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SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

FEBRUARY 2026

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SKY&TELESCOPE
THE ESSENTIAL GUIDE TO ASTRONOMY

February 2026 VOL. 151, NO. 2

ROBERT GENDLER

ON THE COVER

The Sun sets on the large lunar crater Clavius.
PHOTO: SEAN WALKER / *S&T*

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The Moon . . . Again!

WHO ISN'T BEWITCHED BY OUR MOON? I sure am. Oftentimes, while driving home, I really have to focus so as not to swerve into a ditch as I suddenly catch sight of the waxing crescent, a couple days old, ethereally suspended in a pearlescent dusk sky. I'm equally arrested by a view of the full Moon as it pops above the horizon after sunset draped in a deep orange hue.

The Moon offers so much, with its dramatic shadows that transform the lunar surface into a chiaroscuro landscape of fascinating geology. Associate Editor Sean Walker's stunning images starting on page 28 clearly demonstrate why we decided to feature the Moon as a cover story — again! (Just last month, our cover story was on commercial missions to the Moon.) Walker's clear tips might encourage you to acquire some snapshots of your own with which to adorn your walls, so you can enjoy lunar sights even on cloudy nights or new-Moon days. And Contributing Editor Chuck Wood's article on page 52 offers us, as always, a close-up of some inclined features of lunar topography.

▲ The Moon never ceases to fascinate.

SEAN WALKER

Of course, our Moon isn't the only planetary satellite in the solar system. The gas and ice giants are accompanied by a coterie of moons of various shapes and sizes escorting them on their travels around the Sun. Turn to page 14 to read Contributing Editor Javier Barbuzano's lively account of the oodles of oddball satellites buzzing busily around the giant planets.

I suppose it's unsurprising that we pay so much attention to the Moon. The Moon is, after all, the most accessible of all celestial objects — it's visible much of the time, and you need no specialized equipment whatsoever to enjoy it. It's literally the poster child for the "Just look up!" exhortation that so many of us use to encourage people to enjoy the nighttime (and daytime) sky.

In fact, Adrian Bradley's refreshing tale of conducting an outreach event in downtown Ann Arbor, Michigan, reminds us why we so often point our telescopes at the Moon at such events. I don't want to spoil the story for you, so please turn to page 84 to read about his amusing — and inspiring — experiences.

One last thing, not Moon-related. I'm pleased to announce that we'll be conducting a splinter session on pro-am collaborations at the American Astronomical Society winter meeting in Phoenix, Arizona, in early January. If you're planning on attending the meeting, please do consider coming to the session, especially if you're engaged in, or hoping to get involved in, such a collaboration — you can email us at **editors@skyandtelescope.org**, as we'd love to have you participate in the session in some way.

Editor in Chief

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WEBB'S COSMOS

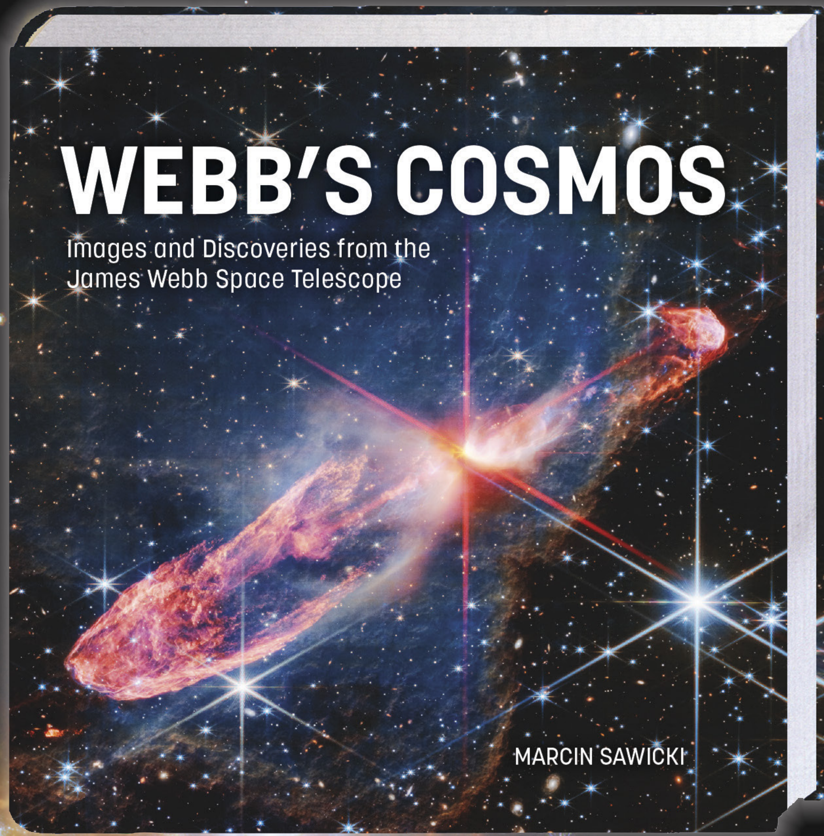
Images and Discoveries from the James Webb Space Telescope

by Marcin Sawicki

Written by a research astronomer involved with the Webb for two decades, this is a splendid album of almost 300 pictures.

But also, a clear explanation of why the Webb, using infrared imaging, detects far more celestial objects — clearer and farther away in distance and time.

Up to date and full of value, an important book!



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More Astronomy Coins

Within weeks of writing my news item on the 2025 Vera Rubin U.S. quarter-dollar (*S&T:* Oct. 2025, p. 11), I discovered that the U.S. Mint issued two other astronomical commemorative coins that flew under our radar. These are part of the American Innovation $1 Coin series, a multi-year effort that will eventually feature one design from every U.S. state, DC, and five U.S. territories.

Delaware's $1 coin, issued in 2019 and still available, celebrates astronomer Annie Jump Cannon (1863–1941), who was born in the First State and later became famous as one of Harvard College Observatory's "computers" who analyzed photographic plates. The system of stellar spectral types she codified over the course of classifying some 350,000 stars is still used today.

Maryland's Innovation $1 Coin, issued in 2020, commemorates the Hubble Space Telescope. Now in its 36th year in orbit, the iconic observatory is controlled by NASA's Goddard Space Flight Center in Greenbelt, while its science program is managed by the Space Telescope Science Institute in Baltimore.

Richard Tresch Fienberg
Placitas, New Mexico

▲ The American Innovation $1 coins for Delaware *(top)* and Maryland *(bottom)* honor "Census Taker of the Sky" Annie Jump Cannon and the Hubble Space Telescope, respectively. Find out more about the coin series at **https://is.gd/InnovationCoins**.

COIN IMAGES COURTESY OF UNITED STATES MINT

Lopsided Galactic Family

I just received the September issue of *Sky & Telescope*. On page 10, there is a short but interesting news article that caught my attention called "Why Andromeda's Dwarf Galaxies Cluster on 'Our' Side." I wonder if I am missing something: The author, Monica Young, a science writer whose work I have admired for years, reports that recent research points to the dwarf galaxies associated with the Andromeda Galaxy clustering on "our" side. Doesn't this infer that there is "another side," one that we don't see? Is it then possible that there are one or more dwarf galaxies on the other side that are not countable?

Bob Rosenstein
Ellicott City, Maryland

Monica Young replies: *If you imagine Andromeda being surrounded in a sphere, "our" side is the side of the sphere facing us. That indeed means that there is "another" side. Anything over there is a bit farther away from us, but not necessarily impossible to see. What astronomers have found is that the difficulty in seeing those more distant objects doesn't explain the asymmetry that deep surveys have turned up. In other words, Andromeda's a bit of an oddball when it comes to its dwarf galaxy family!*

Galactic Attractor

Our galaxy, the Milky Way, and the cluster of galaxies of which we are a part is inexorably attracted by a gigantic structure of superclusters of galaxies called Laniakea.

From what I understand, the closer we get to that Great Attractor, the more the galaxies will be compressed. So the galaxies will get closer to each other.

This appears to be at odds with the accelerated expansion of the cosmos, and in particular, with the expansion of empty space between galaxies, as described by Monica Young in her reply to "Rising Raisins" (*S&T:* Aug. 2025, p. 7), where she writes "at smaller scales [between stars or planets], there is enough mass (gravity) to prevent expansion. . . . It's on larger scales — or in emptier regions of space known as cosmic voids — that expansion occurs."

So, which force is stronger and faster in time: the accelerated expansion of cosmic voids or the concentration of superclusters to Laniakea region?

Luca Martello
Verona, Italy

Monica Young replies: *You raise an interesting instance in which gravity temporarily dominates. Let's start with the example of planets in the solar system: We can see that the planets orbit the Sun in such a way that gravity dominates and space does not expand. Likewise, we can look at the orbits of stars in the Milky Way and see that they orbit in the Milky Way's gravitational well, with no effects due to the expansion of space. Even if you go out beyond our galaxy and into the Local Group, gravity still dominates. It's when you go into the vast scales of the larger cosmos, on the order of 50 million light-years or so, that we begin to see the effects of expansion.*

Now, Laniakea is about 10 times that. So it's reasonable to expect that the expansion of space will ultimately tear Laniakea apart. However, this will take a very long time . . . and given that recent studies suggest that dark energy might not be constant, I don't think we can say for certain!

Internet Stardom

I read Stephen James O'Meara's excellent reply to "An Enchanting Wreath" (*S&T:* Oct. 2025, p. 6) regarding Webb's Wreath and what I've been calling "The faint galaxies of Webb's Wreath." It was his original article in the May issue that spawned much interest and maybe a bit of fame to the humble wreath.

My original Cloudy Nights post continues to receive many views on a daily basis . . . thanks in part to O'Meara's article in *Sky & Telescope*. And now there has been a surge since his reply in the October issue. Webb's Wreath is now one of my most popular posts!

Roger Ivester
Boiling Springs, North Carolina

Farewell, Old Friend

I have never owned a telescope, much less ever considered building one, but Astronomer's Workbench has been my favorite part of every issue. The variety of equipment, the clever designs, the practical engineering, and above all, Jerry Oltion's voice through every article were a delight. It was a pleasure I anticipated every month.

I was saddened to read that he is passing on the baton (finderscope?) in "My Favorite Things" (*S&T:* Sept. 2025, p. 74). I shall miss his byline but hope he enjoys his pursuits away from the monthly deadline.

Dean Fiala
Rockville, Maryland

Astronomer's Workbench is the first section I turn to in every new issue of *Sky & Telescope*. Jerry Oltion's articles have been the inspiration for at least a dozen of my amateur telescope making projects. I expect that Jonathan Kissner will continue to inspire even more projects.

While I respect Oltion's minimalist CTG (cardboard, tape, and glue) method of construction, I'm not a practitioner myself, preferring to 3D-print my projects. I hope to hear more from Oltion as he embraces the new technology!

Charles O'Donnell
Westerville, Ohio

I was saddened to hear of Fred Espenak's passing (*S&T:* Sept. 2025, p. 11). I believe that his guides for the 2017 and 2024 solar eclipses were the main reason that I was able to find great viewing locations. His detailed maps enabled me to find cities to use as a home base and to pick alternate observing sites.

I'm sure his guide for the 2045 eclipse will be used by the next generation of observers.

Kenneth Pulkkinen
Lanham, Maryland

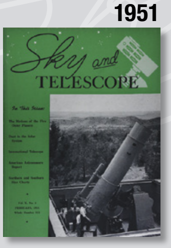
FOR THE RECORD

● In "Some TESS Planets Bigger Than Thought" (*S&T:* Dec. 2025, p. 10), the *stars* appear larger than they are, thus leading to an underestimate of the *planet's* size. See the original article at **https://is.gd/BiggerPlanets**.

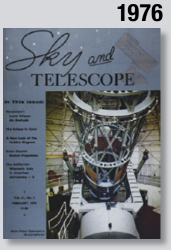
SUBMISSIONS: Write to *Sky & Telescope*, 1374 Massachusetts Ave., 4th Floor, Cambridge, MA 02138, USA, or email: letters@skyandtelescope.org. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

75, 50 & 25 YEARS AGO by Sabrina Garvin

1951



1976



2001

◖ February 1951

Zodiacal Origins "A cloud of very small dust particles circling the sun in the plane of the earth's orbit scatters sunlight to produce the glow known as the zodiacal light. It appears after sunset and before sunrise as a wedge-shaped area extending along the ecliptic. . . .

"Fred L. Whipple, of Harvard Observatory, has developed a theory to explain the origin of the zodiacal light particles as material blown off comets when their icy surfaces are vaporized by sunlight. The particles so expelled then spiral slowly into the sun . . ."

This cometary origin is still one of the prevailing theories, but in 2020, a team of scientists from NASA's Juno mission proposed that much of the zodiacal dust the space probe encountered likely came from Mars. However, astronomers are still debating this new theory. Learn more at **https://is.gd/ZodiacalDust**.

◖ February 1976

Global Eclipse Observers "Among the many total eclipses of the moon described in *Sky & Telescope* over the years, that of November 18–19, 1975, is remarkable for the wide geographical spread of its observers. Reports came from the Philippines and India, where the eclipse began shortly before moonset, and Mauritius, Ethiopia, Iraq, and Israel. There were about 50 reports from . . . Europeans . . .

"Two-thirds of the observers' reports came from the United States and Canada, some as far west as California and Washington, where when the moon rose the eclipse was already over except for some vestiges of penumbral shading. There were also letters from amateurs in Brazil and Colombia. The span of geographical longitude between the extreme observing positions is no less than 243 degrees!"

◖ February 2001

Bortle Scale "How dark is your sky? A precise answer to this question is useful for comparing observing sites and, more important, for determining whether a site is dark enough to let you push your eyes, telescope, or camera to their theoretical limits. Likewise, you need accurate criteria for judging sky conditions when documenting unusual or borderline observations, such as an extremely long comet tail, a faint aurora, or subtle features in galaxies. . . .

"To help observers judge the true darkness of a site, I have created a nine-level scale. It is based on nearly 50 years of observing experience. I hope it will prove both enlightening and useful to observers — though it may stun or even horrify some! Should it come into wide use, it would provide a consistent standard for comparing observations. . . . All around it could be a boon to those of us who regularly scan the heavens."

This article was the first publication of John E. Bortle's now-famous Bortle Scale. See the full article at **https://is.gd/bortle**.

GAMMA-RAY BURSTS

Black Hole Might Have Eaten Its Way Through a Star

THE LONGEST-DURATION gamma-ray burst on record might mark the moment a black hole tunneled through a star and blew it up from within.

NASA's Fermi Gamma-ray Space Telescope detected the burst on July 2, 2025. Gamma-ray bursts longer than 2 seconds (typically lasting a few minutes at most) occur when massive, fast-spinning stars collapse into a black hole at the end of their brief lives, blasting particle jets into space. But the exceptional GRB 250702B remained active for an unprecedented 7 hours.

The burst, which faded several times only to brighten again, is hard to explain with the usual long-GRB scenario. A team led by Andrew Levan (Radboud University, The Netherlands) investigated the event's near-infrared afterglow with the European Very Large Telescope in Chile and used images from the Hubble Space Telescope to pinpoint the burst to the outskirts of a faint galaxy near the border between Aquila and Scutum. Following up with the James Webb Space Telescope, a team led by Benjamin Gompertz (University of Birmingham, UK) found that the galaxy is distant, its light traveling for 8 billion years before arriving at Earth. The gamma-ray burst must have been extremely luminous to be so bright despite being so far away.

▲ *Left:* This artist's concept shows a gamma-ray burst, with narrow jets of speedy particles. *Right inset:* The Very Large Telescope captured GRB 250702B's near-infrared afterglow.

By late September, several papers had appeared on the arXiv preprint server, describing observations of the GRB's afterglow. Some of these results were also presented in October at the meeting of the High Energy Astrophysics Division of the American Astronomical Society, in St. Louis, Missouri. Various groups agree that the afterglow observations can best be explained by powerful

---

SCIENCE POLICY

What the Government Shutdown Means for NASA

ON OCTOBER 1ST, the U.S. federal government officially shut down. For 15,000 NASA employees, that means an unwanted stay on the couch. For others, it spells work without pay. And depending what happens when the government does reopen, the agency might face a precarious funding situation.

"No one really knows what's going to happen, because the climate is just changing from day to day," says Tanya Harrison (Outer Space Institute, Canada). Harrison previously worked at NASA's Goddard Space Flight Center and has been on the science teams of the Curiosity, Perseverance, and Opportunity Mars rovers.

The government shutdown has put roughly 85% of NASA's civil servants on furlough, says Casey Dreier, Chief of Space Policy at The Planetary Society. The remaining 15% encompass those who work on missions deemed critical by the Trump administration (that is, the Artemis initiative), on basic spacecraft and satellite operations, or on critical maintenance of the International Space Station.

The situation has raised concerns for the agency's long-term planning, such as for solar system missions with tight launch windows. Exacerbating fears, the Trump administration has also threatened to enact further reductions in force (RIFs) during the shutdown. Dreier notes that NASA has already lost one-fifth of its workforce due to previous RIFs and early resignations.

Theoretically, when the federal government reopens, NASA's new operating budget should be similar to 2025. A NASA memo dated September 26th and

GRB ART: ESO / A. ROQUETTE; AFTERGLOW: ESO / A. LEVAN / A. MARTIN-CARRILLO ET AL.

shock waves generated by unusually narrow and fast-moving particle jets. But the burst's extremely long duration and its rapid (sub-second) gamma-ray variability, as well as X-ray emission detected before the burst went off, are "incompatible with all confirmed gamma-ray burst progenitors and nearly all models in the literature," according to a team led by Eliza Neights (George Washington University).

Instead, Neights and colleagues suggest that GRB 250702B is the result of a unique merger. In their scenario, a massive, helium-rich star was in a mutual orbit with a stellar-mass black hole. As the bloated star expanded beyond the black hole's orbit, the black hole consumed more and more stellar material. Eventually, the black hole ate its way into the core, spouting jets that blew the star to smithereens from within.

If the hypothesis of a black hole falling into a star correctly explains GRB 250702B's unusual behavior, then it's the first example of a new but rare progenitor system. "It makes sense to come up with a very unique explanation for a single, unique event," says Ralph Wijers (University of Amsterdam, The Netherlands), who was not involved in studying this particular gamma-ray burst. "The challenge is to think of something that is very rare but not impossible. The merger model seems to be cleverly conceived."

■ GOVERT SCHILLING

SOLAR SYSTEM

Mars Orbiters See Comet from Front-Row Seats

SPACECRAFT ORBITING Mars aimed a suite of instruments at the interstellar comet 3I/ATLAS when it passed within 30 million kilometers (20 million miles) of the Red Planet on October 3rd. (The comet will never come closer than 270 million km to Earth.)

Two European Space Agency (ESA) spacecraft, Mars Express and ExoMars Trace Gas Orbiter (TGO), attempted to image 3I/ATLAS as it passed by. The comet was too faint to be seen in Mars Express's 0.5-second exposures. However, ExoMars TGO was able to image the coma of gases and dust surrounding the comet's nucleus, though it didn't have the resolution to make out the nucleus itself. Both spacecraft also carry spectrometers that collect light from near-infrared to ultraviolet wavelengths; scientists were still analyzing those data as of press time.

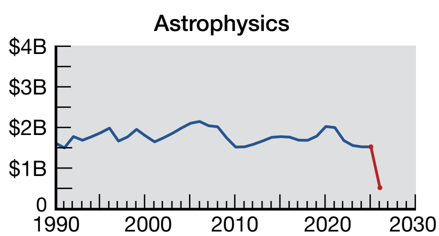
Meanwhile, NASA's Mars Reconnaissance Orbiter also attempted images, with observations already planned before the U.S. federal government shutdown (see below). The team used the orbiter's High Resolution Imaging Science Experiment camera, which has a half-meter mirror and 14 sensors that cover visible to near-infrared wavelengths. NASA will not be able to release those data or even comment on the observations until the shutdown ends.

▲ The ExoMars Trace Gas Orbiter captured Comet 3I/ATLAS using its Colour and Stereo Surface Imaging System.

As Comet 3I/ATLAS approached the Sun for perihelion on October 29th, it remained lost in the Sun's glare from Earth's perspective. But ESA's Jupiter Icy Moons Explorer (JUICE) is positioned to begin observing the comet from November 2nd through the end of the month. Those observations will cover a period during which the comet might be at its most active, having just experienced maximum solar heating. The data will be sent to Earth in February 2026.

■ DAVID L. CHANDLER

For updates as they're released, visit skyandtelescope.org/3IATLAS



▲ If the President's budget request were enacted, it would slash NASA science funding (shown here for the astrophysics division). Enacting the House's version would be a smaller change but would still reduce the agency's science budget by almost 20%.

3I/ATLAS PHOTO FROM MARS ORBITER: EXOMARS / TGO / CASSIS; GRAPH: THE PLANETARY SOCIETY

shared with *Sky & Telescope* states that "in the event of a Continuing Resolution," the agency's astrophysics division "plans spending to align with the FY 2026 House Appropriations Committee," which should ensure "normal operations" for much of NASA science.

However, three days after that memo was issued, the Senate Committee on Commerce, Science, and Transportation released a report stating that the White House Office of Management and Budget has instead been illegally directing NASA to align its 2026 spending with the President's budget request — a document that slices the agency's science funding nearly in half.

Why the switch-up? Dreier notes that the Senate report was compiled over the summer; since then, NASA leadership has experienced personnel changes. Also since then, the House and Senate have put forward appropriations legislation that far surpasses what President Trump proposed for the agency.

Uncertainty and unease are the throughlines of the year, and scientists are following the news now more than ever. "Even if you think that science as a study is apolitical, your funding comes from the government," says Harrison. "You can't just sit in your lab and think that this doesn't impact you, because it's very clear now that it does."

■ HANNAH RICHTER

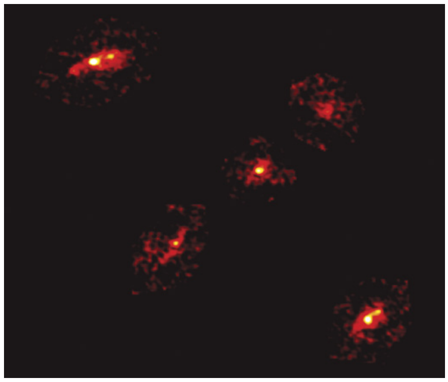
COSMOLOGY

Astronomers Spot Rare Einstein Cross — and a Clump of Dark Matter

THE DISCOVERY OF a rare quintuplet of galaxy images has revealed an intervening clump of dark matter that's as massive as several trillion Suns.

The so-called *Einstein cross* originates from a single galaxy, known as HerS-3, residing in a universe just 2.1 billion years old. On the way to Earth, the photons from that galaxy passed by a massive galactic group before traveling another 7.8 billion years to our telescopes. The foreground group's gravity bent the background galaxy's light into five separate images in a phenomenon known as *gravitational lensing*.

Alongside the Atacama Large Millimeter/submillimeter Array (ALMA), the team also drew on the Northern Extended Millimetre Array (NOEMA) in France, the Very Large Array (VLA) in New Mexico, and the Hubble Space Telescope. With NOEMA and ALMA, the astronomers mapped cold molecular gas that's fueling star formation in HerS-3. They used the VLA to trace radio emission. Meanwhile, Hubble helped pin down the lensing galaxies' shapes and positions.



▲ The ALMA telescope revealed detailed morphology in the five images of the starburst galaxy HerS-3.

Einstein crosses normally consist of four main images. The fifth, central image, when it appears, is faint because the lens demagnifies and outshines it. For HerS-3, however, the central image is unusually bright.

"The only way to reproduce the remarkable configuration we observed was to add an invisible, massive component: a dark matter halo at the center of the galaxy group," says Pierre Cox (Sorbonne University, France), who led the study in the September 20th *Astrophysical Journal*. "This halo weighs several trillion times the mass of our Sun." Adding the dark clump offsets the cluster's center of mass from its brightest galaxy, allowing the fifth image to appear brighter than it normally would.

"There are only a couple of known examples of crosses with a fifth image," says Justin Read (University of Surrey, UK), who was not involved in the research. HerS-3 may help provide an independent estimate of the current cosmic expansion rate, he adds. This unique shape in the sky may thus turn out to hide deeper clues about the universe's enduring mysteries.

■ **COLIN STUART**

GALAXY

A "Great Wave" Is Crashing Through the Milky Way

PRECISE STELLAR measurements provide evidence for a wave that's propagating outward from our galaxy's center — perhaps from a long-ago collision with another galaxy.

The Milky Way's stars revolve in a disk warped like a misshapen sun hat. In recent years, though, studies have hinted that there's more action in the galaxy's outskirts than can be explained even by a warped, spinning stellar disk.

To dig into that action, Eloisa Poggio (Astrophysical Observatory of Torino, Italy) and colleagues mapped the motions of 17,000 young giant stars and 3,400 Cepheid variables using data from the European Space Agency's Gaia mission. Both types of stars sit squarely in our galaxy's spiral arms, having only recently been born out of the gas that clumps there. The abundant young giants are typically found closer to the galactic center, while the brighter Cepheids can be seen all the way out to the edges of the spiral arms.

The stars' positions and velocities have revealed what the researchers call a "Great Wave" rippling through the Milky Way's outer edge — that is, between 33,000 and 46,000 light-years from the galactic center, well past the Sun's galactic orbit at some 26,000 light-years. Poggio and colleagues report the results in the July 2025 *Astronomy & Astrophysics*.

Previous studies have found evidence of ripples and associated features, but this is the first time they've been defined in such detail. Reminiscent of the ripples that expand around a pebble thrown in a pond, the stellar undulations might indicate something dropped into our galaxy's disk in the past.

Attempts to mimic a single past galactic collision in computer simulations haven't reproduced observations, though, opening the door to multiple hits. Another possibility is that a glancing blow set off the ripples (*S&T:* Oct. 2019, p. 10). Poggio's team doesn't land on any one explanation — work remains to unearth our galaxy's past.

■ **MONICA YOUNG**

▲ In this edge-on view of the Milky Way, the stellar disk's known warp is clearly visible. The velocities of stars offset from this warp (lying above and below it; red and blue, respectively) indicate that a "great wave" is propagating outward in the galactic outskirts.

EINSTEIN CROSS: P. COX ET AL. / ALMA (ESO / NAOJ / NRAO); MILKY WAY STARS FROM GAIA DATA: ESA / GAIA / DPAC / S. PAYNE-WARDENAAR / E. POGGIO ET AL (2025)

EXOPLANETS

Water Worlds May Be Few and Far Between

PRIMORDIAL CHEMISTRY might destroy most of the water on a particular kind of exoplanet, new research finds. If so, there could be far fewer "water worlds" than previously thought.

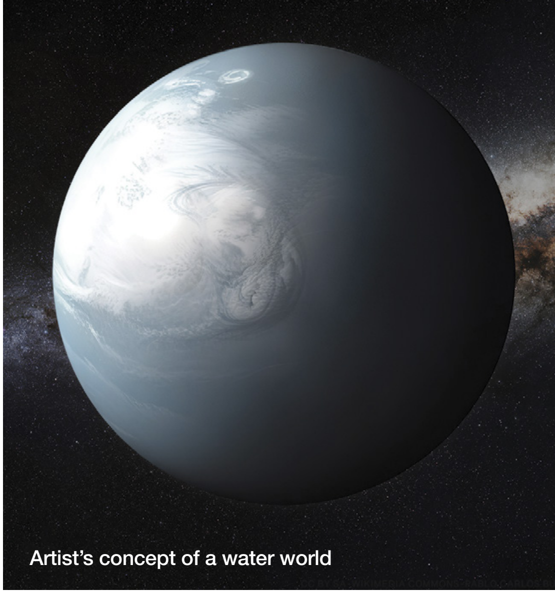
Planets smaller than Neptune with a gaseous atmosphere don't exist in the solar system, but they're plentiful around other stars. Some astronomers have suggested these strange worlds might be water-rich, potentially even hosting global oceans.

However, a new study in the September 20th *Astrophysical Journal Letters* has shed doubt on this scenario, instead making the case that most such *sub-Neptunes* should be relatively dry.

Like the giant planets in our own solar system, sub-Neptunes should have atmospheres composed primarily of hydrogen and helium. But they could also accumulate large amounts of water if they form beyond the *snow line*, where water condenses as ice.

The hydrogen-helium atmosphere traps the heat of formation, argues graduate student Aaron Werlen (ETH Zurich, Switzerland). "Numerous studies have shown that this naturally leads to long-lived magma oceans." In simulations of 248 different planets, spanning a range of conditions expected for young sub-Neptunes, Werlen and colleagues found that reactions with this magma ocean would destroy most of the atmosphere's water. Under the high pressures and temperatures in these planets' interiors, chemical processes break water into hydrogen and oxygen atoms, which are then sequestered in metals. Scientists have not previously considered such reactions.

The interactions leave less than 1.5% of the planet's mass in water — even for planets that had initially gathered up to 30% water when first forming. While that's more than Earth's water content (which is only around 0.02%), the result makes global oceans unlikely.


Artist's concept of a water world

The team hopes to look at more sub-Neptune and water-world candidates to verify their models. "A key goal is to compare our predictions to James Webb Space Telescope spectra by computing atmospheric compositions directly," Werlen says. "But much more work — both in modelling and in observations — is needed to achieve this."

■ ARIELLE FROMMER

IN BRIEF

Two Novae Discovered

Astronomer John Seach of Grafton, Australia, discovered a binocular nova on the first day of fall, visible in Centaurus to viewers in the Southern Hemisphere. He recorded the object on September 22nd in three photos made with a DSLR camera and 40-mm f/1.4 lens. Follow-up observations by Ernesto Guido, Marco Rocchetto, and Luca Izzo, using a 0.35-meter telescope in Australia operated by Spaceflux, confirmed the new nova, putting it at magnitude 5.8. Its peak was short-lived: Two days later, it had already started to fade. Located at R.A. $14^h 37^m 22^s$ and declination –58° 47′ 40″, it has received the formal designation V1935 Centauri. As if finding one nova weren't enough of an achievement, Seach captured a second, fainter nova in Sagittarius one night earlier, on September 21st, with the same camera setup. This new object, now permanently designated V7994 Sagittarii, is located at R.A. $18^h 03^m 53^s$ and declination –31° 27′ 30″ just off the spout of the Sagittarius Teapot. Not a half hour later, Japanese amateur Tadashi Kojima reported his independent discovery of the nova and put its magnitude at 10.5.

■ BOB KING

Three Missions to the Sun

NASA's Interstellar Mapping and Acceleration Probe (IMAP) launched on September 24th, accompanied by two smaller missions: the National Oceanic and Atmospheric Administration's Space Weather Follow On-Lagrange 1 (SWFO-L1) and NASA's Carruthers Geocorona Observatory. All three spacecraft will observe from the L_1 Sun-Earth Lagrange point, located 1.5 million km (1 million mi) sunward from Earth (*S&T:* Oct. 2025, p. 72). IMAP carries 10 instruments to study the outer boundary of the *heliosphere*, the region of space dominated by the Sun's magnetic field. Key to this science goal are *energetic neutral atoms*, which receive their energy from collisions with speedy particles both from the Sun and from outside the solar system. The neutral atoms are unaffected by the solar magnetic field, so scientists can use them to trace activity that the field would otherwise obscure. "[The mission] will create a more complete picture of solar activity . . . to advance space-weather forecasting," says IMAP project scientist and co-investigator Matina Gkioulidou (Johns Hopkins University Applied Physics Laboratory). The accompanying SWFO-L1 will continuously monitor the Sun, while the Carruthers Geocorona Observatory, named for space physicist George Carruthers (1939–2020), will measure far-ultraviolet emissions from Earth's tenuous outermost atmosphere, or *exosphere*. The observations will detail the size and shape of this region, which extends nearly halfway to the Moon, as well as its reaction to space-weather events. The missions will begin observing mid-2026.

■ DAVID DICKINSON

VIPER: New Lease on Life

NASA's Volatiles Investigating Polar Exploration Rover (VIPER), a water-seeking mission bound for the lunar south pole, has hitched a ride that could put it on the Moon in 2027. Originally slated to fly with Astrobotic's Griffin lander in 2023, VIPER's cost overruns resulted in its cancellation in 2024 even though the rover was fully built. Despite initial plans to disassemble the rover and reuse its instruments elsewhere, NASA changed gear in early 2025, ultimately awarding a contract to Blue Origin on September 19th. The aerospace company will launch VIPER on its New Glenn rocket and deliver it to the surface on the Blue Moon Mark 1 lunar lander. The Commercial Lunar Payload Services task order, worth $190 million, is contingent on the success of Blue Origin's pathfinder flight of its MK1 lander, due in early 2026.

■ DAVID DICKINSON

A Curious Total Lunar Eclipse

The Moon was especially dark when it was immersed in Earth's shadow last September.

THE SEPTEMBER 7, 2025, total eclipse of the Moon was a most unusual event — at least as seen from my home in Maun, Botswana. To my unaided eyes, totality didn't live up to its "Blood Moon" reputation; instead, it looked ashen, like a dying ember. This was one of the darkest eclipses I've seen since totality on December 9, 1992, which was the first to occur after the 1991 Mount Pinatubo eruption in the Philippines. Volcanic ash spewed into Earth's upper atmosphere, forming aerosols that blocked and scattered sunlight from reaching the Moon (*S&T:* Mar. 2025, p. 58).

The main reason for totality's duskiness from Botswana was soot from rampant wildfires across south-central Africa. However, volcanic aerosols from the 2025 eruption of Mount Lewotobi in Indonesia, as well as possible lingering dust particles injected into the stratosphere and mesosphere following the 2022 Hunga Tonga eruption in the South Pacific, might have also contributed.

Although September's umbral phase began about 10 minutes after local moonrise, the Moon didn't emerge from the dense smoke hanging near the horizon until it was about 40% eclipsed. Its illuminated portion had a raw sienna hue so muted that I saw no pronounced *irradiation effect* — that is, when the limb of the illuminated portion of the partially eclipsed disk appears to be part of a larger circle than the limb of the darkened portion — an illusion that's common with bright lunar eclipses.

By the time the Moon was 90% immersed in the umbral shadow, it had risen to an altitude of 15°, where the smoke was thin enough to create an *aureole* — the atmospheric corona in its simplest form — with an aqua core that faded to reddish-brown toward the edge. Its oval shape mirrored the fact that the Moon's slender illuminated portion was longer on the north-south axis than on the east-west. I noted, too, that the aureole wasn't centered on the Moon but on the bright crescent (see above). This phenomenon mimicked the appearance of a total solar eclipse's diamond ring.

▲ **DARK TOTALITY** The author captured this sequence of the September 2025 total lunar eclipse from Maun, Botswana. Note the aureole at upper left (*S&T:* June 2025, p. 12). North is to the left.

To the naked eye, totality itself was unremarkable. I could see the northern half of the Moon only with keen, averted vision, while the southern highlands were visible but dull, looking like a bruised banana. When I used my 8×42 binoculars to estimate totality's brightness — by holding the binoculars in reverse so the objective lenses are facing my eyes and then comparing the lunar image to stars of known brightness — I couldn't even see the Moon!

The eclipse through my 3-inch refractor at 22× was slightly more rewarding. Shortly after the onset of totality, the highlands north of Mare Crisium on the Moon's eastern limb glowed like heated copper, while the southern highlands on the lunar east of Tycho were light mauve. By mid-totality, the Moon's dark northern region had a lavender slate hue that reddened to terracotta toward the south. Only the extreme southern limb was rimmed with a touch of lilac. The second half of totality was marginally brighter than the first. After mid-eclipse, the southwestern part of the Moon became increasingly cornflower-yellow, with hints of dusty rose and pale lilac.

As the partial phases waned, Earth's umbral shadow was deep orange bordered by a uniform band of charcoal sage. This slight greenish hue might have been a color-contrast illusion. To the unaided eyes, Earth's shadow didn't look smoothly curved but instead very jagged and irregular — an effect created as the dark umbral shadow blended with the murky lunar maria where they met. When the shadow slipped past Mare Serenitatis and then Mare Tranquillitatis, it fooled my eye into seeing two inky, thumblike protrusions. The shadow was so dark that discerning lunar features through it took effort.

Then, only 20 minutes before the partial phases ended, I noticed through the telescope yet another optical illusion — the strong appearance of an extremely dark band draped along the inside edge of the receding umbral shadow. This phenomenon, known as the *Mach band effect*, is due to the human eye-brain system, which causes it to perceive an object's edges as being brighter (or darker) than they actually are (*S&T:* July 2025, p. 12). In this case, the edge of the dark umbral shadow seen next to the Moon's bright disk appears even darker than it should.

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

THE IRRE

The giant planets host swarms of odd satellites, captured in the solar system's early days.

Order and disorder coexist in the universe like two sides of the same coin. Nature often favors order: Molecules organize to build the intricate structure of DNA, seashell spirals follow predictable mathematical patterns, and the planets orbit the Sun in a flat disk aligned with our star's equator.

Yet irregularity sometimes prevails. When it does, it offers glimpses into nature's hidden mechanisms, including the past events that warped its patterns.

This tension between order and chaos extends to the moons of the outer solar system. Among the hundreds now known, the most familiar examples — such as Saturn's Titan and Jupiter's Galilean quartet — fall into a category astronomers call *regular* moons. These bodies are typically large and round and orbit close to their planets, following stable, nearly circular paths aligned with the planet's equator and the direction of its rotation. The regular moons' behavior is linked to their origin, as they likely formed where they are, in some cases condensing from the same primordial gas and dust disks that built their planetary hosts.

But beyond these inner satellites lies a stranger popula-

◀▶ **TWO FACES** The Cassini spacecraft caught these views of Saturn's irregular moon Phoebe in 2004 as it approached *(left)* and receded *(right)* during a flyby. Each image is a mosaic of several frames. Phoebe is roughly 1⁄16 the size of Earth's Moon.

NASA / JPL-CALTECH / SPACE SCIENCE INSTITUTE

GULARS

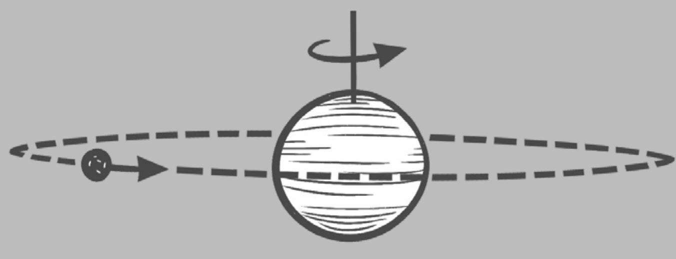
tion: the *irregular* moons. What defines irregular moons isn't size or shape — though few are round — but their orbits. Scattered at great distances from each of the four giant planets, they follow eccentric, tilted, and often *retrograde* orbits, moving in the direction opposite to how their planet spins, as if defying the solar system's gravitational choreography. Most of them are also small and faint, which enabled them to largely elude detection until the late 20th century.

These moons' rebellious orbits suggest a radically different origin story than for the regular moons. Irregulars are thought to be interlopers — objects born elsewhere and later permanently captured by the giant planets' gravity. While scientists largely accept this idea, many questions remain unanswered. When and how were the objects captured as moons? Where did they come from?

