted the two-page spread formally known as Images, now Beautiful Universe. When I first started reading my dad's old *Sky & Telescope* issues from the late 1990s and early 2000s, that was one of my favorite departments. Not only did I get to see a cool astronomical image in those pre-internet days, but I really enjoyed reading several well-written paragraphs about it. So, thanks to Diana and her team for bringing it back. I've been tempted a few times in the last few years to mention that I really enjoyed it and would like to see it brought back.

Scott Harrington
Evening Shade, Arkansas

Sunlight Satellites

Anthony Mallama's "A New Kind of Satellite Could Damage Your Eyes" (*S&T:* Jan. 2026, p. 11) was eye-opening in more ways than one. This business venture to sell reflected sunlight for solar energy via low-orbiting satellites has got to be one of the most shortsighted and potentially damaging projects ever. What a waste of time, money, and resources — a misuse of technology and thinly disguised money-making scheme.

One day, we will devise a method to develop clean, efficient energy. But I can already envision how invested companies will then attempt to block its implementation to protect their profit margins.

Philip Levine
Millis, Massachusetts

Reflect Orbital's satellites with huge reflecting surfaces are frightening, not only to astronomers but to environmentalists as well and to all those concerned with human safety. Launching satellites that create artificial daylight into space is the celestial equivalent of heedless oil and natural-gas drilling. Even the safety and health of humans and wildlife are being crassly disregarded! It seems the inexorable march of technology and the amassing of profit take precedence over the preservation of dark and clear skies.

It's bad enough that Earth-bound light sources are making darkness a precious and dwindling commodity. Now, light pollution is being rocketed right into the sky itself!

Jay Bruesch
Minnetrista, Minnesota

High Density Destruction

In Kai Hebeler, Achim Schwenk, and Anna Watts's "Journey into Neutron Stars" (*S&T:* Jan. 2026, p. 62), the authors illustrate the density of these stars with the analogy that a sugar cube of their material would rival the mass in Mount Everest. If a small amount of material from these stars were somehow transported to a separate location, what would happen? Would it explode? Or would the nuclear force hold it together?

John Stone
Via email

Monica Young replies: *The extreme gravity in neutron stars squeezes neutrons together more than they would like. In the core, the density of neutrons is five to eight times that of an ordinary atomic nucleus. The strong force, which holds neutrons together in an atomic nucleus, becomes repulsive if the distance between them is too small. So while there is a binding effect, there's also a repulsive effect.*

If you extract a sugar-cube-size volume of neutron star and teleport it immediately to Earth, you'll be releasing the tremendous pressure from the neutron star's gravity, causing the neutrons to fly apart. As they get farther away from each other, the strong force would first be repulsive, then attractive for a short time, then too weak to do anything.

Keeping in mind the tremendous mass in that sugar cube of neutrons, if even a small percentage of that is transformed into kinetic energy, the explosion would likely pulverize a good chunk of Earth.

Also, while neutrons bound within atoms don't decay, free neutrons do so within about 15 minutes. Assuming that they are all freed from each other, there'd be an additional energy release from that process.

Curious Delay

Ken Hewitt-White's "A Bang and a Whimper" (*S&T:* Jan. 2026, p. 55) and Diana Hannikainen's "The Pleiades" (*S&T:* Jan. 2026, p. 70) reminded me of a quirk in Charles Messier's celebrated catalog. Surely the Parisian astronomer was cognizant of this grand open cluster when logging his first entry, the Crab Nebula, in 1758. Both M1 and the Pleiades dwell in the same constellation, with the latter being conspicuously naked-eye. And yet, he didn't list the cluster until almost a decade later. It thus appears that the Seven Sisters were tagged M45 because, initially, Messier did not regard them as a credible faux comet.

Mark Gingrich
Mendocino, California

John Cordiale (1958–2025)

It's with great sadness that I report the passing of John Cordiale, 67, on November 25th after a hard-fought battle with cancer. He was a founder and proprietor of Adirondack Astronomy and a great friend to the astronomy community. He and his business partner were early pioneers in video astronomy with their ASTROVID cameras, which became a benchmark. He also introduced very affordable CCD and CMOS cameras to the market. He was an avid science advocate in both photometry and spectroscopy and brought gear and support to the amateur market. John was also a long-time advertiser and supporter of *S&T* until his business closed after the financial crisis of 2008.

He inspired many people in the astronomy community to explore all the rewards of amateur astronomy and science by organizing star parties and performing outreach for local residents and schools. He will be sorely missed.

Kevin Brennan
Anderson, South Carolina

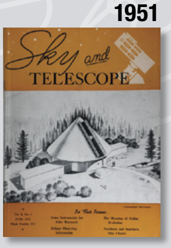
FOR THE RECORD

- In "Star Wars: The Chandrasekhar-Eddington Clash" (*S&T:* Apr. 2026, p. 14), Chandrasekhar Venkata Raman was awarded the 1930 Nobel Prize for Physics for his discovery of the scattering of inelastic light.
- In "Star Wars: The Chandrasekhar-Eddington Clash" (*S&T:* Apr. 2026, p. 14), Sirius B was one of the first white dwarfs to be discovered.

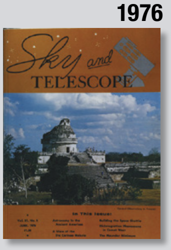
SUBMISSIONS: Write to *Sky & Telescope*, 1374 Massachusetts Ave., 4th Floor, Cambridge, MA 02138, USA, or email: letters@skyandtelescope.org. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

75, 50 & 25 YEARS AGO by Sabrina Garvin

1951



1976



2001

June 1951

Solar Beginnings "Now under construction are two of the world's largest coronagraphs, perhaps the most powerful tools yet devised for solar studies. Plans call for installation of one of these instruments at the High Altitude Observatory of Harvard University and the University of Colorado, at Climax, Colo. The other will be at a companion station located on Sacramento Peak, near Alamogordo, N. M. Two instruments of this type are a minimum if scientists are to [get] at least one set of basic observations each day. . . .

"Studies made during World War II show clearly that solar activity exerts a powerful influence on radio communication. Disturbances of several varieties occur in the earth's upper atmosphere as the result of solar explosions which bathe the earth in an unaccustomed glow of ultraviolet light or spray it with a shower of atoms ejected during the outburst. [But] the exact nature of the solar disturbances is not fully understood. Hence the imperative need for further study of the phenomena."

June 1976

Chinese Fireball "On the afternoon of March 8th, a brilliant fireball traveling southwestward exploded high in the air, dropping stony meteorites over a wide area near Kirin City, in northeastern China. One fragment weighing 1,770 kilograms (3,900 pounds) is the largest stony meteorite ever seen to fall. . . .

"Two other fragments from the Kirin City fall weigh more than 100 kilograms each, and as of April 21st more than 100 additional pieces had been recovered from an area greater than 500 square kilometers. They have black or brownish-black fusion crusts and consist mainly of the minerals augite and olivine. Experts from the Chinese Academy of Sciences describe the Kirin City meteorites as olivine-bronzite chondrites."

June 2001

Radio Brown Dwarf "Thirteen astronomy students using the Very Large Array . . . in New Mexico got the thrill of their lives when they detected the first-ever radio emission from a brown dwarf. . . .

"Edo Berger (Caltech) and his team aimed the VLA's dishes at LP 944-20 in the southern constellation Fornax last July. They detected a constant flux of radio waves at wavelengths of 6 and 3.6 centimeters — as well as three flare-ups when the emission intensified by a dozen or more times for up to an hour. The team's findings, reported in the March 5th *Nature*, are forcing theorists to reexamine their ideas about how a brown dwarf works.

"The university students' project was part of the National Science Foundation's summer science program at the VLA. They chose LP 944-20 as their target because the Chandra X-ray Observatory had detected X-ray flares on it in 1999."

STARS

Second Failed Supernova Candidate Discovered

▲ This artist's illustration shows a previously ejected cloud of dusty gas surrounding a massive unseen object at center.

ASTRONOMERS MIGHT HAVE spotted a star in the Andromeda Galaxy collapsing directly into a black hole, without the accompanying supernova.

A team led by Kishalay De (Flatiron Institute) investigated a known supergiant star 2.5 million light-years away in Andromeda. Archival data from the Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) showed that this star brightened slightly at mid-infrared wavelengths between 2014 and 2016 before swiftly dimming to well below its original luminosity. In the last mid-infrared observations from 2022, the star was still fading. And in archival near-infrared and visible-light data, the star had already vanished by 2018.

"This star used to be one of the most luminous stars in the Andromeda Galaxy, and now it was nowhere to be seen," says De, who led the study published in the February 12th *Science*.

Normally, when a star of this heft — about 12–13 solar masses — runs out of nuclear fuel, it collapses in on itself to form a neutron star or a black hole. A flood of tiny neutrinos coming from the core helps power the accompanying blast wave as it rips through the outer layers in a supernova.

But in this case, De argues, the supernova failed. The star did eject some dusty gas, which still glows dimly at mid-infrared wavelengths. But most of the material that should have been blasted outwards instead fell inwards, leading to the formation of a black hole.

"Instead of taking months or a year to fall in, it's taking decades," says collaborator Andrea Antoni (also at Flatiron Institute). "And because of all this, it becomes a brighter source than it would be otherwise, and we observe a long delay in the dimming of the original star."

A previously discovered failed supernova candidate in the more distant galaxy NGC 6946 (*S&T:* Sept. 2017, p. 10) followed a similar pattern of brightness changes, the team says.

"The interpretation as a failed supernova seems very promising," says Joseph Lyman (University of Warwick, UK), who was not involved in the research. But he adds that it's not an open-and-shut case.

Stephen Smartt (University of Oxford, UK) is likewise cautious: "This is an intriguing find, but I'm not yet convinced it really is a failed supernova and the death event of a massive star," he says. For one, the star is less massive than the theoretical threshold for failed supernovae.

More data will be key to see how this remnant — whatever it is — evolves.

■ COLIN STUART

STARS

The Ring Nebula Has an Iron Bar

THE RING NEBULA in Lyra (Messier 57) is one of the best-studied planetary nebulae — the castoffs of dying low-mass stars. But Roger Wesson (Cardiff University, UK) and colleagues have found something new: A gaseous iron "bar" that spans the nebula. The bar is 500 times wider than Pluto's orbit and contains enough iron to form a planet the size of Mars.

Key to their discovery, Wesson explains, was the integral-field spectrograph on the 4.2-meter William Herschel Telescope on La Palma in the Canary Islands, Spain. In a single observation, 547 fibers record spectra in pixels 2.6 arcseconds wide across a hexagonal field that measures 90 by 78 arcseconds. The team needed three such fields to cover M57.

"One thing popped out as clear as anything," Wesson recalls. "This previously unknown 'bar' of ionized iron atoms, in the middle of the familiar and iconic ring." (The ionized iron atoms have had their outermost electrons stripped off.)

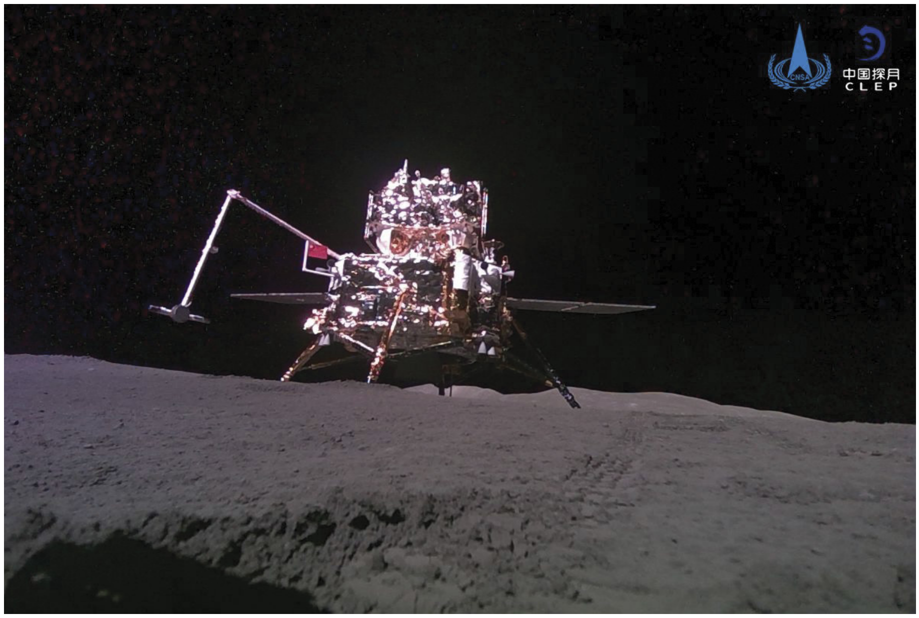
The iron bar has gone undetected until now because, while more typical spectra might have seen the ions' emission, the observations wouldn't have been able to trace its shape. And narrowband filters, which *can* trace the shape of emission, aren't usually available for these wavelengths (422.7 and 567.8 nanometers).

The star at the heart of M57 wasn't massive enough to fuse iron in its core,

KEITH MILLER / CALTECH / IPAC-SELAB

SPACE

Chang'e 6 Finds Oldest Moon Rocks on Record



▲ The rover deployed by Chang'e 6 snapped this image looking back at the lander.

MOON ROCKS BROUGHT back from the lunar farside are only slightly younger than the solar system itself, challenging long-held notions about what the earliest days of our system were like.

While the solar system itself was born 4.6 billion years ago, isotopic dating techniques, which measure when a given rock solidified, showed that the Moon rocks brought back by Apollo astronauts peak at 3.9 billion years old. By implication, the impact basins they come from are of the same age.

In response, some scientists suggested that a disruption — perhaps caused by the giant planets' migration — had sent a torrent of asteroids careening through the inner solar system at the time. That influx, known as the *Late Heavy Bombardment*, would have occurred well after the planets had formed, leaving its mark as an uptick in the number of craters on airless worlds like the Moon.

Not everyone was on board. "The idea was wild at the time," says William Bottke (Southwest Research Institute), who wasn't involved in the current study. "I remember thinking at first there was no way it could be right."

A weak spot of the Late Heavy Bombardment was the limited evidence: Most of the Apollo missions landed in or close to the Imbrium Basin on the lunar nearside. That basin might have come from an unusually late impact, Bottke and colleagues proposed in a 2023 paper. They went on to suggest that there were more ancient impacts, but those basins are missing because they were covered up by later impacts.

China's Chang'e 6 offered an opportunity to sample older lunar territory. In 2024, the spacecraft collected samples from the South Pole–Aitken Basin on the Moon's farside (*S&T:* Sept. 2024, p. 9). It is not only the largest and deepest basin on the Moon, but also the most ancient. "We wanted to know if the farside has the same history," says team lead Zongyu Yue (Chinese Academy of Sciences).

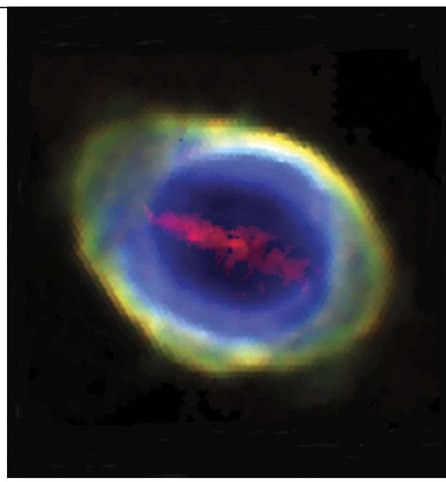
The most abundant pieces Chang'e 6 returned erupted from a lunar volcano, solidifying 2.807 billion years ago. But the sample also included older fragments, including some that cooled 4.247 billion years ago, after a massive impact. The latter pieces likely mark the age of the basin.

Incorporating the new data from Chang'e 6, Yue's team plotted the frequency of impacts by age and found no evidence of the Late Heavy Bombardment, confirming skeptics' ideas. The results are published in the February 6th *Science Advances*. "We are finally seeing the true, smooth evolution of our early solar system," Yue concludes.

■ **JEFF HECHT**

---

so the ions couldn't have come from the star. Instead, the team speculates that the iron might have come from a planet destroyed during the nebula's formation. "We'd expect it to be vaporized," Wesson says. "The outer layers of the star would have had temperatures above the boiling point of iron."



▶ In this composite image of the Ring Nebula, the bright outer ring is made up of light emitted by three different ions of oxygen, while the bar across the middle is seen in light emitted by ionized iron atoms, each stripped of four electrons. North is up and east is left.

But that scenario remains speculative for now. For one, it's unclear why a vaporized planet's remains would have taken the shape of a bar. Additional observations could develop this scenario by identifying other elements in the bar.

In addition to studying M57 in more detail, Wesson's team plans to look for bars in other such nebulae, too. Intriguingly, another group has recently found a similar iron bar in NGC 6818, a bright planetary nebula in Sagittarius. That group will report their analysis soon.

■ **JAN HATTENBACH**

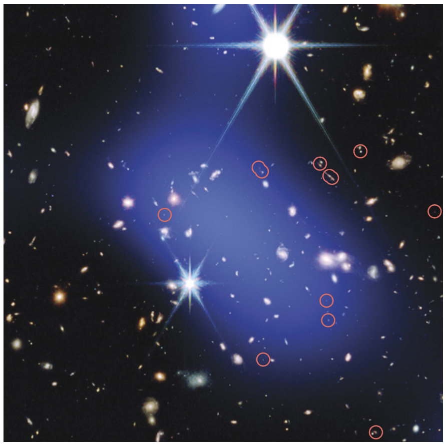
PROTOCLUSTERS

Infant Galaxy Clusters Grew Faster Than Expected

ASTRONOMERS HAVE DISCOVERED extreme examples of still-growing galaxy clusters (or *protoclusters*) in the early universe, perhaps pointing to a faster track of evolution than expected.

The farthest known protocluster, dubbed JADES-ID1, was found thanks to teamwork between NASA's James Webb Space Telescope (JWST) and Chandra X-ray Observatory. Scientists first identified the protocluster as a candidate in the JWST Advanced Deep Extragalactic Survey (JADES). Chandra then followed up, picking up the faint blush of hot gas — the smoking gun of a galaxy cluster. Ákos Bogdán (Center for Astrophysics, Harvard & Smithsonian) and colleagues published the X-ray results in the January 29th *Nature*.

The protocluster contains roughly 20 Milky Ways' worth in total mass, an unexpectedly large heft given that the universe at the time was only 1 billion years old. Under the standard



▲ The most distant protocluster known, JADES-ID1, is visible as Webb-detected galaxies (circled) and Chandra's X-rays (blue).

model of cosmology, there's only a 1 in 5 million chance of finding that much matter clustered within the tiny volume that Webb was surveying.

"JADES-ID1 is giving us new evidence that the universe was in a huge hurry to grow up," Bogdán says.

Rogier Windhorst (Arizona State University), who wasn't involved in the JADES study, agrees with the team's mass assessment. He emphasizes that the result doesn't mean cosmology is broken, just that we might not fully understand how protoclusters form.

A second record-breaker is COSMOS-z3.1A, discovered as part of the One-hundred-deg^2 Dark Energy Camera Imaging in Narrowbands (ODIN) survey. With more than 5,000 Milky Ways' worth of dark matter, gas, and galaxies, this is the most massive protocluster known. It consists of 10 smaller clumps, some of which could evolve into galaxy clusters in their own right, said Vandana Ramakrishnan (Purdue University), who presented the results January 8th at the 247th American Astronomical Society meeting.

COSMOS-z3.1A has had twice the time to grow as JADES-ID1. Yet the mass is still striking for its rarity. Only one protocluster this massive is expected within the volume that ODIN had surveyed, Ramakrishnan said.

These extreme protoclusters will help astronomers fill in the evolution of the most massive structures in the universe.

■ **MONICA YOUNG**

Read more: **skyandtelescope.org/proto**

SOLAR SYSTEM

Streaks Suggest Mercury Is Geologically Alive

MERCURY LOOKS LIKE it's dead. From what we know, it's a small husk of a planet, its proximity to the Sun leaving it blasted by radiation. Its global magnetic field is weak, and most water once on its surface is gone.

But in perusing data from NASA's Messenger orbiter, which ended its mission at Mercury in 2015, scientists have detected a surprising hint of activity.

Using artificial intelligence, Valentin Bickel (University of Bern, Switzerland) and colleagues focused on an intriguing surface feature in the Messenger images called *lineae*. First described at a conference in 2019, Mercury's lineae appear as bright, straight features, often clustered near the rims of impact craters. Their presence suggests that asteroid impacts have cracked the planet's crust, exposing deeper layers and releasing *volatiles* (substances that easily turn to vapor).

The team thoroughly examined lineae in Messenger's image archive. The researchers trained a *convolutional neural network* — a type of AI (*S&T:* April 2026, p. 62) commonly used in image recognition — to spot these features. Then they let it loose on the whole dataset, where it mapped out 402 lineae, published January 27th in *Nature Communications Earth & Environment*.

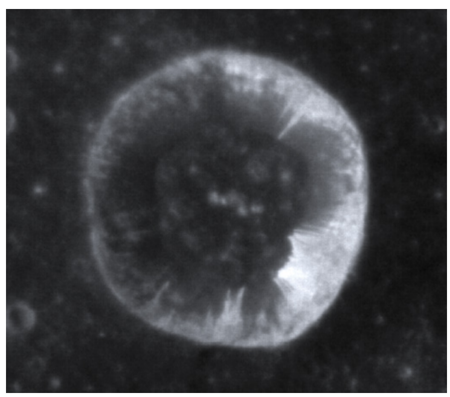
The researchers confirmed that lineae appear mostly on steep, Sun-facing slopes of young impact craters. They extend from hundreds to thousands of meters long. Supporting the idea that they are cracks in the crust, the lineae appear deep enough to have penetrated Mercury's upper layer, reaching volatile-rich material below. The team suggests the volatiles move up toward the surface, then flow down the steep slopes.

▶ A Messenger image shows bright streaks, known as *lineae*, starting near the upper part of a crater's rim and flowing down steep slopes.

It's still unclear whether lineae are freshly exposed materials or, if somewhat older, the residue left behind by escaping material.

The findings are a great appetizer for BepiColombo, a joint mission between the European Space Agency and the Japan Aerospace Exploration Agency, currently on its final approach to Mercury. The spacecraft is expected to begin returning images in early 2027.

■ **JAVIER BARBUZANO**



PROTOCLUSTER JADES-ID1: X-RAY: NASA / CXC / CFA / Á. BOGDÁN, INFRARED: NASA / ESA / CSA / STSCI; IMAGE PROCESSING: NASA / CXC / SAO / P. EDMONDS AND L. FRATTARE; MESSENGER IMAGE OF LINEAE: NASA / JHUAPL / CARNEGIE INSTITUTION OF WASHINGTON

An artist's concept of the red dwarf LHS 1903 and its four planets

ESA

EXOPLANETS

Planetary System Breaks the Rules

AN EXOPLANET SYSTEM'S unexpected arrangement might change how we think about planet formation. In most planetary systems, terrestrial worlds orbit close to their star, while planets with extended gaseous envelopes (like Jupiter and Neptune) lie farther out. But around LHS 1903, a red dwarf 116 light-years from Earth, the exoplanets don't all follow this rule: The innermost planet is rocky and the next two have extended gaseous envelopes, but the outermost planet is rocky, with a radius 1.7 times that of Earth and almost six times our planet's mass.

On February 12th in *Science*, researchers led by Thomas Wilson (now at University of Warwick, UK) argue that the outermost planet, LHS 1903e, was likely born this way.

NASA's Transiting Exoplanet Survey Satellite (TESS) revealed the three innermost planets. Then, the European Space Agency's Characterising Exoplanet Satellite (CHEOPS) as well as ground-based telescopes uncovered the fourth, rocky world.

While planets between Earth and Neptune in size are the most common in the galaxy, those with just less than twice Earth's radius are slightly less common. LHS 1903e lies within this "radius valley."

Many astronomers attribute the valley to stellar radiation, which strips gas from closer-in planets. But that doesn't seem to have happened here: If LHS 1903e had lost its gases to irradiation, then the two middle planets would have lost their gaseous envelopes, too.

Instead, the planet might have formed in what team member Sara Seager (MIT) calls "a depleted disk environment." Early-forming planets would have had access to abundant gas, allowing them to build thick atmospheres. But if the outer planet for some reason formed later, after the gas dispersed, it would form rocky.

This scenario hinges on the planet's mass relative to its siblings. Seager acknowledges the mass is uncertain, and there's a possibility its mass is less than both of the inner gaseous planets. Future observations will refine LHS 1903e's mass as well as tell us if other systems exist like this one.

"In exoplanets, where there's one, there are usually more," Seager notes. "So hopefully there will be more data points soon."

■ ANA GEORGESCU

IN BRIEF

Chilean Project Canceled

Northern Chile's skies are safe, for now. AES Andes, a subsidiary of the U.S. power company AES Corporation, will no longer pursue a large-scale industrial project in the country's Atacama Desert, according to a January 23rd statement. This news comes as a relief to astronomers, who feared the installation would pollute the night skies above some of the world's most important astronomical facilities. The large, $10 billion project would have been installed near several world-class telescopes of the European Southern Observatory. In March 2025, Nobel Prize winner Reinhard Genzel visited Paranal Observatory with President Steinmeier of Germany, and in November that year, 28 renowned astronomers appealed to the Chilean government to call for the project's relocation. Chile's president elect, José Antonio Kast, spoke out against the energy project during his campaign. Now, the company will discontinue the installation "following a detailed review of its project portfolio." Chilean Science Minister Aldo Valle Acevedo welcomed this turn of events, saying: "This private decision is good for Chile, for science, and for all of humanity."

■ JAN HATTENBACH

Read more details: **skyandtelescope.org/ChileObsSaved**.

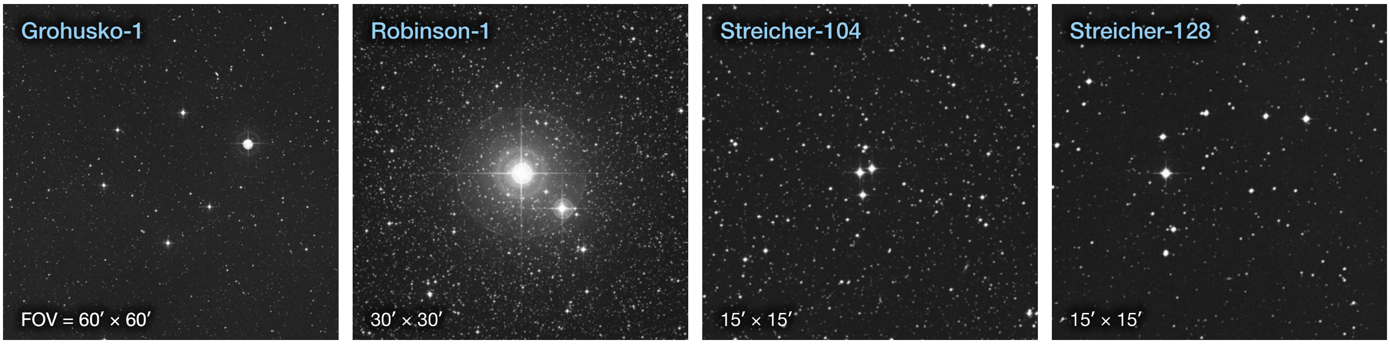
Apophis Mission Approved

The European Space Agency has greenlighted its Rapid Apophis Mission for Space Safety (RAMSES), which will rendezvous with 99942 Apophis just before the asteroid's close encounter with Earth in 2029. RAMSES is scheduled to launch on a Japanese rocket in April 2028, potentially ridesharing with Japan's DESTINY+ mission to 3200 Phaethon, source of the Geminid meteor shower. Before heading there, DESTINY+ will fly by and image Apophis, too. Meanwhile, RAMSES will take a longer route, reaching Apophis around February 2029, two months before the close approach. (NASA's OSIRIS-APEX mission will arrive at Apophis one month *after* the close pass.) RAMSES will image selected areas down to about 1.5 centimeters in resolution. The spacecraft will carry eight science instruments as well as two CubeSats named Farinella and Don Quijote. Farinella will measure dust around the asteroid and use radar to probe its interior; Don Quijote will land on the surface, taking high-resolution images as it descends.

■ DAVID DICKINSON

Delightful Telescopic Asterisms

Personal discovery awaits those who scan the skies with imagination.



▲ **NEW STELLAR GROUPINGS** Try to spot these asterisms in (from left) Virgo, Puppis, Lupus, and Scorpius. North is up in all images.

POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY (4)

THE NIGHT SKY is a frontier not fully explored. New wonders, especially binocular and telescopic *asterisms* — minute gatherings of stars that form familiar or fanciful patterns — are fast becoming popular, as more skywatchers discover the celestial scenery with the sails of their imagination open. Here are four examples.

Grohusko-1. On May 20, 2025, Christopher Grohusko of El Paso, Texas, was scanning Virgo at 32× with his 5-inch Celestron telescope when he encountered a ring of six stars "ordered very perfectly and nearly symmetrical." The asterism formed the apex of an imaginary triangle with Iota (ι) and Kappa (κ) Virginis. "The arrangement of the six stars, with three across the top and three across the bottom, was striking and jaw-dropping," he said, so he decided to christen it the "Six Sentinels." The circlet of stars — centered at right ascension $14^h\ 01^m\ 00^s$, declination –08° 15′ 00″ — is punctuated by a 6.6-magnitude orange giant; the remaining five stars shine between 8th and 9th magnitude, making it a wonderful target for small telescopes.

> "Asterisms are the hidden jewels of the starry skies."
> —MAGDA STREICHER

Robinson-1. Paul Robinson of Longmont, Colorado, also chanced upon a new asterism, this one in Puppis. He first noticed it in the late '70s, "while learning the sky with great enthusiasm." At the time, he was scanning the Milky Way east of Canis Major when he spotted a smattering of stars in an arc southwest of 3.3-magnitude Xi (ξ) Puppis, "with each star appearing progressively dimmer than the previous." The view through his 8-inch telescope added a couple of progressively dimmer stars that followed the arc-like arrangement. He dubbed the asterism "The Arc to Infinity" because "it seems to go off into the depths of space, conjuring a 3D effect unlike most asterisms." Xi Puppis is located at right ascension $07^h\ 49^m\ 18^s$, declination –24° 51′ 35″.

Streicher-104 and **Streicher-128.** Prolific asterism hunter Magda Streicher conducts both planned and random searches of the night sky with her 16-inch Schmidt-Cassegrain telescope in the western part of the South African bushveld. Two of her recent finds are visible in the June evening sky.

In May 2023, while observing the 12.5-magnitude planetary nebula NGC 6026 in Lupus, Streicher noticed a tiny, 3.2′-wide asterism consisting of only four stars. The grouping, later designated Streicher-104, was so well-defined, with magnitudes ranging from 8 to 11, that she named it "the Splendid Four." You can find it at right ascension $15^h\ 57^m\ 27^s$; declination –32° 47′ 09″.

Then, last August, Streicher was sweeping her scope across northwestern Scorpius when she encountered "a handful of stars in a broken half-Moon shape," only some 3° southeast of the 4th-magnitude double star Xi Scorpii. The brightest star in the roughly 9′-wide group shines at 9th magnitude and was "super white," she noted. The remaining stars range between roughly 11th and 13th magnitude, making the group best for large-size telescopes. You'll find Streicher 128 at right ascension $16^h\ 16^m\ 20^s$, declination –13° 38′ 47″.

All these new asterisms are *personal* discoveries being shared for the first time. "Asterisms are the hidden jewels of the starry skies," says Streicher. "For me, searching for these small groupings is an exciting personal pursuit. Whenever I find one, I'm always amazed at how my imagination can so vividly create a lasting impression."

As always, go out under the stars and enjoy the night. Who knows what wonders you, too, will sweep up with your telescope?

■ Contributing Editor **STEPHEN JAMES O'MEARA** loves to share the visual wonders of the day and night skies.

 by Joe Barry

Freedom's Beacon

Enslaved people looked to the sky when escaping north.

JEANINE MICHNA-BALES / THROUGHDARKNESSTOLIGHT.COM

FOLLOW THE DRINKING GOURD The asterism referred to as the Big Dipper or Drinking Gourd has assumed other identities throughout the world. Only in America did it mark the path to freedom. This photo of it was taken in Tennessee along an Underground Railroad route.

On the early morning of November 13, 1833, Araminta “Minty” Ross gazed in rapture as thousands of meteors rained down from the heavens. As an 11-year-old enslaved girl on Maryland’s Eastern Shore, already well attuned to her surroundings, she realized something remarkable was occurring. The adults were on their knees praying for salvation on what appeared to be Judgment Day. A nearby resident remembered seeing “a snowstorm of fiery flakes — so thick and numerous were they.” That night’s Leonid meteor storm was a profound moment in Minty’s life, but she could not yet comprehend its full portent, much less predict she would become a lodestar for her people’s liberation.

Thirty-five miles north in St. Michaels, Maryland, a 15-year-old enslaved boy named Frederick Bailey was similarly awestruck. “I was not without the suggestion, at the moment, that it might be the harbinger of the coming of the Son of Man,” he recalled. “I had read, that the ‘stars shall fall from heaven’; and they were now falling.” Suffering a crisis of faith at the time, Frederick interpreted the meteors as “descending messengers” delivering him to a better path.

The Underground Railroad

Beginning in the early 16th century, more than 10 million Africans were uprooted from their lives and sent to the Americas and the Caribbean. The vast majority — an estimated 85% — were sent to Brazil, Spanish South America, and the Caribbean islands; around 5% or 6% arrived in the United States. Unlike those other regions, America was unique as a country divided between free and slave states.

As slavery took root in America, so too did a swelling resistance. Thousands of people voiced opposition to its inhumanity, and thousands more established a network of pathways to freedom. Fergus M. Bordewich, a leading historian of what came to be called the Underground Railroad, estimates that up to 100,000 enslaved people escaped in the six decades prior to the Civil War. Most fled north from Kentucky, Virginia, and Maryland, which shared borders with free states. Some had the help of guides, called “conductors,” while others made their own way. Of this total, approximately one-quarter to one-third settled in Canada.

More than 160 years after the Civil War, the Underground Railroad continues to inspire, and a growing number of safe houses, hide sites, and escape routes are being discovered, preserved, and commemorated. The Underground Railroad was America's first integrated civil-rights movement, as well as the source of countless acts of bravery, sacrifice, and triumph.

Conventional wisdom holds that the Underground Railroad was centrally organized, with a top-down leadership structure. In reality, it operated at the grassroots level, with innumerable local cells, and often relied on volunteer Vigilance Committees in Northern cities to help formerly enslaved people integrate into free society. As one Ohio conductor noted, "There was no regular organization, no constitution, no officers, no laws or agreement or rule except the 'Golden Rule,' and every man did what seemed right in his own eyes." It was precisely this informal structure that made the Underground Railroad so effective — and impossible to stop.

