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SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

MARCH 2026

Did Life Come from Outer Space?

Page 28

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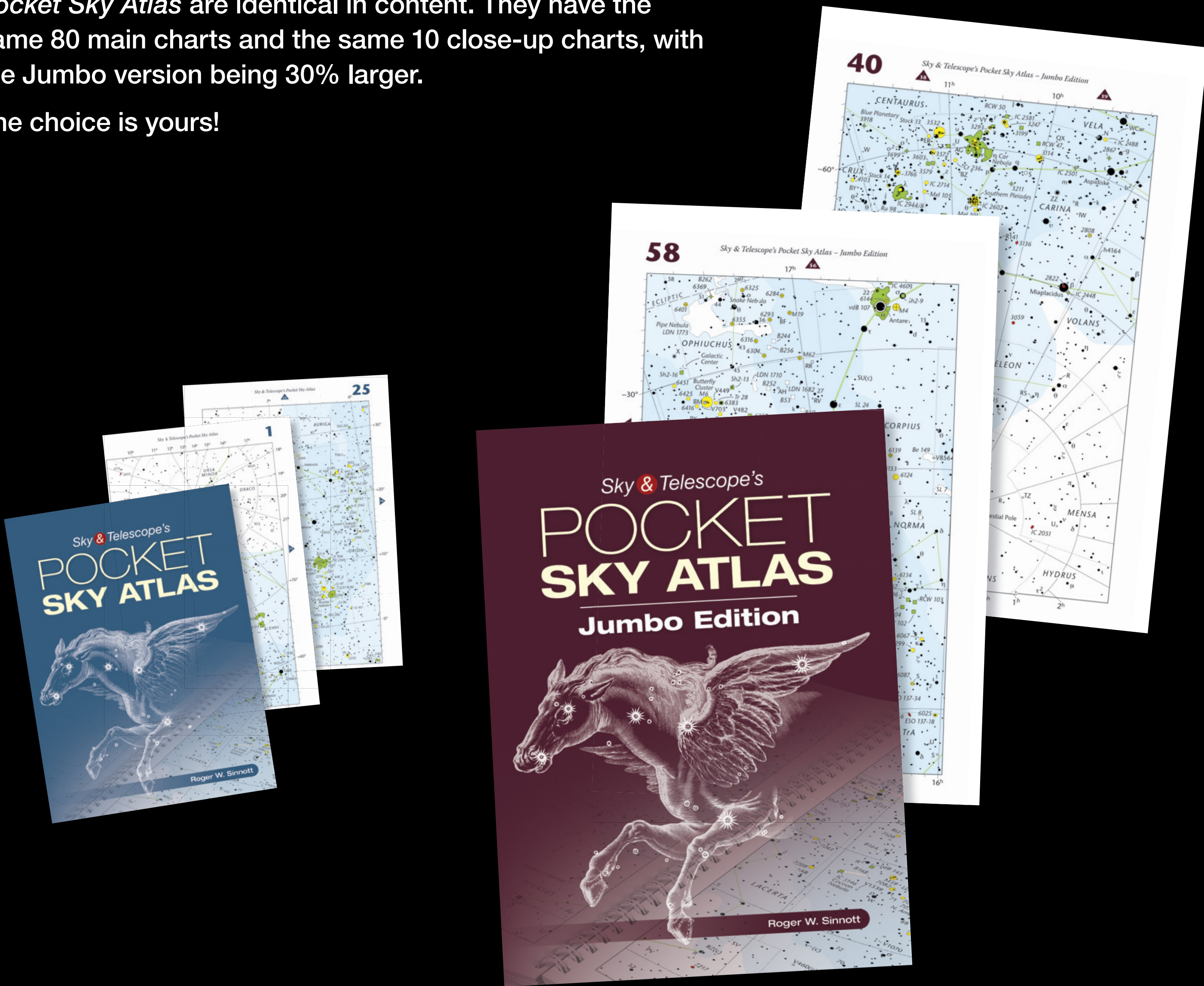

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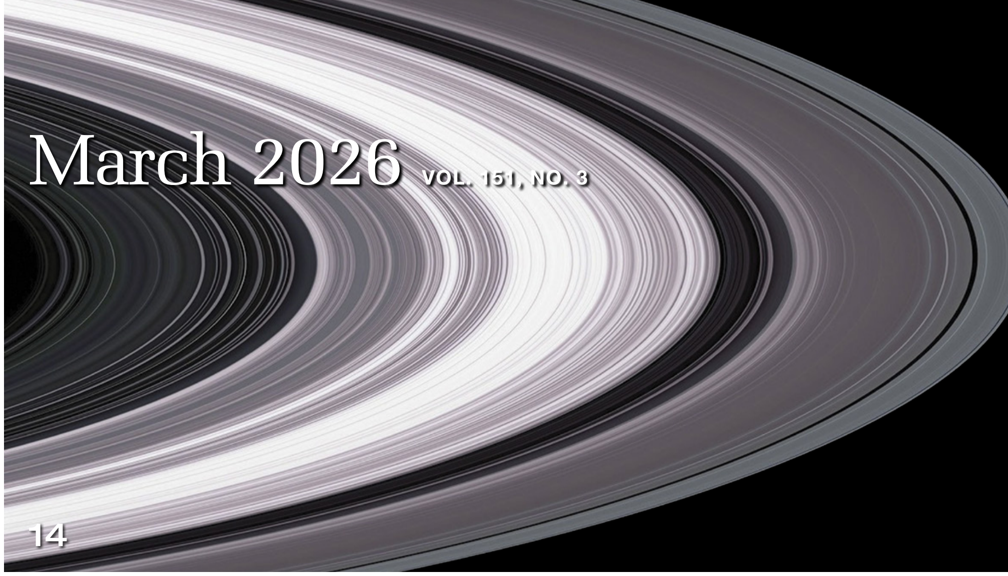

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ON THE COVER

Life-bearing meteorites bombard the primordial Earth.
PHOTO: RICHARD BIZLEY

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A Year Gone By

IT'S BEEN ONE YEAR since I sat down at my desk to write my very first Spectrum. I remember feeling the weight of the responsibility — not just of this column, but of being editor in chief. I was humbled. And terrified.

After this first year, I'm in absolute awe of my colleagues who, month after month, work tirelessly to produce the content that you hold before you, whether in paper or digital form. Having been a part of the editorial team since 2017, I was already aware of how the process works. But to see it from this new angle, to see how the various cogs and wheels grind in synchrony, is just marvelous.

It's been a challenging year, but it's also been fun. And that's something we should remind ourselves, when life becomes overwhelming: We're in this business of astronomy because it *is* fun and inspiring. Whether it's star-hopping in our backyard, or wowing children with views through the eyepiece, or testing new equipment, or piecing together notes to turn into observing guides for readers, or interviewing scientists, or being that scientist gathering data at a mountaintop telescope — let's not forget: We're in the business of pulling back the curtain to reveal the mysteries of the cosmos. What can be more rewarding than that?

▲ Gary Seronik leading an *S&T* tour in Iceland

GARY SERONIK

Now our team is undergoing another change: Longtime *S&T* staffer Gary Seronik is hanging up his editor's hat. Gary started subscribing to the magazine as a wee 12-year-old lad, shortly after getting his first telescope. His debut column appeared in the June 1997 issue, and he joined the staff as an associate editor a mere year later. Gary moved back to his native British Columbia in 2006 and became *S&T*'s first remote editor before it was a thing.

Among the numerous feathers in his hat is penning the Binocular Highlight column for many years (as well as the book). An award-winning author, he also played a significant role in developing the ever-popular *Pocket Sky Atlas*. For three years from 2016 he served as editor for the Canadian astronomy magazine, *SkyNews*, but the allure of *S&T* was strong, and in November 2019 he returned to the folds of this magazine. In 2023, the International Astronomical Union named a bit of space rock after him — an asteroid now known as 20046 Seronik.

But, fear not. Gary is not leaving us entirely. You can look forward to his ongoing musings on solar system activities in the monthly Sun, Moon & Planets column. We're sad to no longer have the daily dose of his wit and expertise but happy to know he'll be spending time doing things he loves: taking photos, making music, and, yes, doing some night-time observing without dreading waking up the next morning to magazine deadlines.

Clear skies, Gary, and thank you for all the laughs.

Editor in Chief

SKY&TELESCOPE
The Essential Guide to Astronomy

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

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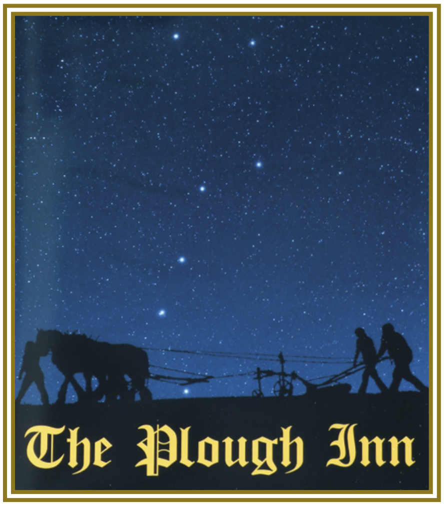
Asterism BINGO

In “Dipper Dilemma” (*S&T:* Oct. 2025, p. 7), Jeremy Tatum asks whether the Plough is still the common term for the seven bright stars of Ursa Major in Britain. It certainly is, though the Big Dipper is known to amateur astronomers from reading American publications. It’s not uncommon to see pubs named “The Plough” with a sign showing the asterism. A quick internet search will turn up several examples. However, the stars of Ursa Minor aren’t referred to as the “Little Plough.”

In France, I believe, the Big Dipper’s stars are known as *la Casserole* (the saucepan). But if you go to Australia, this refers to a completely different asterism, which is only obvious in dark skies when Orion is rising from southerly latitudes. The Belt stars of Orion form the base, while Eta (η) Orionis marks the lip, and the line of stars incorporating M42 are the handle.



▲ The late Paul Sutherland captured this image of an Ursa Major–themed sign in the village of Ripple, Kent, in the UK.

Robin Scagell
High Wycombe, England

The Big “E”

I enjoyed reading Howard Banich’s “Exploring Barnard’s E” (*S&T:* Oct. 2025, p. 58). Kudos for the correct use of the myriad, refreshing!

I was out at a decent observing site (Bortle 4) and had the issue with me but didn’t see the E because the location wasn’t clear. When I got home, I looked into it further. It seems there’s a mistake — the bright star in the photo is not Gamma (γ) Aquilae, but actually Altair. The mix-up happens in the caption and the body of text. Gamma is actually right behind the E.

So now that I know where to look, I’m eager to get another crack at it soon.

Scott Ewart
Campbell Hall, New York

Howard Banich’s review of Barnard’s E evoked a pleasant memory of viewing it with my 10×42 binoculars from Cedar Breaks in 2019. The bottom cave was so distinct. We had wonderful seeing.

I always read and especially enjoy his articles. I’m astonished by his artistic observing skills and discipline.

Bob Wieting
Simi Valley, California

Measuring the Distance

I always enjoy *Sky & Telescope*’s forays into the history of astronomy, and Govert Schilling’s “A 17th-Century Pale Blue Dot” (*S&T:* Oct. 2025, p. 22) about Christiaan Huygens’ book *Cosmotheoros* was no exception.

I especially appreciated being shown the line from Huygens to Carl Sagan, but I think the assessment by Schilling and recent Huygens translator Daphne Stam of the book’s solar system scale was a bit harsh.

Although Kepler had provided the means to establish the relative scale of the solar system using units of the Earth’s distance from the Sun, the actual length of this astronomical unit (au) wasn’t precisely known in Huygens’s time. As Albert Van Helden explains in *Measuring the Universe*, attempts to fix the length of the au using the parallax of Mars and transits of Mercury were at the limits of observational capabilities at the time and produced values that varied by more than a factor of 2. This situation didn’t really improve until the transits of Venus in 1761 and 1769.

Ernie Wright
Laurel, Maryland

Govert Schilling replies: *You’re right that the length of the astronomical unit was not yet precisely known by the end of the 17th century; that should have been stated more explicitly in the story. However, even with knowledge of just the relative distances in the solar system, it’s really surprising that Huygens made such a gross error in establishing the dimensions of Jupiter and Saturn as compared to the diameter of the Sun. The relative sizes are of course independent of the value of the au.*

Martian Rivers

Camille Carlisle’s “When Rivers Ran Through It” (*S&T:* Oct. 2025, p. 14) is excellent. Years ago, when I was president of the Cuyahoga Astronomical Association in Cleveland, Ohio, I gave a lecture about Mars, so I have some idea of the amount of research it takes to prepare such a presentation. Carlisle must have done weeks and weeks of

William Murmann presents a talk about Mars for campers at Ohio’s Findley State Park.

SIGN: ROBIN SCAGELL; LECTURE: ALAN STUDT, COURTESY: WILLIAM MURMANN work to research and write her article. Hats off and thanks to her!

William Murmann
Strongsville, Ohio

Credit must be given to Camille Carlisle for her article "When Rivers Ran Through It." It's chock-full of geologic information on Mars that I've never before seen in one place.

I noticed, however, that there was no mention of what astronomers have learned about the historical state of Mars's magnetic field.

It may be that our satellites and rovers can't gather information on that, but it felt strange that the magnetic field was never even mentioned in the context of the loss of atmospheric pressure. Has our thinking changed on the importance of the magnetic field in protecting the ancient Martian atmosphere from solar emissions?

Jim Hartley
Fair Oaks, California

Camille Carlisle replies: *The short answer is yes; scientists are increasingly dubious about magnetic fields being the interplanetary sneezeguards we once thought them to be. Mars may simply have been too small to hold on to its atmosphere — it's only $\frac{1}{10}$th as massive as Earth, and its gravitational grip is therefore much weaker.*

You'll find a detailed discussion of this topic in my feature on planetary magnetic fields on page 34 of the December 2023 issue, "Shields Up."

Over the Moooon

Congratulations to John Sebas for bringing to life the lunar pareidolia of the "the cow jumping over the Moon" nursery rhyme for me in "Holy Cow" (*S&T:* Oct. 2025, p. 84).

I really believe that at one point it was widely known but has been lost to history. I've found early copies of *Mother Goose Melodies* with illustrations that show the aforementioned cow jumping from left to right as it appears on the Moon. I'm with Sebas on this topic.

I, too, got interested in astronomy after viewing a daylight bolide that passed over the Grand Tetons in August 1972 and appeared later in an edition of *Sky & Telescope*. I was on the Idaho side of the bolide, whereas the photos in *Sky & Telescope* (*S&T:* Oct. 1972, p. 269) were from Springville, Utah, on the other side.

Dan Olsen
Butte, Montana

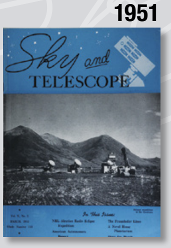
FOR THE RECORD

- In "Fly Me to the Moon" (*S&T:* Jan. 2026, p. 34), NASA pays around \$1 million/kg, or \$500 thousand/lb, for science payloads.

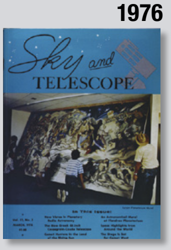
SUBMISSIONS: Write to *Sky & Telescope*, 1374 Massachusetts Ave., 4th Floor, Cambridge, MA 02138, USA, or email: letters@skyandtelescope.org. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

75, 50 & 25 YEARS AGO by Sabrina Garvin

1951



1976



2001

◖ March 1951
Radio Galaxy "At Jodrell Bank Experimental Station of the University of Manchester, England, R. Hanbury Brown and C. Hazard have completed the first successful detection of radio noise from an external galaxy, M31, the Andromeda nebula. They employed the world's largest antenna, a paraboloid built of wire mesh to have an aperture of 218 feet . . .

"At the frequency employed, 158.5 megacycles, the dimensions of the source of radio energy appear to be by ¾° by ½°, of the proper size and orientation to be [M31] . . .

"From the intensity of the radiation, the effective black-body temperature is about 1,000° K., which compares with Reber's similar determination for the nucleus of our galaxy, 1,500° K."

◖ March 1976
2062 Aten "The first asteroid discovered in 1976, provisionally called 1976 AA, is also the first proven case of an asteroid whose mean distance from the sun is less than the earth's.

"This remarkable object was detected by Eleanor Helin on photographs taken with the Palomar Observatory 18-inch Schmidt telescope on three consecutive nights beginning January 7th. It was of magnitude 13 or 14, near Gamma Geminorum, and moving northwestward at the rapid rate of two degrees per day, about 12 million miles from Earth. . . .

"The unusual nature of the orbit in which this asteroid is moving around the sun is clearly shown by the elements calculated by Brian G. Marsden [Harvard-Smithsonian CfA.] He finds that the mean distance of 1976 AA from the sun is only 0.96600 astronomical unit (89.8 million miles); the orbital period is just 346.8 days!

"The asteroid is now approaching the sun, and will reach the perihelion point of its orbit on May 20th. It will then be 0.79059 astronomical unit from the sun, slightly outside the orbit of Venus."

◖ March 2001
Christmas Eclipse "Amateur astronomers across North America enjoyed an extra holiday present last December 25th, when many were favored with uncharacteristically clear skies for the millennium's final [solar] eclipse . . .

"Like countless others, I [Gary Seronik] fitted eclipse viewing in with more traditional Christmas activities. While unwrapping presents, my wife and I followed the Moon's progress across the solar disk from the comfort of our suburban Boston living room with a telescope set up for solar projection. Meanwhile, my trusty Questar Maksutov endured bitter cold and gusty winds . . . to build a sequence of photographs . . .

"From eastern Massachusetts the Sun's diameter was 57½ percent covered at maximum, but an hour beforehand I noticed a slight dimming of the Sun's light."

COSMOLOGY

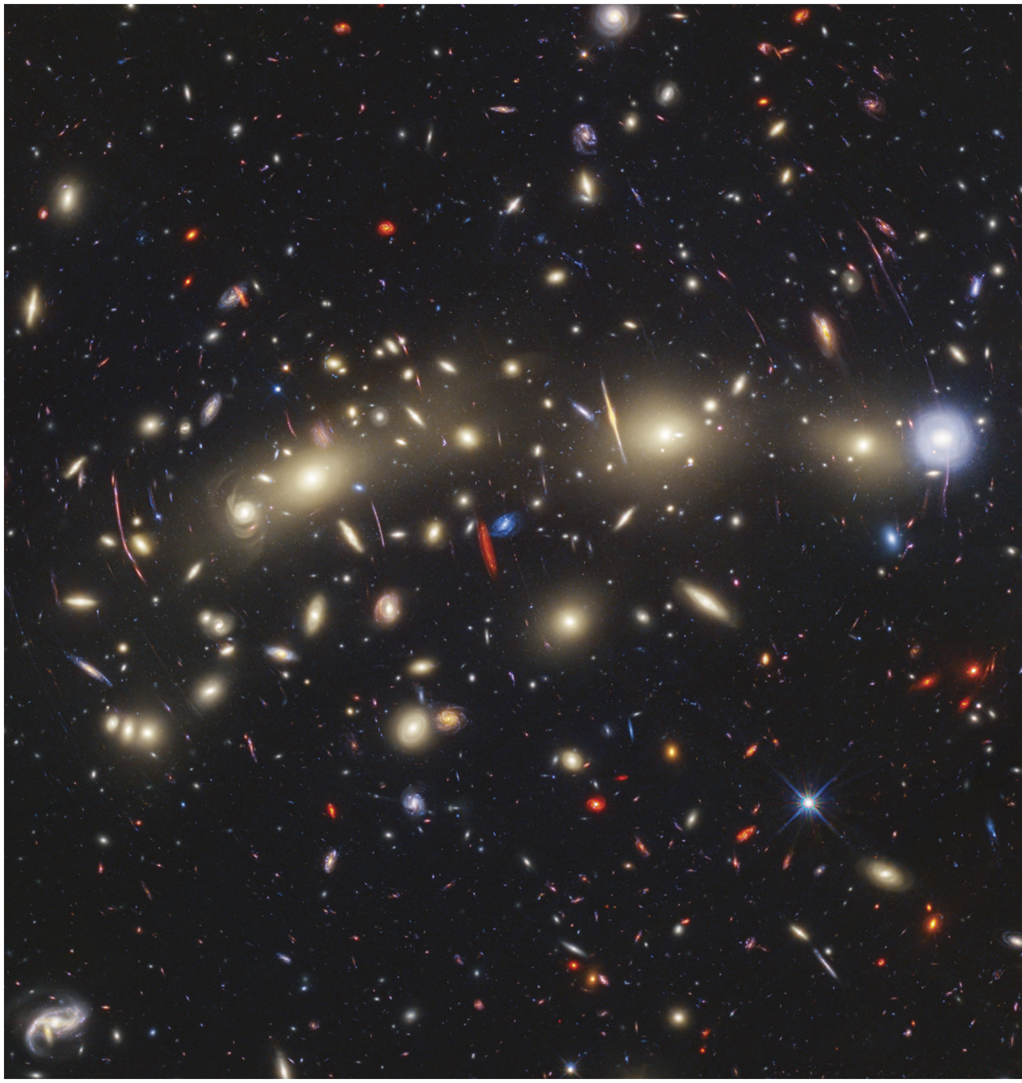
Have We Spotted the First Generation of Stars?

WITH THE HELP OF an intervening galaxy cluster, astronomers have found what might be the first generation of stars — but the jury's still out.

Just like humans, stars exist in multiple generations. We can deduce their lineage from the amount of elements heavier than hydrogen and helium that they contain. Forged in the bellies of stars, heavier elements are virtually nonexistent in the first generation of stars, known as *Population III*. But as these stars are not only far away, in the early universe, but as short-lived entities, they're challenging to observe.

Now, a team led by Eli Visbal (University of Toledo) has reported in the November 1st *Astrophysical Journal Letters* the discovery of potential Population III stars. The cluster they're in, known as LAP1-B, resides in a universe 800 million years after the Big Bang. The observations, taken with the James Webb Space Telescope, were aided by the magnification effect of a foreground galaxy cluster, MACS J0416.

There have been claims of finding Population III stars before, but none has satisfied all three of the main theoretical predictions for how and where these stars should appear.



▲ The galaxy cluster MACS J0416, imaged by the Hubble and James Webb space telescopes, has magnified light from distant sources in the background — including an early cluster that might host Population III stars.

COSMOLOGY

Early Galaxies Were Messy

MOST STAR-FORMING galaxies today have settled into orderly disks of gas and dust, but a new study presents evidence that the first galaxies were far more turbulent.

Previous studies had identified single, massive galaxies in this early epoch that have stable, rotating disks (e.g., *S&T:* Sept. 2020, p. 12). Those galaxies challenge formation scenarios that had predicted turbulent, unsettled systems so early on. But it turns out the more typical, lower-mass galaxies in the early universe have expectedly messy disks.

A team led by Angelica Lola Danhaive (University of Cambridge, UK) used the James Webb Space Telescope to examine 213 star-forming galaxies that existed 850 million to 1.6 billion years after the Big Bang. They found that most of these galaxies had puffed-up disks. The results were published in the November *Monthly Notices of the Royal Astronomical Society.*

Using slitless spectroscopy from Webb's Near-Infrared Camera, the team mapped the behavior of ionized gas across each galaxy via hydrogen-alpha emission, which traces star formation. From these maps, the team determined each galaxy's *rotational support* — how well the galaxy can sustain a disk — and the *velocity dispersion*, which quantifies turbulent motions in the gas that puff up the galaxy.

The team found that turbulence dominates over rotation in more than half the galaxies; only a small number of early star-forming galaxies show the rotational support needed to form disks.

"We are now seeing the transition phase — the dawn of ordered disks emerging from turbulent, clumpy systems," says team member Sandro Tacchella (University of Cambridge, UK).

NASA / ESA / CSA / STSCI / JOSE DIEGO (IFCA), JORDAN D'SILVA (UWA), ANTON KOEKEMOER (STSCI), JAKE SUMMERS (ASU), ROGIER WINDHORST (ASU), HAOJING YAN (UNIVERSITY OF MISSOURI); IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI)

"In the standard model of cosmology, Population III stars are expected to form in very small dark matter structures that serve as building blocks for larger galaxies," Visbal says. LAP1-B ticks that box. Second, the cluster's spectrum is consistent with a total mass of around 1,000 Suns. "This is about the total mass of Population III clusters we see in numerical simulations," Visbal adds. Finally, that population, as expected, is weighted toward high-mass stars.

Harley Katz (University of Oxford, UK), who was not involved in the research, agrees that these observations may be consistent with the trio of predictions regarding the first stars. "Unfortunately, this does not necessarily mean this is a Pop III system," he says. "Nevertheless . . . it is so far the closest we have come."

One key issue is that LAP1-B's spectrum shows weak emission lines from heavier elements, such as oxygen. These elements might come from winds blowing off the Population III stars, or they might indicate an even earlier stellar generation in the cluster's past.

Visbal concedes that the stars he has observed may not truly be Population III: "Deeper observations, improved simulations, and additional similar sources would help to build confidence."

■ **COLIN STUART**

SOLAR SYSTEM

Many Kuiper Belt Objects Rotate Backwards

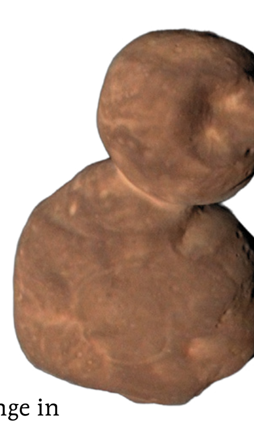
AT THE EDGE OF the solar system, small chunks of ice and rock tend to come in connected pairs, a new analysis finds. What's more, they rotate opposite the way they move around the Sun. The results have implications for those objects' formation.

"This is not what I expected," says Simon Porter (Southwest Research Institute), who presented at September's Europlanet Science Congress, run jointly with the American Astronomical Society's Division of Planetary Sciences.

NASA's New Horizons has studied several Kuiper Belt objects (KBOs) since it passed Pluto in 2015. The first of these was 486958 Arrokoth, a *contact binary* that looks like an icy red snowman (*S&T:* June 2025, p. 22). Its shape and surface suggest that its two lobes came together with a light touch rather than a devastating collision.

New Horizons has observed more than 30 other KBOs, seven of them from multiple angles. Porter reconstructed shapes for those seven, combining the data from different angles and the objects' changing brightness as they rotated. He used Arrokoth as a reference for how to interpret the data. Four of the seven turn out to be likely contact binaries.

Previous Earth-based observations had suggested that only 10% to 25% of KBOs were contact binaries. Although Porter's study was based on a small number of objects, the change in percentage is significant and indicates that contact binaries are common in the outer solar system, as was their gentle mode of formation.



▶ New Horizons imaged Arrokoth up close in 2019.

Intriguingly, most of the contact binaries also exhibit *retrograde* rotation, spinning in a direction opposite to their orbital motion around the Sun. Previous studies have suggested that *detached* binaries — two objects that orbit each other without touching — are more likely to have a *prograde* rotation. That contact binaries appear to prefer retrograde rotation "might be telling us something about the formation of KBOs from the protoplanetary disk," Porter says. "That, in turn, can really constrain planetary formation models across the solar system."

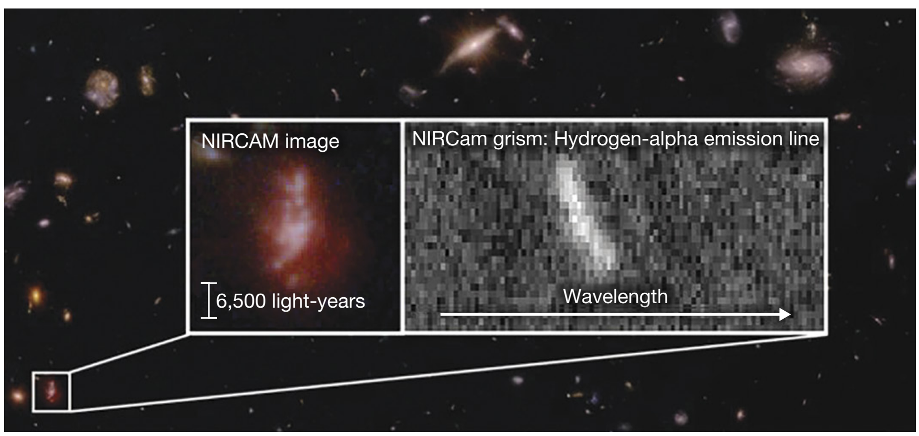
Whether the retrograde finding pans out will depend in part on the Vera C. Rubin Observatory, which astronomers expect to detect large numbers of the brighter KBOs. "Over the full 10-year program," Porter pointed out to the conference audience, "we're going to get an awful lot of objects."

■ **NOLA TAYLOR TILLMAN**

Mahsa Kohandel (Scuola Normale Superiore, Pisa, Italy), who wasn't part of the study, agrees that the work aligns with predictions. However, she cautions that measuring only ionized gas can make galaxies appear more chaotic than they are; observing these sources at different wavelengths will help.

The team now plans to combine Webb observations with data from the Atacama Large Millimeter/submillimeter Array, which measures longer-wavelength light coming from cold gas and dust, to study the assembly of these early galaxies.

■ **ARIELLE FROMMER**



▲ Webb's Near-Infrared Camera can spread the faint light of ionized hydrogen gas into a spectrum. An image *(left inset)* and spectrum *(right inset)* are shown here for one of the puffed-up, star-forming galaxies in the early universe that the team studied.

ARROKOTH: NASA / JOHNS HOPKINS APPLIED PHYSICS LABORATORY / SOUTHWEST RESEARCH INSTITUTE / ROMAN TKACHENKO; JWST IMAGE: NASA / ESA / CSA / STSCI / B. ROBERTSON (UNIV. OF CALIFORNIA, SANTA CRUZ), B. JOHNSON (CFA), S. TACCHELLA (CAMBRIDGE), P. CARGILE (CFA)

SOLAR SYSTEM

Escapade Mission Launches for Mars

A SMALL BUT UNIQUE mission launched on November 13th on Blue Origin's New Glenn rocket. The pair of small satellites, collectively named the Escape and Plasma Acceleration and Dynamics Explorers (Escapade), will reach the Red Planet in late 2027.

The spacecraft will study the interactions between the solar wind and the magnetic field and upper atmosphere of Mars from a stereo perspective.

"We know the magnetosphere changes on minute time scales," says principal investigator Robert Lillis (University of California, Berkeley). "Both spacecraft will be following each other in the same orbit, between two and 30 minutes apart, so we can actually observe the changes in Mars's highly dynamic space environment."

Escapade is the fourth mission for NASA's Small Innovative Missions for Planetary Exploration (SIMPLEX) program, which to date has included Q-PACE, LunaH-Map, and Lunar Trailblazer — all of which were unsuccessful (*S&T:* Jan. 2026, p. 34).

Escapade took off outside the usual Mars launch window, which comes several months prior to the planet's opposition. Due to delays in the New Glenn rocket's development, the spacecraft instead launched 10 months *after* opposition. It will head to the L_2 Lagrange point, 1.5 million kilometers (930,000 miles) from Earth in the anti-sunward direction, loiter in a halo orbit, and monitor space weather while it waits for the Mars transfer window that opens later this year.

▲ The Escapade mission launched successfully on November 13th on Blue Origin's New Glenn rocket.

Watch for the maneuver in November that will take Escapade swinging past Earth and on to Mars.

■ DAVID DICKINSON

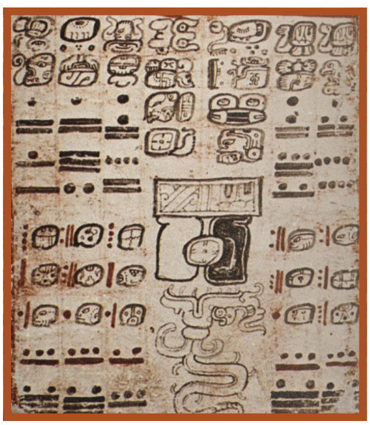
ASTRONOMY & SOCIETY

Maya 260-day Calendar Key to Solar Eclipse Predictions

THE MAYA 260-DAY "ritual calendar" provides the key to understanding the culture's solar-eclipse predictions, a new study has found.

The ancient Maya used sophisticated mechanisms to predict eclipses that we don't fully understand today. Among the few records left to us is an eclipse table that spans eight pages of a hieroglyphic book known as the Dresden Codex. Researchers have devoted years to teasing out the eclipse table's origins.

By comparing the table to 145 solar eclipses visible in the Maya area between AD 350 and 1150, John Justeson (University at Albany) and Justin Lowry (SUNY Plattsburgh) have developed new insights into the table's evolution, published in the October 22nd *Science Advances*.



▶ The glyphs at center bottom refer to a solar eclipse: The serpent is poised to swallow the Sun, thereby plunging the world into darkness.

The eclipse table pinpoints celestial and seasonal events within interlocking calendrical cycles of 260 and 365 days. Those cycles are anchored in linear time through the Long Count calendar.

Justeson and Lowry conclude that the original function of the table was to record lunar months. By making and documenting observations over many generations, Maya calendar specialists, known as *daykeepers*, found that 405 successive new Moons were equivalent to 46 cycles of 260 days. Knowing this, they could predict the dates of full and new Moons during that whole 11,960-day period.

Only later was the table repurposed for eclipses, when daykeepers noticed a striking pattern: Solar eclipses in their lunar tables of 405 months tended to recur on the same day in the 260-day calendar. Justeson and Lowry propose that the final version of the Dresden table records eclipse dates over a 32¾-year period starting around AD 1100. The table would then have been restarted.

But there would eventually have been slippage between the predicted and actual eclipse dates, which the daykeepers knew. One of the contributions of the new study is the recogition of two specific points in the table that the daykeepers would have used for reentry to maintain its accuracy.

Specialists welcome the study's insights, though some suggest further evaluation is needed in light of models previously proposed for dating and recycling the table.

Cultural astronomer Anthony Aveni (Colgate University) notes that naked-eye astronomy around the world advanced by way of repeated observations and long-term time averaging. But nowhere else did people use the 260-day period for eclipse prediction. "Culture," Aveni remarks, "recognizes different aspects of nature."

■ GABRIELLE VAIL

Read more details about Maya eclipse predictions at skyandtelescope.org/MayaEclipses.

LAUNCH PHOTO: KIRBY KAHLER; DRESDEN CODEX: SÄCHSISCHE LANDESBIBLIOTHEK DRESDEN

OBITUARY

Al Nagler (1935–2025)

ALBERT H. NAGLER, a pioneer of telescope optics, passed away at the office of his company, Tele Vue Optics, on October 27th. He was 90 years old.

Nagler's interest in astronomy was sparked by a visit to the Hayden Planetarium. While attending the Bronx High School of Science in New York, he built his first telescope: an 8-inch f/6.5 Newtonian reflector with a hexagonal tube, which rode on an iron-pipe equatorial mount. It earned him an award when he graduated in 1952. He also described the telescope's design and construction in the December 1955 *Mechanix Illustrated*.

That article gave him the confidence to pursue a career in optics and helped land him a job at Farrand Optical Company. NASA had contracted Farrand to develop visual simulators for astronauts training to land on the Moon. Nagler designed infinity displays for both the Gemini program and the Apollo Lunar Module spacecraft.

In 1969, Nagler completed his Bachelor of Science in physics through night courses and took a position as Chief Optical Engineer at Keystone Camera Company.

◀ At the 2007 Stellafane convention, Al Nagler was presented with a copy of the December 1955 issue of *Mechanix Illustrated* that helped launch his career in optical design.

DENNIS DI CICCO

Then in 1977, Nagler, together with his wife, Judi, founded Tele Vue Optics, Inc. It was here that Nagler developed his first wide-field eyepieces, which revolutionized telescope eyepieces in the 1980s. Until Nagler's well-corrected, wide-field designs, telescope oculars were essentially an afterthought. He showed the amateur community that the quality of an eyepiece is just as important as the quality of a telescope's main optics. What's more, he showed the industry that amateurs are willing to pay a premium for excellent oculars. Today, seasoned observers covet his eyepieces. Almost every eyepiece manufacturer today stands on the shoulders of Nagler's work.

It's difficult to convey how much Al Nagler has brought to the amateur community. In addition to his innovations at Tele Vue, Nagler continued to attend trade shows, conferences, and particularly Stellafane, where he was awarded the 2025 Astronomical League Award this past July. He was always generous with his time and knowledge and was always happy to share the view through his wonderful optics.

■ SEAN WALKER

IN BRIEF

A Nearby Super-Earth

Astronomers have discovered a candidate super-Earth just 18 light-years away, with at least four times the mass of our own planet. The red dwarf star GJ 251 was already known to host one super-Earth. But a new analysis of more than 20 years of data has turned up a second planetary signal, published in the November *Astronomical Journal*. This signal could come from a planet a little farther out than the first. The star, which is 4.6 billion years old, is past the flaring phase of its youth, but stellar activity could still masquerade as a planetary signal, acknowledges the team, led by Corey Beard (University of California, Irvine). The astronomers uncovered six repeating dips in luminosity, four of which are associated with the star's rotation and activity, and one of which comes from the known planet GJ 251b. The sixth one they identify as the signal from the new candidate planet. While technically in the habitable zone, the new planet's size, mass, and orbit would require a thick, carbon dioxide–based atmosphere to protect liquid water on its surface. The Thirty Meter Telescope, if it moves forward, could directly image this planet.

■ MONICA YOUNG

Second Asteroid Inside Venus's Orbit

Found on September 27th by Scott Sheppard (Carnegie Institution for Science), an asteroid now designated 2025 SC_{79} turns out to orbit almost entirely inside the orbit of Venus — only the second asteroid ever found so close to the Sun. (The first is 594913 'Ayló'chaxnim, *S&T:* Jan. 2023, p. 11.) "It was very exciting to discover 2025 SC_{79}," says Sheppard. He first observed it using the Dark Energy Camera in Chile, the night before leaving on a hiking trip. Because the object was moving fast, he knew it must be very close to the Sun, so he'd need to image it again soon to confirm its orbit before it became lost in the Sun's glare. "I had to schedule new observations to re-observe the object while deep in the forest of Pennsylvania," he says. While the orbit of 2025 SC_{79} does not cross Earth's, gravitational nudges from close approaches to Venus could send it careening on another path. "There appear to be many twilight asteroids yet to be found, as we are only scratching the surface," Sheppard notes. "We have to keep covering as much sky as possible in twilight, waiting for these near-Sun asteroids to poke their heads out."