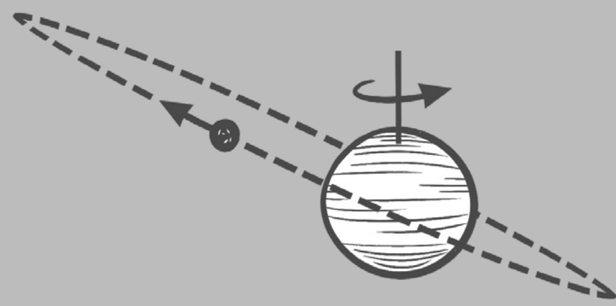
In answering these questions, scientists hope to learn more than the backstory of a few weird satellites. They hope to open a window to some of the most turbulent episodes in the solar system's evolution.

A Moving Family Photo

For more than a century, astronomers have known that not all moons in the solar system follow the same rules. The first clue came with the discovery of Neptune's Triton, found on October 10, 1846, by British amateur astronomer William Lassell — just 17 days after the discovery of Neptune itself. Roughly 2,700 kilometers (1,700 miles) in diameter, Triton remains not only Neptune's biggest satellite but also the largest known irregular moon in the solar system. It follows a retrograde orbit, and this orbit is tilted such that it dips 23° below the plane of Neptune's equator.



Regular satellites have nearly circular orbits, near the plane of their planet's equator. They orbit in the same direction as their planet rotates.



But irregular satellites tend to have elongated, tilted orbits. Most also travel in the opposite direction as their planet rotates.

LEAH TISCIONE / *S&T* (2)

More than half a century later, in 1898, astronomer William Pickering followed up with the discovery of Saturn's ninth moon, Phoebe. Like Triton, Phoebe moves in a retrograde and highly inclined orbit, but their similarities end there. Detailed observations from the Voyager 2 flyby and the Cassini mission later revealed that while Triton is a frozen world with a layered interior and signs of recent geological activity, Phoebe is a battered, potato-shaped space rock only about 210 km across — more asteroid than moon, with a surface pockmarked by countless impact craters.

For much of the 20th century, irregular moons remained little more than astronomical curiosities, as discoveries came at a glacial pace. By 1997, the count had barely crept into the double digits, with the addition of the first two irregular satellites found around Uranus.

But then, the trickle became a flood. In the first decade of the 21st century, the number of confirmed irregular moons surged past 100. And in a single announcement in 2025, astronomers reported 128 new irregular satellites orbiting Saturn, raising its total moon tally to 274 and making it the most moon-rich planet in the solar system. It's followed by Jupiter with 97, Uranus with 29, and Neptune with 16. These numbers almost certainly underestimate the real population.

This moon-spotting boom was powered by technical advances, especially the development of sufficiently large digital image detectors. Charge-coupled devices (CCDs) allowed astronomers to ditch the cumbersome photographic plates that had long been the standard. Discovering moons on plates was a "goddamn ugly way to find things in the sky," says planetary scientist and veteran moon discoverer David Jewitt (University of California, Los Angeles). Plates had to be physically hauled to telescopes, mounted in total darkness, exposed, and chemically developed — typically all in a single night. Then observers had to do it again on subsequent nights to reveal a moon's motion relative to the background stars. Comparing images involved careful inspection by eye. Chemical and temperature variations during development could yield uneven results that produced inconsistent data, making faint objects nearly impossible to track. "The whole exercise is wall-to-wall pain," Jewitt says.

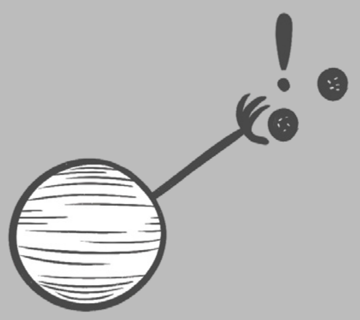
CCDs changed everything. By converting light into digital data, researchers could automate image analysis and dramatically increase sensitivity. Using techniques such as image stacking — which combines multiple exposures of the same field gathered hours or even nights apart — astronomers could amplify faint signals while filtering out noise. Armed with this technology, astronomers started to yank tiny moons out of the darkness.

Still, the moons are so small and distant that it requires time and dedication to find them. "In a single photo they appear as faint point sources, just like stars," says astronomer Mike Alexandersen (Center for Astrophysics, Harvard & Smithsonian). To confirm they're moons, astronomers need to take multiple images over several nights to calculate their orbits. If observers detect an object only once, they cannot be sure that it's a moon. The International Astronomical Union's Minor Planet Center maintains a long, private list of candidate observations that haven't yet been confirmed, Alexandersen says.

Moon discovery has different challenges for each planet. Uranus and Neptune are so distant that moons smaller than 10 km across likely remain unseen. Jupiter, although closer to Earth, presents different problems. Its *Hill sphere* — the zone where its gravity rules over the Sun's — is immense, some 15 times wider on the sky than the full Moon. This means that although the moons' movements relative to background stars are larger, astronomers must hunt across a large area to find new satellites. In other words, Jupiter's irregulars are easier to spot but harder to track.

Saturn sits at a more favorable distance for ground-based observation. While astronomers estimate that they've likely found all of its moons larger than 1 km, countless smaller ones probably remain undetected.

The next leap will probably come from new ground-based



These moons could not have formed in place — they must have been captured. Planets might have caught these satellites by snagging one member of a passing binary . . .

. . . or while planets were migrating in the outer solar system to their present locations.

survey telescopes, like the Vera C. Rubin Observatory, which will repeatedly scan vast regions of the sky with unprecedented sensitivity (*S&T:* June 2024, p. 34).

A Messy Neighborhood

The orbits of irregular moons are among the most complex in the solar system. Their wide orbits mean that although they're held by the gravitational pull of their host planet, they also feel the distant tug of the Sun. This combination causes their orbits to rapidly *precess*, transforming their trajectories into strange, shifting loops. As the long axis of the ellipse slowly rotates, the orbit never fully closes, tracing a complex, flower-like pattern around the planet.

This variability can produce weird gravitational effects with catastrophic results. One of them is the *evection resonance*, which occurs when a moon's orbital precession matches the rate of the planet's motion around the Sun. In this case, the effect of the Sun's gravitational influence compounds over time, stretching a moon's orbit until the satellite either crashes into its planet or is hurled away.

Another destabilizing effect, the *Kozai resonance*, creates orbital "forbidden zones." When the inclination of a moon's orbit falls between about 50° and 130° with respect to the planet's equator, a dynamic link forms between the orbit's tilt and its eccentricity. As the inclination shifts, the orbit elongates, increasing the chances of collision (with either the planet or other moons) or escape.

Together, these resonances suggest that today's irregular moons are the survivors of a larger population, culled by gravitational quirks. These effects also create an imbalance between prograde and retrograde moons: Retrograde orbits are generally more stable, while prograde ones are more easily disrupted by resonances. As a result, about 80% of the 358 irregular moons known today are retrograde.

But gravity isn't the only force shaping this strange family. Collisions have played a major role as well. Many irregular moons appear in orbital clusters, or *families*, that follow similar paths around their host planet, suggesting that they are the shattered remains of larger bodies that continue to inhabit the parent object's original orbit. Jupiter hosts several such groups, some retrograde, like the Carme family, with 31 known members, or the prograde Himalia family with nine.

If this interpretation is correct, then many of today's irregular moons are not primordial captures but second-generation objects. Yet collisions are exceedingly rare today, with maybe one happening every billion years or so, says planetary scientist David Nesvorný (Southwest Research Institute), who has modeled the disruption of captured moons in detail.

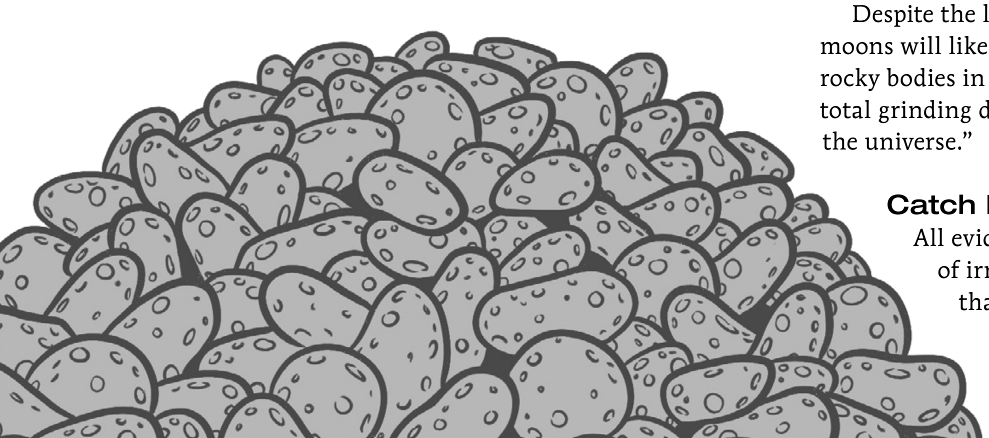
Despite the low collision rate, with enough time these moons will likely grind one another into dust, as will the rocky bodies in the asteroid belt, Jewitt says. "It's just that the total grinding down is going to take longer than the age of the universe."

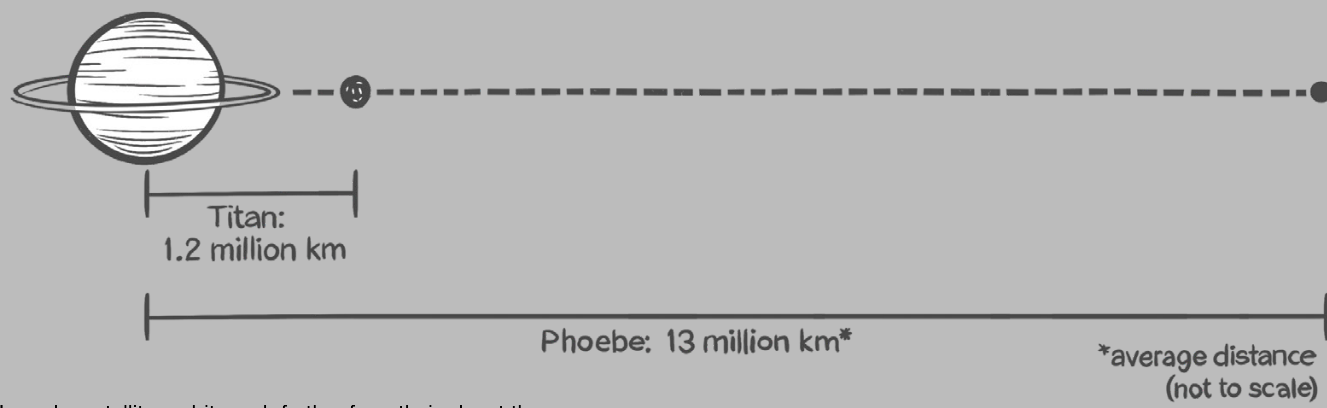
Catch Me a Moon

All evidence points to capture as the ultimate origin of irregular moons. There's no known process that can naturally form moons on such distant,

358
Number of known irregular moons, as of October 2025

ABOUT 80%
Fraction of irregular moons with retrograde orbits





Irregular satellites orbit much farther from their planet than regular satellites do.

tilted, and elongated orbits. "Even if you put a jet on a satellite and try to tilt it, it would be hard," Nesvorný says.

But capturing a moon isn't easy. For a passing object to be pulled into orbit around a planet, it has to lose enough energy to avoid simply flying past. In today's solar system, there's no effective way to lose that energy, meaning these captures must have happened long ago, under very different conditions.

In the 1970s, theorists proposed several capture mechanisms to solve the problem. One was *gas drag*: If Jupiter and Saturn had extended atmospheres during formation, friction might have slowed passing bodies enough for capture — a kind of natural aerobraking. This idea could work for the gas giants, but not for Uranus and Neptune, which likely never had such large atmospheres.

Another concept, called *pull-down capture*, suggested that as Jupiter and Saturn rapidly accumulated mass from the solar nebula, their increasing gravity swept up nearby objects into orbit. But this requires planets to grow extremely quickly — in a matter of millennia — a time scale that most formation models find unlikely. This mechanism also struggles to explain Uranus and Neptune's irregular moons, because the ice giants never had this sudden growth spurt.

"There's a problem with lots of capture theories: They're relatively inefficient," Nesvorný says. "I tried to simulate some of these ideas and realized they have zero efficiency or wouldn't produce [the expected] results."

The leading model today is *n-body capture*, in which capture is enabled by gravitational interactions between three or more bodies. (The *n* stands for an unspecified number of bodies.) One version of this idea involves a giant planet and a pair of smaller objects. During the encounter, one member of the pair is slowed down and captured by the giant planet, while the other is flung away into space. This scenario works well for large binaries, akin to the one comprising Pluto and its partner Charon, and may explain Triton's capture by Neptune. But it struggles with smaller objects and the sheer number of irregular moons seen today, Nesvorný says.

Another version involves interactions between the giant planets themselves. Modern models of solar system evolution suggest that the giant planets didn't form where they are today but spread outwards from a more compact arrangement. This migration could have caused close encounters between the giant planets, perhaps as close as one-tenth of the Earth-Sun distance. These encounters would have enabled the giants to wield their gravitational muscle more effectively on passing smaller bodies, slowing them enough for capture.

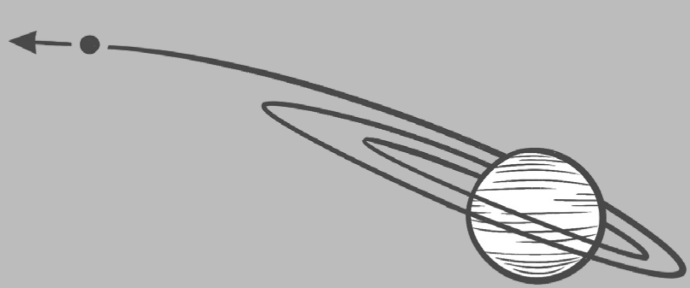
"THE EARLY SOLAR SYSTEM WAS MUCH MORE CROWDED, AND THAT JUST GAVE MORE POTENTIAL FOR CAPTURING THESE THINGS IN THE FIRST PLACE."
—DAVID NESVORNÝ

When Nesvorný modeled this process, he found that although its efficiency was extremely low — with a capture probability of roughly one in 10 million — it could nevertheless account for the observed population, provided the early solar system was sufficiently crowded. "If you have a billion [objects], you capture 100," he says. Estimates suggest there may have been as many as 100 billion objects of tens-of-kilometers size roaming the young solar system, creating countless opportunities for capture. "It's a game of very low capture probability and a very large population."

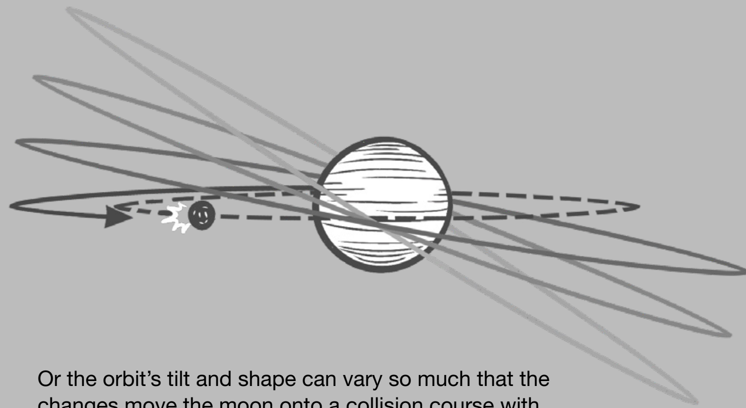
By the time the giant planets finished migrating, they had swept up or ejected much of this debris. The opportunities for new captures largely vanished.

"The solar system is empty today," Nesvorný says. "The early solar system was much more crowded, and that just gave

LEAH TISCIONE / *S&T*



They're so far out that the Sun's gravity can shift their paths over time. For example, the moon's orbit might become so elongated that, once at its farthest reaches, the satellite escapes the planet's gravity and drifts away.



Or the orbit's tilt and shape can vary so much that the changes move the moon onto a collision course with another object.

more potential for capturing these things in the first place."

The same applies to collisions in orbit: With fewer wandering objects, impact probabilities are now much lower than they once were, meaning that the moons' collisional families also date from this brief, chaotic window.

Captured from Where?

With all this planetary stirring, the question of where in the solar system the irregular moons formed before they were captured remains open.

One idea is that some irregular moons originated locally, as leftover planetesimals that never formed planets. These small bodies orbited in the giant planets' neighborhood during formation and thus moved more slowly relative to their hosts, making them easy to capture with even a minor gravitational nudge. Some of those small bodies might have become Trojans, small objects captured into stable gravitational regions along a planet's orbit (*S&T:* Oct. 2025, p. 72).

But an alternate possibility traces irregular moons' origins to the vast, icy expanse beyond Neptune that today holds dwarf planets like Pluto and a sparse population of frozen leftovers from the solar system's formation. This idea is supported by the presence of water and carbon-dioxide ices on Saturn's Phoebe and Neptune's Triton and Nereid, which suggests that these bodies formed far from the Sun. Early on, this trans-Neptunian region, which includes the Kuiper Belt (*S&T:* June 2025, p. 22), contained far more mass and in a flatter configuration than it does today. As Neptune migrated outward, the planet's gravity flung many objects into new orbits, sending some inward near the giant planets where they could be captured.

Regardless of whether the captured objects originated from the outer solar system or were locally sourced, the timing of the capture aligns well with evolving views of planetary migration. For years, the Nice model — a specific version of the giant-planet reshuffling idea — placed the giant planets' migration several hundred million years after their formation. But newer studies suggest the reshuffling likely occurred much earlier — perhaps within the solar system's first 100 million, or even the first 10 million, years.

Other destabilizing events may also have contributed. Some astronomers suggest that a stellar flyby — a close pass by one of the Sun's sibling stars in its crowded birth cluster — could have nudged objects inward. Such encounters are often invoked to explain oddities like Sedna, a body that follows a distant, elongated orbit far beyond Neptune.

Since one mechanism doesn't preclude the other, all could have played a role. "It's more a question of what was the dominant effect," says Susanne Pfalzner (Julich Supercomputing Center, Germany), who has simulated thousands of these scenarios. A stellar flyby, she notes, would naturally yield more retrograde than prograde captures, matching observations without relying solely on gravitational interactions.

Still, capturing an object coming from the icy reaches of the outer solar system isn't easy. "If you throw something out of the Kuiper Belt, by the time it reaches Jupiter's orbit, it's been falling toward the Sun for years and years," Jewitt says. And as it falls, it accelerates. "There's a huge amount of kinetic energy that has to be lost somehow in order for Jupiter to capture that body." Collisions or gravitational interactions could do the trick, but the odds are low. Fast-moving bodies are just hard to catch.

Judging by the Looks

One way of unraveling the origin of the irregular moons would be by determining their compositions. If some of these bodies indeed formed out beyond Neptune, their makeup should resemble that of known trans-Neptunian objects (TNOs) — primitive, volatile-rich relics from the outer solar system. But so far, the available data raise more questions than they answer.

The most accessible clue available today is color. TNOs tend to display a range of hues — from reddish to neutral — which reflect differences in surface chemistry. If the irregular satellites shared a common origin with those bodies, scientists might expect them to show similar patterns. But their colors just don't quite match, Jewitt says.

The mismatch could have several explanations. It's possible that some irregular moons were indeed born beyond Neptune but had their surfaces altered after capture. "When you bring a body in, it gets warmer," Jewitt explains. "Certain ices sublimate away, and everything just changes." Alternatively, objects that were scattered inward might have come from a specific part of the TNO region with a different initial composition, one more similar to what's observed in the irregular satellites. And not all of today's TNOs may have originally formed out beyond Neptune: Many were likely tossed there during the giant planets' rumble.

Color alone, however, is a poor proxy for composition. "My sweater is brown or orange," Jewitt says, "but that doesn't tell you what it's made of." To get more insights, astronomers are turning to spectroscopy — analyzing the light reflected from these moons to identify the molecules on their surfaces. Capturing spectra of such faint objects is difficult, but the James Webb Space Telescope, with its sensitive infrared instruments, is beginning to open this window.

Infrared spectra can reveal the presence of molecules such as carbon monoxide or carbon dioxide, which could tie a moon to a particular region of the solar system: Each of these compounds should solidify as ice at a different distance from the Sun during the planet-forming era. But even this method probes only the uppermost surface of a moon — just a fraction of a millimeter — leaving the moon's interior hidden.

Ultimately, uncovering the full story of these satellites may require direct exploration. A spacecraft mission — even a modest one — could transform our understanding of these moons, Jewitt says. The best would be to directly sample what the moons are made of, either by drilling a hole or blasting a crater into the surface and studying the debris. There is precedent from missions such as NASA's OSIRIS-REX or the Japanese Hayabusa 2, which both visited near-Earth asteroids and returned the collected samples to Earth.

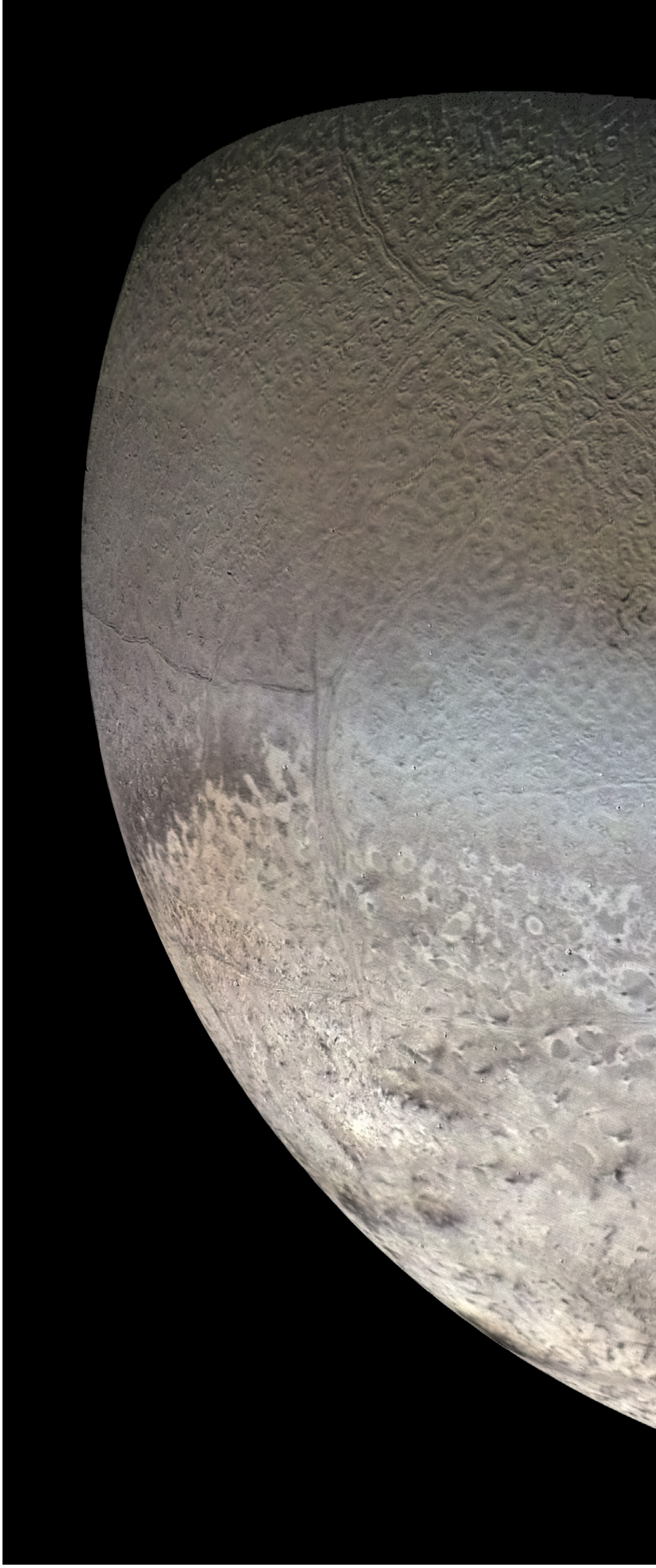
What we'll learn from the irregular satellites, we don't fully know yet, Jewitt says. "But the hope is that they'll tell us something about the early solar system, because that seems like it's the best time and place to capture these bodies."

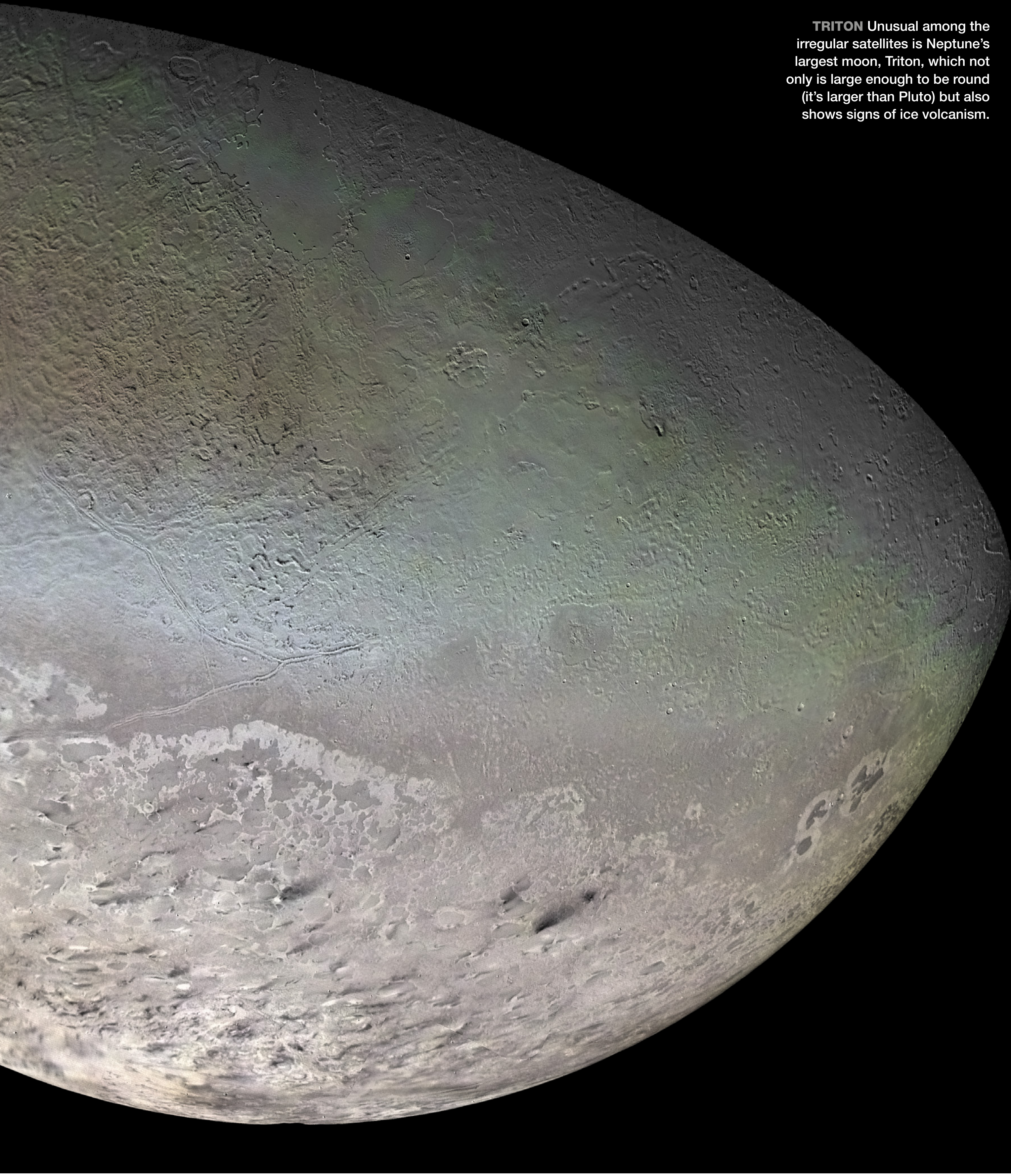
If the link between irregular moons and planetary encounters holds, then these odd moons are one more proof that a tumultuous chapter of migration in our solar system's history really occurred.

"We have evidence for that [upheaval] from the Kuiper Belt, from the Trojans, from different places in the solar system," Nesvorný says. Irregular satellites are an important record of that ancient chaos, another warped pattern revealing nature's dramatic disruptions in the distant past.

■ Contributing Editor **JAVIER BARBUZANO** is a science journalist fascinated by nature's mess and the unexpected rhythms and patterns that often emerge from it.

NASA / JPL / USGS





TRITON Unusual among the irregular satellites is Neptune's largest moon, Triton, which not only is large enough to be round (it's larger than Pluto) but also shows signs of ice volcanism.

BRIGHT ASTERISM The Winter Hexagon provides the hunting ground for this article's galaxy survey. The figure is outlined by some of the most prominent stellar luminaries in the night sky, namely Capella, Aldebaran, Rigel, Sirius, Procyon, Pollux, and Castor.

AKIRA FUJII

Galaxy-Hopping in the Winter Hexagon

Hunt for faint fuzzies in Orion, Gemini, and more.

In *Sky & Telescope*'s August 2025 issue, I presented my survey of small, faint galaxies that lie along the plane of the summer Milky Way, particularly the region within the Summer Triangle. For this article, we'll explore galaxies situated along the band of the winter Milky Way, this time with the Winter Hexagon as our hunting ground.

So why track down the tiny, nondescript galaxies there, while so many other showpiece targets adorn the winter sky? For me, it's the thrill of the chase and being able to view objects I haven't seen before. I suspect these galaxies rarely get more than a cursory glance from most observers. Perspective matters, too — observing objects lying outside the Milky Way is humbling when contemplating their great sizes and vast distances.

As before, I used *SkySafari* as well as José Ramón Torres's TriAtlas C charts (**https://is.gd/triatlas**) and *Uranometria 2000.0* to compile a list of potential targets. Connecting the vertices of the hexagon in *SkySafari* also helped me to visualize which galaxies reside within the asterism.

However, the Winter Hexagon covers more than 1,700 square degrees of sky, making my list — with more than 250 galaxies — too unwieldy. I pared it down by choosing objects suited to my 12.5-inch f/5 Dobsonian rather than the 20-inch Dob I used for the Summer Triangle project. That decision enabled me to excise 100-plus galaxies fainter than 15th magnitude. The *interstellarum Deep-Sky Atlas* (*iDSA*) also helped filter the list even further.

I completed my observing sessions in March 2025, having viewed only a quarter of my intended targets as health and poor weather limited my telescope time. The two dozen galaxies discussed here represent the highlights. Despite being small and faint, the majority of them should be visible in scopes smaller than my 12.5-inch. In most cases, my size estimates made at the eyepiece were quite a bit smaller than cataloged values (see the table on page 25). I used only two eyepieces for my observations: a 14-mm TeleVue Delos yielding 112× and a 0.6° true field of view and a 7-mm TeleVue Nagler yielding 225× and a 0.4° true field. Several constellations, such as Taurus, Eridanus, Canis Major, and Lepus, aren't represented, as either their galaxy-rich regions lie outside the Hexagon or their denizens were beyond the reach of my scope.

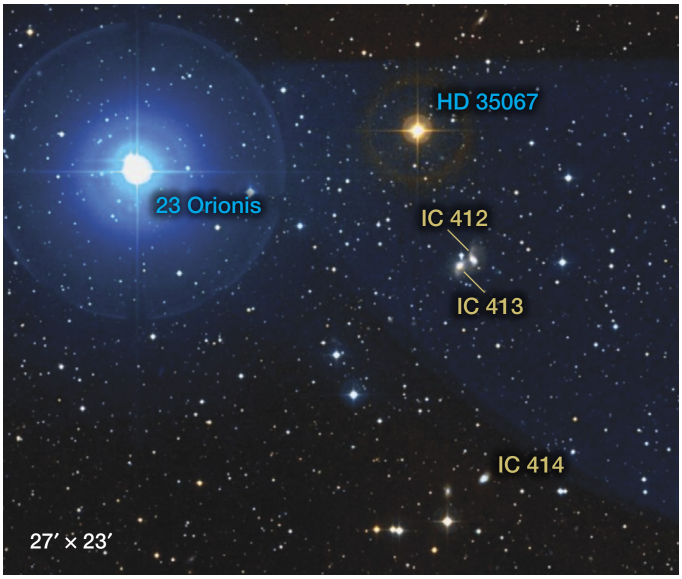
With that in mind, let's start with Auriga's lone representative in this survey: **UGC 3205**. I found this inclined spiral insidiously difficult. I estimate it's no more than 0.3′ × 0.25′ in size with some northeast-southwest elongation, but I didn't see any other detail. The galaxy marks the northeastern vertex of a small trapezoid with three 12th- and 13th-magnitude stars. The reflection nebula van den Bergh 31 as well as the dark nebulae Barnard 26, Barnard 27, and Barnard 28 lie ½° north of UGC 3205, but these eluded my detection.

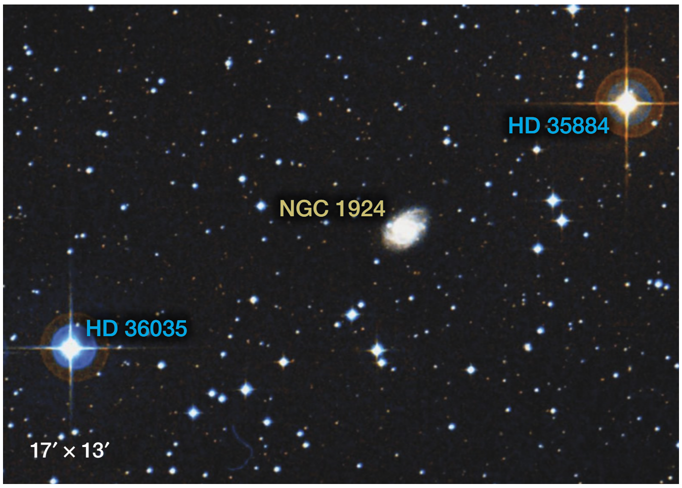
The Orion Contingent

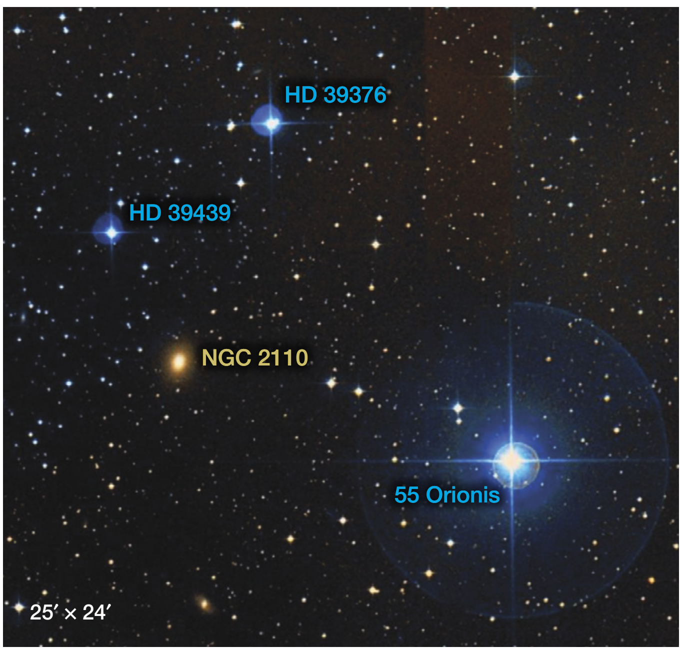
While working through my list, I quickly discovered that few of the galaxies could be called "big and/or bright." However, the *iDSA* rates **NGC 1762** to be visible through 8-inch scopes. Located 1¼° east-southeast of 4.5-magnitude Pi^6 (π^6) Orionis, this spiral appears 0.5′ × 0.3′, extending north-south. Although a 10th-magnitude star just east of the galaxy's center interferes with the view, with averted vision I suspected a stellar nucleus at 225×. NGC 1762 has hosted two supernovae this

▶ **DAVID AND GOLIATH** The spiral galaxy UGC 3205 looks minuscule compared to the vast expanse of the reflection nebula van den Bergh 31 in Auriga, but in reality, it's merely an effect of perspective. The galaxy lies about 170 million light-years away, while 7th-magnitude AB Aurigae, the variable star that illuminates the nebula, is much closer, at about 470 light-years (*S&T:* Jan. 2026, p. 14).

DANIEL NIMMERVOLL







◀ **ZOOMING IN** Use the following STScI Digitized Sky Survey images to help guide you to the exact locations of the objects featured in this article (see the text for additional star-hopping instructions). North is up in all the images. Not all the targets are represented (see the note on page 27).

FINDER DIAGRAMS THROUGHOUT THE ARTICLE: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY (7)

century (SN 2002cy and iPTF 13dge), so if you see an extra embedded star there, you might be onto something!

Sweeping ¾° west of the 5.5-magnitude star HD 34043, we find **NGC 1819**. As with most faint fuzzies, it can be difficult to catch under light-polluted skies. From my dark site, it appeared to span only 0.5′ × 0.3′, but its northwest-southeast elongation was reasonably obvious with averted vision. The barred spiral's vaguely defined halo appears lenticular; its arms are tenuous and require patience to hold steady in direct vision. You'll need to keep two 7th-magnitude stars — HD 33635, which is 13′ to the north, and HD 33447 lying 20′ to the west-northwest — out of the field to see the galaxy well.

You can find an intriguing trio of galaxies ¼° from 5th-magnitude 23 Orionis. **IC 412** and **IC 413** lie to the west-southwest and huddle close to a 12th-magnitude star tucked between them. IC 412 is the bigger of the two at 0.3′ × 0.2′ and elongated north-south; IC 413 appears rounder and 0.2′ across. I mostly saw the galactic cores, as their extended halos were all virtually invisible. At lower magnifications the pair blur together — I needed 225× to separate them. The extra magnification also kept 23 Orionis — and the 7th-magnitude star HD 35067 that lies 5.5′ north-northeast of the galaxy pair — out of view. In photographs, these little galaxies resemble NGC 4676 A/B, nicknamed The Mice, in Coma Berenices. I've dubbed IC 412 and IC 413 The Winter Mice as a result.

IC 414 hides just 8.5′ south of the pair. It's similar to its neighbors, but even more difficult to spot! I needed three nights and 225× magnification to pull this indistinct little vapor from the depths of winter darkness. The galaxy, spanning a mere 0.3′ in diameter, was visible with direct vision only at the best moments of seeing. A 1′-long east-west line of 10th- and 11th-magnitude stars 4′ to the southeast serves as a useful signpost for finding IC 414, but the 9th-magnitude star 2′ southeast of the galaxy can be a nuisance.