Guiding Light

Because this movement was largely driven by the independent actions of enslaved individuals, we cannot underestimate the importance of the night sky in the effectiveness of the Underground Railroad. And as the movement grew in magnitude, it transformed the North Star from a navigational aid into a guiding light for freedom. Those seeking safety knew to head northward, in the direction of the bright stars of the Big and Little Dippers.

The spiritual "Follow the Drinking Gourd" celebrates enslaved people escaping toward the Big Dipper. Its first verse instructs:

When the sun comes back,
When the first quail calls,
Then the time has come.
Follow the drinking gourd.

This song, preserved by a folklorist in 1928 and popularized by several 20th-century folk singers, may have derived from pre-Civil War oral traditions. Whether or not the song should be interpreted literally, those in flight used the Big Dipper both as a pointer to Polaris and as a general northern signpost. Its bright stars are easy to spot, and the asterism is part of the star lore of many cultures (*S&T:* May 2025, p. 45).

▶ **THE NIGHT STARS FELL** For millions of Americans, 1833's Leonid meteor storm was a life-altering event. Two enslaved youths in Maryland interpreted it as a divine sign and took action.

The Journey Northward

Even with the benefit of the North Star, freedom seekers confronted numerous obstacles. They endured sweltering summers, frigid winters, dense forests, stagnant swamps, stinging insects, wild animals, and venomous snakes. Many enslaved people, especially children, traversed unfamiliar terrain barefoot and in threadbare clothing. Food was limited. And then there were the slave-catchers and their hunting dogs. Quite simply, escape was a life-threatening commitment — often with severe repercussions for family members who remained behind.

Such was the case for Josiah Henson, who learned in September 1828 he would soon be sold and separated from his wife and four children in Kentucky. His wife, Charlotte, was terrified, but she agreed to join him in escaping. She fashioned a large knapsack that allowed Josiah to carry their two smallest children. She would accompany the middle son, and the eldest would go by himself and carry food to their rendezvous point. On a dark, moonless night in the middle of the month, they stole away in the direction of Polaris.

The Henson family followed the Dipper through the Kentucky forests to the bank of the Ohio River. A fellow enslaved man, at great risk to himself, piloted them to the shore of the free state of Indiana in a small skiff. They travelled an additional fortnight to Cincinnati, where they received a warm reception from local abolitionists. In deference to the North Star, Josiah exclaimed, "Blessed be God for setting it in the heavens! Like the Star of Bethlehem, it announced where salvation lay."

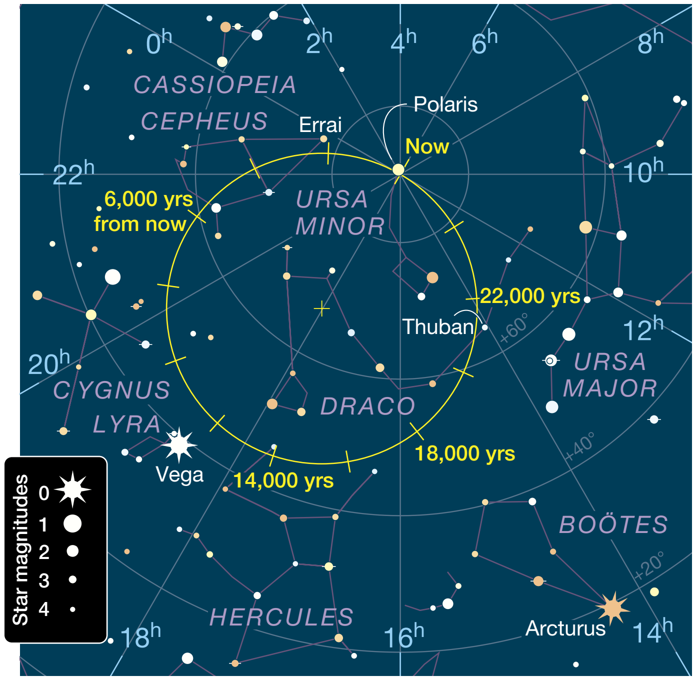
The family eventually settled in Ontario, Canada, where Josiah established a settlement employing several hundred formerly enslaved people. His life story before and during his journey northward served as one of the models for the protagonist in Harriet Beecher Stowe's *Uncle Tom's Cabin*, the most influential work in anti-slavery literature. Stowe's novel was the best-selling book in 19th-century America after the Bible.

Although Polaris and the Great and Lesser Bears point the way northward, the Underground Railroad did not always follow its direction. Rarely reported, several thousand enslaved people from Texas and other Southern states escaped to Mexico and the Caribbean. Conductors and abolitionists also set their backs to the North Star when traveling into slave states to rescue those in bondage.

Among these conductors was Minty Ross, who more than a decade after witnessing the Leonid storm, changed her name to Harriet Tubman. After escaping herself in 1849, Tubman made 13 southern trips, liberating more than 70 people and providing information that enabled 50 more to escape. Small wonder Tubman became known as the "Moses of her people." As with Henson, Tubman cited divine intervention: "He gave me my strength, and he set the North Star in the heavens; he meant for me to be free."

Inconstant Moon

Compared to Polaris, the Moon's role in the Underground Railroad was more complicated. The new Moon's darkness afforded the best cover to fugitives, and several freedom



▲ **SPINNING TOP** The precession of Earth's axis operates in a 26,000-year cycle. Over this time, several stars besides Polaris will function as the North Star, including zero-magnitude Vega 12,000 years from now.

The North Star

Beyond its navigational function, Polaris is fascinating in its own right. At visual magnitude 2.0, Polaris is a triple-star system located 446 light-years from the Sun. The primary, Polaris Aa, is a yellow supergiant five times the mass of the Sun. Polaris B, first recorded by William Herschel in 1779, is a yellow, 8th-magnitude star of 1.4 solar masses. Polaris A and B are separated by 18″ (2,460 astronomical units at the distance of Polaris) in a 40,000-year orbit.

In 1899, William Wallace Campbell from Lick Observatory discovered the main star was a close spectroscopic binary. Nancy Evans (Center for Astrophysics, Harvard & Smithsonian) and her colleagues have used spectroscopy and imaging to determine the system's orbit and component masses. The close companion, Polaris Ab, is a yellow star of 1.3 solar masses, hundreds of times fainter than Polaris Aa. Together, the Polaris A system has an orbital period of 29 years in an elongated orbit ranging from 6.2 to 27 au (0.05″ to 0.2″).

Shakespeare's Julius Caesar declares: ". . . I am constant as the northern star, Of whose true-fix'd and resting quality, There is no fellow in the firmament." But Polaris Aa is the nearest and brightest Cepheid variable to Earth, fluctuating between magnitude 1.86 and 2.13 every 3.97 days. Visible tens of millions of light-years away, Cepheids enable us to measure the expansion rate of the universe through Henrietta Swan Leavitt's period-luminosity law (*S&T:* Dec. 2021, p. 12; *S&T:* Oct. 2022, p. 12). Over the years, Polaris Aa has shown small changes in its pulsation rate, likely caused by close approaches of Polaris Ab. And the Polaris system as a whole has apparently brightened from 3rd to 2nd magnitude since Ptolemy's observations in AD 137 — perhaps a twofold increase or more. Over larger scales of time the North Star has been decidedly inconstant.

In addition to its inconstant brightness, Polaris is slowly changing position over time (*S&T:* Mar. 2019, p. 14). The gravitational pull of the Sun and the Moon causes a positional drift in Earth's rotational axis, called *precession,* a motion similar to the wobble of a spinning gyroscope. Precession operates in a 26,000-year cycle. Third-magnitude Errai (Gamma Cephei) will become the next North Star in 2,000 years. Within 8,000 years, 1st-magnitude Deneb will hold the title, situated 7° from the pole. Twelve thousand years from now the brightest star to hold the title will be Vega. In 21,000 years, the closest will be Thuban (Alpha Draconis), which will precess to within 0.1° of the pole, though at a relatively dim magnitude 3.7. It is serendipitous that Polaris was in the optimal station when enslaved Americans were making their way to freedom.

seekers' personal narratives paid homage to American abolitionist poet John Pierpont's ode to the North Star:

I, too, lie hid, and long for night:—
For night:— I dare not walk at noon,
Nor dare I trust the faithless moon . . .

Enslaved people made a wish at the initial sighting of the young crescent Moon, and many believed that seeing its light filtered through foliage brought bad luck.

Slave-catchers also patrolled by moonlight, indicating that freedom seekers absconded whenever the opportunity presented itself, regardless of lunar phase. Indeed, any enslaved person discovering they would be separated from their family — or their removal to a worse location was imminent — did not have the luxury of waiting for the new Moon.

And yet, it would be unfair to judge the full Moon as unfaithful to liberty. On the early morning of June 2, 1863, Tubman accompanied 300 soldiers from the 2nd South Carolina Colored Infantry Regiment and an element from the 3rd Rhode Island Heavy Artillery Regiment in a raid on plantations along the Combahee River in South Carolina. Aboard the USS *John Adams*, she watched the full Moon rise over the river; its light and the high tide helped raiders avoid mines and quicksand. The mission was a resounding success, liberating more than 750 people who were denied their freedom after Lincoln's Emancipation Proclamation earlier that year.

▲ **CELESTIAL INSPIRATION** Frederick Douglass's *North Star* was the leading anti-slavery newspaper of its day, and a source of scientific learning. Its 1850 masthead included an image of a freedom seeker following Polaris northward.

Cloudy Skies

Weather was another significant variable on the Underground Railroad. Cloud cover subdued moonlight, but it also obscured Polaris. One can sense the North Star's significance in the plaintive spiritual "My Way's Cloudy":

▲ **PERILOUS JOURNEY** Freedom seekers conquered numerous dangers on their journey to freedom. Contrary to popular belief, most set out without instructions from Underground Railroad conductors or abolitionists. But once begun, a vast support network existed to ensure safe passage.

NORTH STAR MASTHEAD: LIBRARY OF CONGRESS; FREEDOM SEEKERS: LIBRARY OF CONGRESS, REMIXED BY BEATRIZ INGLESSIS / *S&T*

O brethren, my way,
My way's cloudy.
My way,
Go send them angels down.

Alfred S. Thornton, who fled from Virginia in 1858, endured a week of nonstop rain before finally sighting Polaris and continuing his journey to Philadelphia. William Wells Brown, a prolific author and the first Black American playwright, escaped from a steamship in Cincinnati and hid in the woods until nightfall. His elation, however, soon turned to dread: "I looked in vain for the North Star; a heavy cloud hid it from my view. I walked up and down the road until near midnight, when the clouds disappeared, and I welcomed the sight of my friend — truly the slave's friend — the North Star!"

What were travelers to do during the cloudy months? One answer is found in John Brown, a formerly enslaved man who employed a secondary solution while escaping through Tennessee: ". . . I began to look about for signs. I soon noticed that on one side of the trees the moss was drier and shorter than it was on the other, and I concluded it was the sun which had burnt it up, and checked its growth, and that the dry moss must therefore be on the south side." Reading moss was an imprecise method, but it was better than nothing.

From Inspiration to Action

After seeing the descending messengers on the night stars fell, Frederick Bailey toiled for several years in the fields and shipyards of Maryland and taught himself to read and write. He escaped in 1838, traveling via railroad and steamboat by impersonating a free Black sailor. He immediately changed his name to Frederick Douglass and emerged as the preeminent abolitionist in America. While living in Rochester, New York, Douglass started a Black newspaper, naming it, appropriately, *The North Star*. Beyond its anti-slavery focus, its pages regularly featured articles such as "The Science of Optics," "The Moon," and "Our Wonderous Atmosphere."

Astronomy played a decisive role in the Underground Railroad. Shakespeare was correct about Polaris being peerless in the northern sky. The Moon, too, ever waxing and waning, bore witness to immeasurable bravery. In an 1868 letter to Tubman, Douglass affirmed the night sky's importance to the Underground Railroad: "The midnight sky and the silent stars have been the witnesses of your devotion to freedom."

Just as the historic sites of the Underground Railroad conjure the ghosts of our ancestors — summoning their trials, their shortcomings, and their triumphs — the Moon and the northern stars illuminate the bravery of those who imperiled their lives and livelihoods in liberty's cause. These celestial beacons of freedom shine every clear night. All we need do to receive their inspiration is to focus our gaze upward.

■ **JOE BARRY** is a retired U.S. Air Force officer and avid visual astronomer living in Tampa, Florida. For more of his writing, visit **joebarryauthor.com**.

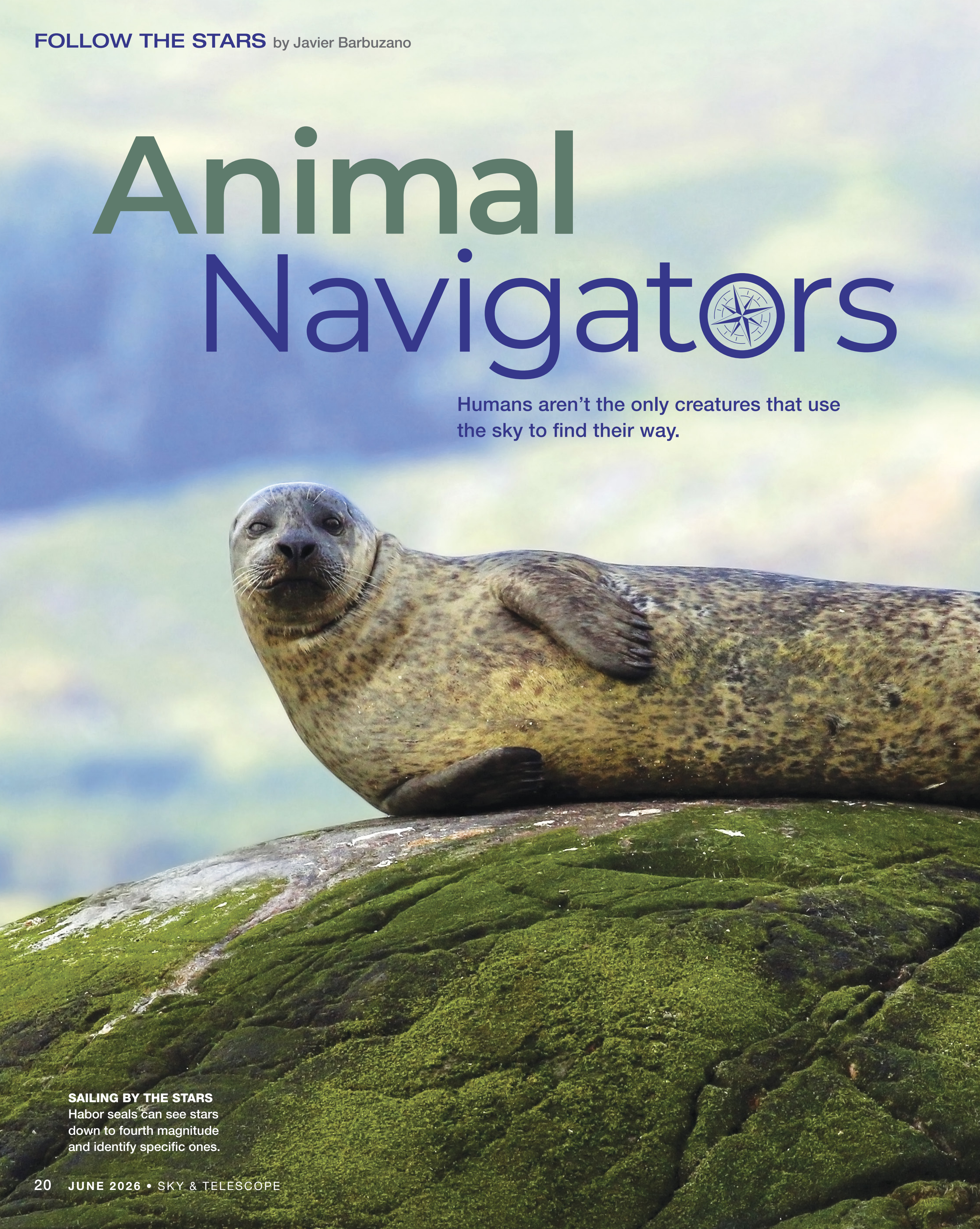
"MY WAY'S CLOUDY" When clouds obscured the North Star, freedom seekers sought other means to find north, such as examining the moss on trees.

JEANINE MICHNA-BALES / THROUGHDARKNESSTOLIGHT.COM

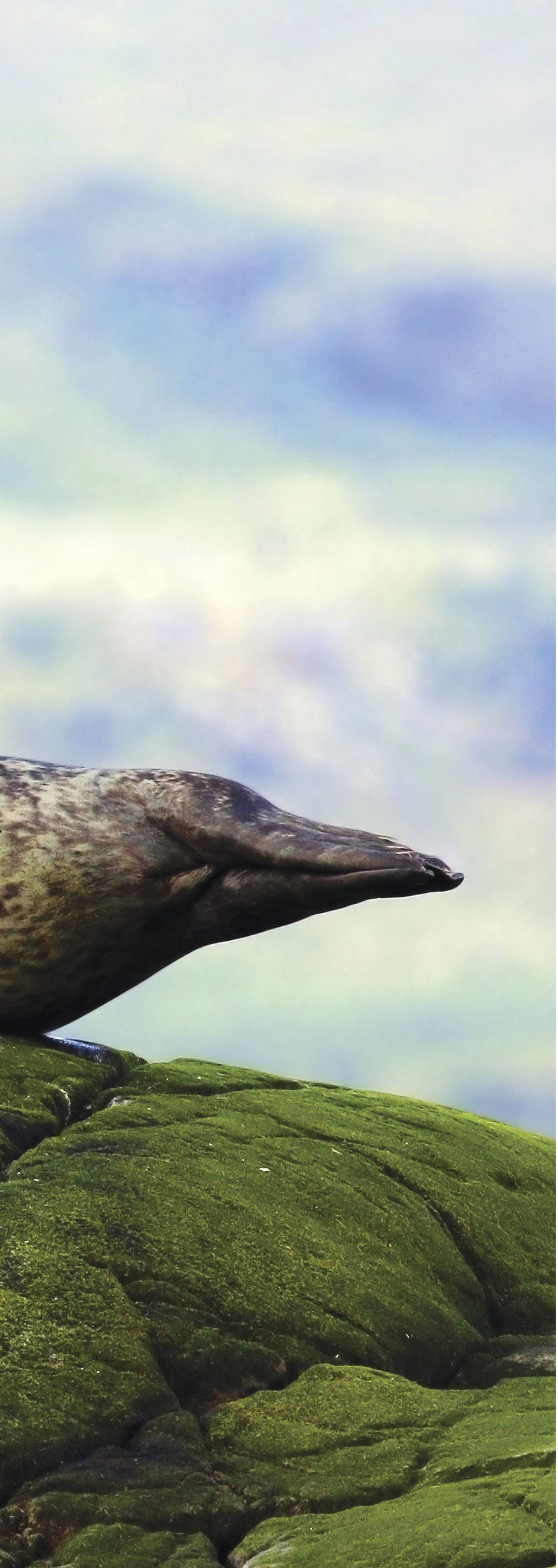
FOLLOW THE STARS by Javier Barbuzano

Animal Navigators

Humans aren't the only creatures that use the sky to find their way.



SAILING BY THE STARS
Habor seals can see stars down to fourth magnitude and identify specific ones.



Every November, a mountainous region in the southeastern part of Australia becomes the finish line of a unique migration. Millions of Bogong moths (*Agrotis infusa*) — inconspicuous, medium-size, grey-brown insects — undertake a challenging, 1,000-kilometer flight from their breeding grounds all over southeast Australia to escape the torrid summer heat. In the cool caves of the Australian Alps, the moths cuddle together to form a dense, living tapestry, every moth's head buried under the wings of the moth ahead of it. About 17,000 moths per square meter cover every wall and crevice, entering a lethargic state that lasts until February.

After summer ends, the moths return to their birthplaces to reproduce, lay eggs, and die. Their descendants will return to the caves, a place where they've never been.

How do they find the way? Researchers have only recently discovered the secret: The moths follow a celestial compass, using the north-south axis formed by the Milky Way as their guide.

Moths aren't the only animals that use the starry night for orientation. A South African dung beetle relies on the Milky Way as a reference point during excrement-rolling escapades. Some mammals resort to various forms of celestial steering. And given that about two-thirds of all migratory birds travel at night, many likely use the stars as a guide, although definitive proof is currently limited to a few species.

Proving that animals employ celestial navigation requires extraordinary experimental ingenuity. Animals gather all sorts of directional cues from their environment, and since they can't be questioned, scientists have had to come up with various tricks to isolate and manipulate these cues in order to determine which ones matter. The arsenal includes miniature helmets for beetles, flight simulators for moths, and floating planetariums for seals. Through this meticulous experimentation, scientists have revealed what animals actually see when they look to the night sky and how they use it for orientation — whether they are making a rapid escape from a predator, returning home from a foraging trip, or embarking on epic migrations.

From Dusk till Dawn

Animals are defined by movement. They walk, run, fly, swim, crawl, creep, or slime their way to new places. With the capacity to move comes the necessity to set a course. Finding one's bearings is especially difficult at night, when light levels can diminish by as much as 11 orders of magnitude compared to daylight.

But operating at night has its advantages. Nocturnal animals avoid diurnal predators and competitors, and shunning sunlight reduces heat stress — critically important in warm climates or during physically exhausting activities such as long migrations.

To prevail in the dark, nocturnal species have evolved specific adaptations, such as larger eyes and specialized photoreceptors, which enable them to exploit the few photons available. The design of the eyes — whether the camera eyes of mammals or the compound eyes of insects — plays a crucial role in whether animals can see the stars at all.

Once the Moon sets and the stars become the only celestial reference, the first challenge for navigators is realizing that the

SEAL: CHARLES J. SHARP / CC BY-SA 4.0 INTERNATIONAL; COMPASS: CEZAR911 / SHUTTERSTOCK.COM stars are not static. The celestial vault rotates across the sky with a schedule based on date and latitude. It's a reliable compass but requires careful observation. For some species, reading this compass is an innate skill. For others, it has to be learned.

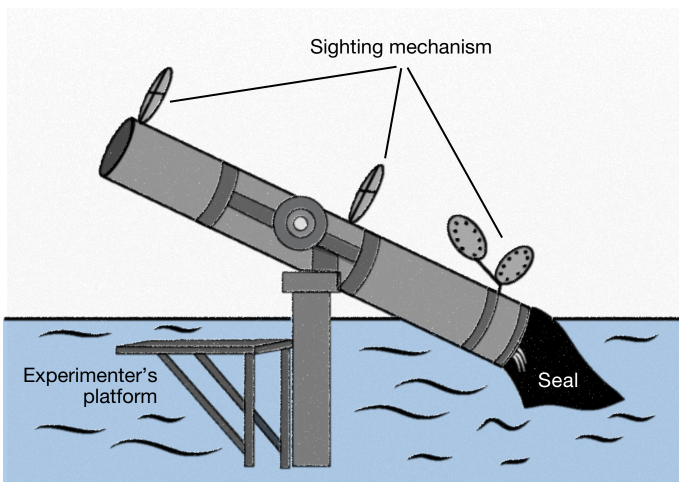
An Observatory for Seals

Bothered by the question of whether marine animals could navigate using celestial cues, Guido Dehnhardt (now University of Rostock, Germany) and his colleagues decided to test their resident harbor seals, *Phoca vitulina*. It was unclear whether seals could even see the stars, given that their eyes are adapted to underwater vision. Previous studies had suggested that they are severely myopic and astigmatic above water.

The researchers built an astronomical observatory for seals. Instead of a telescope, they installed a long tube wide enough for the seals to stick their heads into, complete with a seat for the aquatic astronomers. They devised a pointing mechanism that allowed the researchers to find stars for the seals. They next trained Nick, a young seal, to look through the tube and react only if he saw something, rewarding correct responses with fish. "It was really amazing to see the seal sitting in a chair there and checking the night sky," Dehnhardt says.

Surprisingly, the experiment revealed that seals can see stars down to magnitude 4.4, leaving a considerable number of bright stars and most of the easily recognizable constellations available as potential navigational cues. This limited visual range may, in fact, work in the seals' favor, Dehnhardt suggests, acting like "a filter system" that removes unnecessary visual information and leaves only the most conspicuous stars for reference.

In a second experiment, the scientists tested whether seals could use the stars for orientation. They built a floating planetarium in a pool and projected a simplified version of the night sky. Then they trained Nick and his brother, Malte, to locate the bright star Sirius. Initially, they used a laser pointer to help the seals find the target, rewarding them when they pressed their snouts near the correct location. The researchers then removed the laser, letting the seals find Sirius based on stellar patterns alone. The creatures learned the task with remarkable ease, giving the researchers the impression that finding the stars was a natural process for them.



▲ **SEAL TELESCOPE** Scientists constructed a special apparatus to test seals' ability to see stars.

"It was really impressive," Dehnhardt says. In some experiments "you train, and you train, and at the end the animal learns something, but it's more convincing if the animals picks it up with ease," he says. "It gives you a feeling that it's natural information to them."

To confirm that the seals were genuinely following stellar patterns and had not simply learned a shortcut to collect rewards, the scientists increased the difficulty. They rotated the sky projection, placing Sirius and the surrounding constellations at different locations within the dome. The seals, however, were adept navigators, correctly locating Sirius every time — an impressive success rate for a seal, Dehnhardt says.

These experiments do not definitively prove seals use the stars in the wild. But given the featureless environment of the open ocean where the animals hunt, the stars would be an easy cue for finding their bearings, he explains. Seals are known to be extremely sensitive to other sensory clues as well, including smells, salinity, and water currents. Perhaps the animals use stars when they're visible and resort to these alternative senses when the skies are overcast.

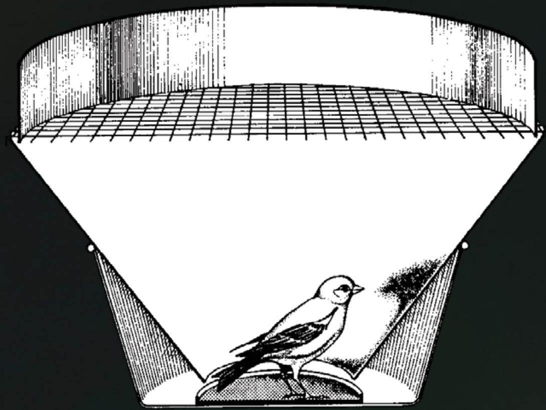
Taking the Long Route

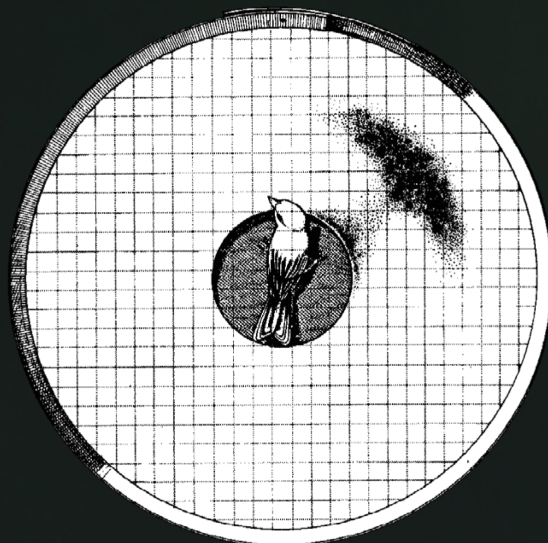
Stellar navigation might be unproven for seals, but researchers have confidently demonstrated that some migratory birds use it. Already by the 1940s, ornithologists noticed that migratory songbirds kept in captivity became restless at night during their normal migration periods in fall and spring, jumping often and opening their wings as if ready to fly. If placed outdoors while in this agitated state, known as *Zugunruhe* (a German word that translates to "migratory restlessness"), the birds tended to orient their movements toward the direction of their intended migration.

In the 1950s, German ornithologists E. G. Franz and Eleonore Sauer demonstrated that European warblers use the stars for orientation. They realized that caged birds placed outdoors oriented towards their intended migratory direction on clear nights but became erratic when the sky was overcast. To confirm their suspicion, the Sauers brought the birds to a planetarium in Bremen, where they confirmed that the birds could use the information displayed on the simulated sky.

American ornithologist Stephen Emlen (Cornell University) significantly expanded this work, looking for the precise mechanisms that birds use to follow the stars. Emlen focused on the indigo bunting (*Passerina cyanea*), a small, hardy songbird found across the eastern half of the United States and southeastern Canada. It performs a 3,000-kilometer (2,000-mile) migration to winter in the Caribbean, southern Mexico, and Central America.

BEATRIZ INGLESSIS / *S&T*, SOURCE: B. MAUCK ET AL. / *MARINE MAMMAL SCIENCE* 2006





MIGRATION ROUTE Using a funnel-shaped cage with an ink pad on the bottom *(insets above, side and top views)*, Emlen confirmed that indigo buntings hop in their preferred migratory direction when they can see the circumpolar stars.

Animal Astrophotographers

Nocturnal insects have ways to boost their low-light sensitivity. Like living digital cameras, they can increase the integration time, just like keeping the shutter of a camera — or telescope — open for longer times. They can also combine the light gathered by several ommatidia, with the tradeoff of reduced spatial resolution. These tricks, referred to as *summation*, don't help for distinguishing point sources like individual stars, however, because the aperture of the individual eyes remains the limiting factor.

"I chose it because it's a strong bird, easy to keep in captivity," Emlen says. "It eats seeds, so you don't have to find insect food to keep them going."

Emlen developed conical cages made from a funnel of blotting paper, with an inkpad at the bottom for the bird to stand on, and covered on top by wire mesh or a clear plastic sheet. These devices — now widely known as Emlen funnels — were a simple and economic tool to precisely track and quantify the birds' directional movements. As the birds became excited with Zugunruhe, jumping and fluttering around, their ink-stained feet left marks on the paper, revealing their preferred travel direction.

After confirming that the buntings oriented themselves correctly under normal skies — south in fall and north in spring — Emlen moved the birds to a planetarium to test their reliance on the stars. He first rotated the artificial sky, placing the North Star towards to the east or west. The buntings immediately shifted their orientation to adapt to the new north-south axis, demonstrating that they were relying on the stars and not using some kind of built-in sense of direction.

To find which stars were important to the birds, he systematically turned off select constellations, and then entire sections of sky. He found that the birds rely on the circumpolar stars, within 35° of the North Star. This region includes prominent patterns such as the Big and Little Dipper, Draco, Cepheus, and Cassiopeia. The birds used the same references regardless of whether they were flying north or south. Removing one or two constellations didn't seem to bother the buntings too much; they would just rely on the remaining stars. That suggests the birds can function on nights with partial cloud cover that might block part of their view.

In another experiment, Emlen showed that while stars provide the compass, it's the bird's physiological state — driven by hormones — that determines the travel direction. After placing birds captured in summer in rooms with controlled lighting, he put half on them on natural day length and the other half on an accelerated light schedule, with longer days during December and January followed by shortening days in March and April. By May, both groups of birds showed Zugunruhe, but the accelerated group had already molted into and back out of its spring plumage. When Emlen placed them in the planetarium under identical spring skies, the birds tried to take off in opposing directions.

Emlen also showed that stellar navigation in birds is a learned skill, not an innate quality. He hand-reared young birds in the lab under diffuse light, then tested them in the planetarium. Although they showed Zugunruhe, they jumped in random directions. This showed that birds must learn their stellar map by observation. The process is similar to how ducks or geese learn to follow a moving object they see after hatching, a process called *imprinting*. "There's a particular time before the bird starts its first migration when it is open to imprinting and locking on to things," Emlen says.

To find how they learn to navigate, Emlen imagined another test for the birds. "I don't like to use the words 'trick them,' but depending on what sky you show them, [that] determines what they then use," he says. Emlen hacked the projector to make the sky rotate around Betelgeuse, in Orion, instead of Polaris. Then he let a group of younglings see this warped sky every other night. After two months, Emlen put these birds back in the planetarium under a normal sky, and the buntings continued to point away from Betelgeuse.

The birds learn where north is by watching the heavens pivot, Emlen concluded. "They are primed and ready" to look at the axis of rotation and lock onto the stars and constellations around it, he says. Presumably, this only happens in the first weeks after the birds are born, but no experiments have tested if they can learn later in life. Once "imprinted," the birds do not need the sky to rotate to find their way.

Relying on the sky's overall rotation instead of a specific star or constellation makes birds' navigation method resilient over eons. Our planet's rotation axis wobbles over thousands of years, and the center of stellar rotation in the sky slowly changes as a result (*S&T:* Mar. 2019, p. 14). In about 2,000 years, the axis will point towards Gamma Cephei instead of Polaris. But this change won't affect migratory birds. They will just continue to look at the rotation center, a change that they have endured numerous times over their evolutionary history.

My Way of the Milky Way

In recent years, scientists have discovered that insects use the Milky Way for orientation, a rather serendipitous find made by researchers studying the nocturnal dung beetle *Scarabaeus satyrus* in South Africa. Unlike migratory birds, these beetles don't embark on long journeys. What they need is to find a quick escape route after performing an audacious heist.

At night, these beetles fly around sniffing for fresh dung. When they find it, they carve out a piece, mold it into a massive ball, and escape with it by rolling it away before competitor beetles can snatch it. Since the shortest escape route is a straight line, all they need is a reference point to keep their bearings.

Scientists already knew that these dung beetles used the Moon as a reference point to guide their escape. But observing them in the field during a moonless night, Eric Warrant

(Lund University, Sweden) and his colleagues noticed that the beetles continued rolling their balls in straight lines in the dark. "We looked up in the sky and saw this fantastic Milky Way . . . and we wondered whether it was possible for them to use that as an orientation cue," Warrant says.

Determined to find out, Warrant and colleagues built a flattened, circular sand arena. They then placed the beetles with dung balls at the center, but not before fitting them with little cardboard helmets, specially built for the occasion, that blocked the upward-facing portion of their vision. Control beetles wore similar but transparent helmets. The results were clear: The blindfolded beetles became disoriented and walked in circles, while control beetles were unaffected and continued along a straight path.

The team also took the beetles — and their dung — to the planetarium. When presented with the Milky Way alone, without point-source stars, the beetles performed about as effectively as when presented with the full sky. When only bright stars were visible, without the Milky Way, the bugs fared noticeably worse, although still slightly better than without any clues.

This is puzzling, since beetles' compound eyes aren't well suited to seeing individual stars. Animals with compound eyes, like most arthropods — a large group of invertebrates that includes insects, spiders, and crustaceans — have limited resolving power. Their eyes are composed of many small light-sensing units called *ommatidia*. Each ommatidium has its own cornea and lens. The units work together in an array to create mosaic images, like pixels in a digital image. This setup maximizes photon capture, increasing sensitivity at the cost of spatial resolution.

