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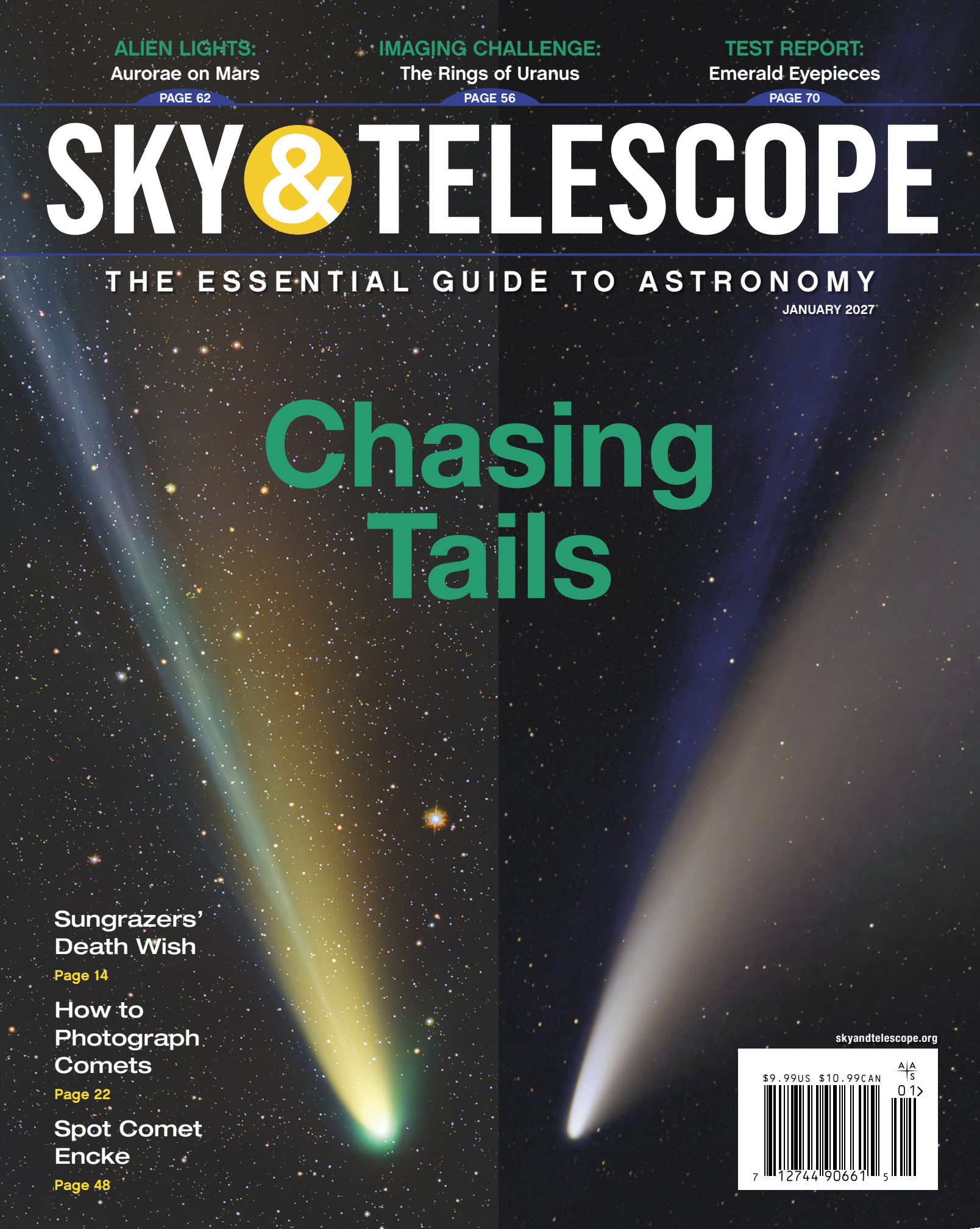
THE ESSENTIAL GUIDE TO ASTRONOMY

JANUARY 2027

Chasing Tails



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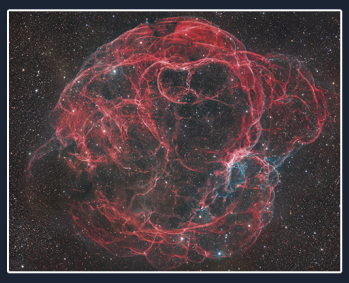
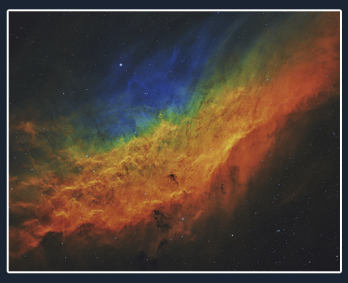


The Spaghetti Nebula
Image Credit: Matt Harbison



NGC 1499, the California Nebula
Image Credit: Terry Hancock



The Soul Nebula
Image Credit: Terry Hancock



Alnitak, Alnilam, and Mintaka
Image Credit: Matt Harbison

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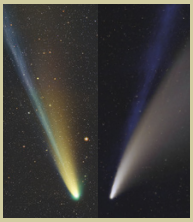

Celestial visitors C/2025 A6 *(left)* and C/2020 F3 *(right)*
PHOTOS: CHRIS SCHUR (2)

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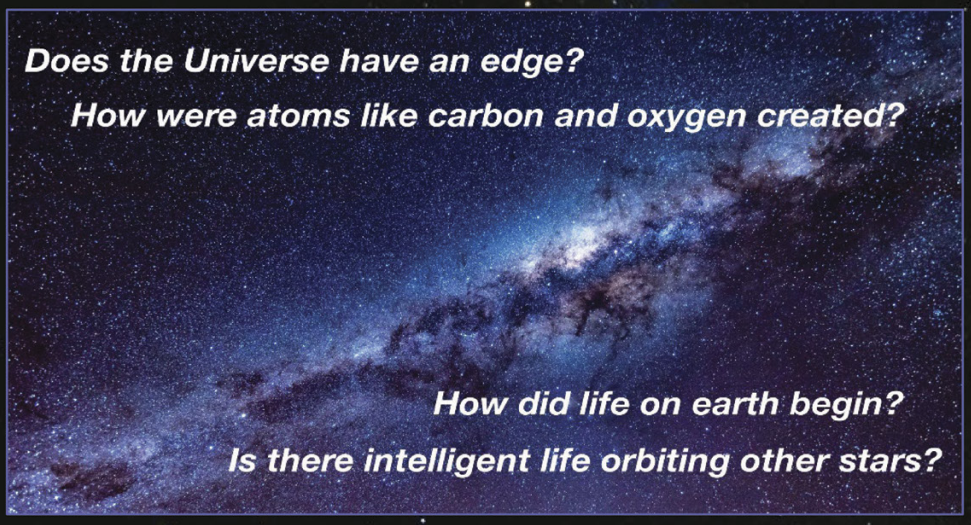

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Frosty Subjects

HAPPY NEW YEAR! We have myriad celestial treats to help usher us into 2027, lucky us!