Leaving tiny, dim galaxies behind, let's move on to Orion's flashiest: **NGC 1924**. It may not be a showpiece galaxy, but it's a fine object nonetheless and conveniently situated a little less than 2° west of M42, the Orion Nebula. This face-on, barred spiral might even be visible in a 6-inch scope under good sky conditions. In his 2010 book *Cosmic Challenge*, Phil Harrington describes NGC 1924 as "a faint, oval disk accented by a stellar nucleus" as seen in his 8-inch Newtonian. It appeared more diffuse to me than photographs suggest and showed no central concentration in my 14-mm eyepiece, but its mottled texture and irregular 1.3′ × 1.0′ outline hinted at the object's spiral structure. The galaxy is flanked by two 8th-magnitude stars roughly along its major axis: HD 35884, which is 7′ to the northwest, and HD 36035 some 9′ to the east-southeast.

My final Orion galaxy is a great one for closing out the celestial Hunter. Lying 13′ east-northeast of 5.4-magnitude 55 Orionis, **NGC 2110** is impressive by winter galaxy standards — an ill-defined, 0.8′ × 0.7′ glow elongated north-south. It's bright enough for an 8-inch scope, particularly if you can keep 55 Orionis and a couple of other stars (8th-magnitude HD 39376 and 9th-magnitude HD 39439) out of the field. This intermediate spiral has a smallish, gradual oblong core, but no nucleus was visible at 112×.

Into the Hinterlands

I failed to spot my single target in Canis Major, but I managed to catch one in the densely crowded star fields of Monoceros. **UGC 3457** is as tough to see as it was to find. It's tiny — 0.3′ × 0.3′ — and elongated northeast-southwest. A magnification of 225× makes this lenticular galaxy stand out better; however, it's still minuscule and poorly defined, but revealed a slightly brighter core and hint of a stellar nucleus. Like NGC 1762, UGC 3457 was also host to a pair of supernovae this century, SN 2005ha and SN 2022blm. You can find UGC 3457 around 1.3° west of 5th-magnitude HD 45416 and 2½° south of the loose open cluster Collinder 91.

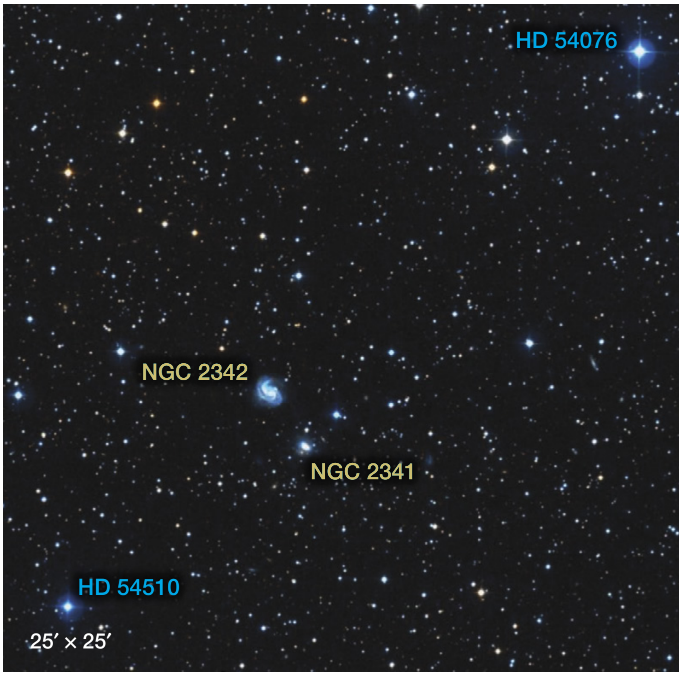
Canis Minor is teeming with galaxies, though very few present well in moderate apertures. Most eluded my best efforts, but the lenticular galaxy **NGC 2350** practically leaped out of the field at 112× as a 0.3′ × 0.2′ sliver oriented west-northwest to east-southeast with reasonably high surface brightness. No core or nucleus was visible even at 225×, though the extra power boosted the galaxy's contrast nicely. You'll find NGC 2350 nearly halfway from 5.4-magnitude 1 Canis Minoris to 4.7-magnitude 38 Geminorum. The 5.7-magnitude star HD 55730 lies 22′ to the galaxy's east-southeast.

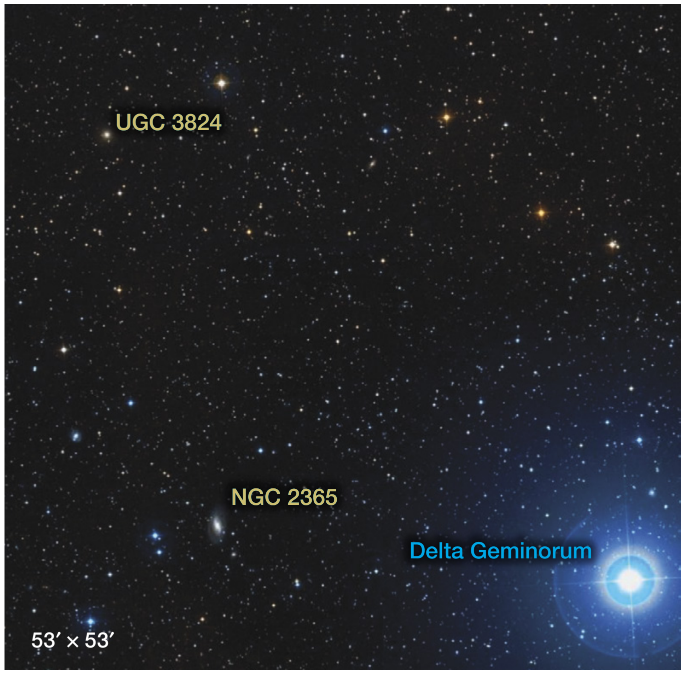
Heading northward into the realm of Gemini, we make our first stop at **NGC 2418**, an elliptical located 43′ west-northwest of 5th-magnitude 74 Geminorum. In my 12.5-inch scope at 112×, it appeared as a round, 0.8′ fuzz, with a small, gradually brighter core but no visible nucleus. The "diffuse

A Selection of Winter Hexagon Galaxies

Object	Constellation	Type	Mag	Surface Brightness	Size	RA	Dec.
UGC 3205	Auriga	Spiral	~14	14.1	2.1′ × 0.6′	$04^h\ 56.3^m$	+30° 03′
NGC 1762	Orion	Spiral	12.6	13.1	1.7′ × 1.1′	$05^h\ 03.6^m$	+01° 34′
NGC 1819	Orion	Barred spiral	12.4	12.6	1.3′ × 1.0′	$05^h\ 11.8^m$	+05° 12′
IC 412	Orion	Spiral?	13.7	13.2	1.3′ × 0.6′	$05^h\ 22.0^m$	+03° 29′
IC 413	Orion	Spiral?	13.8	13.5	1.0′ × 0.9′	$05^h\ 22.0^m$	+03° 29′
IC 414	Orion	—	~14	11.8	0.5′ × 0.3′	$05^h\ 21.9^m$	+03° 21′
NGC 1924	Orion	Barred spiral	12.5	13.1	1.6′ × 1.2′	$05^h\ 29.2^m$	–05° 18′
NGC 2110	Orion	Spiral	12.5	13.1	1.7′ × 1.2′	$05^h\ 53.4^m$	–07° 27′
UGC 3457	Monoceros	Lenticular	~14	13.8	1.2′ × 0.8′	$06^h\ 21.8^m$	+00° 22′
NGC 2350	Canis Minor	Lenticular	12.3	~12	1.3′ × 0.7′	$07^h\ 13.2^m$	+12° 16′
NGC 2418	Gemini	Elliptical	12.2	13.4	1.8′ × 1.8′	$07^h\ 36.6^m$	+17° 53′
NGC 2339	Gemini	Spiral	11.8	13.5	2.7′ × 2.0′	$07^h\ 08.3^m$	+18° 47′
NGC 2341	Gemini	Peculiar	13.2	12.6	0.8′ × 0.8′	$07^h\ 09.2^m$	+20° 36′
NGC 2342	Gemini	Spiral/peculiar	12.6	13.1	1.4′ × 1.3′	$07^h\ 09.3^m$	+20° 38′
NGC 2365	Gemini	Spiral	12.4	13.7	2.8′ × 1.4′	$07^h\ 22.4^m$	+22° 05′
UGC 3824	Gemini	Lenticular	13.4	12.9	0.9′ × 0.8′	$07^h\ 22.9^m$	+22° 35′
NGC 2274	Gemini	Elliptical	12.1	12.5	1.2′ × 1.1′	$06^h\ 47.3^m$	+33° 34′
NGC 2275	Gemini	Spiral	13.2	13.3	1.3′ × 1.0′	$06^h\ 47.3^m$	+33° 36′
NGC 2290	Gemini	Spiral	13.2	12.9	1.3′ × 0.7′	$06^h\ 51.0^m$	+33° 26′
NGC 2289	Gemini	Lenticular	13.2	12.8	1.1′ × 0.7′	$06^h\ 50.9^m$	+33° 29′
NGC 2294	Gemini	Elliptical?	13.8	12.5	0.9′ × 0.3′	$06^h\ 51.2^m$	+33° 32′
IC 2196	Gemini	Elliptical	12.7	13.2	1.4′ × 1.1′	$07^h\ 34.2^m$	+31° 24′
IC 2193	Gemini	Spiral	13.4	13.3	1.5′ × 0.7′	$07^h\ 33.4^m$	+31° 29′
IC 2199	Gemini	Barred spiral	13.2	12.6	1.1′ × 0.6′	$07^h\ 34.9^m$	+31° 17′

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.





filaments" that led American astronomer Halton C. Arp to include NGC 2418 in his 1966 *Atlas of Peculiar Galaxies* (as Arp 165) were well beyond my reach; experienced observers such as Barbara Wilson and Dave Tosteson were also unable to detect these filaments, even with 20-inch-plus Dobsonians.

More than half of the way from 5th-magnitude 51 Geminorum to 4th-magnitude Zeta (ζ) Geminorum, we find one of the better sights in this survey: the face-on, intermediate spiral **NGC 2339**. At 225×, it yielded a faint, starlike nucleus inside a gossamer 1.3′ glow. (Hubble Space Telescope observations indicate that NGC 2339 may have two nuclei!) In their *Observing Handbook and Catalogue of Deep-Sky Objects*, Christian B. Luginbuhl and Brian A. Skiff noted that it's "fairly faint" in a 10-inch scope. A star at the threshold of visibility is perched on the galaxy's northeastern edge, while the 8th-magnitude star HD 54511 lies 23′ east-northeast of it.

Sweeping 1¾° north-northeast from NGC 2339 brings you to one of the better galaxy duos in Gemini: **NGC 2341** and **NGC 2342**. At 1.3′ × 0.8′ in my eyepiece, NGC 2342 is hefty as late-winter galaxies go. Its poorly defined halo extends roughly east-west and appears of even, low surface brightness, with no central concentration. NGC 2341, lying 2.5′ to the southwest, is brighter but much smaller (0.5′ × 0.3′) and also elongated east-west. Luginbuhl and Skiff described NGC 2342 "only just visible" in a 6-inch telescope but didn't indicate that they saw NGC 2341 in the same instrument.

After several underwhelming galaxies and a number of misses, **NGC 2365** is a treat! Look for this highly inclined intermediate spiral 32′ east-northeast of 3.5-magnitude Wasat, Delta (δ) Geminorum. At 225×, it appeared 0.8′ × 0.5′ and oriented north-south, with an abruptly bright center and well-bounded halo. Several close pairs of stars ring the field at lower magnification, providing a picturesque foreground.

Just more than halfway from NGC 2365 to 6th-magnitude 58 Geminorum you'll find **UGC 3824**, a feeble, 13.2-magnitude round spot with a 0.3′ halo but no central brightening. You'll see this lenticular galaxy best when the 8th-magnitude star 10′ to its west-northwest is excluded from the field.

Last Stop: The Northern Tier

Our remaining galaxies all reside in northern Gemini. A little more than 1° west-southwest of 3rd-magnitude Theta (θ) Geminorum, we find the interacting pair **NGC 2274** and **NGC 2275** — the former an elliptical and the latter a spiral. At 112×, NGC 2274 is the more obvious of the two. It has a small core inside a faint, round 0.7′ halo, while NGC 2275 is an attenuated north-south streak, 0.5′ × 0.3′ in size. The pair is actually a triple system, as they're also interacting with UGC 3537, about 7′ west-northwest of NGC 2275. However, my efforts to find this 15th-magnitude phantasm proved futile.

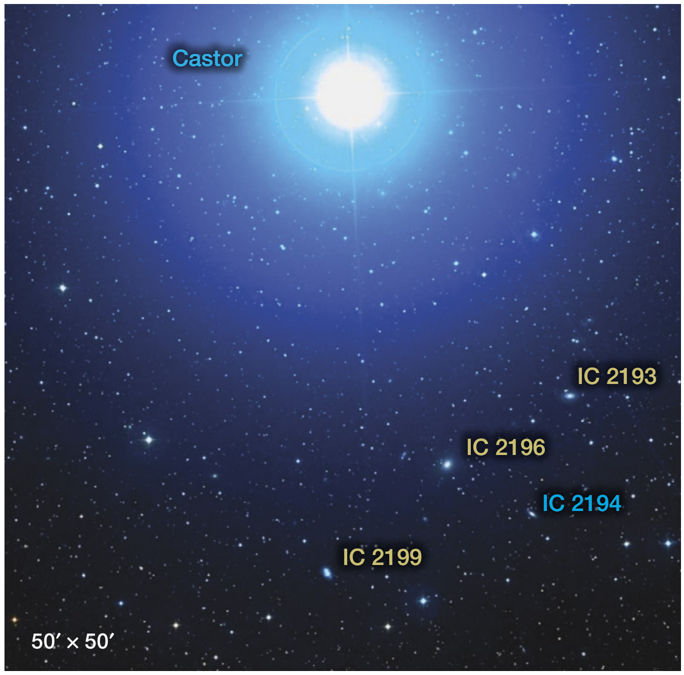
A richer group of galaxies lurks 38′ southwest of Theta Geminorum, but it took 225× to coax any of them into visibility. Paramount among these is the spiral **NGC 2290**, sitting 3′ north of a 10.6-magnitude star. Its insubstantial 0.7′ × 0.3′ halo is oriented northeast-southwest; a small, slightly brighter central region and embedded threshold star on its northern edge were visible at 225×. About 3′ north of NGC 2290 lies **NGC 2289**, which is also very diffuse and tenuous. Only 0.3′ across, this lenticular galaxy has a 14th-magnitude star 0.7′ to the north and a threshold star 1′ south-southwest of it (though this might have been the core of nearby NGC 2288 that I misidentified!). I completely whiffed on NGC 2291, despite several attempts, but I was able to glimpse **NGC 2294**, a little less than 5′ northeast of NGC 2289. NGC 2294 was extremely difficult, and I needed averted vision to extract its dim, 0.5′ × 0.3′ north-south halo from the background sky.

It can be frustrating to use 5th-magnitude stars as guideposts to find galaxies, especially when observing from light-polluted sites where 5th-magnitude stars need guideposts themselves! That's why I was relieved that our final group lies only ½° south of 1.6-magnitude Castor, Alpha (α) Geminorum. **IC 2196** is the middle galaxy in an evenly spaced trio that cascades northwest-southeast. (A fourth galaxy, IC 2194, evaded my attempts to spot it.) At 112×, IC 2196 appeared 0.7′ in diameter, with a vague central brightening and a weakly bounded halo.

Just 11′ northwest of IC 2196 is **IC 2193**, a well-defined wisp only 0.5′ × 0.3′ in size. It's elongated east-west and displays a small, abruptly bright core. A 13th-magnitude star hovers on the northeastern edge of the spiral galaxy's halo.

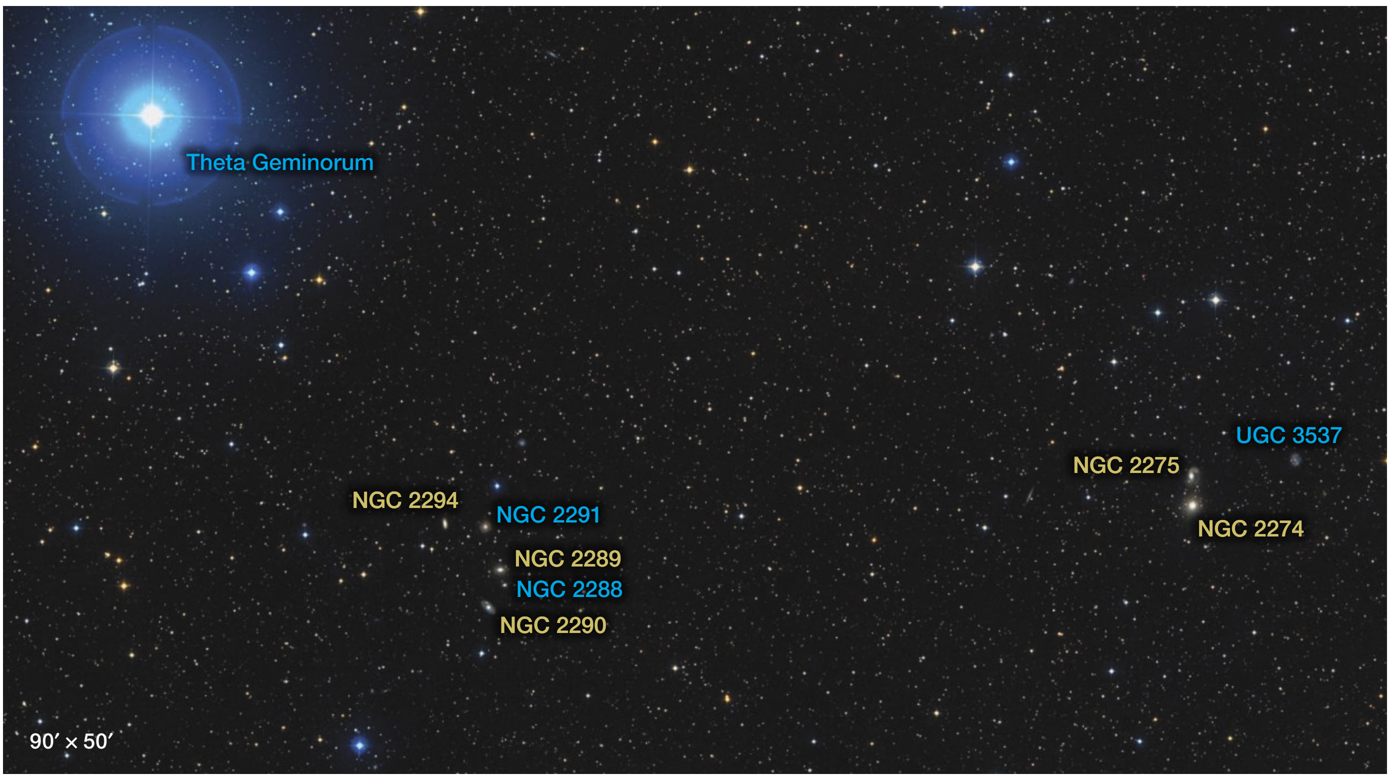
Lying about 12.5′ southeast of IC 2196, **IC 2199** is the largest and brightest member of the Castor trio — a face-on, barred spiral with an irregularly illuminated halo spanning 1.0′ × 0.5′ and extending northeast-southwest. It doesn't have a visible core or nucleus per se, but at 225× there were definite hints of spiral structure. While high power makes IC 2193 more difficult to observe, IC 2196 can handle magnification, and you'll want as much of it as possible to draw out details in IC 2199. Both IC 2196 and IC 2199 should be visible in an 8-inch scope but will require excellent sky conditions to reveal themselves.

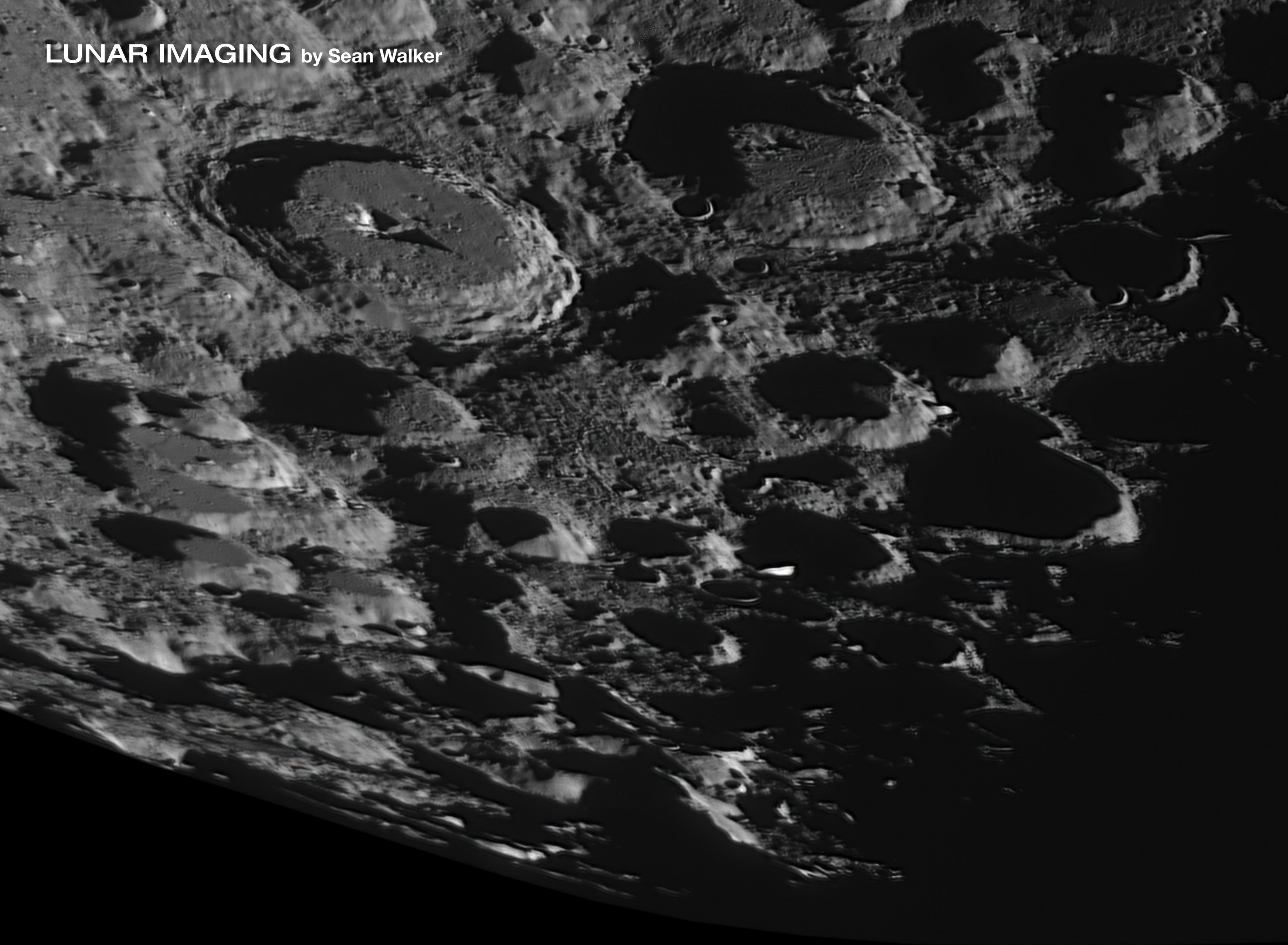
The winter Milky Way isn't all about glittering star clusters and breathtaking emission nebulae. Those looking for a challenge or with a yen for the obscure could spend many evenings tracking down the extragalactic denizens lurking in this shimmering swath of sky. So, the next time you're wondering what the winter sky holds besides the usual, consider peering out of our own galaxy toward the island universes that dot the vast cosmic ocean beyond.



■ You can follow Delaware-based **ANDY EDELEN**'s deep-sky adventures at **unfrozencavemanastronomer.wordpress.com**.

RESOURCE: To see the full set of finder images, you can go to **skyandtelescope.org/Winter_Hexagon_charts**.





Shoot the Moon in HD

Here's how you can capture detailed images of lunar features.

As the brightest object in the night sky, the Moon was likely the first astronomical target you saw in a telescope. It's also typically the first astronomical object that a fledgling astrophotographer aims a camera at. Usually, beginners hastily move on to other targets like the planets, clusters, nebulae, and galaxies. But the Moon deserves more attention. After all, it's the nearest world to ours and any optic reveals a wealth of detail unseen anywhere else. Imagers like me are continually drawn to this alien landscape's innumerable craters, mountains, and valleys. Here are some tips on how to get the most out of your conditions to reveal the smallest features your equipment can resolve.

▲ **LUNAR HIGHLANDS** The picturesque crater Moretus (top left) shows off its 2.1-kilometer-tall central peak in this sharp photo. A QHY5III678M camera was paired with the author's C14 for a scale of 0.1 pixels per arcsecond.

Choosing Your Optics

Lunar imaging is similar to photographing the planets, so if you want to record the finest details, you'll need a scope with a fairly large aperture. (A great introduction to imaging the Moon appeared in our February 2025 issue, page 55.) I'd suggest at least an 8-inch scope, or the largest your conditions can support. And tracking is a must — while you can take lunar snapshots at low resolution, you'll need tracking and slow-motion controls in order to capture specific areas, particularly if you want to create mosaics that encompass expansive areas of the Moon at high resolution.

While refractors produce the highest contrast and require the least amount of maintenance, they get rather expensive at apertures greater than 6 inches. A more economical choice is a Newtonian reflector or a Schmidt-Cassegrain telescope (SCT). These optical systems are much more affordable, with the Newtonian having the lowest cost-per-inch of any design. But each type also has several drawbacks. A typical Newtonian has a relatively long tube and requires a large equatorial mount or tracking platform for imaging. Even a fairly "fast" Newt, such as a 10-inch f/5 has a tube measuring 1.2 meters (3.9 feet) or longer. Additionally, when an equatorial mount is used, the scope's focuser can often end up at an awkward angle by the time you have centered your subject. And a long tube can flex as it changes orientation while tracking across the sky, requiring frequent recollimation.

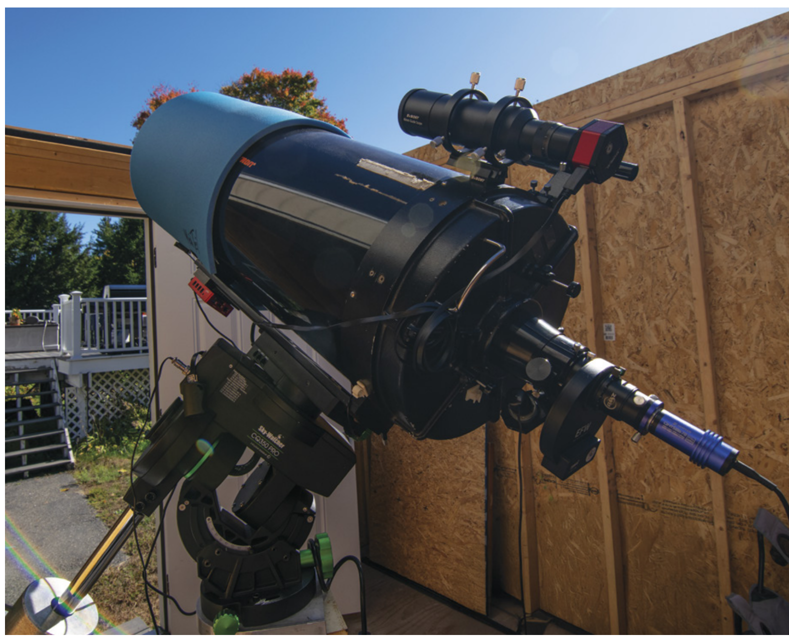
SCTs and Maksutovs are much better suited for lunar and planetary imaging due to their folded optical paths and generous focal lengths. Such scopes pack a relatively large aperture into a small tube using a perforated primary mirror and a curved secondary mirror to push the focal plane outside the rear of the telescope. The most common type, the Schmidt-Cassegrain, has a focal ratio of f/10 or greater, though some f/8 models are still available. Maksutovs are typically in the range of f/13 or greater. This rear-focuser position makes it easier to use certain accessories that we'll get into later. The drawback to using an SCT or Mak is the designs utilize a corrector plate at the front of the tube, which is prone to dewing up on moist evenings. As a result, you may need to take additional measures to prevent dew from forming or addressing it when it does. A dew shield can help, and a hair dryer can come in handy when dew forms on the optic. Another drawback to the Cassegrain design is these scopes most often focus by moving the entire primary mirror. This can cause the view to shift slightly when focusing and can throw off your collimation, too. To avoid this issue, most Cassegrain owners use an accessory focuser that attaches to the scope's visual back, eliminating the problem. Like Newtonians, Cassegrains can also fall out of collimation when the tube orientation changes while tracking a target across the sky — particularly when mounted on a German equatorial mount.

Despite the problems I've just described, many of the best lunar and planetary images today are recorded through large Cassegrains and even larger Newtonians. I've used all of these myself and for some 15 years my primary instrument was a 12½-inch f/5.1 Newtonian with an excellent mirror. More recently, I acquired a used Celestron C14 for imaging. But whichever instrument you choose, the key to getting the best lunar images is understanding and addressing the potential pitfalls of your system.

Cameras and Barlows

Once you've settled on a telescope, your next decision is what kind of camera to choose? The key parameters are its field of view and what resolution it provides.

Hands down, the best choice for lunar imaging is a high-speed video camera that sends its data to a laptop or other computer. You'll get your best results by recording thousands of images in a short period of time, then using software to identify, align, and stack the sharpest frames together to "beat the seeing." Other cameras, such as DLSRs, mirrorless models, and most deep-sky astrophotography cameras lack the high frame rates that specialized video cameras provide. Additionally, they are large, heavy, and require additional adapters to connect to your telescope. Fortunately, afford-



▶ **TINY CAMERAS, BIG DETECTORS** Most any camera can be used to photograph lunar craters, but the best results require a high-speed video camera like any of the models pictured at right. Look for those that have fairly large monochrome detectors. Cameras designed specifically for planetary imaging will work but may require mosaicking multiple fields in order to frame larger craters.

▶ **APERTURE IS KEY** Any telescope can take a pleasing picture of the Moon, but you'll need a good amount of aperture to resolve small-scale features. The author has imaged the Moon with all kinds of telescopes and currently uses a vintage Celestron C14 as his primary lunar and planetary instrument.

ALL PHOTOS COURTESY OF THE AUTHOR

▲ **ADDITIONAL ACCESSORIES** Along with an accessory focuser to avoid mirror-shift problems with SCTs, the author uses an electronic wheel loaded with red, green, blue, and near-infrared filters to shoot the Moon under various conditions. Attached to the wheel is a ZWO Atmospheric Dispersion Corrector (ADC), which corrects the prismatic separation of colors while shooting the Moon when it's at lower altitudes.

able planetary cameras are sold by a variety of manufacturers including Celestron (**celestron.com**), iOptron (**ioptron.com**), Player One Astronomy (**player-one-astronomy.com**), QHY (**qhyccd.com**), Touptek Astro (**touptekastro.com**), and ZWO (**zwoastro.com**). Most models are about the size of a typical eyepiece and come with a nosepiece adapter to allow you to attach the camera to your scope's focuser. In the pursuit of high-resolution lunar images, two specifications you should look for in a camera are the pixel size and the physical dimensions of the detector. When considering pixel size, bear in mind that lunar imaging requires a much finer *pixel scale* than deep-sky astrophotography. Pixel scale refers to the angular width of the area of sky covered by a single pixel, typically stated as arcseconds per pixel. This parameter depends on the focal length of your telescope and your camera's pixel size. To calculate pixel scale, plug your telescope's focal length (*F*, in millimeters) and your camera's pixel size (*P*, in microns) into this equation:

$$\textit{Pixel Scale} = 206.265 \times (P\ /\ F)$$

For example, let's say you have telescope with a focal length of 2,000 mm paired with a camera having 2-micron-square pixels. This produces a scale of 0.2 arcseconds per pixel. This is quite good, assuming your scope can resolve that level of detail. According to the Rayleigh criterion, a 14-inch aperture scope can theoretically resolve features as small as 0.33 arcsecond, so you'll need pixels about half that size to resolve those small features in an image (*S&T:* July 2025, p. 60). A good rule of thumb for lunar and planetary images is aim for 0.25 arcseconds per pixel under typical seeing conditions. Under near-perfect seeing, you can go as high as 0.1 per arcsecond.

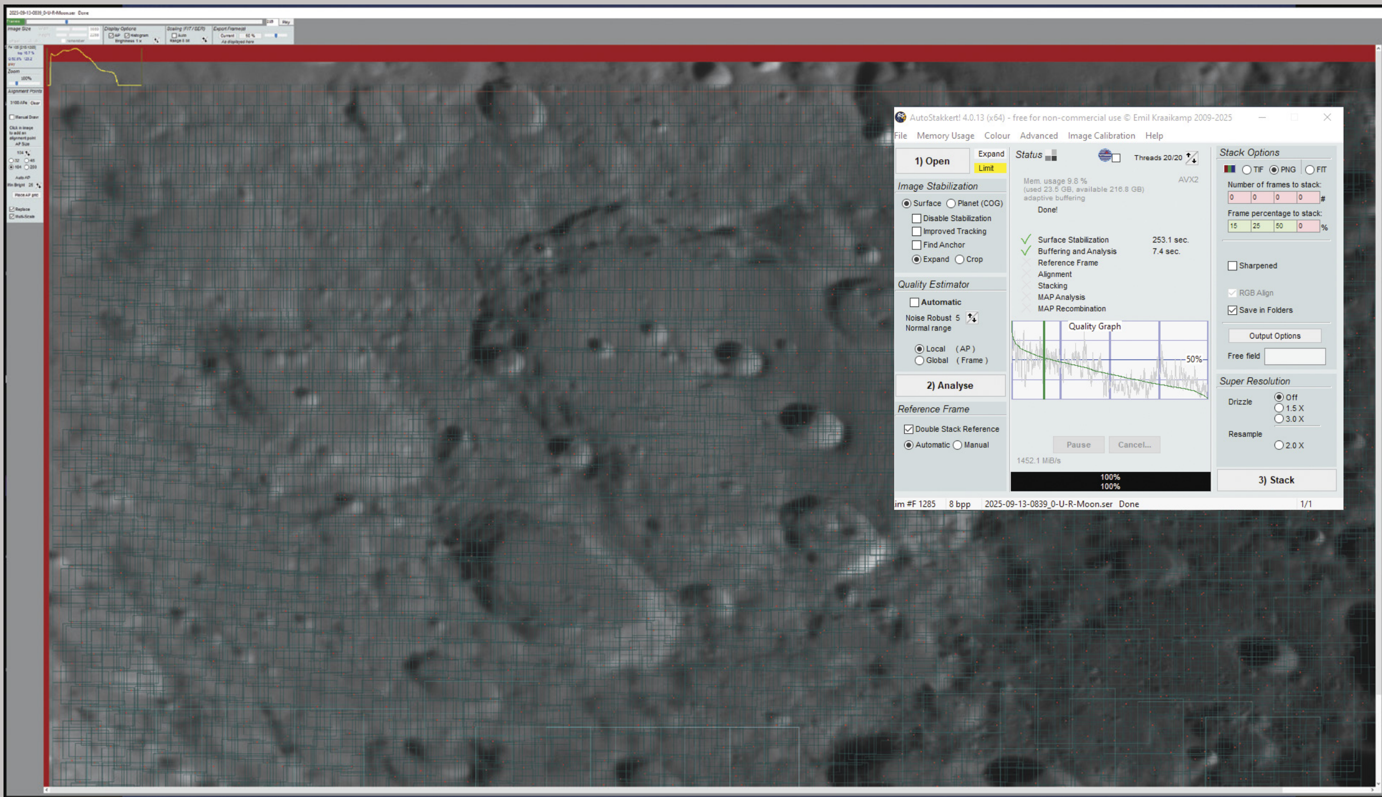
Of course, cameras have many different pixel sizes, so you may not find one that produces the perfect scale for your particular scope without requiring additional magnification. This is where a Barlow or a Powermate comes in. These devices are placed in the light path just in front of your camera and can get you to the pixel scale you desire. I own several Barlows and Powermates with amplifications between 1.3× and 4× and use them frequently with a variety of cameras. Just be aware that there is a point where more magnification won't improve the resolution no matter how good the seeing conditions are. *Empty magnification*, as it is known, occurs when your pixel scale exceeds the theoretical resolving power of your scope.

After pixel scale, the physical size of the camera's chip will determine how wide a field you can capture. Many planetary cameras have modest pixel arrays, often 2 or 3 megapixels. Thankfully, the planets (even Jupiter) are quite small and are recorded adequately with a relatively small chip. When imaging the Moon, you're better served by a larger detector that lets you capture expansive vistas at high magnification. With a small chip, you may not be able to fit many of the largest and most interesting craters on the detector — you'll need to shoot many overlapping fields and stitch the results together later in software to get the coverage desired. Fortunately, there are many great cameras suited for lunar imaging. My current favorite is the 8.4-megapixel QHY5III678M that I reviewed in the January 2024 issue (p. 66). Of course, cameras with large detectors can also be used for planetary imaging with the magic of *region-of-interest cropping*, where you set your control software to only record the region of the detector where the planet appears.