"There are a lot of good things about insect eyes, but it's really not a good design if you want to have high resolution," says James Foster (University of Konstanz, Germany). For most insects, "it'd be much more like a Van Gogh painting, where everything just blends together."

For this reason, experiments suggest, little guys like the dung beetles are more likely to follow the Milky Way, which for them appears as a large, luminous pattern in the sky. Particularly noticeable in the Southern Hemisphere, the Milky Way has a gradient of light intensity — dim in the northern part of the sky and bright in the southern half, like a big arrow pointing south.

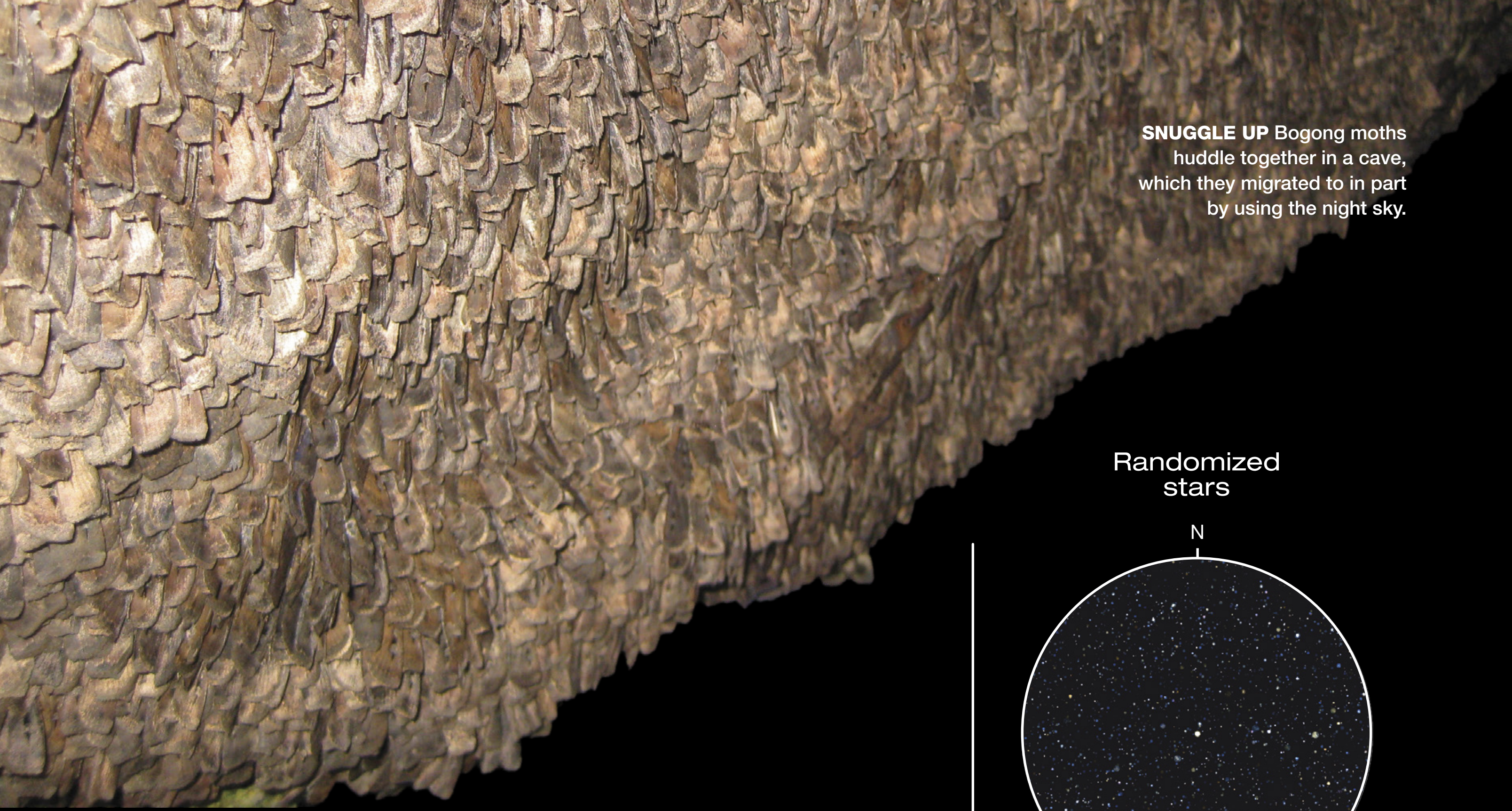
Mothing Around

The Milky Way is also the celestial compass used by the Bogong moths during their annual migration. To confirm the moths are stellar navigators, a team of researchers, including Warrant and Foster, took the insects to an instrument not unlike Emlen funnels, which they dubbed the moth flight simulator. In it, moths are tethered to a thin wire and allowed to fly under a projection of the

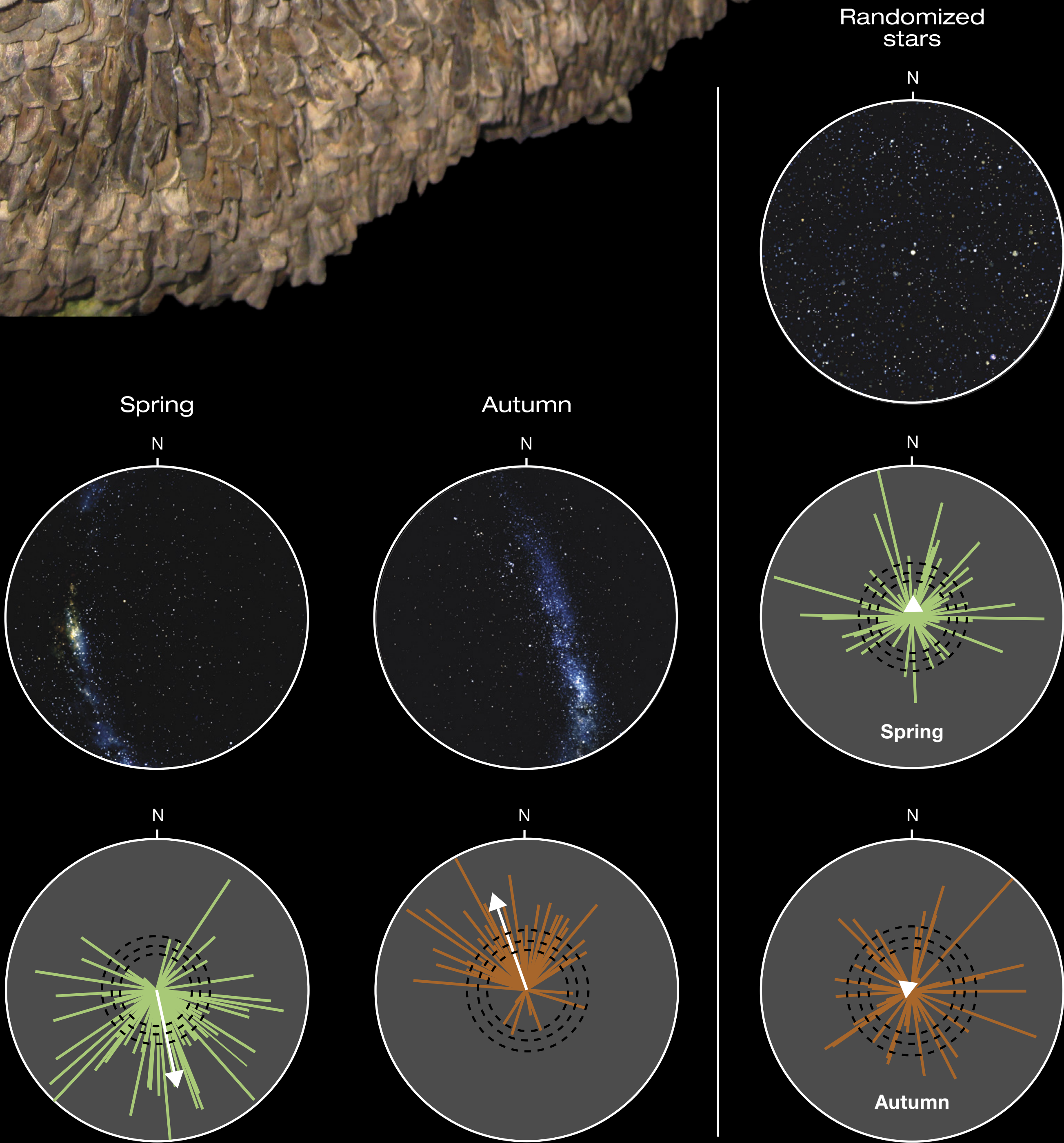
▲ **BEETLE EYES** This simulated view shows the Milky Way as a dung beetle may see it. North is at top, with the north celestial pole about halfway up from center.

▼ **KEEP ROLLING** Dung beetles like this one use the Milky Way to plot their escape route when snatching balls of dung.

SKY TO A DUNG BEETLE: JAMES L. GOULD / *CURRENT BIOLOGY* 2013; DUNG BEETLE: DRAGO PRVULOVIC / AFP VIA GETTY IMAGES



SNUGGLE UP Bogong moths huddle together in a cave, which they migrated to in part by using the night sky.



ERIC WARRANT (2)

sky that the scientists can manipulate. The researchers record the moths' movements using fiber optic wires connected to the tether. The entire setup is placed inside Helmholtz coils, magnetic devices that locally cancel Earth's magnetic field, which ensures the moths (which can sense this field) are responding only to visual cues.

These experiments showed that under a normal sky, the moths oriented to their appropriate migratory directions during both spring and autumn. When the researchers rotated the projection of the sky 180°, the moths changed course accordingly. The scientists also scrambled the stars into random positions, finding that the moths were unable to orient under those manipulated skies. "They were completely lost," Warrant says.

In a second set of experiments, the researchers immobilized the moths using special 3D-printed molds and used electrodes to measure their brains' visual activity as the sky rotated. They found that the activity in the moth's brain peaked when it was oriented towards the seasonally appropriate migratory direction.

While the exact visual cues the moths use as a compass remain under investigation, Warrant thinks that the moths, like the dung beetles, are likely navigating based on the Milky Way's intensity gradient rather than individual stars. This hypothesis is supported by the moth's highly specialized eye structure. The moth's eye has a remarkably low focal ratio, with a value of about 0.5 — much lower than the f-number of about 2 in the dark-adapted human eye. As a result, these moths see the Milky Way much better than we do. "The image of the world seen by the eye of a moth is 16 times brighter than the image that we see," Warrant says.

On the other hand, it's not a terribly detailed view. The number of stars animals can see is determined by the size of the pupil. Larger pupils capture more light. The pupil of a night-adapted human eye can be up to 8 millimeters wide, whereas the pupil of a Bogong moth is a tenth of that, 0.8 mm. "Obviously a moth's eye is going to see fewer stars," Warrant says. "We don't know exactly how many at this point in time, but we intend to find out."

Where Are We Going?

Apart from Emlen's stellar navigation experiments, ornithologists have confirmed that birds also have a highly sensitive magnetic compass, can utilize the Sun to recalibrate their position, and likely use familiar smells or learned landmarks to zero in on their destination.

◀ **STELLAR COMPASS** Moths suspended under projected spring and autumn skies *(first two columns)* and left free to flap oriented themselves to their correct migration route. But under a sky of randomly arranged stars, the moths could not consistently find their way. The white arrows are the averages.

ERIC WARRANT

◀ **FLIGHT SIMULATOR** To track Bogong moths' navigation abilities, researchers tethered the insects to wires and studied their movements in response to a projected sky.

These various systems are redundant and well-integrated with one another, such that when one cue is unavailable — say, when there's a cloudy night — the others can compensate. Emlen thinks that while these systems are interconnected, the relative importance of each cue may vary across different species.

Despite these findings, exhaustive experiments have only been made in a handful of species. "I think these are going to be general principles that are going to apply to a large number of birds," Emlen says. "I wish more people did more of these experiments and we had evidence from lots and lots of species, but we don't."

"The birds that we know that are doing this are the ones that are easiest to capture and test. I don't know of any migratory bird that has been tested and wasn't able to do it. And it's kind of similar with the moths," Foster says.

The same happens with marine mammals. While cautious when extrapolating his findings beyond seals, Dehnhardt suggests that other species might also use these celestial cues. Whales, for instance, occasionally emerge in the open ocean, look around briefly, and then submerge, correcting their course. "What kind of information are they looking for if there is nothing to see above the water's surface?" he asks. "But there are the stars!"

Not knowing how many animals use the stars to navigate makes it difficult to assess the damage that light pollution may be inflicting on wildlife. Recent estimates show that global light pollution is growing at an alarming rate of 10% annually, hiding the vital celestial information that animals need to hold their course. Even areas not directly illuminated might suffer the effects of skyglow, which extends far beyond urban centers.

Studies already show concrete negative effects: When dung beetles abandon their celestial compass and rely on artificial light to guide their escape, their routes more often converge, which leads to increased competition between beetles. And the attraction of lights — even from kilometers away — forces migratory birds off course and into potentially dangerous areas (*S&T:* Jan. 2024, p. 34).

While the loss of pristine night skies might only affect species with sophisticated navigational systems, the fact is we don't know what the impact is, Foster says. "If we don't stop the light pollution expansion now, then we might never be able to find out what we lost," he adds.

■ In contrast with Nick, the astronomer seal, Contributing Editor **JAVIER BARBUZANO** is a terrible navigator who often gets lost in his own neighborhood.

Trojan Stars

The Milky Way's mighty bar marshals billions of stars into two vast celestial whirlpools.

Most of the solar system's asteroids orbit the Sun between the paths of Mars and Jupiter, but Jupiter's gravity has enticed thousands of others to revolve in its own orbit as they journey around the Sun. Known as Trojans, these asteroids reside roughly 60° ahead of Jupiter and 60° behind it. The two positions, called *Lagrange points*, represent stable locations balancing the centrifugal force the Trojan asteroid feels with the gravitational tugs from the planet and the Sun.

Incredibly, the same phenomenon transpires on a far grander scale. For three decades astronomers have known that the Milky Way is a *barred* spiral: A cucumber-shaped column of stars runs through its heart. Spinning around the center of our galaxy's disk, this bar herds billions of stars into two gargantuan whirlpools, one of which permeates both our neighborhood and our night sky.

"The bar is not a wimpy little planet," says Walter Dehnen (Heidelberg University, Germany), referring rather disparagingly to Jupiter. "The bar is a *massive* perturbation." Harboring one-third of the galaxy's total stellar mass, the bar's stars outweigh the Sun 18 billion times over. The bar therefore exerts tremendous gravitational sway, even over stars that are thousands of light-years away, ensnaring them into two enormous swarms on opposite sides of itself.

You can see these stars tonight (see table on page 31). One Trojan star, Zeta Herculis, resides just 35 light-years from Earth, shining at magnitude 2.8 in the keystone of the constellation Hercules.

The Zeta Herculis Moving Group

In 1957, Olin Eggen, then at the Royal Greenwich Observatory, examined catalogs of stars that speed fairly quickly through space relative to the Sun. He discovered 22 nearby star systems all over the sky moving through space in a similar direction, outward from the galactic center. They also revolve around the Milky Way's core more slowly than would a star on a perfectly circular orbit.

The two brightest of these stars are Beta Hydri, 24 light-years away in the far southern sky, and Zeta Herculis. Both are yellow *G*-type subgiants. That means their centers have recently run out of hydrogen fuel, making the stars slowly expand as they leave the main sequence and transition to the orange- and red-giant stages.

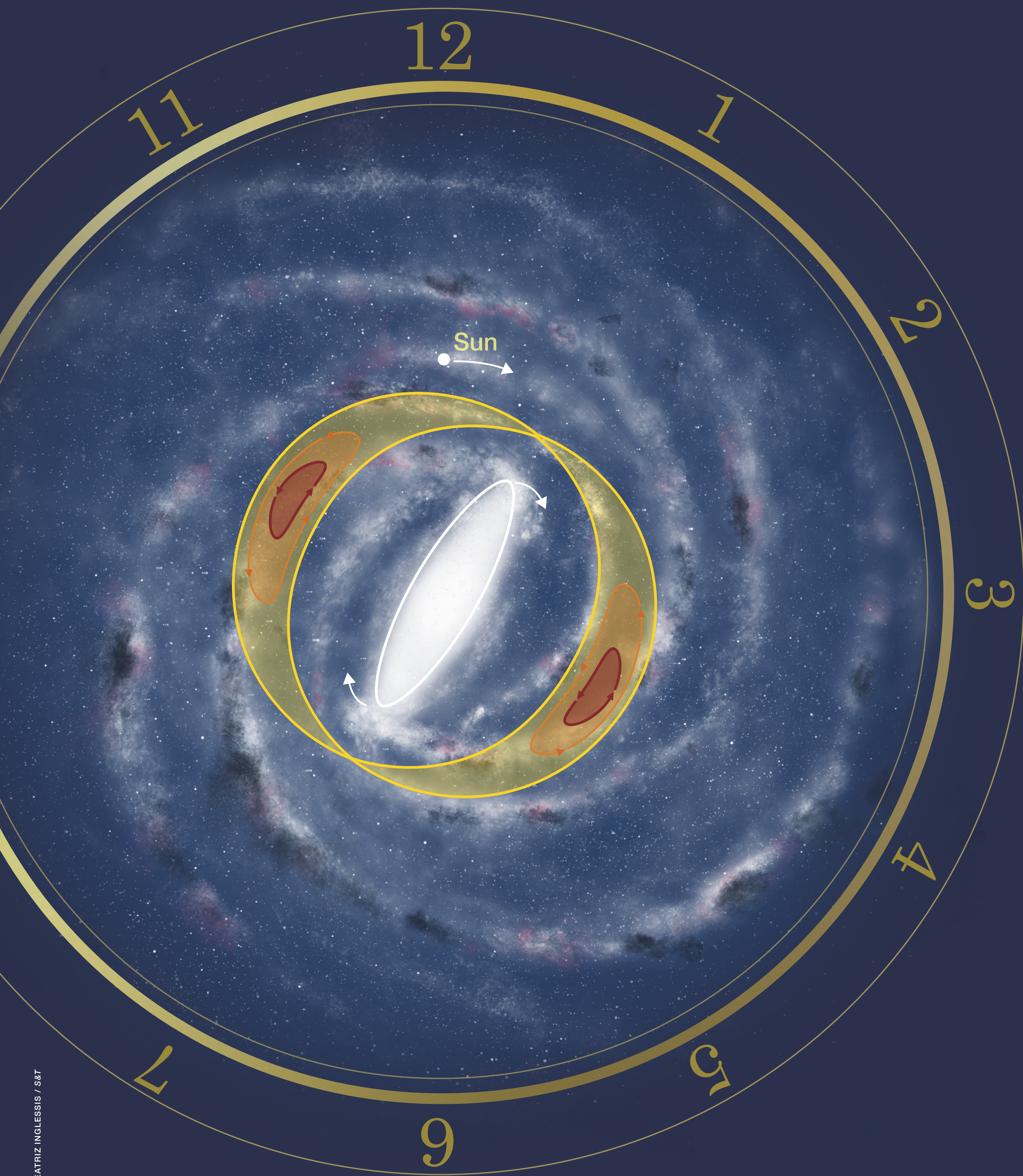
Eggen named the 22 fellow travelers the Zeta Herculis group. His stars — a mix of main-sequence, subgiant, and giant stars — share more than just common motion. They also have similar colors: All are yellow, orange, or red.

Yellow, orange, and red, Eggen knew, meant the stellar group must be at least moderately old. Gone are the short-lived blue and white stars more massive than the Sun. Instead, all that endure are long-lived Sun-like stars, plus the subgiants and giants they are maturing into. In fact, Eggen compared the group with the classic old open star cluster M67 in Cancer. M67 is nearly the same age as the Sun.

Eggen thought the stars in the Zeta Herculis moving group were born together in the same star cluster. Although this cluster broke up, he reasoned, its former members still speed through space together, a remnant of their shared heritage.

Eggen died in 1998. A year later, Dehnen advanced a radical new idea: The Zeta Herculis moving group is not a former star cluster; instead, it's a throng of stars summoned by a great gravitational resonance with the Milky Way's then-newly discovered bar.

▶ **GALACTIC CLOCK** The Milky Way's bar shepherds stars into two whirlpools (banana-shaped orbits). Stars in the galaxy's inner regions were caught earlier than those in the outer regions. The orbits shown here are the approximate paths; since stars follow elliptical orbits around the galactic center, at any time some stars will be farther or closer to the bar than the norm. Some even enter the solar neighborhood. The diagram looks down from the north galactic pole.



BEATRIZ INGLESSIS / S&T

Good Vibrations

In the 1990s, near-infrared observations penetrated the dust cloaking the central Milky Way and revealed our galaxy's bar. Separately, astronomers released data from the Hipparcos satellite, which measured distances and proper motions of stars near the Sun.

The Hipparcos data held a hidden treasure. "It was very surprising," Dehnen says, "because everybody thought we have a rather smooth distribution" in the velocities of nearby stars. Instead, he found large clumps of stars moving the same way. One of these was the Zeta Herculis group — now called the Hercules stream — which he said arose from a gravitational link with the Milky Way's far-off bar.

To understand this link, let's step back and picture the scene. Imagine a giant clock 120,000 light-years in diameter. This represents our galaxy's stellar disk, home of every star you see with the naked eye. The galactic center is at the center of the clock. We are at 12 o'clock, 27,000 light-years from the center, or about halfway from the clock's center to its edge.

As we now know, the bar points toward 1 o'clock and 7 o'clock, making a 30° angle with our line of sight to the galactic center. In both directions, the bar extends about 16,000 light-years from the galactic center. That's 60% as far out as we are.

Just as planets orbit the Sun, so the Sun orbits the galaxy's center — but in a clockwise direction, opposite to what we're used to for planets in the solar system. The bar also rotates around the Milky Way's center clockwise.

Lagrange Points

When one object goes around another — such as Jupiter revolving around the Sun (*S&T:* Oct. 2025, p. 72) or the galactic bar rotating around the Milky Way's center — regions of relative stability called *Lagrange points* can arise where various forces balance one another, thereby allowing the possibility that smaller objects will accumulate there.

Like Jupiter, our galaxy's bar has five Lagrange points, but only two capture Trojans. The bar's Lagrange points L_1 and L_2 lie beyond the ends of the bar and represent only a precarious balance between centrifugal and gravitational forces, so they don't trap Trojans. Nor does the bar's L_3 point, because it's at the Milky Way's center.

In contrast, L_4 and L_5 lie along the bar's minor axis. They balance the competing forces so that objects near here tend to stay near here. In fact, as the bar rotates more slowly and these Lagrange points migrate outward, the stars follow — just as if Jupiter were to migrate slowly away from the Sun, the planet's Trojan asteroids would do the same and stay in its orbit.

Unlike Jupiter, the bar does *not* have Lagrange points 60° away. Instead, the Lagrange points that trap Trojan stars are 90° from the bar's tips. Why the difference? It's because Jupiter is just a single planet, whereas the bar is spread out.

Jupiter can be on only one side of the solar system at a time. Therefore, Trojan asteroids must stay near the planet so that its gravitational force is strong enough to balance both the Sun's gravitational pull on them and the apparent force (known as centrifugal force) that their motion around the Sun induces.

In contrast, the bar exists on — and throws its weight around — both sides of the galaxy equally. So the stable points where a star balances centrifugal force with the gravitational forces that both the bar and the overall galaxy exert are located on opposite sides of the galaxy, along the bar's minor axis. On our giant imaginary clock, the Trojan-trapping Lagrange point closer to us is at 10 o'clock; the other is at 4 o'clock, on the far side of the galaxy.

How far each Lagrange point is from the galactic center depends on how long the bar takes to rotate. Just as Jupiter's Trojan asteroids revolve around the Sun with the planet's 12-year orbital period, so the bar's Trojan stars revolve around the galactic center with the same orbital period as the bar takes to rotate. The longer the bar's rotation period, the farther from the galactic center these Lagrange points must be, because farther-out stars in the galaxy take longer to complete their orbits.

In the 1990s, astronomers thought the bar was short and had a short rotation period. This meant that the bar's Trojan-trapping Lagrange points should reside much closer to the galactic center than we do. Since the Hercules stream exists near us, Dehnen therefore proposed a resonance other than the Trojan one to explain it. Two decades later, new near-infrared observations imaged a longer bar, one with its Lagrange points located closer to us. In 2017, motivated by this discovery, Angeles Pérez-Villegas (now at the National Autonomous University of Mexico, Ensenada) and her colleagues instead invoked the Trojan resonance to explain the Hercules stream.

"It's now been well established that this is the correct interpretation," Dehnen says. According to modern estimates, the bar rotates every 173 million years. That's also the orbital period of the Hercules stream around the galactic center. For comparison, the Sun revolves every 230 million years. The two Lagrange points are 22,000 light-years from the Milky Way's center, somewhat closer-in than we are.

The Trojan resonance explains the motion of the Hercules stars that first caught Eggen's eye, namely why they move outward from the galactic center and revolve more sluggishly around it. The resonance traps its stars in a slow-motion whirlpool. As the stars race clockwise around the Milky Way's center, they gradually orbit the Lagrange point counterclockwise, opposite their direction around the Milky Way. (Jupiter's Trojan asteroids do the same thing.) A Trojan star's counterrevolution, called a *libration*, can take more than a billion years. Because we are at 12 o'clock and the nearest Trojan-trapping Lagrange point is at 10 o'clock and closer to the galactic center, the Trojan stars that happen to be nearest to Earth are moving away from the galactic center and revolve more slowly around it.

The Trojan stars' metallicities thereby serve as a time stamp indicating when the bar snagged them into the resonance.

Slow Down

Even after astronomers recognized the Hercules stream as a Trojan resonance, one problem persisted. Hipparcos and, later, Gaia saw far more stars in the Hercules stream than scientists could generate in their simulations of the resonance.

"That was the fundamental problem they faced with the 2016–17 models, that their models, no matter how they cranked them up, they couldn't get the density contrast they needed, because Hercules has so many more stars in it," says Ralph Schönrich (University College London).

To seek the solution, Schönrich worked with two students, Rimpei Chiba and Jennifer Friske. Says Schönrich, "We said OK, let's try one thing, which is let's try and have the bar slow down. The first simulation we did with that was literally like the nail on the head. It fit, it worked out, everything looked great."

The bar's rotation slows because dark matter in the Milky Way's halo gradually retards the bar's spin. As the bar slows, its Trojan-trapping Lagrange points migrate outward to match the location corresponding to stars with a similar orbital period around the galactic center. But the stars already trapped aren't released; the decelerating bar carries them with it. In this way, a slowing bar can use the Trojan resonance to ferry lots of stars away from the Milky Way's crowded urban center and into the suburbs, where we reside, so that we see the Hercules stream around us. This, Schönrich says, explains why the Hercules stream has so many stars.

Different stars therefore glom onto the resonance at different times and at different distances from the Lagrange points. "The stars that were captured earlier, from the inner disk, will be occupying the core of the resonance, near the Lagrange point," says Chiba, now at the University of Tokyo, "whereas the stars that were captured later will kind of accrete around it."

Chiba and Schönrich found evidence for this stellar transportation service in the stars' metallicities. Like most other giant spiral galaxies, the Milky Way's disk has a metallicity gradient: Stars in the disk closer to the galactic center tend to have more metals than stars farther from it.

The Trojan stars' metallicities thereby serve as a time stamp indicating when the bar snagged them into the resonance. Schönrich compares the process to the creation of tree rings: "The resonance grows like a tree, where the new layer just gets added on the top," he says. "You expect the center to be metal-rich and the outskirts to be metal-poor and start matching the local metallicity. And we saw precisely that."

On the other hand, Pérez-Villegas explains, if the Hercules stream were really a disintegrated star cluster, then all the stars would have been born together from the same cloud of gas. In that case, they should be nearly identical in terms of metallicity and age. But the Hercules stars aren't. For example, Zeta Herculis is about as metal-rich as the Sun, whereas Beta Hydri is somewhat metal-poor. Also, scientists estimate that Zeta Herculis is 3 to 4 billion years old, whereas Beta Hydri is 6 to 7 billion years old.

Trojan Globular Clusters

The Trojan resonance can capture more than just stars. It can even capture entire star clusters. In 2024, Adam Dillamore

Select Trojan Stars Visible in June

Star	Constellation	Distance (ly)	Mag	Type	RA	Dec.
HD 68788	Camelopardalis	101	8.4	Orange dwarf	$08^h 20.1^m$	+73° 25′
HD 89668	Sextans	104	9.4	Orange dwarf	$10^h 20.7^m$	–01° 28′
29 LMi	Leo Minor	438	6.5	Orange giant	$10^h 25.7^m$	+35° 26′
71 Leo	Leo	592	7.0	Orange giant	$11^h 22.5^m$	+17° 26′
HD 106365	Coma Berenices	443	6.9	Orange giant	$12^h 14.1^m$	+32° 47′
84 Vir	Virgo	248	5.4	Orange giant	$13^h 43.1^m$	+03° 32′
HD 150275	Ursa Minor	362	6.3	Orange giant	$16^h 30.6^m$	+77° 27′
Zeta Her	Hercules	35	2.8	Yellow subgiant	$16^h 41.3^m$	+31° 36′

All stars are from Olin Eggen's original list, compiled in 1957. Distances are from Gaia, except for Zeta Herculis, whose distance comes from Hipparcos. Star types refer only to the brightest member of the star system. Right ascension and declination are for equinox 2000.0. Magnitudes are visual.

◀ **MESSIER 22** Is this the original nucleus of the Milky Way Galaxy? Maybe. The galaxy's bar might have dragged it out of the galactic center eons ago to its current location, some 10,000 light-years from Earth.

(now at University College London) and his colleagues used the positions and motions of globular clusters to simulate which clusters the resonance might have transported outward.

His best case is 47 Tucanae, one of the most luminous globulars. "In pretty much every simulation I did — so whatever realistic rotation rate of the bar I chose — it always seemed to be in a resonant orbit," Dillamore says.

Another bright globular cluster, M22 in Sagittarius, might also be a Trojan. Unlike most other globulars in our galaxy, M22 has stars with various metallicities, and it might even have once constituted the original central star cluster of the ancient Milky Way (*S&T:* Aug. 2023, p. 34). Consistent with this idea, Dillamore's simulations indicate that the Trojan resonance could have ferried the cluster out of the Milky Way's inner sanctum.

The Trojan resonance might also have saved a lesser globular, Palomar 11. The cluster is diffuse, with its stars spread out from one another. It would have had a tough time surviving the rough-and-tumble of the crowded inner galaxy.

"The bar could have prevented it being disrupted," Dillamore says. By transporting Palomar 11 outward to safer pastures — it now resides about as far from the galactic center as we do — the bar could have preserved the cluster's existence to the present day.

Still, Palomar 11 is dim and distant, located about 44,000 light-years from us in Aquila, so the cluster's parameters are uncertain. Thus, Dillamore says, its true migration through the Milky Way is unclear.

Our Future as Trojans

Even the Sun may someday join the Hercules stream. "Indeed, that is possible," Chiba says. He puts the odds at about 20%.

Right now, we are 5,000 light-years farther from the galactic center than the bar's Trojan-trapping Lagrange points. But as the bar continues to slow, its whirlpools will move outward. About 2 billion years from now, Chiba estimates, the bar's rotation period will match the Sun's 230-million-year orbital period, letting a Lagrange point sweep over the solar system and possibly capture it into the Trojan resonance.

At that time, the Sun will still be a G-type main-sequence star, converting hydrogen to helium in its core. But rather than merely witnessing the Hercules stream in the motions of yellow, orange, and red stars all around us, we may be admitted to this exclusive stellar club and become Trojans ourselves, resonating with the mighty bar of stars that twirls around the Milky Way's heart.

■ Contributing Editor **KEN CROSWELL** thinks the Milky Way is the universe's best galaxy — bar none. He earned his PhD for studying the Milky Way and wrote a book, *The Alchemy of the Heavens*, about our galaxy.

ESA / HUBBLE & NASA

 by David J. Eicher

Venture Into the Eagle's Nest

COSMIC MONOGRAM Together comprising Barnard's E, the prominent dark nebulae B142 and B143 cover an area of sky equal to that of the full Moon. In a dark sky they offer observers a nice portrait of dark dust clouds against a rich star field.

ALAN DYER

Prominent in the summer sky, Aquila holds a stockpile of planetary nebulae, dark nebulae, clusters, and even a stray galaxy.

Wedged along the glow of the summer Milky Way between Cygnus and Scutum, Aquila, the Eagle, offers observers an intriguing array of deep-sky wonders. Its brightest star, +0.8-magnitude Alpha (α) Aquilae, or Altair, is one of the three beacons comprising the Summer Triangle, along with Alpha Cygni, Deneb, and Alpha Lyrae, Vega. Not as widely recognized as Cygnus or Lyra, Aquila nonetheless contains great vistas of the universe that can be enjoyed by users of small and medium telescopes.

Early skywatchers attributed the shape of Aquila to that of a bird — thus, the mythological eagle. I always see the brightest part of the constellation as a prominent V shape, with lines starting at Gamma (γ) and Delta (δ) Aquilae and meeting at the bottom of the V, Theta (θ) Aquilae. Altair, a main-sequence sun of spectral type *A*, appears bright chiefly due to its proximity, at 16.7 light-years. The rest of the constellation, however, is far more subtle, more enticing, and even more mysterious.

Realm of the Planetaries

Like some of its neighbors, Aquila is known primarily for being loaded with a variety of ethereal nebulae. Someday, what remains of our solar system will lie encased within a *planetary nebula*, a cocoon of luminous gas expelled by the Sun into the interstellar medium. This phase of evolution will mark the end of our star's normal life and will return elements such as carbon, nitrogen, and oxygen back into the galaxy. These short-lived phenomena, typical endgames for solar-mass stars, come in a variety of shapes. They last for perhaps 50,000 years as observational targets; after that, the remnant white dwarf star remains in the center of an increasingly dark world as it, too, cools and fades.

The best and most interesting planetary in Aquila is **NGC 6781**, which I've especially liked since my early days of observing. Sometimes called the Snowglobe Nebula, it's one of my favorite planetaries in the entire sky due to its unusual shape in the eyepiece. The object, which lies about 4° north-northwest of 3.4-magnitude Delta Aquilae, spans 1.8′ across and shines at magnitude 11.8, making it visible in small scopes at moderate magnification. Its relatively close distance of 2,300 light-years explains its large apparent size. An 8-inch scope shows this object as a glowing shell of grayish-green light, circular in shape and appearing dimmer in its center, surrounding a 17th-magnitude central star. The unevenness of the shell's light gives the nebula a distinctive look — one side of the shell is dimmer than the other, which produces a 3D effect. The relative faintness of the nebula's center enhances this illusion, and the central star is, of course, too dim to see in all but the largest backyard telescopes at moderate to high magnifications.