To begin with, who doesn't love a good comet? I'd venture that most of us do. We collectively relish every time one of those icy dirtballs from the farther reaches of the solar system delights us with a visit. And to whet our appetites, we've packed the pages of this issue with two feature articles on comets.

First, Douglas MacDougal regales us with tales of *Kreutz sungrazers*, objects that zip around the Sun at terrifyingly close quarters. Ultimately, the fate of these cometary kamikazes is either to fragment or to self-immolate in the Sun. MacDougal traces the histories of some of these remarkable objects back to an intriguing origin, starting on page 14.



▲ Comet C/2022 E3 passes Mars on February 11, 2023.

While it's a real treat for our eyes to witness comets as they grace the skies, some might consider it more satisfying to freeze their ethereal passages in frames for posterity. On page 22, seasoned comet photographer Chris Schur presents a comprehensive guide on how to best capture these icy visitors. It would behoove you to heed Schur's advice when you next gear up to catch a celestial snowball, lest overconfidence leave you unprepared.

But what fun would all this be without a *real* comet in the sky to chase? On page 49, contributing editor and comet curator Bob King advises us on how to spot Comet 2P/Encke. It'll be a challenge, but I'm sure it will be well worth it.

Happy comet hunting, be it with your eye or a digital detector!

Before you step outside to search for gems in Orion (page 53) or treasures from the first *Index Catalogue* (page 34), do take the time to read Contributing Editor Ken Croswell's fascinating breakdown of how the structure of the Milky Way close to home plays into what we see this time of year. I guarantee it will give you a new perspective as you seek out, for example, the open clusters M35, NGC 2158, and NGC 2244. And, if you're stepping outside at the more frigid, northerly latitudes, you might first want to read Doug Newman's frosty tale of woe on page 84 — and ensure that the same fate doesn't befall you!

The new year often means new beginnings. After nine years scribbling Sky at a Glance in these pages, I'm happy to pass the baton to Associate Editor Meg Thacher. I know she's going to do a sterling job of it, and I'm sure you'll all agree with me.

Have fun observing, and please do let us know if you catch a comet or two.



Editor in Chief

SEAN WALKER

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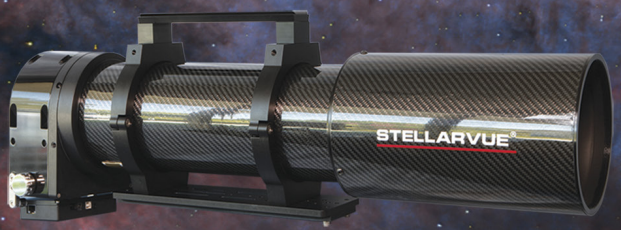

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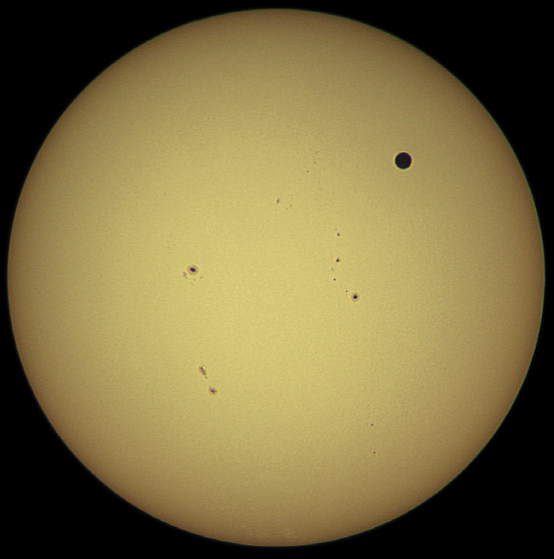
SVX180T IMAGE OF THE HEART NEBULA BY TONY HALLAS

Swell Beginner Scope

I just wanted to commend Joshua Roth for his endorsement of the Celestron Astromaster 70AZ as a good scope for a beginner in "Four Scopes for New Observers" (*S&T:* Aug. 2026, p. 70). I was pleasantly surprised by the smooth and stable mount, and the optics are pretty good as well.

Jeff Phillips
Eugene, Oregon



▶ Jeff Phillips captured this transit of Venus with his Celestron Astromaster 70AZ, a solar filter, and a Canon Powershot camera a few years back.

Exeligmos Experience

Joe Rao's "Turning the Eclipse Wheel" (*S&T:* Aug. 2026, p. 84) brought to mind the realization that I had achieved an exeligmos experience in Granbury, Texas, at the Great American Eclipse of April 8, 2024. Fellow eclipse chasers had to remind me that my first solar eclipse on March 7, 1970, was 54 years and 32 days prior to the Texas event.

On that clear day in 1970 I flew one of our flying club's aircraft from New Jersey to South Norfolk, Virginia, to experience what became a life-changing event for me. In between these two eclipses were 10 others that shaped my almost lifelong love affair with amateur astronomy.

Phil Zollner
Howell, New Jersey

Joe Rao replies: *It's not at all surprising that Phil Zollner's first total solar eclipse was the March 7, 1970, event. Indeed, many amateurs began their eclipse-chasing careers with this event, which paralleled the U.S. East Coast.* Sky & Telescope *likely "jump-started" the excitement with a feature article written by eclipse expert Charles H. Smiley in the March 1968 issue. The March 1970 eclipse is a member of saros cycle 139. Other members of this family include March 18, 1988, visible from Sumatra, Borneo, and the Philippines; March 29, 2006, visible from Africa, Turkey, and Asia; as well as the aforementioned April 8, 2024, eclipse, which crossed Mexico, the United States, and eastern Canada.*

Colonial Eclipses

I read Stephen O'Meara's "The Heavens in 1776" (*S&T:* July 2027, p. 12) about the celestial fireworks happening near the time of our nation's birthday with much interest. I would like to make an addendum to this fine article, if I may.

A solar eclipse occurred on June 24, 1778, that was visible throughout the colonies, and later in the day in Great Britain as well. My source for this information is Fred Espenak's *Thousand Year Canon of Solar Eclipses 1501 to 2500*. This was a major event: At least 75% of the Sun was eclipsed everywhere in the colonies. The path of totality came ashore in Louisiana, tracked northeast through northern Georgia, western North Carolina, Virginia, then out to sea to be viewed as a 50% partial in Great Britain later. The northern edge of totality just missed Cape May, New Jersey. Therefore, most of New Jersey experienced at least a 90% partial eclipse.

The British began their withdrawal back to New York from Philadelphia on June 18th, and so they were on the move when this eclipse happened. Assuming clear skies, the British troops would've noticed it — even a 75%-covered Sun mutes the light enough for people to detect. (The Sun was 60% covered in Florida during the October 2023 annular eclipse, and I noticed.) Of course, the colonial army in Valley Forge would've seen it, too. Washington chased and caught up to the British rear guard in New Jersey, and the Battle of Monmouth was fought on June 28th on fields that only four days previously had experienced a greater than 90% partial eclipse. I wonder if Mount Vernon was in the path of totality?