■ DAVID L. CHANDLER

Read more: **skyandtelescope.org/SC79**.

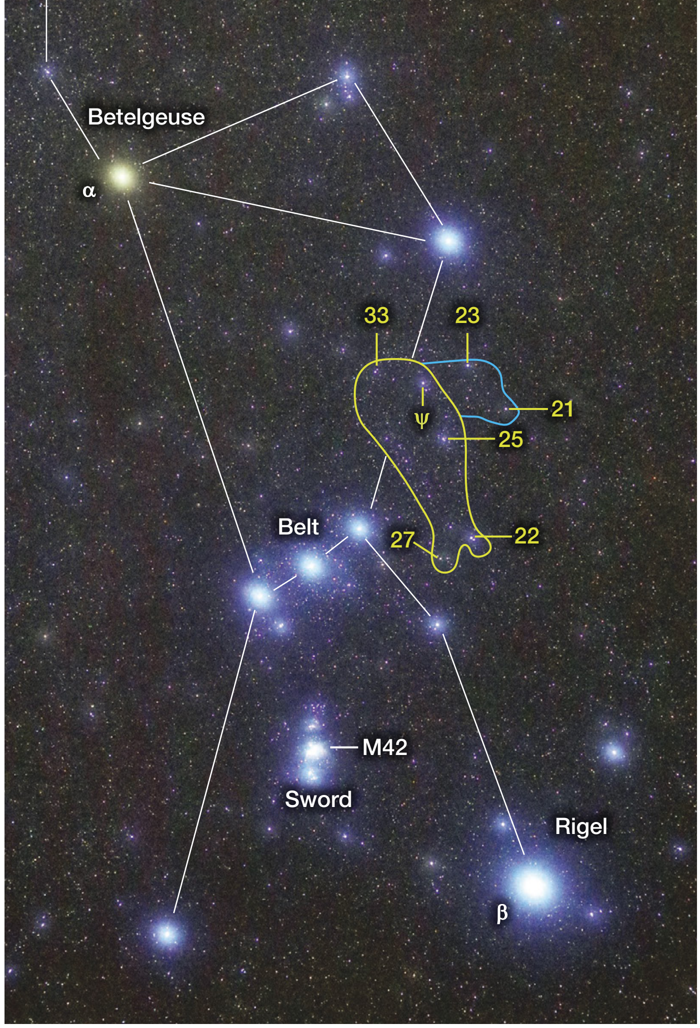
Near-Earth Asteroids Spin Surprisingly Fast

The fast spins measured for small near-Earth asteroids suggest that scientists need to revise their ideas about what holds these bodies together. An asteroid spinning too quickly can break itself apart; for "rubble pile" asteroids, that limit occurs at a rotational period of about 2.2 hours. Miguel Alarcon (Institute of Astrophysics of the Canary Islands, Spain) set out to see if a similar limit holds for smaller objects, reporting results at the October meeting of the Europlanet Science Congress. At the Teide Observatory on the Canarian island of Tenerife, he and his colleagues mapped 142 near-Earth asteroids over nearly two years. They found that 79% of asteroids spanning less than 140 meters (460 feet) spin faster than the 2.2-hour limit. The fraction only increases for even smaller objects. The fastest object that the team spotted, 2025 KS_1, completes a turn every eight seconds! The fast spins indicate that, while larger asteroids are loose collections of boulders and pebbles, smaller asteroids are more likely to be stronger structures made of single pieces of rock.

■ NOLA TAYLOR TILLMAN

The Orion OB 1a Association

A neglected wonder of the celestial Hunter is within reach of the unaided eye.



▶ **NAKED-EYE STELLAR GROUPING** The author likens the Orion OB 1a association (outlined in yellow) to a fish swimming upstream. Through binoculars and telescopes, a dorsal fin of stars (outlined in turquoise) joins the group.

STEPHEN JAMES O'MEARA

THE MAJESTIC Orion Nebula (M42) and other visual treats in Orion's Sword and Belt beckon in the evening sky. But this month, shift your gaze slightly northwest of the Belt to take in a true hidden gem, a curious aggregation of moderately bright stars called the Orion OB 1a association. I wonder how many readers have ever seen it or even heard of it, as it's not listed in many observing guides and charts.

OB associations are large, loose groupings of mainly young, hot, and massive blue giant stars of spectral type *O* and *B* and about 10 to 50 solar masses. As its name implies, OB 1a belongs to the Orion OB 1 association — a 10° × 20° complex of intermediate- and low-mass stars, open clusters, and nebulae that comprise one of the largest and nearest star-forming regions.

In 1964, Dutch astronomer Adriaan Blaauw (1914–2010) divided the association into four subgroups: OB 1a (our target); OB 1b, a band of stars around the Belt, including possibly, Sigma (σ) Orionis; OB 1c, the Sword region, though M42 itself isn't part of it; and OB 1d, comprising M42 and the bright emission nebula NGC 2024, also known as the Flame Nebula.

In terms of age, OB 1d is youngest (less than 1 million years old), followed by OB 1b (about 2 million years), and then OB 1c (around 5 million). The oldest is OB 1a, at about 11 million years. It includes young but relatively more evolved stellar populations in which the primordial hydrogen cloud has mostly dissipated. OB 1a also includes the 25 Orionis cluster — a well-defined group of nearly 200 low-mass, pre-main-sequence stars, concentrated around the early *B*-type star 25 Orionis. The cluster is one of the most numerous and spatially dense populations of 7- to 10-million-year-old stars within 1,600 light-years of the Sun that we know of.

For me, the OB 1a group is a visual itch that I've wanted to scratch for more than a decade. However, only recently did I investigate it and learn of its true identity. Unfortunately, as with all the subgroups in the OB 1 association, OB 1a's boundaries are not precisely defined in the professional literature. To the unaided eye, its main region is a tapered ellipse covering about 4° × 1° of sky, trending northward from the southwestern side of the Belt (outlined in yellow in the image above). Under dark skies and using averted vision, the ellipse looks like a detached part of the winter Milky Way, punctuated by five stars: 22, 25, 27, 33, and Psi (ψ) Orionis. They mark the northern, southern, and western sides of the ellipse. The eastern side is a milky strand of largely unresolved starlight.

Binoculars immediately reveal about a dozen stars, while a small telescope easily quadruples that number. Through binoculars, the ellipse widens to the north and tapers to the south, giving it the appearance of a fish swimming upstream — with 4.7-magnitude 22 Orionis and 5.1-magnitude 27 Orionis marking the tips of the fish's tail. Psi Orionis, at magnitude 4.6, lies near the fish's snout, which is marked by 5.5-magnitude 33 Orionis. Also, look for a triangular-shaped extension of starlight west-southwest of, and including, Psi Orionis (outlined in turquoise above). This dorsal fin of stars spans about 2° and is bound to the north by 5.0-magnitude 23 Orionis and to the west-southwest by 5.3-magnitude 21 Orionis. Telescopically, the fish's belly comprises what appear to be braided strings of 6th-magnitude and fainter suns.

So, the next clear, dark night, scan the OB 1a region and see if this stellar aggregation catches your fancy.

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

Rings Around the

Loops of rocks, dust, and ice adorn a variety of worlds in the outer solar system.

The rings of Saturn have dazzled astronomers for hundreds of years, and for most of that time, humankind thought they were the only rings around. Then, in the second half of the 20th century, astronomers discovered humbler ring systems around Jupiter, Uranus, and Neptune.

But rings aren't just for planets anymore. In the past decade, astronomers have found four more sets around smaller bodies in the outer solar system. We now know of eight ring systems in our little corner of the cosmos — and there are probably more that we haven't discovered yet.

All of these ring systems, regardless of which body they orbit, consist of countless pieces of solid debris. The debris can be as fine as dust particles or as big as moonlets. They usually orbit their parent body near what astronomers call the *Roche limit*. Within this zone, tidal forces tear objects apart, preventing material from clumping together into large bodies. Beyond it, debris is more likely to coalesce into moons.

Rings interest planetary scientists because they are a kind of artifact, hinting at the history of the parent body. Their composition and structure give researchers unique insights into past collisions and how the solar system has formed and evolved over billions of years.

Let's explore all the (known) rings of the solar system, beginning with Jupiter — whose rings were the first to be discovered by spacecraft, and which owe their existence to a few small moons.

Jupiter: Dust to Dust

In 1979, Voyager 1 detected a small, dusty ring around Jupiter. Three more have since been observed. The innermost ring, called the halo, has a doughnut-shaped structure; the others are far flatter. They appear darker, less massive, and more diffuse than Saturn's rings. In fact, all four rings are so ephemeral that they are typically only visible when backlit by the Sun. This is because Jupiter's rings are made of residual dust kicked up by continuous, high-speed micrometeoroid impacts on a few of its small, inner moons.

The outermost two "gossamer rings" are called Amalthea and Thebe, each made of a broad, faint sheet of dust sourced from their namesake moonlets. The main ring — a narrow, reddish band — is next. Its material comes from the moons Metis and Adrastea, as well as from particles migrating inward from the outer rings and the fragmentation of rocks within the annulus.

The halo lies between the main ring and the planet. It isn't as closely confined as the others; instead, it's molded by Jupiter's magnetic field into a vast toroidal structure. When its tiny particles become charged — which happens fairly easily, due to interactions with sunlight or plasma — they "sense" the planet's inclined magnetic field, explains Shawn Brooks (Jet Propulsion Laboratory). The field can then loft the particles above and below the ring plane.

The continuous supply of particles from moon impacts — balanced by the particles' steady infall into the planet — means that the material currently in Jupiter's rings is young, likely less than 1 million years old, even though the ring system itself may have persisted for billions of years (assuming moons have been in place to replenish it). In fact, if conditions are right, the *ring rain* phenomenon can happen in any ring system, draining small particles out of the rings and down onto the parent body.

Saturn: Rings of Power

Saturn's brilliant rings consist primarily of water ice, ranging in size from tiny grains to large chunks. The rings extend hundreds of thousands of kilometers out from the planet in a remarkably thin band that's only tens of meters thick.

This is the most extensive ring system in the solar system, featuring both dense rings (A, B, and C) and tenuous rings (D, E, and G), along with additional minor ringlets, arcs, and the narrow F ring.

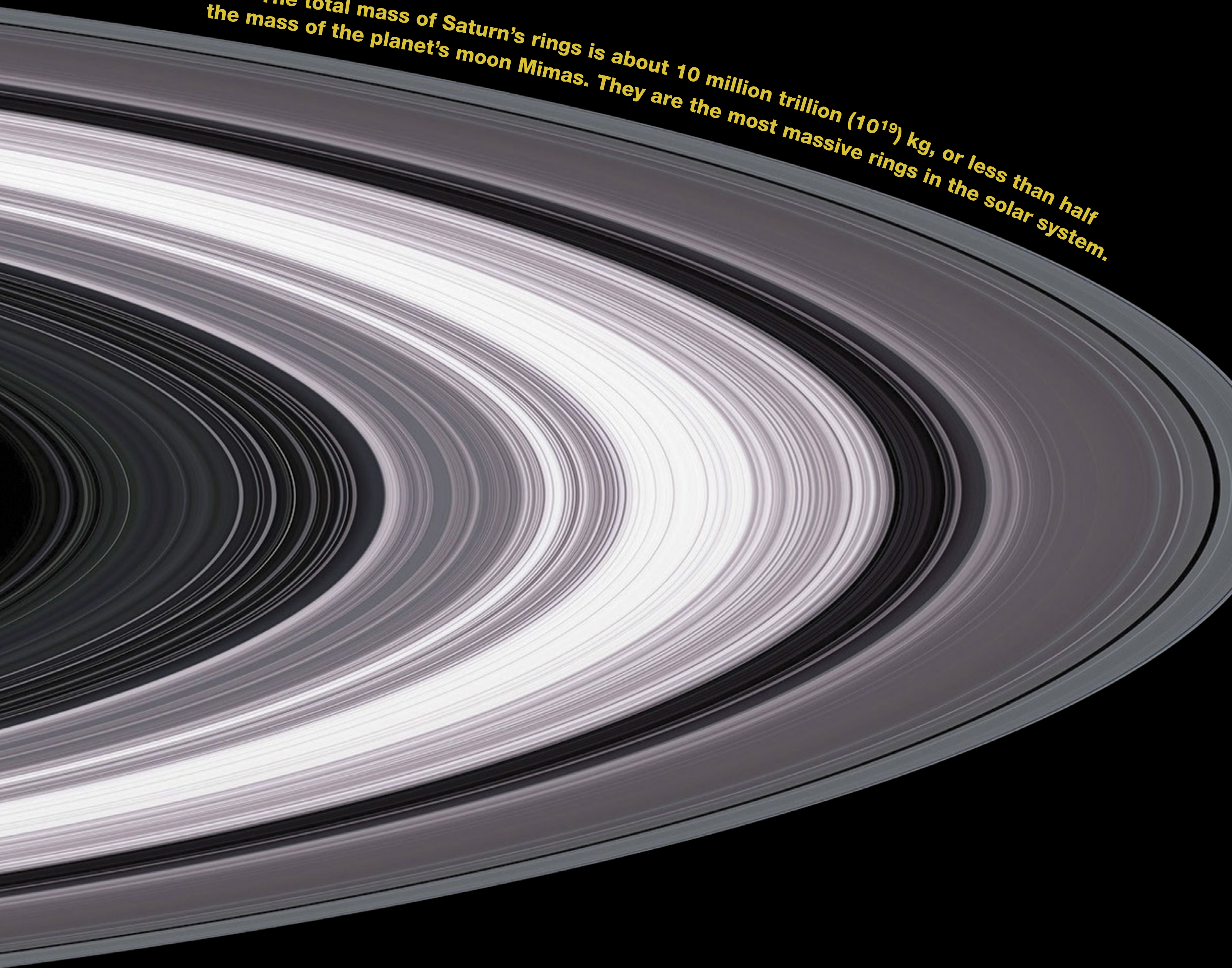
Almost as famous as the rings themselves are the remarkable divisions within and between them. *Shepherd moons* — which "herd" ring particles near the satellites' orbits — produce many of these divisions. For example, the shepherd moon Prometheus influences the narrow F ring's shape, while an orbital resonance with Mimas, which orbits in the outermost E ring, creates the Cassini Division between the A and B rings.

Plumes of water ice erupting from the moon Enceladus

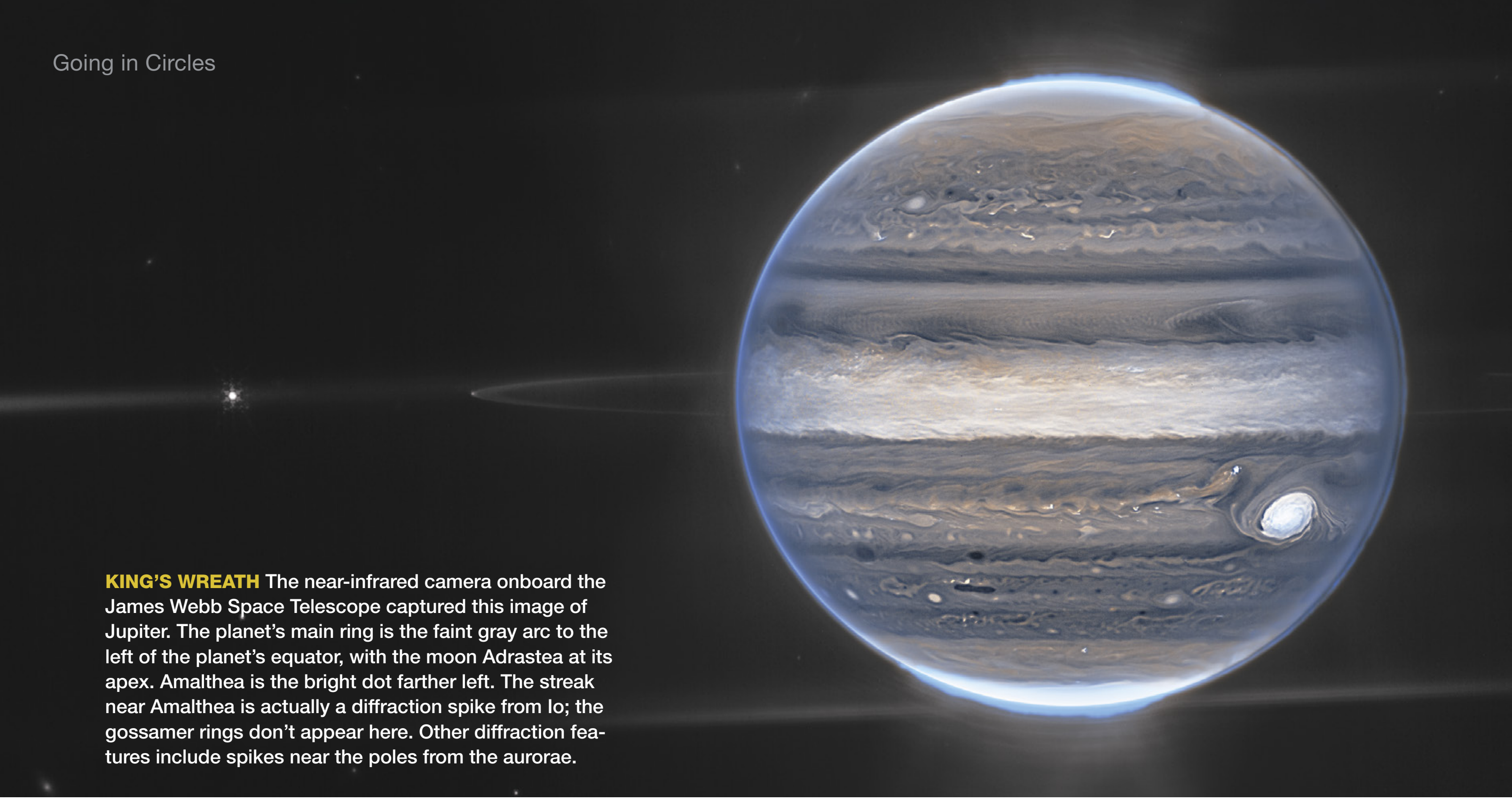
▶ **SATURN'S MAJESTY** This simulated image is derived from radio signals sent by the Cassini spacecraft through Saturn's ring system to Earth. As the radio waves passed through the rings, they were blocked to varying degrees. Scientists then constructed this image of the rings' structure based on how the radio signals changed. It's color-coded by the size of the smallest particles detected. Purple indicates a lack of particles less than 5 centimeters (2 inches) wide, whereas greenish and bluish tints indicate where those small particles do reside — primarily in rings A and C (see page 18).

NASA / JPL

Solar System



The total mass of Saturn's rings is about 10 million trillion (10^{19}) kg, or less than half the mass of the planet's moon Mimas. They are the most massive rings in the solar system.

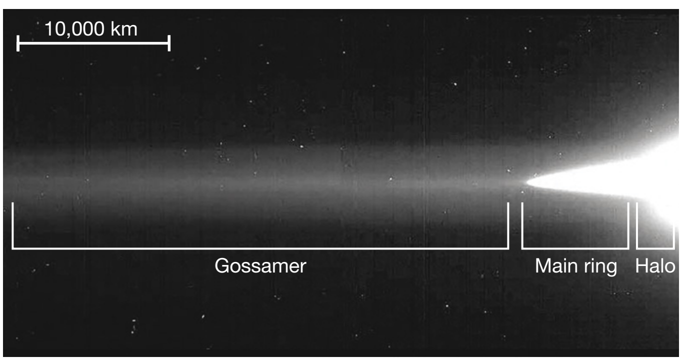


KING'S WREATH The near-infrared camera onboard the James Webb Space Telescope captured this image of Jupiter. The planet's main ring is the faint gray arc to the left of the planet's equator, with the moon Adrastea at its apex. Amalthea is the bright dot farther left. The streak near Amalthea is actually a diffraction spike from Io; the gossamer rings don't appear here. Other diffraction features include spikes near the poles from the aurorae.

create Saturn's E ring. But the origins of the other rings remain debated. Most astronomers believe that their big, bright appearance — unlike the faint, dark rings of the other giants — indicates that the rings are comparatively young. Meteoroid impacts should darken the rings over time, yet Saturn's rings are pristine: The Cassini mission found the ice particles have relatively low levels of space-dust contamination, suggesting the rings may be only 100 million years old.

One theory suggests the rings are moon debris. "Maybe a moon formed around Saturn that was large enough to differentiate, with all the heaviest material in the core and an icy shell on the outside," says Linda Spilker (NASA Jet Propulsion Laboratory), who served as Cassini's project scientist. A gravitational encounter could have disturbed the moon's orbit and pushed it within the planet's Roche limit. "Then tidal forces could have easily torn it apart, and the icy shell would have formed the rings, while the rocky interior fell into Saturn."

Conversely, some astronomers think that collisions



▲ **JUPITER'S FAINT HOOPS** This 1996 image from the Galileo spacecraft shows the gossamer rings, main ring, and halo.

between boulder-size chunks and the chunks' subsequent fragmentation might expose pristine surfaces to space, warding off the expected darkening. This process could affect a youthful appearance, even if the rings are ancient. A recent study also suggests that scientists might have overestimated the effects of micrometeoroid pollution.

But regardless of the rings' true age, everyone agrees that the rings are not likely to be around for much longer. As with Jupiter, Saturn's ring material steadily drains out as ring rain down onto the planet. But unlike Jupiter, Saturn's rings are not constantly replenished. By comparing the observed infall rate with the system's total mass, scientists calculate that Saturn's iconic rings might vanish entirely within the next 300 million years.

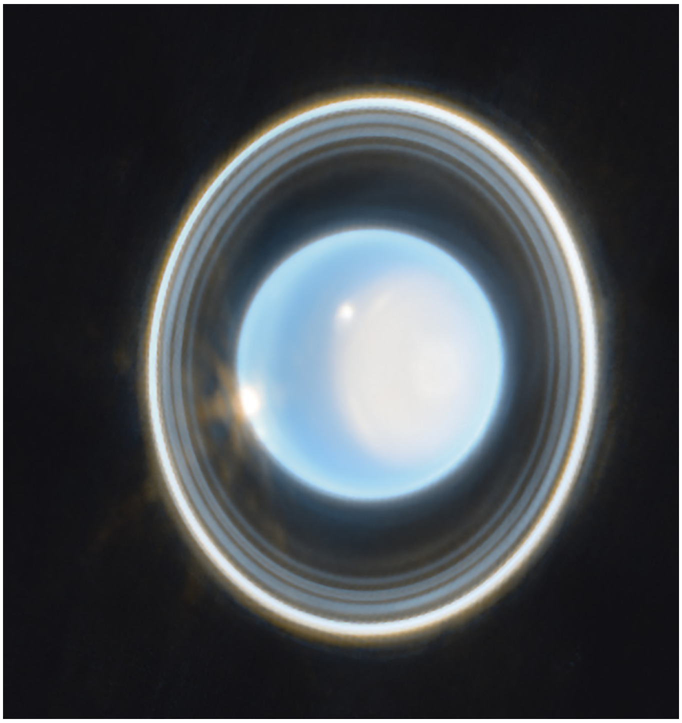
Uranus: Thin Dark Lines

Although Uranus lies farther from the Sun than Jupiter does, scientists discovered the Uranian ring system before they did Jupiter's. This detection occurred in 1977, when researchers studying Uranus's atmosphere fortuitously observed at least five distinct rings.

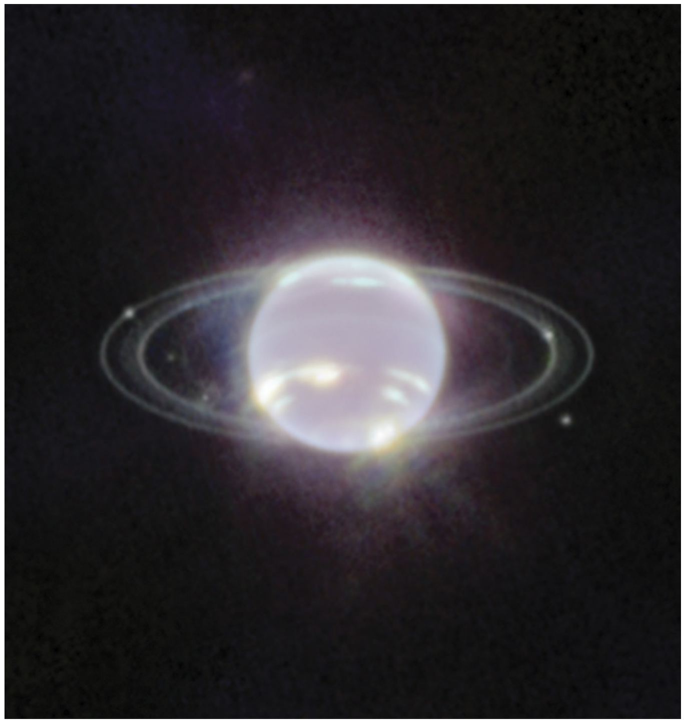
The astronomers found the rings when the planet passed between us and a distant star, an event called a *stellar occultation* (*S&T:* Sept. 2023, p. 34). During a stellar occultation, the star's brightness dims or winks out while the object is passing directly in front of the star. When observers in different locations on Earth carefully time this brief dimming at each site, they can determine the size and shape of the intervening object — and any moons or rings it has.

Further studies of Uranus, including observations by NASA's Voyager 2 spacecraft in 1986, later identified a total of 13 separate rings. There are 10 narrow rings and three diffuse

JUPITER: NASA, ESA, CSA, JUPITER ERS TEAM, IMAGE PROCESSING BY RICARDO HUESO (UPV / EHU) AND JUDY SCHMIDT; RING SYSTEM: NASA / JPL AND CORNELL UNIVERSITY



▲ **URANIAN RINGS** This false-color, near-infrared image from JWST shows Uranus's polar cap and its ring system. The moons among the rings aren't visible in this image.



▲ **AT NEPTUNE** Also a false-color, near-infrared image from JWST, this image reveals Neptune's rings and several of its moons. Clockwise from center right are Despina, Larissa, Thalassa, Naiad, and Galatea.

URANUS: NASA, ESA, CSA, STSCI, IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI); NEPTUNE: NASA, ESA, CSA, STSCI, IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI) AND NAOMI ROWE-GURNEY (NASA / GSFC)

ones, with faint dust sheets in between. The rings generally appear dark and rocky, though recent observations of the outermost rings by the James Webb Space Telescope (JWST) also showed evidence of water ice.

Scientists think shepherd moons influence the boundaries between the rings. However, over the decades, researchers have identified only two such satellites: Ophelia and Cordelia, which straddle the epsilon ring. The epsilon ring is the brightest of the rings and contains particles as small as golf balls.

Scientists remain uncertain about the rings' origin but doubt they are primordial. Comets often pass close to or across Uranus's orbit, and it seems likely that one or more have interacted with the system in the last billion years, leading to its current configuration.

Brooks hopes that a proposed Uranus orbiter mission (*S&T:* July 2023, p. 14) will help answer some of these enduring questions.

"It could be that the ring systems at Uranus and Neptune are just the very last remnants of much more massive ring systems that existed," he says. "We don't really know."

Neptune: Stranger Rings

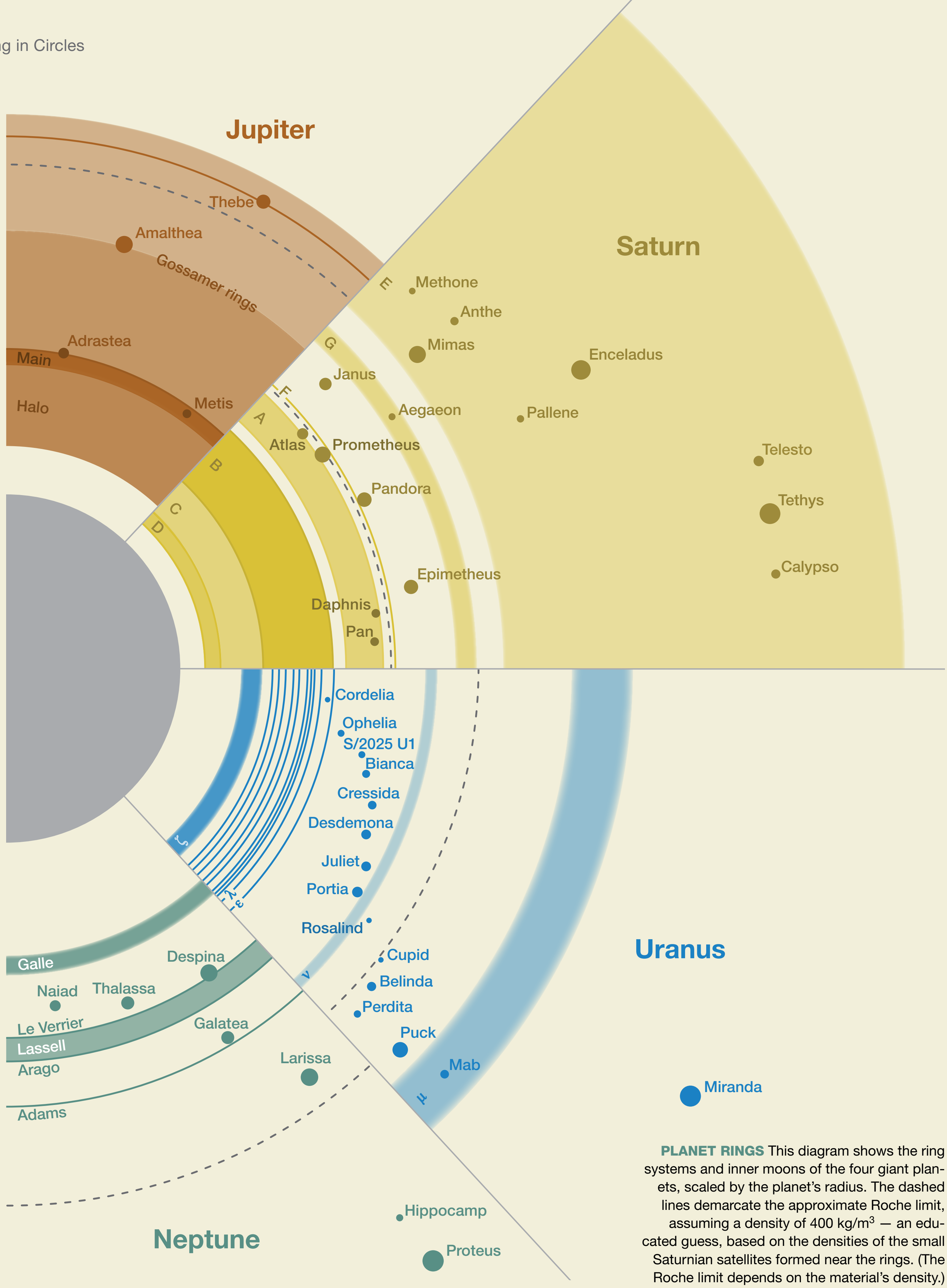
In 1984, astronomers also discovered Neptune's rings during a stellar occultation; they later verified them during Voyager 2's 1989 flyby. There are five principal rings (Galle, Le Verrier, Lassel, Arago, and Adams) and a tenuous unnamed sixth ring. Most of the system is quite faint. The rings are made up primarily of dark, irradiated particles, and astronomers have detected water ice as well.

Neptune's brightest and most studied ring is Adams. When it was first observed, five arcs called Courage, Liberté, Fraternité, Égalité 1, and Égalité 2 were detected within it. They are clumpy segments that are considerably brighter and denser than the rest of the ring. Since then, two of the arcs, Courage and Liberté, have faded away.

"When they first observed [Neptune's rings], they saw a dip on one side, but they didn't see a dip on the other side," says Heidi Hammel (Association of Universities for Research in Astronomy), who was part of the team imaging Neptune with Voyager 2. "And they're like, 'That can't be a ring then, right? Because rings are uniform.' So it was a big argument — what was really going on? Then finally, when Voyager got there in 1989 and took a picture, we saw it: clumpy sections in the ring."

The most common explanation for the arcs is that the nearby moon Galatea, which orbits just inside the Adams ring, is gravitationally causing particles to cluster together. But models show that this scenario doesn't fully explain the arcs' structure and motion. Perhaps the combined influence of multiple moons is responsible.

Neptune's largest moon has clearly sculpted its moon-ring system, though. Triton is the only Neptunian satellite massive enough to be fully rounded by gravity, and it's the only large moon in the solar system with a retrograde orbit. This is why astronomers think Triton was probably a dwarf planet captured from the region beyond Neptune billions of years ago (*S&T:* Feb. 2026, p. 14). Simulations predict that the Triton-capture event would have disrupted any preexisting



PLANET RINGS This diagram shows the ring systems and inner moons of the four giant planets, scaled by the planet's radius. The dashed lines demarcate the approximate Roche limit, assuming a density of 400 kg/m^3 — an educated guess, based on the densities of the small Saturnian satellites formed near the rings. (The Roche limit depends on the material's density.)

BEATRIZ INGLESSIS / S&T

ring-moon system, with the satellites and rings we see today emerging from the resulting debris.

Chariklo: Put a Ring On It

The rings of the giant planets are well known, even sometimes to the general public. But new studies have recently revealed that much smaller objects, such as the Centaur 10199 Chariklo, can also host ring systems.

A Centaur is a small celestial body originally from around or beyond Neptune that's now migrating through the giant-planet region, on its way to become a Jupiter-family comet (*S&T:* Jan. 2022, p. 14). Although astronomers have not fully accounted for the population, they believe that thousands of Centaurs are in unstable orbits between Jupiter and Neptune.

Chariklo is the largest known Centaur, with an estimated diameter of some 250 km (160 miles). In 2013, a stellar-occultation campaign led by Felipe Braga-Ribas (Federal University of Technology in Paraná, Brazil) detected two rings around it: C1R and C2R. They are only a few kilometers wide, but they are remarkably dense and sharply defined. Observations with the X-Shooter spectrograph on the Very Large Telescope in Chile determined that the rings consist of mostly silicates, a small amount of water ice (about 20%), and a smaller amount of carbon.

Astronomers speculate that *tidal disruption* — triggered when the Centaur passed near a gas giant and was partially torn apart by the larger body's gravity — might have produced Chariklo's rings. They could also stem from a collision or from past cometary activity. The rings' well-defined appearance suggests that at least one shepherd moon might be present, acting to clear the gap between the rings. So far, though, astronomers have not directly observed any satellites.

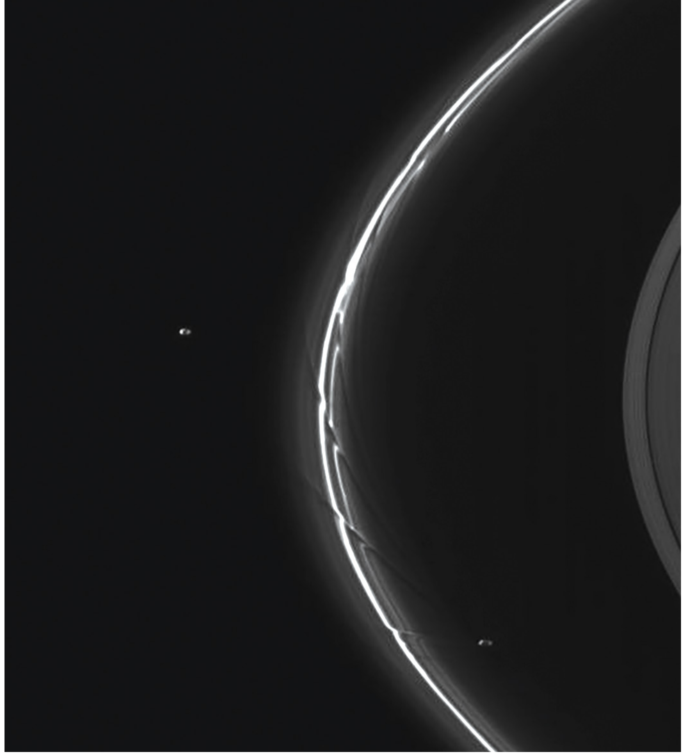
"Giant planets have giant gravitational fields that dominate the region, so we need to have a very efficient mechanism to confine the rings around a small gravitational field." Braga-Ribas says. "Is the mechanism related to the rotation of the object, to the shape of the object? Is it related to the presence of a small satellite? This is what we are trying to understand."

Chiron's Evolving Rings

After Braga-Ribas's team detected rings around Chariklo, planetary scientists began to wonder if other Centaurs might have rings as well. Jose-Luis Ortiz (Institute of Astrophysics of Andalusia, Spain) and his collaborators took another look at archival data of 2060 Chiron, the first Centaur ever discovered. They re-analyzed earlier studies and found that some features previously reported as comet-like activity closely resembled Chariklo's rings.

The scientists ran a new observing campaign of Chiron in 2022 and found even more material surrounding the Centaur. According to Ortiz, it was clearly dynamic — perhaps a ring system in the middle of either being formed or destroyed — but its true structure remained unknown.

That uncertainty narrowed in October 2025, when a team



NASA / JPL / SPACE SCIENCE INSTITUTE

▲ **COSMIC SHEEP** The moon Prometheus shepherds Saturn's delicate F ring, its gravitational influence carving the dark channels visible in this Cassini image.

led by Chrystian Luciano Pereira (National Observatory, Brazil) published a new analysis, incorporating results from a stellar occultation by Chiron recorded at 31 sites across South America on September 10, 2023. Their work revealed three narrow rings, as well as a broader, more tenuous disk of material and a faint outer feature, both farther out.