NGC 6781: ESO; NGC 6804: BERNHARD HUBL

▲ **SNOWGLOBE NEBULA** The finest planetary nebula in Aquila, NGC 6781 is a ring-shaped object that's bright enough to spy in small telescopes under dark skies. The term *planetary nebula* is a historical misnomer, as early observers mistook the object's round appearance for a planet. These bright emission nebulae actually represent expanding shells of ionized gas ejected by dying, solar-mass stars. North is up in all images.

▲ **TURQUOISE BUBBLE** Complex structure is visible in the planetary nebula NGC 6804, at least for large telescope users. "A bright ring encased in a fainter halo of nebulosity characterizes this unusual object," the author notes.

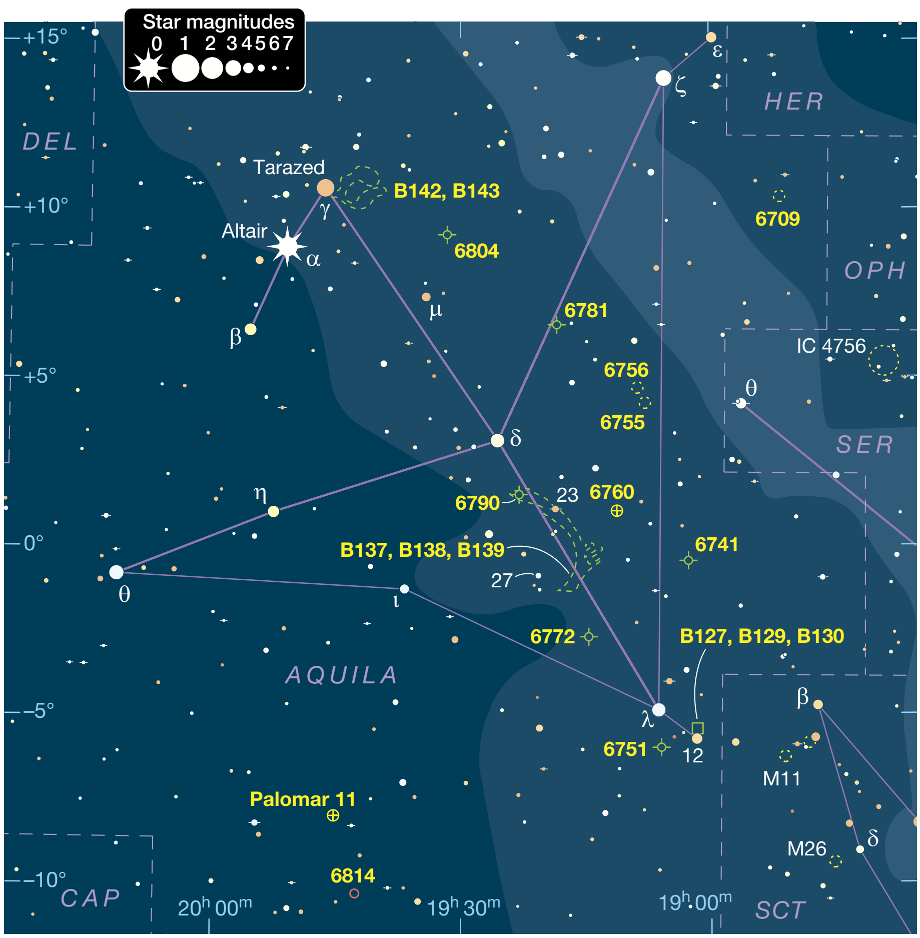
Shifting about 4° northeastward toward 2.7-magnitude Gamma Aquilae, also called Tarazed, brings us to another great planetary, **NGC 6804**. This is a highly unusual nebula lying in a rich star field; it might well become a sleeper favorite of yours. It spans 1.1′ and shines at magnitude 13.4. Its faintness may suggest that it's a tough object, and it does display a low surface brightness, but the nebula's ghostly glow can be seen with a 6-inch scope at moderate magnification under a dark sky. Also situated 2,300 light-years away, NGC 6804 appears far different than NGC 6781. An 8-inch scope shows the object as a faintly glowing ring surrounding a somewhat brighter inner ring that's elongated. Both envelopes of nebulosity encase a 14th-magnitude central star that will be detectable to users of large telescopes at moderate powers.

Dropping about 2° down from Delta takes us to a nice planetary, **NGC 6790**, in the righthand corner of Aquila's distinctive V shape. This object presents a marked contrast to the previous two. Glowing at magnitude 10.5, NGC 6790 is young with a relatively high surface brightness, and it lies much farther away at nearly 13,000 light-years, which explains its small angular size of 4″. This is a target that asks for and can withstand magnifications higher than you might ordinarily use, especially under good seeing conditions. An 8-inch scope reveals it as a tiny, oblong disk, and sharp-eyed observers will detect an inner, slightly brighter ring. The central star glows faintly at magnitude 15.5, making it visible in large backyard scopes at high powers.

Moving about 5° southwest toward 3.4-magnitude Lambda Aquilae, we encounter yet another impressive planetary: **NGC 6772**. This large, evolved nebula with an unusual, flattened shape is eye-catching in moderate-sized backyard scopes. Lying roughly 4,200 light-years away, NGC 6772 glows feebly at magnitude 12.7 and covers an area 1.1′ wide. Its central star makes a meek appearance at 18th magnitude, effectively out of the range of backyard telescopes. The object is truly attractive in the eyepiece, however. Its elongated ring, the nebula's brightest feature from our perspective, appears oval and unevenly illuminated. On a very dark, moonless night, an observer with an 8-inch scope at moderate magnification will see its mottled appearance, with the whole entity shrouded in a larger, much fainter, and smoother envelope — especially with averted vision. Inside the non-luminous areas of the ring appear what look like two small lobes, almost reminiscent of a squashed version of the larger and brighter planetary, M97, the Owl Nebula, in Ursa Major.

Another really nice planetary nebula is tucked in the southwestern corner of Aquila, not far east from the bright open cluster M11, the Wild Duck Cluster, in Scutum. This is **NGC 6751**, which has taken on the recent nickname of the Glowing Eye Nebula. (Are there any deep-sky objects left that have not been named by some sleep-deprived observer in the middle of the night?) The object, which is about 1° south of Lambda Aquilae, shines at about 12th magnitude and spans some 0.4′, sending its photons to us from a distance of around 8,500 light-years. Its central star glows dimly at about 15th magnitude. NGC 6751 is a curious nebula in the eyepiece of a medium-sized amateur scope at moderate magnification. It appears as a fuzzy aura surrounding the star, which will be faintly visible in larger scopes, and it's characterized by striations of nebular light flowing away from the center. The very uneven surface brightness of this object makes it appear fainter than it otherwise might and gives it a blotchy look in large backyard scopes.

Almost 6° due north of NGC 6751 lies another of Aquila's extensive catalog of planetaries, **NGC 6741**. This odd-looking but attractive object yields a



◀ **CELESTIAL BIRD OF PREY** Use this finder chart to plan the itinerary of your star-hopping. Aquila's lucida, Altair, and the constellation's distinctive, stretched-out wings can serve as jumping-off points, and you can refer to the text for further tips on how to find your way around.

very different appearance than we've seen in most planetaries, so it's worth exploring. Given its recent moniker of the Phantom Streak Nebula, NGC 6741 shines at about magnitude 11.5 and covers an area 8″ wide, giving it a high surface brightness that accompanies its tiny angular size. At a distance of roughly 12,000 light-years, it's bright and compact enough to withstand high magnification in most scopes when the seeing is steady and the sky is dark. The object is appealing because its geometry appears (from our perspective) boxy — that is, it looks like a small, glowing rectangle of gray-green light. Its central star is impossibly faint even for large telescopes, and so just spotting the nebula itself is about as well as any observer can do, no matter the size of their backyard scope. An 8-inch scope at high magnification will show it as a tiny, reasonably bright nebulosity in a relatively sparse star field.

Other Denizens of the Eagle

Starting at NGC 6741 and moving about 14° to the southeast brings you to an unusual object in this area of Aquila: the galaxy **NGC 6814**. Visible on the edge of the Milky Way's bright disk, this challenging object is within the range of medium and large amateur scopes. It's a Type 1 *Seyfert galaxy* — it exhibits bright ultraviolet and X-ray emission produced by material spiraling at very high speeds around its central black hole. The galaxy, which lies about 74 million light-years away, is a barred spiral glowing at magnitude 14.2 and covering an area of 2.8′ × 2.6′. This means it'll appear relatively small and certainly faint to observers equipped with small scopes. NGC 6814 is a little smaller than the Milky Way Galaxy but relatively similar in brightness, and so gives us an approximation of what our galaxy would look like from such a distance. With an 8-inch scope at moderate magnification, you'll see a relatively bright, elongated hub surrounded by a gauzy enve-

▲ **AN OVERLOOKED GEM** The planetary nebula NGC 6772, rarely observed or photographed by the amateur community, displays a slight resemblance to larger and brighter M97, the Owl Nebula in Ursa Major, with a pronounced ring surrounding two darker holes within.

PETER GOODHEW

Targets for Eagle Eyes

Object	Type	Mag	Size	RA	Dec.
NGC 6781	Planetary nebula	11.4	1.8′	$19^h\ 18.5^m$	+06° 32′
NGC 6804	Planetary nebula	12.0	1.1′	$19^h\ 31.6^m$	+09° 14′
NGC 6790	Planetary nebula	10.5	4″	$19^h\ 22.9^m$	+01° 31′
NGC 6772	Planetary nebula	12.7	1.1′	$19^h\ 14.6^m$	−02° 42′
NGC 6751	Planetary nebula	11.9	0.4′	$19^h\ 05.9^m$	−06° 00′
NGC 6741	Planetary nebula	11.5	8″	$19^h\ 02.0^m$	−00° 27′
NGC 6814	Spiral galaxy	11.2	2.8′ × 2.6′	$19^h\ 42.7^m$	−10° 19′
NGC 6760	Globular cluster	9.0	4.8′	$19^h\ 11.2^m$	+01° 02′
NGC 6755	Open cluster	7.5	10.6′	$19^h\ 07.7^m$	+04° 14′
NGC 6756	Open cluster	10.6	3.4′	$19^h\ 08.7^m$	+04° 43′
NGC 6709	Open cluster	6.7	16.8′	$18^h\ 51.3^m$	+10° 20′
B142, 143	Dark nebula	—	1° × 0.5°	$19^h\ 40.7^m$	+10° 57′
B127, 129, 130	Dark nebula	—	30′ × 20′	$19^h\ 02.1^m$	−05° 19′
B137, 138, 139	Dark nebula	—	4° × 0.5°	$19^h\ 18.0^m$	−01° 27′
Palomar 11	Globular cluster	9.8	2.4′	$19^h\ 45.2^m$	−08° 00′

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. Magnitudes are visual.

lope of low-surface-brightness nebulosity. The galaxy's central black hole has an estimated mass of about 18 million suns.

Returning to central Aquila will present you with a varied set of deep-sky targets. The small globular cluster **NGC 6760** lies a short distance west of the 5.1-magnitude binary star 23 Aquilae (see the photo on page 40). The cluster shines at a respectable magnitude 9.8 and spans 4.8′, making it a pretty straightforward target for small- and medium-sized scopes. At about 24,000 light-years away, it lies far beyond the Milky Way's hazy disk through which we spy it. Reasonably distant as it is, the cluster's individual members won't be resolved in any but the largest amateur scopes, some of which will reveal mottling along its edges. Most backyard scopes show it as a fuzzy disk, pretty bright and with a noticeably condensed core.

Almost 4° due north of NGC 6760, you'll find two open clusters in close proximity: **NGC 6755** and **NGC 6756**. While globular clusters formed early on in the history of the universe, before our galaxy's disk fully accreted, open clusters come from young stellar birthplaces similar to the one in which our Sun formed, and before gravitational interactions with our neighbors sent our stellar sisters off in myriad directions.

NGC 6755 is bright at magnitude 7.5 and stretches more than 10.6′ across. It contains a couple hundred stars and lies

▲ **ACTIVE SPIRAL** A rare galaxy lying near the plane of the Milky Way, NGC 6814 is a barred spiral not terribly unlike the Milky Way, but visible across a 74-million-light-year chasm of space.

▲ **STELLAR SPHERE** Discovered by English astronomer John Russell Hind in 1845, the small, 9th-magnitude globular cluster NGC 6760 contains approximately a few hundred thousand stars. It's considered a part of the Milky Way's halo and orbits the galactic center.

about 6,500 light-years away. Owing to its size and brightness, this is a nice target for small telescopes, appearing as a fairly rich group in an 8-inch scope at moderate power. NGC 6756, some 30′ to the northeast and visible in the same low-power field, contains fewer stars. The cluster stars shine collectively at magnitude 10.6 and are packed into an area just 3.4′ wide. This group lies about 10,000 light-years away and offers a nice contrast to its neighbor.

Another noteworthy open cluster lies in the western reaches of Aquila, near its border with Ophiuchus. **NGC 6709**, located about 5° southwest of 3.0-magnitude Zeta (ζ) Aquilae, is bright enough for binoculars, with its total magnitude of 6.7 and angular size of 16.8′. At a distance of some 3,200 light-years, its brightest stars form a relatively compact, approximate V shape, which is quite apparent in any scope on a good night.

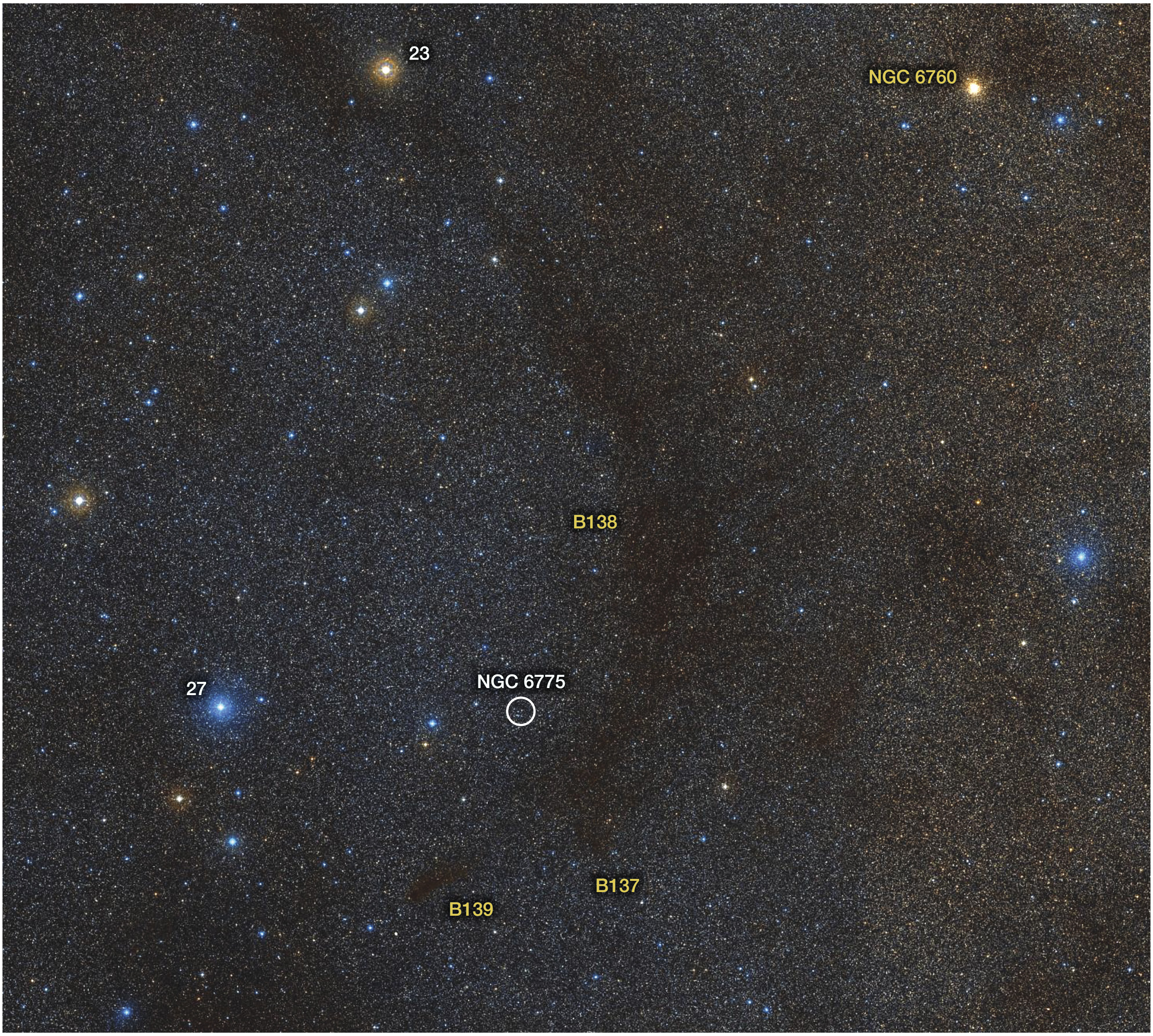
Aquila also harbors a retinue of lesser-known objects. A great target for observers under a dark, moonless night is Barnard's E — two dark nebulae, Barnard 142 (**B142**) and Barnard 143 (**B143**), that seem to form a capital letter E in shape (for a deep dive, see *S&T:* Oct. 2025, p. 58). The features are named after American astronomer Edward Emerson Barnard, who cataloged hundreds of such dark clouds photographically in the 1900s. The field of Barnard's E lies about 1½° west of 2.7-magnitude Gamma Aquilae at the top left corner of the big V. Dark nebulae consist of vast, dense clouds of fine-grained dust that block light from stars behind them and are therefore challenging targets for visual observers. Barnard's E is a prominent one, however, as it stretches across 30′, the size of the full Moon. Small- or medium-sized scopes at low magnifications are needed to pick out the form of this nebula against the Milky Way's rich backdrop, and binoculars will also do a nice job. These clouds lie about 2,000 light-years away.

Other treats await at lower declinations, such as **B127**, **B129**, and **B130**. This compact group of dark clouds is notable because the objects are pretty opaque, making their silhouettes stand out nicely in medium-sized scopes at low powers on a moonless night. The nebulae are all clustered near each other, despite the separate Barnard designations, just less than 1° north of the 4th-magnitude star 12 Aquilae.

About 5° north-northeast of this site lies another unusual complex of dark nebulae, formed by **B137, B138,** and **B139**. This long, arc-shaped dust cloud is aligned roughly north-south and appears to cut across an open cluster, NGC 6775. The cluster is a loose aggregation lying in a very rich star field and is approximately 8,500 light-years away. The object is poorly studied, so its magnitude and size are not reliably known. The

POSS-II /STSCI / CALTECH / PALOMAR OBSERVATORY

▲ **COSMIC DUST BUNNIES** This compact chain of dark interstellar clouds obscures light from stars behind them. Many of these dense, opaque nebulae, which are themselves likely sites of future star formation, can be discerned in medium-sized scopes on a moonless night.



▲ **MORE OF BARNARD'S DARK NEBULAE** This sprawling complex of dark nebulae, formed by the 4°-long, arc-shaped dust cloud B138, nicknamed the Black Lizard, and the smaller clumps of B137 and B139, is situated about halfway between Delta and Lambda Aquilae.

accompanying dark nebulae make an interesting sight in large, low-power binocular fields under a dark sky.

About 10° southeast of this area lies a distant globular cluster belonging to a modern catalog. American astronomer Albert George Wilson discovered **Palomar 11**, which lies roughly 47,000 light-years away behind the glow of the Milky Way, on Palomar Observatory's 1955 photographic survey plates. This little object is reasonably bright at magnitude 9.8 but spans a mere 2.4′. An 8-inch scope at high power under a dark sky will show it as a mere concentration of the rich stellar background, a smudge of nebular light. But it's an interesting object to see for yourself, given the somewhat exotic nature of its discovery and the great distance involved.

The sprawling constellation Aquila holds a treasure trove of tempting deep-sky objects. Heavily weighted toward planetary nebulae and an obscure set of star clusters, the region is nonetheless worth exploring with small and medium telescopes. The planetaries, in particular, give us a really nice range of examples of how our own solar system will end several billion years after we're gone, and long after our descendants are mere memories in the history of planet Earth.

Happy exploring!

■ **DAVID J. EICHER**, editor emeritus of *Astronomy* magazine, is an avid deep-sky observer with 50 years of experience viewing clusters, nebulae, and galaxies.

SKY AT A GLANCE
June 2026

7 **DUSK:** Face west-northwest after sunset to catch the delightful gathering of two planets and Gemini's brightest light. Venus is some 4½° lower left of Pollux, with Jupiter about 2¼° to its left. See if you can spot Mercury at lower right just above the horizon.

9 **DUSK:** Venus is a mere 1½° upper right of Jupiter. Turn to page 46 for more on this event and others listed here.

13 **DAWN:** Look low in the east-northeast to witness the waning crescent Moon leading the Pleiades above the horizon (see page 50). Mars is farther to the right. Be sure to catch this sight before the rising Sun washes it away.

16 **DUSK:** Turn to the west-northwest to spot the day-old Moon delightfully framed by Jupiter 4½° at upper left, Pollux, 4° at upper right, and Mercury 3° at lower right, while Venus guards the tableau from farther to the upper left.

17 **DUSK:** In the west, the waxing crescent Moon visits the Beehive Cluster (M44) in Cancer with Venus blazing 2½° lower right. You'll need binoculars to tease out the Beehive's stars. Go to page 50 for details.

19 **DUSK:** The Moon, two days shy of first quarter, trails Regulus, Leo's lucida, by about 6°. Watch as the pair sinks toward the western horizon in deepening twilight.

21 **THE LONGEST DAY OF THE YEAR** in the Northern Hemisphere. The solstice occurs at 4:25 a.m. EDT (1:25 a.m. PDT) heralding the start of summer.

23 **DUSK:** Face west-southwest to see the waxing gibbous Moon hanging some 4½° lower left of Spica, Virgo's brightest star.

25 **DUSK:** Find an unobscured horizon to the west-northwest to catch Jupiter with Mercury a bit more than 3½° to the lower right.

27 **DUSK:** The Moon, two days from full, follows Antares by 5¾° as they climb in the south-southeast.
—DIANA HANNIKAINEN

▲ Summer stars wheel around Polaris at Dinosaur Provincial Park, Alberta (Canada). ALAN DYER

JUNE 2026 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				

LAST QUARTER

June 8
10:01 UT

NEW MOON

June 15
02:54 UT

FIRST QUARTER

June 21
21:55 UT

FULL MOON

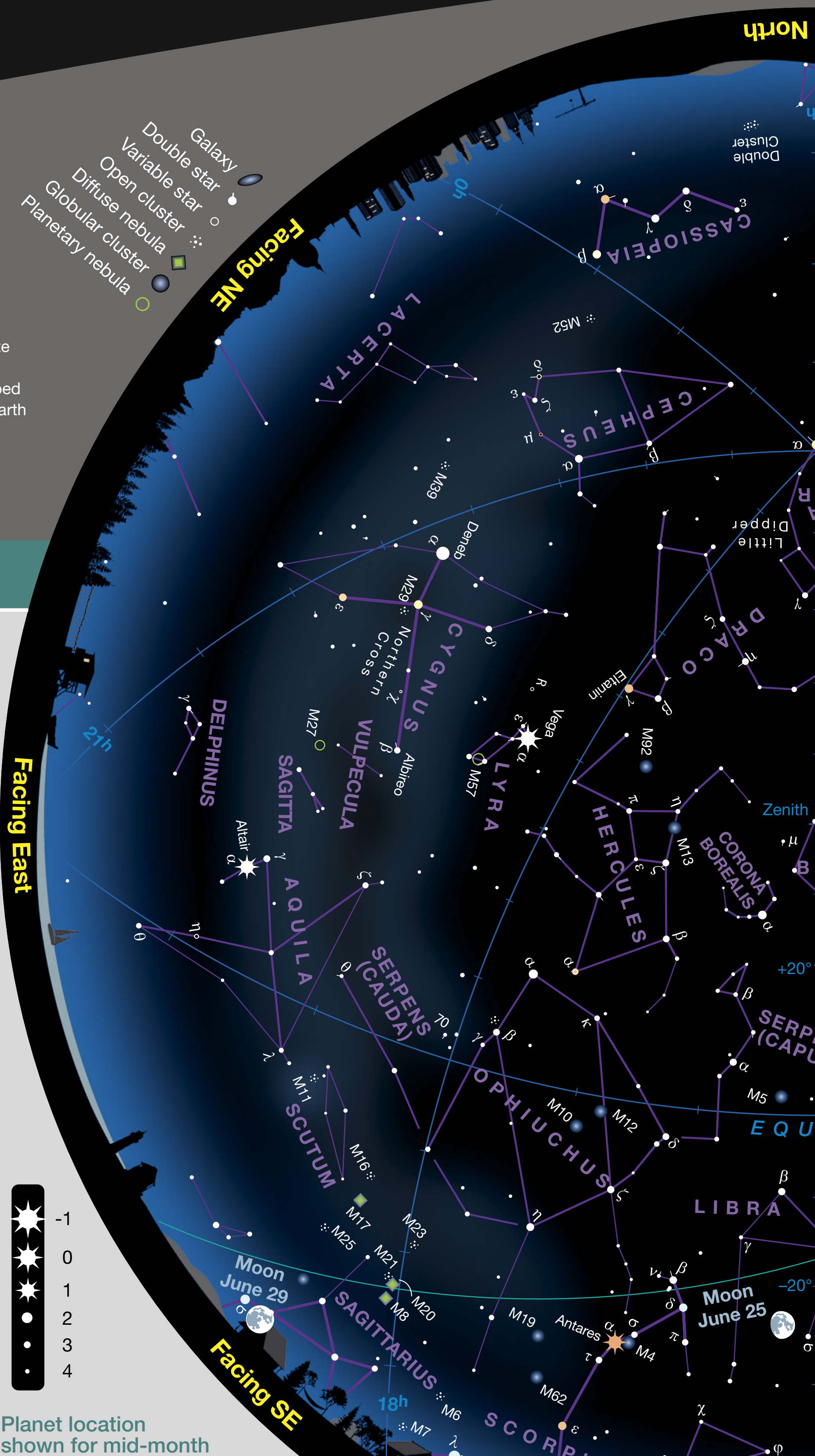
June 29
23:57 UT

DISTANCES

Apogee	June 1, 05^h UT
406,366 km	Diameter 29′ 25″
Perigee	June 14, 23^h UT
357,200 km	Diameter 33′ 27″
Apogee	June 28, 07^h UT
406,264 km	Diameter 29′ 25″

FAVORABLE LIBRATIONS

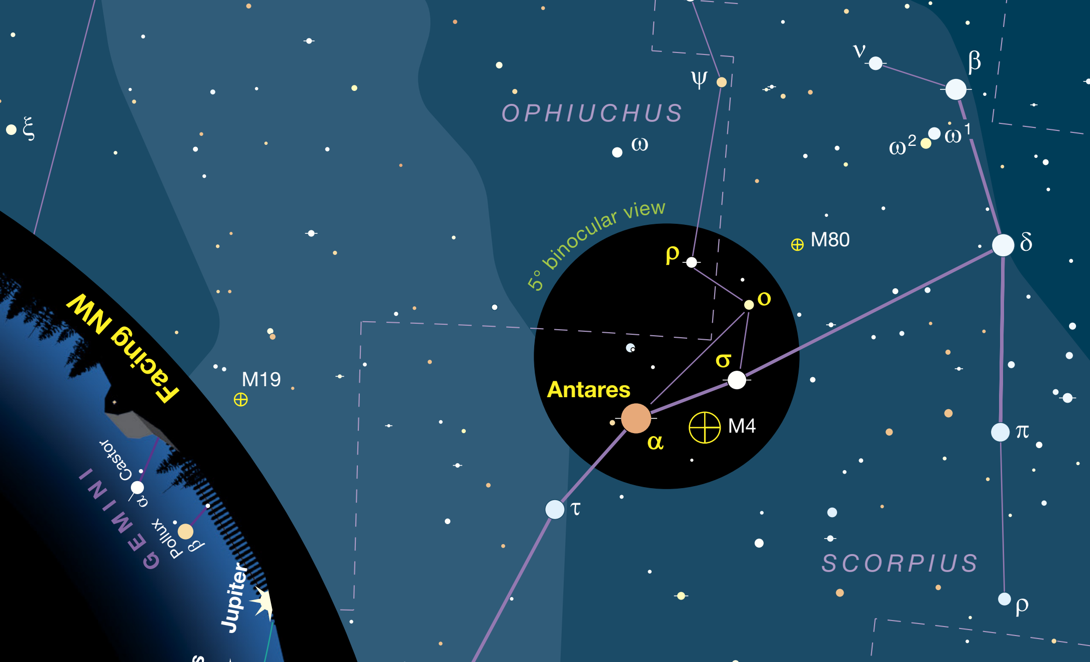
• Mare Orientale	June 10
• Krasnov Crater	June 11
• Humboldt Crater	June 18
• Goddard Crater	June 21



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

Revisiting the Scorpion

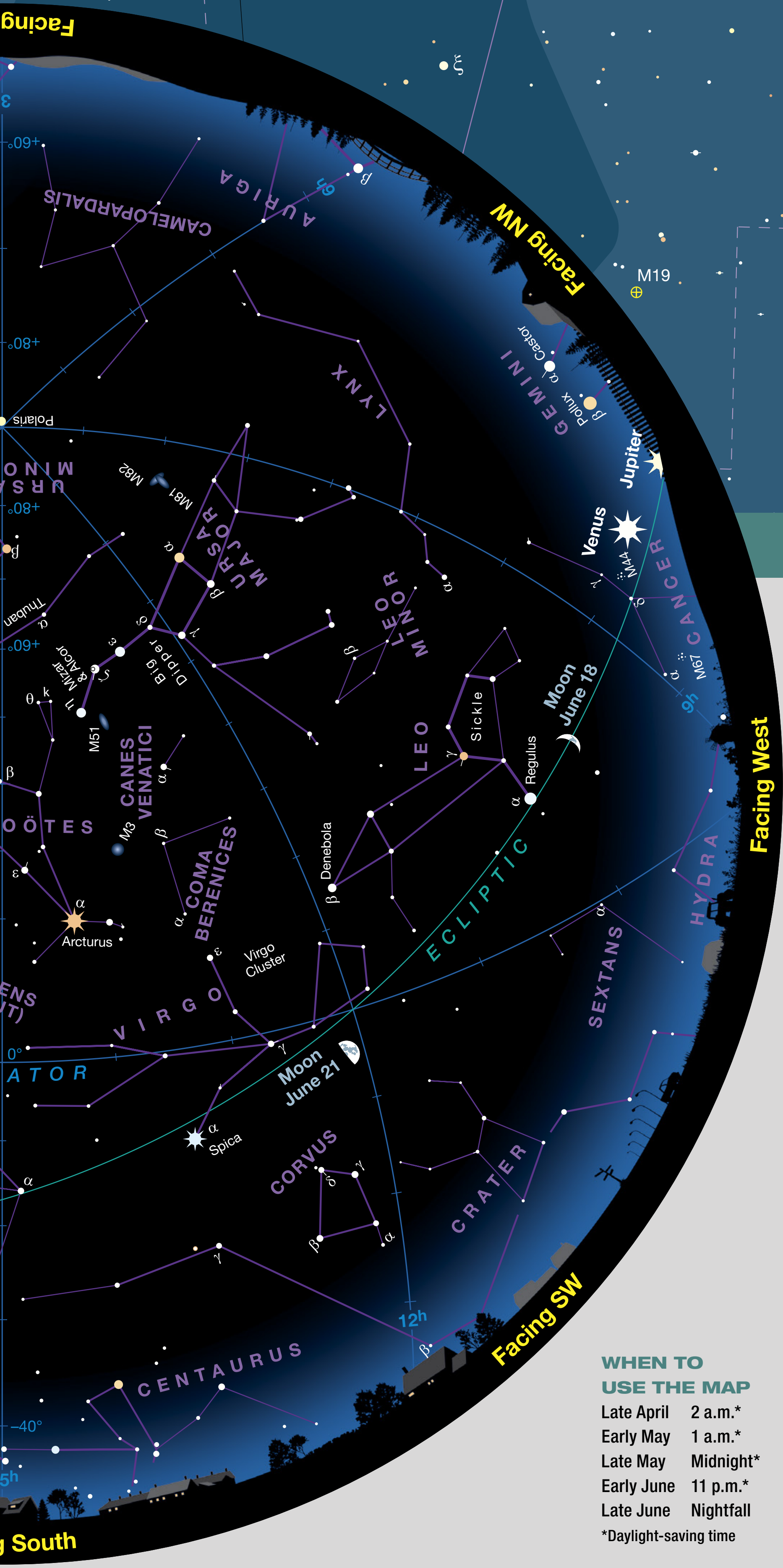
Scorpius, the zodiacal Scorpion, has always been my astronomical herald of summer. There might be more obvious choices — the stars of the Summer Triangle, perhaps — but I'm a night owl and I see the more northerly candidates long before. Being farther south, Scorpius takes longer to crawl out of the near-horizon murk. By the time the Scorpion rears its claws above my neighbor's roof, it feels like summer.

Just like Earthly scorpions, Scorpius looks sharp at both ends. Its tail is freckled with open clusters, and its front end is marked by the familiar claw asterism and its baleful red heart, 1st-magnitude Antares, or Alpha (α) Scorpii. Deep-sky enthusiasts come to Antares as a guidepost to the globular clusters M4 and M80, as I have done before in this column (see *S&T:* July 2021, p. 43). But now I'm coming back for another look at the neighborhood.

What catches my eye is the curve of stars northwest of Antares, formed by 4.6-magnitudes **Rho (ρ) Ophiuchi** and **Omicron (ο) Scorpii**, and 2.9-magnitude **Sigma (σ) Scorpii**. This arc is admittedly more sharply bent than the larger and more famous claw asterism farther west, but now I can't help but see them as a sort of miniature set of claws.

Almost all the bright stars at the head end of the Scorpion, including Antares and the big and small sets of claws, are members of the Scorpius-Centaurus Association, the closest OB association to our solar system. Omicron Scorpii is the odd one out — at about 900 light-years away from us, it's almost twice as distant as most of its prominent neighbors, and probably not a member of the stellar association. But it makes for a nice "group photo" anyway.

■ If **MATT WEDEL** has missed many asterisms near famous Messier objects, he might have just doubled his workload, or at least earned some job security.