Scott Galbraith
Zephyrhills, Florida

Stephen J. O'Meara replies: *Thanks so much for sharing your thoughts about the 1778 eclipse over the colonies. I was aware of it, but considered it a little too outside the scope of the article, which was to focus on the events of 1776. However, in my original article, I did write about the January 1777 solar eclipse. Unfortunately, due to space constraints, it was edited out from the final version. I believe the content of that cut might be of interest you. Here is what I wrote:*

> *After crossing the Delaware, and while encamped in New Jersey, George Washington was alerted by letter of an impending partial solar eclipse on January 9, 1777, so that he may "guard against a superstitious fear in the Army." Washington agreed, replying that "this event, without a previous knowledge of it, might affect the minds of the Soldiery, and be attended with some bad consequences.*

Planet Crumbs

I enjoyed Meredith Hughes's "The Wonder Years" (*S&T:* Aug. 2026, p. 34), but one thing I didn't understand was why "the leftover crumbs of planet formation . . . collide and grind themselves down into smaller and smaller pieces." Wouldn't the larger pieces have accreted smaller pieces by gravity instead of everything grinding down into dust? Or am I just stuck in the thinking of Pierre-Simon Laplace and Immanuel Kant?

Craig Borders
Ridgefield, Connecticut

Meredith Hughes replies: *In general, whether things fragment or stick depends on several things, but a few of the most important are: (1) how big are the fragments, (2) how fast are they moving when they collide, and (3) what are they made of. Three is a relatively minor factor, but icy things are in general a bit more likely to stick than rocky things. Two is the main issue here. Once you get rid of the gas, it's tough to keep things on circular orbits. Given the sizes of the fragments (which we think start out roughly Pluto-size), and critically, their relative velocities (which get more extreme as the orbits get less circular), as far as we can tell we're very much in the fragmentation rather than sticking regime. Protoplanetary disks have lots of gas, which is nice for slowing down velocities because it can create drag that circularizes orbits, and especially causes roughly millimeter-size grains to migrate inwards over time (in a process called* radial drift*), which provides a nice steady supply of pebbles for the larger planets to accrete. Once you get rid of the gas, all bets are off, planets shake up the little stuff, and you get more collisions that result in fragmentation.*

The idea of the collisional cascade goes back all the way to the 1960s . . . here's the classic paper that derived the size distribution, which is pretty consistent with what we observe in debris disks: ***tinyurl.com/Collisional-Model****.*

Fireworks in July

You knocked it out of the park with the July 2026 issue. Explaining helium glitches with pressure waves, relating astronomical events to the revolutionary period, bringing us current with globular cluster formation theory, providing an insightful tour of part of the summer Milky Way, and even looking for NGC 6522 with binoculars are just a few of the excellent pieces in this well-done issue. Now, I'm going to have to try to catch NGC 6528 and 6522 in the same eyepiece. Thanks for the deeper appreciation and understanding of what I find in the night sky.

Ted Harp
Tuttle, Oklahoma

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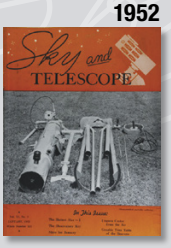
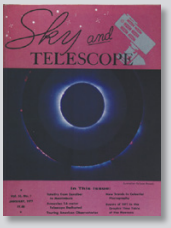
75, 50 & 25 YEARS AGO by Sabrina Garvin

1952



1977



2002



January 1952

Las Cruces "A meeting was held this fall at the home of Mr. and Mrs. Clyde W. Tombaugh, attended by 20 persons, to organize the Astronomical Society of Las Cruces, New Mexico. The group is made up of personnel from the Harvard meteor stations, White Sands Proving Ground, New Mexico A. and M. A. College, and interested amateurs. The society may later include interested persons from Holloman Air Force Base and the Harvard solar station on Sacramento Peak, both of which are some 75 miles to the northeast of Las Cruces.

"Subjects for meetings include the history of astronomy from ancient times to the present, telescope making, and the techniques of planetary, lunar, and meteor observing. Serious organized observing is planned, in addition to the professional work . . . The skies of the vicinity are especially favorable to astronomical work.

January 1977

Is Astrophotography Dead? "As was true for Mark Twain, rumors of the death of astronomical photography are greatly exaggerated. Despite competition from image tubes, TV scanners, and other electronic devices, astrophotography is a thriving art. In recent years there has been a quiet revolution in celestial photography that has not only strengthened its competitive position, but has also enabled it to serve even more effectively as the final recording medium for the electronic devices themselves.

"The revolution has taken two forms. One was the development, by J. C. Marchant and A. G. Millikan of Kodak Research Laboratories, of new, slow, fine-grain astronomical emulsions that have improved resolution and reach deeper into space. The second was the discovery of new methods of hypersensitization . . . that speed up the older emulsions and . . . are the key to practical use of the new slow ones."

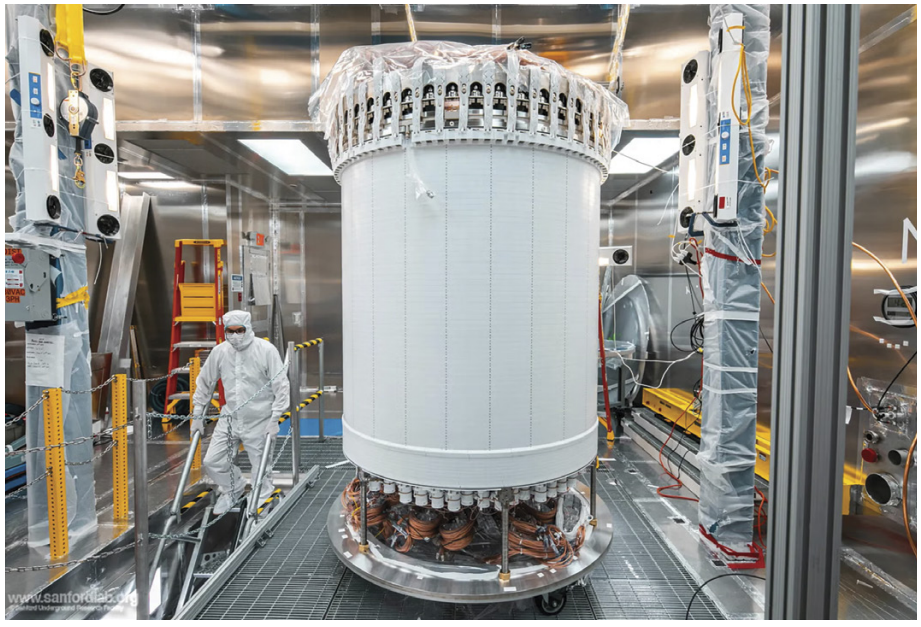
January 2002

Snack Time "Anybody who is that committed to astronomy on these marathon winter nights understandably gets hungry. When your glucose is depressed after hours beneath a cold, starry sky, you want something sweet . . .