Comparing the 2023 occultation with earlier observations, the team inferred that the diffuse disk likely emerged within the last 10 years, possibly triggered by a major outburst seen by astronomers in 2021.

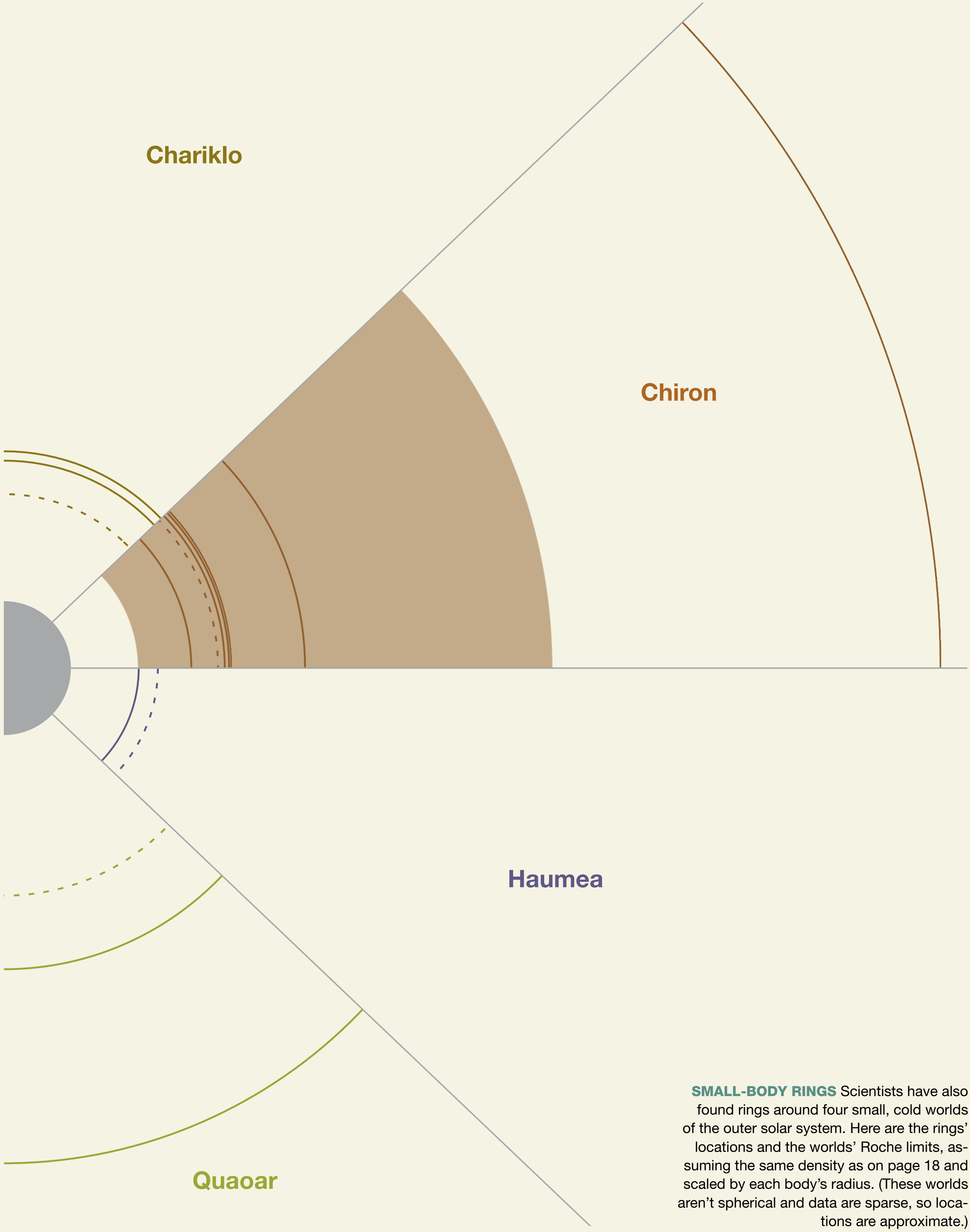
Notably, the farthest ring and the structures beyond it all lie outside Chiron's estimated Roche limit. These are not the only rings in the solar system to orbit outside their parent body's Roche limit: The same holds true for Saturn's F, G, and E rings, for example.

But the environments around giant planets are extremely complex, with many ways to sustain a far-flung ring — such as with particles from a nearby moon, as is the case for Uranus's mu ring. Around much smaller objects like Chiron, scientists must look for new mechanisms. The reasons why some of Chiron's ring system lies outside its Roche limit remain under active study.

Haumea: Spin City

To investigate the last two known ring systems, we have to go farther out, beyond Neptune. The first girds Haumea, a dwarf planet located in the Kuiper Belt. Haumea is known for its oval shape, two satellites, rapid rotation, and — since 2017 — for being the first trans-Neptunian object (TNO) observed to have a ring.

Small solar system bodies are often pieces of larger bodies that broke up. Haumea belongs to its own *collisional family*



SMALL-BODY RINGS Scientists have also found rings around four small, cold worlds of the outer solar system. Here are the rings' locations and the worlds' Roche limits, assuming the same density as on page 18 and scaled by each body's radius. (These worlds aren't spherical and data are sparse, so locations are approximate.)

BEATRIZ INGLESSIS / *S&T*

— a group of objects that originated from a single disrupted body. Such violence can beget rings like Haumea's.

"We think that at least the rings of Haumea . . . may have resulted from the same process that generated the largest satellite, which has a coplanar orbit with the ring," says Ortiz. "It is also likely that the same event gave rise to the cluster of bodies that have similar orbits to Haumea."

Quaoar: Stranger than Fiction

Astronomers discovered Quaoar, another dwarf planet in the Kuiper Belt, in 2002. About 20 years later, scientists detected a pair of rings around it.

"Our observations of Quaoar's occultations were initially conducted to place constraints on the presence of an atmosphere and to characterize the body itself," says Pereira, who led the discovery paper for the second ring. "In four stellar-occultation events between 2018 and 2021, the star was seen to dim not only due to Quaoar itself, but also due to a structure surrounding it."

The odd thing is, both rings are located far beyond Quaoar's Roche limit. As with Chiron, this bucks the traditional understanding that says debris at this distance should quickly coalesce into satellites.

The dwarf planet's one confirmed moon, Weywot, might partly explain its rule-breaking ring system. The satellite orbits in a 6:1 resonance with the outer ring, Q1R, meaning the ring particles complete six orbits around Quaoar for every one of Weywot's. Such resonances can create regions of space where push-pull interactions between the moon and the ring particles naturally balance out, both confining and continuously stirring the material so that it can neither disperse nor accrete. This resonance may be what creates and shapes Quaoar's outer ring.

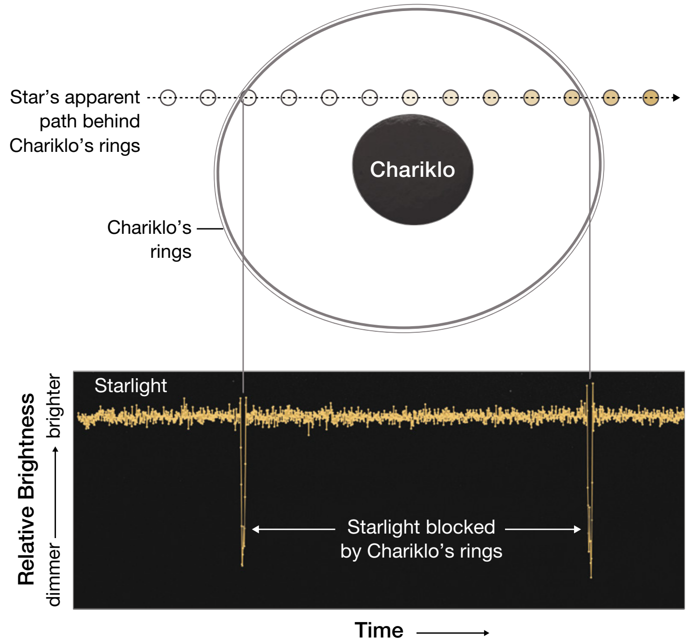
Another theory is that Weywot might not always have been in its current orbit. Over time, tidal forces could have slowly moved it farther out. If the ring was trapped in resonance with Weywot early on, then that resonance could have shifted outward with the moon, dragging the ring to its current location beyond the Roche limit.

But the moon might not be (solely) to blame. At Quaoar's distance from the Sun, material is extremely cold, making ring particles more likely to bounce off each other than to stick together. Those conditions might prevent — or at least slow down — accretion into satellites.

Finally, recent impacts or geologic activity on the TNO might have created the rings. Some evidence suggests that Quaoar's surface is young, which supports this theory. In this case, the ring might not be stable — meaning there's a small chance we could observe it form a new moon sometime in the next few decades.

Rings Without Borders

To date, astronomers have successfully conducted stellar occultation observations for more than 60 Centaurs and TNOs. The four ring systems found in that group suggest that a significant minority of small solar system bodies might have rings. An intriguing possibility arises: Ring systems might be far more common than we once assumed.



▲ **RINGS REVEALED** As Chariklo passed in front of a background star, its rings briefly blocked the star's light, creating dips caught in this light curve from the James Webb Space Telescope (bottom). During this particular event in October 2022, the star passed directly behind the rings, but not behind Chariklo.

NASA, ESA, CSA, LEAH HUSTAK (STSCI), SCIENCE: PABLO SANTOS-SANZ (IAA-CSIC), NICOLÁS MORALES (IAA-CSIC), BRUNO MORGADO (UFRJ, ON / MCTI, LINEA)

Bruno Sicardy (Paris Observatory) is the founder of the Lucky Star project, which predicts and observes stellar occultations by TNOs and Centaurs. Many of the network's members are his former students and postdocs, and the network (which also includes citizen scientists from all over the world) has been involved in all four ring-system discoveries around small bodies.

"I don't think I'm so lucky as to discover the only four existing rings," he says. "Maybe in a few years from now, we will know about many more than those around the giant planets. It could be that rings are just routine."

This realization could extend far beyond the solar system. Several years ago, astronomers saw what they thought was a ringed world crossing in front of the star J1407 (*S&T:* Sept. 2020, p. 34). So far, the signal has not repeated.

For now, the rings around the solar system are our primary means for understanding these structures. They continue to offer valuable clues about the history and evolution of planetary systems. They're not just visual wonders, but active records of impacts, migrations, and other dynamic processes. As scientists improve their techniques and instruments, and as they send more sophisticated spacecraft out to explore, we'll keep refining our understanding — one ring at a time.

■ **ARWEN RIMMER** is a writer and musician based in Cambridge, United Kingdom.

Leo I: A Small Gala

Hiding in plain sight, this object lies close to the Lion's heart.

Dwarf galaxies in the Local Group usually aren't very high on my observing list. They often have low surface brightness, making them difficult to detect. Also, unless you know something about what they represent, their subtle glow in the eyepiece will probably fail to impress. A little knowledge can go a long way toward changing that perception, though.

Leo I, also designated UGC 5470, is an example of a *dwarf spheroidal galaxy* — small, low-luminosity galaxies characterized by older stellar populations and lack of gas and dust. Leo I is also a member of the Local Group, which includes the Milky Way, M31 (the Andromeda Galaxy), and M33 (the Triangulum Galaxy) as the dominant spiral galaxies. The group spans around 10 million light-years, with its

CHRIS COOK

xy with a Big Story

gravitational center somewhere between the Milky Way and M31. According to the most current data, it contains 73 galaxies, the vast majority of which are dwarf spheroidals. Leo I is gravitationally bound to the Milky Way.

I find Leo I exceptional for several reasons, but let's start with how easy it is to locate. This 10th-magnitude object lies only 20′ directly north of the brightest star in the constellation, 1.4-magnitude Regulus, Alpha (α) Leonis. This means that if you place Regulus in the southern half of a medium-power eyepiece, Leo I will be in the northern half. How easy is that?

As usual, what you see depends a great deal on your sky conditions. I'll get into this a bit later, but "easy to find" doesn't necessarily mean easy to see. However, once seen, what are you to make of such a ho-hum smudge near a bright star? I suggest combining that unremarkable view with a summary of the latest astronomical research to get an idea of what Leo I is and why it looks the way it does.

A Fascinating Object

Let's find out why the nondescript glimmer of Leo I is really an exceptionally fascinating object and very much worth your time to observe.

To begin with, it has a mass of only 5.5 million suns, which is pretty tiny as galaxies go. This is roughly the same mass as the Milky Way's largest globular cluster, Omega Centauri, which contains some 4 million solar masses. (For reference, the Milky Way weighs in at 1.2 to 1.9 *trillion* solar masses.)

It might be tempting to think of Leo I as a gigantic globular cluster, but it *does* qualify as a galaxy. The main criteria for a bunch of stars to be considered as such is that it has sustained star formation for hundreds of millions of years and it contains a substantial quantity of dark matter. As we'll see, Leo I passes both those tests.

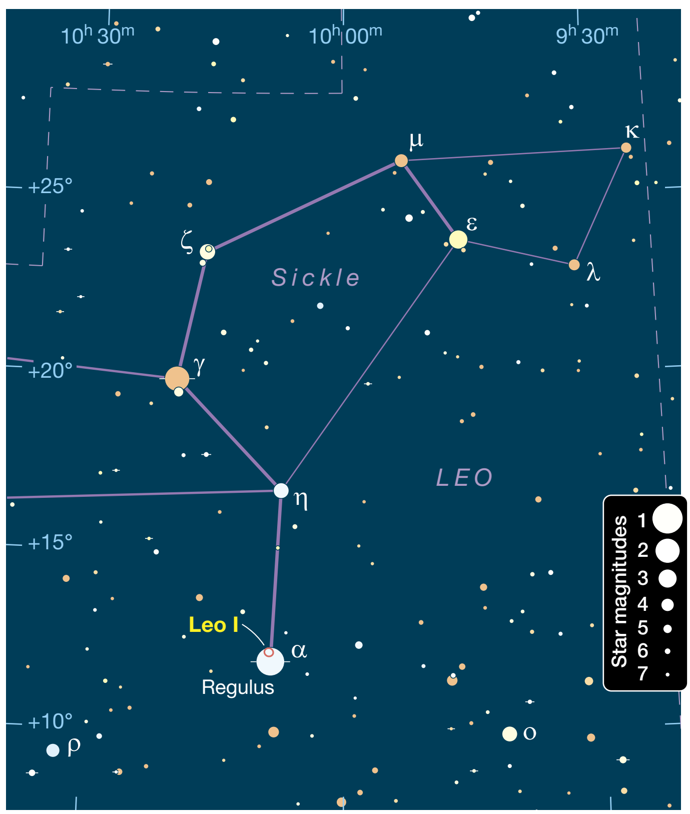
Then again, Omega Centauri passes, too, bolstering the case for it being the remaining core of a galaxy whose outer parts were tidally stripped away by the Milky Way. I'll add that visually, Omega Centauri looks more like Leo I than it does most other Milky Way globulars. Just saying.

At approximately 837,000 light-years away, Leo I is one of the most distant dwarf spheroidals of the Milky Way. Its orbit is fairly well known and indicates it came to within about 100,000 light-years of the Milky Way's center approximately 1 billion years ago. Data also suggest that Leo I is on its first orbit around our home galaxy.

One billion years ago was also the time that Leo I's most recent bout of star formation ended, probably because its hydrogen gas was stripped away as the dwarf spheroidal entered the outer regions of the Milky Way and rammed its way through our galaxy's own gas (see the sidebar on page 25). This *ram pressure stripping* transformed Leo I from a star-forming dwarf irregular galaxy to a non-star-forming dwarf spheroidal.

The galaxy had several older star-formation episodes as well, indicating that it's probably one of the Milky Way's youngest dwarf spheroidals. Its oldest stars are estimated to be about 10 billion years old.

◀ **BRIGHT STAR, DIM GALAXY** The 10th-magnitude dwarf spheroidal galaxy Leo I, also known as UGC 5470, appears as a faint, grainy glow just 20′ north of 1.4-magnitude Regulus, Alpha (α) Leonis, at a right ascension and declination of $10^h\ 08.5^m$, +12° 18′. To the west-southwest of Leo I and equidistant from Regulus lies the tiny, 13.2-magnitude galaxy IC 591. North is up in all images.



▶ **CELESTIAL LION** Leo is one of the most recognizable constellations in the March evening sky. Its Sickle asterism, shaped like a backward question mark, is formed by six bright stars, with Regulus marking the base.

A 2021 paper in the *Astrophysical Journal* inferred that Leo I could have a supermassive black hole at its center. Based on the movements of the little galaxy's stars, an international team concluded that the black hole had about the same mass as all the other stars in Leo I combined, and roughly the same mass as Sagittarius A*, the supermassive black hole at the center of the Milky Way. That surprising result has since been called into question, however: The majority of the available data suggest either a smaller, intermediate-mass black hole or no black hole at all, with equal probability.

The possibility of a supermassive black hole in Leo I prompted another study to see if it had originally been a much larger galaxy that the Milky Way had stripped down to its current size and shape. Simulations showed this scenario to be possible, but the expected tidal stream of stars would be difficult to detect because it would lie directly along our line of sight. However, another study claims this model is based on unrealistic parameters. It seems the jury is still out.

▲ **DISCOVERY INSTRUMENT** Astronomers Robert G. Harrington and Albert G. Wilson found Leo I in 1950 on photos captured with Palomar Observatory's 48-inch Schmidt telescope. However, it's Edwin Hubble shown posing at the guide scope — he discovered lots of things, including the expansion of the universe, but not Leo I.

Nonetheless, Leo I has one of the highest densities of dark matter of any dwarf spheroidal in the Milky Way's neighborhood. And because it lies far out in our home galaxy's dark matter halo, Leo I and its companions' proper motions help scientists study how mass is distributed in that halo.

Pretty cool, huh?

American astronomers Robert G. Harrington and Albert G. Wilson discovered Leo I in 1950 on photographic plates taken with the then-new 48-inch Schmidt telescope at Palomar Observatory in California. Their description matches what you can expect to see with your own telescope:

> *System No. 1 (Leo 1) has an elliptical projection, with the major axis lying in the east-west direction. Estimates of the angular diameters of the system are 10′ by 6′ . . .*

The vast majority of photographically discovered objects are nearly impossible to see in telescopes, but not Leo I. Which begs the question: Why wasn't it discovered visually in the 19th century? My guess is that the long focal ratios of the observers' telescopes, combined with their narrow eyepiece field of views, are probably the reason. Such instruments just weren't very good for viewing large, diffuse targets like this. Leo I simply might have been overlooked. Or perhaps, even looked through.

Observing Requirements

Under good conditions, Leo I can be seen with pretty much any well-made modern telescope equipped with quality eyepieces. Recently, I've even come across one report from an experienced observer who described seeing the galaxy with a 70-mm f/10 refractor!

So, whatever scope you're using will probably be able to do the job if you have decently dark and transparent skies. Transparency and darkness are important for the best view — the clearer and darker the sky, the more easily you'll be able to detect low-contrast objects. Consider that, although Leo I has an apparent magnitude of 10.5, its large size of 9.8′ × 7.4′ spreads out that light to a surface brightness of only 15.2 magnitudes per square arcsecond. A murky or light-polluted sky will completely mask the delicate glimmer of this little galaxy. In addition, you'll need to place Regulus outside the field of view. Otherwise, glare from the bright star will dazzle your eye, rendering Leo I invisible, or at least make it more difficult to detect.

Keeping Regulus outside the field isn't as easy as it might seem — Leo I's apparent distance from the star is almost the same as the dwarf galaxy's apparent size, so you'll have to experiment to find an eyepiece that gives a wide enough field to frame Leo I properly but also keeps Regulus out of view.

Although a 70-mm refractor is ostensibly large enough for an experienced observer to see Leo I under good conditions, all my observing has been with large reflectors. But no matter what scope you use, all you can really expect to see is a faint, oval glow. However, assuming sufficiently dark and transpar-

NASA / ESA

ent skies, success is practically assured. Observing experience will help quite a bit, too, but even if you're new to visual astronomy, give the galaxy a shot anyway. You'll never really know unless you try.

I've observed Leo I only four times so far, and each time has demonstrated how important sky conditions are:

1994: I used my 20-inch f/5 Obsession telescope for this first observation. The sky was only so-so in darkness and transparency, but I was able to see Leo I even so:

> *Very faint, roundish glow just north of Regulus. Took a few minutes to fish out . . . 182×.*

Nothing spectacular, but I remember thinking that I may not have even tried to snag it when I was a beginner because it was such an obscure object. I observed the rest of that night feeling rather accomplished.

2005: Eleven years later, I turned my 28-inch f/4 telescope to Leo I and wrote:

Ram Pressure Stripping

Ram pressure stripping is similar to the process of driving a "car" made of leaves — the faster the car goes, the more leaves get whittled away.

Imagine a dwarf galaxy orbiting a much larger spiral galaxy. As the dwarf galaxy gets closer to the spiral, it encounters the latter's dense interstellar gas. The spiral's gravity holds on to its gas more strongly than the dwarf galaxy can, so the dwarf (in this case Leo I) has its gas "blown away" as it plows onward. Over time, this process can almost completely strip a dwarf galaxy of its neutral hydrogen (H I) gas, nearly extinguishing its ability to form new stars. It can also strip gas from large spiral galaxies within a galaxy cluster (*S&T:* Jan. 2025, p. 12). Depending on the exact circumstances, a spiral galaxy can also lose all its H I gas, but with the additional wrinkle that in the first stages of ram-pressure stripping, the gas is compressed, leading to the spiral's final round of star formation.

▲ **RUNNING OUT OF GAS** The Hubble Space Telescope captured the above view of the spiral galaxy NGC 4402, which is currently being stripped of its gas content as it moves through the dense intergalactic medium within the Virgo Cluster.

▲ **VISUAL BLACK-AND-WHITE SKETCH** The author drew this view of Leo I in 2021, as seen with his 28-inch f/4 telescope at 155× on a nearly perfect night. "Next time, I'll use more magnification to see if I can resolve some of Leo I's brightest stars, and I'll try to see this dwarf galaxy with my 80-mm finder scope," he notes.

A vague oval glow just north of Regulus, about the same distance from Regulus as IC 591, a much smaller and more distinct galaxy. 105×.

2007: Again, with my 28-inch scope:

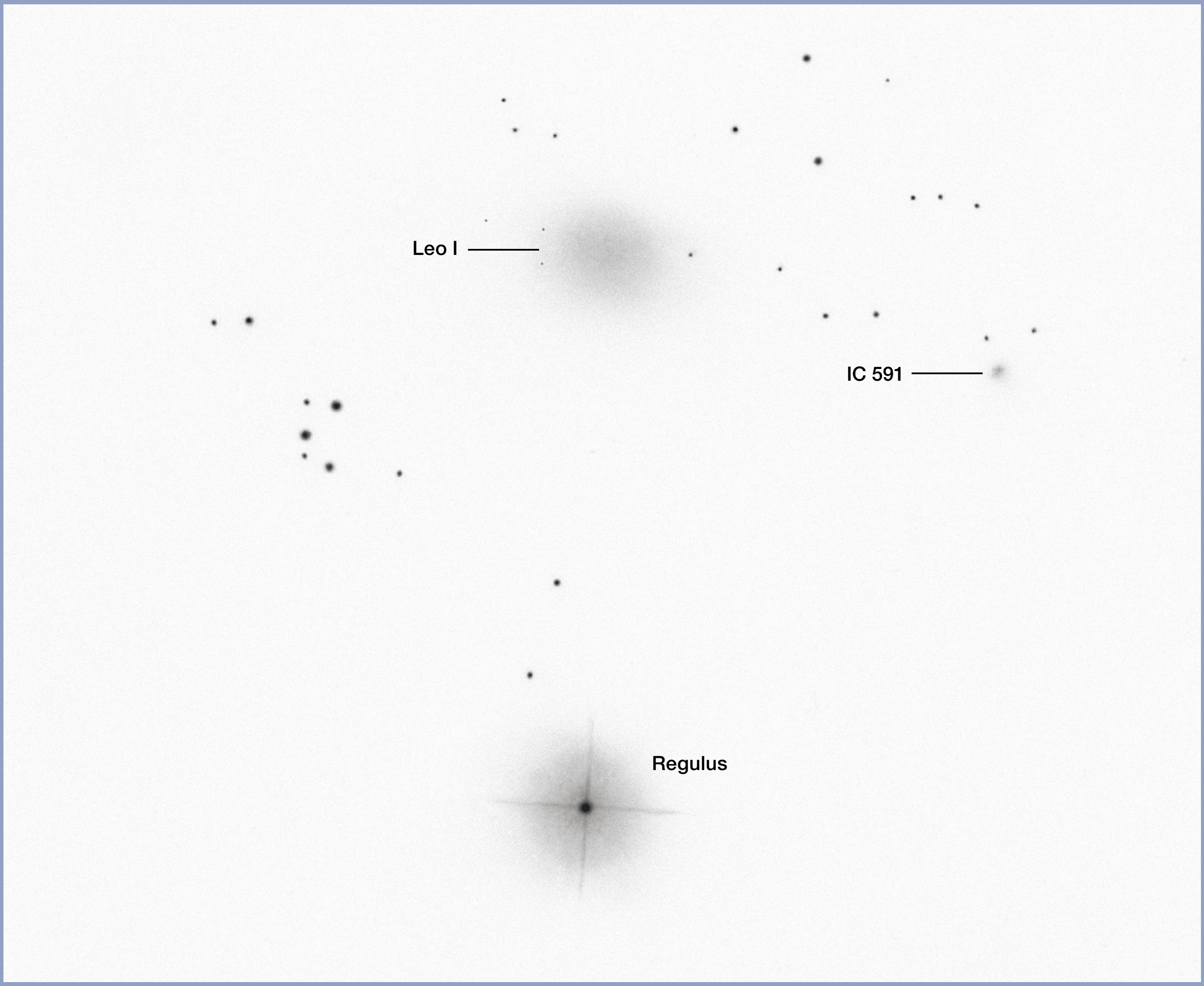
A gradually brightening in an oblong shape just north of Regulus. The tricky part is putting Regulus outside the field of view just so — a ghost image [of the star] pops into view if it's too close. 92×.

This is a good reminder that placing Regulus outside the field is necessary to obtain the most satisfying view, but it can be finicky to get it just right.

2021: During a run of spectacular nights at Chickahominy Reservoir in central Oregon, I had my best look yet, also with my 28-inch scope:

Nice! Leo I is the most evident that I remember, but it's still a large diffuse smudge that's only a little bit brighter in its center. IC 591 — I don't recall seeing it before — is quite easy to see and is small and condensed. 155×, 21.95 SQM [sky quality meter].

I remember how dark and clear the atmosphere was that evening, making it surprisingly easy to see Leo I even with Regulus in the field. That observation also reinforces how important taking notes can be. Yes, making detailed written descriptions isn't for everyone, so I'll just speak for myself.



▲ **NEGATIVE IMAGE** The author's sketch shows the minuscule barred spiral galaxy IC 591, which lies 132 million light-years away — much farther than Regulus (79 light-years) and Leo I (about 837,000 light-years).

While I've been taking notes and making sketches since 1973, I still can't recall everything that I've seen in the eyepiece. A case in point is IC 591 — I'd obviously seen it in 2005, and just as obviously had completely forgotten about it 16 years later. With several thousand observations under my belt, this sort of thing happens all the time.

Knowledge is Good

I barely knew anything about Leo I before I first saw it in a telescope. It was only while reviewing the professional literature that I realized how fascinating it is, and how much work continues to be done to fully understand its astrophysical properties. Once again, an uninspiring visual smudge turns out to be an amazing object.

At times, a little new background knowledge seems to help improve my next observation. The more in-depth my literature research is, the better the chances that my next view will be my best ever. That might sound a little crazy, but my guess is that some confirmation bias might be at work here. But I'm OK with this self-diagnosis — and sometimes a little craziness can be a good thing.

■ Contributing Editor **HOWARD BANICH** is looking forward to seeing Leo I again this spring to confirm his confirmation bias. He can be reached at **hbanich@gmail.com**.

FURTHER READING: To explore other deep-sky targets in Leo, see Scott Harrington's article in the April 2024 issue, page 20.

 by Christopher M. Graney and Dennis Danielson

Lord Kelvin and Space Seeds

The beginnings of life on Earth (and perhaps elsewhere) is one of science's most enduring mysteries.

We live in a dynamic universe of constant change. The best-known watershed of this fact came when the great Danish astronomer Tycho Brahe observed a "new star" in Cassiopeia in November 1572.

For two millennia, it had been assumed that we humans inhabit an eternal "two-story" universe, strictly divided between a changeable terrestrial realm below the Moon, and the unchanging celestial realm of the Moon and beyond. This makes observational sense — wherever you may be right now, the landscape around you looked different 1,000 years ago. By contrast, the Moon and the constellations have remained essentially unchanged.

But with the appearance of Tycho's Supernova, as the star came to be known, humanity had proof positive that the heavens, like Earth, were in the grip of mutability. Some 20 months after it had grown bright enough to rival Venus, the supernova faded to invisibility.

By the middle of the 18th century, the dynamic, evolutionary character of the cosmos was coming more clearly into view. One thinker who grappled with this concept was the great German philosopher Immanuel Kant (1724–1804). In his 1755 *Universal Natural History and Theory of the Heavens*, Kant envisaged the formation of astronomical entities — from Earth itself to the solar system and beyond.

Kant appealed to Isaac Newton's ideas about motion and gravitation, writing that:

> *. . . every world-system is constituted by a mutual drawing together, which persists unceasingly and utterly unhindered, and whereby sooner or later each implodes into a single clump, unless this cataclysm is prevented, as it is with the spheres of our planetary system, by the action of centrifugal forces.*

▲ **NO PLACE FOR LIFE** Developments in the science of thermodynamics in the 19th century led to the realization that Earth was once very hot, and therefore lifeless — leading to the question, "How did life get here?" The subject of life's origin is one that scientists have long grappled with, leading to a number of (often novel) theories, from spontaneous generation to panspermia.

RICHARD BIZLEY

These forces, by deflecting the heavenly spheres from falling in a straight line, produce, in combination with those forces of attraction, the eternal orbital revolutions whereby the edifice of the creation is secured from destruction.

The phrase, "implodes into a single clump," is especially noteworthy. Under Aristotle (384–322 BC), perhaps the premier philosopher of the two-story universe, gravity was the tendency of earthly material to move toward a specific point, namely the center of the universe. So, when you drop a rock, it falls downward to the ground — under Aristotle, the ground is merely the accumulation of all the stuff that tends toward the center. Take the ground away, and the rock would still fall toward the center point. Even if you took the rock to the surface of the Moon and let it go, it would still fall toward that same center point, away from the Moon. (The Moon itself, residing in the ethereal upper story of the universe, would not tend toward that center.)

By contrast, under Isaac Newton (1642–1727), the rock falls toward the ground because gravity is a universal attraction between objects that have mass, an attraction that decreases with greater distance and lesser mass. The rock thus falls toward Earth, not toward a point. Take Earth away, and the rock would not fall. Take the rock to the Moon, and it would fall to the lunar surface, because the gravitational attraction of the much-closer Moon would be greater than that of the distant-but-larger Earth.

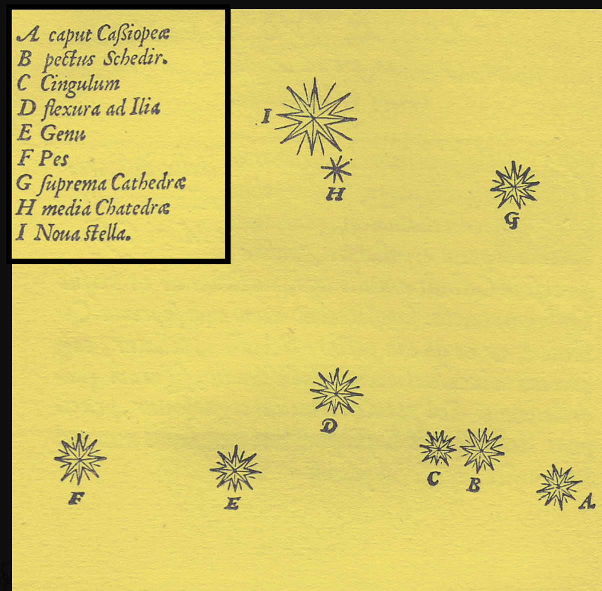
Of course, the Moon itself is gravitationally attracted to Earth. It does not fall, because it's in motion: Newton's (and Kant's) "centrifugal forces" keep it up there. Stop the Moon in its orbit, however, and it would fall to Earth; the Earth-Moon system would "implode." The same goes for the solar system as a whole, the galaxy (which according to Kant is governed by the same Newtonian physics as the solar system), and, presumably, the entire universe (which Kant, thinking far ahead of his time, envisioned as composed of galaxies). Kant concluded that the solar system formed from the gravitational infall of a diffuse mass, "as raw and undeveloped as possible" — what we today would think of as a *nebula*.

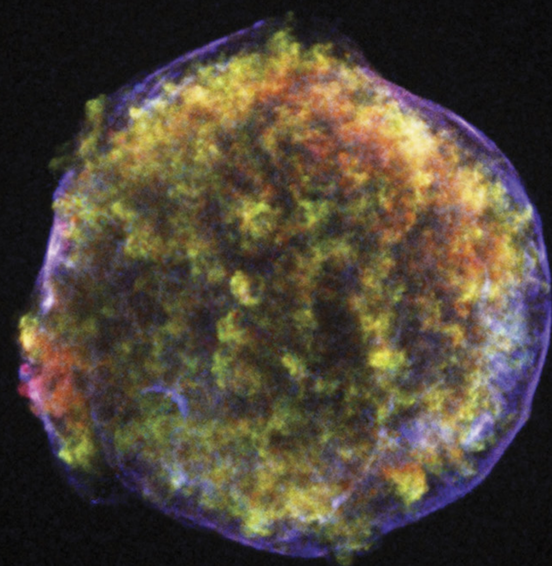
The universe of Kant and Newton was not stable like the two-story universe in which the ethereal Moon stays up and moves by its very nature. Indeed, the universe coming into focus from the mid-1700s on was one in which everything was subject to change. It was increasingly seen as an evolutionary cosmos.

Adding Life to the Mix

Kant's ideas have withstood the test of time. Today, we still think of the solar system as having formed from the gravitational collapse of a cloud of dust and gas. We certainly see the universe as continuously changing and evolving.

Having recognized "the drama of the passing changes of the universe," Kant then postulated that worlds might pass through stages during which they are not yet capable of supporting life. He believed that extraterrestrial life existed — he labeled the last section of *Universal Natural History* "an attempt, based on natural analogies, to establish a comparison between the inhabitants of different planets." Although his numbers are ludicrously low by today's reckoning, he nonetheless astutely observed that "Our Earth perhaps existed for a thousand years or more before it was in a condition to be able to support human beings, animals, and





HARBINGER OF CHANGE The appearance in November 1572 of a "new star" in Cassiopeia (indicated in the chart above from Tycho Brahe's *De nova stella* with the letter '*I*') prompted revisions of astronomers' ideas about the supposedly unchanging nature of the universe. The image directly above was captured in 2003 by NASA's orbiting Chandra X-ray Observatory and shows the churning, superhot cauldron of Tycho's Supernova Remnant in false color.

TYCHO'S SUPERNOVA CHART: WIKIMEDIA COMMONS/ PUBLIC DOMAIN; SN 1572 REMNANT X-RAY VIEW: NASA / CXC / RUTGERS / J. WARREN & J. HUGHES ET AL.

plants." And Jupiter, he stated, is apparently still a "long way from having a calm outer surface, a condition which must pertain for a planet to be inhabited."

Therefore, life is "out there," but in no given place has it always been present. Both Earth and other locations in the cosmos at some point in their formation and evolution were devoid of life, yet now are inhabited.

In Kant's time, life was considered to be a natural product of matter. Under the right conditions, life was *spontaneously generated* from non-living matter. The idea of spontaneous generation was old, dating back to at least Aristotle (*S&T:* Aug. 2024, p. 28). It was thought that you could observe spontaneous generation occurring in many places. For example, frogs could regularly be seen forming from mud. There was even a bit of ancient Roman poetry about this from Ovid's *Metamorphoses*:

Durt hath his seed ingendring Frogs full green,
Yet so as feetlesse and without legs on earth they lie,
So as a wonder unto passers-by is seen,
One part hath life, the other earth full dead is nye.

So, it would follow that if the rest of the universe is formed from the same kind of life-generating matter as Earth, life would be present everywhere.

But spontaneous generation turned out to be as bogus as the two-story universe. By the late 19th century, work by scientists such as Louis Pasteur (1822–1895) had thoroughly discredited the notion. But the nagging question remained: Where did life come from?

Enter Lord Kelvin

Sir William Thomson (1824–1907, later Lord Kelvin) tackled the topic of the origins of life in an address he gave at the 41st meeting of the British Association for the Advancement of Science (BAAS), held in Edinburgh, Scotland, in August 1871.

Thomson was president of the BAAS at the time and dedicated the last quarter of his very long address to the subject. "The old nebular hypothesis," he said, speaking of Kant's idea, "supposes the solar system and other similar systems through the universe which we see at a distance as stars, to have originated in the condensation of fiery nebulous matter. This hypothesis was invented before the discovery of thermodynamics," that is, the physics of heat.

Thomson noted how German physicist Hermann von Helmholtz (1821–1894), "adopting the nebular hypothesis," showed in 1854 that the mutual gravitation within the original nebula would have generated heat — enough to explain "the present high temperature of the Sun" and that it should continue to be hot "for several million years." But

◀ **NEBULOUS NOTIONS** Kant hypothesized in his 1755 book *Universal Natural History and Theory of the Heavens* that solar systems form from nebulae. His ideas have withstood the test of time.

nonetheless, Thomson said, a slow cooling was taking place everywhere, and the current heat of the Sun was in large part a reflection of its enormous "thermal capacity." Smaller bodies like Earth, it follows, simply cool faster.