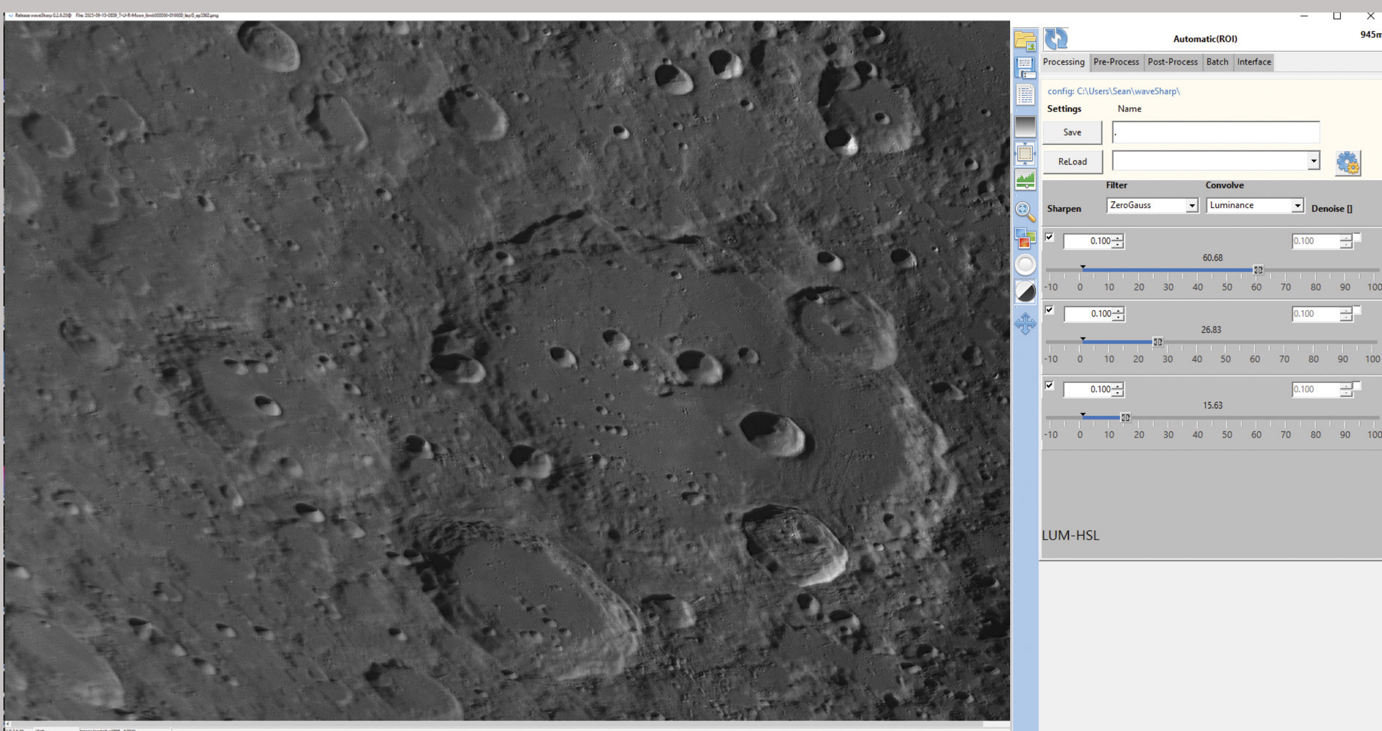
Color and the Atmosphere

The Moon is nearly monochromatic with extremely subtle colors. As such, it's the one target in the sky for which black-and-white images are often just as interesting as those shot in color. While you can use a color camera, your results may not be as sharp as you expect due to an effect known as *atmospheric dispersion*. Our atmosphere acts as a weak prism that slightly smears color wavelengths vertically. The closer your target is to the horizon, the worse this effect is.

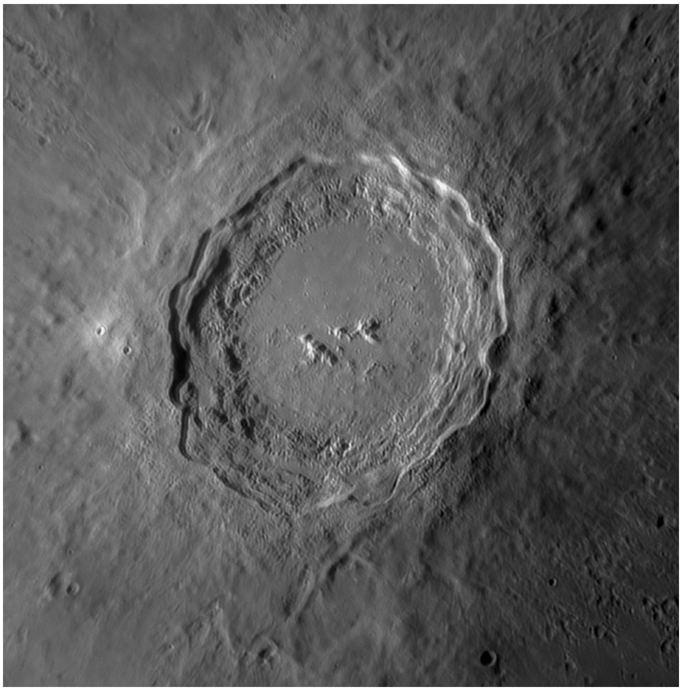
Color cameras are most affected by atmospheric dispersion, though monochrome ones aren't exempt from it either; most lunar imagers with monochrome cameras deal with this problem in two ways. They often image through a color filter in order to limit the bandpass the detector sees and thus reduce the dispersion. However, dispersion still occurs within the 200-nanometer passband of typical red, green, and blue filters. The best way to combat atmospheric dispersion is to image the Moon when it's nearest the zenith, though that would eliminate most phases of the Moon from consideration, particularly for those of us living in more northerly or southerly latitudes far from the equator. Lunar imagers can still take advantage of good seeing at low altitudes by using a small device called an

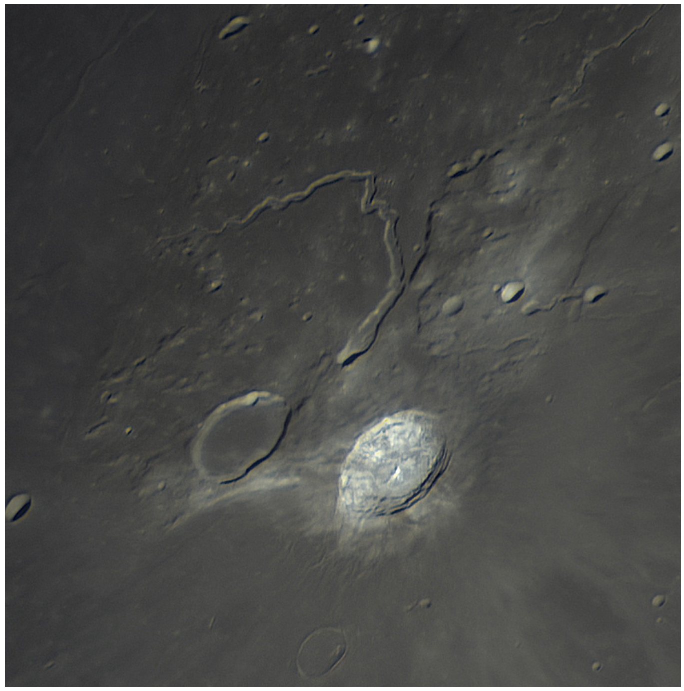


▲ **AUTOMATIC STACKING** *Autostakkert!* can batch-process your videos by simply opening the program and dragging the files into its window. It features multipoint stacking that, with a few prompts, will reduce your videos into 16-bit FIT, PNG, or FITS files ready for sharpening.



▲ **ADVANCED SHARPENING** Cor Berrevoets's successor to his popular stacking program, *RegiStax*, is called *WaveSharp* and makes quick work of sharpening high-resolution lunar vistas as well as letting you save settings that you can apply to each image.





▲ **ZOOMED IN** *Left:* This close-up of the crater Copernicus was recorded through the author's 1990s vintage Celestron C14 operating at f/22 with a Player One Astronomy Mars-M camera. Two videos were stacked, sharpened, and stitched together for this photo, which resolves the crater's central peaks as well as many craterlets on its floor. *Right:* This image of the bright crater Aristarchus and its surrounding plateau displays slightly warmer hues than most other regions on the lunar surface. It was taken with a Player One Astronomy Uranus-C color camera paired with the C14 under good seeing conditions. An atmospheric dispersion corrector was also employed to ensure sharp results free from color fringing.

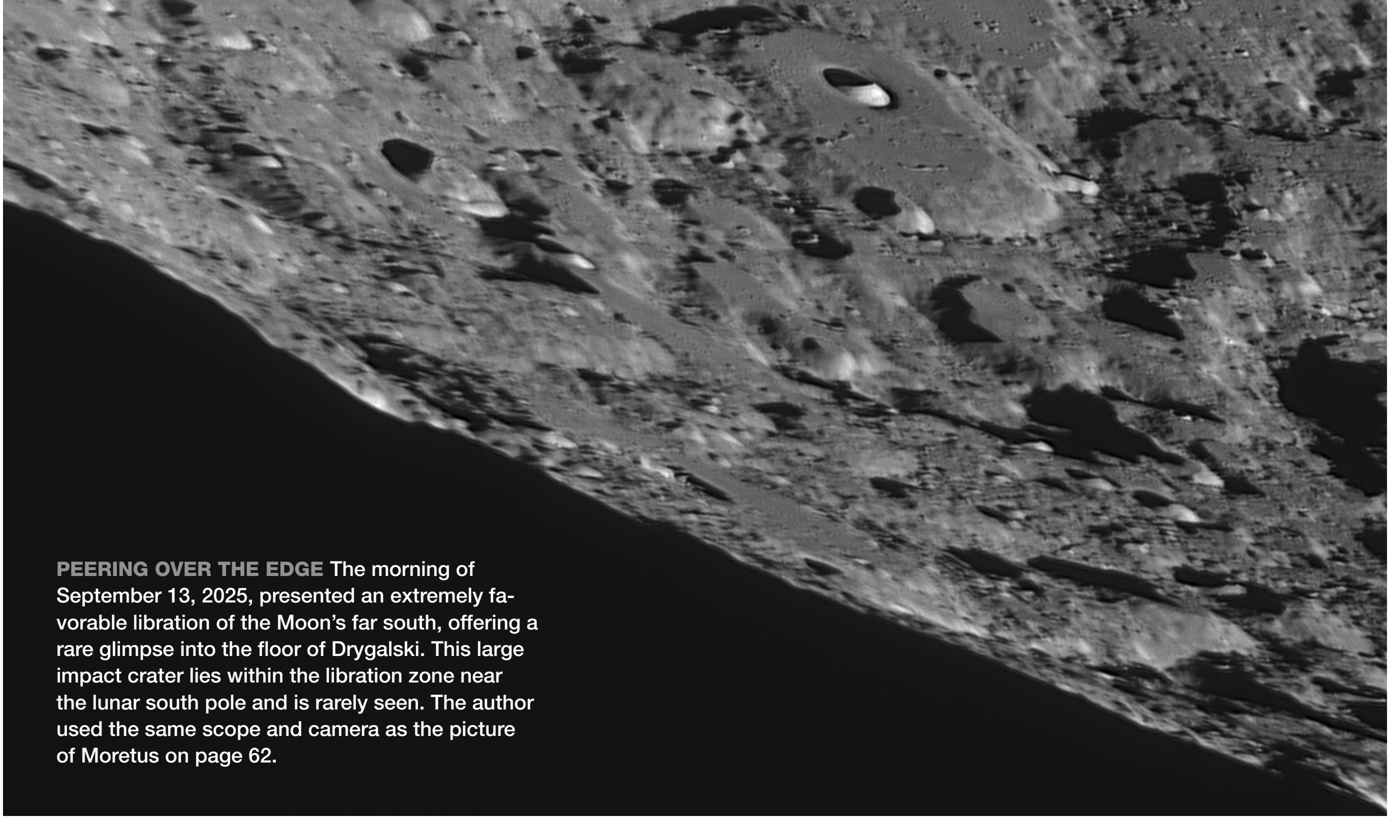
atmospheric dispersion corrector (ADC). An ADC uses two weak prisms that are tilted in small increments so that, when tuned properly, they counteract atmospheric dispersion. These devices work exceedingly well, both for imaging and visual use. The trick to using an ADC is that it must be aligned parallel with the horizon in order to work properly. This is particularly challenging when imaging through a Newtonian reflector, where the secondary mirror diverts the light path out the side of the tube, and one often doesn't know which way "up" is in the view. Cassegrains and refractors are better suited for use with an ADC because the focuser comes out of the back of the tube, so it's a simple matter of aligning the device. Some ADC models like the one from ZWO include a bubble level that makes its alignment a breeze on these scopes.

Other Atmospheric Components

In the pursuit of high resolution, the atmosphere is always the biggest factor affecting how sharp your results will be. And while you can't control the atmosphere, you can monitor the scintillation (seeing) through a variety of websites including ClearDarkSky (**cleardarksky.com**), Astrospheric (**astrospheric.com**) or meteoblue (**content.meteoblue.com**) to get an idea of what conditions should be like in advance.

Seeing, however, isn't limited to what's going on in the upper atmosphere. There are several things you can do to improve local seeing conditions. Set up your scope long before you plan to image so that the telescope can cool to ambient temperature. This can go a long way toward improving your results. Try not to set up on asphalt and avoid imaging when the Moon is above buildings. I've also found that aiming a freestanding fan at the mirror cell of my Newtonian keeps air moving and breaks up the "chimney effect" of warm air inside the tube.

Once all the pieces are in place and conditions are good, it's at last time to shoot the Moon! I control my cameras using the freeware *FireCapture* (**firecapture.de**). It supports most every planetary camera on the market today as well as electronic filter wheels and focusers. Another good option is *SharpCap* (**sharpcap.com**), which also offers a subscription-based version with additional features. Both include important tools such as a histogram readout that displays the signal level produced by your camera and helps you avoid over- or under-exposing your video. I typically set my exposure and gain settings so that the histogram doesn't peak at more than 90%. I record 30-second videos with my QHY camera, resulting in about 1,300 frames per video, simply to keep the videos a manageable size. I also use different color filters, depending on the seeing conditions. If it's extremely steady, I'll use a green filter, as telescopes are generally corrected best in the green as that's where human vision is most sensitive to light. Under less stable conditions, I'll choose a red filter since longer (redder) wavelengths are less affected by atmospheric scintillation than shorter ones. I'll sometimes use a near-infrared filter that passes between 685 and 1000 nanometers when the seeing is poor, though the resulting pictures don't show small craters quite as well as a red filter — telescopes suffer from greater diffraction at near-IR



PEERING OVER THE EDGE The morning of September 13, 2025, presented an extremely favorable libration of the Moon's far south, offering a rare glimpse into the floor of Drygalski. This large impact crater lies within the libration zone near the lunar south pole and is rarely seen. The author used the same scope and camera as the picture of Moretus on page 62.

wavelengths. I'll find the best combination of filter and Barlow then image until I've recorded all the features I'm after.

Stacking and Sharpening

Selecting the right equipment and acquiring a set of high-quality image sequences is only half the battle. To create lunar images that you'll be proud of, you also have to devote time and effort to image processing. Thankfully, good software to accomplish this is readily available, much of which is free. I'm partial to *AutoStakkert!* (**autostakkert.com**), which sorts and stacks all my lunar and planetary videos and needs little user input. Start by launching the program. In a moment or two, the control window will appear — drag and drop all your videos into the preview window. Most important when using the program for lunar video stacking is to first select ***Surface*** in the ***Image Stabilization*** section, then ***Local (AP)*** in the ***Quality Estimator*** section. Click ***2) Analyse*** after which the program will evaluate the video. In a few minutes, the process will complete, and a quality estimator graph will appear in the control window. Using this graph, I'll then choose how many frames to stack and input that value in the Stack Options section.

AutoStakkert! can output in TIF, PNG, or FIT formats, either using a precise number of frames or a percentage of them. Choosing how many frames to stack is often a compromise — more frames increases the signal-to-noise-ratio of the result, but that isn't helpful in poorer seeing where it will simply add more blurry frames, which in turn reduces small-scale details in the final result. So, often less is more. I typically will stack 10%, 20%, and 33% of the frames, but if the seeing is particularly good, I can use 50% or more.

Now on the left of the preview window, I choose the size of my alignment points and click ***Place AP Grid***. A radius of 104 pixels often works best with my particular imaging system, but you'll have to experiment to find what works best with your setup. Too many alignment points simply makes the stacking process take longer and won't produce a noticeably superior result. When the alignment points appear, they may not be placed all the way toward the terminator. If that's the case, lower the ***Min Bright*** value until you're satisfied with the selection, then click ***3) Stack*** in the control window. Depending on how many videos you're stacking and the speed of your computer, it may take a while before all the processing is complete.

After stacking, I often sharpen the result using either *WaveSharp* 2 or *RegiStax* 6 (both are available at **astronomie.be/registax**). There are many ways to approach wavelets in these programs, so I suggest starting with the top two sliders to see how they affect your picture before attempting the lower ones. Sharpen to taste, but avoid overusing the effect. You'll know you've gone too far if you begin to see a bright outline along high-contrast crater rims.

And that's all it takes. After sharpening, I'll either crop the image to frame the most interesting craters in the field or stitch together adjacent panels to increase the field.

The Moon is a fascinating world — familiar, yet full of surprising details. I love the challenge of trying to resolve the collapsed lava tube within Vallis Schröteri, or catching a rare shot of a crater residing just over the limb, brought into view during a favorable libration. The closer you look, the more interesting the Moon becomes. And each time I visit the lunar surface with my scope, I'm reminded of the wonder and awe I experienced with my first telescopic views.

■ Associate Editor **SEAN WALKER** photographs the Moon and other denizens of the solar system from his backyard observatory in Litchfield, New Hampshire.

 by Govert Schilling

Hunting for Terrestrial Twins

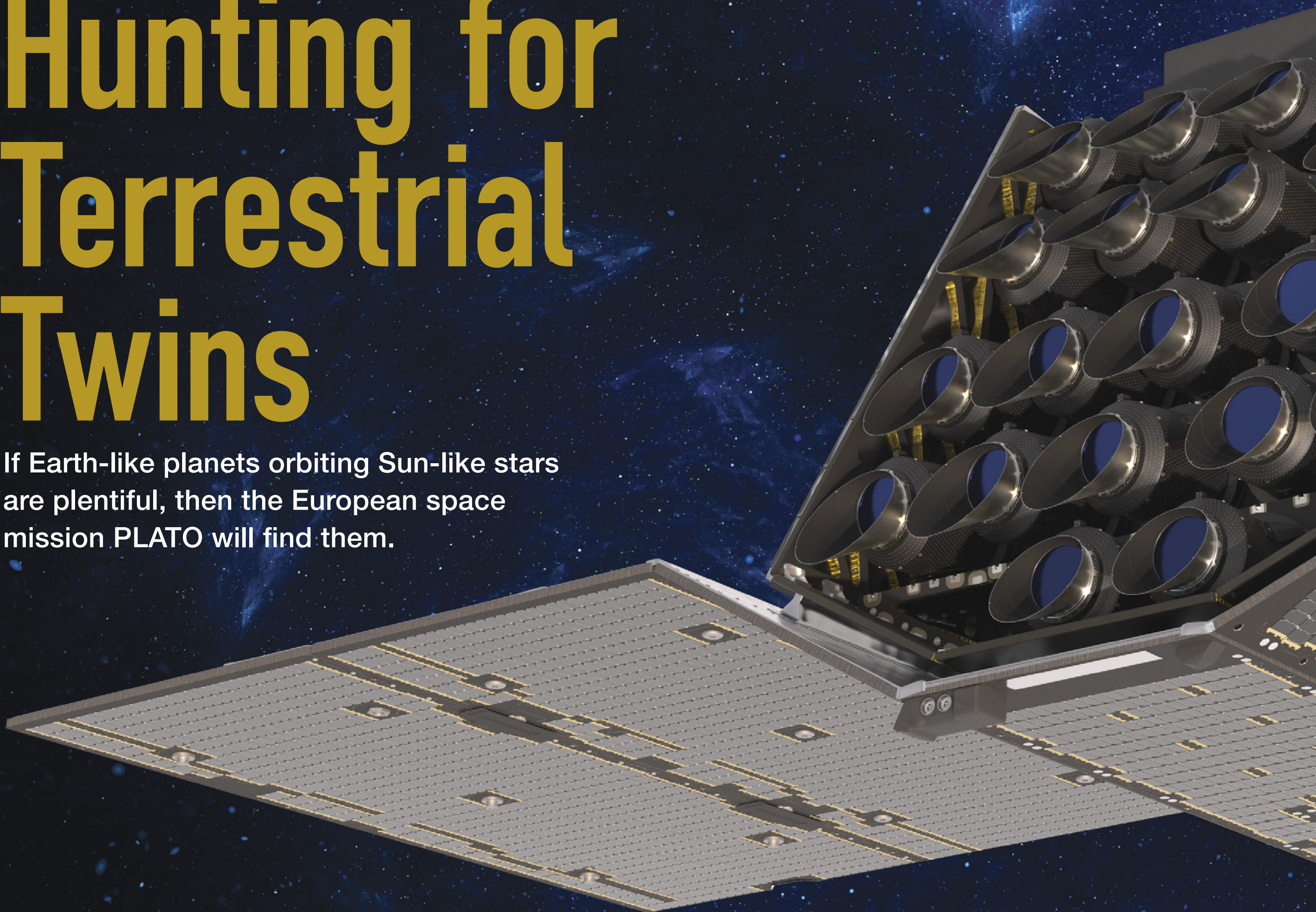
If Earth-like planets orbiting Sun-like stars are plentiful, then the European space mission PLATO will find them.

It's an impressive sight. Looming in the clean room of aerospace company OHB System AG in Oberpfaffenhofen (just southwest of Munich, Germany) sits the scientific payload module of Europe's next exoplanet-hunting space telescope. On this day in May 2025, the last two of the 26 high-tech cameras have just been installed. Technicians now start preparations to mate the huge optical bench (which holds the cameras) with the octagonal service module. Built by Thales Alenia Space in France, the service module holds the craft's electronics, thrusters, communications antenna, gyroscopes, and flywheels.

"Putting everything together was a big challenge," says OHB program manager Pablo Jorba Coloma, while he points out the hinged panel that contains all the electronic connections between the two, 1-ton halves of the European Space Agency craft. "Most satellites have between six and 10 different science instruments that operate independently," he adds. "Here, everything is basically part of one big instrument."

The installation of the solar panels and the final tests will happen at the European Space Research and Technology Centre (ESTEC) in the Netherlands, explains ESA project manager Thomas Walloschek. Planners foresee launch on an Ariane 6 rocket in late 2026 or early 2027. "We're on a pretty tight schedule, but so far, everything is going according to plan." Walloschek has been with the project for almost 10 years. "It's been a lot of fun," he says.

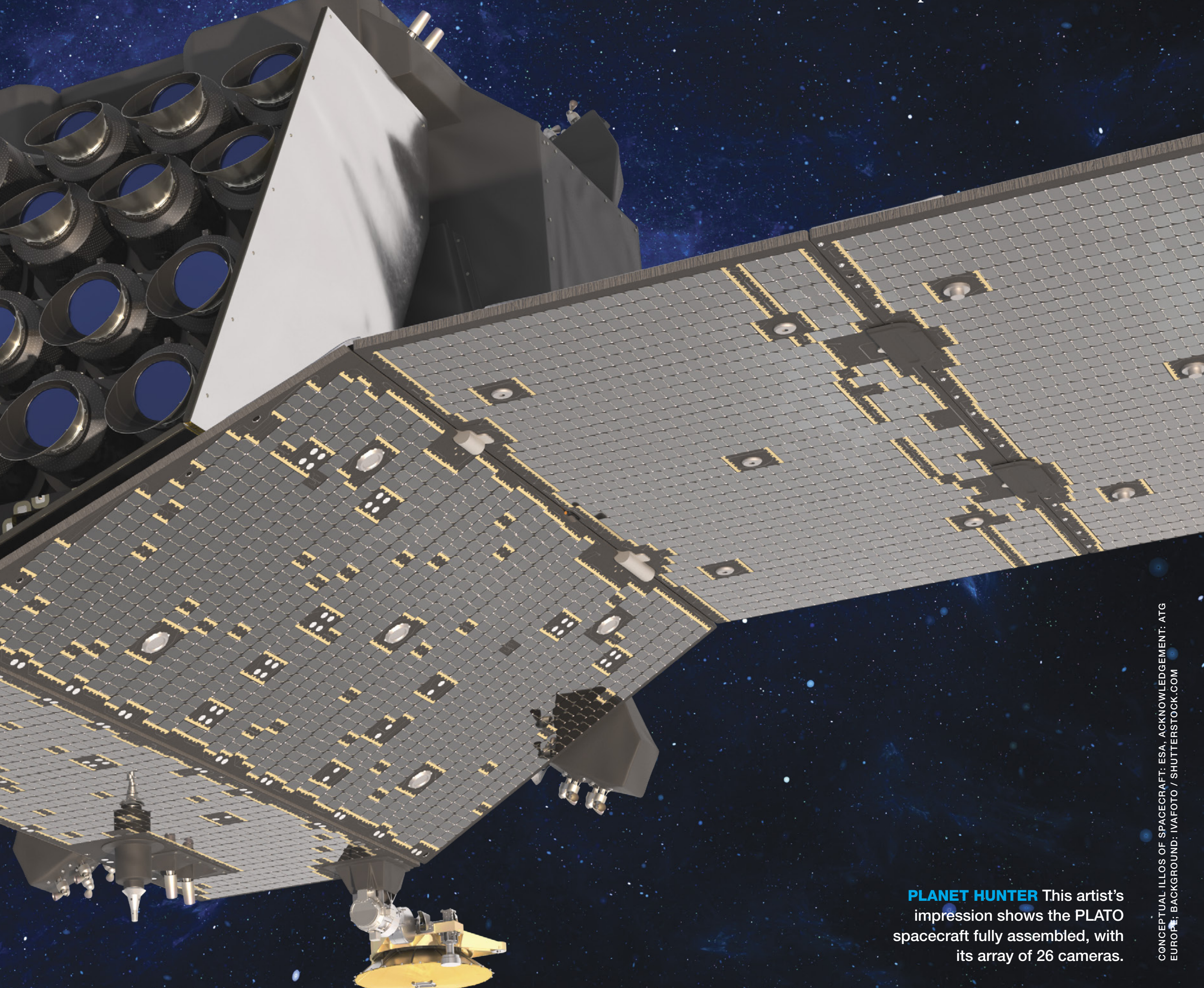
But for scientists, the real fun will only start when the Planetary Transits and Oscillations of Stars (PLATO) craft kicks off its four-year mission: a hunt for terrestrial twins,



rocky planets orbiting stars like our own Sun. The search will be carried out from the second Sun-Earth Lagrangian point, or L_2 — a gravitationally stable region 1.5 million kilometers from Earth's nightside that's also home to the James Webb Space Telescope (*S&T:* Oct. 2025, p. 72).

Like its American predecessors Kepler and the Transiting Exoplanet Survey Satellite (TESS), as well as the earlier European COROT mission, PLATO will find other worlds by looking for tiny, periodic brightness variations in stars' light, caused by planets that transit in front of their parent star as seen from our vantage point. Kepler and TESS discovered many giant exoplanets, as well as smaller ones in tight orbits around dwarf stars. But due to their missions' designs and the stars they studied, neither was able to find true Earth twins. "PLATO's main importance lies in its ability to discover Earth-size planets around Sun-like stars," says exoplanet researcher and TESS co-investigator Sara Seager (MIT).

The mission will also carry out high-precision measurements of stellar oscillations, a pursuit called *asteroseismology.* Stars ring like bells as waves move inside them. The frequencies and amplitudes of these small, periodic vibrations yield detailed information on the stars' sizes, masses, temperatures, and ages. This information, in turn, will enable precise characterization of the stars' planets. Oscillations put the O in the mission's acronym. Of course, the name also refers to Greek philosopher Plato (427–347 BC), one of the ancient founders of European science.



PLANET HUNTER This artist's impression shows the PLATO spacecraft fully assembled, with its array of 26 cameras.

CONCEPTUAL ILLOS OF SPACECRAFT: ESA, ACKNOWLEDGEMENT: ATG EUROPE; BACKGROUND: IVAFOTO / SHUTTERSTOCK.COM

P. SEBIROT / ESA

▲ **UNDER CONSTRUCTION** Engineers inspect PLATO's 24 newly installed cameras on the spacecraft's optical bench, which keeps all the cameras firmly pointed in the right direction. (The two "fast cameras" were still to be installed when this photo was taken.)

From Speculation to Discovery

Ever since Nicolaus Copernicus argued that Earth orbits the Sun (instead of the other way around), and as soon as it was realized that our Sun is just one of the countless stars in the universe, people have speculated about extrasolar planets, or exoplanets for short — worlds orbiting other stars. If rocky planets orbit in the so-called *habitable zone* of their parent stars, where temperatures allow the existence of liquid surface water beneath a suitable atmosphere, then the universe might teem with life-bearing planets.

Even back in the 17th century it was already evident that discovering these distant worlds would be extremely hard. Dutch astronomer Christiaan Huygens believed that it would be outright impossible, as the faint light of even large planets like Jupiter would be completely washed out by the glow of their parent stars (*S&T:* Oct. 2025, p. 22).

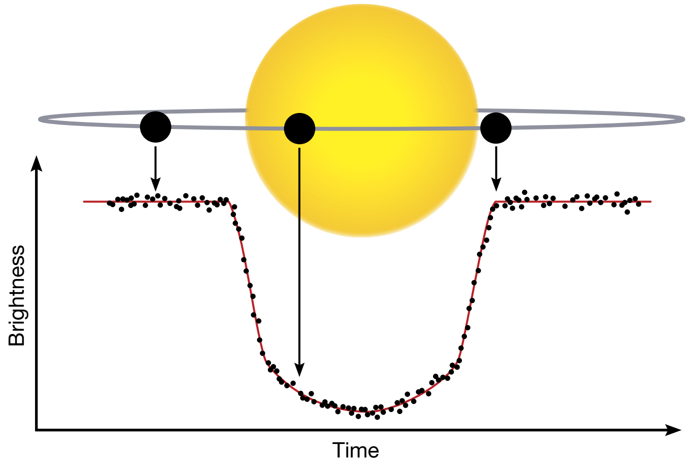
So it was no surprise that the first discovery of a planet orbiting a Sun-like star (51 Pegasi b, in 1995) was not a direct detection. Instead, Swiss astronomers Michel Mayor and Didier Queloz deduced the existence of the planet — a massive gas giant in an extremely tight, short-period orbit — from periodic variations in the star's *radial velocity* (motion along our line of sight), caused by the orbiting planet's gravitational tug. Since this first revolutionary find, which earned Mayor and Queloz a share in the 2019 Nobel Prize in Physics, astronomers have detected thousands of other exoplanets using this radial-velocity technique.

Yet another indirect way of finding exoplanets is by observing periodic transits of a planet across the face of its parent star — PLATO's chosen method. Depending on the relative sizes of the star and the planet, such transits may cause brightness dips of up to a few percent. These transits only occur when we have a nearly edge-on view of the planet's orbit, which is true for only a fraction of planetary systems. So, in order to find transiting exoplanets, astronomers need to observe large numbers of stars.

Eta-Earth

When using both the radial-velocity technique and the transit method, the easiest exoplanets to find are massive planets in short-period orbits around small dwarf stars: They cause the most frequent and conspicuous stellar wobbles and brightness variations. Finding Earth-like planets in Earth-like orbits around Sun-like stars — PLATO's main task — is much harder. First, you need to observe the star long enough to establish that the radial-velocity or transit signal repeats, and at the right cadence — after all, a terrestrial twin is expected to have an orbital period of about one year. Moreover, those signals are extremely weak: just some 10 centimeters per second (4 inches per second) for the radial-velocity variations, and less than 0.01% for the brightness dips.

Despite these challenges, figuring out the relative frequency of Earth-like exoplanets — a number known as η_{Earth}, or *eta-Earth* — was on the wish list of NASA's Kepler mission. Launched in 2009, Kepler monitored a 115-square-degree area



▲ **PLATO'S METHOD** PLATO will search for exoplanets using the transit technique. When a planet passes in front of its star from our perspective, it blocks a small fraction of the star's light. The plot of how the star's brightness changes with time is called a *light curve*.

LEAH TISCIONE / S&T

of sky in the constellations Cygnus and Lyra for four years, measuring the brightness of 150,000 faint stars (down to 16th magnitude) every 30 minutes. In the spacecraft's second life, dubbed K2 (*S&T:* Sept. 2014, p. 16), it stared at a series of fields, migrating from one to the next every 80 days for five years. So far, astronomers have discovered more than 3,300 exoplanets in the telescope's data.

That's a great achievement, of course, but "still these data have not allowed scientists to reach a consensus on eta-Earth," says PLATO project scientist Ana Heras (ESTEC). The reason, she explains, is that the tiny brightness dips produced by Earth-like planets transiting Sun-like stars largely drowned in the measurement noise, which was a mixture of instrumental noise and low-level stellar variability. PLATO's target stars are brighter than Kepler's, so PLATO's observations will have on average a higher signal-to-noise ratio, improving the overall performance.

Kepler also had difficulty in pinning down the stars' characteristics. To work out the true dimensions of a transiting planet, astronomers first need to precisely determine the parent star's width — only once you know the stellar diameter can you translate the depth of the brightness dip into an accurate diameter for the planet. Next, if you also want to learn about the planet's composition, you need to follow up the discovery with radial-velocity measurements to deduce the planet's mass, which combined with the diameter gives you the average density. But these measurements are difficult to make for the star systems that Kepler observed.

With Kepler's successor TESS, launched in 2018 and still operational, planet hunters took a different approach. TESS's four wide-field cameras pan from one field to the next every month, eventually surveying almost the entire sky. Because of the short exposure times, the mission mainly focuses on stars brighter than 12th magnitude. The satellite's observing strategy means that it is especially good at detecting short-period exoplanets (which, incidentally, turn out to be very common). As of October 2025, TESS had discovered slightly more than 700 confirmed planets as well as several thousand candidate transits.

"PLATO fills the gap between Kepler and TESS," says Heras. "Everything is designed to achieve the goal of finding Earth-like planets in the habitable zones of Sun-like stars. Our stars need to be brighter than Kepler's, in order to carry out sensitive radial-velocity follow-up observations." At the same time, the instrument will also observe the stars for longer periods, since a planet in the habitable zone of a Sun-like star will have an orbital period of at least eight months or so. "Neither Kepler nor TESS provided that combination," she adds.

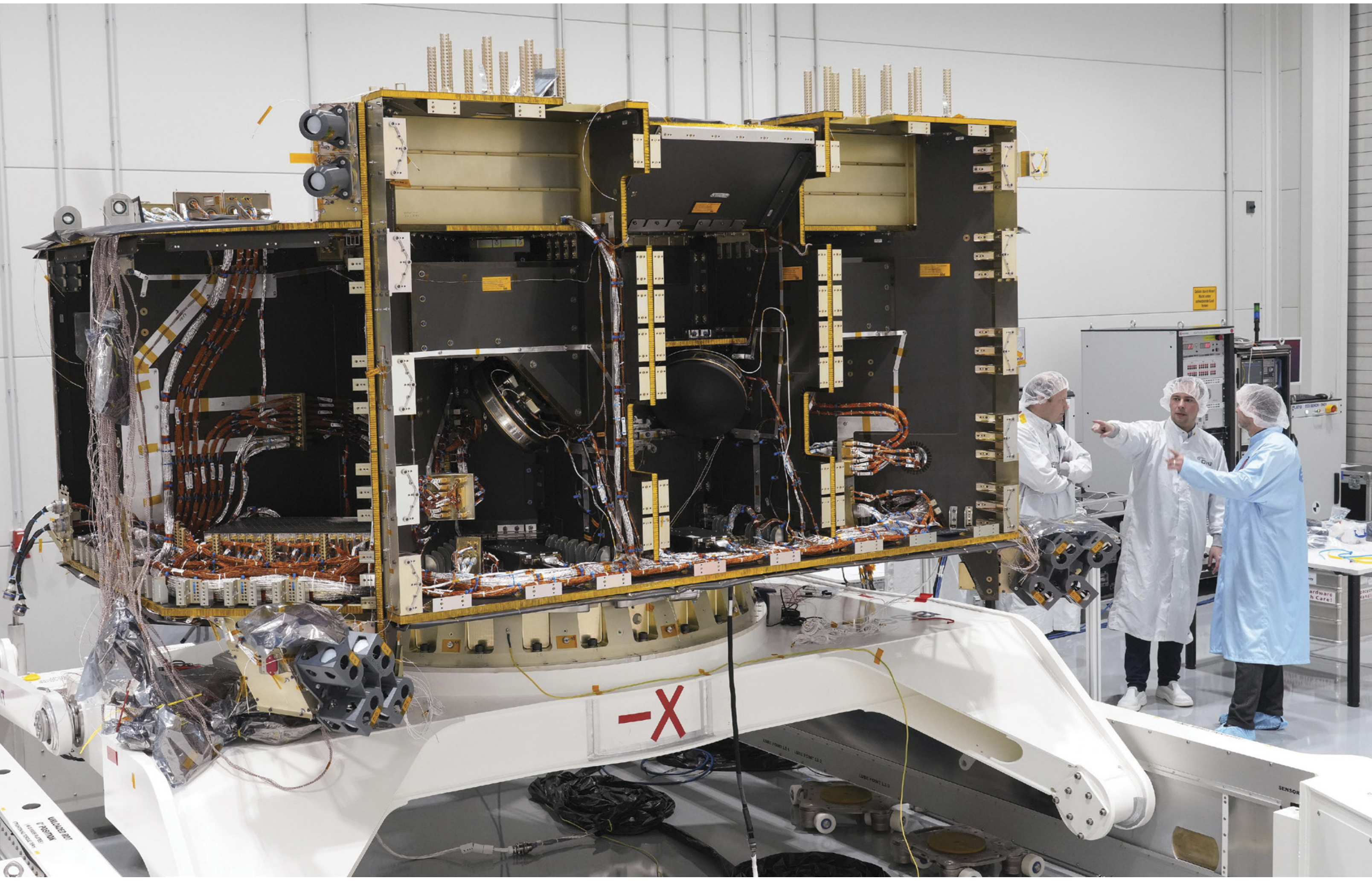
Lights, Camera, Action

At the heart of the PLATO mission is the spacecraft's battery of 26 high-resolution cameras, built by an Italian-Swiss-Swedish consortium. Two of those — known as the "fast" cameras — will be used for navigation and guiding. (Walloschek calls them "our super star trackers.") But because the fast cameras' exposure times are short, just 2.5 seconds, they will also provide brightness measurements of the very brightest stars in the field of view, those between 4th and 8th magnitude. Those stars would saturate the sensitive CCDs on longer exposures.

The 24 "normal" cameras have exposure times of 25 seconds, enabling detections of stars between 8th and 16th magnitude, although precision brightness measurements are limited to stars brighter than 11th or 12th magnitude. Each wide-angle camera has an aperture of 120 millimeters, a large field of view of 1,100 square degrees, and an array of four CCDs measuring 4,510 by 4,510 pixels, for a total of almost 81.4 megapixels. Together, the 26 cameras sport an impressive 2.1 gigapixels. According to Jorba Coloma, PLATO has the largest detector array ever flown in space. "It has about twice the number of pixels that Gaia had," he says, referring to ESA's successful astrometry mission (*S&T:* Feb. 2023, p. 34).

The science cameras are arranged in four groups of six. Each group observes a slightly different part of the sky, angled about 9° away from the central axis. These areas overlap, so that the combined field of view measures 49° on a

▼ **SERVICE MODULE** This part of the spacecraft contains the systems that support PLATO's operation, including the computers and thrusters. The optical bench platform with the cameras connects to the long side that's facing the viewer.



P. SEBIROT / ESA

side. That's a whopping 2,200 square degrees (more than 5% of the whole sky), or 1.7 times the area of the constellation Ursa Major, the Great Bear.

The spacecraft points six cameras in exactly the same direction to improve the signal-to-noise ratio, explains Heras. "Originally, the plan was to build four groups of eight," she says, "but we had to bring that down to four groups of six, because of mass and budget constraints."

Since the center of PLATO's combined field of view is observed by 24 cameras, the measurement accuracy in that area is at its highest. But even for stars observed by just six cameras, brightness variations of about 50 parts per million (0.005%) should be detectable in principle, according to Heras. "In general," she says, "PLATO will be able to detect planets larger than or equal to Earth with orbital periods of up to one year over its full field of view."