WHEN TO USE THE MAP

Late April	2 a.m.*
Early May	1 a.m.*
Late May	Midnight*
Early June	11 p.m.*
Late June	Nightfall

*Daylight-saving time

JUNE 2026 OBSERVING

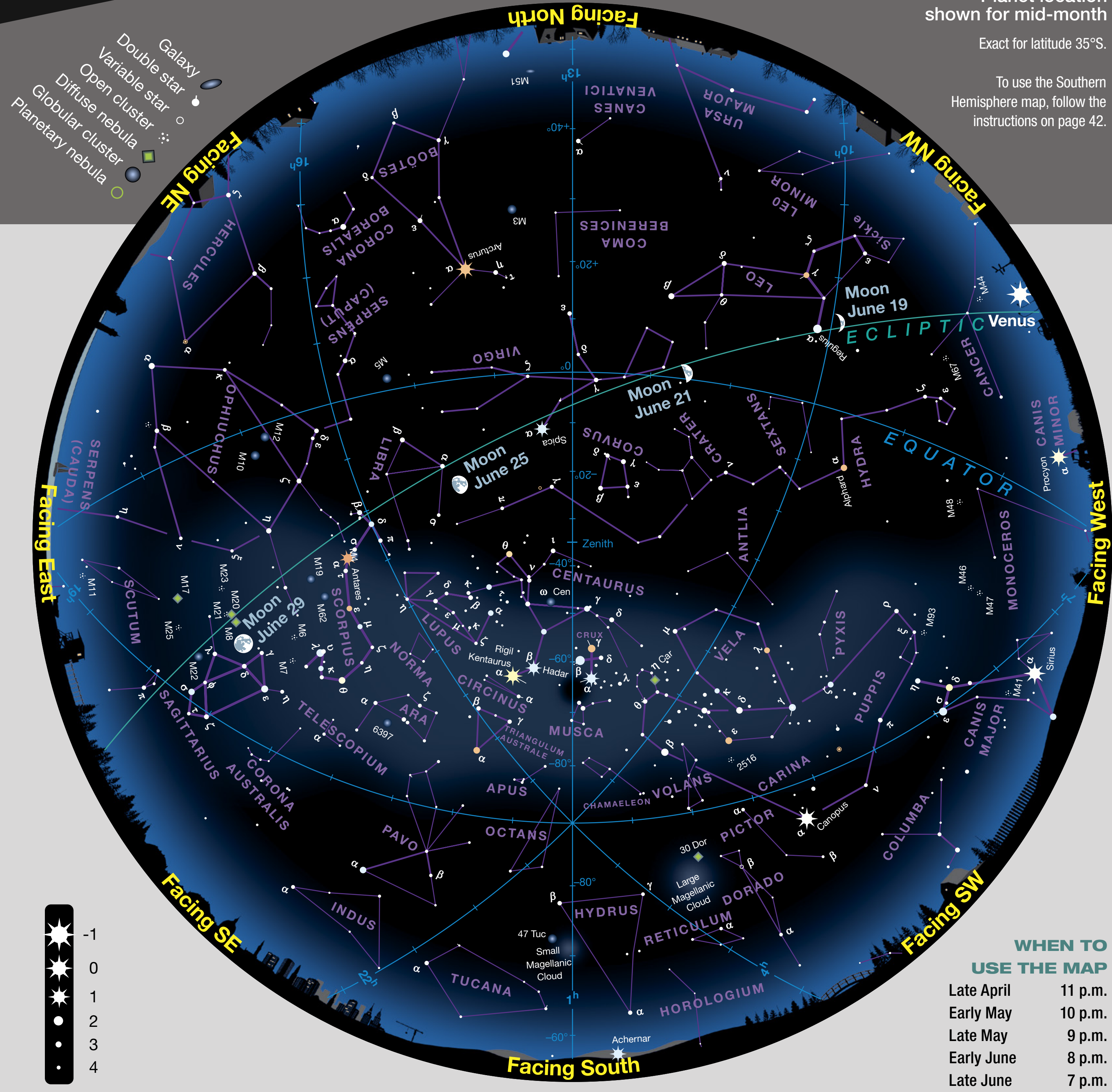
Southern Hemisphere Sky Chart

by Jonathan Nally

Planet location shown for mid-month

Exact for latitude 35°S.

To use the Southern Hemisphere map, follow the instructions on page 42.



WHEN TO USE THE MAP

Late April	11 p.m.
Early May	10 p.m.
Late May	9 p.m.
Early June	8 p.m.
Late June	7 p.m.

MIGHTY CENTAURUS, the Centaur, the ninth-largest constellation by area, rides high in this month's sky. Situated right in the thick of the southern Milky Way, it's full of stellar riches — in fact, it has the largest number of naked-eye-brightness stars of all the constellations.

Centaurus is one of the 48 constellations recognized by Ptolemy in the second century AD. It's interesting to note that his version incorporated what we now recognize as Crux, the Southern Cross, as part of the Centaur's hind legs. But how did ancient Greeks know about Crux, which is below the horizon for modern-day Greeks? It's due to *precession*, the long-term wobble of the Earth's rotational axis. Many low-declination stars were once about 10° higher as seen from the southern Mediterranean — just enough to spot Crux. ■

A Crown by Any Other Name

As we wait for the Blaze Star to blow, let's explore Ariadne's floral crown.

▲This 1826 painting by French artist Sophie Frémiet portrays Ariadne abandoned on Naxos. Note her floral crown.

As of this writing, skywatchers are eagerly awaiting the outburst of recurrent nova T Coronae Borealis (*S&T:* May 2026, p. 48) — which may rise from roughly 10th magnitude to 2nd or 3rd. As we watch and wait, I'd like you not to miss the forest for the tree. In other words, let's focus our attention this month on the constellation Corona Borealis, the Northern Crown, as you await T Coronae Borealis's blaze, and take measure of some of its myths.

As shown on this month's Northern Hemisphere Star Chart on pages 42–43, Corona Borealis lies slightly southeast of the *zenith*, the point directly overhead. Look for a small horseshoe-shaped semicircle of seven stars. Six of them shine between 3rd and 5th magnitude, while its Alpha (α) star, Alphecca, glows brightly at 2nd magnitude, glistening as the precious gem in this celestial diadem. In fact, many skywatchers prefer Alphecca's alternative name, Gemma, as it refers to a valuable stone or jewel. The roots of the name Alphecca, on the other hand, allude to the incomplete-ring aspect of Corona Borealis, which early Arab astronomers saw as the "pauper's bowl" or the "broken platter."

But in the 1775 edition of *Polymetis* — a history and criticism on subjects such as Roman sculpture, mythological art, and Latin poetry — English scholar Joseph Spence says that Gemma should be taken in its original meaning of a "bud," referring to the unopened blossoms of the floral crown, as depicted in early renderings of the figure. "Just by the Pedum [shepherd's crook] in Boötes's right hand," Spence says, "you see a wreath of leaves and flowers, fastened with a riband. This is the Corona, or Ariadne's crown; which makes much such a circular appearance in the heavens . . . tho' we have turned it into a Gothic crown, in all our modern globes."

Note the constellation's association with Ariadne, daughter of Minos, second king of Crete. Ariadne is perhaps best known for helping the Athenian hero Theseus — who was shut up in the celebrated labyrinth of Crete, to be devoured by the ferocious Minotaur. She furnished him with a thread, which he used to extricate himself from that impossible maze after defeating the Minotaur. In return, Theseus promised to marry the beautiful Ariadne. Together they sailed to the island of Naxos, where he encouraged Ariadne to rest. Theseus then abandoned her.

Fortunately, Dionysus, Greek god of wine, heard Ariadne's cries of despair and came to her rescue. With affection, he took the crown she was wearing from her forehead and tossed it into the heavens, buds flaring into stars, before they settled into the constellation that would bring her eternal glory. As Roman poet Ovid (43 BC – AD 17) tells us in his poem *Fasti*, as translated by Sir James George Frazer, Dionysus "loves flowers; that he delights in a floral crown, you may know from Ariadne's clustered stars."

Now imagine, if we are lucky enough to see T Coronae Borealis flare to prominence, we can add yet another bud to Ariadne's Crown. In his 1869 book *Midnight Sky: Familiar Notes on the Stars and Planets*, Edwin Dunkin informs us that M. Ernest Quetelet, of Brussels, Belgium, remarked of the 1866 eruption of T Cor Bor, "that the star, when viewed by the naked eye, decidedly twinkled much more than the other stars near, so much so at times that its variations rendered the observations of its relative brightness extremely difficult." Now I wonder, did an outburst of T Cor Bor in classical times lead to that imagining in the myth — that its stars flared to brightness as the Crown ascended?

■ Cosmic Mythographer **STEPHEN JAMES O'MEARA** has been studying the constellations and their lore for more than 50 years.

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

Venus Meets and Greets

The Evening Star has a busy month visiting the Moon, Jupiter, and the Beehive Cluster.

TUESDAY, JUNE 9

This is an exciting month for planet watchers, with plenty going on both at dusk and dawn. Indeed, with just a little effort, you can easily see all five naked-eye planets. But this is a limited-time offer — two of the three evening targets hovering above the west-northwestern horizon will soon be gone. This dusk trio consists of **Venus**, **Jupiter**, and **Mercury**. And on this particular evening, it's the first two on that list that are most conspicuous. Jupiter has been drifting toward the Evening Star for many weeks, and tonight they're at their closest. The gap between them has shrunk to just a bit more than 1½°!

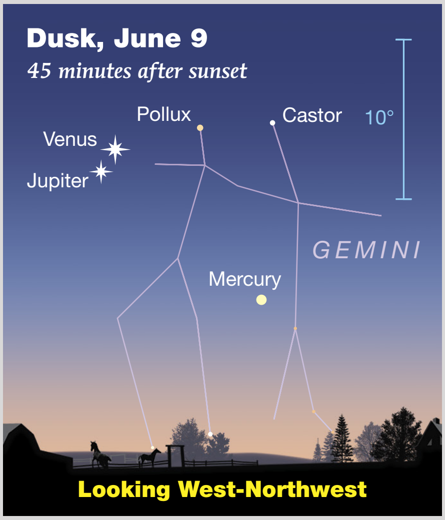
▼ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west). European observers should move each Moon symbol a quarter of the way toward the one for the previous date; in the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your fist seen at arm's length. For clarity, the Moon is shown three times its actual apparent size.

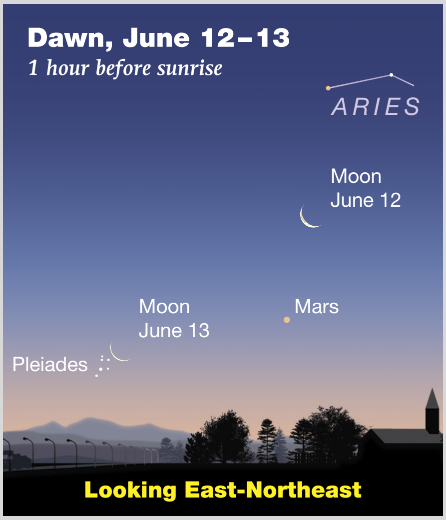
It's an eye-catching sight any time the two brightest planets meet, and you're sure to get questions about "those two bright stars" from your non-astronomy friends and family. It's a good opportunity to talk about how vast distances in space really are. Even though the two planets *appear* close together this evening, in fact Jupiter is more than 900 million kilometers (560 million miles) from Earth — that's more than five times farther than its dusk partner. Venus's relative proximity to our planet is one reason why it appears so much brighter than distant Jupiter (magnitude –4.0 versus –1.8). The inner world's greater albedo is another reason, but that detail probably gets us into the realm of "too much information" for the interest level of casual skywatchers. Jupiter and Venus pair up roughly once a year, but 2027's conjunction occurs with both of them positioned too near the Sun to be viewed. However, the 2028 meetup will be one to look forward to as the gleaming duo will be separated by just ¾°.

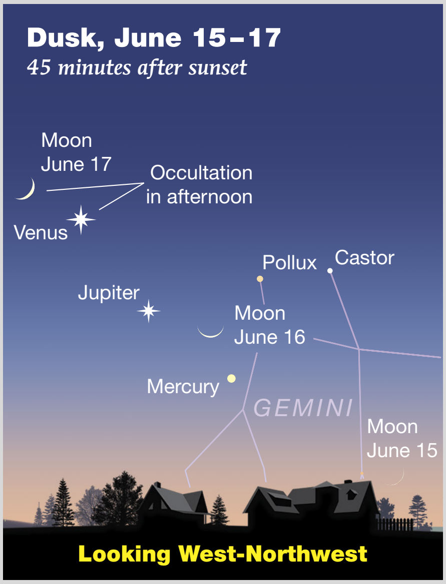
The third planet in this dusk scene is little Mercury, which is easy to overlook since it's both lower and fainter than its showy companions. It shines at magnitude +0.0 and sits 10° above the horizon 45 minutes after sundown. For Mercury, that's actually pretty good. It's presently nearing the climax of its current apparition and will be at its very highest next evening. After that it quickly loses altitude, and by the 24th will be lost in the Sun's glare.

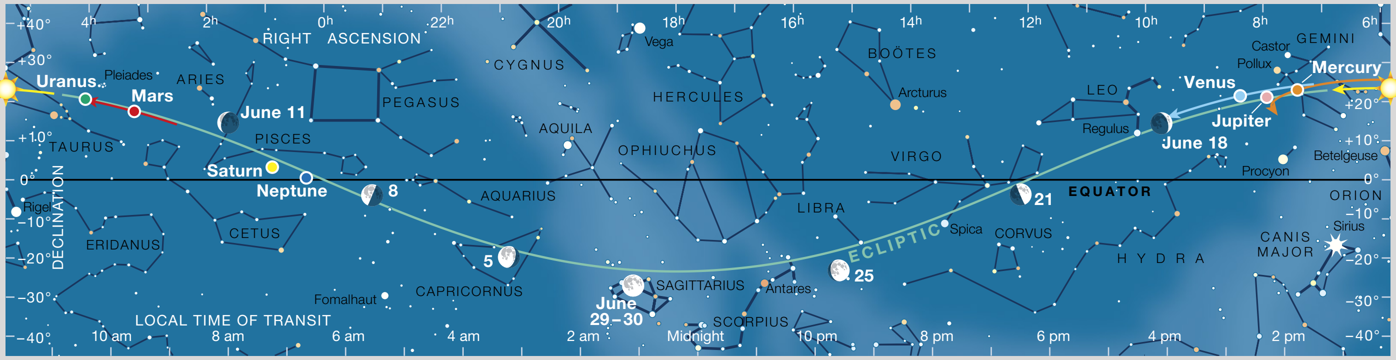
SATURDAY, JUNE 13

If you have an unobstructed view toward the east-northeast and don't mind an early start to your day, you can enjoy the sight of a razor-thin crescent **Moon** parked just to the right of the **Pleiades**, in Taurus. It's a very pretty naked-eye sight — a lunar crescent adorned with earthshine illuminating the "unlit" portion of the lunar disk a short distance from the Seven









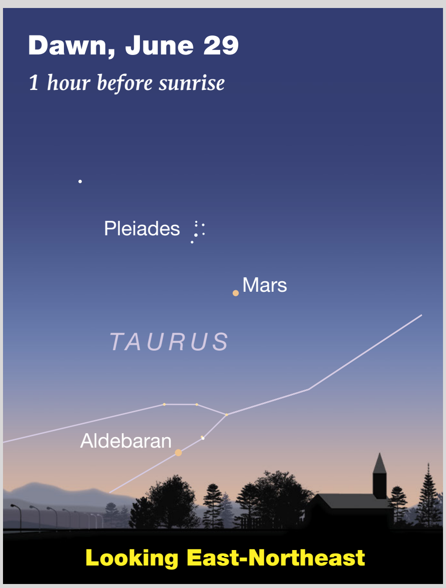
▲ The Sun and planets are positioned for mid-June; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit" 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.

Sisters, as the cluster is also called. The Moon is just 4.5% illuminated, which means its glare won't overwhelm the sparkling Pleiades. However, I'd reach for binoculars to bring in some of the fainter cluster members and make the earthshine even more obvious. Because only 1° separates the Moon from the periphery of the cluster, both objects readily fit into a single binocular field of view. But you'll want to observe early — astronomical twilight is already well underway by the time the Pleiades have cleared the horizon.

WEDNESDAY, JUNE 17

The ongoing **Venus** show takes an exciting turn today — this time its dancing partner is the **Moon**. As described in detail on page 48, the contiguous U.S. and most of Canada get to observe the lunar crescent eclipse the sky's brightest planet in daylight. But the fun doesn't end when Venus re-emerges from behind the Moon in the afternoon. As twilight falls, the two objects are still attractively positioned near each other, with the Moon less than 2½° upper left of Venus. Those using binoculars or a small telescope may notice that the earthlit lunar crescent is passing through the Beehive Cluster (M44), in Cancer. (You can read more about this on page 50.) Venus also shares a binocular field with the cluster's little swarm of stellar bees. This will be more obvious the following evening when the Moon has vacated the scene and Venus is even closer to the Beehive. The Evening Star skirts the northern edge of the cluster on the 19th — something you'll definitely want to catch.

With the unaided eye, Venus and the Moon are part of a lovely, 17°-long string that includes Jupiter and Mercury.



WEDNESDAY, JUNE 24

The last hurrah of the current dusk planet parade takes place this evening when **Jupiter** and **Mercury** meet and are separated by 3¾°. The solar system's innermost planet might give you a little trouble though, as it's faded to magnitude 1.4 and is positioned just 5° above the west-northwestern horizon 45 minutes after sunset. Fortunately, it occupies the same binocular field as easy-to-spot Jupiter. The trick to catching Mercury is to adjust your expectations accordingly — Jupiter is nearly 20 times brighter!

Big Jove has a second alignment to enjoy this evening. It forms a nearly perfectly straight three-in-a-row line with **Castor** and **Pollux**, the two brightest lights in Gemini. Both stars are about as conspicuous as Mercury, with Pollux being slightly brighter than the planet and Castor slightly fainter. Jupiter moves slowly, but keep an eye on it to see how many nights pass before its alignment with the Gemini stars begins to look a bit wonky.

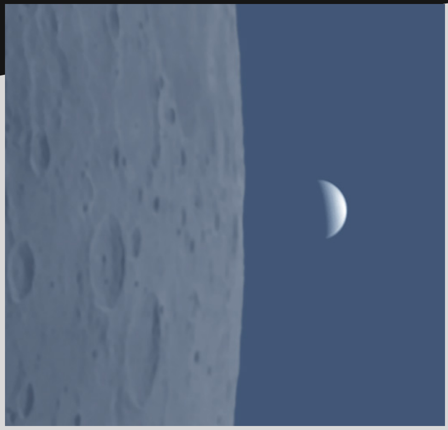
MONDAY, JUNE 29

At dawn today early risers get to see **Mars** sharing a binocular field with the **Pleiades** just above the east-northeast horizon. The 1.3-magnitude Red Planet sits 4.4° lower right of 2.9-magnitude Alcyone, the brightest Pleiad of the bunch. Mars's path along the ecliptic occasionally brings it closer to the cluster than it gets this morning — it passed within 1.6° of Alcyone in January 1991 and, more recently, 2.6° in March 2021. This morning's conjunction, however, is the only time Mars buzzes the Pleiades during its current apparition. You'll have to wait until 2038 to see the planet closer than 2° from Alcyone again.

■ Senior Contributing Editor **GARY SERONIK** keeps tabs on the night sky from his home in British Columbia's Okanagan Valley.

A Daylight Occultation

Watch the crescent Moon occult Venus in the middle of the day.



◀ Venus hovers above the Moon's cratered limb soon after emerging from behind the lunar crescent during the June 8, 2007, occultation.

The Moon is always a helpful guide, pointing the way to the stars and planets that lie along its path. A tireless teacher, it visits more than a dozen constellations and seven planets during each of its circuits around the sky.

This month, Earth's celestial partner has something wonderful in store. On June 17th, the 11%-illuminated waxing crescent will occult Venus in the bright sunshine across the contiguous U.S., much of Canada, northern Mexico, the Caribbean, and northeastern South America. Venus will be in waning gibbous phase, 74% illuminated at magnitude –4.0, neatly complementing the Moon's sickle shape. The pair will lie a comfortable 38° east of the Sun.

When located sufficiently far from the Sun, Venus is readily visible with the unaided eye in the daytime sky, so keen amateurs may attempt to see the Moon cover and uncover it without optical aid. It's easiest (and safest) if you observe the occultation from a shady spot to avoid the Sun's glare. But why make it hard on yourself? A pair of 35-mm or 50-mm binoculars will easily show the duo. A small telescope is best because it will not only reveal Venus as a pure white gibbous "moon" 28″ across, but you'll see the blue sky slowly nibble it to nothing in approximately 30 seconds. Yes, blue sky. The planet disappears at the Moon's dark limb, which appears sky-blue in bright daylight.

Venus will reappear minutes to more than an hour later (depending on your location), emerging from the Moon's bright limb. Coming and going, both sides of this occultation will make for a fantastic observing experience. All you have to do is be there on time. From the East Coast the cover-up begins around 3:30–4:00 p.m. local time; 2:00–2:30 p.m. in the Midwest; 12:30–1 p.m. in the Mountain States; and 11:30–11:45 a.m. on the West Coast. More accurate times for your specific location can be found at **https://is.gd/iota_0617venus**. Rob Robinson, with the International Occultation Timing Association (IOTA), has set up this website with the times of disappearance and reappearance for a host of cities. Or just simulate the event for your location using your favorite planetarium app and note the times.

You can use a telescope to capture photos of the occultation, but a long telephoto lens on a basic tripod will also work well. Both objects are extremely bright, so a tracking drive isn't necessary.

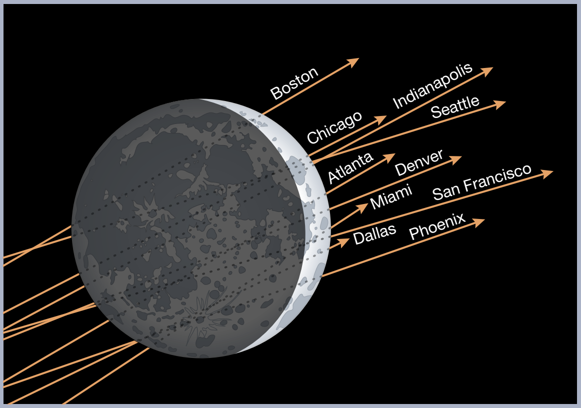
For those not in the occultation zone, there's still some good news. The Moon and Venus will be buddies all day long, so you can aim binoculars at the lunar crescent and catch the starlike planet hovering nearby.

Venus occultations are fairly uncommon for any particular region. The last one seen from the U.S. occurred on April 17, 2024, but it was only visible from the eastern third of the country. Bad weather can often add years to the time between opportunities. Each one means a chance to tune in to the music of the spheres and its ceaseless cycles that go on with and without us.

Occultation of Venus on June 17, 2026

City	Disappearance (UT)	Reappearance (UT)
Atlanta	19:39.4	21:07.4
Boston	20:00.1	21:08.4
Chicago	19:24.8	20:50.1
Dallas	19:18.2	20:34.5
Denver	18:55.6	20:18.1
Indianapolis	19:28.4	20:55.7
Miami	20:06.3	21:24.7
Phoenix	18:50.9	19:55.1
San Francisco	18:33.6	19:44.6
Seattle	18:40.9	19:51.4

Ingress and egress times of the June 17th occultation of Venus. For cities not listed in this table, visit **https://is.gd/iota_0617venus**.



▲ This diagram shows the ingress and egress locations of Venus at the lunar limb for several U.S. cities. Times are listed in the adjacent table. North is up.

MOON OCCULTING VENUS: PETE LAWRENCE; ARROW DIAGRAM: EBERHARD RIEDEL

Perihelic Apparition of Periodic Comet 10P/Tempel

PERIODIC COMETS ARE the best, especially those that belong to the Jupiter family, because they have orbital periods of less than 20 years. That makes them regular visitors, giving us a chance to observe them multiple times in the course of our lives, unlike those fickle Oort Cloud wayfarers. This season, we're due again for a visit from Comet 10P/Tempel 2, which reaches perihelion on August 2nd, just one day before its closest approach to Earth at 62 million kilometers (39 million miles). The combination of fortuitous circumstances makes this go-round a *perihelic* apparition, the first since 2010. Even though 10P/Tempel returns every 5.4 years, circumstances vary due to the comet's position in relation to the Sun and Earth around the time of perihelion. This particular appearance could be a bright one.

I've observed this dependable visitor on five previous occasions, so I'm excited to say "hello" again and follow its progress through the summer and fall. Although the comet will be brightest in late July and early August — likely reaching 7th magnitude — it will bear south, moving from southern Capricornus into Piscis Austrinus, and track relatively low in the southern sky as seen from mid-northern latitudes.

So why wait until its perhelion to point your telescope its way? In June, Comet 10P straddles the Aquila-Capricornus border as a 9th-magnitude fuzzball and ends the month in western Aquarius at around 8th magnitude, possibly bright enough to see in binoculars from a dark, moonless sky.

While it rises before midnight in June, your best views will be in the small hours before dawn, when Comet 10P is highest in the sky. From June 28th through July 1st, 10P/Tempel will lie within about 1° of the 8th-magnitude planetary nebula NGC 7009, better known as the Saturn Nebula. They'll share a similar magnitude and the same low-magnification field of view. What a perfect target for smart-telescope users! Visually, you might be able to discern the comet's short, west-pointing dust tail in a 6- to 8-inch scope.

Comet 10P/Tempel has an orbital inclination of 12° and travels near the plane of the solar system. Although it likely originated in the Kuiper Belt beyond Neptune, Jupiter's gravity has shaped and tamed the comet's orbit into a short-period one. And while water and carbon monoxide ices are abundant in most comets, spectroscopy of 10P/Tuttle in 2010 also revealed methanol, ethane, ammonia, and hydrogen cyanide within its coma. We also know that this Jovian vassal is similar in size to Halley's Comet, with a nucleus about 10.6 kilometers (6.6 miles) across.

I hope you'll find following this comet in June fun and instructive. Starting early means you get to watch it change from something indistinct into its full-fledged cometary self, complete with coma, pseudo-nucleus, tail, and maybe even a surprise or two.

▲ Comet 10P/Tempel 2 is a morning-sky object this month as it travels southeast from eastern Aquila, across northern Capricornus, and into western Aquarius. The comet will gradually brighten during this time and become visible in 4-inch and larger telescopes. It passes less than 1° southwest of 4th-magnitude Epsilon (ε) Aquarii on the mornings of June 20th and 21st and within 1° of the Saturn Nebula (NGC 7009) June 28th through July 1st. It continues on to Capricornus and Piscis Austrinis throughout July and August.

A Dawn Pleiades Occultation

WHAT'S MORE REFRESHING than a summer dawn? Observers situated from about Salt Lake City westward can watch the super-sleek 4%-illuminated lunar crescent occult one or more bright Pleiads on June 13th during morning twilight. Those living in the southwestern U.S. will have the best view due to shorter twilight lengths.

Given the growing light, binoculars or a small telescope will greatly assist in observing the multiple occultation event. From Las Vegas, the bright lunar limb first occults Electra (magnitude 3.7) at about 4:17 a.m. Pacific Daylight Time. Celaeno (5.5) is next at 4:20 a.m., followed by Taygeta (4.3) and Maia (3.9) at 4:41 and 4:42 a.m. Electra flashes back into view at the dark limb at 5:03 a.m., about 20 minutes before sunup.

From San Francisco, the Moon and cluster hover only a few degrees above the horizon when Electra disappears at 4:20 a.m. They'll climb to 7° when it's Maia's turn at 4:47 a.m. A lovely stellar arrangement ornaments the dark limb around 5:10 a.m., half an hour before sunrise. You'll need a telescope to see it, but Asterope (5.8), Taygeta, Celaeno, and Electra form a starry "tiara" just beyond the dark limb, while Alcyone (2.9) and Merope (4.2) shine a short distance below the bright limb. Will you see this potentially amazing sight as daylight approaches? I wish I could be there to give it a whirl.

▲ Low altitude and twilight will interfere, but the view of the Pleiades occultation on June 13th from the San Francisco region could be spectacular. This simulation shows the view about 40 minutes before sunrise, with the cluster-Moon duo about 10° high in the northeastern sky. The Pleiads Asterope, Taygeta, Celaeno, and Electra (left to right) arc around the dark lunar limb, while Alcyone (left) and Merope shine below the bright crescent.

IMAGE COURTESY OF SKYSAFARI ASTRONOMY

Moon Has More Up its Sleeve

AFTER CONQUERING VENUS, the Moon moves on to its next quarry, M44, the Beehive Cluster in Cancer. The evening of June 17th, the crescent tracks across the cluster's center from many U.S. cities and occults numerous 6th- to 8th-magnitude stars. Once again, these occur at the dark limb, so observers can watch the Earth-lit edge slowly snatch them away one by one. The best location is the Eastern Time Zone, where skywatchers will see successive stellar disappearances from mid-twilight into evening.

By the time it's dusk in the Midwest, the crescent will shine within the cluster's east side and occult fainter outliers. Farther west, in the Mountain States and West Coast, the Moon will have departed the Beehive by late twilight, but the pair will still dazzle in binoculars. They'll be ½° apart from Denver and about 1° apart from San Francisco.

Action at Jupiter

JUPITER IS SWIFTLY losing altitude at dusk as it nears its July 29th conjunction with the Sun. So June really does represent the closing act in the planet's current apparition. Your best telescopic views occur shortly after sundown — the earlier, the better. Fortunately, the planet stands up well to bright twilight. Indeed, some of my best views of the planet have been during twilight.

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 Daylight Time is UT minus 4 hours.)

May 1: 9:09, 19:05; **2**: 5:01, 14:56; **3**: 0:52, 10:48, 20:44; **4**: 6:40, 16:36; **5**: 2:31, 12:27, 22:23; **6**: 8:19, 18:15; **7**: 4:11, 14:06; **8**: 0:02, 9:58, 19:54; **9**: 5:50, 15:46; **10**: 1:41, 11:37, 21:33; **11**: 7:29, 17:25; **12**: 3:21, 13:16, 23:12; **13**: 9:08, 19:04; **14**: 5:00, 14:56; **15**: 0:51, 10:47, 20:43; **16**: 6:39, 16:35; **17**: 2:31, 12:26, 22:22; **18**: 8:18, 18:14; **19**: 4:10, 14:06; **20**: 0:01, 9:57, 19:53; **21**: 5:49, 15:45; **22**: 1:41, 11:36, 21:32; **23**: 7:28, 17:24; **24**: 3:20, 13:16, 23:12; **25**: 9:07, 19:03; **26**: 4:59, 14:55; **27**: 0:51, 10:47, 20:42; **28**: 6:38, 16:34; **29**: 2:30, 12:26, 22:22; **30**: 8:17, 18:13; **31**: 4:09, 14:05

June 1: 0:04, 10:00, 19:56; **2:** 5:52, 15:48; **3:** 1:43, 11:39, 21:35; **4:** 7:31, 17:27; **5:** 3:23, 13:18, 23:14; **6:** 9:10, 19:06; **7:** 5:02, 14:58; **8:** 0:54, 10:49, 20:45; **9:** 6:41, 16:37; **10**: 2:33, 12:29, 22:24; **11**: 8:20, 18:16; **12**: 4:12, 14:08; **13**: 0:04, 10:00, 19:55; **14**: 5:51, 15:47; **15**: 1:43, 11:39, 21:35; **16**: 7:30, 17:26; **17**: 3:22, 13:18, 23:14; **18**: 9:10, 19:06; **19**: 5:01, 14:57; **20**: 0:53, 10:49, 20:45; **21**: 6:41, 16:36; **22**: 2:32, 12:28, 22:24; **23**: 8:20, 18:16; **24**: 4:12, 14:07; **25**: 0:03, 9:59, 19:55; **26**: 5:51, 15:47; **27**: 1:42, 11:38, 21:34; **28**: 7:30, 17:26; **29**: 3:22, 13:18, 23:13; **30**: 9:09, 19:05

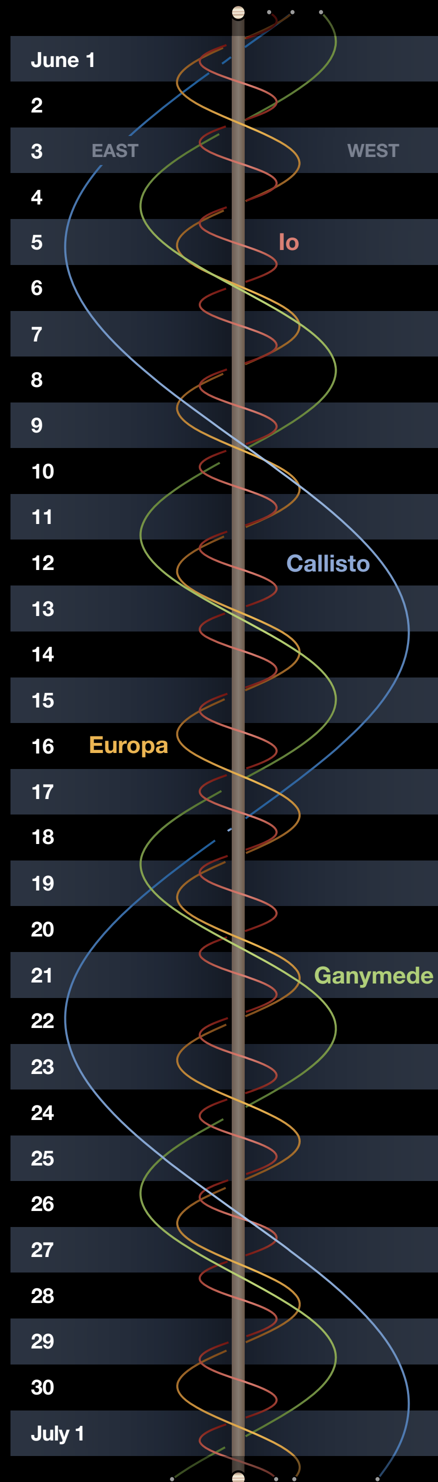
These times assume that the spot will be centered at System II longitude 91° on June 1st. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 91° and 1⅔ minutes later for each degree more than 91°.