"Outer space, of course, has long been conscripted by the confection industry. The name of candy maker Mars, Inc., obviously invokes another world. Besides fortifying candy counters with Mars bars, the same firm is also famous for marketing the Milky Way. . . .

"Manhattan's Rose Center for Earth and Space at the American Museum of Natural History [sold cookies] cut and frosted to depict the Earth, Mars, and Saturn . . . The Cookie Lady in central Florida takes the cake, however, with the launch of her Sweet Treats Lunar Prospector cookie.

"With any luck, the 'dark matter' that is a major ingredient of the universe will turn out to be chocolate."



◀ LZ's central detector sits in a clean room on the surface before its delivery to the Sanford Underground Research Facility.

COSMOLOGY

Did Scientists Find a Dark Matter Particle?

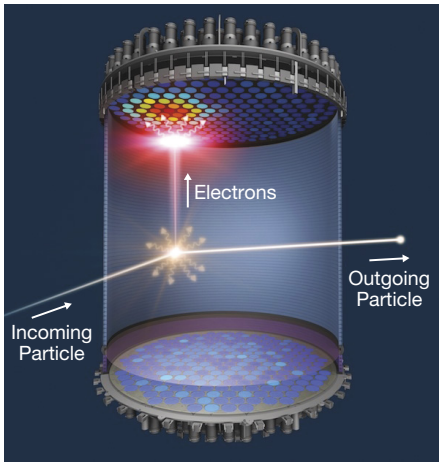
DEEP BENEATH the ground, in a former gold mine, a single particle has attracted some attention. As it passed through a tank containing 7 tons of liquid xenon, it struck the nucleus of one of these large atoms, sending the xenon pinging off with an energy of about 250 kiloelectron volts (keV). Even after accounting for other particles that might cause such an energetic signal, this one stood out: It could represent our first direct detection of dark matter.

The nature of dark matter is a pressing question. Compelling evidence shows dark matter accounts for 85% of the universe's mass; however, despite international efforts, we've never detected these particles directly.

One dark matter–seeking detector, the LUX-ZEPLIN (LZ) experiment located at South Dakota's Sanford Underground Research Facility, began taking data in 2021. If Earth is indeed swimming through a sea of dark matter particles, then one should every once in a while collide with the nucleus of a large atom (hence the tank of pure liquid xenon at LZ's heart). Detectors lining the tank measure the flashes of light and cascades of electrons resulting from particle collisions.

One idea for the composition of dark matter is *weakly interacting massive particles* (WIMPs). The simplest WIMPs have masses 10 to 100 times that of a proton. They're expected to be sluggish, creating ricochets on the order of 50 keV (*S&T:* Aug. 2017, p. 28). But a search through LZ's first few months of data yielded no such events.

So, the team decided to "look beyond just the most generic interaction," explains team member Henning Flaecher (University of Bristol, UK). The team looked at data taken in 2023 and 2024, this time including energies up to 270 keV. After accounting for all kinds of other, ordinary particles in the encounters detected, a single interaction popped out as unexplained.



▶ The heart of LZ is a 5-foot-tall chamber containing 7 tons of pure liquid xenon. Particle interactions produce flashes of light and cascades of electrons that LZ detects.

This signal's statistical significance is too low for scientists to confidently declare a new kind of particle. There may be other rare background processes that scientists didn't know to exclude from their dark matter searches.

"Of course we were very excited," says Flaecher. "But then all the head-scratching begins." For one, the particle is heavier than expected, 200 times a proton's mass. For another, it's unclear why there are no lower-energy signals.

"The one event that they've seen is not very well explained by the simplest story," says Tracy Slatyer (MIT).

One explanation is that the particle might be a WIMP called a *higgsino*, which (if it exists) exhibits "heavy" and "light" states. A higgsino would only send a xenon atom zipping away forcefully when bumped up to its heavy state. That could explain why LZ and so many other detectors haven't found WIMPs at lower-energy bands.

The hunt is now on for more such signals, with similar experiments in Italy, France, and China. These new projects should improve the sensitivity of dark matter searches by orders of magnitude, says Paolo Privitera (University of Chicago), spokesperson for one of these experiments, DAMIC-M, being built in France.

To make sure the particle signals aren't from some other process, cosmologists are looking for another type of signal: gamma rays. Depending on WIMPs' masses, their collisions in galactic centers or even in the Sun might produce high-energy photons.

"It will really be a matter of seeing the same signal consistently, in a variety of data sets," says cosmologist Vera Gluscevic (University of Southern California), "in order to actually really exclude all other possibilities."

■ **HANNAH RICHTER**

LZ DETECTOR: MATTHEW KAPUST / SANFORD UNDERGROUND RESEARCH FACILITY; DIAGRAM: SLAC NATIONAL ACCELERATOR LABORATORY

SPACE

NASA Launches Roman Space Telescope

SHORTLY AFTER SUNRISE on August 30th, NASA's newest flagship took off. The Nancy Grace Roman Space Telescope will provide vast cosmic surveys to probe dark matter and dark energy as well as an unprecedented view of planets across the Milky Way (*S&T:* Sept. 2026, p. 26). After lift-off, precise course-correction burns left enough propellant to extend the telescope's nominal lifetime from 10 to 22 years.

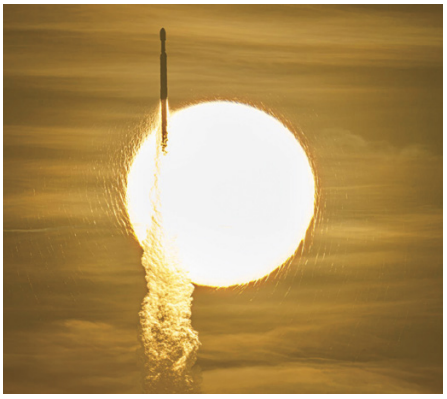
The mission is heading toward an orbit around the L_2 Lagrange point, a gravitationally stable region 1.5 million km (about 1 million mi) from Earth's nightside. This is a thermally stable location that also requires minimal power for station-keeping, while Earth remains near for communication.

Roman carries the Wide Field Instrument (WFI) for imaging the sky in 0.28-square-degree chunks. That field of view is 100 times that of Hubble's Wide Field Camera 3 yet offers Hubble-quality resolution.

Astronomers will piece WFI's images together into enormous sky surveys. To handle the 20 petabytes of data expected from the mission's first five years, NASA has established the Roman Research Nexus, where data will be publicly accessible. "There's going to be 1.4 terabytes of data coming down every day," says Payload Systems Engineer Bear Witherspoon (NASA Goddard), like "listening to a million songs a day."

Roman's wide-field survey capabilities enable it to gauge *gravitational lensing*, in which a foreground object's mass bends and magnifies background light. The phenomenon enables astronomers to discover new exoplanets in the Milky Way and monitor dark matter's effect on cosmic-scale structures. The mission will also map galaxies to measure patterns in their large-scale distribution, known as *baryon acoustic oscillations*, that can shed light on dark energy.