What, then, Thomson asked, does this mean for life? At one point, Earth must have been barren: "Tracing the physical history of the Earth backwards, on strict dynamical principles, we are brought to a red-hot melted globe on which no life could exist." Thomson agrees here with Kant's idea of Earth existing for some time "before it was in a condition to be able to support human beings, animals, and plants."

Thomson continues:

Hence when the Earth was first fit for life, there was no living thing on it. There were rocks . . . water, air all round, warmed and illuminated by a brilliant Sun, ready to become a garden. Did grass and trees and flowers spring into existence, in all the fulness of ripe beauty, by a fiat of Creative Power?

That explanation won't do, Thomson said. While he would end his speech by affirming "one ever-acting Creator and Ruler," Thomson said that invoking that Creator's power to explain life was not the role of science, noting:

Science is bound by the everlasting law of honour, to face fearlessly every problem which can fairly be presented to it. If a probable solution, consistent with the ordinary course of nature, can be found, we must not invoke an abnormal act of Creative Power.

Nor would science allow for the traditional explanation for the existence of life, said Thomson — the hypothesis of spontaneous generation, an idea not entirely dead at the time of his speech. Indeed, as late as the 1880s, the Swiss-German botanist Carl Nägeli (1817–1891) continued to argue that simple living creatures were spontaneously generated all the time, with higher life forms then evolving from those simple life forms.

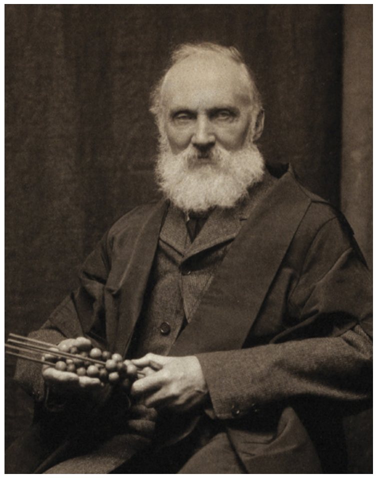
Nevertheless, Thomson rejected that "very ancient speculation, still clung to by many naturalists." Mentioning Pasteur's work among others, he insisted that "science brings a vast mass of inductive evidence against this hypothesis of spontaneous generation. . . . Careful enough scrutiny has, in every case up to the present day, discovered life as antecedent to life. Dead matter cannot become living."

The demise of the stable two-story universe led to an evolving universe in which Earth was born as red-hot, dead matter. Presumably, all worlds were born this way. So, if life doesn't naturally emerge from inanimate matter, and if science shouldn't be invoking the power of God to explain its origin, then what explanation did Thomson propose for life arising on a sterile Earth, or on any other dead world?

Life from Beyond

Things in the universe collide. And as Thomson said, when something large enough collides forcefully enough into a life-bearing planet, bits of material with life on them are hurled into space. These fragments may eventually fall as meteorites on other planets, seeding them with life. In his 1871 address, Thomson remarked:

> *Should the time when this Earth comes into collision with another body . . . be when it is still clothed as at present with vegetation, many great and small fragments carrying seed and living plants and animals would undoubtedly be scattered through space. Hence and because* we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own *[emphasis added], we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space. If at the present instant no life existed upon this Earth, one such stone falling upon it might, by what we blindly call natural causes, lead to its becoming covered with vegetation.*

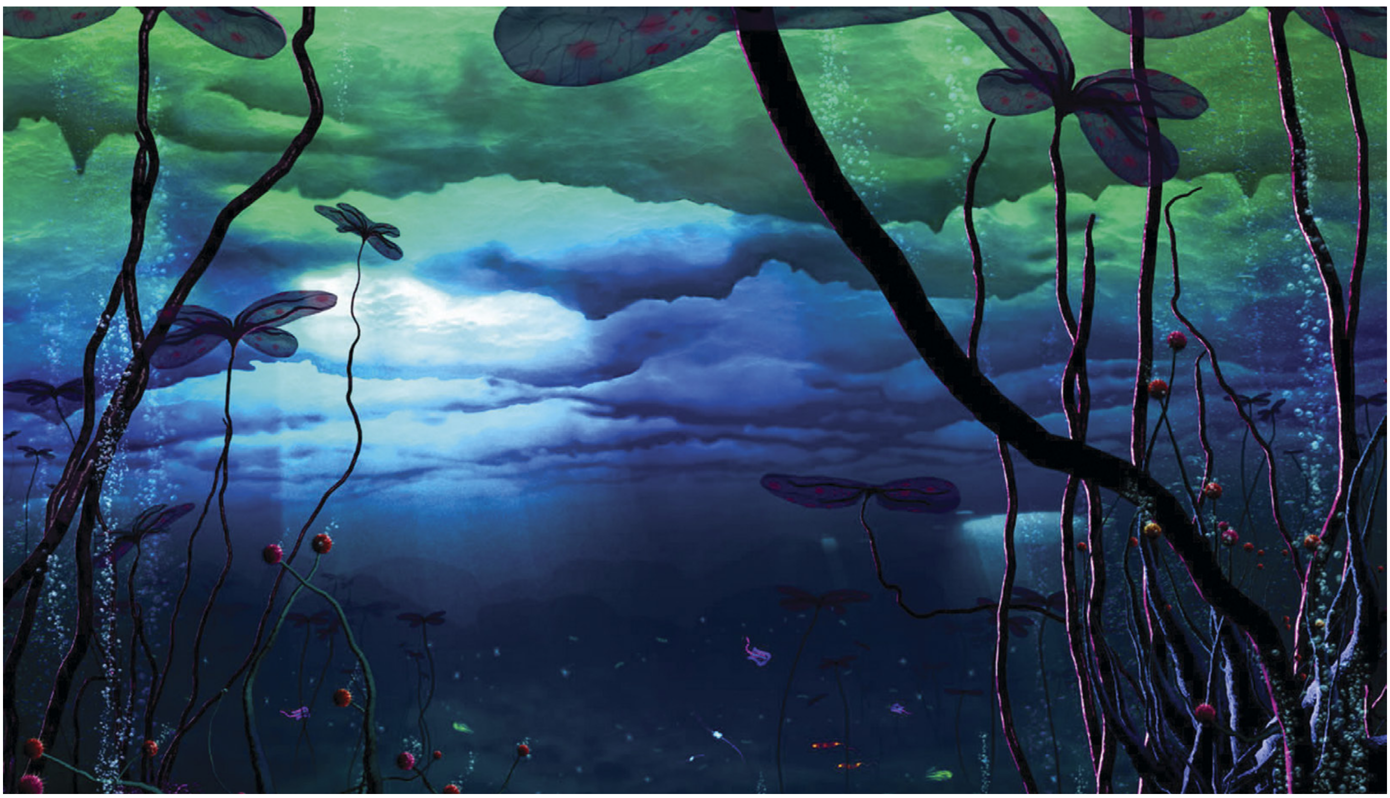


◀ **OF METEORITES AND SPACE SEEDS** William Thomson (later, Lord Kelvin) was already famous for his work on topics ranging from the physics of heat to transatlantic telegraphy when he proposed that meteorites could have carried microscopic life to a young, lifeless Earth. The theory later acquired the name *panspermia*.

He acknowledged that the idea "may seem wild and visionary," but the objections are "all answerable," and that the idea is "not unscientific." Left unsaid was the contrast of this idea with that of spontaneous generation or of invoking Divine Power.

Thomson continued:

> *From the Earth stocked with such vegetation as it could receive meteorically, to the Earth teeming with all the endless variety of plants and animals which now inhabit it, the step is prodigious; yet, according to the doctrine of continuity . . . all creatures now*



▲ **LIFE EVERYWHERE, NATURALLY** Scientists had long believed that life was a natural product of matter and could be regularly observed to arise from inanimate materials through a process called *spontaneous generation*. If this were true, then we would expect to find life anywhere it could possibly survive, as in this artist's rendition of a rich biosphere under the surface ice of the Jovian moon Europa.

KELVIN PORTRAIT: WELCOME COLLECTION GALLERY / WIKIMEDIA COMMONS / CC BY 4.0; PAINTING OF LIFE BENEATH ICE OF EUROPA: MARK GARLICK *living on earth have proceeded by orderly evolution from some such origin. Darwin concludes his great work on "The Origin of Species" with the following words:*

It is interesting to contemplate an entangled bank clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us. . . . There is grandeur in this view of life with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms, most beautiful and most wonderful; have been and are being evolved.

With the feeling expressed in these two sentences I most cordially sympathise.

In essence, Thomson's idea was that Earth was once a lifeless, red-hot globe, but when it had itself evolved to the point where it was ready to become a garden, it was seeded with some organism that had survived the rigors of being hurled from its native world and transported through space. From that space seed, life on Earth evolved into all its elaborately constructed forms, so different from each other.

The idea of space seeds may have been "wild and visionary," but it appealed to others, including Helmholtz, who had also started to advocate for it in the early 1870s. In Helmholtz's view, life was an integral part of the universe, passing endlessly from world to world. The idea may seem improbable, he wrote in a preface to a German translation he made of one of Thomson's books:

But it seems to me a perfectly correct scientific procedure, when all our efforts to produce organisms from lifeless matter fail, to ask whether life ever arose at all, whether it is not just as old as matter, and whether its germs, carried from one celestial body to another, have not developed wherever they have found favorable soil.

The idea of space seeds thus replaced the idea of spontaneous generation, but the inescapable conclusion remained the same: Life was inherent throughout the universe and always had been.

Swedish chemist and physicist Svante Arrhenius (1859–1927) held a similar view to Thomson. The 1903 Nobel laureate for chemistry wrote in his 1908 book, *Worlds in the Making*, that:

SEEDS OF LIFE Could meteorites have carried extraterrestrial life to Earth? In 1871 William Thomson proposed "space seeds" carried on meteorites as a replacement for the failing theory of spontaneous generation.

KPNO / NOIRLAB / NSF / AURA / R. SPARKS (NSF NOIRLAB)

Man used to speculate on the origin of matter, but gave that up when experience taught him that matter is indestructible and can only be transformed. For similar reasons we never inquire into the origin of the energy of motion. And we may become accustomed to the idea that life is eternal, and hence that it is useless to inquire into its origin.

It was Arrhenius who gave the space-seeds idea the catchy name *panspermia*. He also proposed a gentler means of distributing life than by violent collisions: Tiny organisms swept up by winds into the upper atmosphere of a planet could be blown out of that atmosphere by the pressure of light from the planet's sun. The light would accelerate the organisms rapidly enough to transport them across the solar system in months, and to nearby stars in less than 10,000 years. Experiments with microbes at low temperatures suggested that the cold of space would preserve them.

Arrhenius would go on to argue in 1927 that Earth was being seeded even now. He thought that *thermophilic bacteria* (those that live in very high temperatures) could only have evolved on a higher-temperature planet and probably can't sustain a population here on Earth over the long term. Therefore, he proposed that Earth must be supplied with bacteria continuously and that the most likely source was Venus. Arrhenius cited astronomical studies of the time suggesting that the planet's temperature might be around 50°C (122°F) — ideal conditions for the bacteria he was discussing. Organisms blown out of the Venusian atmosphere when the planet passed between Earth and the Sun could make it to Earth in mere days, he said.

Thus, according to Thomson, Helmholtz, and Arrhenius (and 20th-century successors, such as the British cosmologist Fred Hoyle), the panspermic universe is teeming with microorganisms that are being blown continually into space from their home planets. If the seed settles upon a suitable planet that's also lifeless, it can survive and evolve over time to create a life-filled world — an "entangled bank" of diverse creatures that can in turn seed other worlds. The result is a universe in which every planet that possibly can host life eventually will. The picture is, in some ways, not all that different from the "many worlds of life besides our own" imagined under spontaneous generation.

The Trouble with Change

Of course, one problem with this picture of a universe filled with life is that life-sustaining planets might not be so common as once thought. Venus, for example, is a furnace-like, acid-swept hellscape where even Earth's thermophilic bacteria could not survive. But a greater problem is the evolving universe itself.

According to the Big Bang theory, the universe was once very small and far, far hotter than any molten globe. In fact, it was so hot that even atoms couldn't exist. The remnant heat from that early state is still present as the cosmic microwave background radiation, which astronomers study to learn about the Big Bang. The universe has expanded from a hot, small beginning and cooled over time. It's therefore not eternal but rather has a finite age of about 14 billion years.

MARK GARLICK / SCIENCE PHOTO LIBRARY

▲ **THE END OF ETERNITY** Prior to the development of the Big Bang theory, astronomers had presumed that the universe was essentially eternal and unchanging, meaning life could have always been a part of the cosmos. But under that theory, life must have originated at some time after the "bang," forcing scientists to face the question of how, since "spontaneous generation" isn't considered credible.

This evolving Big Bang universe offers no answers to the question of life's origins. Thomson stated that Earth initially had to be lifeless because it was too hot. The universe, however, was once far, far hotter. Moreover, since the universe has a finite age, so too must life. In fact, life can't have started before the time when some part of the universe first cooled enough to allow it to exist. Yet clearly, life originated somehow — we are here, after all! And yet, we don't see life arising from inanimate matter in nature, and we have so far been unable to generate life from inanimate matter in a laboratory. Never in the history of science have we been so in the dark as we are today about the fundamental question of how life came into existence — or, perhaps, so cognizant of how in the dark we truly are. Science has revealed to us a puzzle in the form of an astonishingly vast, but apparently infecund, universe.

So, were Kant and Thomson right to assume extraterrestrial life is common? Are today's scientists correct when they make that same assumption?

■ **DENNIS DANIELSON** is a historian of ideas and professor emeritus at the University of British Columbia. **CHRISTOPHER M. GRANEY** is an astronomer and historian of science with the Vatican Observatory. This article is adapted from portions of their new book, *A Universe of Earths: Our Planet and Other Worlds, from Copernicus to NASA* (Oxford University Press), which discusses in depth the ideas presented here, and their implications.

 by Paul Sutter

Crack

BEATRIZ INGLESSIS / S&T

Recent results hint that our standard picture of dark energy might not match reality.

Billions of years ago, sound waves thundered through the cosmos. Today, their faint echoes remain — not as anything we can hear, but as a subtle imprint in the arrangements of galaxies at the very largest scales.

Maps of these imprints are now adding to growing evidence that suggests we might need to overhaul our understanding of what the universe is made of.

Our current, best model of cosmological evolution is known as *ΛCDM cosmology*. The Greek letter Λ (lambda) stands for *dark energy*, the mysterious something that is currently accelerating the expansion of the universe — and also makes up the vast majority of all the universe's energy content. The CDM stands for *cold dark matter*, the (also) mysterious substance that is so far invisible to direct observations but makes up most of the mass of every galaxy.

"In school and chemistry, we learn about atoms that are made of protons and neutrons and electrons," says Jessica Muir (University of Cincinnati), "but we find that about 95% of the universe is made up of stuff that we don't really know how to describe on a fundamental level."

Despite these vast unknowns, the ΛCDM model is incredibly successful. It's able to explain a wide variety of observations, from the earliest moments of the universe to the grand structures that twist and weave through today's cosmic expanses.

It's also almost certainly wrong.

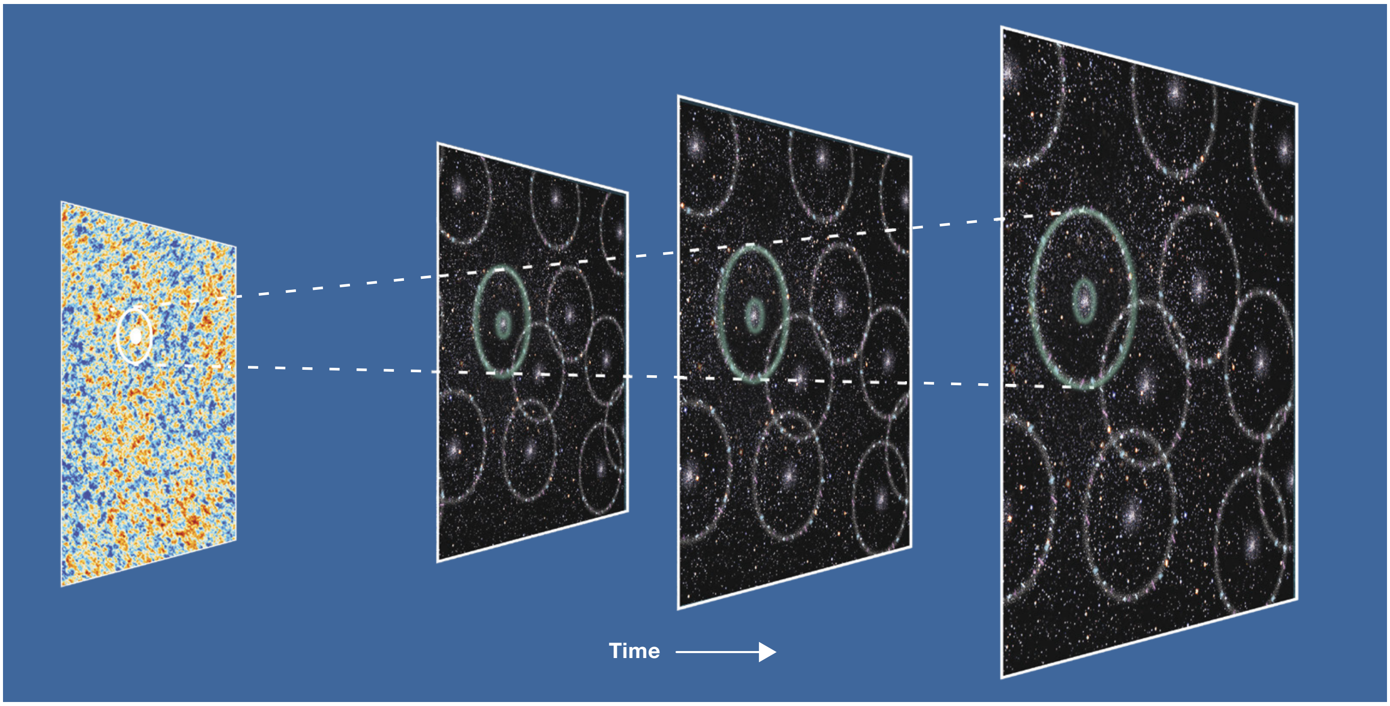
Several years ago, a team of astronomers hunting for distant supernovae (led primarily by Adam Riess of Johns Hopkins University, one of the Nobel prize–winning discoverers of dark energy) found that their measurements of the universe's present-day expansion rate differed from expectations based on measurements of the cosmic microwave background, the relic glow that lingers from the Big Bang era. This *Hubble tension* — so-named because the current expansion rate is known as the Hubble constant — has persisted despite years of efforts to try to resolve it (*S&T:* Mar. 2022, p. 14).

But that's not all.

In 2024 the James Webb Space Telescope, designed explicitly to find some of the earliest stars and galaxies to arrive on the cosmic scene, found that the young universe was full of mature-looking, bright, element-rich galaxies. Like walking into a kindergarten classroom and finding a room full of teenagers crammed into tiny desks, the maturity of the galaxies is potentially at odds with our understanding of structure growth within the ΛCDM framework.

Even before that, the Planck satellite, a European Space Agency mission that precisely mapped the cosmic microwave background, had turned up a different discrepancy. Among its results, Planck measured a parameter called *sigma-8*, which tells cosmologists how clumpy matter is in the universe. The team's measurement suggested the universe should be far clumpier than it appears to be (*S&T:* May 2014, p. 10).

s in Cosmology



▲ **BARYONIC ACOUSTIC OSCILLATIONS** Sound waves rippled through the primordial universe's plasma, and when the universe cooled down and particles and light separated, these waves froze in place as slight density enhancements (left). Galaxies tend to form in clusters along the frozen ripples. As the universe has expanded, the size of these waves, called *baryonic acoustic oscillations*, has increased. Astronomers use their apparent size in a given epoch to measure cosmic expansion.

"[ΛCDM has] done really well for us, and people are reluctant to give it up. But there is something a little bit funny happening in the data," says cosmologist William Percival (University of Waterloo, Canada).

Feeling Tense

And now new measurements of subtle imprints left over from the early universe may be revealing yet another problem with ΛCDM. Those imprints go by the cumbersome name of *baryon acoustic oscillations*, or BAOs. The BAOs were actually generated long ago, when the universe was only a few hundred thousand years old. At that time, the cosmos was about a million times smaller in volume and thousands of times hotter than it is today. It was so small, so hot, and so dense that it was a *plasma*, a state of matter shared by lightning bolts and the Sun.

In this plasma, gravity and radiation squared off, as gravity tried to collapse pockets of plasma while radiation tried to blow them apart. The resulting cosmos-spanning skirmishes sent massive pressure waves rippling through the young universe. But when the universe reached an age of roughly 380,000 years after the Big Bang, the plasma cooled enough (to a temperature of around 3000 kelvin, or some 5000°F) that it neutralized, with electrons joining with nuclei to form the first complete atoms. At that moment, the sound waves froze in place as shells of slightly-higher-than-average density pockmarking the infant universe.

As the plasma became neutral, an enormous amount of light broke free to stream through the universe. In the intervening billions of years, this light has cooled and redshifted to a temperature just a handful of degrees above absolute zero. Its wavelength has therefore stretched beyond the visible range, all the way down to the microwave band — this is the cosmic microwave background, which gives cosmologists an exquisite portrait of the universe at a young age.

Meanwhile, those shells of higher density made their mark. They served as sources of slightly more gravitational attraction, which eventually (billions of years later) manifested as shells of more galaxies than the cosmic average. As the cosmos has expanded, so too have the shells.

We can use the shells to calculate the cosmic expansion rate, because we know the size they began with: We see the shells' imprint in the cosmic microwave background itself, which reveals their size at the time when the universe was less than half a million years old. This initial size is like a circle drawn on a small balloon. As you inflate the balloon, the circle will grow bigger along with it. Your friend can then measure the size of the circle at different times to know the expansion rate of your balloon.

Today, the BAO feature is roughly 1 billion light-years across, rivaling the largest structures of the cosmic web. And cosmologists have been able to measure the feature at several different redshifts as well, going back deep into cosmic history. These observations give astronomers precise measurements of the cosmic expansion rate over time. The measurements in turn tell us the amount of dark energy that has pervaded the universe for the past several billion years.

And there are hints that the real universe doesn't match ΛCDM predictions.

The Old Order

This is not the first time that cosmology has faced the prospect of a revolution. The ΛCDM model assumes that dark energy's density is a constant — it's always been the same throughout cosmic history. This idea goes all the way back to Einstein himself. When he first developed his general theory of relativity in 1915, he found that it naturally predicted a dynamic, changing universe. But this went against the prevailing view of a static, eternal cosmos. So he added a fix, a *cosmological constant*, that kept the universe's expansion locked by creating an antigravity effect that would fight against the natural tendency of matter to clump together. About a decade later, Edwin Hubble confirmed the cosmos is expanding, and Einstein scrubbed away the cosmological constant.

In the 1990s, our understanding of the universe was again at a crossroads. Some observations, particularly of galaxy clusters, revealed that only a relatively paltry amount of matter threaded its way through the cosmos. But observations of the cosmic microwave background suggested there should be much more stuff out there.

Astronomers devised a clever trick to use the universe's expansion to measure the amount of matter contained in the cosmos. All the matter in the universe is gravitationally attractive, and that attraction should be slowing down the expansion rate over time, they reasoned. By measuring the deceleration rate, they could finally get a firm handle on the amount of stuff in the cosmos and resolve the nagging tension.

But what they found was the complete opposite of what they expected: The expansion was accelerating. This was the discovery of dark energy (*S&T:* Feb. 2024, p. 26).

In the span of mere months, the old cosmological model was thrown out. In its place, scientists built a theory that incorporated Einstein's antigravity effect, Λ, to explain why matter could no longer put the brakes on cosmic expansion.

Because for a while, it did. Observations tell us that, for the first several billion years of cosmic history, the universe's expansion did slow down as matter pulled on itself. The average distance between galaxies was still growing, just at a slowing pace. But then around 5 billion years ago, as the matter thinned out due to cosmic expansion, dark energy took over.

Why? What exactly is dark energy? Why is it accelerating the universe now, and how?

"The reason we do physics is to turn magic into a set of boring equations and understanding," says Percival, "and at the moment, dark energy is in the magic realm."

Bolt from the Blue

Soon after the discovery of dark energy, astronomers and cosmologists designed massive surveys of galaxies to explore cosmic expansion's evolution. One of them, the Dark Energy Survey (DES), ran from 2013 to 2019 at the Cerro Tololo Inter-American Observatory in Chile. Even though the survey is completed, the analysis continues.

More recently, the Dark Energy Spectroscopic Instrument, or DESI, began operations in 2021. Sitting at the top of Kitt Peak outside of Tucson, Arizona, DESI consists of roughly 10 tons of instrumentation, including a 4-meter primary mirror and robotically controlled fiber-optic cables that take detailed, simultaneous spectra of 5,000 individual galaxies in a single image.

DESI continues to operate today, but the survey's data sets are massive — planners are aiming to collect spectra for a total of 63 million galaxies and quasars. Astronomers need years to analyze the observations.

"Being involved in an experiment that is doing something a factor of 20 times better than has previously been done is amazing," says Percival, who is also the co-spokesperson for the DESI collaboration. "There is a huge discovery space."

The thinking behind these surveys, and many others like them, is that the 3D arrangement of galaxies at incredibly large scales (as in, so large that entire galaxies are merely tiny dots of light) and across cosmic time is sensitive to the fundamental ingredients that make up the universe.

At those large scales, galaxies arrange themselves to form what's known as the *cosmic web*, which is the largest pattern found in nature. The web's nodes are dense clusters home to thousands of galaxies. Connecting those clusters are the filaments, which stretch for millions of light-years and are the cosmic superhighways that galaxies travel along on their way to the clusters. Spanning huge swaths are the walls, tremendous sheets of galaxy after galaxy. Between all of them sit the cosmic voids, the vast expanses of nothingness that dominate the volume of the universe (*S&T:* Oct. 2018, p. 12).

"The reason we do physics is to turn magic into a set of boring equations and understanding . . . at the moment, dark energy is in the magic realm."

And right there, embedded in all of this grand cosmic structure, is the BAO signal.

In March of 2025, the DESI team released the results of their analysis on the first three years of survey data, covering hundreds of billions of light-years and including more than 14 million galaxies. At the same time, DES announced its own analysis of some 16 million galaxies. The teams combined many probes of the cosmic web to make the most precise measurement ever of BAOs.

Both the DESI and DES results by themselves are compatible with predictions from the ΛCDM model and its assumption that dark energy is constant: Dark energy has had the exact same density all across the universe and for its entire existence; it's only matter's slow dilution that has enabled dark energy to now accelerate things.

But when the DES and DESI results are combined with results from other types of observations, especially measurements of the cosmic microwave background, trouble appears: Dark energy seems to be weakening with time. It could be as much as 30% weaker today than when it was at its peak 5 billion years ago. But, like easing your foot off the gas pedal, just because dark energy is winding down doesn't mean that the universe has stopped accelerating.

The result also tangles the relationship between dark matter and dark energy. With a pure cosmological constant, dark energy only switched on once dark matter diluted enough, which happened a few billion years ago. In an evolving-dark-energy universe, however, the switch-over might have occurred a little earlier.

The result is far from ironclad. Scientists quantify the significance of a finding through a statistical quantity called *sigma*, which measures the chance that a result is a fluke. The more sigmas, the more likely it is that the result is genuine. Typically, a minimum of three sigmas mark a result as publishable in cosmology, but five sigmas are required to say the result is the real deal. Right now, the results point toward a universe with evolving dark energy with around three sigmas of confidence. "Interesting, but let's wait and see," says Muir, who is a member of the DES collaboration.

Nevertheless, the cosmological community is abuzz with activity. "This is the first time we're seeing different observations pulling away from the simplest description of dark energy," she says.

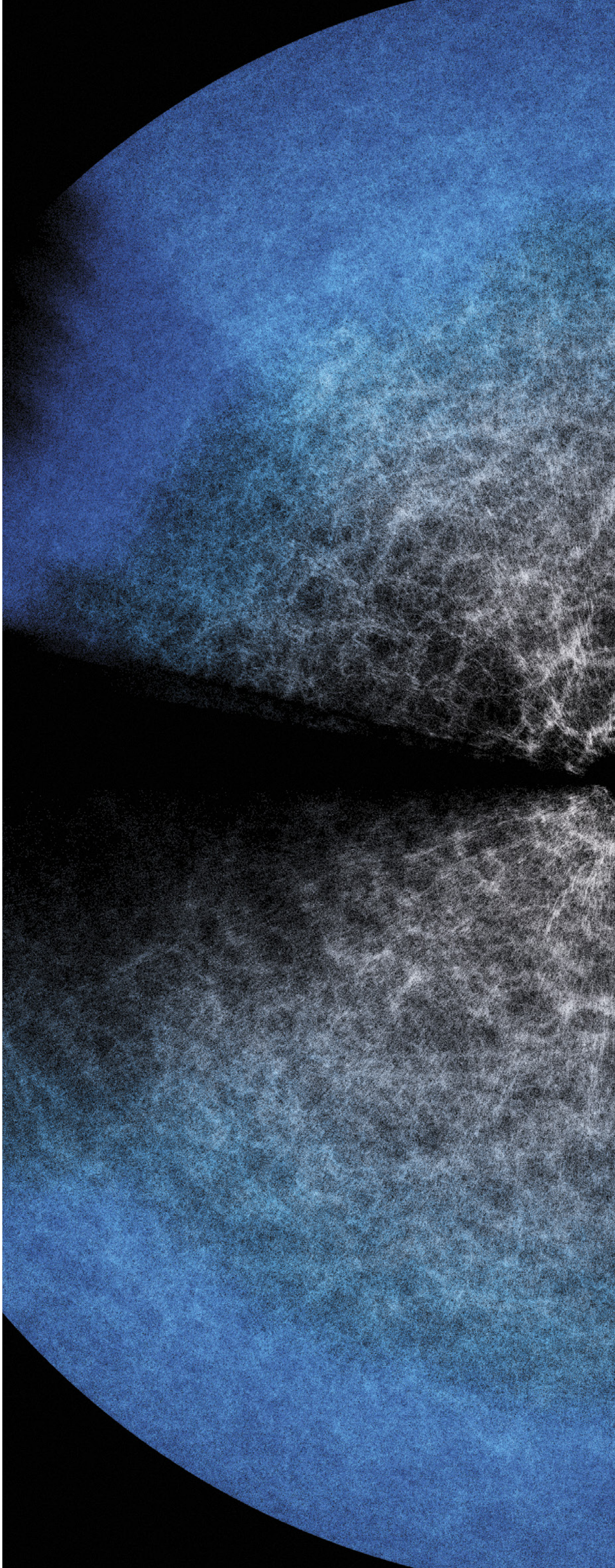
Dark Energy's Designs

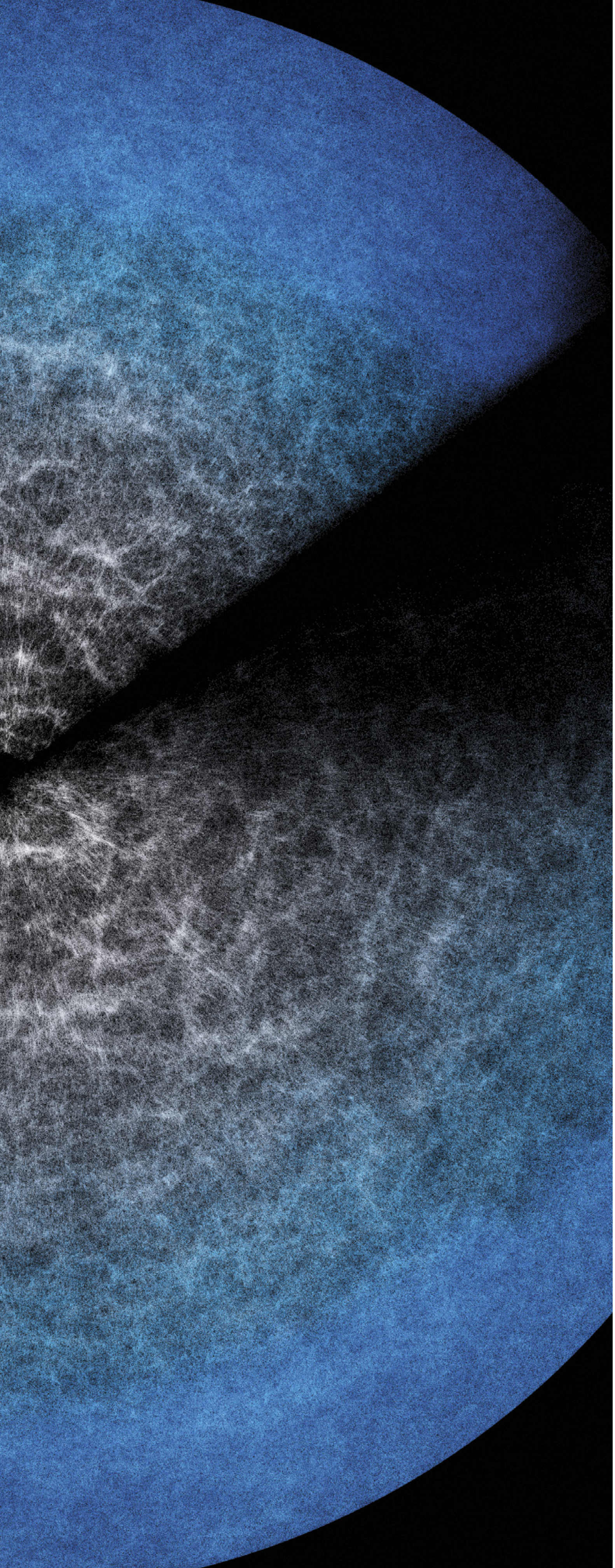
It's obvious by now that the universe is trying to tell us something, but we're not exactly sure what. While some have dubbed this a "crisis in cosmology," for Percival that's not the case at all. "Crisis isn't the right word," he says. "I feel busy and I feel excited."

With the hints that dark energy might be changing in time, taken together with the other tensions and shortcomings of the ΛCDM model, theorists have seized the opportunity to propose a wild variety of alternatives.

One promising idea is that dark energy is powered by some new ingredient in the cosmos, a *quantum field*. Quantum fields are everywhere in physics — and everywhere in the universe. In the view of modern physics, what we call particles are really local vibrations of a larger corresponding field. There's a field for the photons, another for the electrons, and so on. And there might be more that stay largely hidden in the universe.

One of the names for the hypothetical quantum field behind dark energy is *quintessence*, named for the "fifth element" from medieval alchemy. This field might be evolving into some future end state, like a ball slowly rolling down a hill. This means that it might also have been stronger in the past, which has motivated searches for imprints left by





early dark energy in the cosmic microwave background. Or, in some models, dark energy's effect bounces around, oscillating in strength as the universe ages.

Still other models posit a connection between dark matter and dark energy. Perhaps they are tethered by some new, fifth force of nature known only to them. There is no direct evidence for this fifth force, but there is a strange coincidence: Dark matter and dark energy make up roughly the same amount of stuff in the universe, at least from a cosmologist's point of view — dark energy makes up 70% and dark matter 25%, not even a factor of three different. This similarity is cause for concern among cosmologists. It makes researchers wonder if maybe the evolution of dark matter and dark energy are tied together, keeping both of their densities in check as the cosmos ages.

Some researchers have even suggested that massive stars somehow create dark energy when they collapse to become black holes, and that black holes are actually pockets of dark energy. The amount of dark energy would therefore be tied to the rate of star formation, which peaked across the universe roughly 10 billion years ago.

Dark energy may also vary from place to place, with clusters of strong dark energy repelling matter like antigravity machines, disturbing how massive objects like clusters of galaxies and voids behave.

Or maybe something stranger is afoot, like cracks in our understanding of gravity itself.

Lights Out?

The current evolution of the entire universe is largely driven by the accelerating expansion of dark energy. Because of this, the cosmic web is slowly unraveling, the clusters pulling apart and the walls thinning out. Right now, the Milky Way Galaxy is headed toward a giant cluster called the Great Attractor. We will never reach it: In a few billion years, dark energy will start to repel us away from it.

In the far, far future, accelerated expansion will go out of control, with almost all galaxies ripped away from all others, leaving each one in an isolated cosmos to call its own. Despite the ever-greater size of the universe, our view of it will shrink. In time, we won't be able to see any other galaxies, or even the light from the cosmic microwave background. Our observable universe will simply be our galaxy's stars and the endless void surrounding it.

That is, if dark energy's density is constant. But if it instead changes over time, it might do something else. Perhaps it will wind down and fade away. Perhaps it will decay and transform into something else. Perhaps . . . well, who knows.

There is no universally accepted explanation, either for the origins of dark energy in the first place or for the possible

◀ **COSMIC WEB** Comprising millions of sources, this visualization maps the first three years or so of DESI's data. Bluer points indicate more distant objects, with the farthest having a redshift of 3.5 (seen as they were more than 11 billion years ago). The two fans are DESI's view above and below the Milky Way's plane.

DESI COLLABORATION / DOE / KPNO / NOIRLAB / NSF / AURA / R. PROCTOR tensions in the data. At this stage, even with massive galaxy surveys at our disposal, the data are just too shy. There are hints everywhere that ΛCDM may not survive another decade of scrutiny, but not enough to dethrone it quite yet.

For cosmologists, this isn't a dour pronouncement of the death of a well-loved theory. It's a joyful expression of the wonders of science. There's a mystery here. The ΛCDM model is simple and powerful, but it seems to not be good enough. So there's an opportunity to learn from the ultimate teacher: nature itself.

"It's been fun to see papers coming out and how the field is digging into things," says Muir. "There's a lot to learn."