Phenomena of Jupiter's Moons, June 2026

June 1	1:21	II.Oc.D
	1:32	I.Oc.D
	4:42	I.Ec.R
	6:06	II.Ec.R
	6:16	IV.Oc.D
	10:39	IV.Oc.R
	14:39	IV.Ec.D
	19:16	IV.Ec.R
	22:47	I.Tr.I
	23:40	I.Sh.I
June 2	1:04	I.Tr.E
	1:58	I.Sh.E
	20:02	I.Oc.D
	20:05	II.Tr.I
	20:18	III.Oc.D
	21:47	II.Sh.I
	22:55	II.Tr.E
	23:11	I.Ec.R
	23:45	III.Oc.R
	23:48	III.Ec.D
June 3	0:38	II.Sh.E
	3:20	III.Ec.R
	17:17	I.Tr.I
	18:09	I.Sh.I
	19:35	I.Tr.E
	20:26	I.Sh.E
June 4	14:32	I.Oc.D
	14:45	II.Oc.D
	17:40	I.Ec.R
	19:25	II.Ec.R
June 5	11:48	I.Tr.I
	12:38	I.Sh.I
	14:05	I.Tr.E
	14:55	I.Sh.E
June 6	9:02	I.Oc.D
	9:27	II.Tr.I
	10:39	III.Tr.I
	11:04	II.Sh.I
	12:08	I.Ec.R
	12:18	II.Tr.E
	13:55	II.Sh.E
	13:57	III.Sh.I
	14:05	III.Tr.E
	17:27	III.Sh.E
June 7	6:18	I.Tr.I
	7:07	I.Sh.I
	8:35	I.Tr.E
	9:24	I.Sh.E
June 8	3:32	I.Oc.D
	4:11	II.Oc.D
	6:37	I.Ec.R
	8:44	II.Ec.R
June 9	0:48	I.Tr.I
	1:35	I.Sh.I
	3:05	I.Tr.E
	3:53	I.Sh.E
	18:10	IV.Tr.I
	22:02	I.Oc.D
	22:33	IV.Tr.E
	22:50	II.Tr.I
June 10	0:22	II.Sh.I
	0:40	III.Oc.D
	1:05	I.Ec.R
	1:24	IV.Sh.I
	1:41	II.Tr.E
	3:13	II.Sh.E
	5:59	IV.Sh.E
	7:19	III.Ec.R
	19:18	I.Tr.I
	20:04	I.Sh.I
	21:36	I.Tr.E
	22:22	I.Sh.E
June 11	16:32	I.Oc.D
	17:35	II.Oc.D
	19:34	I.Ec.R
	22:02	II.Ec.R
June 12	13:49	I.Tr.I
	14:33	I.Sh.I
	16:06	I.Tr.E
	16:51	I.Sh.E
June 13	11:02	I.Oc.D
	12:13	II.Tr.I
	13:39	II.Sh.I
	14:03	I.Ec.R
	15:03	III.Tr.I
	15:04	II.Tr.E
	16:30	II.Sh.E
	17:56	III.Sh.I
	18:30	III.Tr.E
	21:27	III.Sh.E
June 14	8:19	I.Tr.I
	9:02	I.Sh.I
	10:36	I.Tr.E
	11:19	I.Sh.E
June 15	5:33	I.Oc.D
	7:00	II.Oc.D
	8:31	I.Ec.R
	11:22	II.Ec.R
June 16	2:49	I.Tr.I
	3:31	I.Sh.I
	5:07	I.Tr.E
	5:48	I.Sh.E
June 17	0:03	I.Oc.D
	1:37	II.Tr.I
	2:56	II.Sh.I
	3:00	I.Ec.R
	4:28	II.Tr.E
	5:04	III.Oc.D
	5:48	II.Sh.E
	11:19	III.Ec.R
	21:19	I.Tr.I
	21:59	I.Sh.I
	23:37	I.Tr.E
June 18	0:17	I.Sh.E
	2:30	IV.Oc.D
	7:00	IV.Oc.R
	8:42	IV.Ec.D
	13:22	IV.Ec.R
	18:33	I.Oc.D
	20:25	II.Oc.D
	21:29	I.Ec.R
June 19	0:40	II.Ec.R
	15:50	I.Tr.I
	16:28	I.Sh.I
	18:07	I.Tr.E
	18:46	I.Sh.E
June 20	13:03	I.Oc.D
	15:00	II.Tr.I
	15:57	I.Ec.R
	16:14	II.Sh.I
	17:51	II.Tr.E
	19:05	II.Sh.E
	19:28	III.Tr.I
	21:56	III.Sh.I
	22:56	III.Tr.E
June 21	1:28	III.Sh.E
	10:20	I.Tr.I
	10:57	I.Sh.I
	12:38	I.Tr.E
	13:15	I.Sh.E
June 22	7:33	I.Oc.D
	9:51	II.Oc.D
	10:26	I.Ec.R
	13:59	II.Ec.R
June 23	4:51	I.Tr.I
	5:26	I.Sh.I
	7:08	I.Tr.E
	7:43	I.Sh.E
June 24	2:03	I.Oc.D
	4:24	II.Tr.I
	4:54	I.Ec.R
	5:31	II.Sh.I
	7:15	II.Tr.E
	8:23	II.Sh.E
	9:28	III.Oc.D
	15:18	III.Ec.R
	23:21	I.Tr.I
	23:54	I.Sh.I
June 25	1:39	I.Tr.E
	2:12	I.Sh.E
	20:33	I.Oc.D
	23:16	II.Oc.D
	23:23	I.Ec.R
June 26	3:17	II.Ec.R
	14:29	IV.Tr.I
	17:51	I.Tr.I
	18:23	I.Sh.I
	18:59	IV.Tr.E
	19:26	IV.Sh.I
	20:09	I.Tr.E
	20:41	I.Sh.E
June 27	0:04	IV.Sh.E
	15:04	I.Oc.D
	17:47	II.Tr.I
	17:52	I.Ec.R
	18:48	II.Sh.I
	20:39	II.Tr.E
	21:40	II.Sh.E
	23:53	III.Tr.I
June 28	1:56	III.Sh.I
	3:23	III.Tr.E
	5:28	III.Sh.E
	12:22	I.Tr.I
	12:52	I.Sh.I
	14:39	I.Tr.E
	15:10	I.Sh.E
June 29	9:34	I.Oc.D
	12:20	I.Ec.R
	12:42	II.Oc.D
	16:36	II.Ec.R
June 30	6:52	I.Tr.I
	7:21	I.Sh.I
	9:10	I.Tr.E
	9:38	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

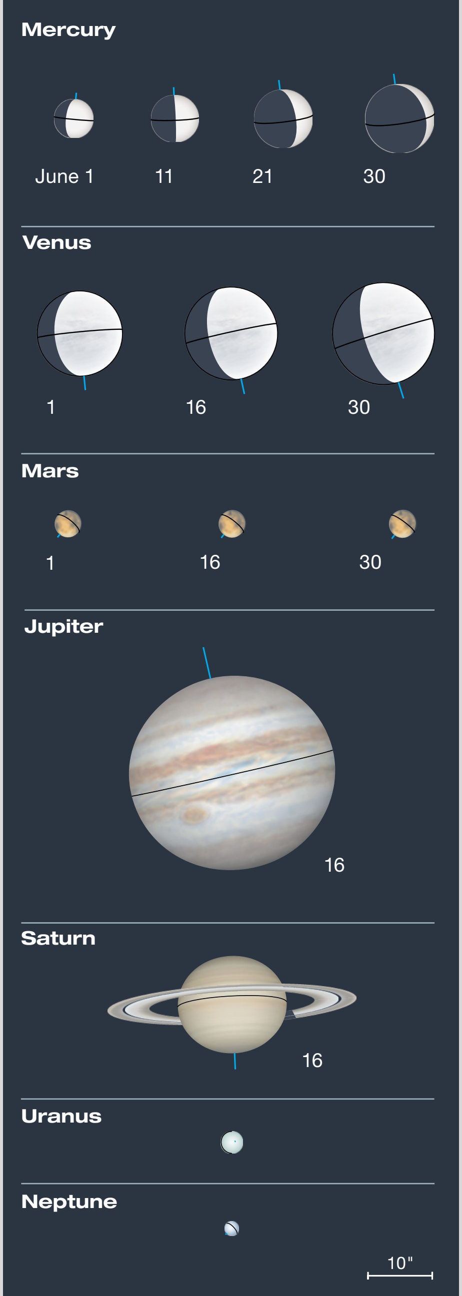


The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites'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

JUNE 2026 OBSERVING

Planetary Almanac

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dusk until the 24th • **Venus** visible at dusk • **Mars** visible at dawn low in the east-northeast • **Jupiter** visible at dusk and sets in the late evening • **Saturn** visible at dawn.



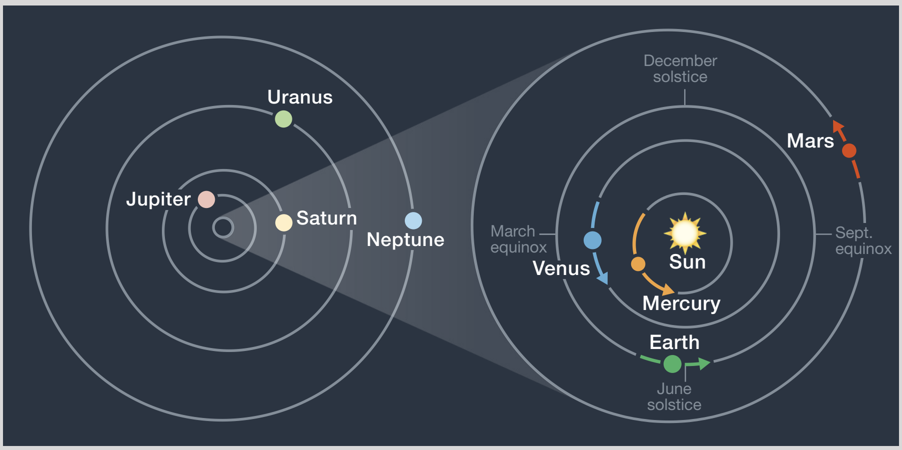
▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

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

June Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$4^h\ 34.2^m$	+21° 58′	—	–26.8	31′ 33″	—	1.014
	30	$6^h\ 34.3^m$	+23° 12′	—	–26.8	31′ 28″	—	1.017
Mercury	1	$5^h\ 54.6^m$	+25° 35′	19° Ev	–0.6	6.1″	70%	1.102
	11	$6^h\ 59.7^m$	+24° 25′	24° Ev	+0.1	7.4″	48%	0.909
	21	$7^h\ 39.4^m$	+21° 29′	24° Ev	+0.9	9.1″	29%	0.738
	30	$7^h\ 49.7^m$	+18° 46′	18° Ev	+2.2	10.8″	13%	0.623
Venus	1	$7^h\ 06.2^m$	+24° 30′	35° Ev	–4.0	13.3″	80%	1.256
	11	$7^h\ 56.9^m$	+22° 48′	37° Ev	–4.0	14.0″	76%	1.189
	21	$8^h\ 45.4^m$	+20° 05′	39° Ev	–4.0	14.9″	73%	1.117
	30	$9^h\ 26.8^m$	+16° 56′	41° Ev	–4.1	15.9″	69%	1.051
Mars	1	$2^h\ 28.8^m$	+14° 02′	31° Mo	+1.3	4.3″	97%	2.184
	16	$3^h\ 12.4^m$	+17° 24′	34° Mo	+1.3	4.4″	96%	2.148
	30	$3^h\ 53.5^m$	+19° 57′	37° Mo	+1.3	4.4″	95%	2.110
Jupiter	1	$7^h\ 42.6^m$	+21° 46′	44° Ev	–1.9	33.1″	100%	5.954
	30	$8^h\ 07.4^m$	+20° 40′	22° Ev	–1.8	31.8″	100%	6.207
Saturn	1	$0^h\ 47.2^m$	+2° 37′	58° Mo	+0.9	16.7″	100%	9.965
	30	$0^h\ 54.4^m$	+3° 14′	84° Mo	+0.8	17.5″	100%	9.513
Uranus	16	$4^h\ 02.1^m$	+20° 31′	22° Mo	+5.8	3.5″	100%	20.399
Neptune	16	$0^h\ 16.5^m$	+0° 19′	81° Mo	+7.9	2.3″	100%	30.030

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 au equals 149,597,871 kilometers, or 92,955,807 international miles.) For other timely information about the planets, visit **skyandtelescope.org**.



Shooting Nightscapes by Moonlight

Learning to make use of the Moon is a key skill in capturing night-sky vistas.

When shooting night sceneries, don't avoid the Moon — embrace it! For anyone starting out in nightscape photography, bright, moonlit nights can be welcome opportunities to learn the basics under less demanding circumstances than dark, moonless nights. For more experienced nightscapers, the Moon can be a wonderful source of warm, natural illumination, if you plan the shoot well.

Here, I'm not talking about shooting the Moon itself, though scenes with it rising or setting over a notable feature on the horizon can add a superb element to your composition. Instead, I'm referring to scenes wherein we use the Moon off-frame to light up the landscape below a starry sky.

Learning in the Moonlight

The compositions that inspire most daytime landscape photographers to ply their craft at night are those featuring the glorious band of the Milky Way over a favorite scenic foreground, taken on a moonless night. Iconic to be sure, but those are the most difficult nightscapes to shoot — exposures are long, producing trailed stars; lenses need to be set to their widest aperture, revealing optical aberrations that distort star images near the corners; and ISO speeds need to be high, resulting in noise. Moonless

DOUBLE ARCH AT MOONRISE Nature did the light painting at Arches National Park in Utah, thanks to a rising gibbous Moon. This is a two-panel panorama, each a stack of four 40-second exposures with a 24-mm lens at f/4 and Canon EOS 6D DSLR camera at ISO 1600. The sky view is from just one of the images.

ALL PHOTOS ARE COURTESY OF THE AUTHOR

▲ **STAR TRAILS AND MOONBOW** Taken during full Moon, this picture frames Bow Falls in Banff National Park in Alberta, Canada, with a short, colorful moonbow (below the center). The sky is a stack of 80 images, each 30 seconds with a 24-mm lens at f/4 and Canon EOS 5D Mark II DSLR camera at ISO 800. The foreground is from one image. (Read Sarah Mathews's article on how to capture star trails in the April 2026 issue, page 55.)

Milky Way nightscapes push the limits of your cameras, lenses, and techniques.

I always advise aspiring nightscape photographers to practice shooting first on bright, moonlit nights near their home to become familiar with their equipment before venturing to more distant scenic sites. That's especially true if you're using older cameras and slower lenses that aren't ideal for low-light photography.

Under moonlight, you can use shorter exposure times and lower ISO speeds, both less demanding of camera quality. Slower apertures are useful — that kit zoom lens that came with your camera might work fine, or you can just stop down a low-cost lens. And in moonlight, it's easier to see what you're doing, a great help when starting out. Moonlight likewise makes it easier to focus and frame a scene, tasks everyone attempting their first nightscapes soon discovers are, in fact, quite hard. Moonlit nights are the best time to learn.

But the Moon isn't just an aid to beginners. It's a valuable resource for all nightscape photographers to use.

Under the Full Moon

Like deep-sky imagers, nightscape photographers usually shun full-Moon nights. Yes, the Moon is dazzlingly brilliant, but it can still be put to use for unique shots. While you won't capture the Milky Way, the moonlit blue sky will be sprinkled with stars above a landscape lit as if by day. Because only the brightest stars will show up, plan to frame easily recognizable patterns, such as Orion, Cygnus, or the Big Dipper in Ursa Major.

As illustrated in the photo captions, moonlit exposure times are short, typically only a few seconds, and low ISO speeds are useful, perhaps 400 to 800, not the 3200 to 6400 often required under moonless skies.

Full-Moon nights work best when the air is clear and dry. Haze, smoke, and humidity will wash out the stars and produce a murky sky. But under full moonlight on a clear night, snow-capped mountains light up, waterfalls may be graced with moonbows, and ugly light pollution is overwhelmed by natural light. Contrary to Hollywood convention, which presents moonlight as blue, it actually has the same roughly 5500 kelvin color temperature as sunlight, because it's sunlight reflecting off neutral-gray lunar rock. So, set your camera's white balance to Daylight.

Lesser Moon Phases

At waning or waxing phases, especially between new and quarter phase, the Moon is much dimmer. It can still do a good job lighting the landscape while the sky remains dark enough for the Milky Way to show up, though perhaps it will be in a blue-tinted sky. Making use of such a Moon requires planning the time and location to ensure the landscape you wish to capture lies in a direction away from the Moon — if it were in the frame, the Moon would appear just as an overexposed blob.

For a waxing Moon in the western evening sky, that means shooting generally to the east. For a waning Moon shining in the late-night or predawn eastern sky, that means shooting to the west. Pick your sites to suit the prevailing lighting direction.

If you wish to include the Milky Way, plan to shoot east on late spring evenings with the photogenic region from Cygnus to Sagittarius rising. Early autumn mornings are a great time to frame the star-studded Milky Way around Orion rising.

For a shoot looking west, late autumn evenings will feature the Cygnus-Sagittarius Milky Way setting. Early spring evenings, on the other hand, will contain Orion and the northern winter Milky Way setting.

Each of those seasons will offer just a few choice nights each year, when the Moon will be well-placed to light the scene but not be in it.

Lunar Golden Hour

While scenes with the Moon fully up and at its brightest can work well, I often plan to be on site and shooting to the west as the waning gibbous or last-quarter Moon is rising in the east in the morning hours. The low Moon is reddened by the atmosphere which illuminates the western landscape in a warm light.

I've been on site in the evening only to find ardent "light painters" flooding the dark landscape with artificial light (a practice now illegal in most national parks). No sooner had they left than the Moon rose to bathe the scene in natural light, an opportunity they were oblivious to.

By day, scenes shot at sunset or sunrise are said to be taken at the "golden hour." The same favorable lighting can come from the Moon as it rises, or sets, for a lunar golden hour. With a waning Moon, the sky can get dark enough in the time before moonrise to allow the Milky Way to record well. That's the time to take the sky images. Then a little later as it rises, the Moon will light the scene for the best foreground images.

▶ **MILKY WAY OVER MOONLIT LANDSCAPE** The rising waning Moon is just beginning to illuminate the peaks around the Columbia Icefields in the Canadian Rockies, but the sky is still dark enough to show off the Milky Way. This is a stack of four 3-minute tracked exposures for the sky, blended with a stack of four 4-minute untracked exposures for the ground, all with a 15-mm fisheye lens at f/3.2 and Canon 5D Mark II at ISO 1600.

Blending the two later during post-processing produces a form of "time-blending" that can push the boundaries of ethics, as it isn't a scene that existed at any one moment. Nightscapers routinely shoot their foregrounds at the "blue hour" in deep twilight, and the sky later once it gets fully dark. I generally avoid this, but I do plan shoots for moonrises, taking images over the time span from just before to during moonrise.

You can do the same at moonset, for scenes where the landscape elements of interest are to the east. Shoot the ground first as the Moon sets, then the sky after moonset when it's darker.

Planning a Shoot

Even for simple single shots, however, the key to successfully using the Moon is to be in the right place at the right time. Great nightscapes rarely happen by accident. They're a result of careful planning, using apps to determine where the Moon and the Milky Way will be and when each will rise or set.

To plan your nightscapes, apps such as *PlanIt! Pro* (**planitphoto.com**) and *PhotoPills* (**photopills.com**) come in handy. I like *The Photographer's Ephemeris* (**photoephemeris.com**) and its companion app *TPE3D*. (Their developer, Stephen Trainor, plans to merge the two apps into a new unified version of *TPE* later in 2026.)

With these apps, you can choose a site, then scrub back and forth in time to see the direction and motion of the Milky Way and the Moon. With the time and place set, switching to *TPE3D* provides a 3D rendering of the natural landscape (with mountains, lakes, and rivers) to accurately preview how and when the scene will light up at moonrise or darken at moonset. You then hope clouds won't spoil your plans!

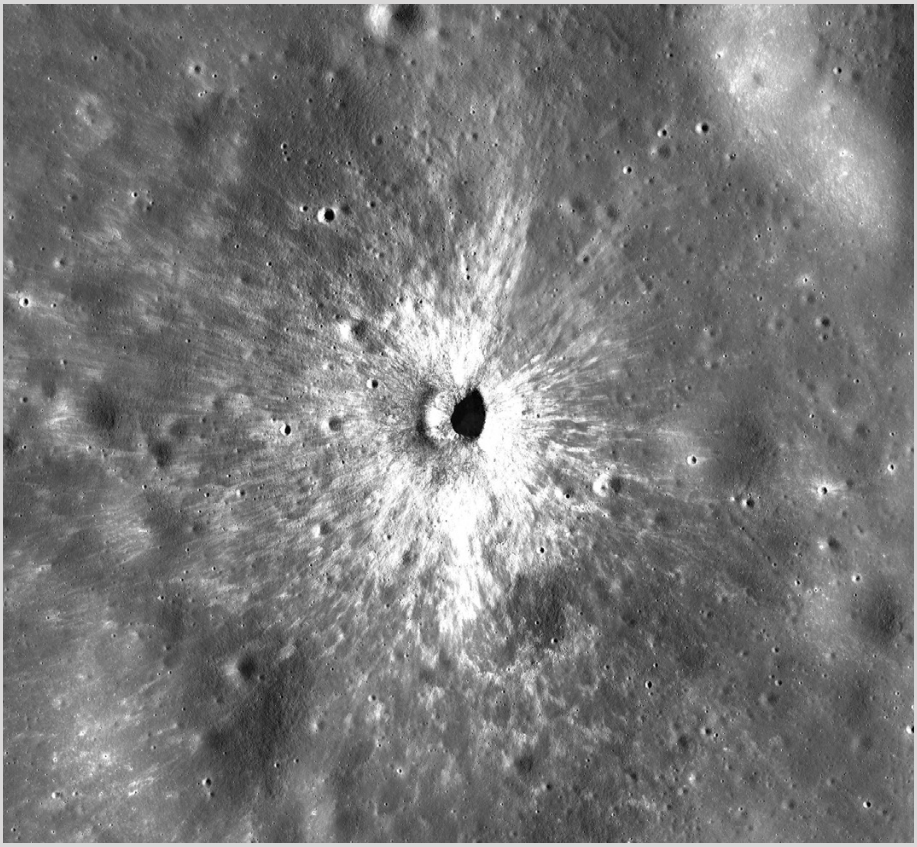
Expanding Your Opportunities

Making use of the Moon is a great way to begin your nightscape photo adventures. In fact, by taking advantage of the Moon, you'll learn more advanced techniques and open up more opportunities for dramatically lit images. Not all nightscapes have to be of the Milky Way in a dark, moonless sky. The Moon provides natural light to use to our advantage, and more nights every month to shoot some wonderful and unique nightscape compositions.

■ Contributing Editor **ALAN DYER** is coauthor with Terence Dickinson of *The Backyard Astronomer's Guide.* He can be reached through his website at **amazingsky.com**.

A Potential Impact

Asteroid 2024 YR4 may put on a once-in-a-lifetime lunar event.



▲The crater Bandfield is a young, 1-km-wide impact feature located on the lunar farside, similar to what asteroid 2024 YR_4 may produce. Its dark impact melt and asymmetrical bright rays indicate an oblique entry angle.

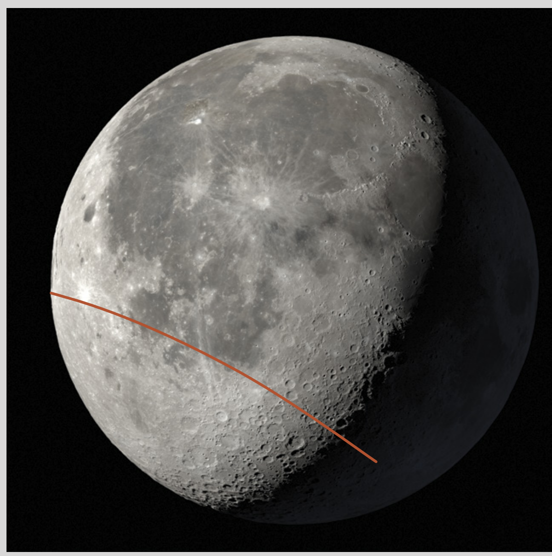
Whether you're a casual lunar observer or a die-hard selenophile, everyone should mark December 22, 2032, on their calendars. On this day at 15:19 UTC (10:19 a.m. EST) or thereabouts, a fairly large asteroid may strike the nearside of the Moon. Or maybe not.

Over the last few hundred years, observers occasionally have witnessed or imaged bright flashes on the Moon caused by impacts of small asteroids or debris shed by comets. Extremely high-resolution images recorded by NASA's Lunar Reconnaissance Orbiter Narrow Angle Camera have revealed newly formed craters at some of these locations. Unfortunately, those events were produced by impactors that were unknown before their demise, so observations couldn't be planned in advance to closely study the process.

This possible 2032 impact event may change all that. The 60-meter-wide (200-foot-wide) asteroid — discovered in December 2024 by the ATLAS survey telescope in Chile and designated 2024 YR_4 — will pass close to Earth eight years later, though it will miss our planet completely. But as of the time of writing, it has a 4% chance of colliding with the Moon. Granted, those odds aren't typically worth wagering on, but if 2024 YR_4 *does* hit the Moon, it would produce an immense treasure trove of data not seen since the impact of Comet Shoemaker-Levy 9 on Jupiter in 1994, with the potential to improve our understanding of the solid-body impacting processes by leaps and bounds.

Astronomers observed the 22nd-magnitude object through May 2025, including once with the James Webb Space Telescope. This established its orbital period of 3.99 years and ruled out the possibility of it colliding with Earth. Discovery team member Andy Rivkin (Johns Hopkins University, Laurel, Maryland) and a second group of researchers led by Paul Wiegert (University of Western Ontario, London, Canada) further analyzed the data. They determined the lunar collision date and most likely times and locations, as well as the characteristics of the crater that would be formed and its ejecta. Recently, a team led by Yifan He (Tsinghua University, Beijing, China) confirmed these results.

Orbital simulations indicate that the most likely impact zone spans a long,



▶The impact corridor of 2024 YR_4 as of early 2026, plotted on a simulation of the lunar phase as it will appear on December 22, 2032.

narrow corridor from the selenographic coordinates 122°W longitude, 39°S latitude on the farside, passing just south of **Mare Humorum** (35°W, 33°S), and ending at 35°E, 40°S, on the dark side of the sunset terminator. This is almost entirely in heavily cratered terrain, making a tiny, new crater harder to recognize compared to one forming in the much smoother maria.

On the date of the event, the Moon will be 20 days old with the sunset terminator crossing western Mare Nectaris. The projected time of impact will most favor observers in Alaska, Hawai‘i, and points farther west through eastern Asia, Australia, and Oceania. Most of North America will see the event, though it will occur in daylight, and the farther west you are the higher the Moon will be. Amateurs should observe and image this impact corridor ahead of time to become familiar with the area.

The first evidence of the asteroid strike should be a very bright flash, somewhere between magnitude –2.5 and –3 lasting up to several minutes. This Jupiter-like point of light should be clearly visible to the naked eye if it strikes the unlit area. Binoculars and small telescopes are necessary if the asteroid hits anywhere in the illuminated area. Imagers should plan to record the entire event with video cameras paired with most any telescope. The diameter of the resulting crater depends on several factors, though it's predicted to be about 1 km (0.6 mile) in diameter. This is too small to be seen visually, but imagers using 8-inch and larger scopes can often resolve such small craters under steady seeing. Orbiting spacecraft with cameras producing at least 5-meter resolution are required to resolve ejecta patterns and smaller features.

Following the impact, observatories around the world will monitor the area's infrared brightness (and hence temperature) for weeks to determine the mass of impact melt on the crater floor and around the rim. Much of the collision's kinetic energy will dissipate around the Moon as up to 5th-magnitude moonquakes. Hopefully, more seismometers will be delivered to the lunar surface before 2032 to provide more precise measurements of the different layers of the lunar interior.

One of the most fascinating elements of this possible crater-forming event is that some lunar ejecta will undoubtedly reach Earth. This is likely to cause a lot of problems with the growing fleets of satellites in orbit. The amount, timing, and terrestrial landing locations greatly depend on the circumstances of the asteroid strike. The maximum amount of Earth-reaching detritus would come from an impact angle of 60° near the center of the corridor, sending as much as a few hundred kilograms of impact material to reach Earth's surface as meteorites. Such large lunar debris may land anywhere on Earth, but most likely within a band from South America across the Atlantic to North Africa and on to Arabia. Additionally, the collision should produce a notable meteor shower of 100 to 400 flashes per hour. This debris reaches us within two to eight days following lunar contact.

Few if any readers are likely to find one of these potential historic lunar meteorites, but anyone can collect another type of lunar sample. *Micrometeorites* are millimeter-size and smaller pieces of asteroids, comets, and other tiny debris traveling through the solar system. While no confirmed lunar micrometeorites have been collected so far, chances are excellent in the weeks following December 22, 2032. Calculations imply that debris from the lunar cratering event will dominate micrometeorites falling everywhere on Earth.

◀ Some micrometeorites as seen through a microscope.

JON LARSEN / JAN BRALY KIHLE

Collecting micrometeorites from rooftops via rain-gutter downspouts requires only a strong magnet, a plastic bag, a paper plate, and a 10× or higher magnification loupe or microscope. Place the magnet inside one corner of the plastic bag and drag it over the area where your downspout directs rainwater away from your house. Any magnetic debris will stick to the magnet through the bag (moondust is known to be magnetic). Hold the bag over the paper plate, remove the magnet from the bag, and the debris will fall onto the plate. Then examine the debris with your loupe or microscope, and look for dark, tiny spherules. These will be distinctly round compared with regular dirt because they were melted when entering Earth's atmosphere.

The asteroid's next close approach in December 2028 offers an opportunity to obtain more observations to refine orbital calculations. This will also establish if impact will indeed occur, and if so, precisely where and when to look. It's estimated that a kilometer-wide crater forms on the Moon once every 5,000 years. Will this be one of them?

■ Contributing Editor **CHUCK WOOD** is coauthor of the *Extreme Illumination Atlas of the Moon*, available at **amazon.com**.

◀ DEEP-SKY CAMERA

Chinese manufacturer SVBony announces a new deep-sky camera. The SV605CC Cooled Color Astronomical Camera ($672.00) is designed around the Sony IMX533 CMOS detector, which has a 3,008 × 3,008 effective array of 3.76-micron-square pixels measuring 11.3 × 11.3 mm, or 1-inch SQR format. This 9-megapixel, back-illuminated sensor has a full-well capacity of 50,000 electrons and native 14-bit A-to-D conversion that together prevent bright stars from saturating quickly during long exposures. Its dual-stage, thermoelectric cooling produces stable operating temperatures of as much as 30°C below ambient temperature. The camera can download up to 20 full-resolution frames per second, and its onboard 256 MB of DDR3 memory ensures no frames are lost. Each camera comes with 1¼ and 2-inch nose-pieces, a 2-meter (6.6-foot) USB 3.0 cable and a soft case.

SVBony
+86 150 3810 6914; svbony.com

◀ SHARED OBSERVATORY CONTROL

Lunatico Astronomia announces the Starling Shared Observatory Controller ($995 USD). This intelligent control hub manages the operations of a remote roll-off-roof observatory that's accessed by multiple users. The Starling allows individual users to remotely control connected devices to safely avoid conflicting commands. It also monitors roof position and alerts users in the event of a weather emergency or power failure. The device is ASCOM-compatible and accepts commands from most cloud-monitoring devices as well as third-party automation software including *N.I.N.A.*, *SGP*, *Voyager*, and more. Starling can operate the manufacturer's Caterpillar SSR roof motors or other third-party drives including garage-door motors.

Lunatico Astronomia
CC El Zoco, Cam. de Valladolid, 33, Local 21, 28250 Torrelodones, Madrid, Spain
+34 91 859 55 67; lunaticoastro.com

◀ DEW CONTROL

PrimaLuce Lab now offers the Environmental Computerized Controller or ECCO2 ($220). This ride-along device works with the company's EAGLE and other third-party controllers to manage your dew-prevention accessories. The device monitors the temperature, humidity, and air pressure and adjusts the power output for all connected heating straps and rings to ensure your optical components remain free from moisture all night long. The ECCO2 is ASCOM compatible and connects to computers via a USB-C interface, which also provides its power. The device includes seven ports for heaters, a Vixen-style finder shoe, a 1.2-meter (47-inch) USB-C cable, and two temperature sensors.