Meanwhile, the Roman Coronagraph — a technology demonstrator that blocks a host star's light with an innovative combination of baffles, deformable mirrors, and software — will help astronomers resolve fainter exoplanets and protoplanetary disks than before.



▲ A SpaceX Falcon Heavy rocket carrying the Nancy Grace Roman Space Telescope transits the Sun as it lifts off on August 30th.

Roman has begun its 90-day commissioning phase en route to its L_2 destination, which it should reach by early December. Expect the first science images by early 2027.

■ DAVID DICKINSON

DARK MATTER

Gaps in Stellar Streams Might Be Common

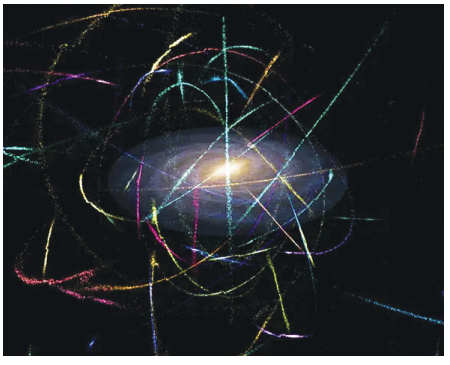
ASTRONOMERS ONCE thought conspicuous gaps in long lines of stars known as *stellar streams* might come from dark matter clumps flying around our galaxy's halo. Now, a study shows that stream disturbances may arise without the need for dark matter.

The Milky Way's gravity peeled off some of these long strings of stars from globular clusters. Their discovery has captured interest in part because gaps and other irregularities in the streams' appearance might come from rare but forceful encounters with concentrated clumps of dark matter, known as *subhalos* (*S&T:* Oct. 2019, p. 10).

But a study in the September 1st *Astrophysical Journal* casts doubt on this scenario. Arpit Arora (University of Washington) and colleagues argue that the gaps arise from multiple factors that are too complex to cleanly distinguish.

The researchers simulated 15,000 stellar streams, orbiting models of a Milky Way–like galaxy. After placing all kinds of streams (smooth, messy, and in-between) around four simulated galaxies, the researchers followed the streams' evolution over time.

Arora's team found that around three-quarters of the streams had gaps, spurs, or kinks. In fact, almost all of the streams, including ones that at first glance seemed smooth, had some kind of structural imperfections. If rare collisions with dark matter clumps happen, they must combine with our galaxy's own gravitational effects to change the streams' appearance.



▶ This visualization shows some of the streams simulated for the study. (Explore the interactive version here: **tinyurl.com/stellar-streams**.)

With so much gravitational injury, the team concludes that it's impossible, at least right now, to work out what's responsible for one particular gap or kink. It might only ever be possible to make such distinctions on a population level, using statistical analysis.

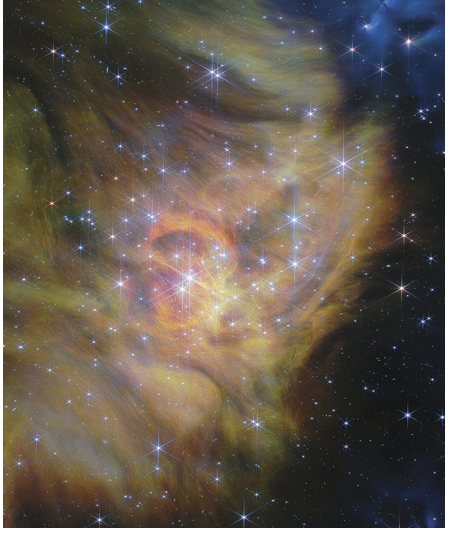
Several deep surveys of the galaxy are growing the number of known streams. Spectroscopic data reveals the motions of their stars, says Sergey Koposov (University of Edinburgh, UK), who wasn't involved in the study. He's optimistic that the retired Gaia mission, the Dark Energy Spectroscopic Instrument, and the European Southern Observatory's 4-metre Multi-Object Spectrograph Telescope will provide the data needed to separate different scenarios.

■ KIT GILCHRIST

ROMAN LAUNCH: NASA / JOHN KRAUS; VISUALIZATION OF STELLAR STREAMS: VISUALIZATION: ARPIT ARORA & ADRIAN PRICE-WHELAN, MILKY WAY IMAGE: STEFAN PAYNE-WARDENAAR

BROWN DWARFS

Webb Panorama Reveals Tiniest Brown Dwarf Yet



◀ The James Webb Space Telescope took this near-infrared panorama of IC 348, a star-forming region about 1,000 light-years away.

IC 348, a 5-million-year-old star-forming cluster 1,000 light-years away in Perseus, contains some 500 stars — and the puniest brown dwarfs we've ever seen. The discovery challenges our ideas about how stars form.

Brown dwarfs straddle the star-planet divide. They can't sustain hydrogen fusion, putting an upper limit on their mass of about 75 Jupiters. But what sets the lower bound is less clear. Kevin Luhman (Penn State University), who led a James Webb Space Telescope panorama of IC 348, prefers dividing by formation: While planets form in gaseous disks around stars, brown dwarfs form more like stars themselves, collapsing directly out of gas clouds.

Luhman and Catarina Alves de Oliveira (European Space Agency) used Webb's images of the region to identify 39 free-floating brown dwarf candidates in 2024. The following year, they obtained Webb spectra of 15 of these candidates, confirming that nine are indeed substellar members of this cluster. One of these objects has only twice Jupiter's mass.

What's more, two of the brown dwarfs — including the pipsqueak — are ringed by disks of dust and gas. Such disks have never been found around a brown dwarf so tiny.

The diminutive brown dwarf challenges our ideas about how stars form. Theory places limits on the smallest masses that can collapse out of a star-forming cloud. "Part of the motivation of our work is to measure the minimum mass of brown dwarfs so that we can test those predictions," Luhman says. "[The 2-Jupiter-mass object] is starting to strain the ability of any models to explain. If brown dwarfs exist below the mass of Jupiter, that would be very challenging for theoretical models."

Webb can find objects down to a single Jupiter mass in IC 348, and the Roman Space Telescope's wide field of view will enable it to search star-forming regions even closer to Earth.

■ MONICA YOUNG

STARS

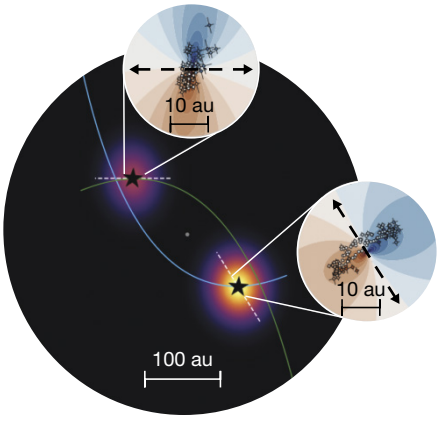
Some Pairs of Stars Weren't Born That Way

TWO MASSIVE STARS might've been born separately before getting tangled in each other's orbits, revealing a new way that binaries can form.