"It's more interesting than working in a field where there aren't tensions between data sets, because we have something to aim the next-generation experiments at, something to try and understand, something to try to actually sit down and work on as a way to try to figure out what's going on," says Percival.

Theorists continue to spin new ideas. Observers design crafty new experiments. And astronomers turn their telescopes to the heavens, eagerly anticipating a new revolution that will rewrite the story of the cosmos again.

PAUL M. SUTTER is a cosmologist at Johns Hopkins University and author of *Your Place in the Universe: Understanding Our Big, Messy Existence*. He's excited for what the future will bring.

BEATRIZ INGLESSIS / S&T, SOURCE: ESA (ACKNOWLEDGEMENT: WORK PERFORMED BY ATG UNDER CONTRACT TO ESA) / CC BY-SA 3.0 IGO

SKY AT A GLANCE
March 2026

2 **MORNING:** Face west to see the waxing gibbous Moon leading Leo's brightest light Regulus by less than 2° as they sink toward the horizon before sunup. Turn to page 46 for more on this and other events listed here.

3 **FULL MOON (7:38 A.M. EST):** A total lunar eclipse is visible across the Americas, the Pacific Ocean, Asia, Oceania, and much of Russia. See page 48 for details.

6 **MORNING:** Look toward the southwest to catch sight of the waning gibbous Moon in Virgo gleaming about 3½° lower right of Spica.

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

10 **DAWN:** The Moon, one day shy of last quarter, is less than 1½° lower right of Antares, the red supergiant in Scorpius. Early risers can enjoy this view in the south.

13 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 9:07 p.m. PDT (see page 50).

16 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 8:57 p.m. EDT.

20 **SPRING BEGINS IN THE NORTHERN HEMISPHERE** at the equinox, 10:46 a.m. EDT (7:46 a.m. PDT).

20 **DUSK:** A splendid scene low in the west greets viewers: Brilliant Venus hangs just above the western horizon with the razor-thin crescent Moon about 8° upper right.

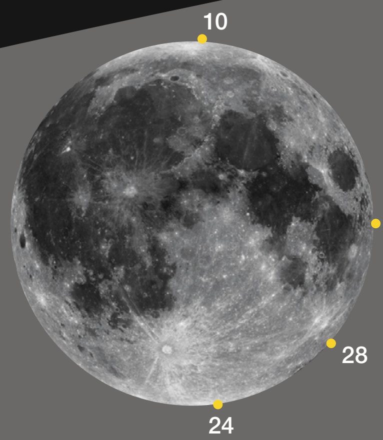
22 **EVENING:** The waxing lunar crescent sits some 5½° lower right of the Pleiades. The gap between Moon and cluster decreases as they set in the west-northwest during the course of the evening.

25 **EVENING:** Look west to see the first-quarter Moon around 6½° lower right of Jupiter. Gemini's twin lights, Castor and Pollux, sparkle above the duo.

29 **DUSK:** Shortly after sunset, face east-southeast to see the Moon, two days shy of full, trailing Regulus by 3° as they climb higher in a darkening sky.
—DIANA HANNIKAINEN

▲ The total lunar eclipse of May 26, 2021, as seen from Penticton, British Columbia.
GARY SERONIK

Lunar Almanac
Northern Hemisphere Sky Chart



MOON PHASES

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

FULL MOON
March 3
11:38 UT

LAST QUARTER
March 11
09:39 UT

NEW MOON
March 19
01:23 UT

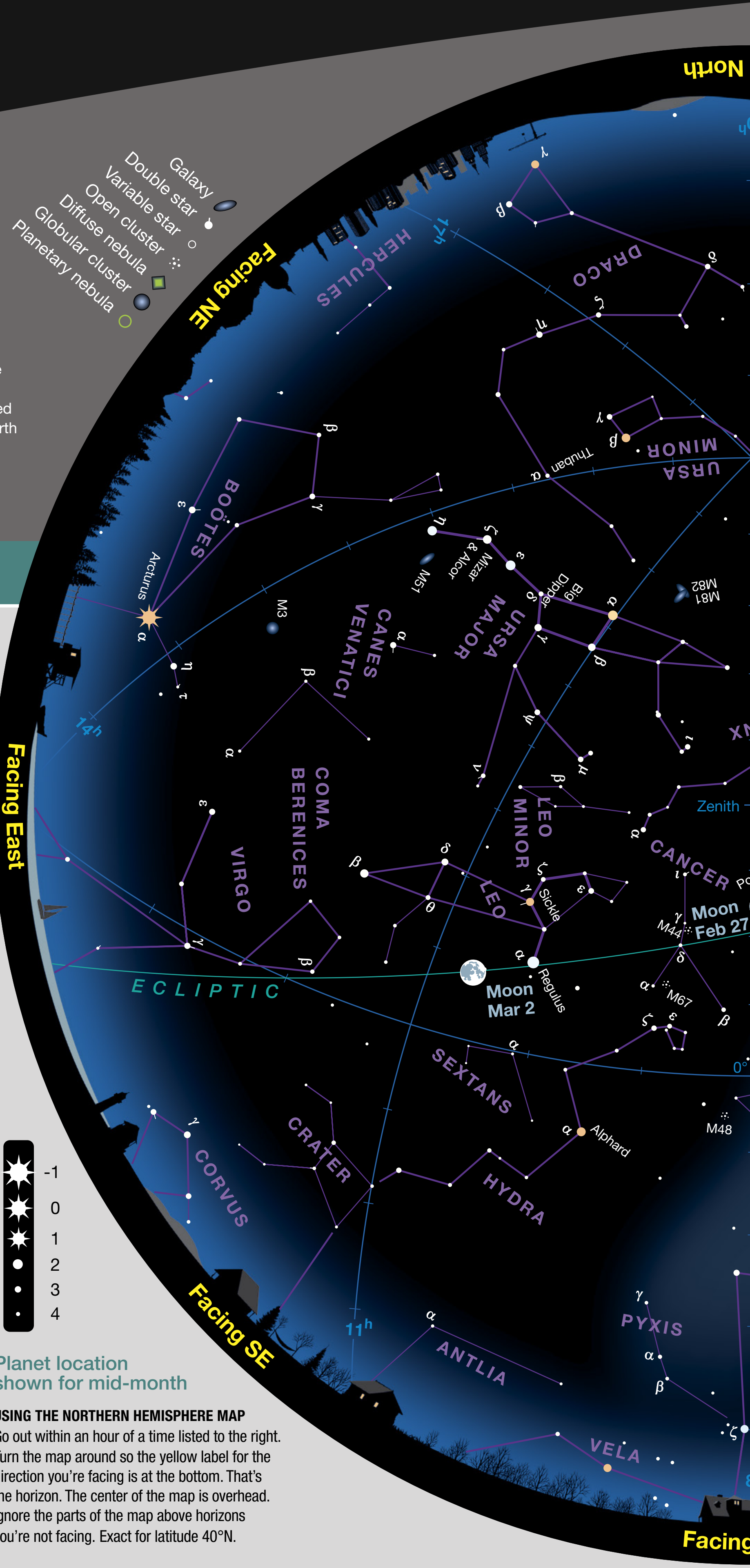
FIRST QUARTER
March 25
19:18 UT

DISTANCES

Apogee	March 10, 14^h UT
404,384 km	Diameter 29′ 33″
Perigee	March 22, 12^h UT
366,857 km	Diameter 32′ 34″

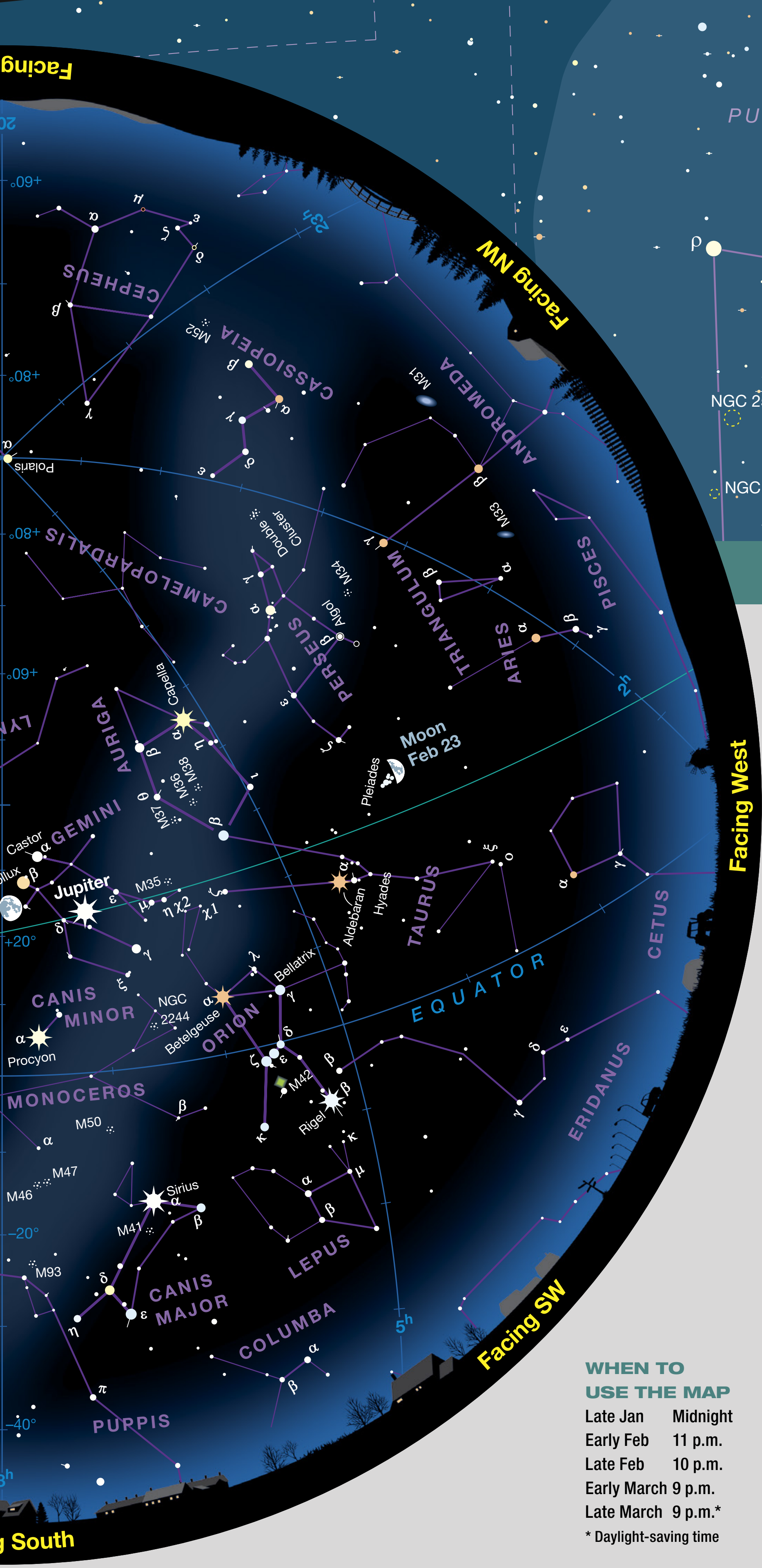
FAVORABLE LIBRATIONS

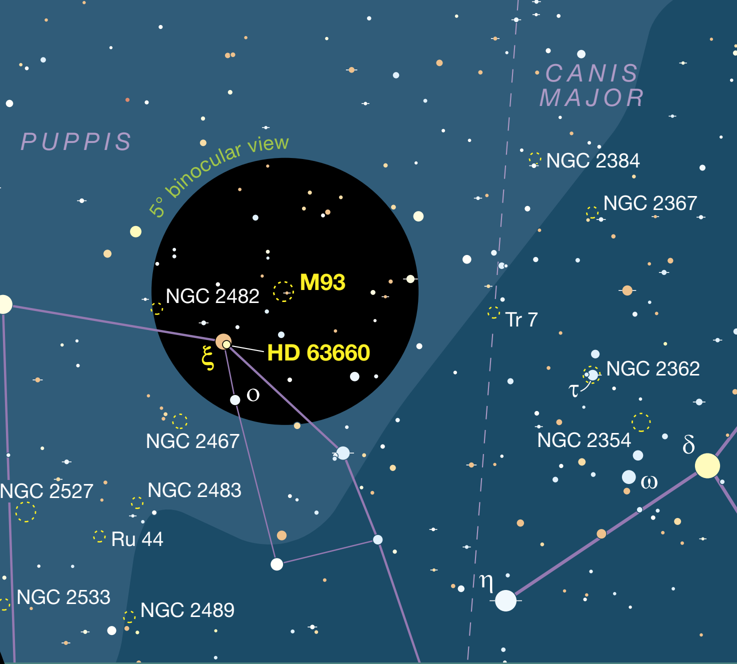
- Mare Smythii — March 3
- Goldschmidt Crater — March 10
- Boussingault Crater — March 24
- Mare Australe — March 28



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

A Double and a Cluster in Puppis

I sometimes claim to champion underdogs in this column, but as often as not, my subjects are objects that even I've overlooked. For example: **M93**, an open cluster in Puppis, the Stern of the cosmic ship Argo Navis. I confess that I've passed by this cluster while rambling among more famous sights. That's a shame, because M93 is a truly rewarding subject for binoculars.

Let's begin with figuring out how to get there. Start at **Xi (ξ) Puppis**, itself a beautiful, 3rd-magnitude yellow supergiant. Before proceeding, let's pause here for a moment to enjoy the wide binocular double formed by Xi and neighboring 5th-magnitude star **HD 63660**, which lies just southwest of Xi. Our main target, M93, is about 1½° northwest of Xi.

If you're under really good skies, see if you can spot M93 without your binoculars — at magnitude 6.2, the cluster is at the threshold of naked-eye visibility. The great deep-sky observer Walter Scott Houston, who wrote for *Sky & Telescope* for many years, reported seeing it without optical aid from his native New England. Now let's try the binocular view, and what you see will at least partly depend on magnification. With 10× binos I start to detect an asymmetry that escapes me with a 7× pair. At 15×, the cluster has a distinct cat's-eye shape, and under clear desert skies, swarms of dimmer stars flash in and out of view when I use averted vision.

To summarize, M93 has interesting neighbors, different characteristics at varying magnifications, and is sometimes naked-eye visible. Mea culpa. This cluster deserves more time in the spotlight.

■ **MATT WEDEL** sometimes feels a little guilty when he thinks about all the other celestial wonders that he hasn't given sufficient attention to.

WHEN TO USE THE MAP

Late Jan	Midnight
Early Feb	11 p.m.
Late Feb	10 p.m.
Early March	9 p.m.
Late March	9 p.m.*

* Daylight-saving time

MARCH 2026 OBSERVING

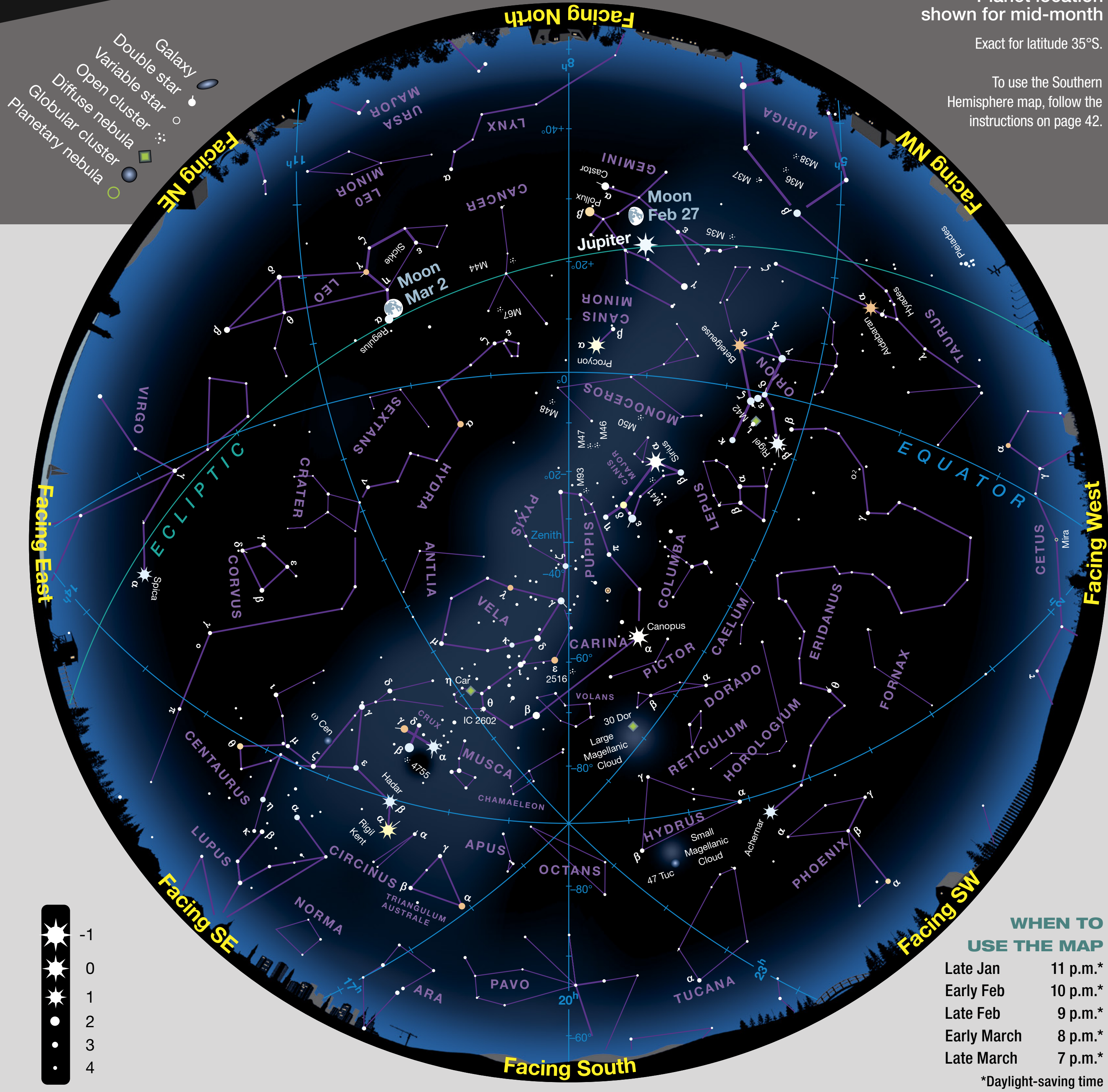
Southern Hemisphere Sky Chart

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

*Daylight-saving time

COLUMBA is one of nine constellations named after mythological or real birds, in this case the Dove. The faint star pattern was first set out in the 1590s by Petrus Plancius (*S&T:* Feb. 2023, p. 24), who named it Columba Noachi, referring to the dove sent forth by Noah to scout for dry land in the flood story from the Old Testament. Some of its stars also represent the olive branch brought back by the dove.

Columba's brightest light is 2.7-magnitude Alpha (α), also known as Phact, a name derived from an Arabic word meaning "ring dove." At a declination of roughly –34°, the star is easily visible for many observers in the Northern Hemisphere. Slightly fainter is Beta (β) at magnitude 3.1. On the chart above, Alpha is the larger (brighter) dot, while Beta is the one slightly lower left of Alpha. ■

A Celestial Rhinoceros

Monoceros may not be the unicorn found in legend and children's stories.

▲ Instead of a magical unicorn, see if you can imagine the one-horned armored Indian rhinoceros among the stars of the constellation Monoceros.

As shown on this month's Northern Hemisphere Star Chart on pages 42–43, Procyon, Alpha (α) Canis Minoris in the Lesser Dog, shines brightly in the sky above the southern horizon. It forms the eastern point of a familiar pattern known as the Winter Triangle — with Betelgeuse, the Alpha star of Orion, the Hunter, to the west, and Sirius, Alpha Canis Majoris in the Greater Dog, to the south. Look in the space between these three for the inconspicuous constellation Monoceros, the Unicorn. You'll need to be under a dark sky, as its brightest members shine only around 4th magnitude. The elusiveness of the constellation mirrors the elusiveness of the animal's namesake.

Dutch cartographer Petrus Plancius (1552–1622), a Flemish monk turned Calvinist theologian, was the first to definitively chart the constellation as Monoceros, labelling it *Monoceros Unicornu* on his 1612 celestial globe — among the first of its kind in the Netherlands (*S&T:* Feb. 2023, p. 24). Monoceros was one of several constellations Plancius introduced based on Judeo-Christian biblical stories. Only two survive today: Columba, the Dove, depicting the bird that Noah sent forth from the ark in search of dry land; and Monoceros, which embodies the unicorn mentioned nine times in the King James Version of the Bible, first published the year before Plancius produced his celestial globe.

The biblical unicorn is not the cute, fairy-tale animal we think of today, but a powerful beast that served, in part, as a metaphor for God's might: "[God] hath as it were, the strength of an unicorn" (Numbers 23:22). "Unicorn" was how the King James Version of the Bible translated the original Hebrew word *re'em*, which basically means "beast with a horn." In the 1865 edition of *An American Dictionary of the English Language*, Noah Webster says, "The unicorn of the Bible is commonly thought to have been the rhinoceros, but more probably it was some species of wild ox." Debate continues to this day, though I'd vote for the omnipotent rhinoceros.

The origin of the unicorn can be traced to at least 400 BC — to the Greek physician and historian Ctesias of Cnidus. In his book *Indica*, which portrays the customs and wildlife of India, he writes, "In India there are wild asses as large as horses, or even larger. Their body is white, their head dark red, their eyes bluish, and they have a horn in their forehead about [18 inches] in length. The lower part of the horn, for about two palms distance from the forehead, is quite white, the middle is black, the upper part, which terminates in a point, is a very flaming red."

In fact, Ctesias never traveled to India. The animal depicted above came from stories related to him by travelers, merchants, and others who actually did journey to this land of mystery and intrigue. According to the online World History Encyclopedia, the animal Ctesias mentions is "most likely a fanciful rendition of the Indian rhinoceros," the horn of which was sometimes "made into drinking vessels decorated with three bands of color."

In Book 8 of *Natural History*, Pliny the Elder describes an animal he calls "monoceros" — and it's almost a dead ringer for the one-horned Indian rhinoceros (*Rhinoceros unicornis*): "a very fierce animal called the monoceros, which has the head of the stag, the feet of the elephant, and the tail of the boar, while the rest of the body is like that of the horse; it makes a deep lowing noise, and has a single black horn, which projects from the middle of its forehead."

So when we look up at the dim splash of stars that comprise Monoceros, see if instead of a unicorn, you can envision the Indian rhinoceros — the largest of the three rhinos in Asia. Admittedly, our cute, fairy-tale unicorns are so much more pleasing to imagine, as they symbolize the wonder and mystery of all that is natural — including starlight.

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

BEATRIZ INGLESSIS / *S&T*, BACKGROUND IMAGE: AKIRA FUJII

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

The Moon Visits a Stellar Bunch

Skywatchers can enjoy a full slate of lunar conjunctions this month.

MONDAY, MARCH 2

The ongoing series of encounters between the **Moon** and **Regulus** has two installments this month — one this morning, the other on the 29th. Tonight's is the closer (and therefore, better) of the two, but even still it isn't quite as exciting as the conjunction that occurred in February.

As the nearly full Moon and Regulus sink toward the west-northwestern horizon at dawn today, the gap between the duo is shrinking. That means the farther west you are, the closer they'll appear. For observers on the West Coast, just ¼° separates the 1.4-magnitude star from the north limb of the Moon. Quite a bit farther west, in Hawai'i, Japan, Korea, and parts of western Asia, the lunar disk actually occults Regulus. And on the evening of the 29th, the Moon and Regulus are roughly 3° apart when darkness falls. As noted in the February issue (page 48), the current series of meet-and-greets started last July and wraps up at the end of this year.

SATURDAY, MARCH 7

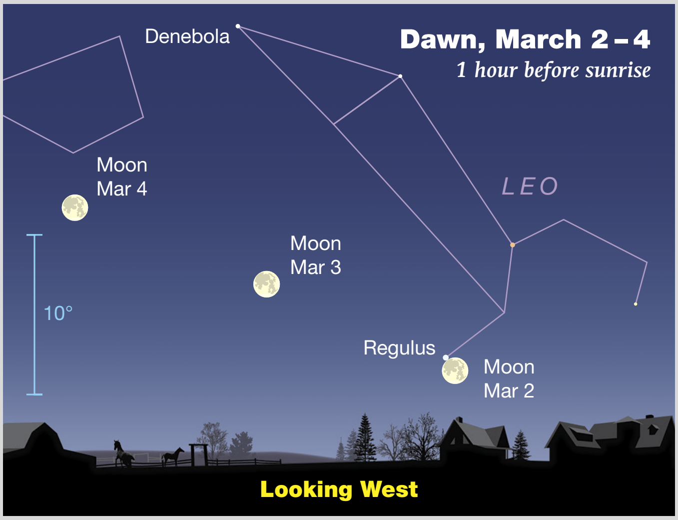
The parade of evening planets is about to gain one participant at the same time it loses another as the two worlds involved in this exchange march past each other. **Venus** is the gain and **Saturn** is the loss. At magnitude –3.9, Venus is the undisputed Evening Star and gleams more than 90 times brighter than its neighbor, the 1st-magnitude Ringed Planet. Tonight's close pass is best enjoyed with an optical assist, either with binoculars or a small telescope. Look for Saturn a touch more than 1° upper left of Venus at dusk.

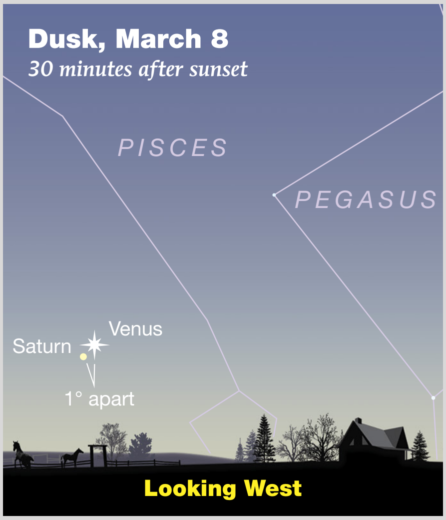
If the weather isn't favorable today, you can try again the following evening. At dusk on the 8th they'll be nearly as close, but instead Saturn is now positioned lower left of Venus. After the encounter, the fainter planet will be very difficult to spot with the unaided eye as it loses its battle against encroaching twilight. You'll have to wait until the end of April to catch Saturn again, when it reemerges from the Sun's glare at dawn. As for Venus, it's at the start of an evening apparition that lasts well into autumn.

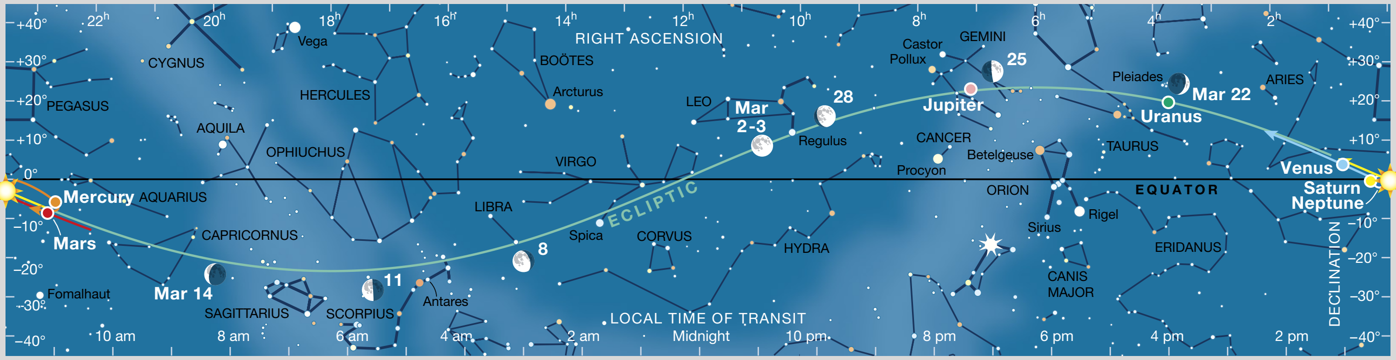
TUESDAY, MARCH 10

This morning the **Moon** checks in with **Antares**, the red-hued heart of Scorpius, the Scorpion. The lunar disk is about 60% illuminated and just one day shy of last-quarter phase as it hangs roughly 1¼° below the +0.9-magnitude star. I always enjoy seeing the silvery gray Moon next to the fiery glint of Antares. To enhance the beauty of the scene, follow the rising pair into brightening twilight, when they'll be at their closest and gleam from a dark, blue sky. Colors in astronomical objects tend to be more suggestive than vivid, but the contrasting hues of Antares, the Moon, and the dusk sky really are striking. And it certainly helps that Antares is so bright. Indeed, of all the stars the Moon encounters as it makes its way along the ecliptic, only Aldebaran in Taurus shines marginally brighter.

▶ 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.





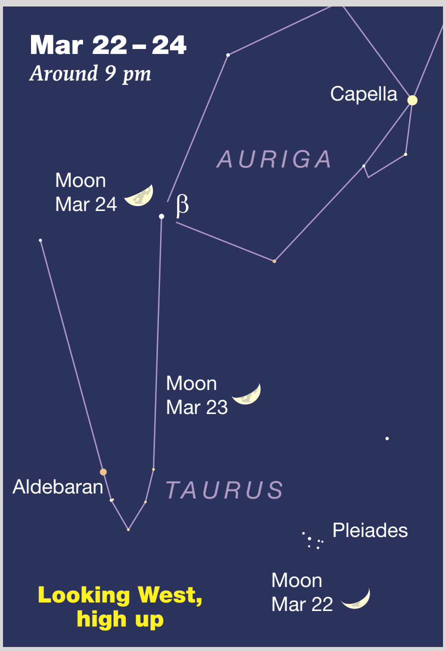


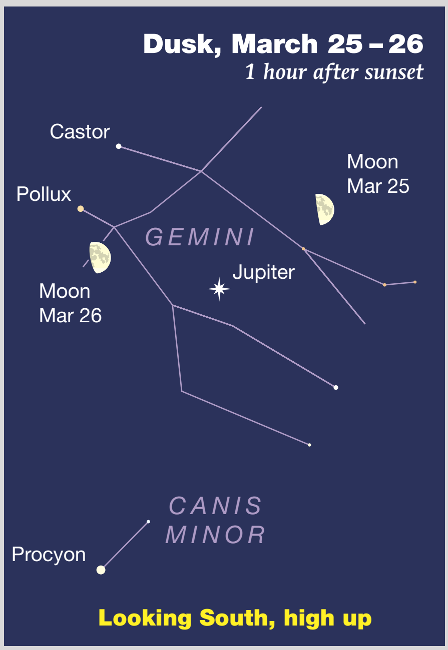
▲ The Sun and planets are positioned for mid-March; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit"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

TUESDAY, MARCH 24

In addition to pairing up with some notable stellar luminaries this month, the **Moon** also closes in on a trio of lesser lights. The first such encounter was on the 13th, when it visited 3.3-magnitude Tau (τ) Sagittarii, as noted on page 50. The second one took place on the 16th when a thin, waxing lunar crescent rose along with 2.8-magnitude Delta (δ) Capricorni. This evening, however, it's **Beta (β) Tauri**'s turn to greet the Moon. Arguably, Beta doesn't get the attention it deserves from skywatchers — and I'm as guilty of overlooking it as anyone. We always take note when the Moon is near Regulus (as we did on the 2nd), yet Leo's leading light is only 0.3 magnitude brighter than 1.7-magnitude Beta Tauri. Maybe it's time to reassess!

As twilight deepens tonight, Beta sits less than 1° right of the 41%-illuminated lunar crescent. Binoculars will definitely enhance the view. But, as is always the case, just how narrow the gap between the two objects will be depends on where you are — and this time, the farther south and east you're located, the better. For observers in New York City, for example, the gap is closer to ½°. And those watching the sky from the eastern Caribbean islands and much of the northern portion of South America are in position to observe the advancing dark limb of the Moon cover the star!





FRIDAY, MARCH 27

This morning **Mercury** achieves its highest altitude for its current dawn apparition. Normally that'd be something fans of the innermost planet would rise early to see. But this time, you might as well sleep in. Mercury has a trio of morning showings in 2026, and this one is by far the worst. The fact that its greatest elongation from the Sun isn't until April 3rd is a clue that something's amiss — and that "something" is the very shallow angle the ecliptic makes to the eastern horizon at this time of year.

Mercury barely rises before daylight, and over the coming weeks it slowly drifts northward before slinking toward its mid-May solar conjunction. But if you're up for a challenge, this is the morning to give the planet a go. You're going to need binoculars (or a telescope), an unobstructed east-south-eastern horizon, patience, and a bit of luck. From mid-northern latitudes, Mercury rises one hour before the Sun, but it only climbs to an altitude of 4½° half an hour before sunrise. Trying to see a +0.5-magnitude glint in a bright sky is going to be tough. Mercury is the trickiest naked-eye planet to catch, but success is mostly a question of timing. Personally I'd wait until June, when the swift little world enjoys a much more favorable appearance at dusk.

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

This sequence samples different phases of the total lunar eclipse on March 14, 2025, starting with the uneclipsed Moon (top right) and ending with the partial phases after totality. During the event, the Moon passed north of the umbra's center. On March 3rd, its path carries it south of the shadow's center, resulting in a bright southern limb during totality.

BOB KING

An Early Morning Total Lunar Eclipse

For most readers, this is the last time the Moon is completely immersed in Earth's dark umbral shadow until 2029.

On March 3rd, observers in the Americas, the Pacific, and East Asia can watch the full Worm Moon crawl into Earth's shadow and undergo a total eclipse. Here in the Western Hemisphere, the event occurs during the morning hours, while across Asia it happens during the evening. In the U.S. and Canada, those on the West Coast are in the best position to take in the entire show.

The Moon first touches Earth's outer penumbral shadow at 0:43 a.m. PST (3:43 a.m. EST; 8:43 UT). Greatest eclipse, when the Moon is deepest within the southern portion of Earth's umbral shadow, occurs at 3:34 a.m. PST. Totality lasts for 59 minutes, from 3:04 a.m. to 4:03 a.m. Finally, our peekaboo satellite leaves the penumbral shadow and sails into the clear at 6:25 a.m. For viewers in the Americas, a long hiatus will follow its exit, with the next total lunar eclipse occurring on June 26, 2029.

To avoid missing this one, it pays to watch the weather carefully. During the March 2025 total lunar eclipse, the sky was mostly cloudy at my home. I checked satellite photos and forecasts for nearby cities, looking for clearings. Fortunately, fair skies ruled just 130 kilometers (80 miles) to the south. I packed my scope, binoculars, and a camera into my car and hit the highway. The move paid off. For more than three hours I enjoyed a spectacular eclipse on a dirt road surrounded by farm fields. While there are many useful resources for monitoring cloud cover, one of my favorites is **windy.com**, which is also available as an app for your smart device.

It was on that occasion I first noticed a lunar eclipse's effect on wildlife. Every spring, at dusk, dawn, and during a bright Moon, the American woodcock (also known as the timberdoodle and by several other fanciful names), performs its mating ritual. From the ground it produces a loud, buzzy "peent!" call followed by an aerial acrobatic performance. As the Moon slipped deeper into the umbra, a nearby woodcock went silent. Then, during the Moon's egress from the umbral shadow, it resumed its activities. I was delighted to witness its response to this bit of cosmic geometry. I encourage readers to keep an eye (and ear) out for changes in the natural world during this eclipse. You never know what you may have missed before.

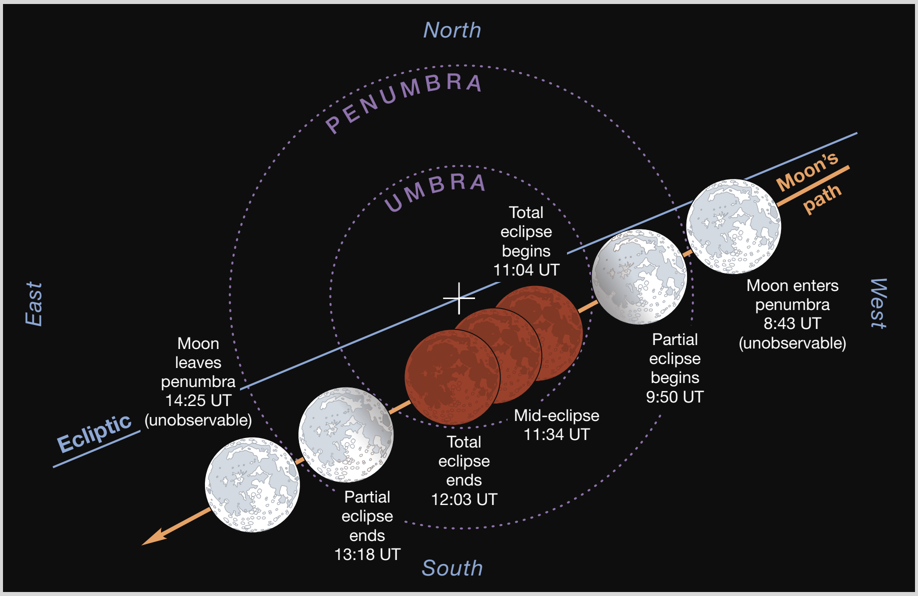
By chance, each phase of this month's eclipse divides neatly among the four contiguous time zones. East Coast observers see the Moon set in the western sky while fully engulfed in the umbral shadow. In the Midwest, the Moon sets after totality while still in partial eclipse; in the mountain states the lunar disk exits the umbra shortly before moonset. Only skywatchers on the West Coast see the entire eclipse from start to finish.

Any eclipse that occurs with the Moon near the horizon unlocks wonderful photographic opportunities. It's only under such circumstances that you can capture the ruddy eclipsed Moon and the landscape together in a single frame with a telephoto lens. Although I've occasionally made composite photos of this kind of scene, I'm sure I'm not alone in preferring a straight shot that combines lunar detail and a distant horizon. Keeping things simple adds authenticity to a photograph.