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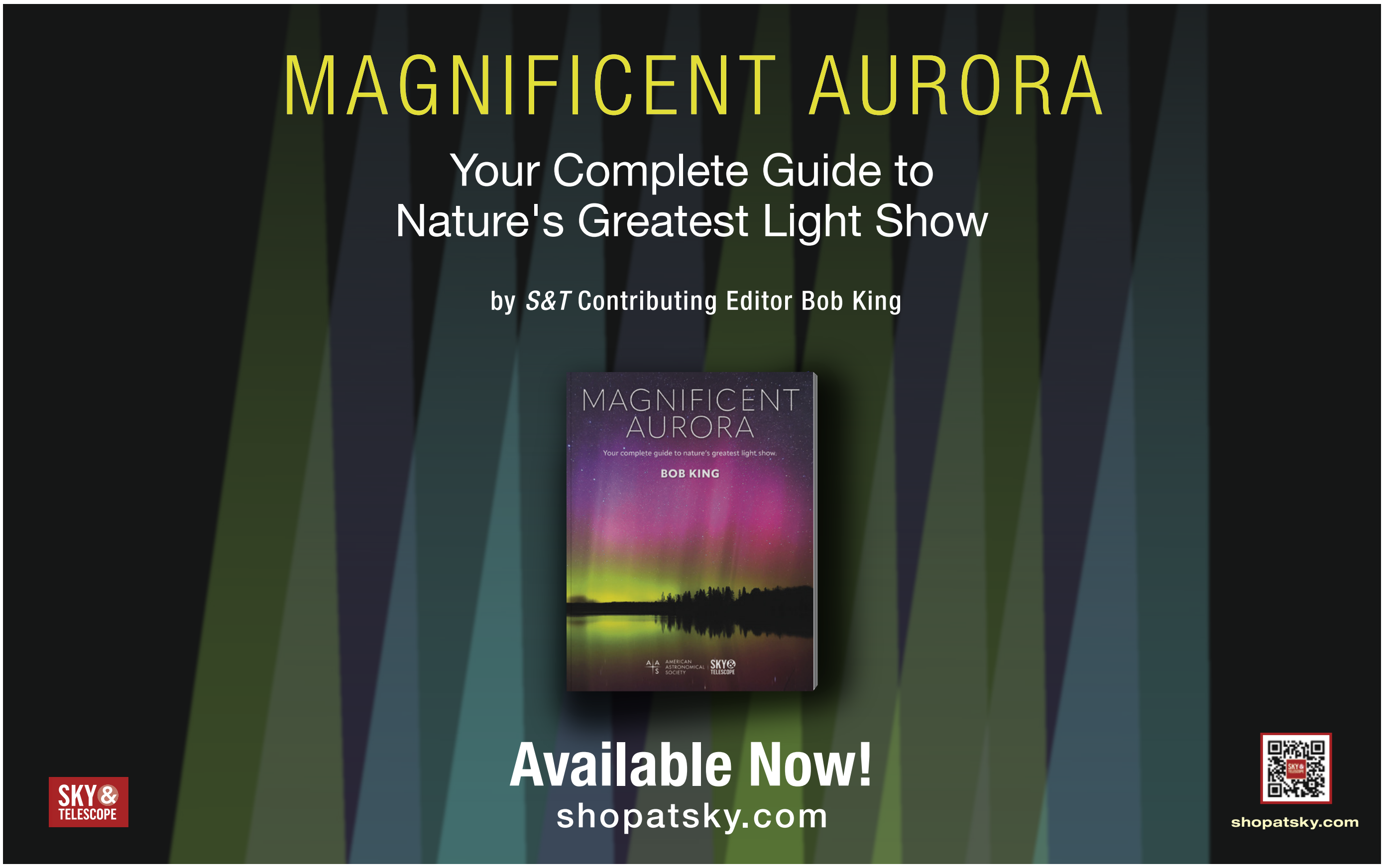
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by S&T Contributing Editor Bob King
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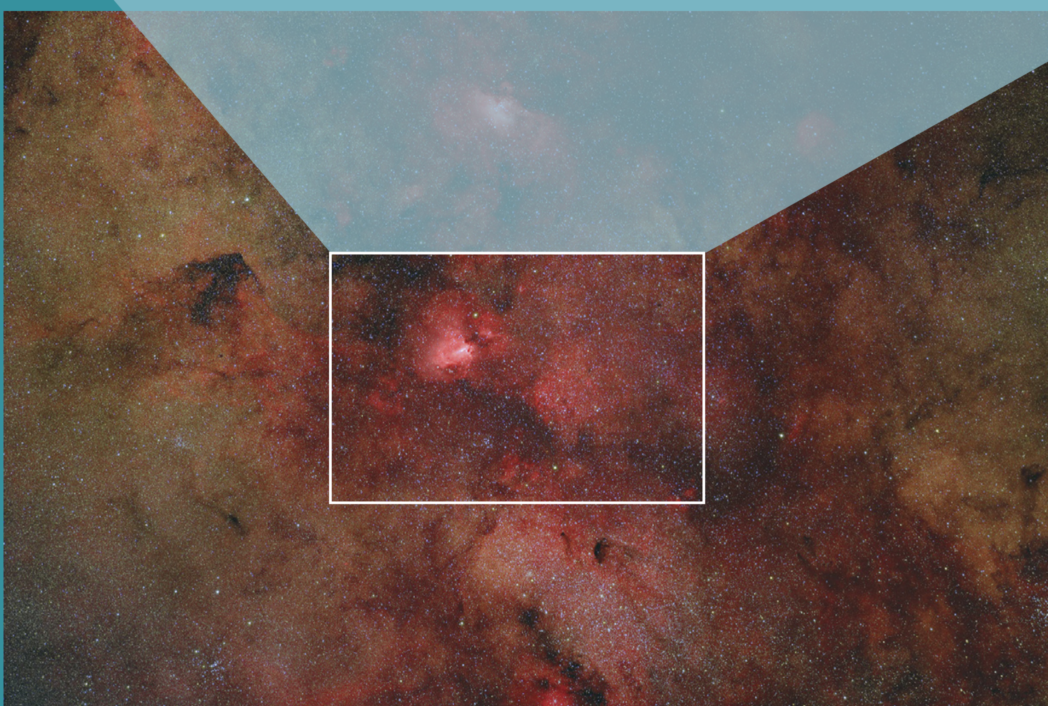


ZOOMING IN Contextual imaging is the technique of photographing a celestial target at two different focal lengths to present the main subject in the context of its surroundings. Here the author shows M17, the Omega Nebula, in Sagittarius shot with an 11-inch Celestron Rowe-Ackermann Schmidt Astrograph (RASA) and ZWO ASI6200MM camera above, as well as a Samyang 135-mm f/2 lens with ZWO ASI2600MC camera at left.

ALL PHOTOS ARE COURTESY OF THE AUTHOR

Contextual Astrophotography

Here's a great way to add to your imaging output while also seeding your future projects.

For an astrophotographer, a clear night isn't something to be wasted. We spend many hours setting up our equipment and readying the cameras and computers to record a small piece of the night sky in exceptional detail. But what lies in the field surrounding your target? Perhaps another potential great shot is lurking, or maybe a new comet or nova is hiding just beyond the bounds of your frame.

What if you added a second, wider-field instrument to capture a larger swath of sky around the main telescope's target? Enter the concept of *contextual imaging* — the practice of shooting with two very different focal lengths simultaneously. The resulting pictures work together to place the main target in relation to its immediate vicinity as a visual narrative. Here's how I do it.

Adding Secondary Optics

In my quest to increase my imaging output on moonless nights, I studied my mount and realized that I could approach it differently. As long as its load is managed properly, my mount could be used as a multi-instrument platform that can carry additional, smaller instruments. Like most long-time astrophotographers, I have unused lenses and cameras that have become obsolete over the years. Rather than relegating them to some forgotten drawer gathering dust, these older instruments were just waiting for a new lease on life. By incorporating them onto my tracking mount either as a piggybacked instrument or installed alongside the main scope, I can put them back into service to perform the parallel task of imaging the field around my primary deep-sky target to produce a wide-field contextual picture. This wide-angle view helps establish the object's place in its surroundings, showing, for example, if it's part of a larger cloud of nebulosity or an isolated object of the Milky Way. An added benefit is that the panoramic view often helps to identify nearby targets for future projects. It's surprising just how many emission and reflection nebulae, dark nebulae, and planetary nebulae I was unaware of have come to light in my own context shots, often because star atlases don't plot everything that's within reach of skilled amateurs with even an old CCD or DSLR camera.

So what's the ideal focal length for the secondary optic? A good rule of thumb is for it to have a focal length in the range of one-quarter to one-sixth of the main astrograph. This gives a generous field around the target to potentially sweep up additional surprises. As for the optic's focal ratio, it should be at least equal to, or faster (lower number), than the primary instrument, which ensures that the depth of the result matches that of the main instrument.

Mounting this context instrument can be as simple as a rigid camera ball head carrying a DSLR or mirrorless digital camera equipped with a suitable telephoto lens. A more complex setup might use a pair of tube rings with adjustment knobs to precisely aim the lens or telescope. If you typically correct your main instrument's tracking with an off-axis guider, then you can position the second optic atop the main scope or perhaps on the tube rings. Most refractors allow for mounting a dovetail plate across the tube rings for this very purpose. Several third-party manufacturers offer piggyback brackets for various types of scopes.

If your guiding setup uses a small guidescope mounted on top of the main instrument, you'll have to install the context instrument on the side. Mounting it this way places the additional weight close to the fulcrum point of the right-ascension axis, which helps minimize the amount of counterweight needed to offset the load. However, mounting the context instrument parallel to the main scope requires rethinking how you'll balance the load on the declination axis. Connecting both scopes to a special plate that permits adjustments to balance both scopes is ideal. Several companies, including Losmandy Astronomical Products (**losmandy.com**) and

◀ **SIDE-BY-SIDE IMAGING** The author's 135-mm f/2 telephoto lens is securely affixed to a wide, 1-inch-thick solid wooden board using a Baader Stronghold Tangent Mount Assembly. The lens as well as the 11-inch RASA that it's paired with are both attached to the board with Losmandy-style dovetail clamps that permit quick and easy balancing in the author's homemade equatorial mount.

ADM Accessories (**admaccessories.com**), offer high-quality machined parts for this type of setup that are compatible with most commercial mounts. An easy solution for do-it-yourselfers is to mount a dovetail bar to a thick, flat board like plywood or solid wood, attaching the context instrument and main astrograph side by side on the board. The platform is then quickly balanced by sliding the bar on the telescope mount's dovetail saddle.

An alternative is to add counterweights on the opposite side of the main instrument to keep the declination axis balanced properly. For larger context instruments, you can attach small barbell weights to fine-tune the balance if needed. These weights are cheap and available at sporting-goods stores or online retailers.

A very important feature for your context scope is that it should have the ability to be aimed precisely at the same point in the sky as the primary instrument. Ideally, the field of the primary will be centered on the context's wide field. A pair of tube rings with a trio of alignment screws works, though this approach might not be compatible with some telephoto lenses where the alignment screws contact the lens focusing ring. An alternative is to use a commercial pan-tilt mechanism offered by several manufacturers. I use the Baader Stronghold Tangent Mount Assembly (see **baader-planetarium.com**) on one of my heavier context setups. A cheap DIY solution I employ on a different setup uses a dovetail clamp on the sideboard that's shimmed and rotated slightly to achieve alignment. The context scope is attached to a short dovetail bar that's perfectly aligned each time it's installed.

◀ **RIDING PIGGYBACK** The easiest way to mount a wide-field setup on your main astrograph is to mount a DSLR and lens directly atop the main telescope using a sturdy ball head.

Aiming both instruments at the same position is easy to accomplish during daytime. Start by using the mount's axes to point the main scope at a distant treetop or other landmark, then adjust the aim of the context optic until the primary scope's target is near the center of the field. When mounting the camera on the context scope, be sure to align it to match the orientation of the camera on the main astrograph, ideally so that both produce pictures with north up.

KEEPS YOU BUSY Context photos are a great source of subject matter for future projects. Here the author has framed several additional deep-sky objects in the context photo of M17 shown on page 60. The frame size corresponds to the RASA 11 and ZWO ASI6200MM's 3.3° by 2.2° field of view.

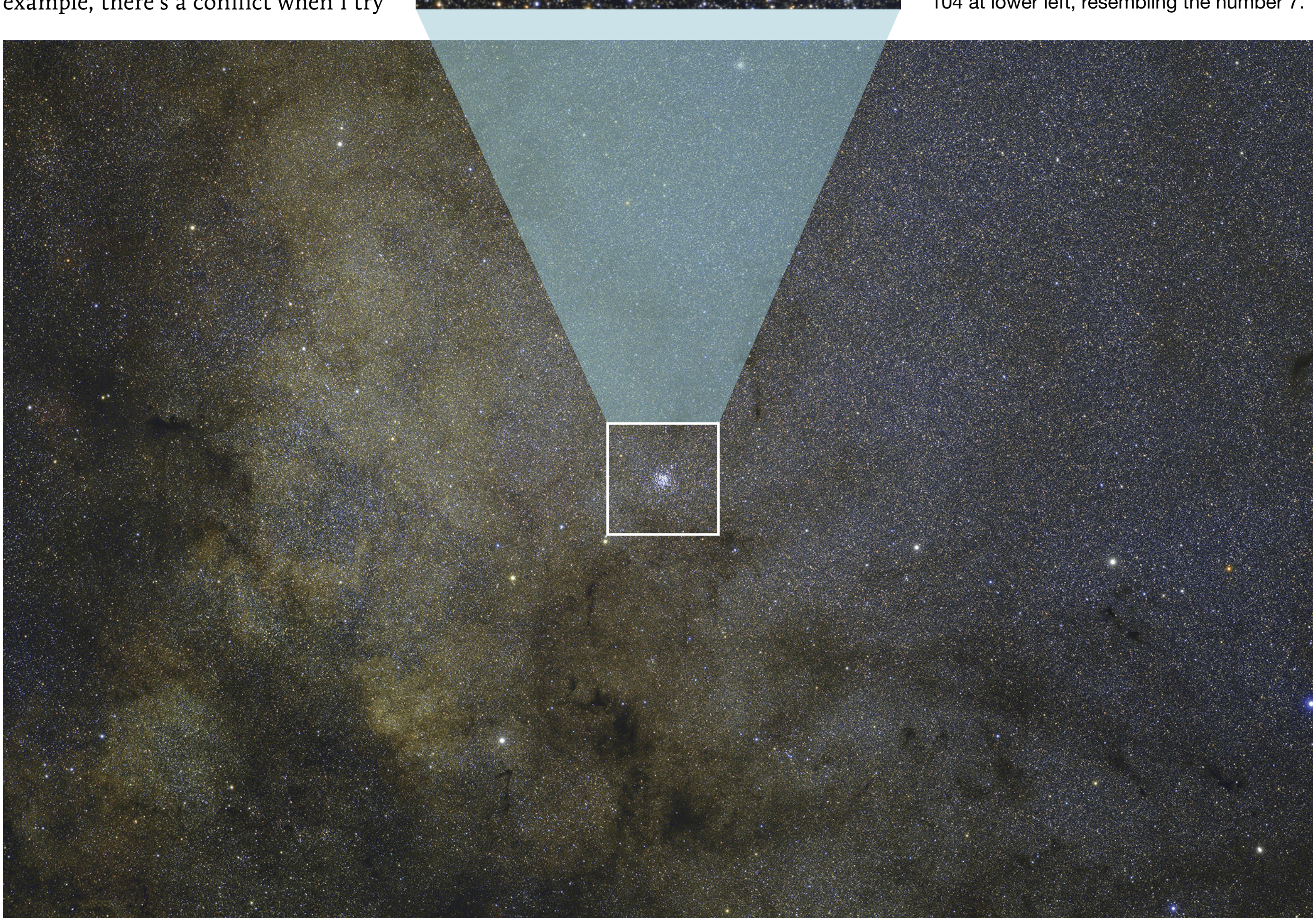
Dual Camera Logistics

Operating two astrographs on the same mount can be challenging — there's a lot to do for one camera, let alone two working on the same mount.

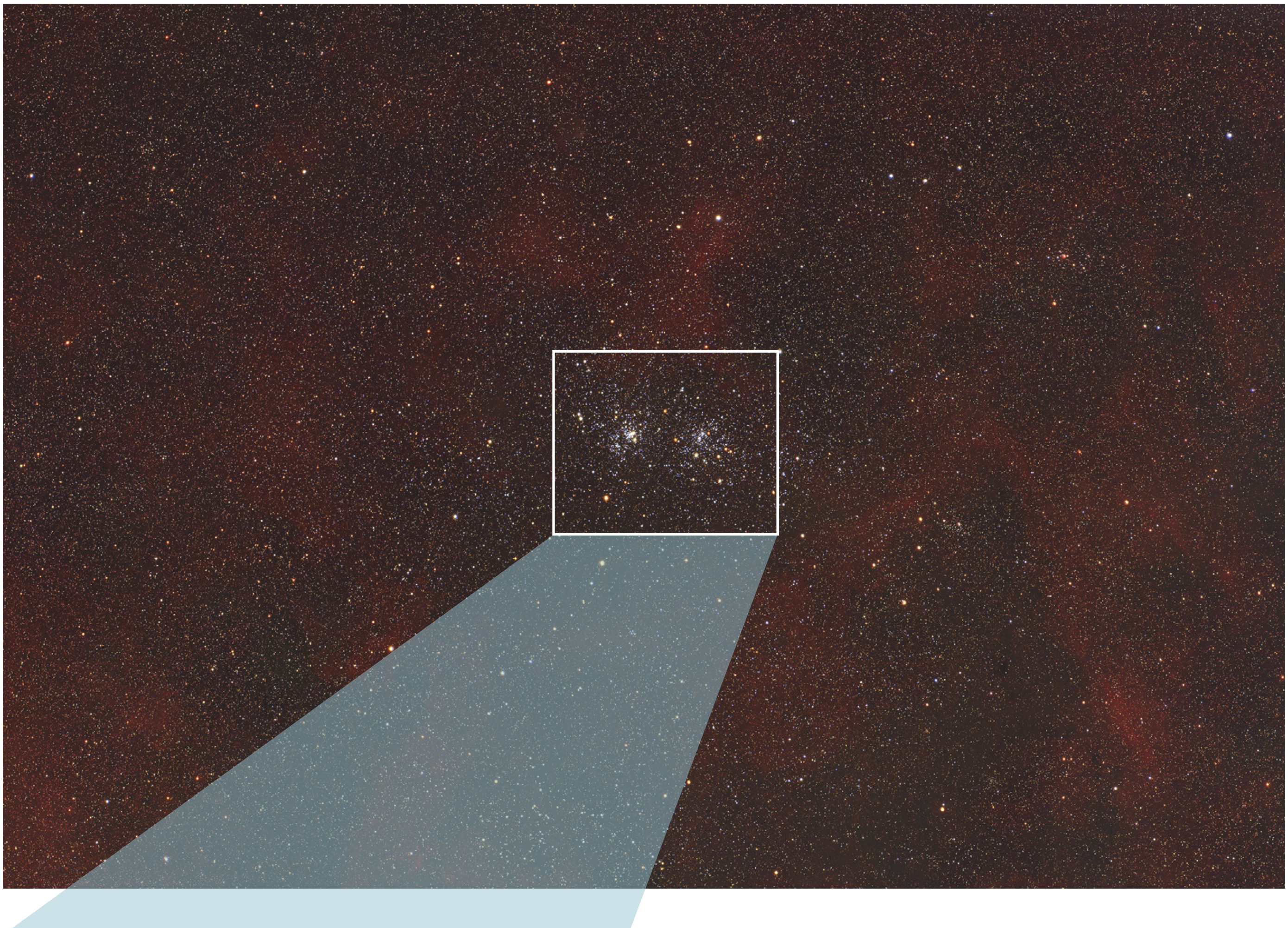
Perhaps the easiest context-imaging setup to operate pairs a primary instrument having a cooled CMOS astro-camera with a DSLR or a mirrorless camera and telephoto lens, or a wide-field refractor. With this configuration, only one computer is required for pointing the scopes, controlling the astro-camera, and autoguiding. The DSLR or mirrorless camera only requires an intervalometer to set the length and number of exposures and a handful of camera batteries or an AC power adapter to keep the camera shooting all night.

Things become a bit more complicated if your context setup also uses a cooled astro-camera. This might require two computers, depending on whether or not you can run both the main and context cameras on one control device. (For example, there's a conflict when I try to operate my two ZWO cameras on a single PC, so to ensure reliability I use a separate laptop for each.) Mini computers like ZWO's ASIair (**zwoastro.com**), the Eagle system from Primaluce Labs (**primalucelab.com**), or those offered by iOptron (**ioptron.com**) and SVBony (**svbony.com**) among others, are all good alternatives to a second laptop. Whichever setup you choose, be sure to test everything at home during the day to work out any compatibility issues beforehand.

All this gear is great for use in a permanent observatory, but you can also perform this type of context imaging in the field. Keep in mind that — in addition to the mount, the



◀▼ **CHANGE OF FOCUS** Context images and the close-ups they accompany often emphasize different things. For example, M11, the Wild Duck Cluster, in Scutum is well-resolved in the zoomed-in view at left captured with a 10-inch f/3.8 Newtonian astrograph and Atik 16200 CCD camera. Compare that to the wide-field result seen below, where dense star clouds and many dark nebulae in the area draw your attention almost as much as the Messier cluster does. Note the dark dust cloud Barnard 104 at lower left, resembling the number 7.



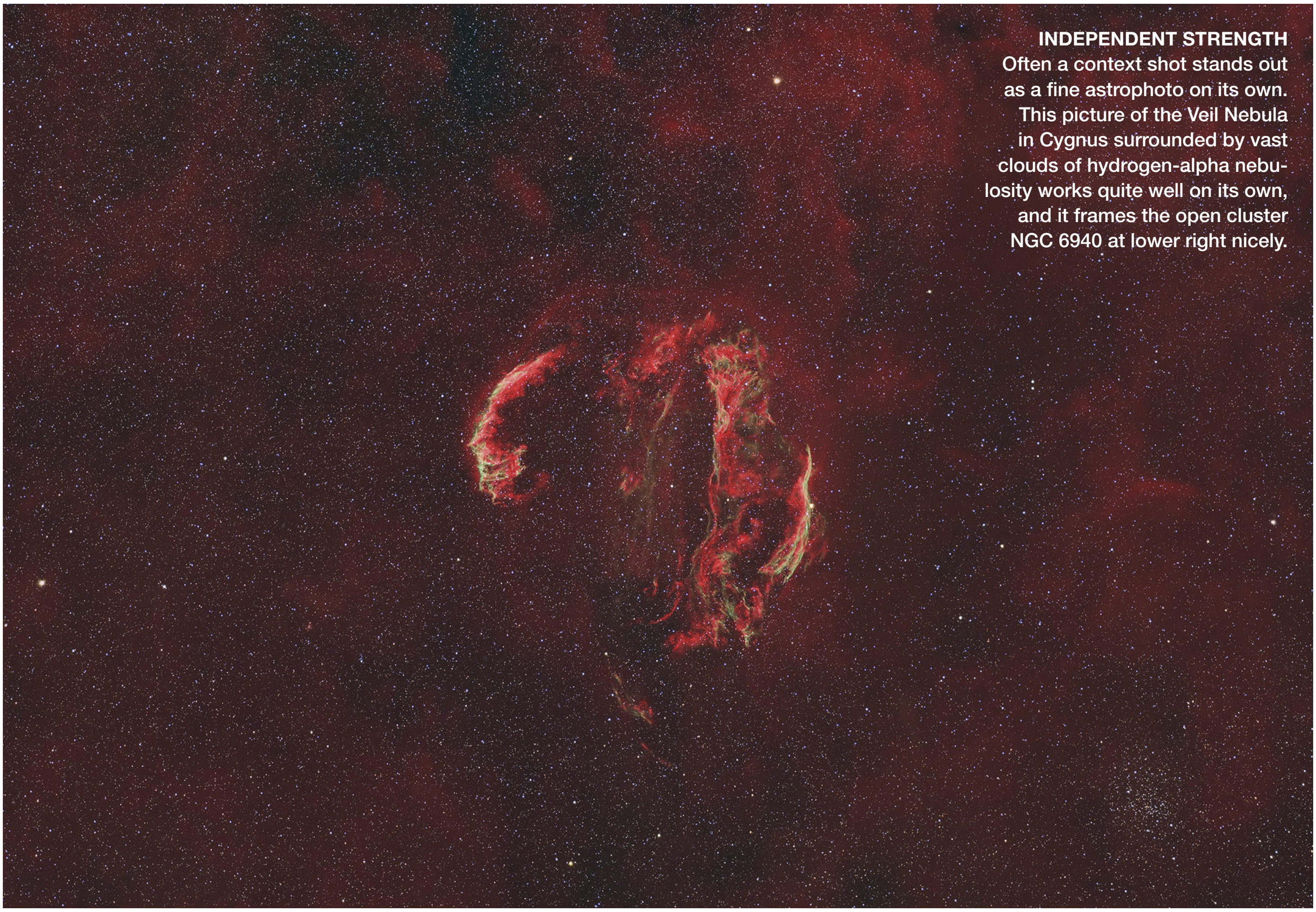
▲ **HIDDEN SURPRISES** Sometimes taking deep exposures with a wide-field lens reveals overlooked features in a well-known area. This long-exposure shot of NGC 869 and NGC 884, the Double Cluster, in Perseus above shows dim nebulosity south of the famous pair. The context image at top shows the field to be awash in faint emission nebulosity rarely seen in amateur photos.

main scope and its imaging camera, the context camera and its lens, and the guidescope or off-axis guider, an autoguider camera, and a bunch of cables — you'll also need a few additional items. Plan on bringing a small folding table, a chair, and a robust power bank or two that can handle the entire setup.

Once you've readied both instruments for a night session, confirm their optical alignment relative to each other using a bright star or planet, or the Moon. If everything checks out, start by focusing the context camera. Its shorter focal length shouldn't let focus drift significantly during the night.

When you're ready to start shooting, start your autoguiding software then commence the exposures on the primary instrument. Next, start the exposures on the context instrument but be sure to use the same exposures as the primary astrograph. This staggered start allows you to check the subframes as they download and appear on the control software screen with ample time in between each instrument, so you can inspect them and adjust parameters if necessary. I'd suggest not dithering between each exposure because this may elongate the stars in every context image, particularly if the dither amount is as large, or larger than, the pixel scale of the secondary system.

When you move to additional targets, only the main instrument's focus will need to be tweaked, since the much-



INDEPENDENT STRENGTH Often a context shot stands out as a fine astrophoto on its own. This picture of the Veil Nebula in Cygnus surrounded by vast clouds of hydrogen-alpha nebulosity works quite well on its own, and it frames the open cluster NGC 6940 at lower right nicely.

shorter focal length of the context camera should stay unchanged for hours on end.

Mining the Results

When you're all done, processing the context images are no different than any other deep-sky astrophoto. These wide-field results are truly a treasure trove waiting to be explored. They often contain rich Milky Way star fields, dark nebulae, reflection nebulae, galactic cirrus, many bright asteroids, and even faint comets that happen to be passing through. Planetary nebulae, even tiny ones, reveal themselves as greenish spots that don't quite look like stars, inviting follow-up observations at higher resolution.

Besides shooting natural color images, you can add one of the dual- or tri-band filters that highlight faint nebulosity. These typically isolate hydrogen-alpha, oxygen III, and other narrowband wavelengths, revealing even fainter emission nebulosity hidden in many star fields.

After processing the context images, you can then use your favorite photo-editing software to superimpose a frame in the center of the image to mark the field of view of the main astrograph. Additionally, you can add similar borders around other objects in the field to target in the future to help plan your framing.

Many of these wide-field pictures make fine astrophotos on their own. Rich areas of the Milky Way, large fields of nebulosity, and bright star clusters are beautiful in their own regard. Posting the close-up shot with the wide-field context photo on your home page or other photo-sharing sites gives an added level of information that helps place your initial subject in context of its surroundings.

Step Up Your Imaging Game Plan

There are many advantages to this approach of astrophotography. Besides doubling your output each night, context imaging can put older, neglected equipment to good use. And the wide-angle perspective helps to increase your knowledge of what's out there that's within reach of your gear that you may not have considered before. Finally, the two images shown together introduce an additional layer of depth to your image presentation. Consider trying the contextual approach for your next imaging session, and you may discover something unexpected is lurking just outside the edges of your main astrograph's field!

■ **CHRIS SCHUR** spends every cloud-filled night reflecting on how to push his astro-imaging endeavors to ever higher levels. Visit his website at **schursastrophotography.com**.

The UltraCat 76

We test the first in a new series of super-sharp "Ultra" astrographs from William Optics.

William Optics UltraCat 76

U.S. Price: $1,888*
williamoptics.com

What We Like

Tiny stars to the corners of full-frame sensors

Minimal vignetting

Smooth internal focuser

What We Don't Like

Tilt adjustments finicky

No filter accommodation

Camera rotator stiff in cold weather

**Prices subject to change*

▲ With its 365-mm focal length, the UltraCat 76 provides a 5.6° by 3.7° field of view on a full frame sensor, large enough to frame several clusters and nebulae in Cassiopeia in this stack of 32 four-minute exposures with a Canon EOS R5 mirrorless camera. *Inset:* The UltraCat 76 is attractively finished with a black matte aluminum tube and red anodized fittings.

IN THE LAST TWO YEARS we've seen a new generation of what I might call "super astrographs" introduced to the market. These are imaging refractors with optics much sharper than we've seen up to now. Spot diagrams provided by manufacturers promise stars to be less than 6 microns, not just in the center of the frame but also at the corners of full-frame (24-by-36-mm) sensors. That figure yields stars as small as the photosites (often referred to as pixels) in many of today's cameras. At least in theory.

By comparison, advertised star sizes in other astrographs, even in models from the same manufacturer, can be on the order of 8 to 10 microns at the center, growing to 20 microns or more at the corners, with astigmatism also distorting star shapes by adding "wings" to the stars at the edges of the field. Imagers have long accepted this level of aberration as normal. But as our cameras improved and sensors grew larger, our demands on optics have also grown.

William Optics, based in Taiwan, is an established leader in the niche of small refracting astrographs. The company's trendsetting RedCat series helped to establish the small astrograph as a popular class of instrument. I tested its little 51-mm RedCat 51LX (*S&T:* March 2021, p. 66) and was impressed with its performance on my full-frame cameras. There was nothing else quite like it at the time. But the market has expanded since, and standards have evolved in just five years.

The UltraCat Series

The UltraCats address that change. Introduced in 2025, the 76 was the first in a series that, as of this writing, also includes 56-, 108-, and forthcoming 131-mm aperture models, all f/4.8. Each one features a patented, five-element Petzval design incorporating premium SuperED and ED glasses and a built-in field-flattener lens. There's no separate flattener or reducer lens needed nor offered.

While perhaps less flexible than other designs, the advantage of Petzvals is that they're forgiving of camera placement. There's no need to achieve precise spacing between the sensor and telescope optics to ensure the sharpest images across the field.

William Optics' own tests on the UltraCat 76 show root-mean-square (RMS) spot sizes less than 2 microns across at the center, growing to slightly more than 3 microns at 22 mm off-axis, which is the distance to the corners of a full-frame sensor. The specs also promise a 50-mm image circle — enough to illuminate even larger sensors.

ALL IMAGES ARE BY THE AUTHOR

A feature unique to the UltraCat 76 and other scopes in the series is their Sensor Tilt Xterminator, a plate with four adjustment wheels that are easy to turn to finely tune out any tilt while the camera remains attached. It's factory-adjusted to produce zero tilt out of the box, assuming your camera's sensor is mounted properly.

Another UltraCat feature is an anti-shrink lens cell technology, which the company representative told us uses "optical-grade elastic materials and specialized silicone to secure the lens after collimation . . . maintaining perfect alignment and lens spacing even in extreme cold." I take that to mean there won't be signs of pinched optics distorting stars on winter nights.

That's a lot to test and verify! Did the UltraCat live up to its name? Yes it did, but not without a couple of issues.

▲ The padded case is included but won't accommodate additional connected accessories such as an electric focus motor mounted off the side of the focuser. The metal lens cap incorporates a Plexiglas Bahtinov focusing mask. Camera adapters and end caps for 48-mm and 54-mm fittings are included, as are wrenches.

Internal Focuser

When I first took the UltraCat 76 out of its padded case, I thought William Optics had loaned us the wrong telescope! It seemed much bigger and heavier than I expected for a 76-mm refractor. At 5.1 kg (11.2 lbs), it weighs about 0.3 kg more than the 85-mm and 90-mm refractors I own. With a maximum tube diameter of 120 mm (4.7 inches), it's also wider by a few millimeters than my 85-mm astrograph.

With two counterweights, it was just able to balance on a Sky-Watcher Star Adventurer GTi, a popular small mount (*S&T:* May 2023 p. 64). But it's not a combination I would recommend. For use on a light, portable rig, perhaps for air travel, the UltraCat 76 would not be my choice.

This is the first William Optics telescope I've tested with their WIFD Internal Focusing Design. As you focus, rather than moving the camera, the optics shift inside the telescope tube. This keeps what can be a heavy imaging train firmly fixed in place and avoids image-plane shifting due to mechanical sagging. My Canon camera being light, I can't attest to the WIFD's advertised benefit.

Nevertheless, despite the WIFD moving all the internal optics, I did find the 10:1 dual-speed focuser to be smooth and precise, even on cold winter nights, with no image shift. The inclusion of a Bahtinov focusing mask within the lens cap, a William Optics exclusive feature, was convenient, as you always have the mask handy.

The internal focuser has 21 mm of travel. It's at the 0-mm end of the focuser scale where the focus point is farthest outward away from the telescope, with the rear lens closest to the back of the scope. At the other

▼ *Left:* The mid-tube internal focuser shifts the optics within the tube more than 21 mm. A window on the tube shows its position, here at 0 mm, with the rear lens closest to the end of the scope. *Right:* The mid-tube focuser has a lock and bolt holes to accept an electric focus motor. The Vixen-style dovetail bar can be shifted over a range of 70 mm to aid balancing the telescope.

end of focus travel, the rear lens moves farthest up into the tube, while the front lens moves farthest forward, even slightly pushing the retracted dewcap outward.

The dewcap stayed securely in place even without locking it down. It extends 60 mm ahead of the objective lens when the focus is at its zero point, decreasing to just 39 mm of extension with the focus at the other extreme of travel. But on frosty winter nights with the dew shield extended about 50 mm, it did its job well.

With my camera attached using an adapter that provided the standard 55 mm of backspace, the WIFD was set to 7 mm. This left just 7 mm of additional outward travel should it be needed. But if your imaging train can be accommodated with no more than 60 mm of back focus, you should be fine.

Adapters and Accessories

The scope's top handle accepts Synta-standard dovetail accessories such as a guidescope, but that's the only attachment point. No other accessory shoe is supplied. The telescope tube has two M4 screw holes to attach an accessory shoe, and the hexagonal tube rings have six M6-threaded holes to bolt on an accessory plate, such as the 120-mm Handle Bar that William Optics offers (not included with the purchase).

The telescope comes with M54 and M48 camera adapters. Each threads in flush with the end of the scope. A small lens wrench is included to help twist off an adapter should it become stuck, as

▲ The five-element optics are fully multi-coated, with the blackened tube interior fitted with five baffles, all working together to suppress lens flares when shooting near bright stars.

did happen one night.

Surprisingly, the 48-mm adapter isn't threaded to accept 48-mm filters. To insert a filter, I had to use a third-party filter drawer to go between the 54-mm adapter and, in my case, a camera T-ring.

What would normally be the focuser (here, it's simply the camera end of the telescope) has a lockable rotator ring graduated in 5° increments. It doesn't shift focus when turned. But it was stiff to turn during my cold test nights, and its smooth surface and narrow width made it hard to grip — and impossible with gloves on.

Nevertheless, I found the rotator and its scale very useful, as I could plan the framing of fields with planetarium software, then dial in the required rotation angle to achieve the exact composition I wanted right away.

Once the telescope cooled down on subfreezing nights, I found the focus stayed put, needing just a tiny touch up after a couple of hours. The thermometer on the focuser proved its worth, as it was easy to check if the night had cooled off enough, or warmed up from our Chinook winds, to warrant a manual refocus.

But most importantly, I didn't see any evidence of distorted stars due to pinched optics from contracting lens cells. Perhaps I can credit the "anti-shrink" technology, but then I've rarely seen cold temperatures introducing pinched optics in other refractors I've tested — problems from tube currents, yes, but not mechanical pinching.