That high photometric accuracy also paves the way for the detection of tiny stellar oscillations. From these, astronomers can work out stars' properties using astrophysical models of stellar interiors, just like terrestrial seismologists learn about the properties of our planet by studying the propagation of earthquakes. With stars' sizes firmly established, planetary diameters can be deduced with just 3% accuracy. If ground-based telescopes also measure the radial-velocity variations of a transiting planet's parent star, astronomers should be able to determine the planet's mass to within 10%.

Observing Strategy

In the clean room at OHB System AG — the prime contractor for the development of PLATO — Jorba Coloma points out the huge optical bench on which the 26 cameras are mounted. The optical bench is made of carbon-fiber-reinforced polymer, a stiff, lightweight material that resists the expansion and contraction that temperature swings cause. Still, to maintain the cameras' precise mutual alignment, temperature variations have to be kept at a minimum, he explains. The solar panels of the spacecraft, measuring some 9 by 3 meters (30 by 10 feet), will double as a sunshield, and the optical bench and service module will be as thermally isolated from each other as possible.

The detectors are kept at –80°C (–112°F) to increase their sensitivity; precise focusing is achieved by minutely changing the temperature using small heaters. "Minus-80° turns out to be cold enough to meet the scientific requirements of the mission," says Walloschek, "so there was no need for even lower temperatures — the spacecraft is complicated enough already."

ARIEL – ESA's Next Exoplanet Mission

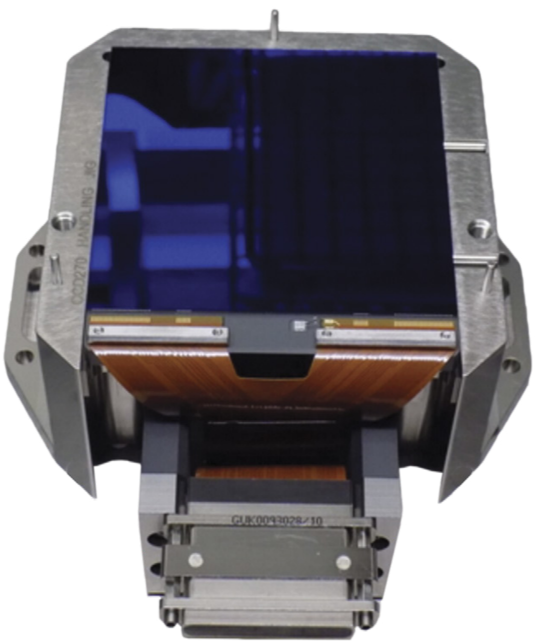
In 2029, ESA plans to launch its next ambitious space mission to study exoplanets. The Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL) telescope will not focus on the discovery of new exoplanets. Instead, it will study the atmospheres of at least 1,000 known transiting planets, including gas giants as well as rocky worlds. Using an elliptical 1.1-by-0.7-meter (3.6-by-2-ft) primary mirror, visible and near-infrared imagers, and a sensitive infrared spectrometer, ARIEL will determine the relative abundances of various gases in each exoplanet's atmosphere, such as water vapor, carbon dioxide, and methane. It is the first mission fully dedicated to the study of exoplanetary atmospheres.

The craft's orientation in space must also be precise. For many months on end, PLATO will stare at one particular area of the sky. But because of its location at L_2, it will orbit the Sun once a year. That means the spacecraft has to be rotated by 90° every three months, to keep the solar panels in sunlight and the cameras in shadow, while continuing to observe exactly the same patch of sky.

Astronomers have so far selected one official observing field for PLATO, south of the ecliptic. This field is centered not too far from the bright star Canopus and overlaps with TESS's southern *continuous viewing zone* — an area in the sky that the spacecraft constantly studies. After observing this field for two years on end, PLATO could keep staring at the same part of the sky for another two years, or it could move to another field. PLATO's mission designers have not yet made a final decision on the observing strategy.

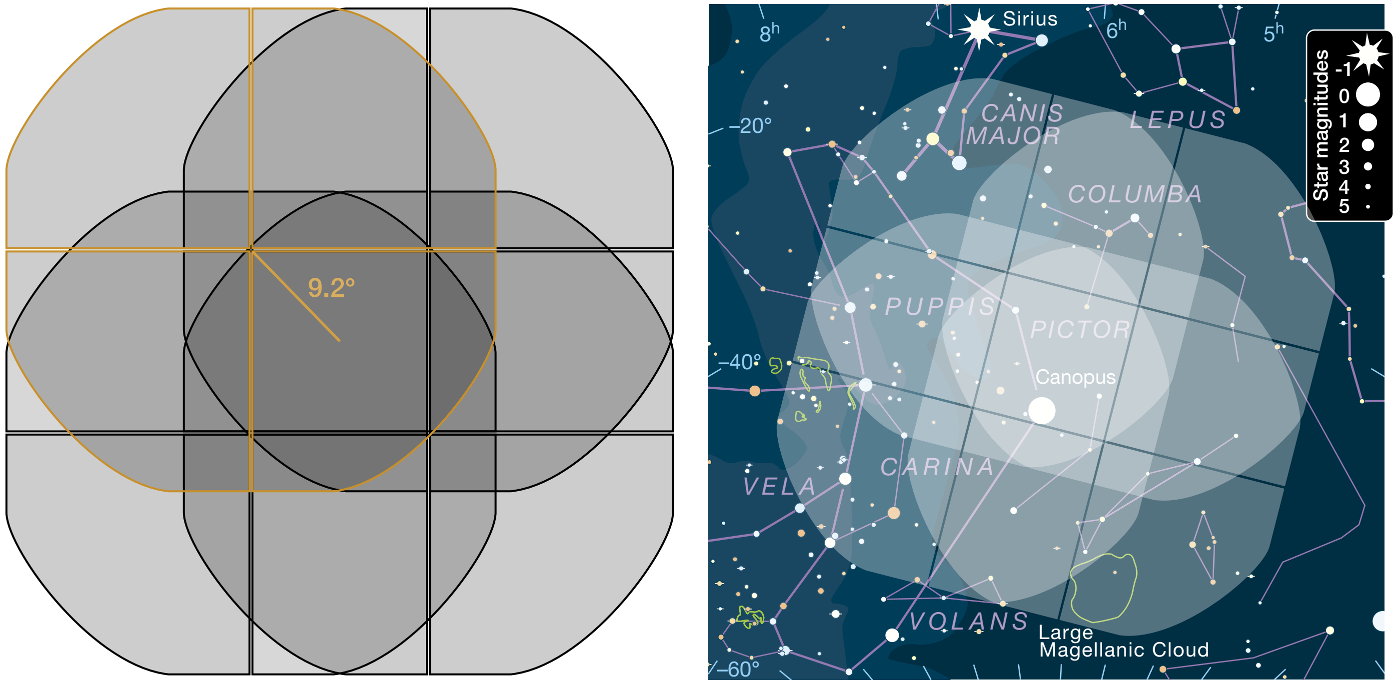
One option would be to point the spacecraft at two different fields for two years each during PLATO's four-year nominal mission. The second field could be one north of the ecliptic that includes Kepler's original field of view. An alternative approach is to stare at the selected field for three years, thus enhancing the probability of detecting three transits of any given exoplanet — astronomers' preferred minimum number for confirming a planet's presence. Researchers could then use the remaining year to search a number of other fields for shorter-period worlds.

One reason to spend more time focused on the chosen southern



◀ **CCD** PLATO will carry 104 CCDs, four for each of its 26 cameras, creating the largest digital detector array ever flown on a spacecraft.

S. MADDEN / ESA



▲ **PLATO'S GAZE** *Left:* PLATO's 24 cameras operate in groups of six. Each group observes a slightly different field of view, offset by 9.2° from center, as shown by the group outlined in orange. The shading indicates the number of overlapping camera fields: From lightest to darkest (outermost to innermost), these are six, 12, 18, and 24. *Right:* The first PLATO observing field lies in the Southern Hemisphere sky, in a region where astronomers have already found dozens of exoplanets. The telescope will observe the field for at least two years. After that, the team might stay in this field or move to another field, either in the Northern or Southern Hemisphere.

field would be the possibility of detailed follow-up observations to precisely characterize any newly discovered exoplanets and their host stars. "The European community has most of its ground-based assets in the Southern Hemisphere, and this will likely be a key factor impacting the observing strategy," says exoplanet researcher Natalie Batalha (University of California, Santa Cruz), who was the project scientist for NASA's Kepler mission.

According to Batalha, long stares at single fields are paramount in the hunt for terrestrial twins. "A two-year stare means that you'd only detect two transits. The possibility for confusion is very high when you only have two transits. We experience this frequently with TESS due to its short, 28-day observing windows."

Obviously, PLATO scientists hope that the mission will eventually be extended. "Technically, the satellite is good for at least 6.5 years," says Jorba Coloma, "and we have enough fuel on board for 8.5 years."

Expectations

PLATO will study more than 200,000 stars and should discover thousands of new exoplanets, says Heras. "Our current estimate is that tens of those will be Earth-size planets orbiting in the habitable zone." Of course, she admits, that number depends on eta-Earth — the frequency of rocky, Earth-like planets in the habitable zone of their host star. "If it's 1%, we have to be very lucky."

To fully characterize a transiting exoplanet found by PLATO, follow-up observations are indispensable. "If PLATO finds an Earth-size planet in the habitable zone, the next steps would involve radial-velocity measurements to determine its mass and assess its potential habitability," says Seager. "If the star is bright enough, it can be a target for future space missions like NASA's proposed Habitable Worlds Observatory."

Batalha, meanwhile, is more skeptical and concerned with the big picture. "I'm not so interested in one detection," she says. "If it's orbiting a Sun-like star in the habitable zone, we won't likely be able to confirm it with ground-based [radial-velocity] measurements. And if it's more than 300 light-years away, we won't likely be able to image it with future missions like HWO. I'd rather like to see PLATO detect a dozen such candidates, so that we can measure eta-Earth."

Then again, even finding one Earth 2.0 would be a monumental achievement. Establishing eta-Earth would constitute a major step forward in determining our chances of finding extraterrestrial life.

As Seager once said: "The whole world is waking up to the fact that we're getting close to finding other Earths and signs of life. It will change the way we see our place in the universe."

■ Contributing Editor **GOVERT SCHILLING** first became interested in planets orbiting other stars when he started reading books by authors like Isaac Asimov, Arthur C. Clarke, and Jack Vance. He feels fortunate to live at a time when science fiction is turning into science fact.

BEATRIZ INGLESSIS / *S&T*, SOURCES: VALERIO NASCIMBENI / PLATO TEAM (2)

SKY AT A GLANCE
February 2026

1 EVENING: Algol shines at minimum brightness for roughly two hours centered at 7:36 p.m. EST (see page 50).

2 EVENING: Face east to see the Moon, just one day past full, rise in tandem with Leo's lucida Regulus. As the pair climbs higher, the Moon occults the star for most of the U.S. and Canada as well as much of western Africa. Turn to page 46 for more on this and other events listed here.

6 EVENING: Shortly after rising above the east-southeastern horizon, the waning gibbous Moon and Virgo's brightest star Spica are about 1½° apart.

11 MORNING: Low in the southeast, Antares, the heart of the celestial Scorpion, smolders 3¾° upper right of the waning crescent Moon.

17 NEW MOON (7:01 A.M. EST) An annular eclipse will be visible along a narrow path across parts of Antarctica. The southernmost tip of Patagonia as well as southern Africa will see partial phases.

18 DUSK: You'll need binoculars to catch the delicate sight of the Moon, just a day past new, and Mercury gracing the west-southwestern horizon right after sunset. The Moon eclipses the tiny world for parts of the southern U.S. and Central America (see page 50 for more). Venus, some 7° below the duo, and Saturn farther to the upper left, make for a pretty tableau.

18 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:33 p.m. PST.

19 DUSK: Above the west-southwestern horizon, you'll see Saturn 3¾° lower left of the waxing crescent Moon.

21 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:22 p.m. EST.

23 DUSK: High in the southwest, the almost-first-quarter Moon gleams right next to the Pleiades cluster in Taurus.

27 MORNING: Low in the west-southwest, the waxing gibbous Moon is in Gemini, with Jupiter around 3° lower left.

27 DUSK: The Moon anchors a line with Gemini's twin beacons, Castor and Pollux, where it hangs a bit less than 4° below the latter. Jupiter completes the scene farther to the upper right.

—DIANA HANNIKAINEN

▶ Orion and Canis Major sparkle above a wintry landscape on Mount Uludağ in the province of Bursa, Turkey. TUNÇ TEZEL

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

FULL MOON
February 1
22:09 UT

LAST QUARTER
February 9
12:43 UT

NEW MOON
February 17
12:01 UT

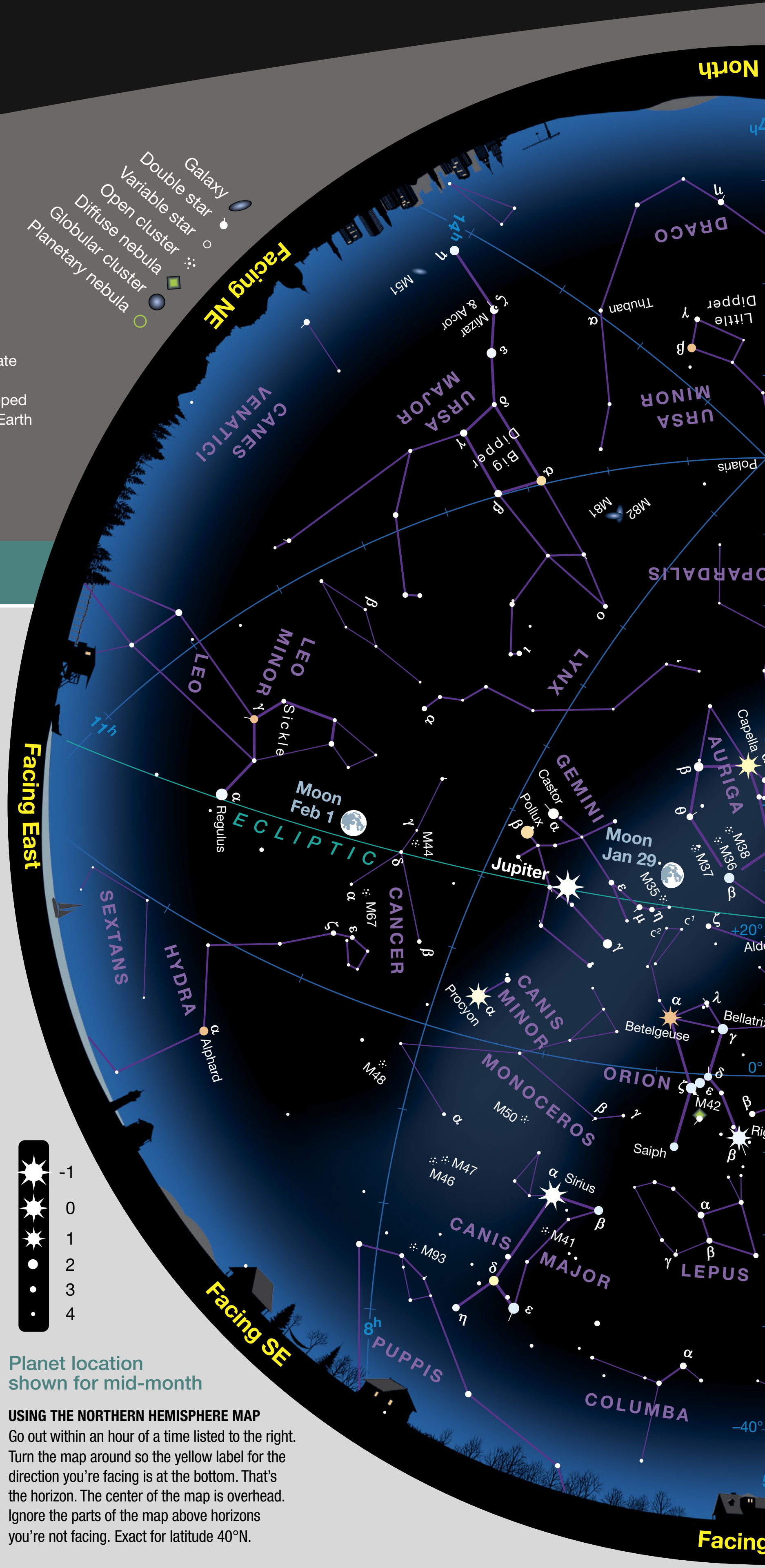
FIRST QUARTER
February 24
12:28 UT

DISTANCES

Apogee	February 10, 17^h UT
404,576 km	Diameter 29′ 32″
Perigee	February 24, 23^h UT
370,135 km	Diameter 32′ 17″

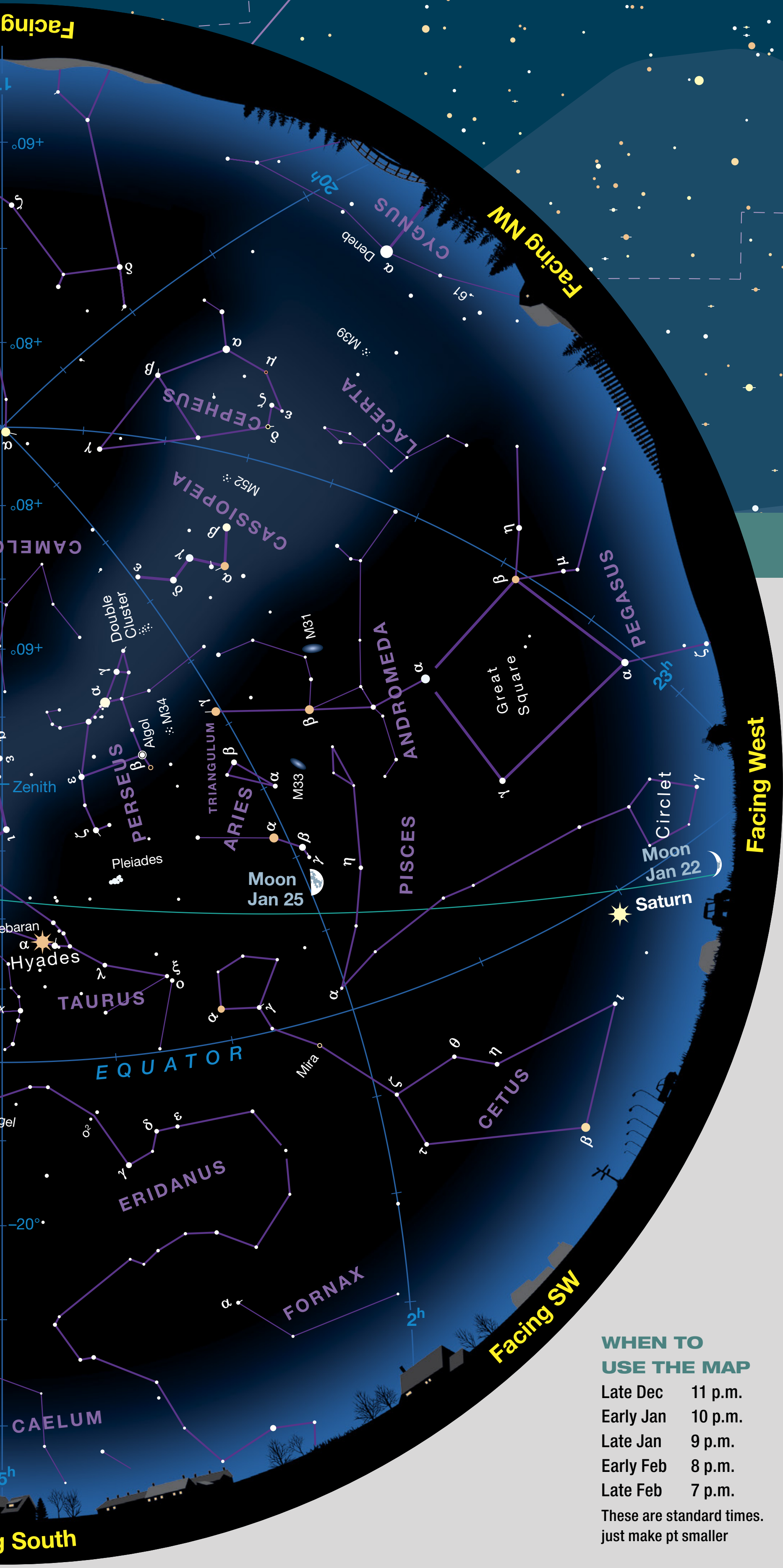
FAVORABLE LIBRATIONS

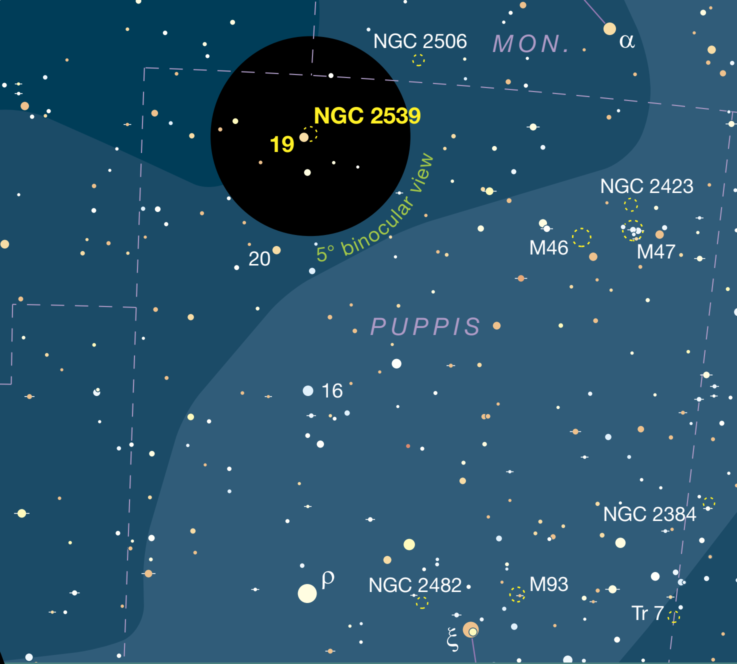
• Mare Australe	February 1
• Abel Crater	February 2
• Scott Crater	February 25
• Neumayer Crater	February 27



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

Off the Beaten Path in Puppis

Some threads run through both my daytime life and my stargazing. I'm fascinated with the three-dimensional structures of things — from dinosaur bones to spiral galaxies. I also enjoy stomping around off the beaten path, searching for the unexpected or overlooked. All these threads intersect with this month's target, open cluster **NGC 2539**.

Lying in the far northeastern corner of Puppis, the Stern, NGC 2539 is reasonably bright with a magnitude of 6.5. That means the cluster should be an easy target even in 7×35 binoculars. But there are a couple of wrinkles to this story. The first is location: NGC 2539 is in the middle of nowhere, so you'll have to take some care when seeking it. Start at 2.8-magnitude Rho (ρ) Puppis and follow a ragged chain of stars northward. It's a 5° hop north from Rho Puppis to 16 Puppis, then 3½° north-northeast to 20 Puppis, and a final 3° jump north-northwest to 19 Puppis.

NGC 2539 borders 19 Puppis immediately to the northwest. With an apparent diameter of about ⅓°, the cluster is decently large but has a low surface brightness. The glare from 19 Puppis doesn't help — if a 5th-magnitude star can be said to produce glare. The contrast between the star and the cluster is more than just visual; 19 Puppis is a yellow-orange giant lying about 180 light-years away, whereas the open cluster is about 4,300 light-years distant. The star and the cluster are one of the celestial odd couples I love observing — two objects in the same field but at wildly different distances. Being able to savor that glimpse of the scale of the cosmos makes the long trek to get there worthwhile.

■ Given his tendency to get lost in his thoughts, it's a wonder that **MATT WEDEL** doesn't get lost far more often in real life.

WHEN TO USE THE MAP

Late Dec	11 p.m.
Early Jan	10 p.m.
Late Jan	9 p.m.
Early Feb	8 p.m.
Late Feb	7 p.m.

These are standard times. just make pt smaller

FEBRUARY 2026 OBSERVING

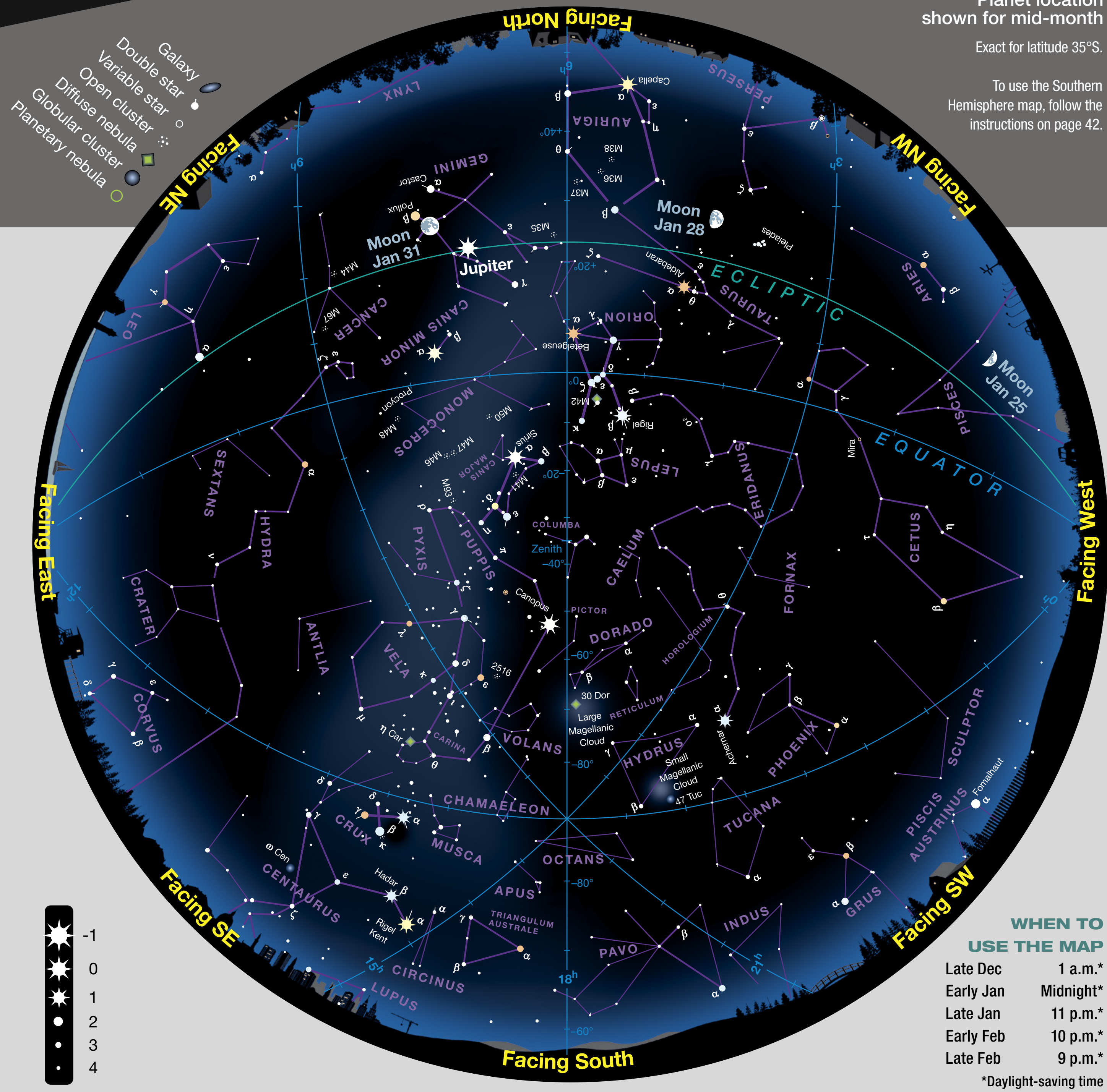
Southern Hemisphere Sky Chart

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 Dec	1 a.m.*
Early Jan	Midnight*
Late Jan	11 p.m.*
Early Feb	10 p.m.*
Late Feb	9 p.m.*

*Daylight-saving time

THE CONSTELLATION Caelum (pronounced SEE-lum), the Engraving Tool, was invented in 1756 by astronomer Nicolas Louis de Lacaille, who named it *les Burins*, a French term for a type of chisel. The name was later Latinized to Caelum Scalptorium and eventually shortened to just Caelum.

Caelum comprises a handful of modest stars, so you need dark skies and good eyes to trace out its shape. Four of them are dotted on the chart above, though none are labeled. From north to south the stars are Gamma (γ) Caeli at magnitude 4.6, Beta (β) at 5.1, Alpha (α) at 4.5, and Delta (δ) at 5.1. Alpha is a binary 66 light-years from Earth, and Beta and its unseen low-mass companion reside 94 light-years from us. Gamma is a multiple-star system 185 light-years away, while solo Delta is far more distant at about 682 light-years. ■

The Hyades: Rainmakers to Snow Maiden

Come visit these teary-eyed maidens hidden away in Taurus.

This month we turn our attention to a splendid V-shaped arrangement of stars. You'll find it high in the south on the Northern Hemisphere Star Chart on pages 42–43. Look for dazzling orange Aldebaran punctuating the tip of the V's southeastern branch. Under the night sky, two fingers held at arm's length will cover the grouping. In classical mythology, the V outlines the face of Taurus, the Bull, one of the sky's most ancient constellations. Except this face has a name. It's called the Hyades, and it has a mythology of its own.

In the 1867 *Dictionary of Greek and Roman Biography and Mythology*, William Smith refers to the Hyades as a "class of nymphs, whose number, names, and descent, are described in various ways by the ancients. . . . But the common number of the Hyades is seven, [namely] Ambrosia, Eudora, Pedile, Coronis, Polyxo, Phyto, and Thyene, or Dione." Unfortunately, no star in the Hyades has been assigned a particular classical name. So you will have to rely on your imagination to pick them out. For instance, we could (for fun) match five of the nymphs' names with five of the Greek letters in the V: Alpha (α) as Ambrosia, Delta (δ) as Dione, Epsilon (ε) as Eudora, and Theta (θ) as Thyene; with a stretch we could also refer to Pi (π) as either Polyxo or Phyto, as that star at least lies close to the V.

In his *Fasti*, a poetic version of the Roman calendar, Roman poet Ovid (43 BC to circa AD 17) refers to the Hyades as the daughters of Atlas and Aethra: Atlas was the Titan condemned to support the heavens on his shoulders, while Aethra was one of the 3,000 daughters of Oceanus — the eldest of the Titans and the personification of the freshwater river thought to encircle Earth. In Ovid's version of the myth, the Hyades earned a place among the stars for their grief over the death of their beloved brother, Hyas, who was killed in Libya by a whelped lioness; the sisters' profuse tears fell to the ground as heavy rain. Indeed, the name Hyades derives from a Greek word popularly connected with rain, and their *heliacal rising* — when the group rises in the dawn before sunrise — announced to the ancients the coming of rainy and stormy weather. "The next day calls up the Hyades," writes Ovid, "and the earth is soaked with heavy rain."

One can find more recent references in literature to the Hyades as "rain-stars." For instance, in his poem "Ulysses," English poet Alfred Lord Tennyson (1809–1892) employs the Hyades as a symbol of the hardships of life's journey: "Thro' scudding drifts the rainy Hyades / Vext the dim sea." And in his poem titled "To —," London-born American poet Edward Coote Pinkney (1802–1828) uses the Hyades in a more sentimental way: "Wet rain-stars are thy lucid eyes / The Hyades of earthly skies."

▶ When night falls in February, the time of year when snows are heaviest across the northeastern U.S. and other upper northern latitudes, the Hyades soar high above the southern horizon. We can imagine the V-shaped star pattern as Snegurochka, the Snow Maiden of ancient Slavic folklore.

STEPHEN JAMES O'MEARA, SOURCE: MINISTRY OF COMMUNICATIONS OF THE SOVIET UNION / WIKIMEDIA COMMONS / PUBLIC DOMAIN

This month, however, at least for those in more northern climes, the rains can give way to snowfall when the Hyades look down from on high upon wintry landscapes. On these crisp nights, as the classical rainmakers slumber, we can awaken our imagination to the Hyades as Snegurochka, the Snow Maiden of Slavic folklore. Historical accounts suggest that the tale may have evolved from pagan winter rituals that honored the changing of the seasons. Today Snegurochka is an essential part of Russian New Year's celebrations.

The myths vary — some say she was the daughter of Father Frost (the Slavic version of Santa Claus and a symbol of Russian winter) and the Snow Queen. But one of the more popular traditions says she was created by a childless elderly couple, who crafted the daughter they so longingly wanted from snow. Glistening in her winter coat, or *shuba*, Snegurochka symbolized youthful innocence and the impermanence of the seasons. According to one version of the tale, Snegurochka joined some girls who built a fire at nightfall and made a game of jumping over its flames. Snegurochka joined them. But when she jumped, the flames greeted her, and she melted away into a white cloud.

The tale is not as sad as it seems, as her death is merely a metaphor for the death of winter and the coming of spring. Looking up now, we can imagine Snegurochka jumping over the flame of Aldebaran on her way toward the promise of spring. May imagining the Hyades in this new form be a warm way to settle into a night of crisp winter observing.

■ Contributing Editor **STEPHEN JAMES O'MEARA** has been studying the stars and their lore for more than 50 years.

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

Lunar Hits and Near Misses

The Moon has a pair of occultations this month — one involving a bright star, the other a planet.

MONDAY, FEBRUARY 2

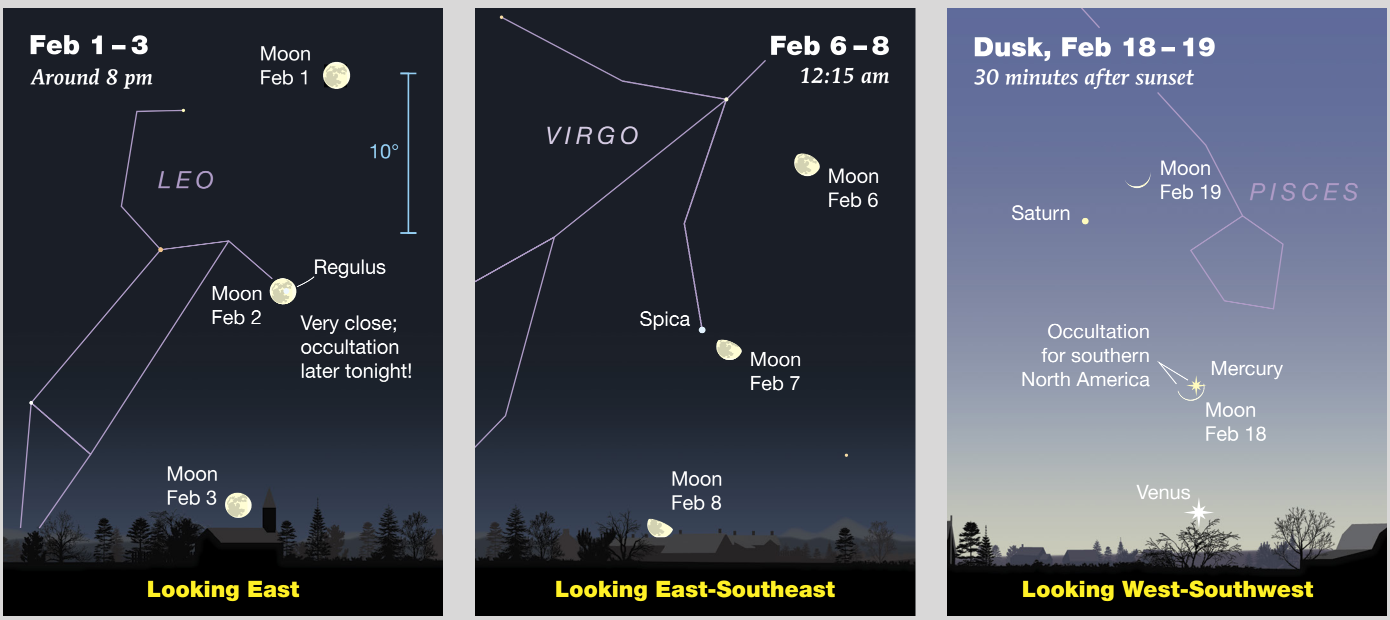
Shortly after sunset today, face the west-southwest and see if you can catch **Venus** hovering just above the horizon. The brilliant planet is making its first naked-eye appearance since its dawn sunward dash back in mid-December. And if mornings aren't your thing, then tonight is your first chance to see the planet in its Evening Star guise since last March. Regardless, the start of a new Venus apparition is always ripe with anticipation — upcoming pairings that include the Moon and other planets are always noteworthy. Indeed, get your binoculars out and see if you can catch **Mercury** this evening shining gamely at magnitude –1.2, less than 2½° upper left of Venus. The innermost planet is a difficult target, but wait a couple of nights and your chances improve substantially as it climbs higher. By the 5th you should be able to easily see both planets, though they'll be 4° apart by then. We'll get to enjoy Venus's company through the summer months and well into autumn, so there'll be plenty of interesting pairings to catch before this apparition wraps up.

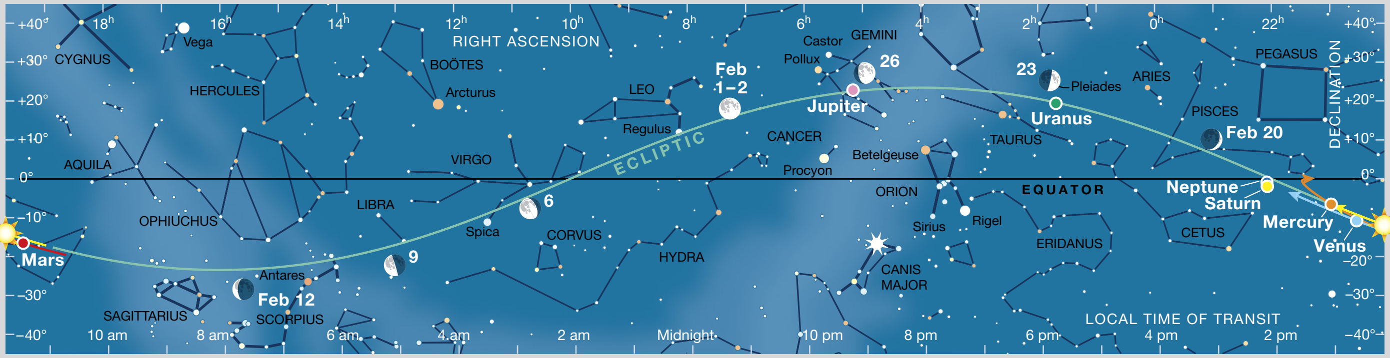
If you manage to see Venus and Mercury, congratulations — but your night isn't done yet. As darkness falls, turn your attention to the east-northeastern horizon at around 6:45 p.m. local time to watch the waning gibbous **Moon** (one day past full) rising. Trailing a short distance behind is **Regulus**, the Alpha star of Leo, the Lion. The gap between the Moon and star is small — very small. And depending on where you are, you might even get to watch the lunar disk cover Regulus. Turn to page 48 for full details.