Massive stars tend to have company, orbiting in groups of two or more. Astronomers thought these groups are born like peas in a pod, coalescing out of the same swirling clumps of gas and dust. Now, observations of two young, massive stars support another scenario: They might have formed on their own before whizzing into each other's orbits.

The binary, dubbed IRAS 07299–1651 and located more than 5,500 light-years away in Puppis, the Stern, is made up of two stars still enveloped in their natal cocoons of gas and dust. If the stars were born together, then the stars' disks — which represent the leftovers of the formation process and gird the stars' equators — should be aligned with the stars' orbit around each other. Yet in a study published September 7th in *Nature Astronomy*, a team of scientists led by Yao Wang (Shanghai Jiao Tong University, China) found that the stars' disks are tilted relative to each other and relative to their mutual orbit, suggesting the stars were born separately.

"This is the first [study] with strong evidence" of such an origin for binary stars, says Qizhou Zhang (Center for Astrophysics, Harvard & Smithsonian), who wasn't involved in the study.



▶ This ALMA image shows the binary pair IRAS 07299–1651 with calculated orbital trajectories overlaid. The insets show the rotation of each star's disk in red and blue (away and toward the observer, respectively); arrows indicate the directions of bipolar jets.

Astronomers used the Atacama Large Millimeter/submillimeter Array combined with the Karl G. Jansky Very Large Array to measure the young stars' proper motions across the sky and around each other. The team also resolved the disks around the stars, measuring their rotation and tilt. Additional observations with the James Webb Space Telescope and the Very Large Telescope revealed jets of material spewing from the infant stars, which also provided information on the systems' orientations.

Using the stars' current motions to wind back the clock, the team found that 100,000 years ago, half a light-year separated the stars. They probably formed in two different clouds, eventually coming together into a mutual, highly elongated orbit.

Determining the stars' trajectories is tricky, though, and a chance remains that they aren't currently gravitationally bound and could fly past each other instead. Additional observations will help sort this out, piecing together the puzzle of how massive stars are born.

■ ARIELLE FROMMER

STAR-STUDDED SCENE: NASA / ESA / CSA / KEVIN LUHMAN (PSU) / CATARINA ALVES DE OLIVEIRA (ESA) / MAHDI ZAMANI (ESA / WEBB); BINARY ORBIT DIAGRAM: ALMA (ESO / NAOJ / NRAO) / Y. ZHANG

AWARDS

ZWO Astronomy Photographer of the Year

THE ROYAL MUSEUMS Greenwich announced the winners of the ZWO Astronomy Photographer of the Year 2026 contest on September 17th: The overall title went to Ali Alobaidly of Kuwait for his detailed photo of LDN 1235, an interstellar dust cloud faintly illuminated by nearby reflection nebulae. The image will be on display alongside the winners of other categories in an exhibition at the National Maritime Museum in London through August 2027.

"Showcasing the intricate structures of a rarely photographed nebula, the image combines remarkable detail with a striking composition and color palette," says ZWO CEO Sam Wen.

Other winners include Czech photographer (and occasional *S&T* contributor) Petr Horálek, who takes home the prize in the Moon category for his series of images depicting the September 19, 2025, occultation of Venus.



▲ "The Quiet Predator" reveals the dust cloud LDN 1235 lit by nearby stars. Ali Alobaidly used an Askar 140 APO telescope and ZWO ASI2600MM Pro camera to capture the scene, with 28½ hours of exposure.

The winner of the Planets, Comets & Asteroids category goes to Tom Williams of the UK. Captured a few months after the planet's ring-plane crossing, his image shows dozens of bands in the planet's colorful atmosphere, both the Cassini Division and Encke Gap in the rings, and several tiny moons.

Another judge favorite, 15-year-old Nikolaos Strimpoulis won the Young Competition for his color-enhanced image of the Moon. His entry covers a broad swath of lunar surface that includes both dark maria and bright highlands, tinged orange and blue by deposits rich in iron and titanium minerals, respectively.

The Astronomy Photographer of the Year contest is sponsored by ZWO in association with the *BBC Sky at Night* magazine.

■ SEAN WALKER

See a selection of the winning photos: **skyandtelescope.org/AotY26**.

IN BRIEF

Star Feels Spin of Milky Way's Black Hole

Astronomers have discovered a star that comes so close to our galaxy's central black hole that it feels the effects of the black hole's spin. When a star orbits a black hole that is sitting still, the location of the star's closest approach, or *pericenter*, shifts over time, and around a spinning black hole it shifts even more. Using the Gravity instrument on the Very Large Telescope Interferometer in Chile, Karim Abd El Dayem (Paris Observatory) and colleagues found a star they named S301 amid the crowded galactic center. At closest approach, it comes within 12 astronomical units of the black hole, only slightly farther out than Saturn is from the Sun. The star's next pericenter pass should be in late 2031, after the 39-meter Extremely Large Telescope (ELT) comes online. Combining ELT observations with those from the VLT, the collaboration hopes to measure the spin of our galaxy's central black hole, the researchers report in the September 10th *Nature*.

■ CAMILLE M. CARLISLE

Once-in-a-Century Moon Impact Makes a Cold Spot

In the spring of 2024, something big hit the Moon. While the impact escaped witness, the crater it made — twice the length of an American football field — has been watched ever since. Tyler Powell (Johns Hopkins University Applied Physics Laboratory) and colleagues conclude in the September 18th *Science Advances* that the impact created not only McGetchin Crater, spanning 222 meters (728 feet), but also a much larger, 7-kilometer-wide cold spot. Cold spots abound on the Moon and are associated with recent craters: Impacts heat the ground but also "fluff up" the surrounding regolith, exposing grains to cold vacuum. A crater of McGetchin's size, the largest of more than 20 fresh impacts that the Lunar Reconnaissance Orbiter (LRO) has spotted, occurs once a century. Using thermal images from the LRO's Diviner instrument, the researchers found that while the crater remained warm, the surface around it cooled by 8 or 9 kelvin (about 15°F). The crater will help researchers interpret the thousands of other cold spots that dot the lunar surface.

■ MONICA YOUNG

Chariklo's Rings Changed

Astronomers using the James Webb Space Telescope (JWST) have discovered that the two rings around the outer-solar-system object 10199 Chariklo have changed significantly since they were first seen in 2013 (*S&T:* July 2014, p. 14). Chariklo, which orbits the Sun between Uranus and Neptune, occasionally passes in front of a background star. By watching such a *stellar occultation*, astronomers discovered rings around this small body. Now, Pablo Santos-Sanz (Institute of Astrophysics of Andalucía, Spain) has led a team in observing another occultation, this time using JWST. While Webb wasn't in line with the shadow cast by the main body, it monitored occultations created by the rings. Compared with previous observations, the inner ring has darkened, while the outer one has thinned significantly. If the observed changes are real alterations in Chariklo's rings, then their density has evolved. Perhaps the outer ring is transferring mass to the inner one, or maybe there's an unseen shepherding moon that shapes and contributes ring material. The team's results appear in the September 11th *Science Advances*.