Optical Testing: Star Shapes

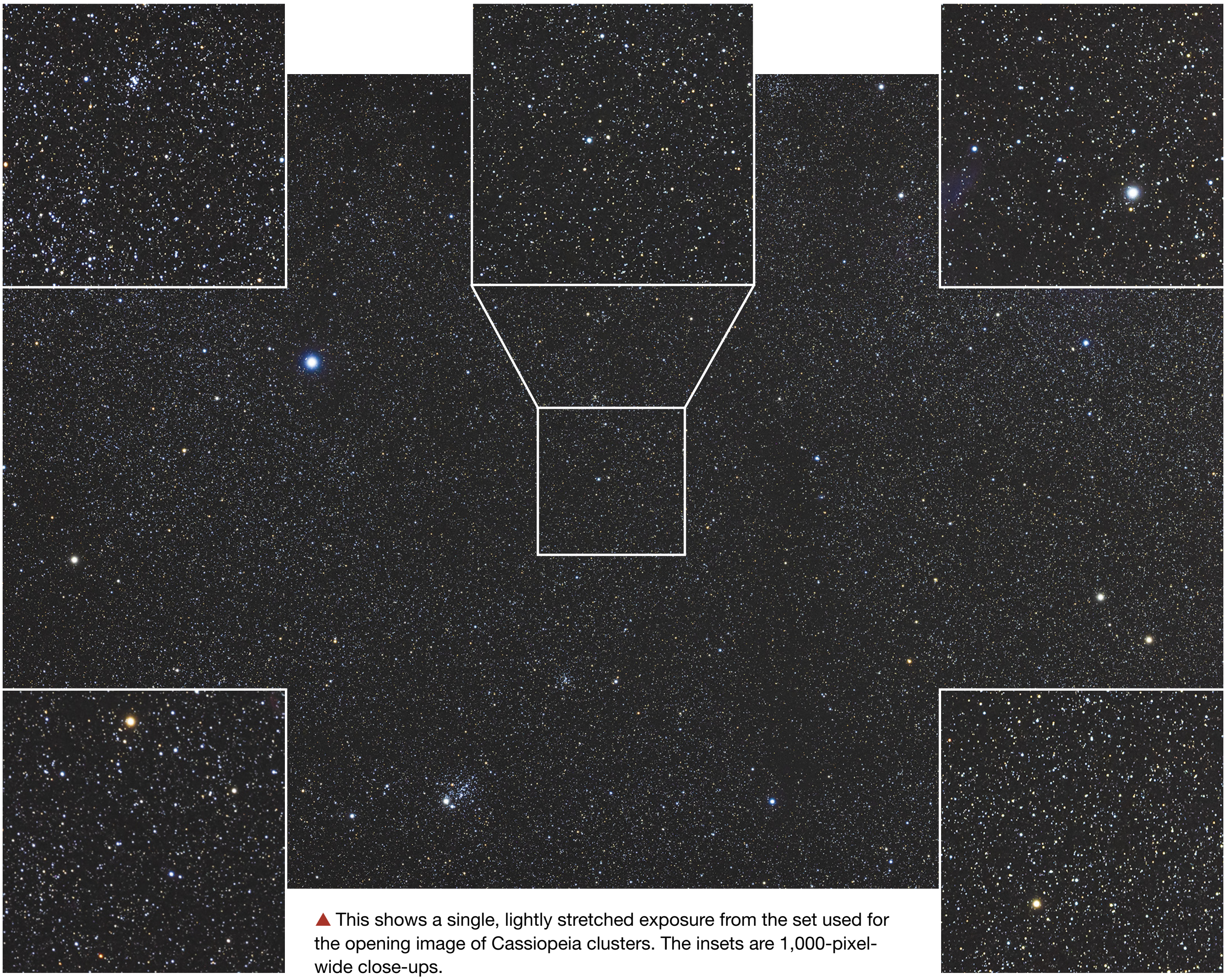
The UltraCat 76 is a photographic instrument only. I tested it using the highest resolution full-frame camera I have, a Canon EOS R5, with a 45-megapixel sensor and 4.4-micron photosites. With the scope's focal length of 365 mm, it produces a plate scale of 2.5 arcseconds per pixel. At present, only cameras using Sony's 61-megapixel IMX455 chip have a higher resolution (with 3.76-micron photosites) than the R5 in a full-frame sensor.

I tested with an adapter that provided 55 mm of backspace, and with two other combinations of a filter drawer and extension tubes that provided 7 to 8 mm less backspacing. Images shot with all of the combinations looked identical across the frame, confirming the Petzval design's tolerance of optics-to-sensor distance.

▲ The tube rings include six M6-threaded holes for adding a top accessory plate. They include riser blocks providing 50 mm of spacing between the scope and dovetail plate.

▲ Although the telescope back has no moving focuser, it does have a 360° camera angle rotator with a graduated scale. The included camera adapters thread into the rear cell.

▲ The rear cell includes a plate for adjusting the tilt of the camera, using four wheels (two are visible here) at 90° spacing, which are turned with a 2-mm Allen wrench.



▲ This shows a single, lightly stretched exposure from the set used for the opening image of Cassiopeia clusters. The insets are 1,000-pixel-wide close-ups.

I saw no evidence of blue or magenta haloes due to longitudinal chromatic aberration on-axis, nor off-axis from lateral chromatic aberration distorting stars into colored streaks. This confirms the promise of the generic spot diagrams provided with the UltraCat 76 (each scope comes with inspection certificates but individual test reports aren't included).

Out of the box, images looked very sharp corner to corner, indeed, the stars are tiny pinpoints. But at the extreme pixel-peeping level, I could see a small amount of tangential astigmatism on the left edge of the frame and sagittal astigmatism on the right side. For some reason, I think due to my camera adapter, the image plane was tilted slightly, just what the Tilt Xterminator can compensate for.

As I discovered, that's easier said than done. A well-hidden webpage at the William Optics site (**https://is.gd/wotiltx**) provides helpful diagrams needed to judge star shapes and know which way to turn the Xterminator's four wheels. It took a few nights of testing to minimize tilt and corner aberrations, resulting in nearly single-pixel-sized stars in each corner, as good as my seeing conditions, guiding, and camera sensor were likely to provide.

Of all the telescopes I've tested over the years, the UltraCat's tilt adjustments are by far the easiest to make. But it was the first telescope where I've needed to make them, and it was a tedious process. Do keep in mind, we are fussing over stars distorted by just a few pixels, at a level that might be masked by the spherical or chromatic aberrations present in other telescopes, even those of very good quality. This new class of super astrograph, ironically while forgiving of backspace, is merciless at revealing any tilt, misfocus, atmospheric turbulence, or inadequate auto-guiding.

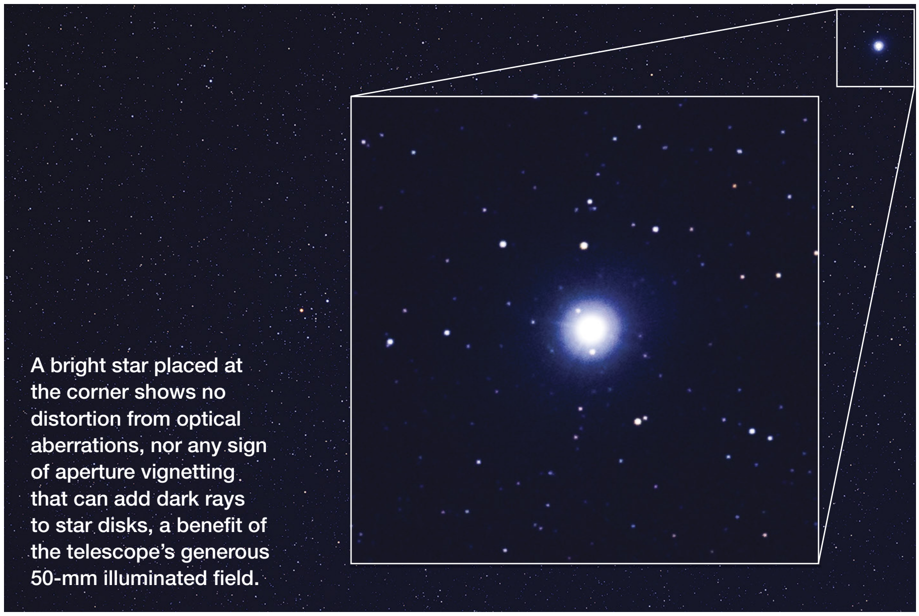
Vignetting

On the other hand, bright stars near the corners of the frame showed no evidence of "aperture vignetting," the cause of the dark bipolar shadows you sometimes see emanating from off-axis star images in refractors, and that are concentric to the center of the image. Often attributed to pinched optics, these twin streaks are from the edge of the sensor not "seeing" the full aperture of the lens and so is being illuminated by what it sees as an oval, or cat's-eye-shaped, aperture.

I measured the projected illuminated circle at the focus of the UltraCat 76 to be about 55 mm, even better than the specs, though the illuminated circle does shrink as you rack the focus in — the optics shift up the tube which introduces some vignetting. Nevertheless, this generous illuminated field, more than what's needed to technically fill a full-frame sensor, eliminated aperture vignetting to ensure clean stars at the corners.

It also resulted in very low light loss toward the corners. I measured a drop in illumination of about 10% at the very corners of the frame, and in a gentle decline over the outer quarter or so of the frame. This matches the promised specs.

All in all, once tweaked, the UltraCat delivered impressive images. One can argue that sharpness can now be achieved at the computer through AI-powered routines. Indeed, William Optics designed its little f/3.5 MiniCat 51 with the scope's corner performance compromised to achieve fast speed, advising buyers its images can be corrected "in post." I, for one, prefer images to be as sharp as possible "in camera." If the 76 is representative, the UltraCats achieve that. But be prepared — attaining that perfection might require some work fine-tuning your system.



A bright star placed at the corner shows no distortion from optical aberrations, nor any sign of aperture vignetting that can add dark rays to star disks, a benefit of the telescope's generous 50-mm illuminated field.

▲ Taken in deep twilight and with the contrast boosted considerably in processing, this image of the region surrounding +0.1-magnitude Capella (Alpha Aurigae) shows the scope's fairly uniform field illumination, with only minor and gradual darkening toward the corners of a full-frame sensor.

Recommendations

I think it's safe to say the new UltraCat 76 provides a level of optical quality a cut above the previous Cats from William Optics, judging from my experience using the original RedCat 51. Indeed, the performance of the 76-mm matches or exceeds what I've seen from competing astrographs in this aperture range.

While the sharpness of the UltraCat will benefit users of cameras with small, high-resolution sensors (such as those having Sony's IMX585 chip with 2.9-micron photosites), you'll fully benefit from the UltraCat's optical quality only if you use cameras with full-frame sensors. And they should be high-resolution sensors with photosites 4 microns or smaller. You'll certainly enjoy very sharp stars across APS- or Micro-Four-Thirds-format sensors, but lower-cost astrographs, perhaps with faster optics, might perform as well as needed for less demanding cameras.

But for those wanting the state-of-the-art in an astrograph, the William Optics UltraCat 76 will deliver excellent image quality that's sure to complement whatever camera you might own now or upgrade to at a later date.

■ Contributing editor **ALAN DYER** is coauthor with Terence Dickinson of *The Backyard Astronomer's Guide*. He can be reached through his website at **amazingsky.com**.

Telescopes at the Top of the World

Mauna Kea. La Silla. Roque de los Muchachos. Siding Spring. These are but a few of the mountain peaks atop which are perched world-class observatories. From Hawai‘i to Chile to the Canary Islands to Australia, and in many places in between, astronomers have hauled their telescopes and instruments to the highest summits to better observe the universe. (In the days of yore, they did this work on the backs of hardy mules).

Why might that be? Well, to begin with, there are those pesky clouds. The higher up you go, the better your chances of clear skies. In addition, the lower layers of Earth’s atmosphere are turbulent and full of moisture, both of which blur images. And, as of late, encroaching light pollution hampers observers even more. By placing observatories high up on mountaintops, we can somewhat mitigate these challenges.

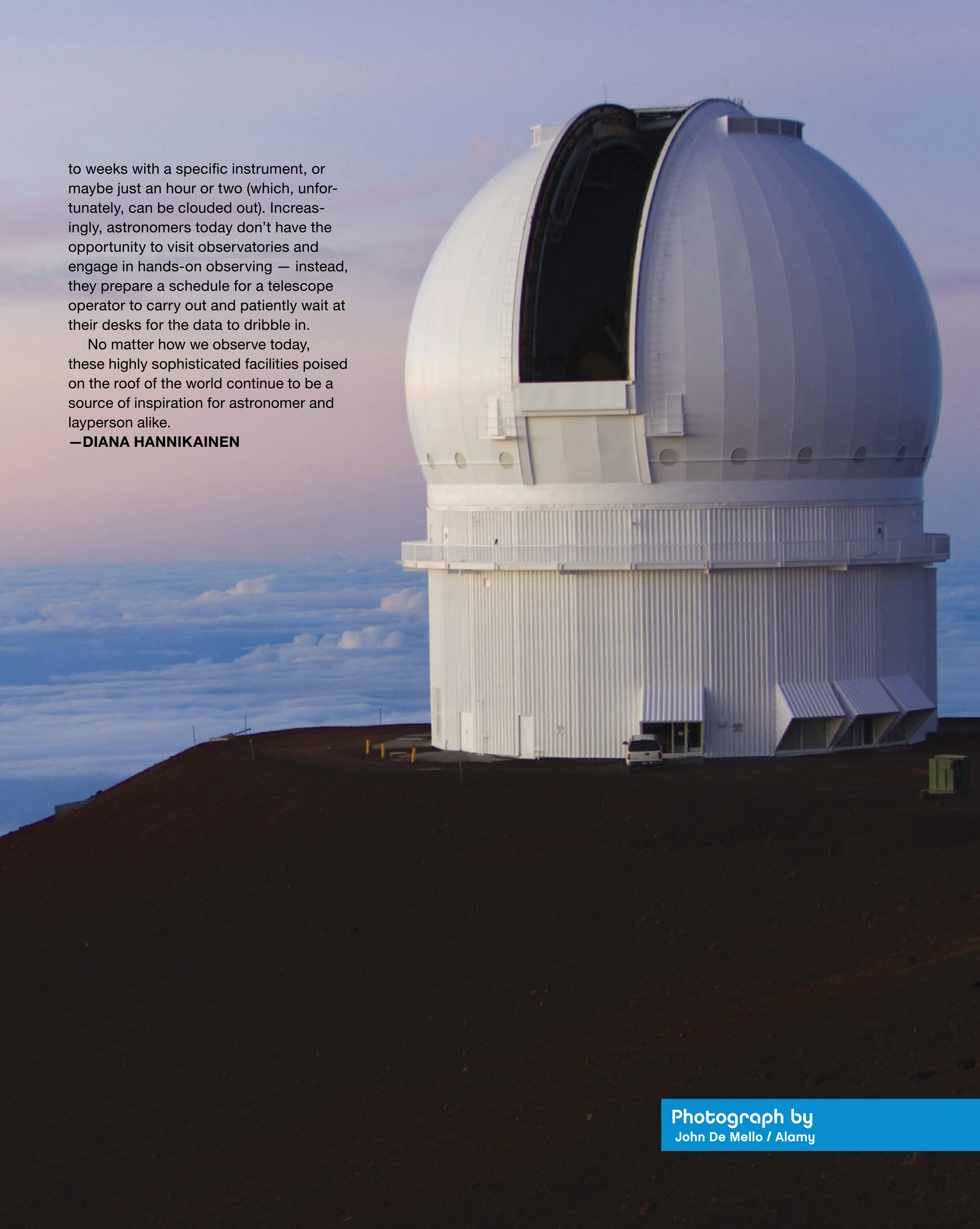
Before the advent of a fully wired world, astronomers would visit these facilities in person, sometimes for weeks on end, pointing their telescopes into the far reaches of space to better understand the physics that governs the universe. Dormitories housed them, with blackout curtains in the bedrooms and signs on the walls exhorting silence during the day, so observers could sleep off their night’s hard work. Cafeterias catered their meals, and common rooms offered a place to share their exciting new results.

Nowadays, the competition for telescope time is fierce. Teams of astronomers write proposals to convince panels of expert reviewers that their idea is the one that warrants granted time. Depending on the nature and scope of the proposal, a group of researchers might be awarded several nights

to weeks with a specific instrument, or maybe just an hour or two (which, unfortunately, can be clouded out). Increasingly, astronomers today don't have the opportunity to visit observatories and engage in hands-on observing — instead, they prepare a schedule for a telescope operator to carry out and patiently wait at their desks for the data to dribble in.

No matter how we observe today, these highly sophisticated facilities poised on the roof of the world continue to be a source of inspiration for astronomer and layperson alike.

—DIANA HANNIKAINEN



Photograph by
John De Mello / Alamy

An Ultracompact Carbon-Fiber Travel Scope

If there's a limit to telescope minimalism, this amateur telescope maker may have found it in his custom composite creation.

IN A WORKSHOP dedicated to travel scopes, French ATM Laurent Bourasseau and his friend Gilles shared ideas. "I can't say which of us had the idea first," Laurent recalls, "but one thing is certain: You *can* fit a 250-mm [10-inch] telescope in a computer laptop bag." This was a bold claim, and it took both a deeply unorthodox approach to scope design and some 800 hours of experimenting for Laurent to prove it.

At the drawing board, he started with a singular focus: to minimize the telescope's volume. Compactness (really, "travelability") is a goal of many hobby astronomers, and to some, it paid off. It heavily inspired most of my designs — my Dobs, currently up to 16 inches in aperture (*S&T:* Oct. 2025, p. 74), all fit nicely in the back of a small hatchback.

There were tradeoffs, though, and once I began to experiment with planetary imaging, I found that the truss's rigidity was not "imaging grade." Laurent, however, didn't compromise here. Instead, he veered away from traditional plywood and aluminum, figuring that modern carbon composites would be up to the task.

While saving weight was a goal, by his reckoning the tradeoffs would follow naturally from his minimized-volume approach. In his own words, "No weight optimization was attempted; compact = less material = lighter, naturally." The choice to pursue carbon-fiber composites followed: While the material is a natural choice for maximizing the stiffness-to-weight ratio, he arrived at a similar place designing for stiffness-to-volume ratio. "I read at the time that a 2-mm-thick carbon fiber sheet was as strong as, or even stronger than, a 1-cm-thick plywood sheet," he said.

This approach didn't crystallize in Laurent's head until he visited online hobby circles. "On astronomy forums, everyone talks about the vacuum-bagging technique. I admit it looks great, but the process is rather complex. It was on a motorcycle forum that I read the solution: simple molding. Not too complicated to do once the mold is made, and it offers sufficient mechanical properties for our astronomical needs."

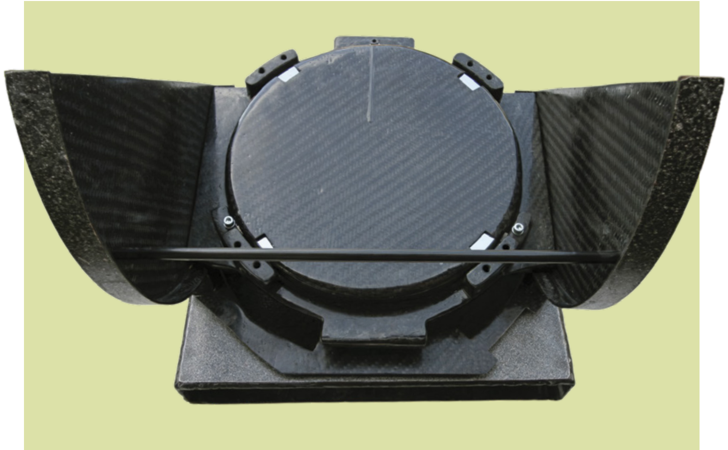
◀ Laurent Bourasseau's innovative 250-mm (10-inch) f/4.5 truss Dobsonian is fully assembled and ready for observing.

▲ Laurent stands with his scope that he named Slim250 at Saint-Véran Observatory in southeastern France, proud of having carried it there inside his backpack.

Simply laminating the carbon-fiber sheet onto wood — commonly seen in hobby circles at the time — missed the point, in Laurent's eyes. To prevent torsion (common with the loads in a telescope), we want "profiles." That means corrugations, boxed forms, and L- and H-shaped profiles to transfer the stress along. Laurent fondly invokes the Eiffel Tower's beam construction as he explains these profiles. He ended up using many methods in this build, largely with off-the-shelf epoxies for adhesive compatibility, and he kept a skin-and-frame design in mind for superior stiffness (specifically, stiffness-to-weight ratio).

The architecture of his scope follows his minimized-volume approach. This largely means designing subassemblies as flat structures to slide into, over, and under one another, all fitting into the rocker box. The upper cage assembly flattens much further with a magnetic register system to pop the removable secondary mirror in and out while remaining close to collimation, and the

ALL PHOTOS ARE COURTESY OF LAURENT BOURASSEAU



▲ *Left:* The upper cage assembly is shown with the secondary mirror attached via magnets. Laurent notes that the detachable secondary saved lots of space when packed. The spider, filter slide, focuser board, finder, and truss fittings all pop off for travel as well. *Right:* The Slim250 is seen partially dismantled for transport. From bottom to top, we see the rocker base with Teflon altitude pads; the large ring just inside this is the upper cage, surrounding the lower cage with truss blocks visible. The primary mirror here is safely ensconced in a carbon-fiber lid. The altitude bearings, monolithic composite hulls with laminate rims, nest snugly over this.

rocker base doubles as a transport case. The repurposed kite tube trusses collapse into thirds. His 1¼-inch KineOptics focuser, already as minimal as it can be without sacrificing function, wound up being the biggest constraint on how flat this would all pack.

Now, anyone who has worked with carbon fiber knows it's extremely tough. Laurent found drill bits and hacksaw and jigsaw blades quickly wore out — he advises anyone following in his footsteps to allocate a significant budget for replacing tools (or even funds for diamond-tipped tools). The material is also hazardous: Carbon dust shorted out some of his power tools. It's also a respiratory hazard, and our skin isn't crazy about it either. Not a casual hobby material.

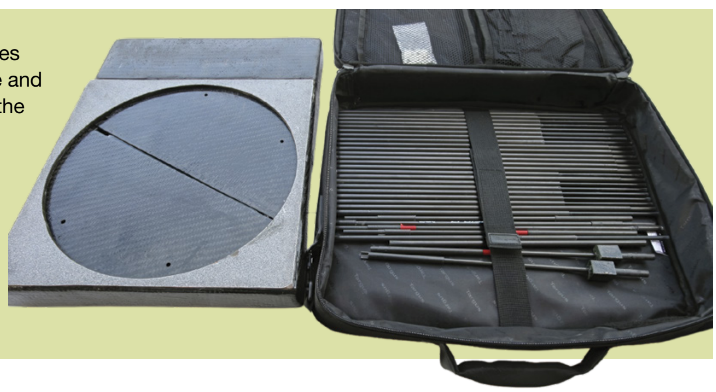
Building while designing is something you "absolutely shouldn't do," Bourasseau admits of his process. He couldn't design a chain of interlocking parts without knowing exactly how large they'd wind up and often used old, finished pieces themselves as molds with release film. This produced either perfect fits or failures costing both the old parts as well as new. Failure was a running companion to this project. Much of this just came with the territory of working with difficult materials — release wax not releasing, cardboard cores flooding with resin and canceling any lightness to the carbon-fiber parts, or firsthand lessons in epoxy becoming imprinted with tool marks after clampdown.

But it all paid off. Hundreds of hours later, he had what may be the most compact-packing 10-inch reflector anyone has made — if there's a flatter one out there, let me know about it. Amateur builders maintain a sort of "high-score" spreadsheet plotting weight to square aperture. And at a meager 7.4 kg (16 lbs) and less than 5 cm (2 inches) high when fully packed, Laurent's Slim250, as the telescope is called, sits squarely at No. 10 in the spreadsheet. A feat of modern telescope building, it's rivalled in capability-to-weight only by some much-larger instruments using thin meniscus primary mirrors (*S&T:* July 2019, p. 72).

For now, Laurent isn't observing with the Slim250, but it remains a cherished traveling demonstrator. In 2023, he proudly finished the Slim400, a not-quite carbon copy of his 10-inch. In the meantime, he hasn't seen anyone surpass the bar he has raised (or, maybe, lowered). Laurent himself thinks this isn't the limit. "Could I make it smaller?" he asks. "Probably. But I'd be shaving millimeters."

■ Contributing Editor **JONATHAN KISSNER** recently re-evaluated compactness as a design goal. And thanks to Laurent Bourasseau, he's doing it again.

Right: The Slim250 fits into a laptop bag, with the dismantled truss tubes stowed underneath the main assembly. *Below:* Parts of the upper cage and rocker base pack into a single box for transport. The focuser is one of the largest components Laurent couldn't shave down or rebuild smaller.



NEBULAE NEAR AND FAR

Djaffar Ould Abdeslam

This unusual image of M31, the Andromeda Galaxy, emphasizes hydrogen-alpha and oxygen III nebulosity. The bluish regions at top left and just below smaller, elliptical galaxy M32 (left of M31's core) are parts of the large, extremely faint planetary nebula SDSO-1 in the Milky Way discovered by a group of amateur astronomers in 2022. North is to the right.

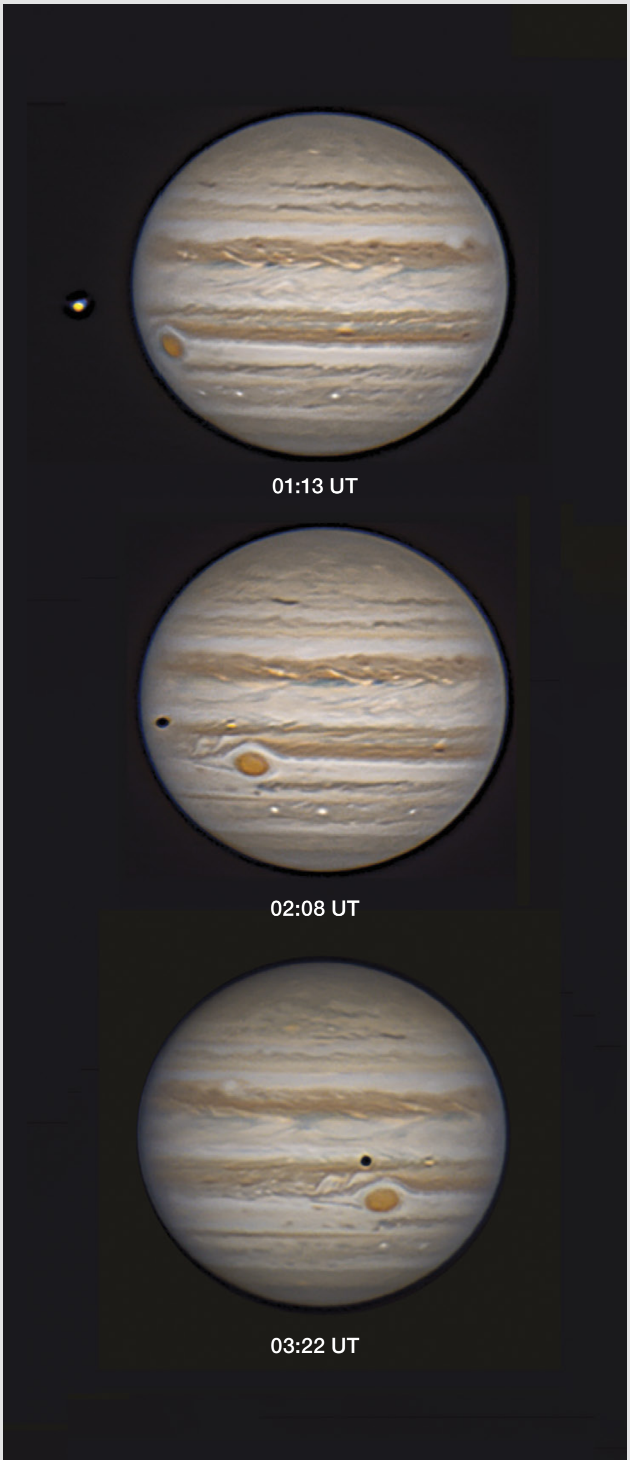
DETAILS: *Askar FRA500 refractor and ZWO ASI2600MM camera. Total exposure: 100 hours through LRGB and narrowband filters.*

THE DUSTY WEAVE OF M43

Bob Fera and Steve Mandel

Often overshadowed by its famous neighbor Messier 42 (parts of which we can see at bottom left), Messier 43 is a fascinating complex of sinuous dust and gas surrounding the bright quadruple star system NU Orionis left of center.

DETAILS: *PlaneWave CDK17 Corrected Dall-Kirkham astrograph with Moravian C3-61000 camera. Total exposure: 6 hours through red, green, and blue filters.*



HIDING AMONG THE STORMS
Tom Nolasco
Jupiter's Galilean moon Io, followed by its dark shadow, transits the face of the gas giant in roughly 1-hour increments on January 29th.
DETAILS: *Home-built 10-inch f/8.6 Newtonian with ZWO ASI462MC camera. Each image is a stack of 1,000 video frames.*

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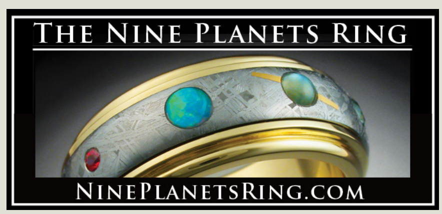

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Music From Numbers

A student creates a symphony out of supernova data.

LEAH TISCIONE / *S&T*

NUMBERS NEVER QUITE CAPTURE the essence of cosmological phenomena. It's hard to feel connected to scientific research when the findings are too complex or abstract to visualize. As supernovae were my first real exposure to astrophysics, I was particularly intrigued by the complexity of their data. Supernovae are intense, cataclysmic events, and I wondered whether we could intuit their behavior through our senses.

While in high school, I wanted to blend music and astronomy — both passions of mine — in a way that felt meaningful. So, I set out to give people a new way to experience supernovae — through sound. My goal was to translate a data set of thousands of stellar explosions into a musical composition that conveyed their scale and energy in a process known as *sonification*. I hoped the piece would feel alive, that it would offer something both scientifically grounded and enjoyable to listen to, an exercise rarely attempted within research settings. More broadly, I wanted this sonification to help non-specialists engage with astronomy in a way that felt digestible, intuitive, and artistic.

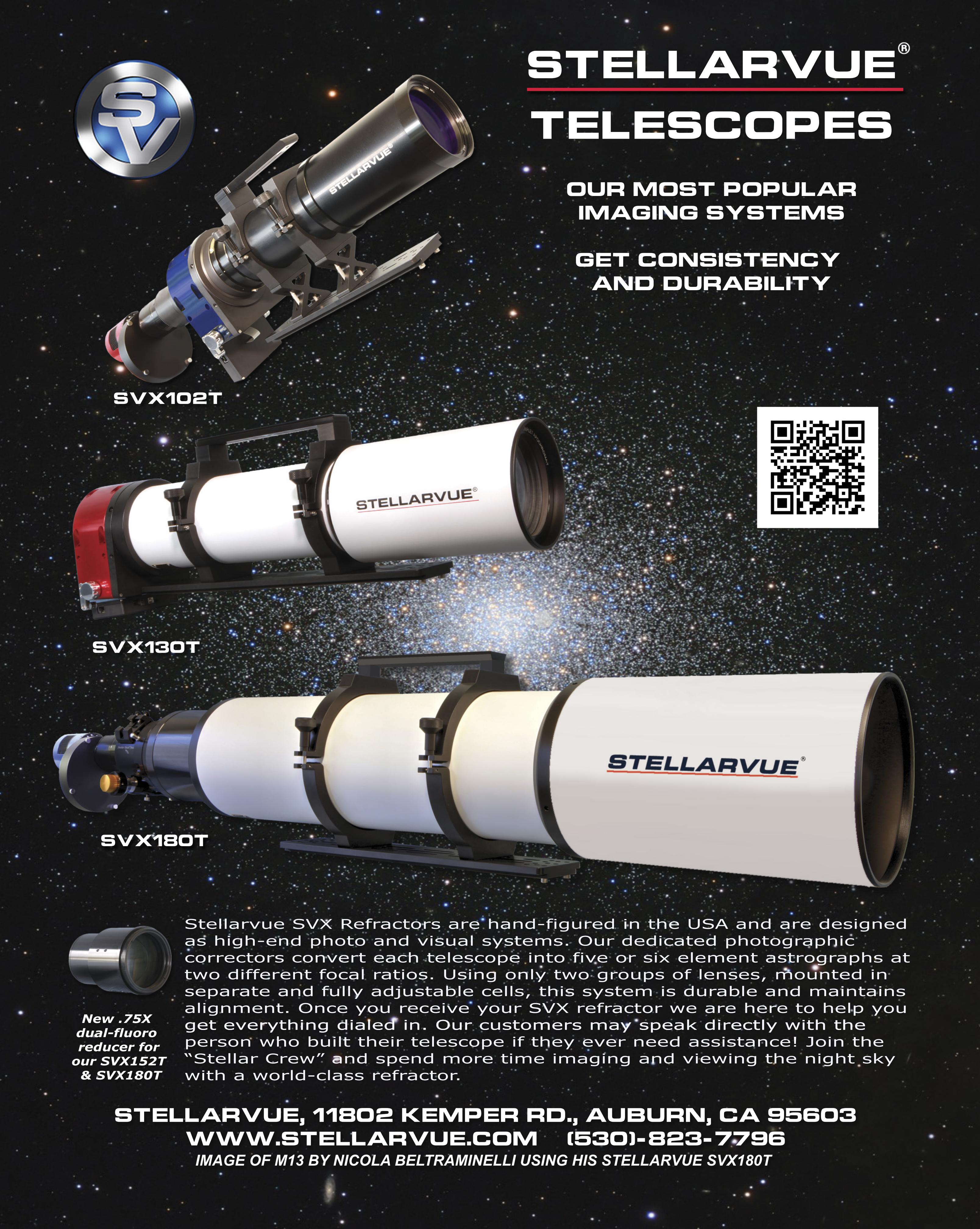
Under the mentorship of Christoffer Fremling and Mansi Kasliwal (both at Caltech), I began with a catalog of more than 8,000 supernovae from the Zwicky Transient Facility (ZTF) at Palomar Observatory and matched each measured parameter to a musical feature that preserved its scientific meaning. The supernova's discovery date became the note's timestamp, the event duration translated to note length, brightness mapped to volume, redshift (indicating distance) became pitch, and supernova type determined the musical instrument. From this slew of parameters, I generated a raw MIDI file that was accurate but overwhelming — a jumble of thousands of unrelated notes. To make it listenable, I placed the notes onto a scale that's neither minor nor major but something in between, to evoke the vastness and wonder associated with space. Then I layered chords, rhythmic textures, and ambient effects to create a cohesive lo-fi composition, blending subtle background noise with hip-hop beats for a mellow feel.

I defined success not only by creating an accurate and musically coherent piece, but also by building a bridge between general audiences and active astronomy research. To expand the project beyond a single composition, I worked with ZTF to create a public tutorial and sonification guide, which enables anyone, regardless of coding or musical background, to generate their own interpretations of the cosmos. We want to encourage people to engage with data creatively and personally.

Seeing astronomers, educators, musicians, and students connect with my piece was incredibly rewarding. The project evolved significantly throughout the process, but the final sonification sparked genuine curiosity about the universe. More than anything else, the fact that people from multiple disciplines found personal meaning in it made the endeavor feel successful.

Accessibility draws attention, and sonification offers one way to bring people closer to space research by humanizing astronomy's vast data sets. It reframes scientific discovery as an experience people can intuitively grasp through sound and emotion. By sharing the tools publicly, we hope to empower others to create their own interpretations, expanding the impact far beyond this piece. Art and science inform each other, and sonification demonstrates how their synthesis can forge new avenues for thinking that neither could achieve alone.

■ **VANYA AGRAWAL** is an astrophysics student at Washington University in St. Louis, Missouri. To hear Agrawal's composition, go to **https://is.gd/SN_sonification**.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