FRIDAY, FEBRUARY 6

If you missed out on the Moon/Regulus event, don't despair. Tonight's offering doesn't include a potential occultation, but it's a nice conjunction, nonetheless. Shortly before midnight, the **Moon** and **Spica**, Alpha (α) Virginis, rise together in the east-southeast. As the clock ticks past midnight and into the morning of the 7th, the view improves considerably as the pair gain altitude. The star is parked roughly 1½° to the left of the waning, 71%-illuminated gibbous Moon, though (as with all things involving Luna) the exact figures depend on your precise location; the pair is

▼▶ 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.





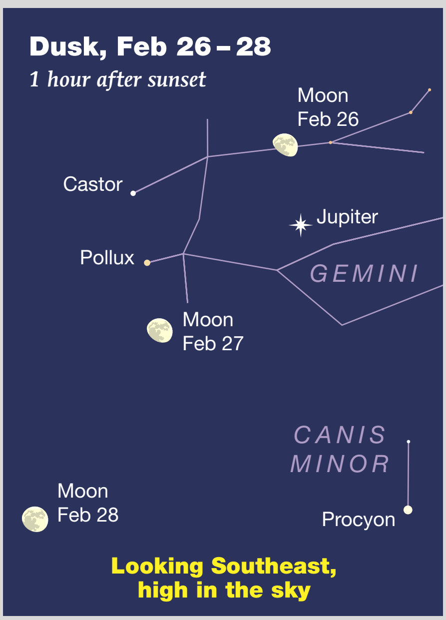
▲ The Sun and planets are positioned for mid-February; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit"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

slightly closer for observers on the East Coast, and slightly farther apart for those on the West Coast. Apart from the aforementioned Regulus occultation, this is the closest meeting between the Moon and a bright star in February. But if you want to see the Moon eclipse Spica, you'll have to wait until 2032.

WEDNESDAY, FEBRUARY 18

The second big event on this month's busy lunar calendar occurs at dusk today when a razor-thin (2.3%-illuminated), crescent **Moon** drifts in front of **Mercury**. As detailed on page 50, a lucky few in the contiguous U.S., Mexico, and much of Central America get to watch this exciting occultation. A *very* lucky few are in the right place to see *two* occultations — the Regulus event on the 2nd and tonight's. Most of us, however, will have to content ourselves this evening with seeing a tight pairing between the innermost planet and the lunar crescent. As consolation prizes go, this isn't a bad one.

Half an hour after sunset, the Moon is still 10° above the horizon and Mercury is positioned to the upper right of the earthlit crescent. Seeing the Moon is rarely a challenge, but glimpsing Mercury often is. Fortunately, the planet is shining brightly at magnitude –0.6 and is about as high as it gets during its current, favorable dusk apparition. Both factors help immensely. Again, depending on your location, most readers see the twosome separated by something close to ¼°, or roughly half the height of the crescent. The nearer you are to the occultation zone, the tighter the gap. If you're struggling to locate Mercury with your eyes alone, fish out your binoculars — a little optical assist makes a world of difference.



MONDAY, FEBRUARY 23

The third big event for the **Moon** this month is its visit with the **Pleiades** cluster in Taurus. On this occasion, the Moon is about half a day from first-quarter phase, so it's throwing off a significant amount of light. That'll make seeing all but the brightest Pleiads tricky with the naked eye. But in binoculars, it's another story. With a little optical boost, you can watch the Moon gradually float nearer and nearer to the mini-dipper shape formed by the cluster's six brightest members. As twilight fades, the Moon is positioned right of the Pleiades. Over the next few hours, it draws nearer until it sits above the cluster as the grouping sinks toward the west-northwestern horizon after midnight. The farther north you are, the nearer the Moon gets to the cluster. Indeed, observers in a few far-north locations can even watch the lunar dark limb temporarily extinguish the light of a few Pleiads.

FRIDAY, FEBRUARY 27

The month wraps up with a delight at dawn and another at dusk. In the early morning hours, the waxing gibbous **Moon** sits about 3° upper right of **Jupiter** in the west-northwest. The big planet gleams at magnitude –2.5, so it stands out easily next to the 80%-illuminated lunar disk. The duo are neatly bracketed by +0.4-magnitude Procyon to their left and +0.1-magnitude Capella to their right. That evening, shift your gaze to the east and notice how the Moon has drifted away from Jupiter and now forms a tidy three-in-a-row with Gemini's brightest lights, 1.6-magnitude Castor and 1.1-magnitude Pollux. The alignment is most perfect a little after 8 p.m. EST. The stars are separated by roughly 4½°, which equals the distance between the center of the Moon and Pollux at that time.

■ Consulting Editor **GARY SERONIK** always looks forward to Venus resuming its role as the Evening Star.

Regulus Versus a Bright Moon

This month features a pair of remarkable lunar occultations.

Regulus, Leo's brightest star, bids a brief farewell when it disappears behind the 98%-illuminated, waning gibbous Moon on the evening of Monday, February 2nd. The occultation is visible across most of the U.S. and Canada, but for observers in the southwestern Iberian Peninsula and western Africa, it occurs on the morning of the 3rd. The 1.4-magnitude Leo luminary disappears on the Moon's bright limb and reappears some time later on the dark limb. Depending on your location, Regulus will be covered anywhere from a few seconds to up to an hour. Because the Moon is nearly full, its trailing unlit limb is very narrow and impossible to accurately gauge in a telescope. That's why you should begin your vigil at least 10 minutes before the predicted time of reappearance for your location, so you're watching like a hawk when the star pops back into view.

The eastern U.S. is favored, and observers there get to watch the entire occultation. Farther west, in the Mountain States, the Moon is quite low in the eastern sky when Regulus disappears, but well placed when the star returns. Along the Pacific Coast only the star's reappearance is easily visible. Skywatchers elsewhere enjoy a close conjunction. For exact occultation times visit the International Occultation Timing Association (IOTA) website at **https://is.gd/occultations**. You can also preview the scene by using an astronomy app, such as the freeware *Stellarium*.

Regulus is one of just four 1st-magnitude stars the Moon eclipses as it makes its monthly journey along the ecliptic. The current series of Regulus occultations began last July and ends on December 27, 2026. During this span, on 20 different occasions the Moon

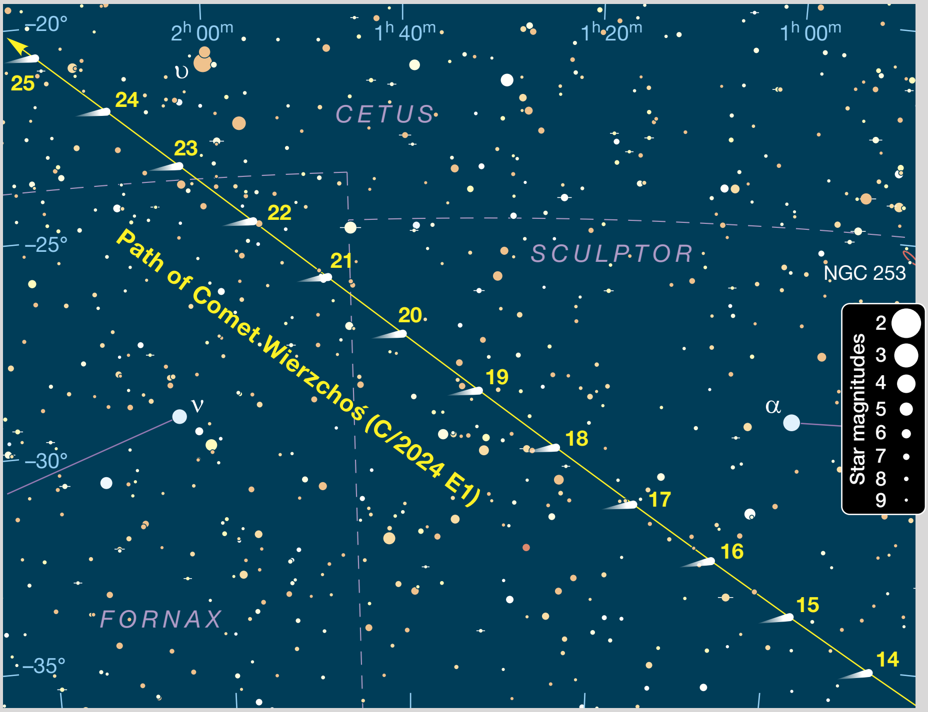
▼ On February 11, 2017, Australian amateur Noeleen Lowndes raced home from an astronomical society meeting to photograph the Moon occulting Regulus with her 5-inch refractor and Canon DSLR camera. In the sequence, Regulus disappeared at upper left and spent more than an hour hidden behind the Moon before reappearing "in a burst of starlight" at lower right. The Moon is at a similar phase when it eclipses Regulus on February 2nd.

covers the star once or twice a month from somewhere on Earth. Incredibly, only one of these is widely visible across the Americas — this one! After a hiatus of about 8½ years, the Moon begins a new series of Regulus occultations starting in June 2035.

It's a pity our one occultation opportunity in this series happens when the Moon is so close to full. While its glare won't prevent anyone with a small telescope from seeing the star disappear and reappear, it does put a kink into attempts to catch sight of Regulus's two companion stars. Like a knife's edge, the Moon's limb excels at splitting close stars, which are revealed when an occultation occurs in two or more steps as one star disappears, followed a moment later by its attendants. Professionals and amateurs alike have discovered stellar partners this way that are invisible under normal circumstances. It's thrilling to see the Moon hide the primary just long enough for a fainter secondary to pop into view before it, too, disappears. This is how I first saw the companion to Antares, and it remains my most thrilling occultation to date.

Regulus is actually a quadruple star with an extremely close white dwarf companion, Regulus Ab, located a whispery 0.015″ from the primary. This pair is only resolvable spectroscopically. Much easier to see is the 8.2- magnitude secondary (Regulus B) 176″ away at position angle 308° (northwest). Despite the large separation, this orange dwarf is a true, physical companion. In turn, Regulus B is orbited by 13.2-magnitude Regulus C just 2.1″ away at position angle 94° (almost due east).

Unfortunately, glare from the Moon on occultation night will almost certainly swamp Regulus's faint companions. Were the Moon at last-quarter phase instead, we could watch them emerge one after another along the dark limb. I wish I could say this will happen sometime during the next occultation series, but alas, not from North America. Of course, nothing prevents you from returning on a night of good seeing to test your observing mettle by trying to split the close B-C pair!



▲ Comet Wierzchoś has its closest approach to Earth on February 17th as it passes through Sculptor. Its position is plotted for 0^h UT on the dates indicated.

Comet Wierzchoś at its Best

THIS MONTH we should see the slowly brightening Comet Wierzchoś (C/2024 E1) peak at around magnitude 8.5 and possibly as bright as 5th magnitude, depending upon which set of predictions turns out to be correct. But even at the dimmer end, observers with 50-mm binoculars may be able to spot it from dark skies through mid-February as it slowly extricates itself from the Sun's glare at dusk.

Comet Wierzchoś is a visitor from the Oort Cloud and follows a weakly hyperbolic orbit due to its gravitational interactions with the Sun and planets during its inbound journey. It took millions of years to drop into Earth's vicinity, and the outbound trip is a one-way ticket out of the solar system. Perihelion occurs on January 20th, and the comet makes its closest approach to Earth on February 17th, at a distance of 151 million kilometers (94 million miles).

▶ Looking like a misty apostrophe, Comet Wierzchoś (C/2024 E1) displays a short tail and a bright pseudo-nucleus in this September 22, 2025, image by Dan Bartlett.

For Northern Hemisphere skywatchers, the comet enters the scene in late evening twilight around mid-February low in the southwestern sky in Sculptor. It could be as bright as magnitude 6.5 or as faint as 8.5 (again, depending on which model proves correct) and should display an east-pointing tail. It hangs some 5° high 75 minutes after local sunset from mid-northern latitudes. It then climbs northeast across Fornax and enters Cetus on February 22nd, gaining altitude while continuing to dim. At month's end, it's expected to fade by about a magnitude as it reaches the border of Eridanus. At that time, it stands about 20° high 1½ hours after sunset.

Southern Hemisphere observers will have a much better view of the comet due to its southern declination. They'll see it at around 5th magnitude (optimistically) in late January and have little difficulty following it in a dark sky throughout February.

Mercury Versus a Thin Moon

▲ Lucky observers in the southernmost U.S. can watch a thin waxing crescent Moon cover the planet Mercury. This simulation shows the planet seconds before the occultation as seen from New Orleans, Louisiana.

AS NOTED ON page 47, at dusk on February 18th, skywatchers across the Americas witness a superb close conjunction of the 1.5-day-old Moon and Mercury low in the western sky. The planet shimmers at magnitude –0.6 within kissing distance of the frail, 2.5%-illuminated crescent.

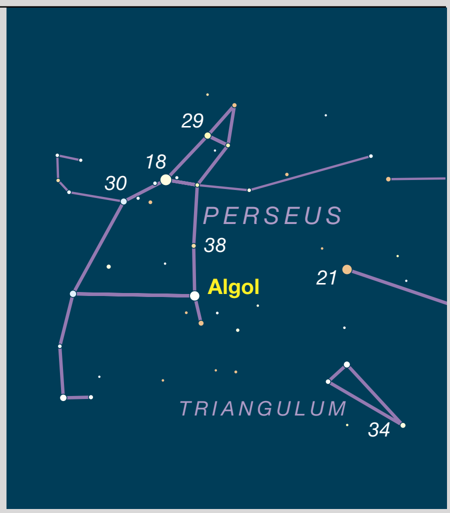
Across the U.S. their separation ranges from about ½° in the eastern states to ¼° in the Midwest, down to just a handful of arcminutes for those watching from the western half of the country. No matter where you call home, the pair is a stunning sight in binoculars 45 minutes to an hour after sunset. Adding interest, two additional planets bracket Mercury: Saturn at magnitude 1.1 some 12½° to the east, and Venus at magnitude –3.9 about 8° to the southwest.

Observers in the southeastern and southernmost U.S. as well as Central America get to witness an even more dramatic event as the Moon covers Mercury. Parts of Florida, Georgia, Alabama, Mississippi, Louisiana, Arkansas, and Texas lie within the occultation zone. From New Orleans, Louisiana, Mercury first touches the dark lunar limb at around 6:36 p.m. CST and completely disappears 15 seconds later. From New Zealand and parts of Western Australia, Mercury re-emerges on the bright limb after sunup. IOTA has a detailed list of cities and times on their website.

Minima of Algol

Jan.	UT	Feb.	UT
1	11:34	2	0:36
4	8:23	4	21:26
7	5:13	7	18:15
10	2:02	10	15:05
12	22:51	13	11:54
15	19:40	16	8:43
18	16:30	19	5:33
21	13:19	22	2:22
24	10:08	24	23:11
27	6:58	27	20:01
30	3:47		

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



▲ Perseus approaches the zenith during evening hours in December. Every 2.87 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Use this chart to estimate its brightness in respect to comparison stars of magnitude 2.1 (Gamma Andromedae) and 3.4 (Alpha Trianguli).

STELLARIUM / S&T

Action at Jupiter

JUPITER IS NOW in the prime of the post-opposition phase of its current apparition. This is usually when even casual observers start checking in on the planet regularly since it's now well positioned in the evening sky, rather than having to wait until after midnight. By mid-February, Jupiter achieves an altitude greater than 30° before 5 p.m. local time, transits the meridian at around 9:30 p.m., and remains higher than 30° until after 2 a.m. In effect, you can enjoy rewarding telescopic views pretty much all night long! As the month opens, Jupiter shines brightly at mangitude –2.6 and presents a disk spanning a generous 45.7″.

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.)

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

31: 4:30, 14:26

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

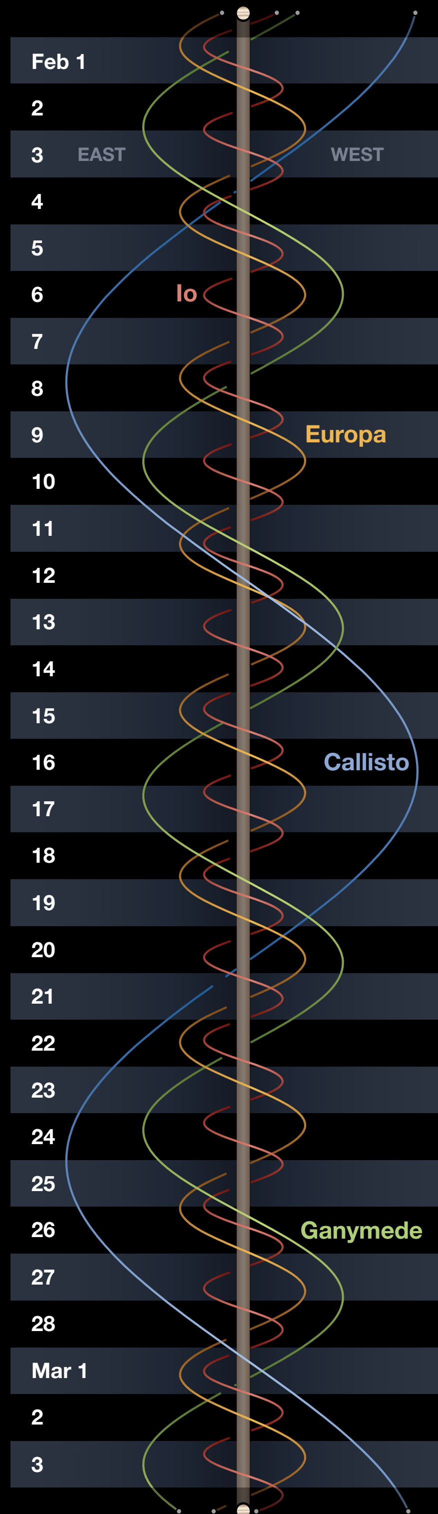
These times assume that the spot will be centered at System II longitude 86° on February 1st. If the Red Spot has moved elsewhere, it will transit 1²/₃ minutes earlier for each degree less than 86° and 1²/₃ minutes later for each degree more than 86°.

Phenomena of Jupiter's Moons, February 2026

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

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.

Impacts on the Edge

Tilted craters hint at the topography that existed prior to their formation.

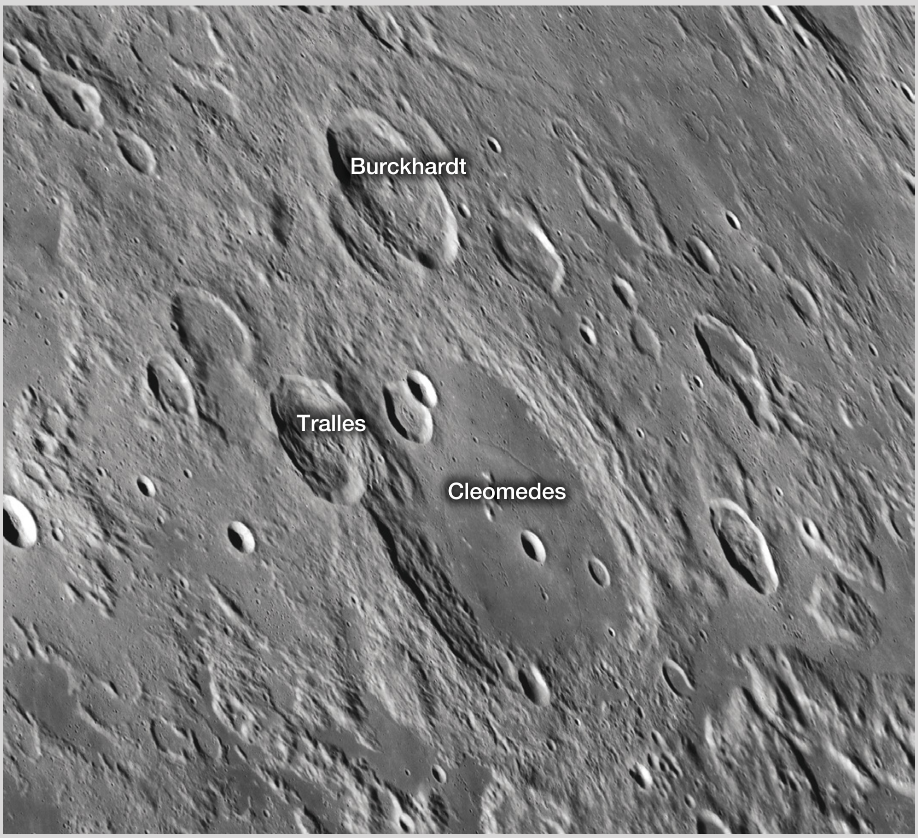
Diagrams that show comets or asteroids colliding with the Moon typically depict impacts occurring on a flat surface. This is a simplification that likely happens only when a cosmic projectile strikes a mare. But 83% of the lunar surface consists of highlands that have been heavily modified by billions of years of prior cratering and are neither smooth nor flat. So how does such morphologically irregular terrain affect a crater's formation?

The Moon's surface is loaded with examples of impactors striking the rim of a large, preexisting crater. Two instances are found along the eastern edge of the 225-km-wide (140-mile-wide) crater **Clavius**. **Porter** and **Rutherfurd** are both approximately 50-km-wide formations located on the northeastern and southeastern rims of Clavius, respectively. The centers of each are halfway down the 3-to-4-km-high rim of Clavius, so the easternmost rims of Porter and Rutherfurd are perched a few kilometers higher than their floor-facing sides. Notice also that the central peaks of both the more recent craters are displaced downslope towards the floor of Clavius. The formation of these craters on the sloping inner wall of Clavius displaced the locations, heights, and morphologies of their borders as well as the positions of their central peaks.

There are many other similarly tilted craters on the walls and floors of older craters. Look at 44-km-wide **Römer** in Montes Taurus, and farther north, **Franklin** and **Atlas** (56 and 87 km wide, respectively). The lack of a preexisting wall to support half of each new crater formed on the rim of an older one allows it to slide downhill, producing a tilted crater. But merely looking at an image or through a telescope often won't show that their rim heights are lower where they cut across those of preexisting craters. You can measure these by using the altimetry tool on the LROC Quickmap website at **https://is.gd/lrocquickmap**. To measure across a feature, select the ***Arc*** tool, click on the starting point, then double-click at the end point. Next, select the ***Inspect*** tab in the ***Feature Inspector*** section that appears on the right side of the screen.

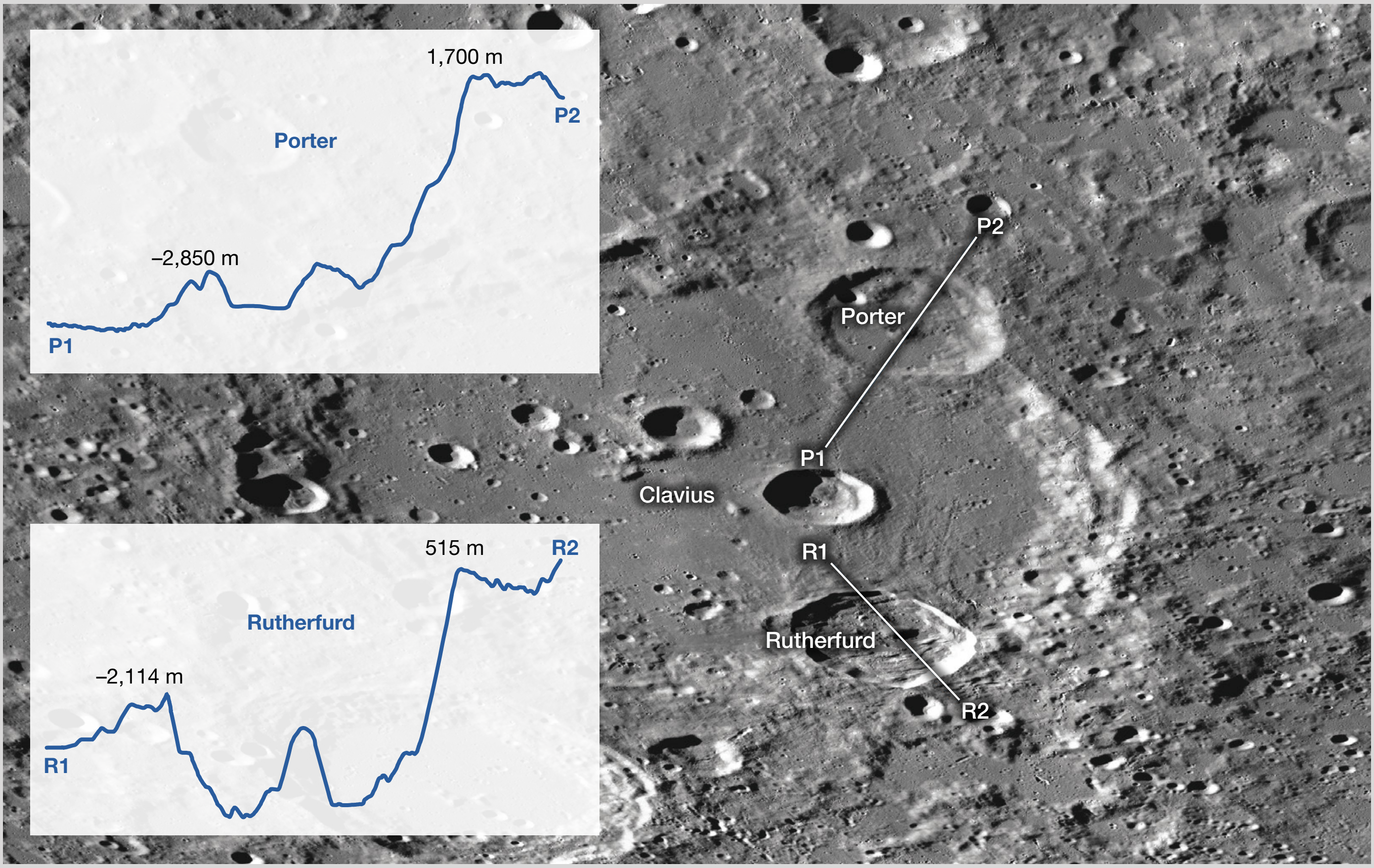
Another unusual, tilted crater is **Burckhardt**, north of Cleomedes. Burckhardt is famous for having two prominent ears — two older overlapping craters that caused Burckhardt's rim to be lower on opposite sides. Nearby is 44-km-wide **Tralles** whose center is just outside of Cleomedes. Tralles's western rim was excavated from higher surrounding terrain, resulting in its western walls being 1.5 km higher than its eastern edge, where it crosses Cleomedes's sloping northwestern edge. The formation of Tralles' eastern wall pushed material far onto Cleomedes's floor.

Tilted craters don't occur exclusively when a new crater forms on an old one — they're also created along the often-rimless edges of large basins. You can find conspicuous examples along the shores of Mare Humorum where craters **Hippalus**, **Lee**, and **Doppelmayer** formed on the tilted basin floor. In these cases, the craters' basin-facing



◀ Craters Tralles and Burckhardt each display lower, partially collapsed rims where they crossed the edge of preexisting craters.

NASA / GSFC / ARIZONA STATE UNIVERSITY



▲ Lunar craters Porter and Rutherfurd formed on the inner walls of Clavius. Graphs at left show altimetry measurements along the highlighted paths using the ACT Lunar/LROC Quickmap website. Measurements are represented as the distance from the average lunar elevation in meters.

rims were later buried by mare lavas. Similarly, at the northern end of Humorum the height of **Gassendi**'s rim noticeably decreases from the crater's northern side towards the mare, illustrating its tilt.

A similar arrangement occurs for **Le Monnier** and **Posidonius** along eastern Mare Serenitatis, and **Fracastorius** on the southern shore of Mare Nectaris. South of Fracastorius is **Piccolomini**, another large crater that's tilted because it crosses 3.4-km-high **Rupes Altai** — the structure that defines the western edge of the Nectaris Basin; Piccolomini's northern rim is 1 km lower than its southern one, which is located on top of the scarp.

Finally, take a look at the 25-km-diameter crater **Triesnecker** in northern **Sinus Medii**. Although it isn't obvious in images, altimetry measurements accessed through Quickmap reveal that Triesnecker's eastern rim is some 600 meters (1,970 feet) higher than its western counterpart. Part of this is due to a large slump block cutting into the western rim, but some of the elevation difference is because Triesnecker formed on the downslope side of a roughly 35-meter-high swell that extends some 60 km to the east.

Prinz is a more convincing example of a tilted crater that formed on the side of a swell. It's located on the western portion of a 150-km-wide, 600-m-high, egg-shaped structure centered on **Montes Harbinger** just east of Prinz. The upsloping eastern rim of Prinz stands some 1 km high, while the western, downslope crater wall is completely buried by mare lavas.

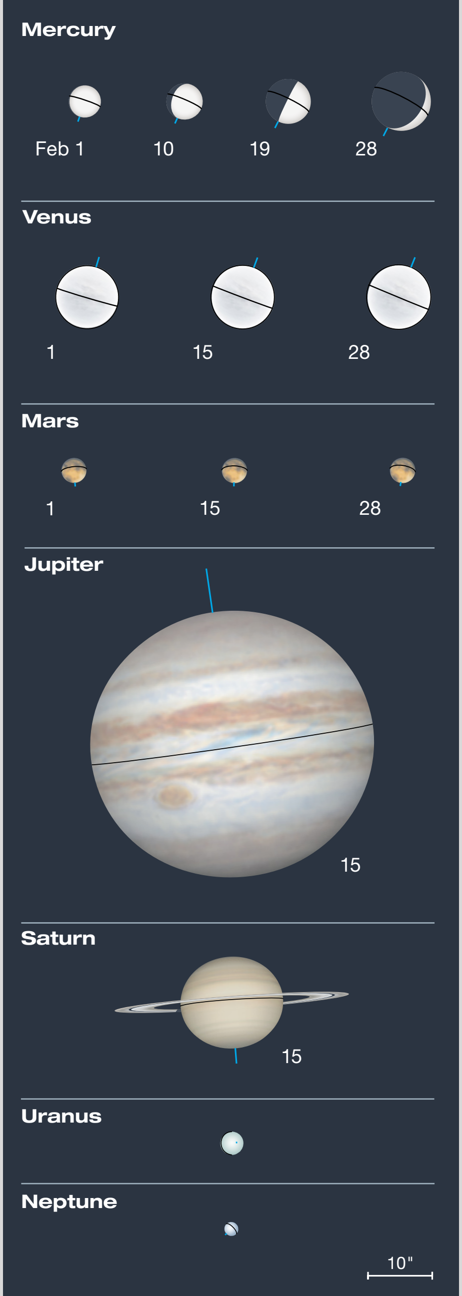
As you observe the Moon, try to detect other tilted craters and the reasons why they appear that way. You can verify your observations by using the digital altimetry traces available on the ACT Lunar/LROC Quickmap.

■ Contributing Editor **CHUCK WOOD** is coauthor of the newly published *Extreme Illumination Atlas of the Moon*, available at **amazon.com** (reviewed on page 58).

▶ While not apparent in most photographs, Triesnecker crater was excavated on the western slope of a large swell, as revealed in this altimetry-derived visualization made using a northern illumination source.

CLAVIUS WITH ELEVATION PATHS: NASA / GSFC / ARIZONA STATE UNIVERSITY; ILLUMINATION SIMULATION: NASA / GSFC / ARIZONA STATE UNIVERSITY; C. WOOD / M. COLLINS

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dusk from the 5th to the 27th • **Venus** visible at dusk beginning on the 2nd • **Mars** lost in the Sun's glare all month • **Jupiter** transits in the evening and sets before dawn • **Saturn** visible in the west-southwest at dusk.



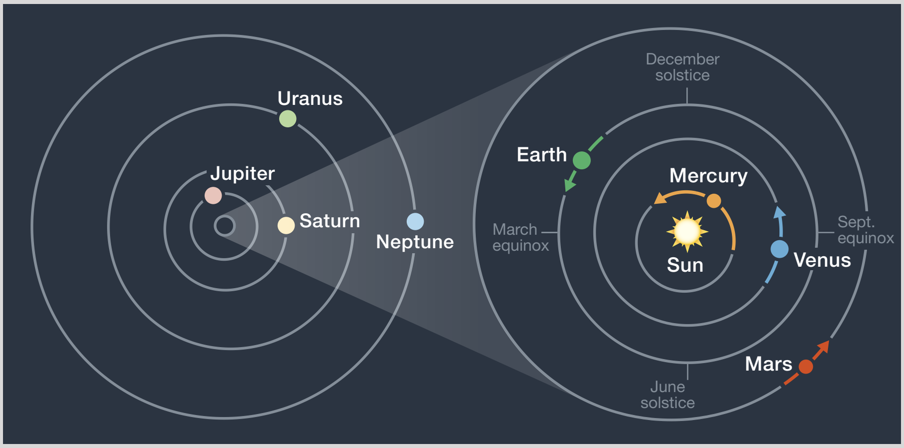
▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

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

February Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$20^h 56.9^m$	–17° 15′	—	–26.8	32′ 28″	—	0.985
	28	$22^h 42.5^m$	–8° 11′	—	–26.8	32′ 18″	—	0.990
Mercury	1	$21^h 28.6^m$	–16° 53′	8° Ev	–1.2	5.0″	97%	1.337
	10	$22^h 28.4^m$	–10° 33′	14° Ev	–1.1	5.7″	85%	1.188
	19	$23^h 14.5^m$	–3° 49′	18° Ev	–0.6	7.0″	53%	0.959
	28	$23^h 25.5^m$	–0° 19′	13° Ev	+1.7	9.2″	14%	0.727
Venus	1	$21^h 22.8^m$	–16° 47′	6° Ev	–3.9	9.8″	99%	1.700
	10	$22^h 07.0^m$	–13° 09′	8° Ev	–3.9	9.9″	99%	1.690
	19	$22^h 49.7^m$	–9° 02′	10° Ev	–3.9	10.0″	98%	1.676
	28	$23^h 31.3^m$	–4° 35′	13° Ev	–3.9	10.1″	98%	1.659
Mars	1	$20^h 36.1^m$	–19° 41′	5° Mo	+1.2	3.9″	100%	2.379
	15	$21^h 20.6^m$	–16° 40′	9° Mo	+1.2	4.0″	100%	2.361
	28	$22^h 00.7^m$	–13° 20′	11° Mo	+1.2	4.0″	99%	2.343
Jupiter	1	$7^h 13.8^m$	+22° 40′	155° Ev	–2.6	45.7″	100%	4.312
	28	$7^h 04.9^m$	+22° 57′	126° Ev	–2.5	42.9″	99%	4.590
Saturn	1	$23^h 57.1^m$	–2° 41′	47° Ev	+1.1	16.4″	100%	10.160
	28	$0^h 08.0^m$	–1° 28′	22° Ev	+1.0	16.0″	100%	10.410
Uranus	15	$3^h 39.6^m$	+19° 20′	91° Ev	+5.7	3.6″	100%	19.436
Neptune	15	$0^h 02.8^m$	–1° 07′	34° Ev	+7.9	2.2″	100%	30.695

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



Bringing the Night Sky to Life

Time lapses turn your still photos into cinematic masterpieces.

▲ **MILKY WAY PANORAMA** Our home galaxy makes a dynamic and photogenic subject for time-lapse photography. The author captured this 30-second single exposure for a movie with a full-frame, tripod-mounted Canon EOS 6D DSLR camera at ISO 3200 and a 15-mm f/2.8 fisheye lens.

What if you could compress hours under the stars into a few breathtaking seconds, revealing the Milky Way's grand sweep overhead, a motion normally far too slow for the eye to perceive?

That's the magic of *time-lapse astrophotography.* Although the process might seem complex, if you've already tried star trails or image stacking, you're closer to time lapses than you realize. The capture workflow is similar; the real difference comes at the end when you animate your frames into a video that reveals the motion of the night sky.

The real beauty of creating time lapses is that it doesn't demand specialized or expensive gear. You can capture stunning results with the same basic setup used for still astrophotos. I covered tripod-based astrophotography and stacking in detail in a previous column (*S&T:* Feb. 2023, p. 54), and time lapses naturally build on those same techniques.

Your essential gear list is refreshingly short and modest:

- A DSLR or mirrorless camera with interchangeable lenses
- The widest lens you have — even an 18-to-55-mm kit lens can be surprisingly effective
- A sturdy tripod to keep everything rock steady
- A remote shutter release with a locking button to fire the shutter repeatedly without touching the camera.

That's all you really need to get started. Even a smartphone or action camera on a tripod can also work — several now offer surprisingly capable time-lapse modes — though dedicated cameras still provide more control and better image quality.

While that simple kit will take you far, I've gravitated toward using a full-frame DSLR paired with a fast fisheye lens. In my case, an older Canon EOS 6D and a 15-mm f/2.8. While the 6D isn't cutting-edge technology, its full-frame sensor handles high ISO settings well, making it ideal for night photography.

A fast lens with a wide aperture gathers maximum amount of light in minimum time. And the fisheye's ultrawide perspective lets me record immense swaths of sky while stretching exposures up to 30 seconds before trailing of the stars becomes noticeable.

Location Scouting

Astrophotography always rewards preparation, and time-lapse photography is no exception. Success depends less on the gear you bring than on the skies you choose.

The top consideration is escaping light pollution. Dark skies reveal more stars, allowing your footage to showcase the Milky Way's intricate structure and subtle background glow. Plan your outing during the new Moon for best results, since even modest moonlight can overwhelm faint details. However, a setting waxing crescent can add beauty to dark locations — its faint glow illuminates the landscape for a few minutes before it dips below the horizon,

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▲ **NOT JUST STARS** Nine frames were extracted from a time-lapse movie sequence and blended together in *Adobe Photoshop* to create this composite of Comet C/2020 F3 (NEOWISE) setting. The author captured the sequence with his Canon 6D camera set at ISO 1600 and a 50-mm f/1.4 lens.

providing a gentle transition for your opening shots.

But even with pristine skies, there's a modern challenge you'll quickly notice: trails from passing satellites and aircraft. Because each exposure is often 20 to 30 seconds long, these intruders show up as bright streaks slicing across the sky. At first glance, it appears you've captured some sporadic meteors. However, closer inspection reveals the disappointing truth: most streaks are artificial. In a single still image, you could painstakingly clone them out, but time-lapse sequences often involve hundreds of individual frames, making manual cleanup impractical.

Even without moonlight, including a few minutes of twilight at the start or end of your sequence can enrich your time lapse. The sky shifts from cobalt to black (or the reverse) in a way that creates a natural, visual arc when compressed into video.

Planning apps like *PhotoPills* and *SkySafari* are invaluable. Their augmented-reality overlays let you preview where the Milky Way or constellations will appear in your chosen frame. This helps you previsualize the arc of motion your time lapse will record.

Settings, Focus, Exposure

Manual control is not optional. Set your camera to full Manual (M) mode and shoot in RAW format for maximum processing and editing flexibility.

Focusing at night is its own challenge. Autofocus works poorly with starlight, so switch to manual focus, magnify a bright star in Live View, and carefully adjust the focus ring until you achieve a sharp, pinpoint of light. This small step separates dazzling time lapses from fuzzy disappointments.