■ DAVID L. CHANDLER

A Magical Sunset Totality

Here's an eclipse the likes of which we'll probably never experience again.

SEEING A TOTAL SOLAR ECLIPSE near sunset has long been on my bucket list. I was keen to observe the effects of reddening on the corona's color. The eclipse on August 12, 2026, provided that opportunity, with totality — as seen from Mallorca, the largest of Spain's Balearic Islands — occurring less than 3° above the sea. The event didn't disappoint.

My wife, Deborah Carter, and I joined our friends Bob Benward and Julie Kim-Zajonz at Port d'Andratx. Except for a band of wispy clouds that lingered a few degrees above the western horizon, the sky was crystal clear.

Prior to the start of the partial eclipse, Bob recorded a temperature of 87°F. Humidity was high, with no wind. First contact occurred only 12.6° above the horizon. Almost immediately through my #14 welder's glass, I saw a bright, white collar extending beyond the advancing edge of the Moon's silhouette — the *Mach band* contrast effect (*S&T:* Feb. 2026, p. 12). Oddly, through binoculars, I had to stare at the Moon's limb for about 10 seconds before this optical illusion manifested.

Only 10 minutes after first contact, we felt a cool breeze, followed soon after by soft, irregular gusts of onshore wind. We felt eerily chilly, even though the temperature had not dropped. At 25% eclipse (with the Sun at about 10° altitude), the landscape's colors appeared muted. At 50% eclipse, the green grasses and leaves rose to prominence, while the sky opposite the Sun turned a rich, cobalt blue. Seagulls headed inland toward the port.

At 75% eclipse (5° altitude), the sky grew dark and the landscape yellowed. Winds began to gust more strongly. Still, the temperature remained a constant 87°F. Shadows became darker, and gulls began circling above us in an ever-rising vortex. Minutes later, a solitary bat came out in search of insects.

In the moments before second contact, the eclipsed Sun slipped behind wispy cirrus. Rather than a detriment, the thin cloud acted like a neutral-density filter, allowing us to watch the approach of totality (at 2.6° altitude) without eclipse glasses. In fact, well before the diamond ring flashed into view, we could see the Moon's trailing limb silhouetted against the smoldering greens and yellows of the Sun's inner corona.

No sooner was the diamond ring extinguished than an immense prominence, tinged with scarlet hues, erupted from that dying ember of sunlight. Meanwhile, the entire edge of the Moon's advancing silhouette began to bleed crimson light as the Sun's chromosphere made a brief appearance. Then, the Sun's outer corona blossomed before our eyes. Yellow and orange hues infused it, with the tips of the coronal petals fringed with fiery reds. The new Moon's face was not black but a mottled purple awash with white speckles, like lunar filigree.

Totality lasted 1 minute and 37 seconds. Then the second diamond ring flashed through the edge of a thicker cloud, creating a highly reddened atmospheric aureole. For the final 18 minutes, we watched in awe as the partially eclipsed Sun sank into the sea, all the while undergoing slight distortions in shape due to atmospheric refraction. As the last fragment of Sun slipped beneath the horizon, Rick Kostelnik imaged the solar crescent's green flash from the neighboring island of Menorca.

In the end, we saw the Sun fully eclipsed twice — once by the Moon and once by the horizon. The show ended with lights-out, leaving us in an eerie twilight, clinging to memories of an event so singular that it's unlikely we'll experience anything like it again.

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



▼ **ECLIPSE PHENOMENA** These views on August 12, 2026, show *(from left)* a reddened atmospheric aureole around the diamond ring at third contact; an iPhone image of totality only 2.6° above the horizon; a partially eclipsed Sun setting with mirage effects; and the green flash.

IMAGES, FROM LEFT: JULIE KIM-ZAJONZ; DEBORAH CARTER; STEPHEN JAMES O'MEARA; RICK KOSTELNIK

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Sungrazing Comets

Do comets have family histories? Some do.

One special family of comets, the so-called *Kreutz sungrazers*, are hands down among the most spectacular celestial apparitions in human history. They are glorious because they are risk-takers: They come close — *exceedingly* close — to the Sun's broiling surface. After their closest approach, or *perihelion*, they release copious amounts of gas and dust, visible in their incredibly long and beautiful tails. If Earth is well situated when that happens, commentaries from awestruck humans fill the history books.

But hazards lurk. With each hair-raising solar passage, the cometary bodies, however tightly or loosely bound, will be disrupted by the Sun's gravity. These *tidal forces* tend to rip them apart. Even the daredevils that survive pay a price: The intense solar heat may cause them to shrink like a snowball in an oven. As the centuries wear on, the risk increases that these objects will inch too close to the Sun's surface and suffer the indignity of fragmentation. Some of these fragments may or may not survive as comets in their own right. Or it can vanish whole and forgotten into the Sun's cauldron.

What is the origin of these spectacular visitors? And what is their future? In the past few decades, scientists have started to unravel the mystery.

The "Great" Comets of the 1800s

Our story properly begins in the 19th century, when four blazing celestial objects set the world astir: the comets of 1843, 1880, 1882 and 1887. Of these, C/1843 D1 and C/1882 R1 were history-making, and they are the primary characters in our story.

The Great March Comet of 1843 was stunning. "The most brilliant comets of the century were suddenly rivaled if not surpassed by the extraordinary object which blazed out beside the Sun, February 28, 1843," wrote historian Agnes Mary Clerke. Astronomers estimated that its 40° tail extended 200 million miles. Thirty-seven years later, the somewhat less brilliant Great Southern Comet of 1880, seen only in the Southern Hemisphere, sported a 50° tail.

Observers discovered those two comets very near or after perihelion, but the Great September Comet of 1882 burst upon the scene two weeks before its perihelion passage. It was visible in broad daylight next to the Sun and caused a sensation everywhere. In Spain, residents stopped in the streets to admire it. After perihelion, the comet began to become visible again in the morning hours before sunrise as "one of the most remarkable cometary apparitions on record," Clerke wrote.

In 1887, yet another Great Southern Comet appeared, also dazzling, but quick to come and go and not seen in the Northern Hemisphere.

Origins

These famed comets had highly eccentric, needle-shaped orbits that wrapped tightly around the Sun. They approached from the south before exiting on nearly the same path. And herein lay a small historical conundrum. Hoping to score a similar success to Edmond Halley's, 19th-century astronomers became obsessed with the idea that the various sungrazers were returns of a single object. Maybe C/1843 D1 was the return of the comet of 1668 (175 years), or of the sungrazer of 1702 (141 years). Perhaps C/1880 C1 was the return of C/1843 D1 (37 years). Or — downright ridiculously — C/1882 R1 was the return of C/1880 C1 only two years later! Retired Jet Propulsion Laboratory (JPL) comet scientist Zdenek Sekanina has summed up this early sungrazer science as "rather pitiful." Clearly, a broader vision was required.