If you plan to try some eclipse photography, I highly recommend the late Fred Espenak's "How to Photograph a Lunar Eclipse" at **https://is.gd/lunareclipsephotography**. Lighting conditions change quickly as night gives way to dawn and as the Moon enters and exits the umbra, so be sure to monitor your exposures to ensure they remain on target.

There's much to observe during lunar eclipses, whether you use binoculars, a telescope, or your eyes alone. And since these events typically last for several hours, there's time to try everything. From the first visible inkling of penumbral shading at the Moon's eastern limb (using sky directions), to the last traces of the shadow near the western edge, this eclipse offers around 4 hours of viewing possibilities, depending on how early and late you can see the last traces of the penumbral shadow. The earliest I've been able to detect the feature with the unaided eye is 30 minutes before the start of the partial phase. I bet you can do better.

Because the Moon passes well south of the umbra's center during this eclipse, its southern limb appears noticeably brighter during totality. This lighter zone slowly rotates from west to south as the Moon tracks through the umbra. It's difficult to predict how bright or dark the Moon will appear



▲ The March 3rd total lunar eclipse is visible from the Americas, the Pacific, and Asia. With the exception of the West Coast, viewers across the U.S. and Canada will see the Moon set in morning twilight while still immersed in Earth's shadow.

once it's fully immersed in the umbra — something that depends on several variables, including how cloudy Earth is at the time of eclipse and if any volcanic aerosols are present in the stratosphere. When there is more of either, the eclipsed Moon appears darker.

You can estimate the eclipsed Moon's brightness using the well-known Danjon scale. Email your estimate to eclipse enthusiast Helio Vital at **lunissolar@gmail.com**. Vital, who has coordinated the eclipse section of the Brazilian Observational Astronomy Network since 1990, compiles observations to make a darkness determination and tries to assess the cause. Vital expects the Moon to appear moderately bright this time "since no major stratospheric eruptions have occurred in the last couple of years."

I also encourage you to contribute crater-timing observations. Carefully note when craters enter and exit the umbral shadow to help astronomers determine the shape and size of Earth's umbra. *Sky & Telescope* Senior Contributing Editor Roger Sinnott provides instructions and a table of estimated times in his "Useful Projects for a Lunar Eclipse" article, found in the Observing section at **skyandtelescope.org**.

In a fun twist, the lunar disk straddles the Leo-Sextans border during the eclipse, so it's in both constellations simultaneously. No particularly bright stars or galaxies are occulted during totality, but the darkened Moon makes it easy to see even dim stars near its limb. The brightest to hide behind the eclipsed Moon is 6th-magnitude 56 Leonis, which is overtaken toward the end of totality.

When the Moon is in shadow, you can also watch for the impact flashes from meteoroids striking the lunar surface — even a small object can generate a brief flash. Video sequences work best for recording these impacts, though still photography also offers a good chance to catch one.

Besides the beautiful color of the eclipsed Moon, caused by sunlight refracted by the sliver of atmosphere above Earth's limb into the umbral shadow, my favorite aspect of these all-too-rare cosmic alignments is the transition from a bright, moonlit sky to the dark hush of night. I love watching the stars slowly return as the Moon slips ever deeper into Earth's shadow. Although the transition back to light as totality ends may feel anticlimactic at first, the symmetry and sense of closure it brings makes for a welcome ending to a silent, majestic procession.

LEAH TISCIONE / *S&T*, SOURCE: FRED ESPENAK

Occultations High And Low

THE MOON PLAYS catch-and-release this month with two 3rd-magnitude stars for observers in parts of North America and the Caribbean. The first event occurs on the morning of March 13th when the thick waning crescent occults 3.3-magnitude Tau (τ) Sagittarii, near the southern extreme of the Moon's wanderings along the ecliptic. Skywatchers in the eastern third of the U.S., much of eastern Canada, and as far south as far as Miami and Cuba will see the orange giant star emerge from the waning crescent Moon's dark limb in morning twilight. The farther east you live, the higher the Moon. The farther east and south, the greater the chance of seeing both immersion and emersion.

About two weeks later, on March 26–27 when the Moon has ascended to the ecliptic's apex, it occults 3.6-magnitude Kappa (κ) Geminorum. This event is widely visible across much of the U.S., and all of Canada and the Caribbean. From the East Coast the cover-up occurs between about midnight and 1 a.m. on the 27th, while farther west it happens late in the evening of the 26th.

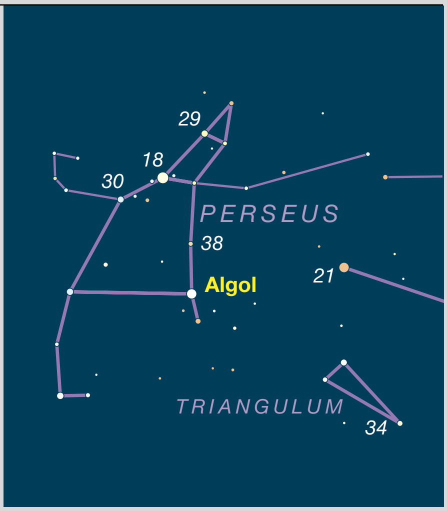
Kappa is an unequal double star with a 10th-magnitude companion 7.0″ away at a position angle of 243° (southwest). Observers with telescopes 6 inches or larger operating at around 100× can see the Moon's dark limb snatch away the fainter secondary star seconds before it covers the primary. When the companion reappears on the bright limb, glare from the lunar surface will make seeing it a challenge.

For exact occultation times for both events, visit the International Occultation Timing Association (IOTA) website at **https://is.gd/occultations**. You can also preview the scene from your location with an astronomy app, such as the freeware *Stellarium*.

Minima of Algol

Feb.	UT	Mar.	UT
2	0:36	2	16:50
4	21:26	5	13:39
7	18:15	8	10:29
10	15:05	11	7:18
13	11:54	14	4:07
16	8:43	17	0:57
19	5:33	19	21:46
22	2:22	22	18:35
24	23:11	25	15:25
27	20:01	28	12:14
		31	9:03

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 is conveniently high in the northwest during evening hours in March. 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).

Action at Jupiter

AS MARCH BEGINS, Jupiter is beautifully placed for evening viewing. The planet shines at magnitude –2.4 and reaches the meridian roughly one hour after the end of astronomical twilight. It remains a fine telescopic target until around 2 a.m. local daylight time, when its altitude slips below 30°. When the month opens, the Jovian disk spans 42.8″ — large enough to present an abundance of telescopic detail. Turn to page 48 of the January issue to learn more about what Jupiter offers.

Any telescope reveals the four big Galilean moons, and binoculars usually show at least two or three. Use the diagram on the facing page to identify them by their relative positions on any given date or time. All the observable interactions between Jupiter and its satellites and their shadows are tabulated on the facing page.

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.)

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

March 1: 3:33, 13:29, 23:25; **2**: 9:20, 19:16; **3**: 5:12, 15:07; **4**: 1:03, 10:59, 20:55; **5**: 6:50, 16:46; **6**: 2:42, 12:37, 22:33; **7**: 8:29, 18:25; **8**: 4:20, 14:16; **9**: 0:12, 10:07, 20:03; **10**: 5:59, 15:55; **11**: 1:50, 11:46, 21:42; **12**: 7:37, 17:33; **13**: 3:29, 13:25, 23:20; **14**: 9:16, 19:12; **15**: 5:08, 15:03; **16**: 0:59, 10:55, 20:51; **17**: 6:46, 16:42; **18**: 2:38, 12:34, 22:29;

19: 8:25, 18:21; **20**: 4:17, 14:12; **21**: 0:08, 10:04, 20:00; **22**: 5:55, 15:51; **23**: 1:47, 11:43, 21:38; **24**: 7:34, 17:30; **25**: 3:26, 13:21, 23:17; **26**: 9:13, 19:09; **27**: 5:04, 15:00; **28**: 0:56, 10:52, 20:47; **29**: 6:43, 16:39; **30**: 2:35, 12:31, 22:26; **31**: 8:22, 18:18

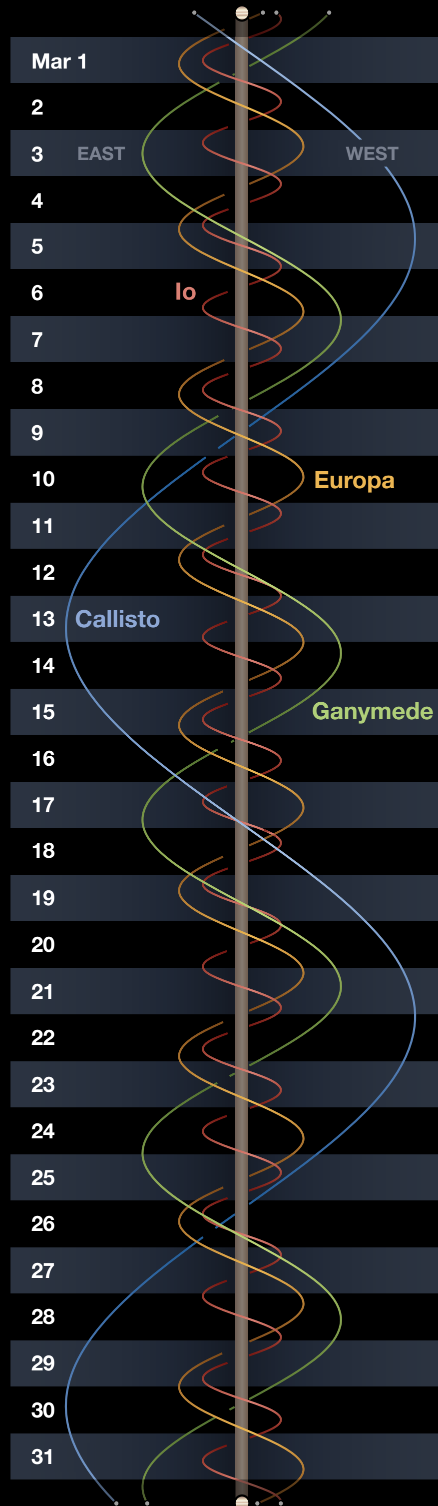
These times assume that the spot will be centered at System II longitude 88° on March 1st. If the Red Spot has moved elsewhere, it will transit 1²/₃ minutes earlier for each degree less than 88° and 1²/₃ minutes later for each degree more than 88°.

Phenomena of Jupiter's Moons, March 2026

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

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.

Imaging the Seventh Planet

Today's technology puts atmospheric details on this distant world within grasp.

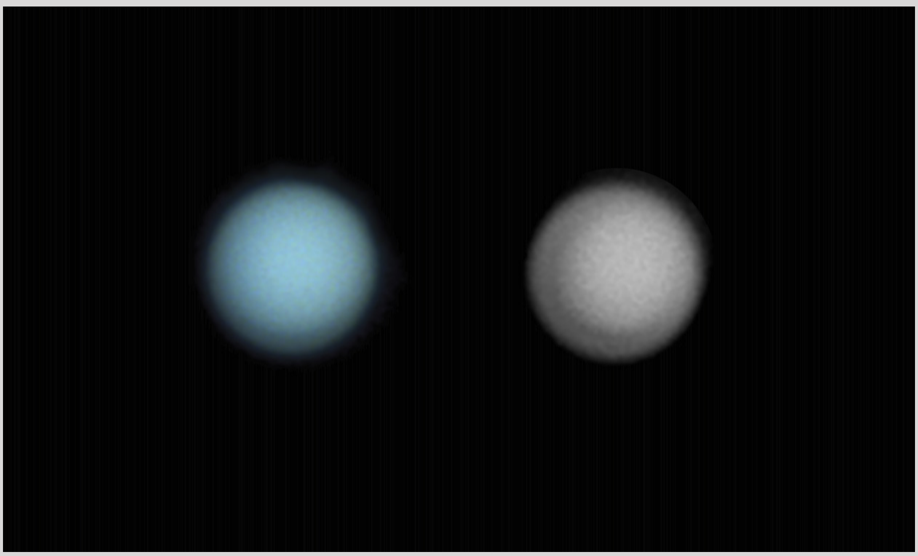
In recent years, an increasing number of amateur astronomers have recorded delicate markings in the atmosphere of Uranus. Capturing these features ranks among the most difficult feats of planetary imaging.

The sheer remoteness of Uranus makes it a challenging target for even the largest telescopes. Viewing the planet through a telescope is comparable to observing a pea across the length of five football fields (or nearly half a kilometer). The planet's apparent diameter never exceeds 3.8 arcseconds — 13 times smaller than Jupiter and five times smaller than Saturn when they're both at opposition.

An even greater handicap is posed by the feeble sunlight at Uranus's vast distance. High noon on Uranus is comparable to gloomy twilight on Earth — the intensity of sunlight we are accustomed to is reduced by more than 350-fold on Uranus. The planet's apparent surface brightness per unit area is almost 14 times less than Jupiter's and five times less than Saturn's.

Uranus has a deep, frigid atmosphere composed of 83% hydrogen, 15% helium, and 2.3% methane, along with traces of ammonia, carbon monoxide, and hydrogen sulfide. The uppermost layers of the atmosphere contain a haze of photochemical smog produced by the interaction of solar ultraviolet radiation with methane and other hydrocarbons. Methane strongly absorbs deep red and near-infrared light, imparting the planet with its characteristic greenish-blue color.

In 1970, NASA's Stratoscope II balloon lofted a 36-inch telescope to an altitude of 80,000 feet and obtained photographs of Uranus free from the effects of atmospheric turbulence. The planet was devoid of any discernible markings. Voyager 2's disappointing visible-light snapshots of Uranus taken during the spacecraft's 1986 flyby also captured an exceptionally bland cloudscape. Even at close range, little more was revealed than a diffuse bright hood over the southern polar regions and a few low-contrast convective storms at lower latitudes.

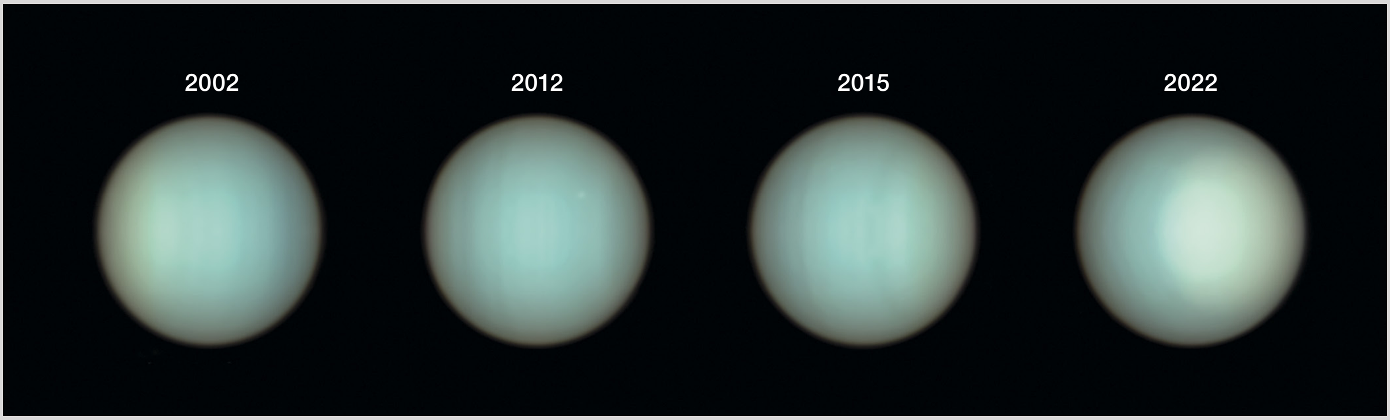


▲This pair of images by Japanese amateur Tomio Akutsu were taken with an 18-inch Newtonian on October 27, 2025. The visible-light color image at left is virtually featureless, while the near-infrared image at right captures a bright polar hood partially encircled by a narrow dusky collar.

Uranus's disk becomes much more interesting when imaged at near-infrared wavelengths. At the far-red end of the visible spectrum and beyond, features display much higher contrast due to methane absorption, revealing a very dynamic atmosphere. At these wavelengths, bright features correspond to sunlight reflecting off crystals of frozen methane or hydrocarbon haze at high altitude, while dark features correspond to sunlight penetrating to greater depths.

In 1994, the Hubble Space Telescope recorded a well-defined polar hood and a pair of conspicuous bright clouds on the planet through a near-infrared filter. And since 2004, the 10-meter Keck telescope, aided by state-of-the-art adaptive optics atop Mauna Kea in Hawai'i, has recorded belts, zones, and periodic outbreaks of bright spots in the near infrared that are imperceptible in visible light. Tracking the motion of bright cloud features indicates that, at temperate latitudes, fierce winds blow at speeds as high as 870 kilometers per hour (540 mph). The planet's wildly exaggerated seasons appear to greatly influence the level of its atmospheric activity.

Uranus's rotational axis is inclined by a whopping 98° to the plane of its orbit. The planet rolls along on its



▲ Recorded over a span of 20 years, these visible-light Hubble Space Telescope images of Uranus show the gradual brightening of the planet's north polar region as it slowly turned toward the Sun. With amateur telescopes, the bright polar hood is easiest to capture through a near-infrared filter.

side almost pole first while making its 84-year-long circuit around the Sun. The poles are alternately pointed almost directly at the Sun at 42-year intervals. In 1986, the planet's south pole appeared near the center of its disk to earthbound observers, bathed in the full glare of the Sun's rays. In 2028, its north pole will be similarly presented. During the intervening equinoxes the planet's equator faces Earth, as was the case in 2007. Currently, it's late spring in the northern hemisphere of Uranus and the south pole is now on the averted side of the planet, out of view and facing the darkness of space.

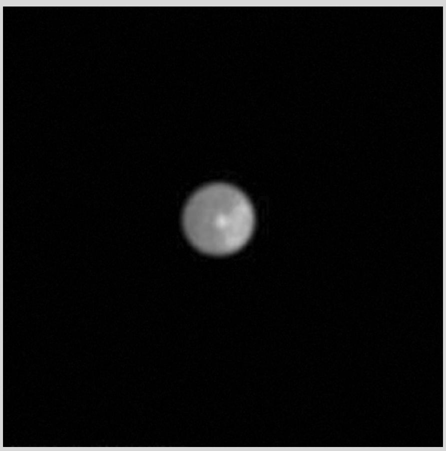
Capturing features on Uranus requires extremely steady seeing and a telescope aperture of at least 10 inches. In recent years, amateurs armed with 12- to 16-inch instruments have recorded truly impressive results, resolving features on the planet's diminutive disk. To do so, you need a monochrome (black-and-white) camera with high sensitivity in the near infrared. Use a deep-red filter that also transmits near-infrared light, like a Wratten 25 or Baader RG 610. However, these filters markedly darken the already dim disk of Uranus, making it difficult to determine if the planet's image is in sharp focus. To overcome this problem, focus on a bright star before turning the telescope on Uranus. The Baader IR-685 filter blocks wavelengths below 670 nanometers, which provides moderately higher contrast at the expense of an even dimmer image.

The dimness of the image necessitates slow capture rates of only five to 10 frames per second, corresponding to exposure times of 200 to 100 milliseconds. Accomplished French planetary imager Christophe Pellier cautions that with instruments of moderate aperture, truly optimal exposures of Uranus in the near infrared would be prohibitively long. He recommends making extended video captures of 10,000 to 20,000 frames to improve the signal-to-noise ratio (by combining a very large number of noisy, underexposed frames).

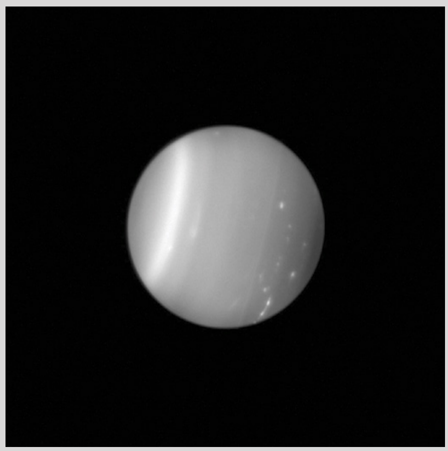
With patience and a large-aperture instrument, capturing a rare, large storm on Uranus is well within the capability of advanced planetary imagers. For example, on October 2, 2014, Australian astroimager Anthony Wesley recorded one such storm using a 16-inch Newtonian and a high-speed monochrome camera equipped with a 650-to-850-nm filter. As the planet approaches its northern hemisphere solstice, it's well worth the effort to monitor its atmosphere and be ready to record any surprises.

Invariably a disappointment for visual observers, Uranus is a demanding but rewarding test of instrument and atmospheric seeing for imagers.

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

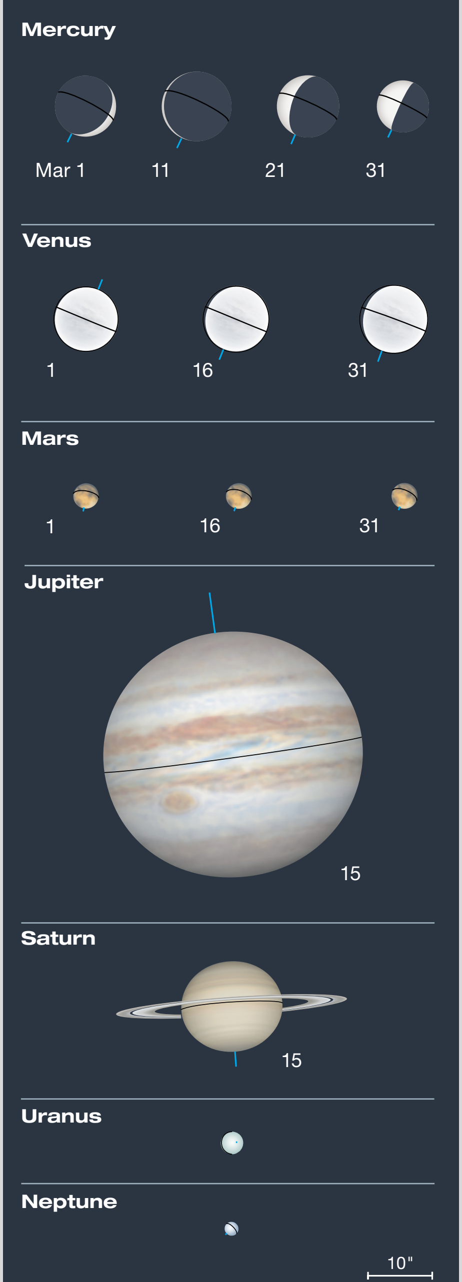


▲ In addition to polar brightening, compact bright storms occasionally break out on Uranus that are detectable with amateur equipment. Australian planetary imager Anthony Wesley captured both phenomena with his 16-inch Newtonian on October 2, 2014, through a red long-pass filter.



▲ Several small storms are seen in this infrared image taken with the 10-meter Keck II telescope atop the summit of Mauna Kea in Hawai'i. Only the largest ground-based telescopes equipped with adaptive optics and the Hubble and Webb space telescopes can resolve minor storms on Uranus.

FOUR URANUS IMAGES BY HUBBLE: NASA / ESA / ERICH KARKOSCHKA (LPL); KECK II URANUS: HEIDI HAMMEL / IMKE DE PATER / W. M. KECK OBSERVATORY



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

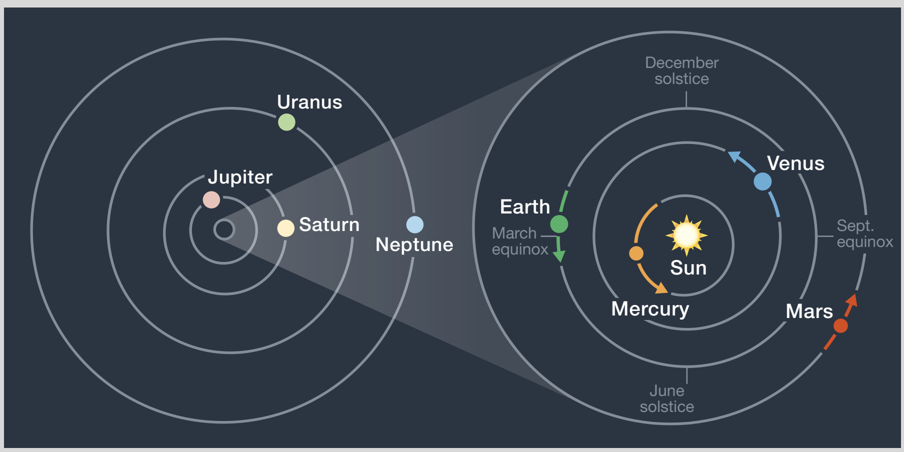
▶ **ORBITS OF THE PLANETS** The curved arrows show each planet's movement during March. The outer planets don't change position enough in a month to notice at this scale.

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** out of view all month • **Venus** visible at dusk • **Mars** lost in the Sun's glare all month • **Jupiter** transits in the early evening and sets before dawn • **Saturn** visible low in the west at dusk until the 9th.

March Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	22^h 46.3^m	–7° 48′	—	–26.8	32′ 17″	—	0.991
	31	0^h 36.5^m	+3° 56′	—	–26.8	32′ 02″	—	0.999
Mercury	1	23^h 24.0^m	–0° 18′	12° Ev	+2.1	9.5″	11%	0.707
	11	22^h 52.4^m	–3° 41′	8° Mo	+4.1	10.9″	3%	0.618
	21	22^h 37.7^m	–7° 39′	22° Mo	+1.1	9.7″	24%	0.692
	31	22^h 57.3^m	–7° 55′	27° Mo	+0.3	8.1″	44%	0.827
Venus	1	23^h 35.9^m	–4° 05′	13° Ev	–3.9	10.1″	98%	1.657
	11	0^h 21.3^m	+1° 03′	15° Ev	–3.9	10.2″	97%	1.634
	21	1^h 06.6^m	+6° 09′	18° Ev	–3.9	10.4″	95%	1.606
	31	1^h 52.5^m	+11° 02′	20° Ev	–3.9	10.6″	94%	1.573
Mars	1	22^h 03.7^m	–13° 04′	12° Mo	+1.2	4.0″	99%	2.341
	16	22^h 48.5^m	–8° 45′	15° Mo	+1.2	4.0″	99%	2.319
	31	23^h 32.2^m	–4° 09′	18° Mo	+1.2	4.1″	99%	2.297
Jupiter	1	7^h 04.8^m	+22° 57′	125° Ev	–2.4	42.8″	99%	4.604
	31	7^h 06.8^m	+22° 55′	95° Ev	–2.2	39.0″	99%	5.054
Saturn	1	0^h 08.4^m	–1° 25′	21° Ev	+1.0	16.0″	100%	10.416
	31	0^h 22.0^m	+0° 03′	5° Mo	+0.9	15.9″	100%	10.485
Uranus	16	3^h 42.2^m	+19° 29′	63° Ev	+5.8	3.5″	100%	19.913
Neptune	16	0^h 06.6^m	–0° 42′	6° Ev	+8.0	2.2″	100%	30.871

The table above gives each object's right ascension and declination (equinox 2000.0) at 0h 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**.



The Lesser Leo Trio

Faint blobs in the belly of the beast present a challenge for city stargazers.

▲ **COMPLEX SYSTEM** The barred spiral galaxy M96 features fragmentary outer spiral arms, a ragged inner ring of young, blue-white stars, and a brilliant central region of older, yellowish stars forming a short bar-like structure. Curving dust lanes appear mostly on the western (right) side of the galaxy because the system is inclined: The western portion is closer to us than the eastern. The linear feature at extreme left is a distant edge-on galaxy.

ESO / OLEG MALIY

Backyard astronomers know that light pollution is kryptonite for galaxies. Photons headed our way for millions of years are drowned at the last instant by a deep ocean of bright city lights. I live north of downtown, so the southern half of my night sky is suffused with a perpetual creamy dawn. My galaxy observations are restricted mainly to prominent specimens residing north of the zenith, or at least very high in the south.

But there are exceptions. One spring evening five years ago, I aimed my 10-inch f/6 Dobsonian reflector southward toward the constellation Leo, the Lion. My daring plan was to probe a collection of galaxies roughly 10° east of Regulus. To avoid the worst of the light pollution, I waited until the target area reached its maximum height — about 50° above the southern horizon. Yet as Leo crossed the meridian that night, it barely surmounted the downtown dome of doom. Was my galaxy quest a foolish exercise? Would the project end in failure? Was there something better on TV?

Getting There

My celestial destination wasn't the tightly arranged and delightfully photogenic Leo Trio beneath the Lion's hindquarters that I'd covered earlier (*S&T:* Mar. 2025, p. 55), but the looser group of three fair-to-middling Messier galaxies in the belly of the beast. In a moment of mirth, I dubbed them the Lesser Leo Trio.

As a dedicated star-hopper, I decided on an indirect route to these Leo galaxies so that I could take in some sights along the way. My staging point was 1.4-magnitude **Regulus**, officially Alpha (α) Leonis. In addition to its brilliant, blue-white gleam, Regulus is attractive because it comes with an 8.2-magnitude companion almost 3′ to the northwest. The secondary star was obvious at 48×. (Any scope operating at low magnification will show it.)

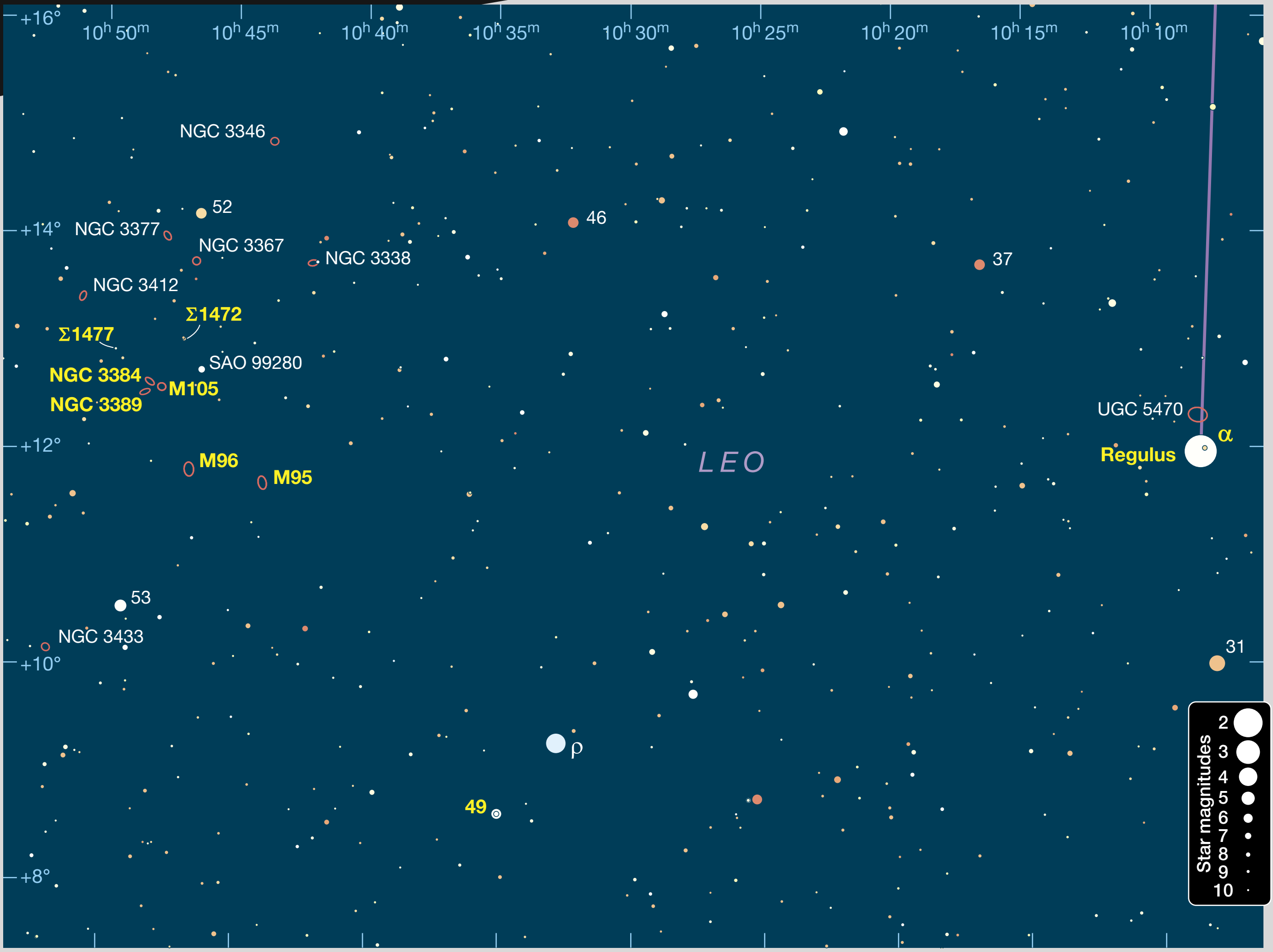
It was time to ramble — carefully, because my aging 10-inch (home-built by a friend in 1993) was saddled with a rather rudimentary 6×30 finderscope. From Regulus, a 6½° hop southeastward landed me on 3.9-magnitude Rho (ρ) Leonis. Nudging the Dobsonian almost 1° further centered 5.8-magnitude **49 Leonis**, a superb binary star. The tight uneven duo is a great test object because its 7.9-magnitude secondary sun lies just 2.1″ south-southeast of the blazing primary. A wave of satisfaction washed over me (I screamed "YES!") when the Dob reeled in the feeble attendant at 218×.

The next hops were tricky. From 49 Leonis, I ventured northeastward 4° to 5.3-magnitude 53 Leonis, then veered north-northwestward 3.7° to 5.5-magnitude 52 Leonis. I expected both stars to show easily in the finder, provided I didn't wander off-course (as I did during my first attempt when I blundered into 5.4-magnitude 46 Leonis, 3.5° west of 52 Leonis instead). I wanted to capture 53 and 52 together in one finder field because the galaxies I was hunting lurk approximately halfway between the two stars.

Having centered 53 and 52 Leonis in the finderscope, I turned my attention to the main scope's field of view. I inserted a 24-mm eyepiece for 64× and yielding a span of sky 1° across. It was time to take a good, long look.

Blobs in the Belly

Happily, the combination of low power, wide field, and patient staring picked



▲ **BLOBS AND DOUBLES** A small region east of Regulus in the constellation Leo contains several relatively bright galaxies. Three of them — M95, M96, and M105 — are listed in the famous Messier catalog of deep-sky objects. A couple of attractive double stars lie just north of the galaxies.

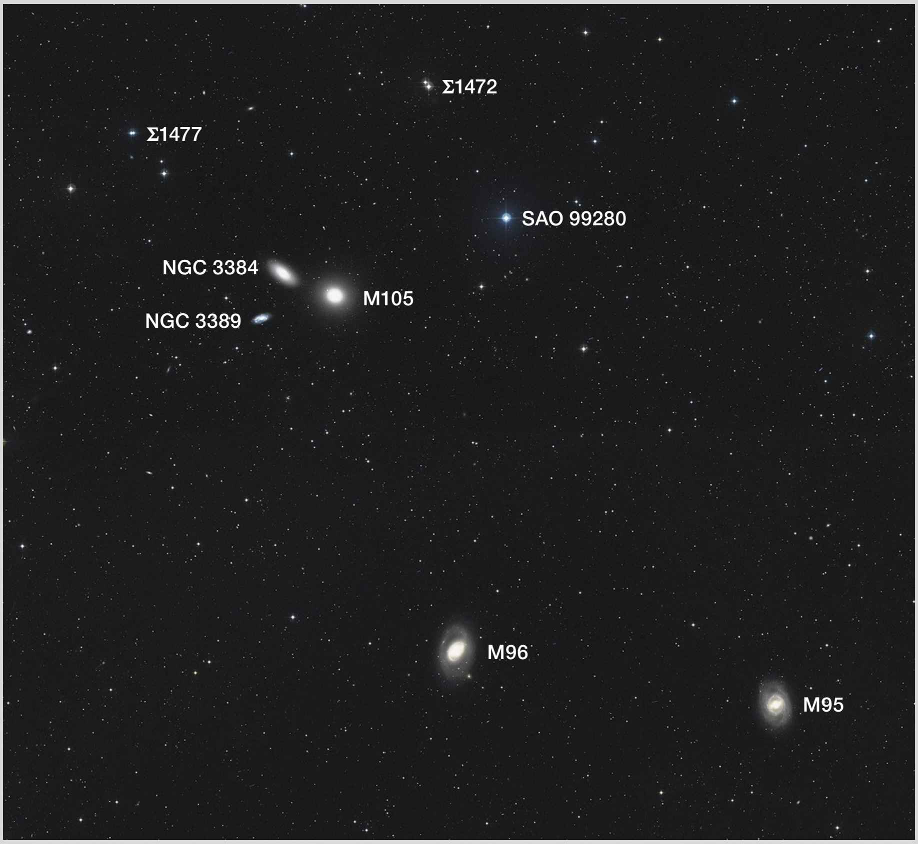
up a wee blob of light. It was the barred spiral galaxy **M96**. The effect on my eye was hardly spectacular. M96 has a respectable visual magnitude of 9.3 but a surface brightness of only 13.1 magnitudes per square arcminute. Although 7.8′ by 5.2′ in size, it seemed spherical and much smaller. Given its prominent core and diffuse periphery, the galaxy resembled an unresolved globular cluster.

Nudging the Dob westward, I found a dimmer blob about 42′ west-southwest of M96. This was the barred spiral **M95**. The galaxy is listed at magnitude 9.7; however, its surface brightness is 13.5 — both values are less appealing than those for M96. Also, the pallid patch isn't as large: It's 7.4′ by 5.0′. I considered M95 a very difficult suburban object; it was hard to detect even with averted vision while cupping my hands around the eyepiece. Fortunately, a 10.3-magnitude star shines just 6.5′ west of the galaxy. As M95 played hide-and-seek, the star helped me hold it.