For exposure, start with a wide-open aperture. An ISO setting of 1600 or 3200 is a good baseline, though don't be afraid to experiment — modern sensors tolerate higher values far better than older models. Shutter speed deserves special attention. You may know "the 500 rule" — divide 500 by your lens focal length to calculate the maximum exposure time before stars trail in still photos. (Use 300 for cropped-sensor cameras.) Here's the good news: in time lapses, trailing is less noticeable because frames are blended into motion.

You can often push exposures longer than the 500 rule suggests, capturing more light without spoiling the effect. This works because each frame appears for only a fraction of a second in the final video, so slight trailing in individual exposures becomes imperceptible when played back sequentially.

A simple starting recipe looks like this: 30 seconds at f/2.8, ISO 3200, with a 16-mm lens on a full-frame camera. From there, tweak to taste.

Capturing Celestial Motion

Once you're ready, set your camera to fire continuously with minimal delay between frames. Turn off image review and long-exposure noise reduction to save on battery and avoid interruptions.

◀ **SIMPLE CAMERA SETUP** Aside from a camera and lens, a basic time-lapse setup consists of a sturdy tripod and a locking remote shutter release. Remote releases from camera manufacturers can be expensive, but third-party versions (such as the one shown here) function well for a fraction of the cost.

◀ **MOTORIZED TRACKING GEAR** A portable, battery-operated sky tracking mount, like the iOptron SkyTracker™ Pro shown here, allows you to track the stars while capturing your time-lapse video. The author attached his camera to the tracker via a ball-head mount.

Plan to take some 200 to 400 frames for a typical 30- to 60-second time lapse. Expect to spend two to four hours to capture enough frames for a compelling sequence. The Milky Way moves noticeably in just an hour, so longer sequences show more dramatic change.

Remember, you don't need one exposure for every frame of video; your captured images can span multiple video frames without appearing choppy. This means 100 exposures could easily create a smooth, 30-second time lapse when each image is held for several video frames during playback.

Take Two . . . or Three

The simplest method is the fixed-tripod time lapse. Here, your camera remains stationary while the stars drift overhead. The resulting footage is a direct visualization of Earth's rotation — the sky wheels gracefully while your foreground landscape stays anchored.

Each location offers endless variety. Point south on a summer night, and the Milky Way will rise tall, pivoting across the frame. Face north, and stars circle endlessly around Polaris, creating hypnotic arcs. Aim east or west to capture constellations rising or setting. On a winter evening, Orion climbing the eastern horizon is particularly dramatic. Shooting multiple directions over several nights (or even during the same night with shorter sequences) builds a diverse time-lapse library from a single location.

If you want to experiment further, try using a portable star tracker or equatorial mount. This way, the camera counters Earth's rotation so the stars remain fixed, while the horizon appears to tilt up into the scene. It's a surreal, almost alien perspective.

And . . . Action!

Once the night is done, the real fun begins. You can transform a single run of exposures in multiple ways — time-lapse videos, star-trail composites, or as stacked stills — making your time under the stars remarkably efficient.

Begin processing your images in a RAW editor such as *Adobe Lightroom* or *Darktable,* a free alternative from darktable.org. Edit one shot from the middle of the sequence, adjusting the exposure, contrast, and color balance until you're satisfied, and then synchronize those edits across the set. I've discussed the fundamentals of RAW processing in an earlier column (*S&T:* Feb. 2024, p. 55).

Crop the sequence to a video-friendly aspect ratio such as 16:9 (for horizontal screens) or 9:16 (for vertical social media). Then, export the frames as high-quality JPEGs with sequential file names, such as 001.jpg, 002.jpg, and so on.

Next, open your video-editing software. *Final Cut Pro*, *Premiere*, and even freeware like *iMovie* and *DaVinci Resolve* will do the job. Drag the numbered images onto the timeline, and they'll fall neatly into order. Adjust the frame duration or playback speed so the sequence runs 30 to 60 seconds, which is usually the sweet spot for viewer engagement.

Visual effects like cross-dissolve transitions between frames can add smoothness, though often the unblended motion is striking on its own. Consider adding a non-copyrighted music track during editing — instrumental pieces work particularly well, letting the celestial motion take center stage without distracting lyrics. Before exporting, check the brightness and contrast across the clip — time lapses can look darker than expected once animated. Render your final video at the highest quality available, and you'll have compressed hours of star-gazing into a minute of cosmic motion.

▲ **GLACIAL AURORA** Fast, ultrawide lenses are helpful when capturing quick-moving subjects at night, like meteor trails or the northern lights, as shown here. The rapid "dancing" of the aurora means you need very short exposures to record them without blurring. A 15-mm f/2.8 fisheye plus ISO 1600 allowed for short, 5-second exposures that helped freeze the action during video capture.

That's a Wrap!

Creating night-sky time lapses is both technically satisfying and emotionally rewarding. The process demands patience and planning, but the payoff is extraordinary: hours of exposures condensed into a flowing minute that reveals Earth's motion against the starry backdrop.

And while your camera works in silence through the night capturing hundreds of exposures, don't just stand around in the dark — bring binoculars or a small telescope and enjoy the real-time sky. In the end, a time lapse is more than just a video — it's a cosmic time machine, turning a long night under the stars into a cinematic performance you can replay forever.

■ **TONY PUERZER**, who calls Vancouver Island, British Columbia, home, is a retired professional photographer and an avid amateur astrophotographer. You can see examples of his time-lapse work at **https://is.gd/astro_timelapse**.

A New Lunar Perspective

EXTREME ILLUMINATION ATLAS OF THE MOON

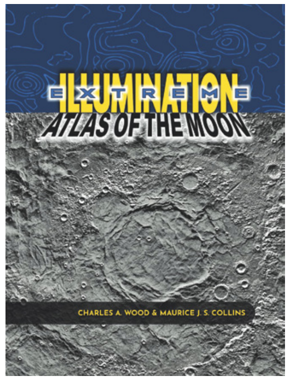
Charles A. Wood, Maurice J. S. Collins
Independently published 2025
182 pages, ISBN 9798323588909
$60.00, hardcover.

BY THE END OF the 19th century, the Earth-facing hemisphere of the Moon had been mapped in greater detail than many remote regions on Earth. It's hard to believe that a quarter of the way through the 21st century, a lunar atlas can appear that contains scores of previously undiscovered features, including many of impressive size. Distinguished lunar scientist and *Sky & Telescope* Contributing Editor Charles A. Wood teamed up with New Zealand amateur astronomer Maurice J. S. Collins to accomplish this remarkable feat.

Their revolutionary *Extreme Illumination Atlas of the Moon* is based on data collected by NASA's Lunar Reconnaissance Orbiter (LRO) and the Japan Aerospace Exploration Agency's Kaguya mission. Both spacecraft were placed in elliptical polar orbits around the Moon to map the contours of its surface with unprecedented resolution.

The LRO uses a laser altimeter to project pulses of light onto the Moon. Timing the round trip of its emitted and reflected beams yields extremely accurate distance measurements between the spacecraft and the lunar surface. Kaguya augmented the data with forward- and aft-looking cameras that took stereo images to gauge lunar elevations.

In 2016, a team led by NASA's Michael Barker painstakingly combined LRO laser altimetry measurements of more than 6 billion discrete locations on the Moon with elevations derived from Kayuga stereo imagery. In so doing, they constructed a global digital elevation model (DEM) of the Moon accurate to an astonishing 1 meter (3 feet) of vertical relief. Wood and Collins have cleverly exploited Barker's work using elegant software called the *Lunar Terminator Visualization Tool,* or *LTVT* (available at **https://is.gd/LTVTsource**), which uses this DEM to depict features under the same extremely grazing (0.1°) illumination angle across an entire field of view, not just in a narrow swath of longitude. By eliminating shadows that conceal nearby features and displaying only light reflected by topographic slopes, *LTVT* images reveal large, low-relief structures spanning unprecedented distances.

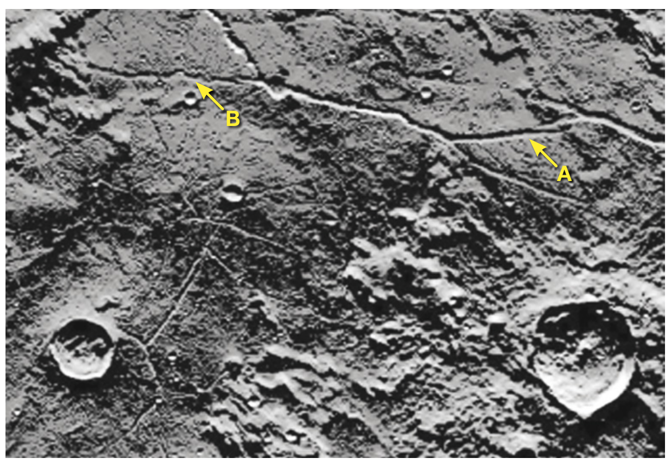


The software also allows users to change the direction of illumination, providing views that never occur in nature. Shallow linear features like trenches, scarps, and ridges that run parallel to the east-west direction of natural solar lighting cast short shadows, so they can only be seen with difficulty and may even elude detection. However, when these features are illuminated in a north-south direction, they cast long shadows and stand out in bold relief.

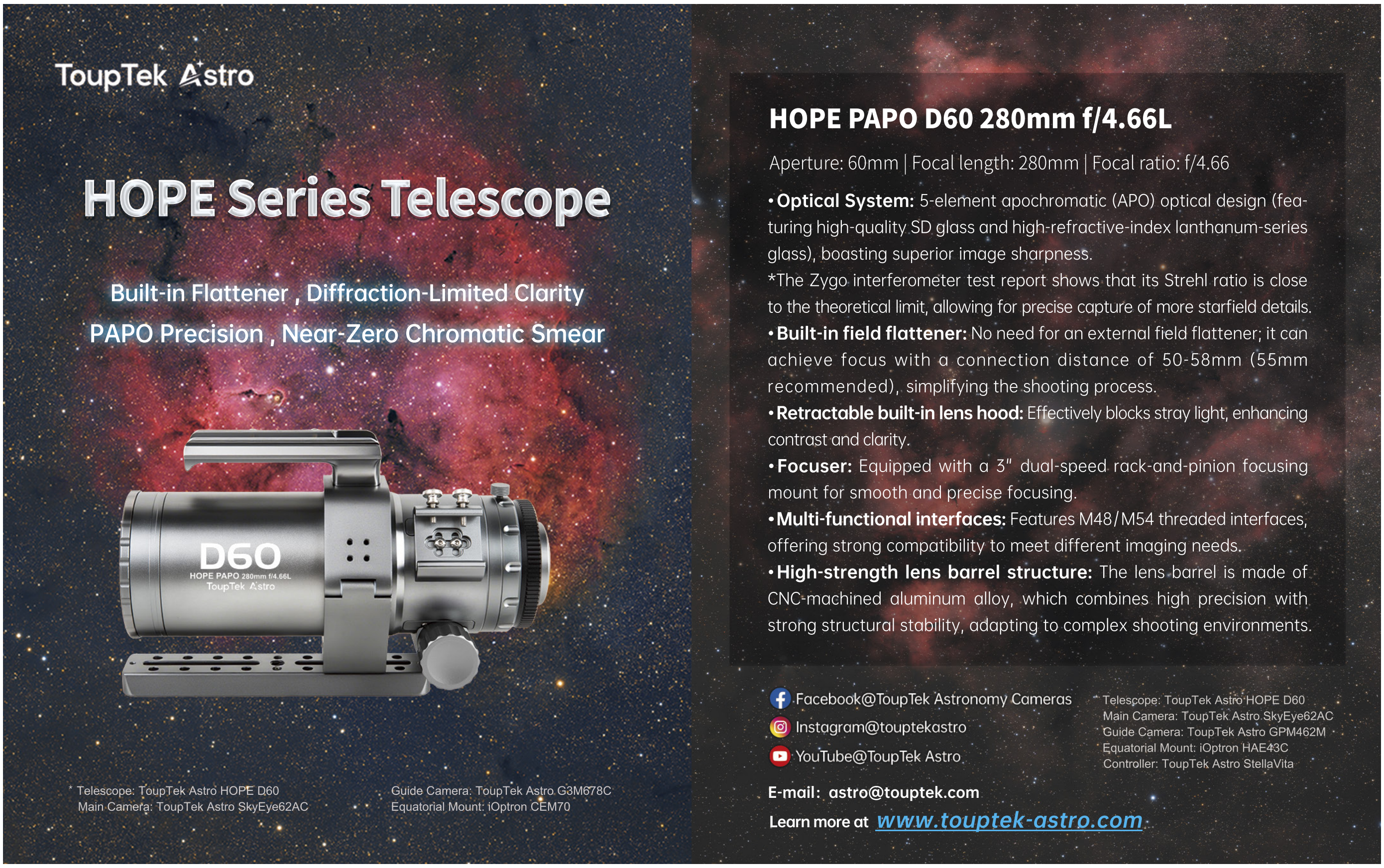
In addition to low-resolution hemispheric views, *Extreme Illumination Atlas of the Moon* depicts 90 selected regions as pairs of high-resolution images. One is illuminated from the lunar east to correspond with the familiar sunrise terminator of the waxing Moon. The second is illuminated from the north, a perspective that invariably reveals features never seen before.

Accompanied by expert descriptions that provide geological context, these truly novel views deliver extraordinary insights into every part of the lunar surface. *Extreme Illumination Atlas of the Moon* is simply a must have for every serious student of our nearest celestial neighbor and a rich source of new, challenging targets for veteran lunar observers.

■ Contributing Editor **TOM DOBBINS** is coauthor of *Epic Moon: A History of Lunar Exploration in the Age of the Telescope*, available at **shopatsky.com**.



▶ The extremely shallow rille connecting the western end of Rima Ariadaeus and the eastern end of the Rimae Hyginus (A) is difficult to see under familiar lighting from the east or west. But when it's artificially illuminated from the north, not only does the rille stand out boldly, but the visualization also reveals a previously unknown, 45-kilometer-long westward extension (B).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PAPO Precision , Near-Zero Chromatic Smear
D60
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Main Camera: ToupTek Astro SkyEye62AC
Guide Camera: ToupTek Astro G3M678C
Equatorial Mount: iOptron CEM70
HOPE PAPO D60 280mm f/4.66L
Aperture: 60mm | Focal length: 280mm | Focal ratio: f/4.66
•Optical System: 5-element apochromatic (APO) optical design (featuring high-quality SD glass and high-refractive-index lanthanum-series glass), boasting superior image sharpness.
*The Zygo interferometer test report shows that its Strehl ratio is close to the theoretical limit, allowing for precise capture of more starfield details.
•Built-in field flattener: No need for an external field flattener; it can achieve focus with a connection distance of 50-58mm (55mm recommended), simplifying the shooting process.
•Retractable built-in lens hood: Effectively blocks stray light, enhancing contrast and clarity.
•Focuser: Equipped with a 3" dual-speed rack-and-pinion focusing mount for smooth and precise focusing.
•Multi-functional interfaces: Features M48/M54 threaded interfaces, offering strong compatibility to meet different imaging needs.
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A Slice of *Nightlife* at

A BAR FULL OF TREASURES Lying at a distance of only 163,000 light-years and almost face-on at an angle of about 35°, the Large Magellanic Cloud offers southern observers an incredible view of its huge, off-center bar structure. Curiously warped, with its ends closer to the Milky Way than the galaxy's center, it's a crowded and dynamic region filled with a vast and complex collection of celestial gems.

ROBERT GENDLER

the LMC's Bar

This region of the Large Magellanic Cloud is unlike anything else in the night sky — north or south.

The off-center stellar bar in the Large Magellanic Cloud (LMC) is one of the nearby dwarf galaxy's most striking and defining features. Roughly 5° long by 1° wide, it's a remarkable shimmer swarming with a multitude of individual deep-sky objects — big and small, bright and faint, complex and modest. A dark location is key, and the darkest night I spent "at the bar" was last December (at the beginning of summer in the Southern Hemisphere) with my 16-inch f/4.5 Dobsonian and Rocket, my greyhound, on a vast and desolate Kalahari saltpan so remote that light and sound pollution are entirely absent. From this location, stars stretch to every horizon, and the Milky Way arches overhead so dazzlingly bright it glints off the site's salt-encrusted surface like tiny, earthbound stars.

The LMC occupies roughly 11° × 9° of sky. Even with the naked eye, in this supremely dark place it lives up to the "Large" in its name. Its bar is visible as a bright axis of starlight fading into an oval gossamer mist that itself gradually fades away at its edges. Because transparency is paramount for observing objects in the bar, I try to choose nights when the Tarantula Nebula shines like a bright, white galactic beacon — the cosmic spider serving as my transparency gauge.

In many previous visits to the bar I ferreted out close to 200 treasures. This tally includes two superbubbles (caverns sculpted by stellar winds and subsequent supernovae explosions of an *OB* association's massive stars), three medium-sized star-forming complexes, around 150 open clusters (38 of which have NGC designations), 11 young massive clusters, and seven NGC globulars. My scopes have also swept up *OB* associations, binary clusters, emission nebulae, supernova remnants, and a solitary planetary nebula. There are even three background galaxies bright enough to shine through the dazzling congestion. It's no surprise that even a busy observer can run out of nights long before running out of interesting objects!

So much of astronomy is at some level a matter of perspective — it's utterly amazing to me that we can sit at our telescopes and actually traverse another galaxy and explore objects within it in great detail, right down to the level of individual stars. I spend half my summers in the LMC and am still astounded each time I embark on another night of exploration. But to keep things manageable, in this article I'm presenting a small selection of showpiece objects. Unless otherwise noted, I made my observations with the 16-inch working at a magnification of 228×. However, the objects I describe were also tremendously enjoyable in my 10-inch Dob, and a handful even qualify as binocular targets.

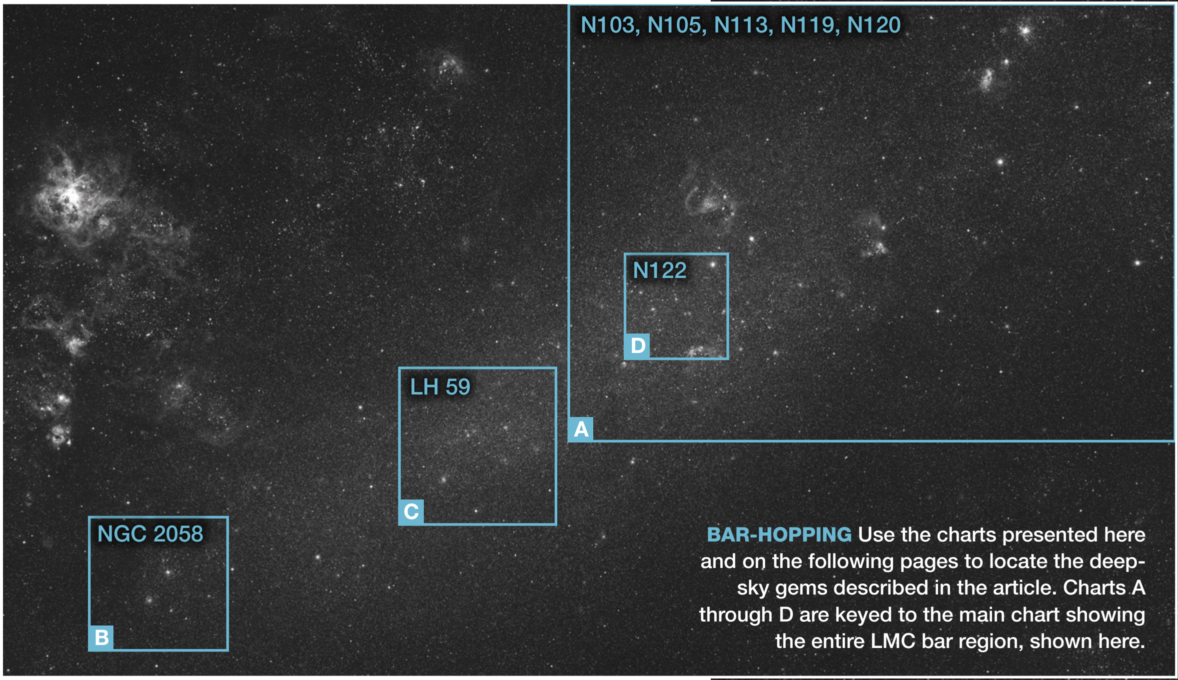
A Trio of Star Factories

Let's begin our night of bar-hopping with **N119** — a large H II region lying on the bar's northern edge. In images it presents a striking structure that mimics a barred spiral galaxy, and it's no less dramatic in a telescope. Three beautiful arcs are visible, giving N119 the appearance of a smoke-drift fantastically wreathed by cosmic winds. With an ultra-high contrast (UHC) filter, these distinct sections clearly delineate the spiral shape. At the center of the structure there's a roundish patch of bright and beautifully uneven nebulosity spanning 3′ and bracketed in the east and west by hazy, swooping arcs.

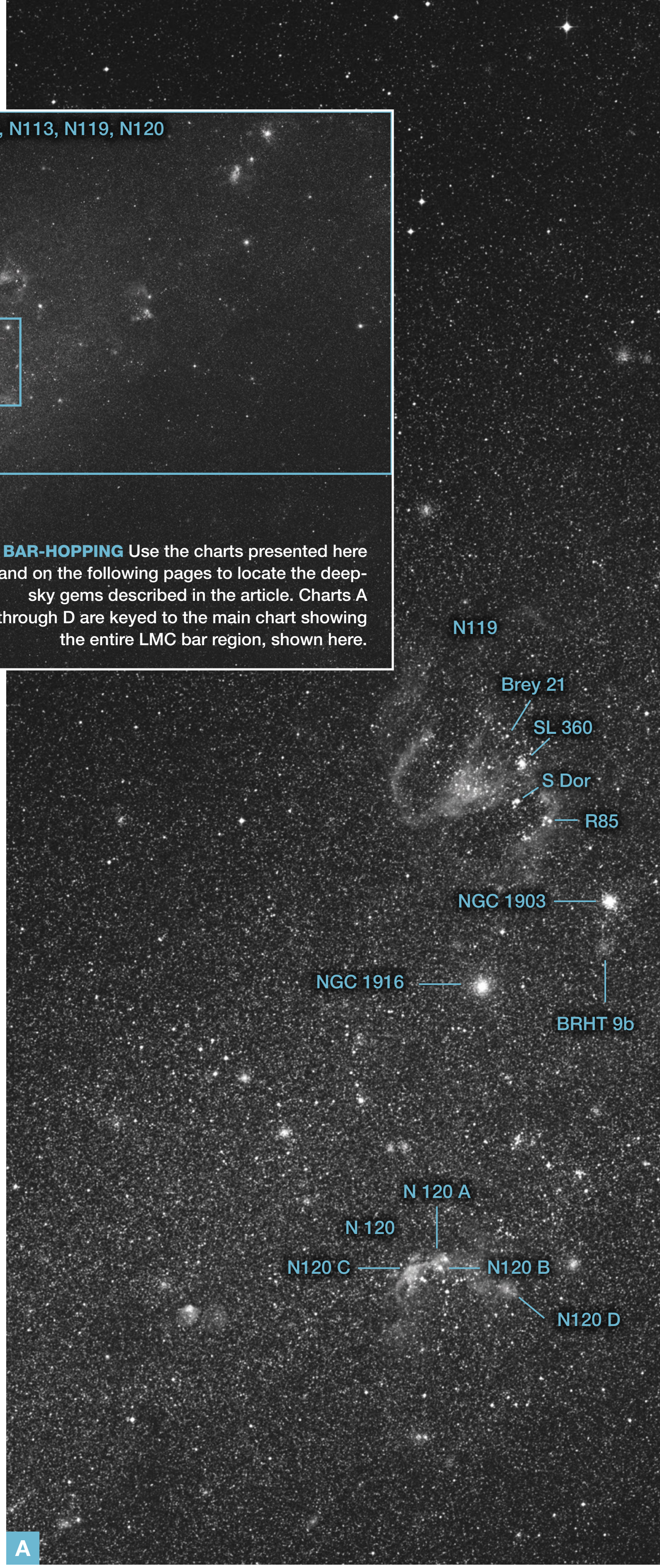
This nebulous complex is drenched with starlight from its resident *OB* association LH 41. It packs a dazzling 90 or so hot, massive stars ranging in magnitude from 11 to 15 into a 7′-diameter area. But outshining them all is the LMC's most fabulous stellar treasure, the magnificent variable star **S Doradus** (S Dor). It typically shines at 9th magnitude (though it varies from 8.6 to 11.5), which makes it the brightest star in the LMC. It's also the prototype for the exceptionally rare luminous blue variables, or LBVs. And as

▲ **ENIGMATIC SPIRAL** The remarkable H II region N119 contains layers of complexity for us to explore with our telescopes. It's also home to the fabulous star S Doradus (at top of the dark void in the center). Its two bright cluster neighbors to the south are equally fascinating – ancient globular NGC 1916 (lower center) and to its upper right, young massive cluster NGC 1903 with its shadowy companion below it.

ESO



BAR-HOPPING Use the charts presented here and on the following pages to locate the deep-sky gems described in the article. Charts A through D are keyed to the main chart showing the entire LMC bar region, shown here.

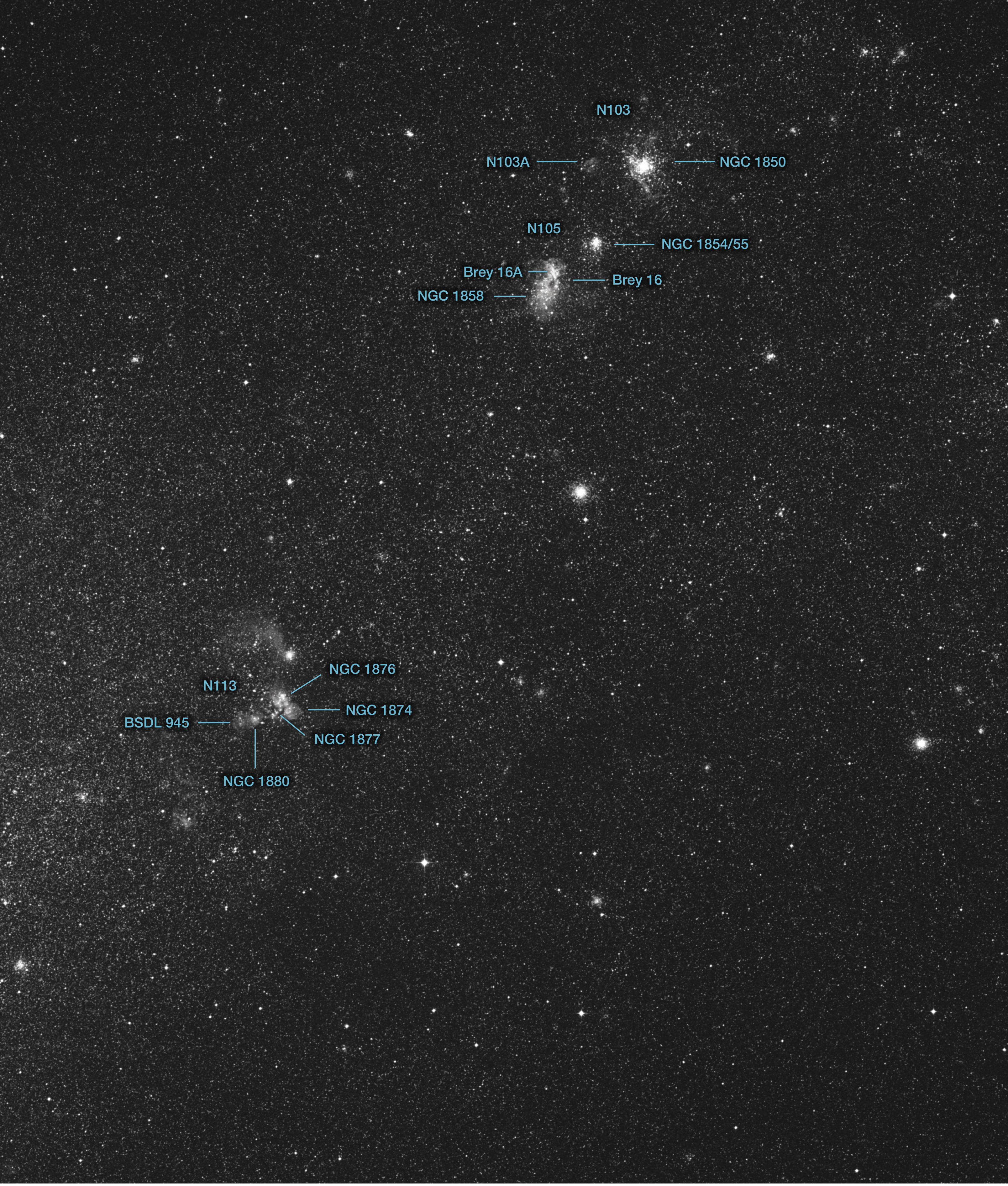


POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY (2)

if S Dor weren't enough, a *second* LBV (**R85**, magnitude 10.8) lives less than 2′ to the southwest. Adding even more stellar magnificence, an 11.3-magnitude Wolf-Rayet star, **Brey 21**, is situated 3.3′ northeast of S Dor, and eight *O*-type stars (magnitudes 12.1 to 13.4) are scattered across N119. What could be more incredible than being able to resolve hordes of stars in another galaxy, some of which also happen to be among the rarest type in the universe? Indeed, across the entire LMC I've picked off nine LBVs, 79 Wolf-Rayet stars, and heaps of *O*-type stars. Amazing.

N119 also has five small clusters, two of which are reasonably bright. S Dor lives in the smaller of these, a collection aptly named the **S Doradus Cluster**. It's a conspicuous, knot roughly 30″ in diameter. Cluster **SL 360** lies 2′ north of S Dor and is a bright, round glow roughly 40″ across, with a hazy periphery and a pair of faint stars at its heart.

Shifting our gaze roughly ½° westward brings us to an example of what I think is one of the most gorgeous telescopic sights of all — a set of razor-sharp stars glinting against an intricate, glowing nebulosity. And that's what the prominent star-forming region **N113** and *OB* association LH 35 deliver. A dozen stars of magnitude 14 to 15 lie in four lush pools of nebulosity, which are themselves encased in a large and faint haze and a scattering of additional stars. Three of the nebulous pools crowd together on the western side of the complex and are occupied by the young open clusters **NGC 1874**, **NGC 1876**, and **NGC 1877**. With a UHC filter, my 16-inch shows both NGC 1874 and NGC 1876 as bright, rich, ragged, and even glows 50″ and 66″ across, respectively. Nearby NGC 1877 is a fainter, patchier oval 30″ across, while a fourth pool of nebulosity, **NGC 1880**, lies on the southeastern side of the complex. It's a moderately bright, round, and intricately uneven haze spanning


N103
N103A
NGC 1850
N105
NGC 1854/55
Brey 16A
Brey 16
NGC 1858
NGC 1876
N113
NGC 1874
BSDL 945
NGC 1877
NGC 1880

▲ **A YOUNG CLUSTER** NGC 1854/55 is a mere fledgling at around 25 million years old, and this plethora of hot, young stars makes it easy to see why its core blazes with light in telescopes despite its distance.

about 45″. Extending to its east is the soft and faint round nebula **BSDL 945**, fading into the background sky.

The bar's third star-forming complex, **N120**, can be found about ½° south-southeast of S Dor. It's an arc-shaped feature open to the south that consists of several H II regions, a wind-blown bubble, and a supernova remnant, with a dozen or so faint stars (*OB* association LH 42) scattered across it. Like the other two complexes, a UHC filter really makes it stand out from the bar's bright haze. **N120C** on the eastern side is the biggest and brightest section — a 1.2′-diameter roundish patch with ragged edges. The rest of the complex's nebulosity extends westward from N120C in a 5′-wide arc.

N120A in the center of the arc is a rare and intriguing bubble, or cavity, blown by a *B*-type star. With a UHC filter, it looks pretty much what one would hope a bubble would look like — a round, soft, and moderately bright haze, spanning about 20″, with fairly well-defined edges. Its soft light belies the ferocity of the violent stellar wind and intense ultraviolet radiation from the hot, young star (12.7-magnitude BI 141), lying serenely on the nebula's western side.

N120B is the smallest and the brightest of the nebulae, appearing as a tiny knot of light with crisp edges. And **N120D** on the western end of the arc appears as a small, faint, misty smudge with one star involved in the nebulosity.

Even with the Kalahari's incredibly dark skies and excellent transparency, there isn't much to be seen of the large, but exceedingly faint supernova remnant (also very confusingly called N120) that lies toward the western end of the arc. Using my O III filter at 130×, I see a very dim, diffuse haze with no definite shape — it simply dissolves away into nothingness. A slightly brighter, wraith-like tendril lies within the haze's southeastern side. Can you see it?

Clusters Young and Old

The LMC has a unique cluster formation history and evolution. It's home to 15 globulars that were formed around

▲ **A SPARKLING GAGGLE** NGC 1858's cluster of stars is estimated to be around 10 million years old, although the presence of a protostar in the field suggests that star formation may still be active or just ceased very recently.

NGC 1854/55: ESA / HUBBLE / NASA; NGC 1858: NASA / ESA / G. GILMORE; PROCESSING: GLADYS KOBER

13 billion years ago. This phase was followed by a period of quiescence, known as the "age gap," which lasted about 10 billion years and during which time only three clusters were formed. Then, approximately 3 billion years ago, a second burst of formation began, and still continues. These objects are variously (and confusingly) referred to as young massive clusters, young globular clusters, massive clusters, young populous clusters, globular-like clusters, *and* young blue clusters! But regardless of what one calls them, they most certainly look like globulars in images and the eyepiece.

The LMC has generously tossed seven ancient globular clusters and 11 young massive clusters into the bar for us. A stunning juxtaposition of young and ancient lies just 7′ south and southwest of S Dor. Young massive cluster **NGC 1903** is simply gorgeous. It glows brightly at magnitude 11.9 and is about 1′ in diameter with a blazing, 20″-wide core. I can resolve 10 stars in its halo, with a number of tiny sparklers popping in and out of view like transient glitter. NGC 1903 is also a binary cluster with its companion, **BRHT 9b**, lying 2.3′ to the south. It's a very faint and very diffuse 30″-diameter object. Although binary clusters are extremely rare in our Milky Way galaxy, they're common in the LMC — the bar alone offers us a dozen pairs to view.

NGC 1903's ancient globular counterpart is 10.4-magnitude **NGC 1916**, lying a mere 8′ to the southeast. It's just as gorgeous as the youngster. NGC 1916 is round and smooth, roughly 45″ across, and features a small, bright core. But even with my 16-inch I couldn't resolve individual stars.

The brightest cluster in the LMC is the massive young **NGC 1850**. To visit it, we need to travel up to the northwestern edge of the bar. Let's go.

A Pair of Dazzlers

Close neighbors **N103** and **N105** are an eye-catching pair of superbubbles. NGC 1850 lives in N103 and is a 9th-magnitude binocular showpiece, appearing small, round, and beautifully bright in my 15×70s.

If NGC 1850 resided within our own galaxy, it would be impressive. It's close to 5′ across with a blazing core roughly 1′ in diameter, out of which a couple dozen stars appear to burst forth in haphazard chains across the cluster's bright halo. NGC 1850 also has a companion, open cluster NGC 1850A, a tiny clump of brightness just off the core's western side. The two have an intriguing age difference — NGC 1850 is around 100 million years old while its tiny neighbor is notably younger, at around 4.3 million years old.

NGC 1850 also marks a significant milestone in astronomy. In 2021, astronomers discovered that it harbors an 11-solar-mass black hole that's part of a binary system with a 4.9-solar-mass *main-sequence turn-off star* (a star that's about to leave the main sequence). This system represents the first of its kind discovered within a young massive star cluster.

In images, N103 bears a marked resemblance to the Cygnus Loop, but alas, the cluster's brilliance washes out the nebulosity except for a small, faint patch designated **N103A**, found on the superbubble's eastern edge. With a UHC filter, N103A appears as a faint, circular haze, about 20″ in diameter that simply fizzles away at the edges.

Neighboring superbubble N105 has two eye-catching residents, the brightest of which is **NGC 1858**, a glowing emission nebula that stretches 3.5′ × 1.5′ elongated north-northwest to south-southeast. Some 16 stars in the range of 13th to 15th magnitude belong to *OB* association **LH31**. Among this stellar collection is 13.7-magnitude **Brey 16**, a rare eclipsing binary consisting of a Wolf-Rayet *WN*4 star and an *O*5-type blue supergiant. A second Wolf-Rayet star (13.9-magnitude **Brey 16A**) lies in a much brighter patch of nebulosity at the northwestern end of the complex. NGC 1858 gains tremendous contrast with a UHC filter, which helps show it to be intricately uneven, with some mysterious dark pools and dense, rich regions along its western and eastern sides.

N105's other dazzling inhabitant is **NGC 1855.** This 10.4-magnitude young massive cluster has a bright core that boasts its own designation, **NGC 1854**. The cluster is a

What's in a Name?

Even showpiece objects in the LMC often have unfamiliar designations. For example, numerous objects have "**N**" numbers that signify they were listed in the *Catalogue of Emission Nebulae in the Large Cloud* published in 1956 by American astronomer-astronaut Karl Henize (1926–1993).

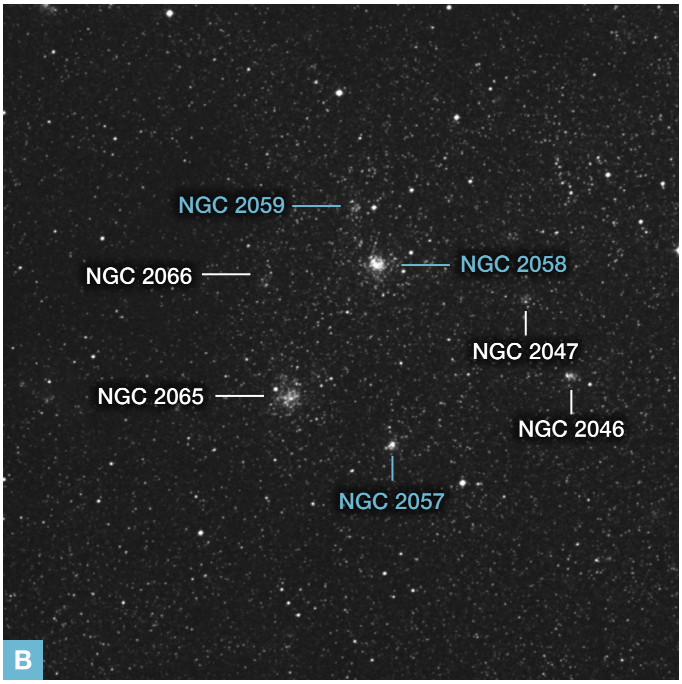
Here are the other designations I have included:

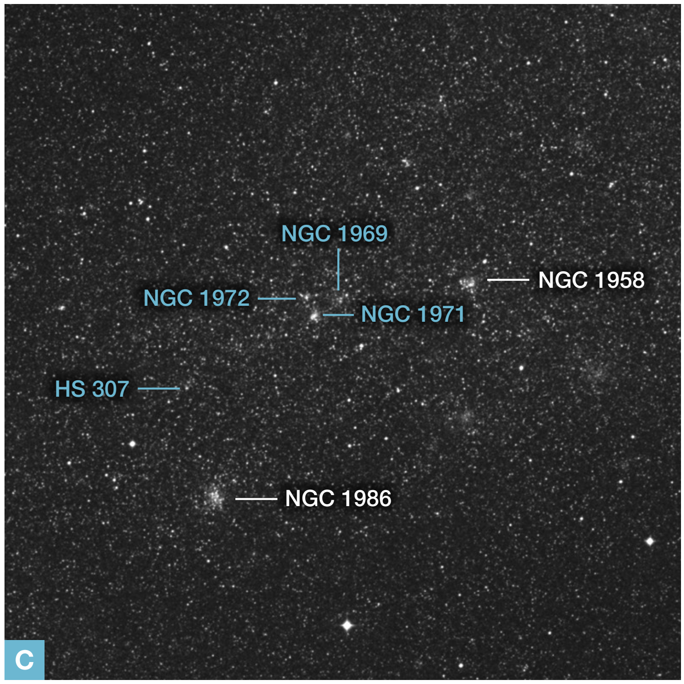
BRHT: Pairs of binary clusters compiled by Raj Kumar Bhatia and colleagues in their 1991 survey of the LMC's cluster system, which consisted of 1,200 objects known at that time.

BSDL: Objects listed in the 1999 survey of extended objects in the LMC conducted by Eduardo L. D. Bica and colleagues. The census provided a whopping 6,659 objects, including star clusters, associations, and objects related to emission nebulae.

LH: *OB* associations in the LMC compiled in the1970 catalog published by Peter Lucke and Paul Hodge, with sizes from 15 to 300 parsecs and with stellar populations ranging from a few to 225 members, down to visual magnitude 14.7.

SL: Clusters listed in the 1963 catalog published by Harlow Shapley and Eric Lindsay. It consists of 898 LMC clusters that cover a range of morphologies, from large, bright aggregations (now known as stellar associations) to open and globular clusters.





POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY (2)

rich, even glow approximately 1′ across that brightens to an intensely bright core. I wasn't able to resolve individual cluster members, but I did see a very small, bright knot of stars attached to the northern end of the cluster's halo.

A Multitude of Open Clusters

If you enjoy wading through thickets of open clusters, the LMC bar is the place to be! Given the aforementioned 150 or so available, the smallest nudge of a scope takes us through the entire gamut of open clusters — from easy, bright, and resolvable, to tiny, faint droplets of unresolved starlight. Both ends of the range offer satisfying observing experiences.

The most impressive aggregation lies at the southeastern end of the bar where seven clusters fit within a 15′-wide field: NGC 2046, NGC 2047, NGC 2057, NGC 2058, NGC 2059, NGC 2065, and NGC 2066. The sight is so impressive that John Herschel sketched the group when he was stationed in South Africa from 1834 to 1838, using his 20-foot (18¼-inch aperture) telescope. Albert Le Sueur did the same in 1870 using the 48-inch Great Melbourne Telescope in Australia, as did Joseph Turner in 1876 with the same instrument.

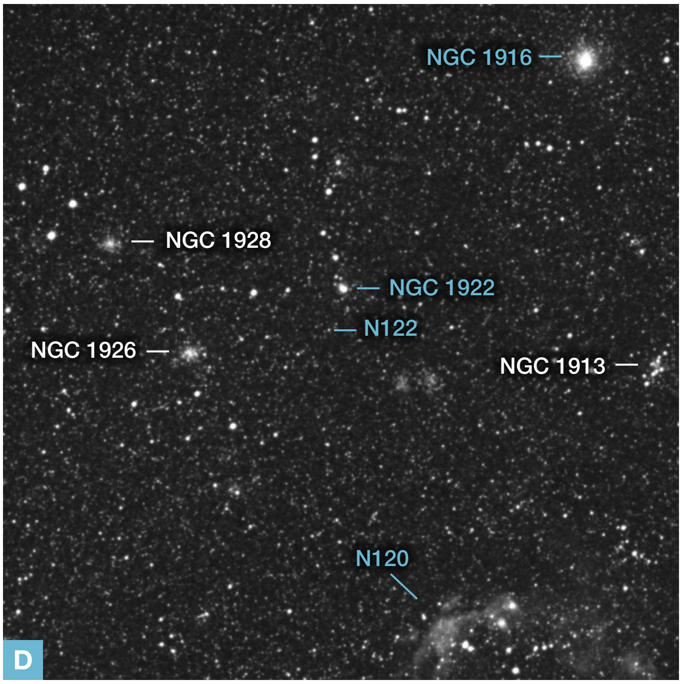
I took copies of their sketches along with me to try to unravel a few discrepancies that intrigued me. Turner showed **NGC 2057** as elongated, while Herschel and Le Sueur depicted it as circular. My observation matched those of Herschel and Le Sueur: a round glow 25″ in diameter and brightening to the center. Both Turner and Le Sueur showed **NGC 2059** as elongated, whereas Herschel had it round. In my eyepiece, the cluster matched Herschel's rendering — a moderately bright glow 30″ across. Do your impressions agree with mine?

Of all the clusters in the group, **NGC 2058** is the most prominent, shining at magnitude 11.9. My eyepiece views matched all three sketches — a round glow roughly 1.3′ in extent, with a large bright core. Herschel's drawing nicely captured the halo as I saw it. It's one of those superbly gritty halos that torture you with lots of stars just beyond your scope's resolution. In the eyepiece, the cluster is highlighted by a pair of 13th-magnitude stars situated just 1′ west-southwest and 1.3′ west-northwest of the core. However, Herschel's depiction included no stars while Le Sueur included six and Turner 11. The lack of stars in Herschel's rendering puzzles me. He made incredibly detailed and precise sketches to document his findings, drawing them over several nights to correct errors. Why did he omit these stars?

Another impressive, cluster-rich *OB* association is **LH 59**, which stands out well against the exceptionally dense eastern part of the bar. Heaps of faint stars are scattered over a 3′ × 7′ region. Set among them is a compact triangle of three NGC open clusters. **NGC 1969**, marking the triangle's northwestern apex, glows at magnitude 12.5. I see it as about 30″ in diameter. **NGC 1971** lies 1.2′ to the southeast and, at magnitude 11.9, is the brightest of the trio — an even, round 30″-wide haze. Finally, 12.6-magnitude **NGC 1972** marks the triangle's northeastern corner, and it also appears about 20″ across, with a bright, starlike core. The association's fourth cluster, **HS 307**, lies about 6′ southeast of the triangle, but it's exceedingly faint and small. It appeared as little more than a slight brightening against the bar's rich shimmer.

One Last Treasure

On this visit to the LMC's bar we've encountered a mere handful of its most notable denizens. As I mentioned at the beginning, the region is not only remarkable for its sheer number of deep-sky gems but also its variety. This is perhaps no better illustrated than with a tiny planetary nebula lying in the same rich field where we began our survey. **N122** is



◀ **NEEDLE IN A STELLAR HAYSTACK** Tiny, 15th-magnitude planetary nebula N122 can be located using this photo. The object lies just 1.1′ south-southeast of 11.5-magnitude open cluster NGC 1922.

nothing more than a 15th-magnitude pinprick, so it's fortunate that it lies just 1.1′ south-southeast of the 11.5-magnitude open cluster **NGC 1922**. Without the cluster to guide one's eye, the tiny speck of light would be lost amongst the many field stars. Blinking with a UHC filter and not a little effort helped me identify this faint, minuscule treasure. As with so many deep-sky objects, its appearance is less remarkable than the fact that it's visible at all.

As dawn approached on that special morning, I packed up the telescope and headed home with Rocket. I drove away with a logbook full of notes and sketches, and with the memory of an incomparable night spent exploring this magnificent, ragged galaxy.

■ **SUSAN YOUNG** lives in South Africa and spends a considerable part of her Kalahari summers exploring her favorite celestial treasure trove, the LMC. She maintains a website at **largemagellaniccloud.com**.

▲ **DISTANT CLOUDS** The sight of the Large and Small Magellanic Clouds, seen here hanging above the ESO's Paranal Observatory in Chile, is one of the night sky's most beautiful naked-eye sights from a truly dark location.

◀ NEW DOB

Explore Scientific announces a new series of midsize Newtonian reflectors. Among the first models to catch our attention is the 8-inch Dobsonian Reflector Telescope ($649.99). The scope features a parabolic, f/5.9 primary mirror and can be carried into the field in two convenient sections. Its optical tube weighs 9 kilograms (20 lbs), and its Dobsonian rocker base weighs just 8.4 kg and includes a convenient carry handle. The altitude axis is secured to the rocker base using springs that keep the scope in balance with a variety of eyepieces. The telescope's focuser is a 2-inch, Crayford-style model with a 1¼-inch eyepiece adapter. Additional accessories include a red-dot finder, a 25-mm, 1¼-inch-format Plössl eyepiece, a smartphone adapter, and a dust cap.

Explore Scientific
1010 S. 48th St., Springdale, AR 72762
866-252-3811; explorescientific.com

◀ WIRELESS FOCUSER

Chinese manufacturer ZWO adds a new electronic, automatic focuser to its line of astrophotography accessories. The EAF Pro ($299) connects to your control computer either using a USB-C cable or wirelessly via Bluetooth. The focuser is designed to attach to both Crayford and rack-and-pinion focusers and is ASCOM-compliant, making it compatible with most astro-imaging software. The unit can also be manually operated using the two buttons located adjacent to the cable port, or with an optional hand paddle. Its internal lithium battery holds a charge that lasts several nights of use without requiring a recharge. The unit accepts an optional temperature sensor that works with advanced imaging programs to automatically make adjustments as the temperature drops and your telescope shifts focus. The package includes a 2-meter USB 2.0 cable, a universal mounting bracket, an assortment of hex wrenches, and additional hardware for coupling to a variety of focusers.

ZWO
6 Moon Bay Rd., Suzhou Industrial Park, Jiangsu Province, China
Phone: +86-512-65923102; zwoastro.com

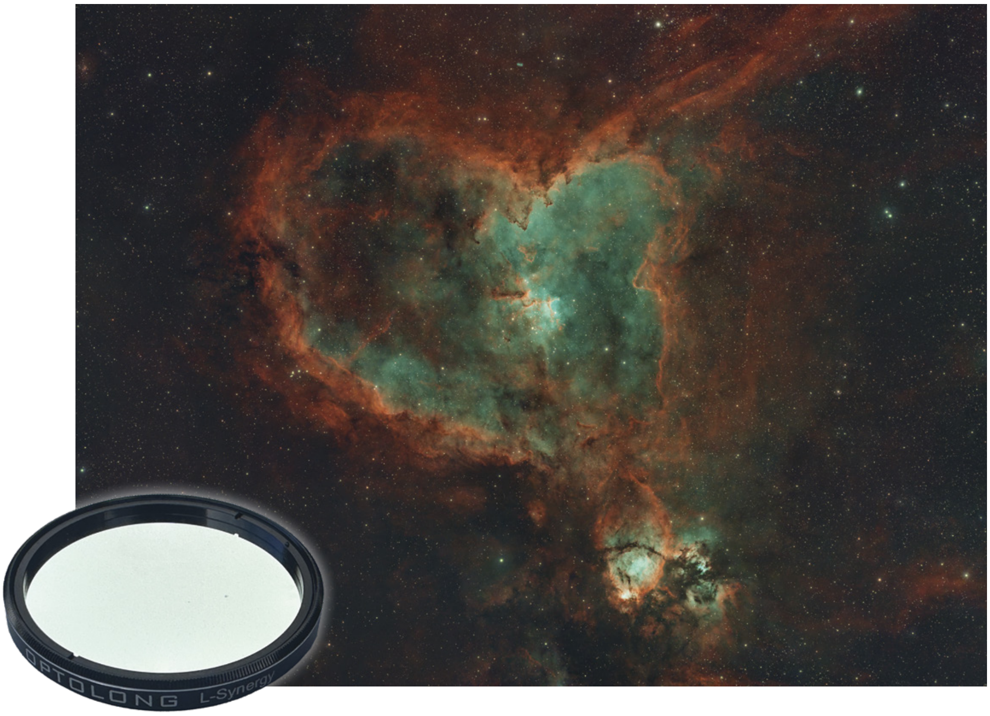
◀ FAST ASTROGRAPH

To celebrate the company's three decades of optical innovation, William Optics now offers its newest addition to its astrograph series. The Ultra-Cat 76 30th Anniversary Limited Edition ($2,198) is a five-element, 76-mm f/4.8 Petzval apochromat that produces sharp, color-free stars across a 50-mm, fully corrected image circle. The telescope weighs 5 kg (11 lbs) and features an internal, dual-speed, rack-and-pinion focuser with Sensor Tilt Xterminator and rotating adapter. It also comes with a Uniguide 32-mm f/3.75 guidescope (not shown). Additional accessories include a pair of machined aluminum tube rings, a Vixen-style mounting bar, a saddle-handle bar that accepts Synta-style removable finder brackets, a Bahtinov focusing mask with aluminum lens cover, and a soft carrying case. Production is limited to 100 units.

William Optics
30F., No.29-5, Sec. 2, Zhongzheng E. Rd., Danshui Dist., 251, Taiwan
+886-2-2809-3188; williamoptics.com

Optolong's L-Synergy Filter

This dual-band filter lets you image narrowband wavelengths with a color camera.



◀ Chinese filter manufacturer Optolong has introduced their new L-Synergy filter which passes doubly ionized oxygen (O III) and ionized sulfur (S II) wavelengths. These allow astrophotographers to use color cameras to create colorful, narrowband images of nebulae. This photo of the Heart Nebula (IC 1805) was captured with a Sky-Watcher Esprit 70EDX telescope and QHC367C Pro camera fitted with the L-Synergy filter.

Optolong L-Synergy

U.S. Price: $309, $569 for L2 Dual-Combo Set with L-eXtreme filter*
optolong.com

What We Like

Passes both O III and S II wavelengths

Enables narrowband imaging with color cameras

Enhanced performance when paired with L-eXtreme filter

What We Don't Like

Currently only available in 2-inch format

**Prices subject to change*

NARROWBAND IMAGING has long been the exclusive domain of astrophotographers using monochrome cameras. The technique involves capturing emission nebulae with a monochrome camera and a filter wheel loaded with a set of three narrowband filters, generally doubly ionized oxygen (O III) at 495.9 and 500.7 nanometers, hydrogen-alpha ($H\alpha$) at 656.3 nm, and ionized sulfur (S II) at 672.4 nm. Because these are such narrow slices of the visible spectrum, the resulting color images don't display natural hues. Instead, they present nebulae with a false-color palette that highlights different chemical components.

A beneficial side effect when imaging with narrowband filters is that they block most sources of light pollution and reduce the effects of moonlight. This allows urban imagers to record excellent pictures of colorful nebulae even under a bright sky. Until recently, however, tri-color narrowband imaging wasn't well suited to one-shot color cameras (sometimes referred to as OSC cameras). The advent of dual-band filters that pass emissions of both hydrogen and oxygen partially changed this, but the missing element was sulfur. The problem is that sulfur and hydrogen wavelengths are separated by only about 16 nanometers within the red region of the spectrum. So, a single filter passing $H\alpha$ and S II would combine both in the red channel of a color camera. While a single S II narrowband filter is one way to separate it from $H\alpha$, this would squander the opportunity to record data in the green and blue channels of the resulting color camera exposures.

Enter Optolong's L-Synergy filter. It's intended for narrowband imaging with color cameras and passes S II and O III while blocking everything else. The filter produces wonderful false-color images of nebulae that highlight both chemical components in emission nebulae and supernova remnants within the Milky Way. It's also useful for enhancing the visibility of nebulae in other galaxies (as I wrote about in last month's issue). According to the manufacturer, the filter passes more than 90% of the sulfur and oxygen wavelengths, each with a 7-nanometer-wide passband. At the same time, the filter blocks more than 95% of all other wavelengths, including those related to light pollution. It also blocks natural skyglow and infrared light.

ALL IMAGES ARE BY THE AUTHOR

▲ Imagers can choose from many palette options when combining data recorded with the L-Synergy and L-eXtreme filters, available for purchase as a set in the L2 Dual-Combo. These four images show NGC 281 in Cassiopeia rendered in several popular color-combination choices.

I was sent an L-Synergy filter for testing in mid-2025 to pair with the L-eXtreme filter I already own and quickly began seeing what it could do with my refractors and color deep-sky cameras.

Tri-Color with Two Filters

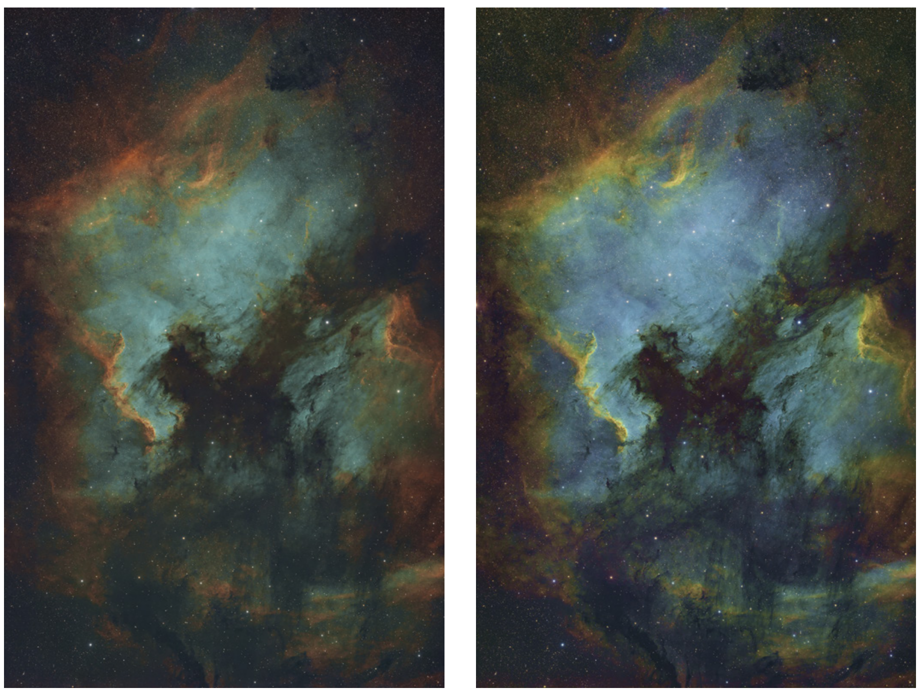
The L-Synergy is intended for narrowband deep-sky astrophotography with color cameras. It's a 2-inch filter that includes a standard 48-mm threaded cell, making it easy to install on any 2-inch camera nosepiece adapter or in a large filter wheel. Currently, this is the only size available and is offered for sale individually or paired with an L-eXtreme filter as part of the L2-Dual Combo.

Pictures taken through the L-Synergy filter appear mostly orange with teal highlights representing sulfur and oxygen, respectively. When examining the images in software, the S II signal appears exclusively in the red channel, while O III is recorded in both the blue and green channels.

The real fun happens when the filter is paired with the L-eXtreme. The L-eXtreme passes both O III and Hα with a 7-nm passband per wavelength and yields similar star sizes as the L-Synergy. By shooting targets with both filters, the resulting images can be combined to make a true, tri-color-narrowband image. This is done by first combining all the exposures with each filter separately (stacking all those taken with the L-Synergy filter to make one color image, and the same with the L-eXtreme-filtered data). Next, align the two results, then split the color channels from both stacked results. With these, you then stack all the O III from both filters' green and blue channels together, saving it as a new file with a unique name (say, O III). The Hα from the L-eXtreme filter's red channel and S II from the L-Synergy (also the red channel) are both saved as new files named after their passband. Finally, simply combine these three images as the individual color channels of an RGB image, assigning O III to blue, Hα as green, and S II is assigned to the red channel (typically referred to as the Hubble palette). After some slight color balance, voilà — true tri-color narrowband imaging with color cameras!

The L-Synergy filter opens up many new opportunities for astro-imagers with color cameras, especially when paired with the L-eXtreme. And the ease of using two filters compared to three and a monochrome camera has made me change my approach to narrowband imaging for the better.

■ Contributing Editor **RON BRECHER** loves finding new ways to improve his astrophotography. Visit his website at **astrodoc.ca**.



▲ *Left:* When paired with a one-shot-color detector, the L-Synergy filter produces images with teal and orange-red hues, corresponding to oxygen and sulfur emissions, as in this portrait of NGC 7000. *Right:* By shooting the same target with an L-eXtreme filter, both data sets can be combined to create true tri-color narrowband images with a broader palette.

The Lion's Mane

Planetary nebulae are among the most fascinating and beautiful denizens of the universe. Their rich variety of shapes, sizes, and hues, as well as their exotic forms and structures, resemble wildflowers blossoming in a cosmic garden. And just as wildflowers attract bees and butterflies, so do planetaries attract the attention of astronomers, observers, and astrophotographers alike.

The term *planetary nebula* is actually deceiving. It was coined by 18th-century observers who likened the objects' round appearance in early telescopes to planets. We know now that these photogenic, glowing shells of gas have nothing to do with planets, but the designation stuck.

Despite their misleading names, planetary nebulae actually represent a dying star's final act. As a solar-mass star depletes its hydrogen fuel, it swells into a red giant star before shedding its outer layers into space. The hot core at the center collapses into a white dwarf, which emits intense ultraviolet radiation that causes the expanding gases to fluoresce in vibrant colors. Our own Sun will meet the same fate, becoming a planetary nebula in roughly 5 billion years.

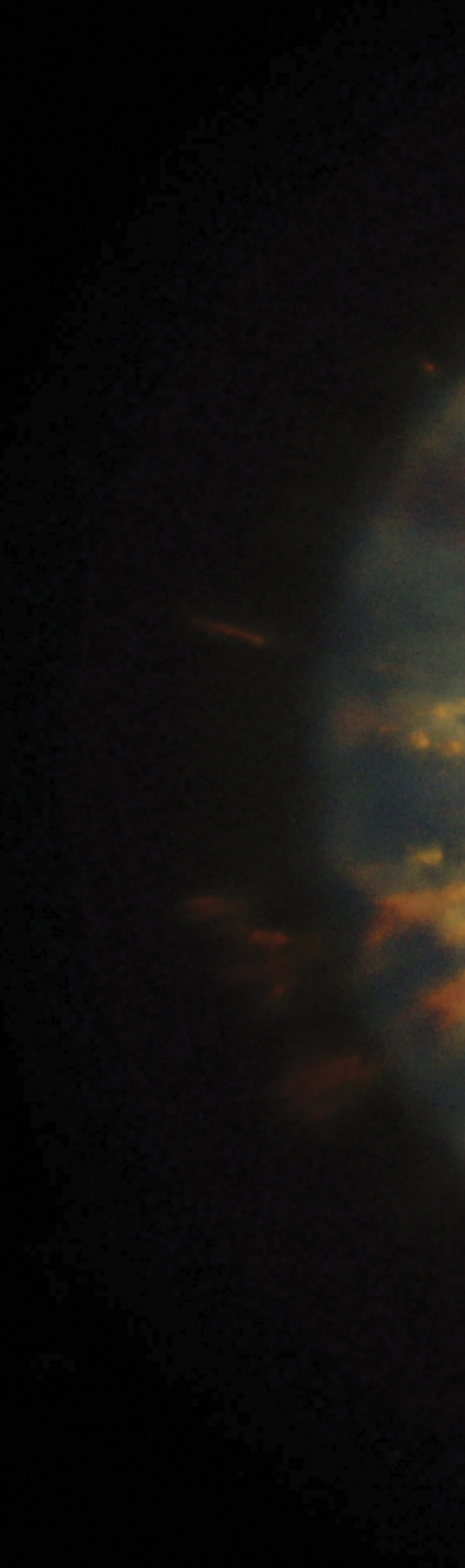
The Hubble Space Telescope captured this stunning view of one of my favorite planetaries, NGC 2392 in Gemini, highlighting the object's unique appearance and complex morphology. Also known as Caldwell 39, its semblance to the regal face of a feline beast surrounded by a majestic, tawny mane has led to one of its monikers, the Lion Nebula. (Turn the page upside down to see the lion's face.) Another object, the emission nebula Sharpless 132, or Sh 2-132, in Cepheus, is also known by the same nickname — to avoid confusion, perhaps we should call NGC 2392 the Lion's Mane Nebula.

NGC 2392's distance is estimated to be between 3,000 and 6,000 light-years. The planetary began forming approximately 10,000 years ago. Hubble's image shows the 10th-magnitude, *O*-type central star, designated HD 59088, shrouded in bright, overlapping lobes of materials. Intricate reddish orange filaments that thread the fuzzy inner ring represent matter being blown by high-speed winds of charged particles from the star. Embellishing the ghostly outer ring are long, orange tendrils like comet tails, all pointing away from the central star.

Look for NGC 2392 some 2.4° east-southeast of the 3.5-magnitude star Wasat, Delta (δ) Geminorum. The planetary glows at 9th magnitude and its disk measures about 1′ across, making it accessible to backyard telescopes (*S&T:* Mar. 2022, p. 54). The nebula's remarkable wealth of detail makes it a favorite target of deep-sky astro-imagers.

Astronomers estimate that our Milky Way Galaxy has some 20,000 planetary nebulae, but most of them are faint and obscured by dust — only about 3,400 have been cataloged so far. Planetaries are also relatively short-lived — they last for only tens of thousands of years (a heartbeat on cosmic timescales) before the white dwarf, now a dying ember, can no longer sufficiently heat and energize the surrounding gas, and the nebula gradually fades into oblivion.

—EDWIN L. AGUIRRE



Photograph by
NASA / Andrew Fruchter and the ERO Team, Sylvia Baggett (STScI), Richard Hook (ST-ECF), Zoltan Levay (STScI)

by Jonathan Kissner

Something from Nothing

This brass-spangled Newtonian is a master class in upcycling.

▲ Susan Snow poses with her telescope and eyepiece case.

IT WAS HER GRANDMOTHER who taught Susan Snow you could always make something out of nothing — a design ethos that won Susan five awards at the 2025 Stellafane Telescope Maker's Convention. Her 6-inch (15-cm) reflector sports everything from dumbbells to a broom handle. The patchwork project matches its builder: Snow has done everything from operating heavy machinery to fighting fires, caretaking, and lobstering.

Snow lives in Nahant, a small peninsula northeast of Boston, Massachusetts. Her family has been in this historic area for five generations; her father was a local fisherman and boatbuilder. Carrying on this legacy, she initially set out to build a boat. Though she soon changed course, echoes of nautical styling remain in the final design of her telescope, as do a literal boat part or two. Almost every bit of the tube and mount was upcycled into a second life as astronomy hardware.

Snow has always been fascinated with astronomy ever since her mother taught her about constellations, comets, and planets. That interest was rekindled when a neighbor suggested she build a telescope, which prompted her to create something "as beautiful to look at as it was to look through." The project was on — and boy, was it a project! It began with monthly round trips (three hours each way) to the Stellafane Mirror Class

▲ *Left:* A darning hoop and a serendipitously snug bezel from a banjo clock together make up the dust cover. *Middle:* An antique doorknob caps the counterweight shaft. *Right:* Parts from an antique chair, a window, and other scavenged bits form the altitude and azimuth adjustments for this scope. The counterweight shaft juts out at an odd angle, allowing the scope to reach low-altitude targets.

ALL IMAGES COURTESY OF SUSAN SNOW

up in Springfield, Vermont. She ground her own 6-inch f/5.4 primary mirror, which tested on the club's interferometer to be $1/20$ wave. When the result was announced, the room erupted in celebration. "I didn't know why yet, but all the other people in the room started cheering," Snow reported.

Then came the telescope structure. This process took a little more than a year, finishing just in time for last year's Stellafane Convention. Brass and mahogany dominate its design, reinforcing a sailing motif. "Found hardware" is a staple in my own workshop — the azimuth bearing on my very first build, also a 6-inch, boldly reads, "Bless this kitchen," betraying its origin as a large lazy Susan.

But Snow takes this to another level: A pair of embroidery hoops cradle a wood-veneered, phenolic tube. Another pair of these hoops secure bezels from a "banjo clock" and glass to serve as dustcaps; this feature netted her an innovative-component award at the convention. As did her connectors — in lieu of a commercial dovetail interface, window latches snugly secure the scope to her homemade mount.

"One of the most challenging parts of the process was balancing the scope to keep the altitude," Snow shares. It's worth noting that this telescope isn't a Dobsonian, but rather an alt-azimuth on a heavy-duty tripod. A swivel chair, a honing steel for knives, and bits of an old casement frame form the steering action of the scope.

This setup makes balancing it tricky: The optical tube has torque about the altitude axis to deal with — a problem she'd have to invent her way around, since neither equatorial- nor Dobsonian-mounted telescopes experience this. She solved the problem with more odds and ends — some railing from an old boat, a brass knob, and a broom handle that juts out at an odd angle, all working to balance the optical tube perfectly. The counterweight shaft on a typical telescope is almost universally a utilitarian pile of heavy metal. Yet in Snow's scope, it's like a ship's figurehead.

The focuser is the only major component she bought, and even this she had a field day customizing. Anywhere machine screws lived (the finderscope, focuser tension, and locking screws), brass fittings now shine. Focuser knobs were replaced with drawer pulls, and a brassy chain was draped over the finderscope, which is veneered to match everything else.

The telescope views it provides are a delight. Snow described the "diamond stars" of the Pleiades and her disbelief at seeing Saturn in all its glory. She managed to catch the Seeliger effect, in which the rings appear dramatically brighter during the planet's opposition. Her first-light experience was with Vega, and Snow was struck by its brilliant color. When the Moon's out, she sets up the scope for her husband to continue exploring our nearest celestial neighbor.

▲ *Left:* The darning hoop tube ring and finderscope are styled to match — a brass chain secures the lens caps (one of which was pulled from a Karo syrup bottle). *Right:* Snow replaced the hardware on her commercial focuser with brass thumbscrews, which sells the whole nautical effect swimmingly.

▲ Snow figures her primary mirror at the Springfield Telescope Maker's clubhouse.

Not just nice to look through, this telescope is also nice to look at. The five awards she clinched at Stellafane were first in craftsmanship, second for mechanical design, and two innovative-component awards, detailed above. She also netted first in a special category for her observing chest, where her tools and eyepieces now live. A favorite story she tells about this outing, much like in many of her careers, is that she's shining in a field with proportionately fewer women. "A few onlookers seemed surprised I had built this myself," she says.

Content with her scope, she's thinking once again about building a boat. "I never imagined the telescope would become such a project," she says. "It took a lot of trial and error, and a lot of patience, but it's something I will treasure for the rest of my life."

■ Contributing Editor **JONATHAN KISSNER** has already found some old snare drum shells to "upcycle."

SHARE YOUR INNOVATION

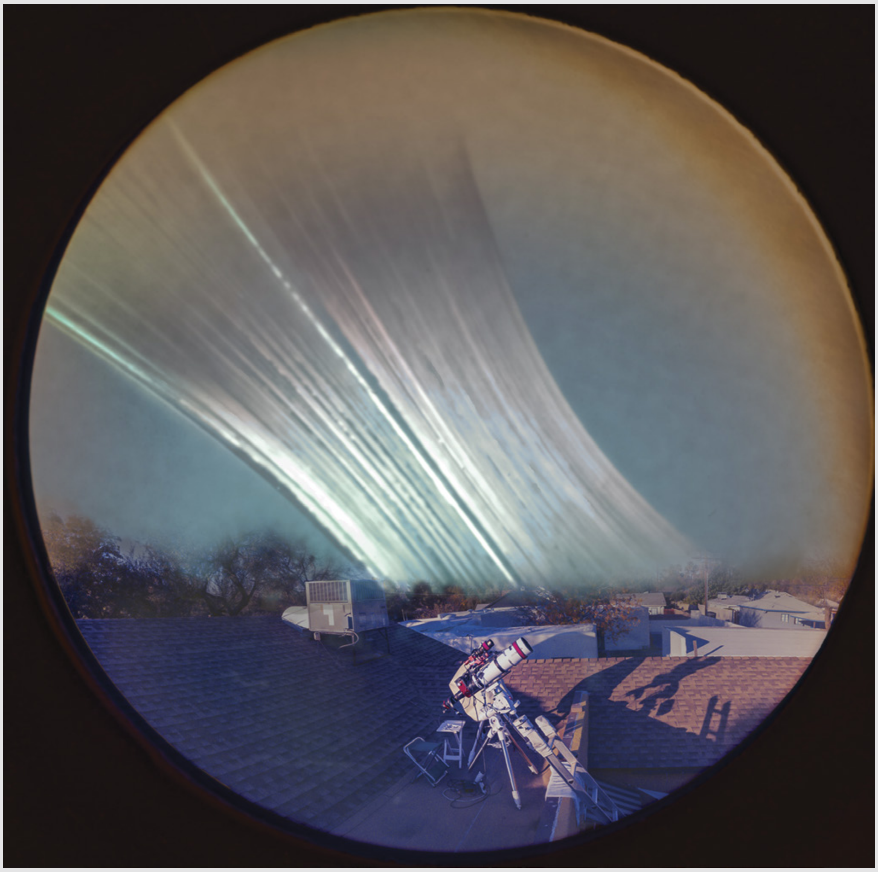
Enthused tinkerers interested in having their work featured here can share their projects at **workbench.kissner@gmail.com**.

EARTHSHINE ENCOUNTER

Chirag Upreti

The thin, waning Moon in Leo lines up with Venus and Regulus on the morning of September 19, 2025.

DETAILS: *Sony α7R III mirrorless camera with Tamron 150-to-600-mm lens. Stack of six images, each a total of ⅓ second at f/8, ISO 6400.*



◁ SOLSTICE TO SOLSTICE

Greg Meyer

Curved streaks trace the Sun's daily path from December 21, 2022, until June 22nd the following year in this solargraph composite. The foreground shows the photographer's rooftop observing spot in Phoenix, Arizona.

DETAILS: *Pinhole camera solargraph combined with a daylit panorama from the same location. Total exposure: 6 months or 183 days.*

▽ RIVER OF DARKNESS

Chris Schur

This row of dark clouds of dust in Ophiuchus make up the stem of the Pipe Nebula and is easily seen under dark skies. Individual sections from left to right are Barnard 67 (B67), B66, B65, and B59.

DETAILS: *Celestron 8-inch Rowe-Ackermann Schmidt Astrograph with ZWO ASI2600MC Pro camera. Total exposure: 65 minutes from Happy Jack, Arizona.*

OCCULTING ECLIPSE
Peter Anderson
The 7.8-magnitude star HD 217591 (left) in Aquarius was about to slip behind the eclipsed Moon just as this photo was snapped on September 8, 2025, from Brisbane, Australia.
DETAILS: *Sky-Watcher Evostar 150DX ED APO refractor with Canon EOS 90D DSLR camera. Total exposure: 8 seconds at ISO 400.*

◁ LEMMON APPROACHES

Alessandro Casprini

Comet Lemmon (C/2025 A6) sports a long, thin ion tail and a greenish coma in this composite image captured on the morning of October 4, 2025, from Monte Romano, Italy.

DETAILS: *Vixen R200SS Newtonian with Omegon Pro veTEC 571 C camera. Total exposure: 1½ hours.*

▽ TOTALITY TRIO

Khosro Jafarizadeh

This composite image captured (from left to right) the start, middle, and end of the September 7–8 total lunar eclipse. Together they display the edge of Earth's umbra demonstrating just how much larger it is compared to the Moon.

DETAILS: *Vixen VC200L Cassegrain with Canon EOS 6D DSLR camera. Composite of three exposures each 6 seconds long.*

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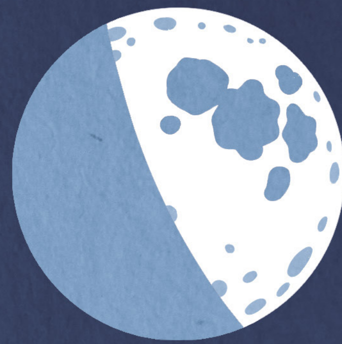

From Swagger to Smiles

The Moon captivates in surprising ways at outreach events.

IN A RECENT SURVEY at one of my astronomy clubs, members were asked to rate things according to interest. High on the list was astrophotography. Lowest? Outreach.

This actually hurt my heart to learn that most of the members were interested in pictures of space and not of the very work that may have motivated them to join our club in the first place.

I believe outreach is not only the lifeblood of a successful astronomy club, but it's also personally very rewarding. Outreach activities can take many forms, and none of them need be complicated — you can use a green laser (where it's permissible, of course!) to pinpoint stars and planets. Or you can set up a telescope — increasingly nowadays smartscopes draw in the crowds — in a public outdoor space (be sure to check with the local authorities beforehand) and wait for eager stargazers to show up.

Last summer, one of my clubs held an "on the Moon again" event where we all trained our telescopes and cameras on our satellite. We set up on the corner of two busy streets in downtown Ann Arbor, Michigan. Not only did students from the nearby University of Michigan walk by and stop to peer through our eyepieces, but so, too, did residents of the city.

At some point during the evening, a trio of young men ambled over to our scopes with the kind of swagger and bravado that may be off-putting to some. I'll call them "The Three Bros." Each of the threesome exuded the overconfidence and arrogance typical of the young man that loves to brag about himself. I was pretty sure that these bros wouldn't be impressed by views of the Moon in a telescope.

It turned out I was very wrong!

The bros asked us what we were doing here on the corner. I responded with an invitation to look through a 14-inch Dobsonian trained on Mare Tranquillitatis and its surroundings. The first bro eyed me suspiciously, then cautiously leaned over to look through the telescope. Instantly his "cooler than school" persona fell away. All you could hear coming from him was "OH MY GOD Y'ALL GOTTA SEE THIS!" After a couple of minutes, it was the second bro's turn and — his face shining with anticipation — he, too, peered through the eyepiece. Occasionally, he'd utter a "WOOOW!" in hushed tones. We knew he was impressed. The third bro finally had a go as well. Their swaggering bravado was replaced by the childlike wonder of seeing something amazing for the first time — and this just by looking up at the Moon through a telescope.

Eventually, they tore themselves away from the eyepiece and thanked us. We in turn thanked them for stopping by, and as I said farewell I added, "Tell all your friends!" They nodded and went on their way, slowly regaining their swagger, but with wide smiles still plastered on their faces.

If we want astronomy to be relevant and important to the general public, then we need to share the night sky with them. Don't be intimidated! Even the cool kids love seeing the Moon up close. You might be planting the seed in a young person's mind for a future in astronomy — or some other science.

■ **ADRIAN BRADLEY** is an avid amateur astronomer and astrophotographer from the Detroit area. His motto is "The night sky belongs to everyone!"

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