The final galaxy in this Messier trio, **M105**, lies 48′ north-northeast of M96 and exactly half that distance east-southeast of a 6.9-magnitude star (SAO 99280). From M96, I shifted the telescope one eyepiece field northward (and a tad westward) to capture the star, then gently aimed the required amount east-southeastward to the faint fuzzball. An elliptical galaxy of nearly spherical eccentricity, M105 has a visual magnitude of 9.3 and a fairly generous surface brightness of 12.8. It's a seemingly more alluring object than the other two galaxies, though M105 is smaller, measuring just 5.3′ by 4.8′. Observing at 64× that night, M105 appeared round and sharply brighter toward the middle. Not bad. Mission accomplished!

But wait, is there more? My charts show that M105 has a couple of neighbors. The nearest indicated is **NGC 3384**, an elliptical system 7′ northeast of M105. Some 5.4′ by 2.7′ in extent, NGC 3384 has a visual magnitude of 9.9 and a surface brightness of 12.7. At 64× it was an oval mass boasting a strong core, which made me wonder: How could Charles Messier have missed it? The answer is that the galaxy we call M105 was actually discovered

▶ **CELESTIAL SIBLINGS** Observations made with the Hubble Space Telescope of Cepheid variable stars within M95 indicate that the barred spiral galaxy is a little less than 33 million light-years from Earth. Similar observations of the barred spiral M96 show a distance of almost 36 million light-years. The elliptical galaxy M105 lies between 33 and 38 million light-years away. These bright galaxies, together with NGC 3384, are members of the sprawling Leo I galaxy group. The spiral system NGC 3389 is not a family member, as it's much more distant.



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

by Messier's colleague, Pierre Méchain — Messier himself never observed it, so he wouldn't have chanced upon the neighboring galaxy. (M105 was added to the Messier Catalog in 1947 on the advice of Canadian astronomer Helen Sawyer Hogg.) Of course, this doesn't explain how Méchain instead missed NGC 3384!

A second neighbor, **NGC 3389**, is a shy guy hiding in the celestial weeds 6′ south-southeast of NGC 3384. The loosely wound spiral is no champion. NGC 3389 is an 11.9-magnitude galaxy with a surface brightness of 13.2 and dimensions of 2.9′ by 1.3′. I was able to glimpse its weak glow after I doubled the magnification and because I knew exactly where to look.

Beyond the Blobs

In total, I had netted five galaxies in a 1° by 1° square of bland suburban sky. After such concentrated deep explorations, I like to cast my gaze around for double stars I'd otherwise never notice. On this occasion, I found two. A really obvious double cataloged as **Σ1472** shines slightly less than ½° northwest of M105. The can't-miss twosome consists of 8.5- and 9.5-magnitude stars separated by a breezy 43.4″, on a northeast-southwest slant.

A dimmer double named **Σ1477** sits a little more than ½° northeast of M105. The pairing marks the top of a 12′-wide triangle of 9th-magnitude stars and features 9.4- and 9.7-magnitude components 17.6″ apart, oriented east-west. Taken together, Σ1477 and Σ1472 show well at low magnification in a single field of view. The easy tandems provided a satisfying conclusion to an evening of difficult galaxy hunting.

When I completed this Leo galaxies project in the spring of 2021, my home sky was bad but not as horribly light-polluted as it is today. Sadly, I must report that the Lesser Leo Trio is now beyond the pale for my backyard gear except on the most pristine of nights — the sort that come around rarely. If your south isn't as awful as mine, you'll do better. I hope you'll embrace this field of doubles and give these fuzzy blobs a go.

■ Contributing Editor **KEN HEWITT-WHITE** rates the 1958 cult classic *The Blob* as his favorite sci-fi flick.

A Belly Full of Blobs (and Doubles)

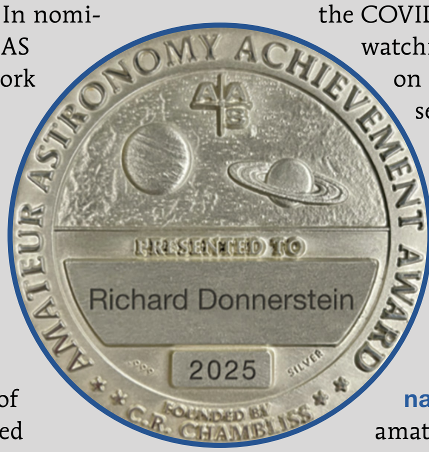
Object	Type	Mag	Size/Sep	RA	Dec.
Regulus	Double star	1.4, 8.2	176″	$10^h 08.4^m$	+11° 58′
49 Leonis	Double star	5.8, 7.9	2.1″	$10^h 35.0^m$	+08° 39′
M96	Galaxy	9.3	7.8′ × 5.2′	$10^h 46.8^m$	+11° 49′
M95	Galaxy	9.7	7.4′ × 5.0′	$10^h 44.0^m$	+11° 42′
M105	Galaxy	9.3	5.3′ × 4.8′	$10^h 47.8^m$	+12° 35′
NGC 3384	Galaxy	9.9	5.4′ × 2.7′	$10^h 48.3^m$	+12° 38′
NGC 3389	Galaxy	11.9	2.9′ × 1.3′	$10^h 48.5^m$	+12° 32′
Σ1472	Double star	8.5, 9.5	43.4″	$10^h 47.0^m$	+13° 02′
Σ1477	Double star	9.4, 9.7	17.6″	$10^h 49.6^m$	+12° 56′

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

An Award for Amateurs

Recognizing the hard work of dedicated backyard observers.

The American Astronomical Society (AAS) established their Amateur Affiliate division in 2018 in response to increased interest from the amateur community in the AAS's activities — indeed, some of you might even be members. But some years earlier, the society's head honchos understood that amateurs were making not-insignificant contributions to research.



▶ Thirteen awardees, including 2025's Richard Donnerstein, have held one of these medals in their hands in the past two decades. Who will be next?

AAS

Chambliss Arrives on the Scene. To recognize these efforts, in 2006 the AAS granted the very first Chambliss Amateur Achievement Award, for "an achievement in astronomical research made by an amateur astronomer — that is, a person not employed in the field of astronomy in a professional capacity" for contributing to the "advancement of the science of astronomy." There's one caveat, though: Nominations are currently only accepted for residents of North America.

The award is named for Carlson R. Chambliss, a professor of astronomy at Kutztown University, Pennsylvania, until his retirement in 2003. He donated the funds to establish the award. Lucky recipients become the proud owners of a 224-gram (½-pound) silver medal engraved with their name and award year, as well as $1,000 in cash.

Since 2006, the AAS has honored 13 talented and motivated amateurs with the coveted silver medal and prize money. The first-ever awardee was Brian D. Warner, who performed extensive photometric studies of asteroids from his backyard in Colorado. His discoveries include several main-belt binary asteroids that greatly contributed to our understanding of the pairs' formation. In nominating Warner, the AAS also recognized his work on relativistic explosions and gamma-ray bursts.

From asteroids to exoplanets to galaxies. The observers who have been recognized for their efforts have covered a wide range of subjects. Some deployed their own backyard equipment and collected data on variable stars, the host stars of exoplanet systems, and comets. Others instead contributed to citizen-science programs, mostly supported by Zooniverse, such as the Kepler mission's Planet Hunters program (awardees in 2012 and 2016).

The 2011 recipient, Tim Puckett, established a whole network of supernova hunters. Don Bruns (2018) coordinated a collection of eager observers in 2017 to recreate Arthur Eddington's 1919 total solar eclipse experiment that proved Einstein's theory of gravity was right. (See *S&T:* Aug. 2018, p. 22.) And 2025's awardee, Richard Donnerstein, worked with the research group at the University of Arizona's Steward Observatory and has nearly 30 refereed publications under his belt! (To see the full list of inspiring recipients, go to **https://is.gd/AAS_Chambliss_Winners**.)

While some recipients have always been diehard observers, with equipment bristling to be deployed nightly, others stumbled into the field purely by accident. Dan Caselden (2024) has recounted how he became bored during the COVID-19 pandemic just watching TV as he exercised on his treadmill. While searching for something more stimulating to engage in, lo and behold he came across Zooniverse's Backyard Worlds program (*S&T:* July 2024, p. 58).

Nominate, nominate! For a deserving amateur to win the award, they first need to be nominated. And the nomination can come from you. The AAS accepts nominations each calendar year until the end of June. Self-nominations are allowed, too. Should the deliberating committee bestow the recognition upon someone (some years they don't), they'll announce the winner at the AAS winter meeting the following January.

Who's eligible? Any amateur who has contributed significantly to research in some capacity or another. So, get cracking!

For guidelines and submission form, head to **https://is.gd/AAS_Chambliss**. Do consider nominating someone — this is a marvelous opportunity to highlight the incredibly hard work amateurs do toward advancing scientific research.

■ A recovering research scientist, Editor in Chief **DIANA HANNIKAINEN** is unendingly impressed by the amateur community's scientific achievements.

◀ REMOTE CAMERA ROTATOR

Chinese manufacturer ZWO adds a new electronic camera rotator to its growing line of astrophotography accessories. The ZWO CAA Camera Angle Adjuster ($349) lets you remotely turn the camera on your telescope to aid with framing your subject. The device is 16.5 mm thick and connects to your scope and camera via M54 threads (an additional M48 camera adapter is also included). It connects to your control computer and is powered via a USB-C interface, or is manually driven via an optional hand controller. It rotates in 0.02° increments at up to 7.5° per second. The unit can support accessory loads of up to 5 kilograms (11 lbs). Purchase includes an M54 adapter, M48 adapter, a 2-meter USB-C cable, and a 1.5-mm hex wrench.

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

◀ CHROMOSPHERE SCOPE

Daystar Filters unveils the Sol100 Dedicated Solar Telescope ($4,995). This 4-inch refractor incorporates a permanently mounted, temperature-regulated Quark hydrogen-alpha solar filter operating at an effective focal length of 1,690 mm, or f/16.9, and can produce full-disk images of the Sun when paired with APS-C-size sensors. Its tunable filter passes 0.05 nanometers of the solar spectrum centered at 656.28 nanometers and can be tuned in 0.01 nm increments. The scope weighs 3 kilograms (6.6 lbs) and comes with a permanently mounted blocking filter yielding a 19-mm clear aperture. Its 12:1 dual-speed focuser is compatible with most third-party focus motors. It requires 5V at 1.5 amps input through a USB-micro port and reaches operating temperature in approximately 5 minutes. Each scope comes with mounting rings, a Vixen-style dovetail mounting bar, a solar finder, a 1.25-inch eyepiece adapter, an AC power adapter with U.S. and international plugs, and a hard case. Specify Chromosphere or Prominence model when ordering.

Daystar Filters
149 NW County Road OO, Warrensburg, MO 64093
866-680-6563; daystarfilters.com

◀ PORTABLE NEWTONIAN

Explore Scientific now offers their 134mm Newtonian Reflector Telescope with Equatorial Mount ($279.99). This observing package features a 5¼-inch, f/4.9 parabolic primary mirror with a lightweight but sturdy equatorial mount weighing a little more than 18 lbs fully assembled. The mount's flexible slow-motion controls on both its right ascension and declination axes allow for precise tracking of celestial objects as they move across the sky. Its 650-mm focal length produces 26× and 65× with the included 25-mm and 10-mm Plössl eyepieces. The scope comes with tube rings, a Vixen-style dovetail mounting plate, a 6 × 30 finderscope, and a 2¼-kilogram (5 lb) counterweight.

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

New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. Sky & Telescope assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor. Announcements should be sent to nps@skyandtelescope.org. Not all announcements can be listed.

It's always a pleasure to image the universe from a pristine, dark sky. But these days, not everyone has easy access to such favorable locations. According to the United States Census Bureau, some 80% of U.S. residents live in urban areas awash in light pollution from streetlights, billboards, and dense traffic. And while it's nice to be able to drive out to a remote dark site, doing so severely limits the amount of time city dwellers can collect photons. Fortunately, there's a lot of astrophotography you can do from home, even under Bortle 7 or brighter skies. It just takes the right approach. Here are some tips and targets for the 80%.

Close to Home

The most obvious astronomical object for city dwellers to image isn't up at night at all. It's the Sun. The nearest star is obviously the brightest object in the sky and completely impervious to light pollution. Its proximity offers a wealth of detail for photographers with any scope equipped with a suitable solar filter.

The Sun is visible from most anywhere on Earth, though it's best targeted in the early morning hours before it gets very high and heats up surrounding buildings, asphalt, and rooftops. Most telescopes are capable of solar imaging, though catadioptrics like Schmidt- or Maksutov-Cassegrains require a front-aperture solar filter to protect the instrument's internal components (and you) from the intense heat. As the Sun is so bright, full-disk pictures and even close-ups are possible with an untracked small scope — so you only need short exposures, though you'll get better results with tracking.

Another great thing about photographing the Sun is that it appears different depending upon which wavelength of light you choose to image. The most common (and inexpensive) method is to equip your telescope with a white-light solar filter to reveal the *photosphere*, the visible surface of the Sun's atmosphere. These filters pass a tiny (safe) percent of sunlight, revealing dark sunspots, bright plage regions, and granulation. There are two types of white-light filters popular among amateurs. Most common are those made of coated glass or

Urban Astrophotography

There's a lot to image in the night sky even under city lights.

▲ **BRIGHT-SKY IMAGING** Smartscopes like the Seestar S30 shown on the facing page can take good images of deep-sky targets even under a cloak of heavy light pollution. The author often uses his Seestar from his apartment balcony under the Bortle 9 skies of Washington, DC, to record images like this example of M42, the Orion Nebula.

▲ **BIG, BRIGHT TARGET** Much like the Sun, the Moon is a great subject for imagers everywhere and doesn't require a tracking mount to photograph. The author snapped this image of the waxing gibbous Moon with an Astro-Physics 92mm Stowaway and a ZWO ASI6200MM camera.

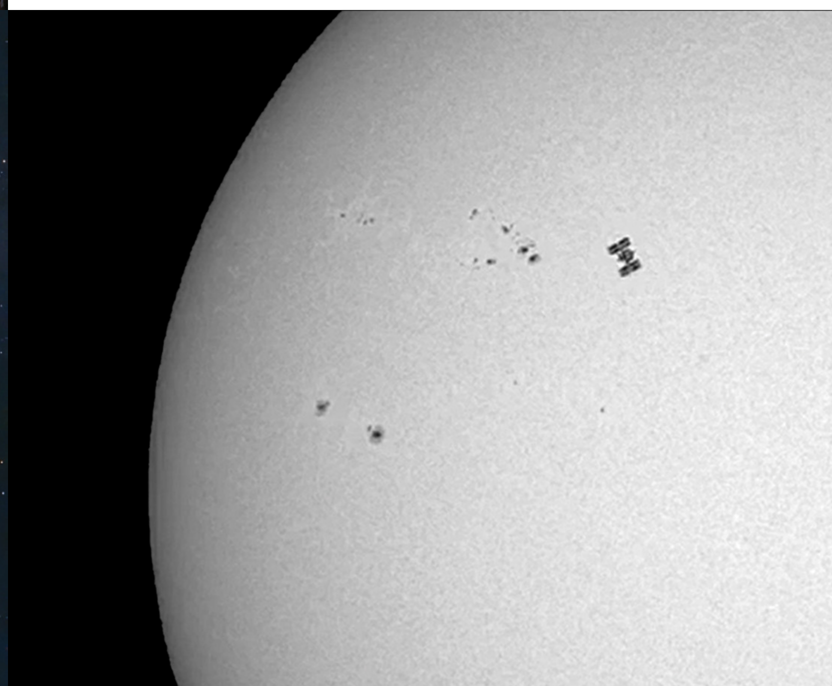
ROBERT CAPON (5)

Mylar that are fitted to the front of the telescope. The other is a device called a Herschel Wedge, which is a special type of diagonal placed near the focal plane and diverts 95% of the light away from the eyepiece, while the remainder is further attenuated with neutral-density filters. You can use a front-aperture solar filter on any type of telescope, while a Herschel Wedge is designed exclusively for use with refractors.

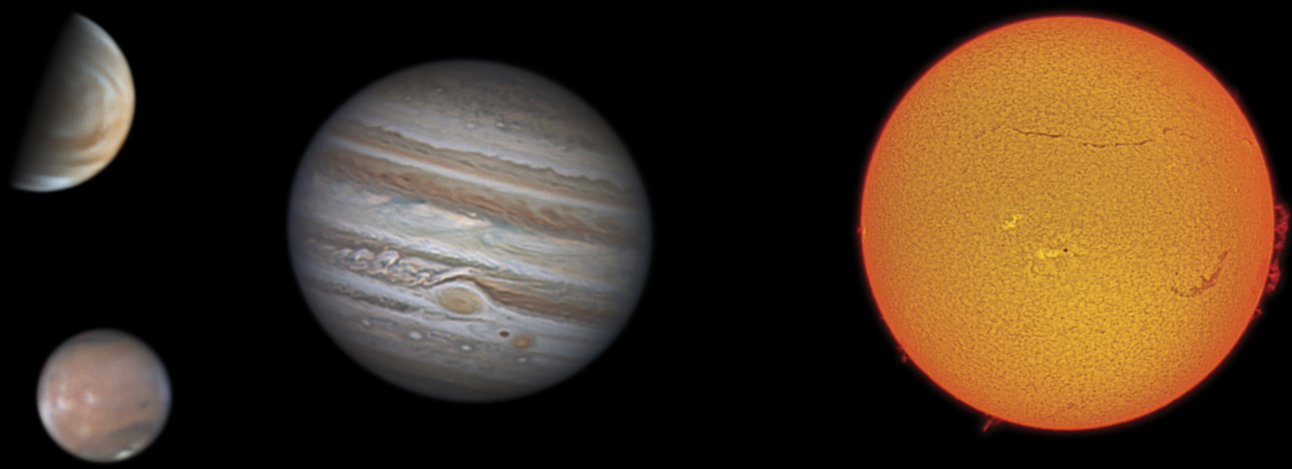
There are also very specialized solar filters that reveal the second layer of the solar atmosphere called the *chromosphere*. Such filters pass specific regions of the solar spectrum to show features invisible in white light. The most common filters are those that isolate calcium K, often called CaK (at 393.4 nanometers) and hydrogen-alpha (Hα) at 656.3 nm. The CaK filter reveals the lower region of the chromosphere showing sunspots, plages, and prominences along the solar limb. Calcium K is primarily an imaging filter as it resides in the deep violet end of the spectrum at the limits of human vision. The other, Hα, is more popular and shows a higher level of the chromosphere visible at the red end of the spectrum where prominences are much brighter than in CaK, as well as features such as filaments, spiculae, and flares.

Most smartscopes can track and record images of sunspots and come equipped with a white-light solar filter, or one can be purchased seperately. If you desire greater magnification and resolution or are interested in CaK or Hα solar imaging, you can add a solar filter to a larger refractor. While you

▲ **GALACTIC VIEWS** Galaxies are perhaps the most difficult target from urban locations but are still achievable. This Seestar S30 shot from the author's balcony reveals the core and dust lanes of M31 as well as satellite galaxies M32 and M 110 in Andromeda.



▲ **SPECIAL EVENTS** Transits of the International Space Station are particularly fun and can be imaged from wherever they occur. The author captured this event from his home using an Astro-Physics 92-mm Stowaway fitted with a full-aperture solar filter and a ZWO ASI294MM camera in video mode.



IMPERVIOUS TO LIGHT POLLUTION Each major planet is just as bright in the city as it is in the countryside. *Left:* The images presented here were captured by Associate Editor Sean Walker from downtown Manchester, New Hampshire, using a 12½-inch Newtonian and various high-speed video cameras. *Right:* The Sun is an excellent target for residents of any metropolis. This shot was recorded from Cambridge, Massachusetts, by Walker using a Coronado PST solar hydrogen-alpha telescope and Imaging Source video camera without tracking.

can photograph the Sun with most types of cameras, your best results come from pairing your filtered scope with a high-speed video camera in order to capture those fleeting moments of clarity (see *S&T:* October 2025, p. 62, for a guide on photographing the Sun with these filters). A monochrome camera typically produces the best images since the Sun is essentially colorless, and is also the best option if you're targeting specific wavelengths.

Our Nearest Neighbor

Like the Sun, the Moon is bright enough to be an excellent target for urban dwellers. Best of all, the Moon reveals more detail than any other celestial target. Imaging the Moon is similar to imaging the Sun, though it doesn't require specialized filters. You can photograph the Moon with any telescope and camera combination — smartscopes can take small, yet satisfactory pictures, while a DSLR, a mirrorless camera, or even a smartphone connected to the eyepiece of a small conventional scope produces good snapshots of the entire lunar disk. Even better results are had with a high-speed video camera paired with a larger telescope to record videos that can be stacked and sharpened later. And the Moon is nearly colorless, so it looks just as good when photographed with a monochrome camera as it does in color. An excellent guide to imaging the Moon appeared in last month's issue, on page 28.

When shooting in an urban setting, avoid doing so when the Moon is positioned directly over buildings or your neighbor's house, as they tend to radiate heat, which blurs the view. Additionally, setting up your gear in a grassy park is better than an asphalt parking lot that radiates the heat it accumulated during the day.

Before moving on, I should note that a thrilling project that both citybound and rural imagers can pursue is to record the International Space Station (ISS) as it transits the disk of the Sun or Moon. These events are extremely brief as it takes less than one second for the ISS to cross the lunar or solar disk, so the best camera for the job is again high-speed video. An easy way to catch a transit is to first look for events at your particular location on **transit-finder.com**, or *S&T*'s own *Satellite Transit Tool* at **https://is.gd/transittool**. Set up your

▶ **TRACK AND STACK** Many of the author's deep-sky images are taken from home with either his Seestar or one of his larger refractors on tracking mounts using the live-stacking technique. This shows his Astro-Physics 130mm f/6.3 StarFire GTX 130 atop a Rainbow Astro RST-135e strain-wave mount, with ZWO camera and ASIair control computer.

PLANETS AND SUN: SEAN WALKER / *S&T* (2); ACCESSORIES: ROBERT CAPON

ADVANCED NARROWBAND Narrowband filters can penetrate even strong light pollution and can help create some amazing images. Gowri Visweswaran of Clifton, Virginia, took this deep image of Sharpless 157 in Cassiopeia from under a Bortle 6 sky. She used an Astro-Physics 92-mm Stowaway refractor and ZWO ASI2600MM Pro camera equipped with individual S II, Hα, and O III narrowband filters as well as RGB filters. A total of 45 hours of exposure and extensive image-processing skills went into this eye-catching result.

GOWRI VISWESWARAN

scope and start recording about a minute before the predicted time, stopping about a minute or two later. High-altitude passes are best as the ISS is closest to you and appears larger, so even small scopes can resolve the silhouette of the space station and its solar panels.

Major Planets and Small Bodies

Leaving the Sun and Moon behind, the major planets also make excellent targets for urban imagers. Venus, Mars, Jupiter, and Saturn are all bright enough to be impervious to light pollution. Some of the best planetary imagers in the world shoot from big cities.

You can use any type of scope for planetary imaging, but ones with large apertures and long focal lengths are favored since the disks of all planets appear quite small compared to the Sun and Moon. Even with such a telescope, you'll likely need to add a Barlow lens or PowerMate to magnify the image enough to resolve albedo markings on Mars, the belts of Jupiter, Saturn's ring divisions, or shadow transits of their moons.

Unfortunately, smartscopes are mostly out of the running for planetary photography (though that will doubtlessly change as the technology continues to evolve), but you can still take fairly impressive shots with apertures of 4 inches or greater. Once again, high-speed video and stacking will produce the best results. And you can even take good planet photos with an untracked scope by aiming it so that the target planet drifts through the field. Even in a dozen seconds or so enough frames can be acquired for stacking and sharpening (*S&T:* August 2020, p. 58). Color video cameras yield shots you'll be proud to share with your friends and family.

Other objects in the solar system are within the grasp of city dwellers. The surprise of a bright comet can offer excellent photo opportunities even from the brightest locations. But those can be few and far between. More common are near-Earth-objects (NEOs) that are sometimes bright enough to capture with a smartscope. These NEOs can be quite interesting to watch, as they move fast enough that you can see their motion in an exposure that's only a few seconds long. Users of Unistellar's smartscopes can receive alerts for interesting NEO passes through the scope's control app, while apps like *NEO – Asteroid Tracker* for Android devices and *Near-Earth Asteroids Tracker* for iOS devices can keep you informed about these events.

Beyond the Solar System

All the targets mentioned so far are bright and relatively impervious to light pollution. Things get a bit more challenging when you focus on deep-sky objects, but there are still plenty of targets for urban imagers. Perhaps the best examples are star clusters. Unlike extended objects such as nebulae or galaxies, stars are point sources that can punch through light pollution with enough exposure. Open clusters like M11 in

STELLAR POWER Images of open clusters like the Double Cluster in Perseus (NGC 869 and NGC 884) at left or globular cluster M15 at right turn out well even from bright skies with smartscopes like the Seestar. Stars are point sources that are visible even through bright skyglow.

Scutum, the Pleiades (M45) in Taurus, M35 in Gemini, the Double Cluster in Perseus (NGC 869 and NGC 884), and the Beehive (M44) in Cancer are all prime targets. Globular clusters like M3 in Canes Venatici, M13 in Hercules, M15 in Pegasus, and M22 in Sagittarius are perfect for imaging under the pall of a washed-out sky.

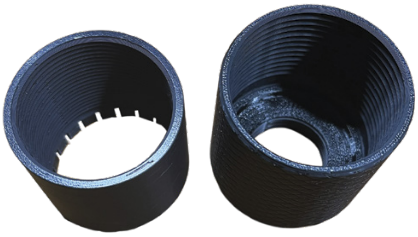
Star clusters require a tracking telescope to image at the very least, and larger scopes with a narrow field of view can produce very good images of smaller objects. Your best approach is to shoot them when they're highest, or in the least light-polluted area of your sky. Some smartscopes are equipped with built-in light-pollution filters that do an excellent job mitigating the problem. These little scopes automatically acquire and assemble many short exposures called *subframes* lasting between 10 and 30 seconds each. This technique is known as *live-stacking* and can be performed with any telescope on a tracking mount by using the camera control program *SharpCap* (*S&T:* May 2023, p. 58). Larger scopes equipped with light-pollution filters can do even better and resolve more stars.

Emission Nebulae and Galaxies

You might think that imaging nebulae from the city is a fool's errand, but that's not the case at all. You can equip a telescope with *narrowband filters*, which pass only the specific wavelengths emitted by immense clouds of ionized gases, planetary nebulae, and supernova remnants. Because these filters only transmit a very narrow sliver of the visible spectrum (typically 3 to 7 nanometers), they prevent all other wavelengths from reaching your sensor, and that includes most sources of light pollution.

Narrowband wavelengths of interest for imaging nebulae are doubly ionized oxygen (O III) at 495.9 and 500.7 nanometers, hydrogen-alpha, and ionized sulfur (S II) at 672.4 nm.

Until recently, the best way to image with these filters was to install them in a filter wheel paired with a monochrome CCD or CMOS camera and acquire long, cumulative exposures. But with the advent of duo-, tri-, and quad-band narrowband filters such as those sold by Optolong, Apertura, and others, that's no longer the case (see last month's issue, page 70). You can add one of these filters to a color camera (even a DSLR) used with a tracking scope to capture colorful images of nebulosity even under exceedingly bright



SHIELDS UP! Preventing local lights from shining directly into your telescope optics can go a long way toward improving the quality of your imaging. The author added 3D-printed extended light shields (right) for each of the scopes he uses at home.

ROBERT CAPON (3)

skies. This opens up a long list of targets in the Messier, Caldwell, NGC, IC, and Sharpless catalogs that can keep you busy for a very long time.

The good news is that you can perform narrowband imaging with Seestar smartscopes, as they include an O III and Hα duo-band filter for nebula photography, which is automatically selected when you target a nebula. There's even an upgrade kit offered by ZWO that lets you add 2-inch filters in front of the scope's objective lens so that you can take advantage of tri-band or quad-band filtering. Stepping up to a larger astrograph on a tracking mount produces even better results.

Possibly the most difficult targets to image from light-polluted locations are galaxies. There are really no special filters that help with broadband targets such as these which emit light across the entire visible spectrum. But you still can capture respectable images of the brightest examples from the city. Smartscopes are great for getting shots that reveal the spiral nature of some galaxies or at least differentiate elliptical galaxies from foreground stars. The best strategy to bag a few of these is again to target them when they're highest or where you see the least amount of sky glow. Long cumulative exposures are necessary to get enough signal so that your chosen galaxy is above the background sky levels, but it's still doable. Some bright galaxies to start with are M31 in Andromeda, M33 in Triangulum, and the Ursa Major pair of M81 and M82.

Imaging Strategies

For deep-sky objects, you can get better results by shielding your scope from direct illumination emitted by nearby sources. A long dew shield is very helpful for blocking off-axis light from streetlights or the neighbor's balcony. Alternatively, you can make a folding screen with PVC piping, fabric, and a little ingenuity.

For all of these targets, a carefully thought-out shooting strategy can go a long way toward improving your results. When using my Seestar, I activate the light-pollution filter and expose for as long as I can on a target. With my larger refractor on a tracking mount paired with an astronomical camera, I typically aim for 15- to 30-second subexposures for star clusters and galaxies. For nebulae I go as long as 3 minutes or so per subexposure through narrowband filters, and record as many frames as I can in an evening. You'll need extra exposures to accumulate sufficient signal than you would under a dark sky. This is because a large fraction of the signal you record is background light pollution, which reduces the signal-to-noise ratio (SNR) of your chosen object. A good rule of thumb is to plan to acquire some four times as many exposures for a target than you would in a dark location in order to achieve a similar SNR.

Image processing will also help you squeeze out as much as possible from your results. By far, the most important tool for any deep-sky imaging done from this city is software that corrects an uneven brightness gradient. All of your deep-sky images taken under light pollution will have

ROD MOLLISE

▲ **FILTERED NEBULAE** Even fainter nebulae like NGC 1499, the California Nebula, are within an intrepid urban imager's grasp, particularly those armed with modern light-pollution and narrowband filters.

this issue, so it's important to learn how to apply this to your data. My favorite tools are ***GradientCorrection*** and ***DynamicBackgroundExtraction*** in *PixInsight*, but there's typically some type of gradient correction found in most every astro-imaging software, and plug-ins for more general photography software like *Adobe Photoshop*. PixInsight's ***Weighted Batch Pre-Processing*** script also does a great job removing satellite and aircraft trails allowing me to salvage as many subframes as possible. Beyond correcting gradients and removing satellites, the process for stacking and stretching your deep-sky images is no different than processing data obtained at a dark-sky site.

Contrary to assumptions, plenty of quality astrophotography is within the grasp of amateurs living in a metropolis. By adjusting your technique to suit your surroundings, you can take some eye-catching images from surprisingly bright locations. The sky's the limit, even from the city!

■ **ROBERT CAPON** has observed the night sky for 50 years. He supplements his remote deep-sky imaging from the StarFront Observatory in Texas with astrophotography from his south-facing balcony near the Potomac River in Washington, DC. Visit his astrobin site at **https://is.gd/RobWashDC**.

Cooler than Cold

The Boomerang Nebula, pictured here in an image from the Hubble Space Telescope archive, has long captured my imagination. Not for what it looks like on the sky — it's 5,000 light-years away in Centaurus and too dim to see — but for what it represents. These layers of gas, shed from a dying star, are the coldest place in the universe.

The afterglow of the Big Bang bathes everything in a mild warmth known as the *cosmic microwave background*, which has a modern-day temperature of 2.73 kelvin (–455°F). In other words, even the void of space is still 2.73K above *absolute zero*, at which point heat-related motions halt completely.

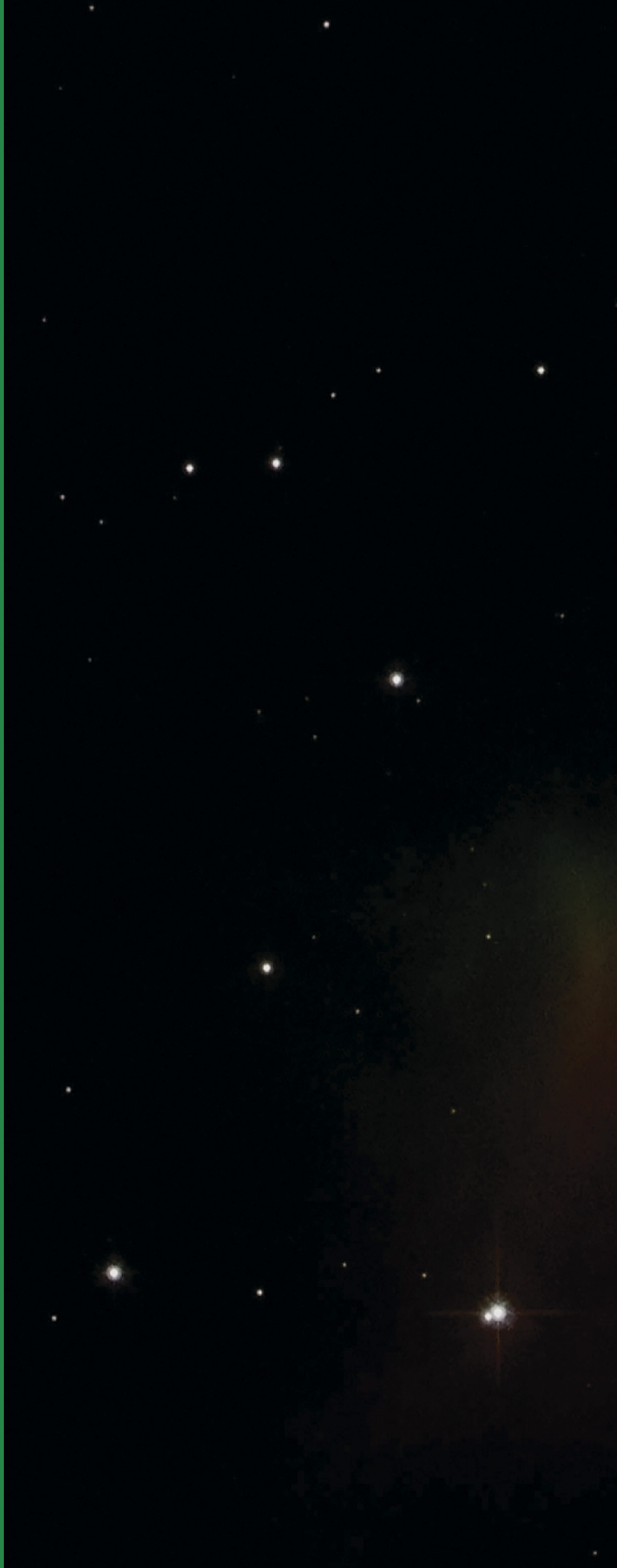
But the Boomerang Nebula shows up as a sort of shadow against this background radiation. The nebula can absorb the cosmic microwave background because it's chillier than the rest of space. Processes at play within the Boomerang are cooling parts of it to only 0.5K.

The red giant star at the nebula's heart was once at least four times the mass of our Sun. Now, most of its mass is flying outward at more than 150 kilometers per second (340,000 mph). The rainbow colors of the Hubble image capture polarized light scattered off dust grains forming within the gas.

Astronomers think that the star might have collided with a stellar companion several thousand years ago in a merger that ejected the giant's outer layers. Those layers now span some 120,000 astronomical units (roughly 1,200 times the size of our solar system). The rapidly expanding gas cools even more quickly than the cosmic microwave background can heat it up, bringing the gas it to its ultra-cold state. It's simple physics with an extraordinary outcome.

But nothing lasts forever — not even in this excessively frosty corner of the cosmos. The dying star at the nebula's heart is in the process of becoming a brilliant white dwarf. Within the next 1,000 years, its intense radiation will set the gaseous layers aglow in a true planetary nebula, and the Boomerang will warm again.

—MONICA YOUNG



Photograph by
NASA / ESA / The Hubble Heritage Team (STSCI / AURA), Acknowledgement: J. Biretta (STSCI)

ZWO's Wireless Smart Camera

The new ASI2600MC Air camera integrates several devices to take much of the frustration out of deep-sky imaging.

ZWO ASI2600MC Air

U.S. Price: $1,999
zwoastro.com

What We Like

Compact, all-in-one solution

Supports a variety of Go To mounts

Good Wi-Fi range and stability

What We Don't Like

Not compatible with most third-party accessories

Off-axis guider requires a large image circle

**Prices subject to change*

THERE'S NO QUESTION that ZWO's ASIair minicomputer has changed the way many of us perform deep-sky astrophotography. Introduced in 2018, the small device was the first commercially available product of its kind that automated many of the tedious and often error-prone tasks of getting an imaging rig ready for shooting for an evening. Wireless control, via a mobile device, allowed astrophotographers to escape mosquitoes or brutal cold and image remotely, even if "remotely" was only 15 feet away in a vehicle or tent. We've reviewed this groundbreaking product twice now during its evolution — the original ASIair unit in September 2019, and most recently the ASIair+ in our May 2022 issue, page 66.

Now ZWO has embedded its tiny computer directly into a camera to further simplify the imaging platform. We borrowed the color version, the ASI2600MC Air, to see how it performs. The company also offers a monochrome version, the ASI2600MM Air.

Fit and Finish

The ASI2600MC Air is built around one of the current favorite CMOS sensors in use today, the Sony Starvis IMX571. This APS-C format detector has 3.76-micron pixels in a 6,248-by-4,176 array measuring 23.5 × 15.7 millimeters. The camera produces true 16-bit data and the sensor's quantum efficiency is 80%. The Sony detector uses a standard Bayer color filter array in a RGGB pattern.

ZWO has gone even further than just embedding their computerized system into the camera — they've also included a smaller, secondary sensor for on-axis

▲ ZWO's new ASI2600MC Air camera packs a lot more than just a sensor into its red-anodized housing. The device contains an ASIair control computer accessed with the ASIair app (seen above) running on an Android or iOS device via Wi-Fi.

◀ The camera ships with most of the cables and spacers needed, including Velcro strips to help keep your cables tidy (see the accompanying text for details).

ALL IMAGES ARE BY THE AUTHOR

▲ *Left:* The camera includes two detectors — an APS-C-size imaging sensor and a smaller one for autoguiding mounted nearly 19 mm (¾ inch) above it. Given the guider's distance from the center of the field, a 43-mm imaging circle is required to ensure the guide sensor sees any stars. *Middle:* An external antenna threads into the back of the camera to maximize the range of its Wi-Fi network. *Right:* The ASI2600MC Air includes a four-port USB-A hub, a USB-C port, and three-port, bi-directional power hub. Users power the device by plugging a power cable into any of the three power ports, and the other two are then used as power outputs.

autoguiding. This SmartSens Technology SC2210 monochrome chip has an array of 1,920 × 1,080 with 4-micron pixels measuring 7.68 mm × 4.32 mm that's seated 18.85 mm above the primary sensor. Doing so eliminates the need for an external autoguiding camera and any off-axis pick-off system or guidescope in most cases. This design was first pioneered by SBIG (Santa Barbara Instruments Group) in the 1990s with their ST-series dual-sensor CCD cameras.

Both sensors in the ZWO unit are mounted 17.5 mm from the front of the housing, which is threaded to accept M54 accessories. The camera comes with both 16.5-mm- and 21.0-mm-thick spacers, and an M54-to-M48 zero-profile adapter ring that takes up no additional backfocus. Together this gives you a flexible set of extenders that position the sensor 55 mm from the rear optic of most reducers and correctors and allows users to add an additional ZWO filter wheel if desired.

Also included are an external, hinged antenna for improved Wi-Fi performance, a set of Velcro strips for cable management, and an assortment of cables: a 1.5-meter male-to-female power extension cable, a 1-meter male-to-male power cable, and two ½-meter USB-A-to-USB-B cables. There is no power brick included with the camera, and all power connections are via standard 2.1 mm barrel connectors. Also provided is a 2-mm M2.5 hex wrench for adjusting the integrated tip/tilt adapter for fine-tuning your camera's alignment.

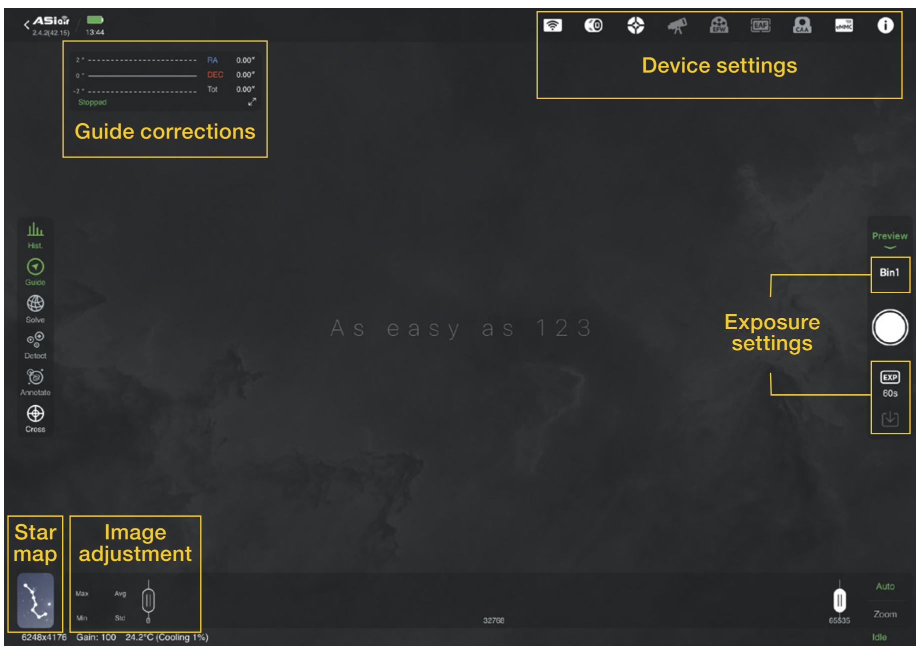
One limitation of the ASIair line of products is a closed technological ecosystem that doesn't communicate with accessories from other companies. The ASI2600MC follows the same trend. While it works with and controls most third-party Go To mounts, it cannot communicate with astronomy cameras, filter wheels, or auto focusers from other manufacturers.

More Than a Camera

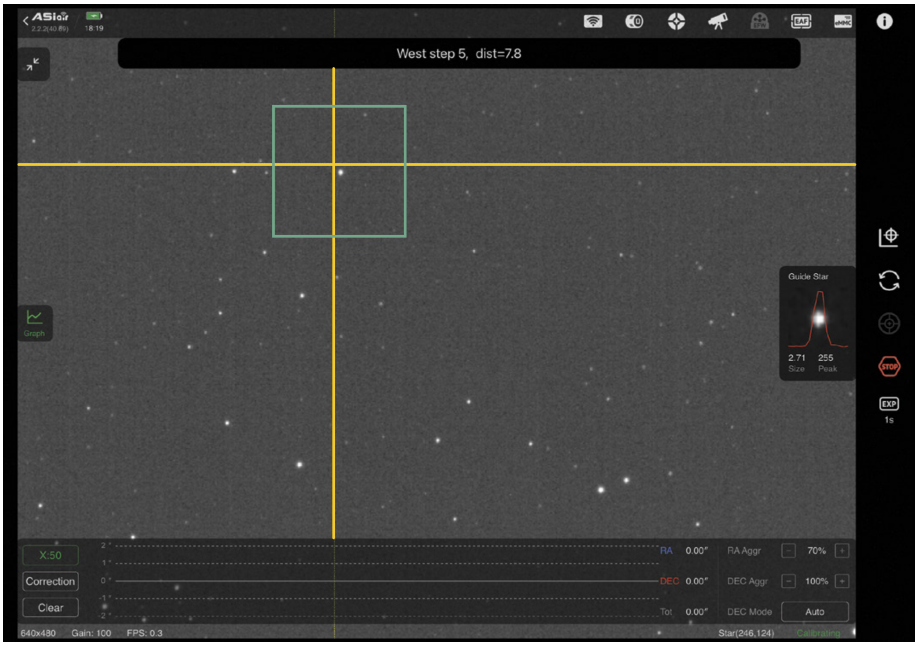
The ASI2600MC Air itself not only acts as a camera and a control computer, but also as a power and connectivity hub for additional devices such as the company's EAF focus motors or its EFW filter wheels. These are connected via four USB-A ports and one USB-C port on the rear of the camera body. Note that none of these ports operate at USB 3.0 speeds, which makes sense because images produced by the sensor transfer directly to its onboard ASIair computer. However, when moving files from the internal memory to an external drive, a USB 3.0 connection might have been nice to speed things up a bit — it often took several minutes to copy a night of data to an external drive for processing on my main computer.

There are three 2.1-mm, 12-volt DC-power ports on the back of the camera. Any one of the three accepts power, and you can use both of the other two to power additional accessories, such as dew-prevention straps or even your mount. ZWO specifies the camera needs at least 3 amps for proper operation, and the system accepts up to 10 amps.

The integrated ASIair computer has 256 GB of eMMC onboard storage and 2 GB of RAM. The system is controlled via the *ASIair* smart-device app loaded on an Android or iOS device via built-in Wi-Fi. This Wi-Fi operates at both 2.4GHz, which is better for longer dis-



▲ The *ASIair* control app contains everything you need for imaging. Icons along the top right provide access to settings for each feature or connected accessory. Clicking on the Big Dipper icon at bottom left opens a planetarium program that makes easy work of finding and framing targets.



◀ The autoguider calibration gave this seasoned astrophotographer some anxiety, but the app can be trusted to do the right thing. After clicking the calibrate icon at right, it quickly selected a guide star, performed movement measurements in both axes, then started guiding.

tances or when there may be multiple obstructions in your line of sight, and at 5 GHz when you are closer to the camera. ZWO claims a connectivity range of up to 20 meters (about 66 feet). Despite some reports from the ASIair's earlier days, I found the connection to be quite robust paired to either my Mac laptop or iPad, when both outdoors and from inside my house. It also includes Bluetooth wireless connectivity, but this only works to connect to the ZWO AM3 or AM5 mounts, which I didn't test.

Seestar on Steroids

When paired with a Go To mount, the ASI2600 Air turns an existing telescope system into a ZWO smartscope of sorts. If you're familiar with the ASIair or a Seestar, you know how to use this camera. As soon as it's powered up, it states "Powering on, waiting for connection." Then you open the *ASIair* app and connect to the camera. It's not necessary to repeat the deep dive into the ASIair or Seestar we made previously, but I'll summarize that it's the most painless imaging experience I've had to date. The system can even perform just as a Seestar does, aiding with polar alignment, and allowing you to pick and frame targets in the app with its star map. You can also live-stack each exposure as it comes off the sensor.

I'd never used an ASIair myself before this review and was pleasantly surprised at how easy it was to set up and get running on its first night under the stars. Everything just worked with very few adjustments compared to what I was used to with my other imaging rigs.

One of my biggest pet peeves with modern imaging is all the cables needed to make the gear work together. By integrating the computer into the camera itself, ZWO has done a great deal to simplify this. I used this camera mostly with a Sky-Watcher Wave 150i mount, which has a single power and USB input. This turned out to be a perfect pairing with this device. One cable went from the USB-C port of the camera into the mount, and no other power cable was necessary. Only one additional USB cord was needed as well, and that was the included short line to the EAF focuser (also loaned from ZWO for this review).

Over several months I used the camera with a Sky-Watcher Quattro 150 (reviewed in the September 2024 issue, p. 66) for most of this review. In addition to the Wave 150i, I also had success shooting with it on a Sky-Watcher Star Adventurer GTI and a Canon 200-mm lens. Switching the camera to different telescopes, I found that the on-axis autoguiding sensor isn't entirely the panacea one might think. Autoguid-


The author captured this 50-minute exposure showing the Horsehead Nebula in Orion using 5-minute subexposures with the rig shown on page 70.

ing with a second sensor mounted next to the main sensor can make finding a suitable guide star challenging compared to having the versatility of a separate guidescope and autoguiding camera, or even one in an off-axis guider. With either external option, you can adjust their pointing independently from the main camera.

Another important consideration is the telescope you plan to pair this camera with. Off-axis autoguiding works quite well, if your optical system produces a light cone that can accommodate the autoguider's off-axis position. Most telescopes today sufficiently illuminate the 28.3-mm-diameter image circle required by the ASI2600MC's main sensor. But note that to illuminate the secondary autoguider sensor you'll need a scope that yields about a 43-mm image circle. I found pairing the camera with a Sky-Watcher Quattro 150 and its coma corrector blocked most of the light from reaching the autoguider's sensor. In this case, I used a second guidescope and an ASI120MM camera to autoguide. This was easy with the built-in USB hub where I connected the external autoguider. The control app instantly recognized another ZWO camera when it was plugged into any of the USB ports on the back of the ASI2600MC Air. The device is then offered as a choice to use as the guiding camera.

I suspect users of the monochrome version of this camera, the ASI2600MM Air, will likely be employing the external guide port more often than those with the color version. With an added filter wheel and color filters needed to produce tri-color images, the guider chip also looks through the filter placed inline. This in turn makes faint guide stars even fainter, particularly when imaging through narrowband filters.

As long as the guiding chip can see stars, it can autoguide with them. That goes the same for ugly, deformed stars, too. When using the camera paired with a 200-mm Canon lens, I was surprised that my guide stars were quite messy at the extreme edge of the field. Nevertheless, the *ASIair* software picked

▲▶ Wright mated the ASI2600MC Air to a Canon 200-mm lens, an EAF focuser, and a Sky-Watcher Star Adventurer GTi mount seen at right to image the Rho Ophiuchi nebula complex along the border of Scorpius and Ophiuchus. The resulting photo above is a stack of 98 individual, 1-minute exposures.

a guide star, calibrated, and did a fair job of autoguiding even with far-less-than-perfect off-axis stars.

Outside the ZWO Ecosystem

If the ASIair system isn't for you, the ASI2600 Air cameras are usable just like a non-air model and can be controlled by third-party software. While there's no provision to directly connect to the camera with a USB cable, you can communicate with it via its Wi-Fi using either the *ASI Studio* software (a free download for Windows and Macintosh computers), or as an ASCOM Alpaca device on your local network. I joined its Wi-Fi network using my MacBook Pro, and the *ASI Studio* software. Downloading images over the 5G Wi-Fi network is a bit sluggish — it takes about 15 seconds to download each 26-megapixel image via the 5G connection.

The camera will also serve as an ASCOM Alpaca server and can be controlled from other third-party software. I tried this on the desk only with both *N.I.N.A.* and *TheSkyX Professional* desktop software. Honestly, using it this way was clumsy compared with the smooth and curated experience of the *ASIair*, but the capability is there if necessary.

With computers continually getting smaller and more powerful, the ASI2600MC Air is a smart step forward in ZWO's march toward portable, easy-to-use astrophotography gear. Paired with a good astrograph and a Go To mount, the system gives an advanced Seestar experience. Its 26-megapixel color sensor produces excellent data that should satisfy even the most demanding astrophotographers. Its onboard guiding works and the device includes provisions for the times when that method isn't the ideal choice. The *ASIair* software eliminates much of the chore of autoguiding while also significantly reducing the number of cables that can cause grief in the field. I think it's a keeper.

■ Contributing Editor **RICHARD S. WRIGHT, JR.** has used minicomputers and iPads for deep-sky imaging for more than a decade.

Carlin's Shadow Collimation

Here's a fresh way to align the optics of your fast reflectors.

◀ Stalder's illumination source for his collimation device consists of an LED flashlight that he's inserted into the open end of a 1¼-inch Cheshire collimation eyepiece.

THESE DAYS, I swear by the star test as the ultimate collimation "tool." After all, satisfactory star images are what visual collimation is all about. The other methods I like to use all hinge on tight machining like lasers, Cheshire eyepieces, and collimation caps. So, when Swiss physicist Roland Stalder described an easy, flashlight-based technique that he uses on his 12-inch f/3.7 Dobsonian, I was skeptical — at least until I tried it myself.

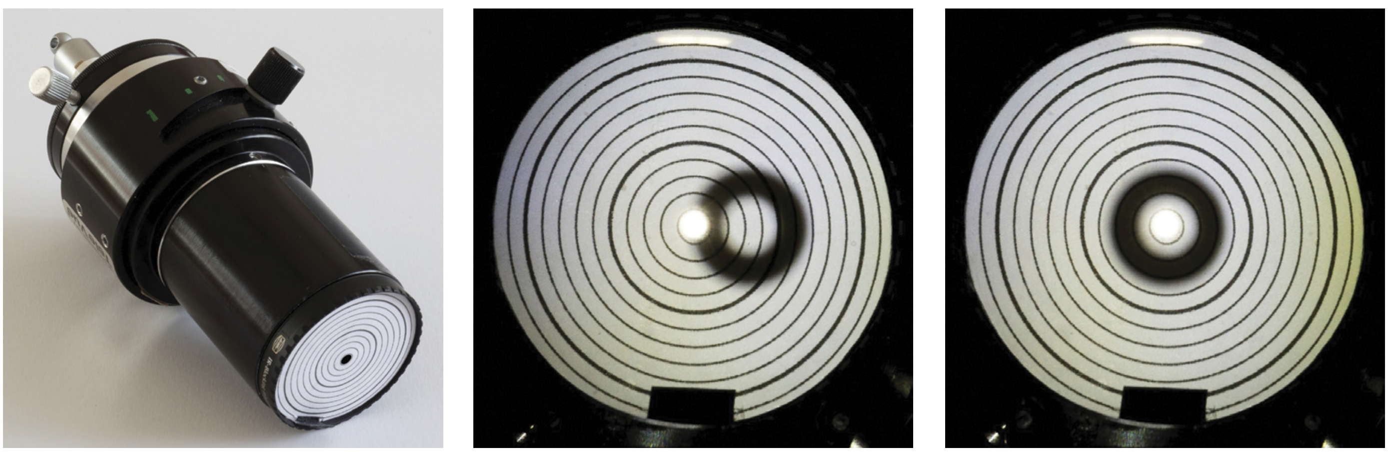
My first Newtonians had focal ratios of f/8 or slower. Collimation difficulty scales up with decreasing f-ratio; at f/8, I consider collimation more a state of mind than an exacting science (that is to say, trivial) — a collimation cap or even an empty drawtube will suffice. My faster telescopes have the benefit of having collimation mechanisms within reach while at the eyepiece, so the star test is only a natural choice. For my little 6-inch f/3 rich-field telescope, things are trickier.

The relationship between f-ratio and the collimation "sweet spot" size is cubic (axial tolerance in millimeters is roughly $0.005 \times f^3$). So, an f/8 mirror has eight times more room for error here than an f/4. This means the margin for alignment error a discerning viewer has in a fast scope becomes tiny, and using a laser collimator won't necessarily fix this.

Swedish ATM Nils Olof Carlin (whose work Stalder builds upon) explained that the reported error seen while aligning via a narrow-beam laser is the average error in primary tilt, and any other tilt in the optical system (focuser, laser, and so on). In *Sky & Telescope*'s January 2003 issue, Carlin presented his invention, the Barlowed laser. Here, a laser is paired with a screen and a Barlow lens. This makes the beam slightly diffuse, like that of a flashlight. This diffuse beam is less sensitive to tilt at the secondary, focuser, or even the laser body itself — commercial lasers often arrive untrue to their own axis.

This puffy laser point makes the center mark on the primary mirror cast a shadow in the return beam, which is then centered on a shadow screen placed in the focuser. The method reportedly works well in the dark, and it magnifies any collimation error, showing twice the displacement (due to the beam going down to the primary and back).

Stalder had practical reasons to update this method. Like me, he



▲ *Left:* A screen is threaded onto a Tele Vue Paracorr, with the LED flashlight inserted. Stalder has drawn lines every 2 millimeters from center, with the 10- and 20-mm marks bolded for easy reference. *Middle:* The reflected silhouette of the parabolic mirror's center mark, made with a reinforcement ring sticker. The ring's shadow is offset by 6.5 mm, which is exactly half that distance in off-axis error. *Right:* The shadow is centered on the illuminated hole, indicating proper collimation.

ALL IMAGES COURTESY OF ROLAND STALDER

▲ Stalder with his 12-inch f/3.7 Newtonian in the Swiss Alps, where he enjoys dark skies and speedy collimation.

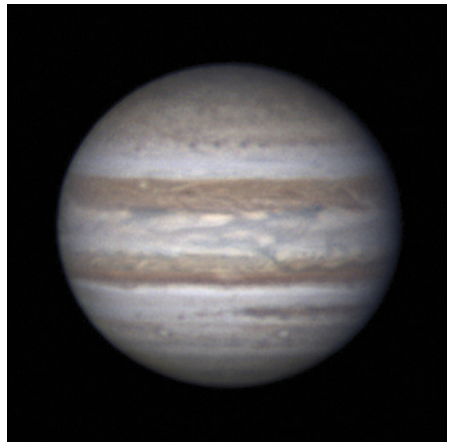
views the fast Newtonian as a system completed by the addition of a coma corrector — to him, the absence of this optical element is a shortfall of most collimation setups. "Ideally, collimation is done with the complete telescope optics involved," he notes. "Additional optical elements, which aren't used during observation, are best avoided." Lasers are also a problem. Besides some handheld models being illegal in his country, lasers are somewhat unsafe, often producing far-higher output wattage than advertised. They're also prone to speckling, even when passed through a diverging lens.

So Stalder tossed the Barlow lens, instead leaving the coma corrector in place. His device is straightforward: A small, matte screen with a bullseye pattern is attached to the front of the corrector. This slips into the focuser, and he wedged a flashlight into part of a Cheshire collimation eyepiece, which is next installed behind the corrector. This arrangement then shines into the tube at the primary mirror through a 2-mm hole in the matte screen. No precision machining is necessary; someone especially dedicated could make one with a pen, a compass, and a pair of scissors. Other materials needed include a bright flashlight that fits into the drawtube, a center-marked primary, and a coma corrector, if you observe with one.

While this technique is quite similar to Carlin's original, the name was a bit of a problem — it uses neither a Barlow nor a laser! Still, wanting to credit the late Carlin, Stalder calls it "Carlin's shadow method."

To make a faithful copy of Stalder's collimator, the first piece is the screen. This is simply a disk that's then affixed to the coma corrector via its M48 × 0.75 filter thread. With care, you can 3D-print a threaded housing; otherwise, a spare 2-inch filter cell is perfect. The screen's 2-mm hole and measurement reticle must be positioned with as much precision as one wants to get from the collimation. But the precision ends there — the flashlight's diffuse light simply needs to be pointed down the focuser. Spacer rings, 3D printing, and a thick wad of tape all do the job. Lastly, once this is all put together, turn the flashlight on and look for a large shadow of the center spot; if this is centered, you're good to go.

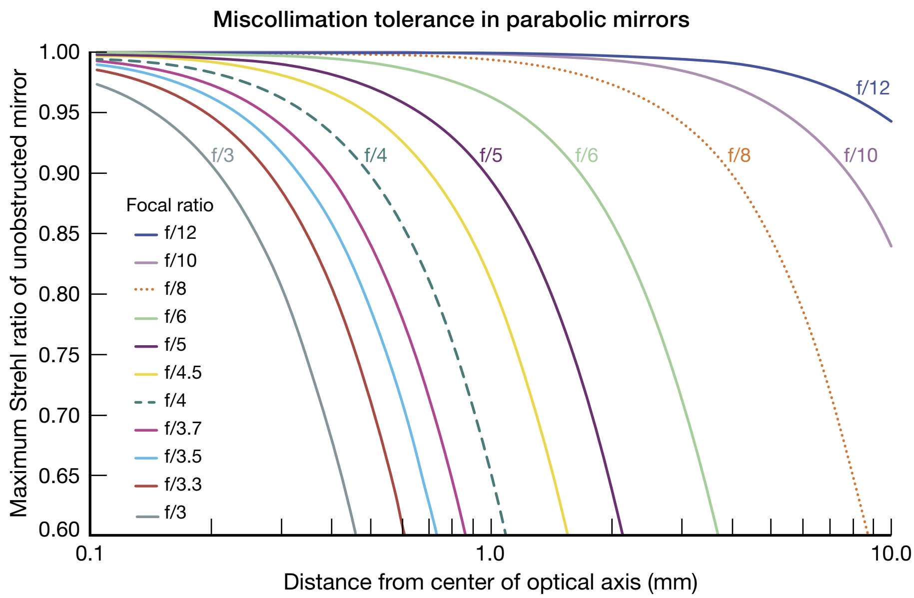
"I am using this updated method with my 12-inch f/3.7 Newtonian and enjoy its accuracy and simple execu-



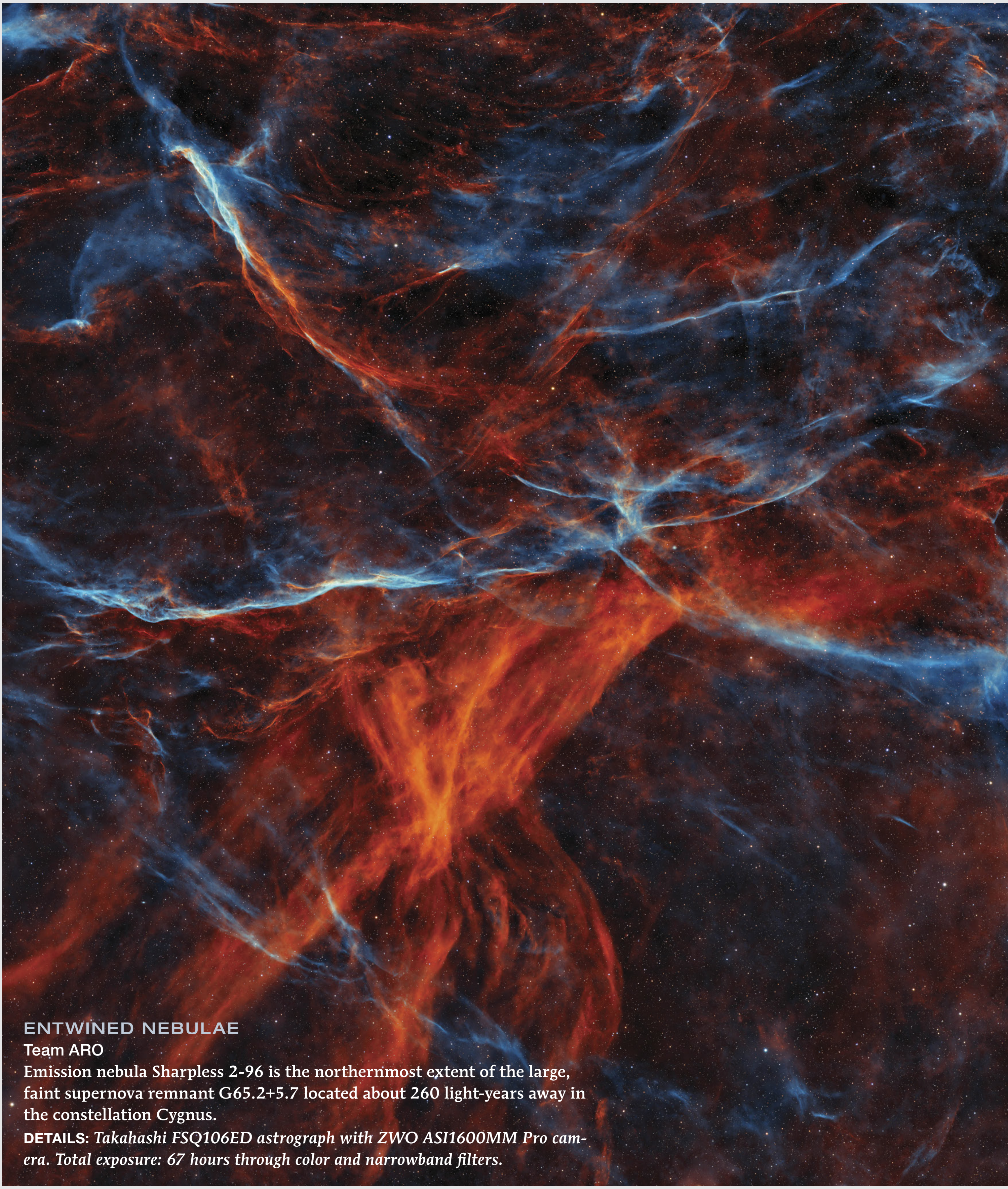
▲ Stalder's image of Jupiter shows a crisp limb and clear festoons that are the result of precise collimation.

tion," said Stalder. His approach elegantly sidesteps all the problems he outlined. No extraneous optical elements, no laser speckling, no legal liabilities. And more importantly, collimation is done with the final optical arrangement, corrector and all. "The method is speedy and elegant," he adds. "It can be done with any small torch (flashlight), and the result is easily repeatable."

■ Contributing Editor **JONATHAN KISSNER** is glad to add another trick to his collimation toolbox.



▲ The Strehl ratio is a measure of an optical system's ideal performance, roughly corresponding to how much energy is concentrated into the Airy disk. By convention, 0.8 (or 80%) Strehl is accepted as "diffraction limited" or good enough. Here, we see the relationship between focal ratio and how collimation error affects the maximum Strehl ratio.



ENTWINED NEBULAE

Team ARO

Emission nebula Sharpless 2-96 is the northernmost extent of the large, faint supernova remnant G65.2+5.7 located about 260 light-years away in the constellation Cygnus.

DETAILS: *Takahashi FSQ106ED astrograph with ZWO ASI1600MM Pro camera. Total exposure: 67 hours through color and narrowband filters.*

WHITE MOUNTAIN FIREBALL

Erik Fraser

This brilliant fireball blazed across the sky over Bartlett, New Hampshire, at precisely 11:26 p.m. on the evening of October 17, 2025.

DETAILS: *Sony α7R V camera with 24-to-70-mm zoom lens at 24 mm, f/2.8. Total exposure: 8 seconds at ISO 6400.*

TWISTED TAIL

Devesh Pande

In the early evening of October 26th, the long, blue ion tail of Comet Lemmon (C/2025 A6) appears to twirl off into space as it passed Beta (β) Serpens Caput.

DETAILS: *William Optics Fluorostar 91 refractor with Player One Poseidon-M Pro camera. Total exposure: 21 minutes through Antlia RGB filters.*

△ STILL GOING . . .

Gerald Rheman and Michael Jaeger

Comet Lemmon continued to produce a long, forked ion tail and curved whitish dust tail weeks after reaching perihelion on October 21st.

DETAILS: *ASA 12-inch Newtonian astrograph with ZWO ASI6200MM camera. Two-panel mosaic, each exposure totaling 13 minutes through LRGB filters recorded on November 10, 2025.*

▽ ALL LIT UP

Chirag Upreti

Bright red and green aurorae pierce the clouds above the Tarrytown Lighthouse in Sleepy Hollow, New York, during the huge geomagnetic storm on November 11, 2025.

DETAILS: *Sony α7R III camera with 14-mm lens operating at f/2.8. Total exposure: 2½ seconds at ISO 1600.*

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Event Calendar

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

February 6–7
EUROPEAN ASTROFEST
London, England
europeanastrofest.com

February 6–8
DEATH VALLEY DARK SKY FESTIVAL
Death Valley National Park, CA
https://is.gd/DVNPDSF

February 16–22
WINTER STAR PARTY
Scout Key, FL
scas.org/winter-star-party

March 7
TRIAD STARFEST
Jamestown, NC
https://is.gd/tristar

April
GLOBAL ASTRONOMY MONTH
Everywhere!
https://is.gd/GlobalAstroMonth

April 11–12
NORTHEAST ASTRONOMY FORUM
Suffern, NY
neafexpo.com

April 13–20
INTERNATIONAL DARK SKY WEEK
Everywhere!
idsw.darksky.org

April 22–25
MIDSOUTH STARGAZE
French Camp, MS
rainwaterobservatory.org/events

April 25
ASTRONOMY DAY
Everywhere!
astronomyday.astroleague.org

May 10–17
TEXAS STAR PARTY
Fort Davis, TX
texasstarparty.org

June 6–13
GRAND CANYON STAR PARTY
Grand Canyon, AZ
https://is.gd/GrandCanyonStarParty

June 10–14
ROCKY MOUNTAIN STAR STARE
Gardner, CO
rmss.org

June 11–14
CHERRY SPRINGS STAR PARTY
Cherry Springs State Park, PA
https://is.gd/CherrySpringsSP

July 14–19
OREGON STAR PARTY
Indian Trail Spring, OR
oregonstarparty.org

July 12–17
NEBRASKA STAR PARTY
Valentine, NE
nebraskastarparty.org

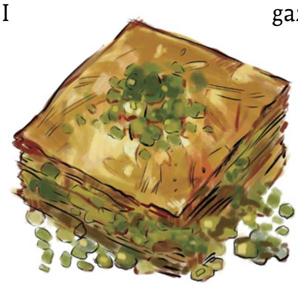
July 14–18
WASHINGTON STATE STAR PARTY
Jameson Lake, WA
tmspa.com

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

Sated by Astronomy

A particular type of food looms large in this astronomer's memory.

ONE THING THAT I've learned over the years is that astronomy is best done on a full stomach. Many is the night I've sat engrossed chasing faint fuzzies when, suddenly, a menacing growl permeates the night. Then I realize — it's not coming from the nearby trees but my stomach! I interrupt for a snack, but not just anything will do — it'll have to be baklava. It's not only a sweet treat, but it's also a bittersweet memory.



Years ago, as a reporter in Ontario's Muskoka cottage country, I participated in establishing one of Canada's first Dark-Sky Preserves, the Torrance Barrens. This was an effort spearheaded by Muskoka residents Mike Silver and Peter Goering who were joined by someone whose name many of you will likely recognize: noted astronomy author Terence Dickinson.

One particular weekend, I joined some fellow amateur astronomers from Toronto to christen the new dark-sky preserve. The celebration involved two clear nights of moonless — and light-pollution-less — observing. I reveled in being surrounded by dedicated star-gazers. But the highlight was sharing some baklava that someone brought — that sugary wonder-food made the evening even better!

Sadly, Terry passed away on February 1, 2023. But his legacy of bringing astronomers together to enjoy the stars (and something tasty to boot) lives on.

Baklava looms large in another bittersweet memory. Some time back, I gathered with three friends from Sudbury, Ontario — Harold, Donna, and Lynn — for an intense night of tackling deep-sky challenge objects. Lynn also taught at our local community college, which had a culinary program, and for that night she had procured baklava, of all things. Lynn and Harold have since passed away, but the taste of baklava still brings a smile at the memory of my friends.

Stargazing sessions with friends is one thing. But, it's the big events like star parties that offer an experience to feast on that involves more than just stunning dark skies!

I'm fortunate to have attended Starfest, Canada's premier star party held every August in Mount Forest, Ontario. The talks are inspiring and informative. The clear nights are dark and filled with the buzz of new and experienced astronomers alike as they discuss the amazing celestial sights. But the highlight for me has got to be the food. Oh, the food!

It can start small. It can simply be a shared meal between friends at the campsite after the hard work of setting up tents. Or it can be a cup of steaming hot cocoa that's just come off someone's camp stove. One of the memories that lives happily rent-free in my head is when on an unseasonably chilly morning, waiting for breakfast, someone quipped that we were having the "warmest winter on record" . . . this was in August! Maybe it was the chill, but the sausages and pancakes smothered in maple syrup that morning were like ambrosia.

And then, there's the Saturday night banquet. I have many a mouth-watering memory of juicy roasts, succulent vegetables, and to-die-for mashed potatoes swimming in a veritable ocean of gravy.

Surrounded by old friends and new, we all dine together as the buffet tent is filled with excited voices — stories of astronomical adventures and hope for the future rising into the night air.

It's moments like this that we realize that food is more than simply a meal. It's the glue that keeps our community together. And maybe there'll be some baklava.

Bon appétit!

■ **ANDREW WAREING** is an avid amateur astronomer based in Sudbury, Ontario. Baklava is now a fixture of his observing sessions.

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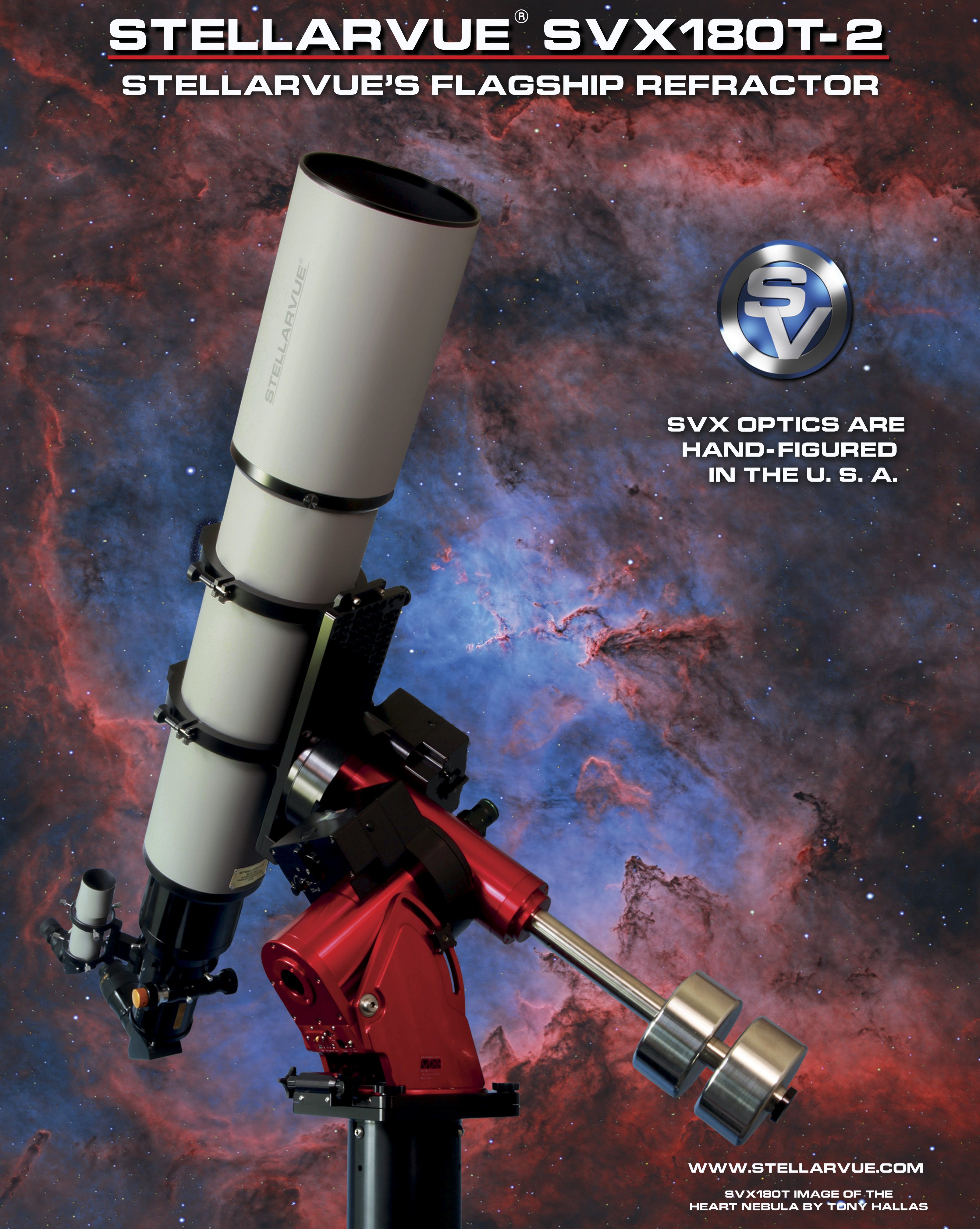
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