In 1831, Danish mathematician Thomas Clausen suggested the notion of *cometary systems*, an idea later pursued by Martin Hoek, director of Utrecht Observatory in the Netherlands, in 1865. According to Clerke, Hoek noticed that "the paths of two or three comets had a common point of intersection far out in space, indicating with much likelihood a community of origin," perhaps arising from the ancient disruption of a common parent mass. In other words, comets with similar orbits aren't necessarily a single object that keeps coming back — they may be separate pieces of a larger, now-absent body. His insight raised the question of how we may define these cometary communities and discover their origins.

Decades later, German astronomer Heinrich Kreutz authored a multi-part work investigating the "comet system" of C/1843 D1, C/1880 C1, and C/1882 R1. His



▲ **COMET LOVEJOY (C/2011 W3)** Many remember this glorious sungrazer, seen here near Roma, Queensland, Australia. According to Sekanina, its apparition was an important event in our evolving understanding of sungrazer dynamics. Comet Lovejoy's exceptionally tight perihelion distance, misfit nodal longitude, and later disintegration led to a wholesale rethinking of the previously assumed Kreutz system architecture.

1888 study began with the Comet of 1882 and delivered a surprise: The comet appeared to be connected to another bright visitor in 1106. "To calculate the comet ephemeris" he wrote, "I transferred my elements of Comet 1882 II [now known as C/1882 R1] to 1106." To his delight, the fit was remarkably good. "With a slight modification of the orbital period I found for Comet 1882 II, one encounters the famous Comet of 1106."

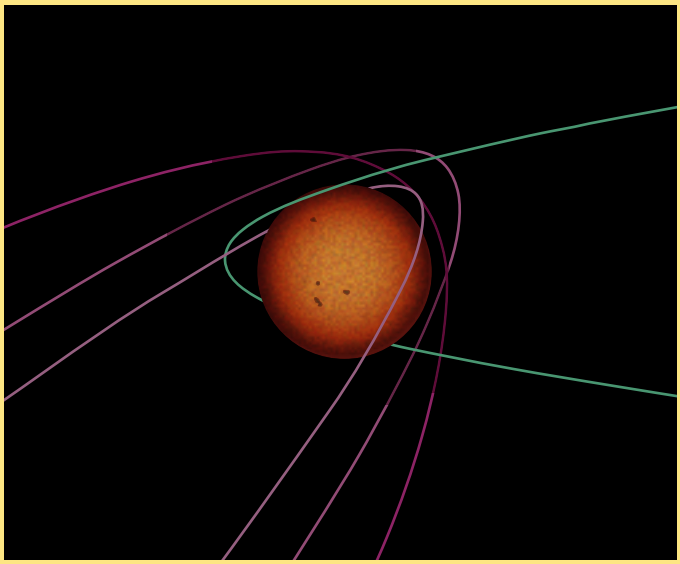
This was a path of footprints apparently leading straight to the scene of the crime. Or was it? Maybe the Comet of 1106 wasn't the ultimate origin, either. Just how far back did the Kreutz cometary family tree go, and how many branches did it have? And where did the other sungrazers fit in?

Population Genetics (of Comets)

Following Kreutz's work, scientists struggled to crack the deeper mysteries of these celestial showstoppers. Their goal was to determine the lineages of these members of the sungrazer family tree.

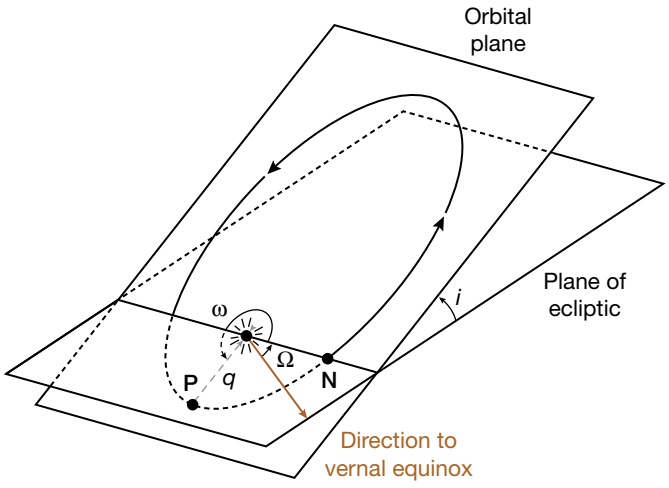
Being a legendary comet that blazes scarily close to the Sun to become a history-making apparition does not necessarily make one a Kreutz sungrazer. For example, the famous Great Comet of 1680, usually called Newton's or Kirch's Comet (*S&T:* Sept. 2025, p. 28), came as close as any Kreutz sungrazer but was not one of the family. So how can we tell?

Scientists turned to the celestial mechanic's version of genetics. There are a handful of mathematical quantities describing comet orbits that serve to distinguish one from



▲ **SUN AND COMET PATHS UP CLOSE** The author's computer simulation of the perihelion paths of three Kreutz sungrazers, C/1843 D1, C/1965 S1, and C/2011 W3 coming up from the left, and C/1680 V1 arriving from the right. It is evident by their paths how a sungrazing comet like C/1680 V1 could not qualify for membership in the Kreutz group.

COMET LOVEJOY: DAVID LIU / CC-BY-SA 3.0;
COMET PATHS: BEATRIZ INGLESSIS / *S&T*



▲ **IT'S ELEMENTARY** This diagram shows the elements of a comet's orbit. The point marked **N** is the ascending node; **P** is the perihelion.

another. The figure above shows them: *q*, the perihelion distance in astronomical units (au); Ω, the longitude of the *ascending node*, which indicates where the comet crosses Earth's orbital plane from below; ω, the *argument of the perihelion*, or the angle measured along the comet's orbit from that crossing point to the perihelion; and *i* (for inclination), the angle between the comet's orbit and Earth's. When combined, these quantities give us a 3D picture of the size and orientation of a body's orbit around the Sun. (All of the sungrazers have near-parabolic orbits, so eccentricity — an orbit's shape — isn't a useful distinguishing feature.)

From similarities in the orbital elements of earlier-seen comets, Edmond Halley was able to conclude that the comets of 1531, 1607, and 1682 were a single comet whose return in 1758 he famously predicted. We can apply the same look-back method to match the markers for each of the four great 19th-century comets to see how they resemble one another, as seen in the table below.

For all four, perihelion distances are exceedingly close to the Sun; their arguments and longitudes of perihelion and inclinations to the ecliptic plane are similar, too. But C/1882 R1, the Great September Comet (highlighted), seems slightly out of place in this otherwise tightly knit group, like a Scotsman in an Irish family.

The late Brian Marsden — formerly of Harvard & Smithsonian's Center for Astrophysics and a modern pioneer in this field — divided the known sungrazers into two subgroups: one led by the Great March Comet of 1843 (table below left), and the other by the Great September Comet of 1882 (table below right). Following more recent scholarship, we'll call the subgroups Population I and Population II. The key orbital elements of comets in Population II connect C/1882 R1 with C/1965 S1. At the time, Marsden believed that the Comet of 1106 was the best candidate for the ancestor of both C/1882 R1 and C/1965 S1.

But this table has problems, too. Comet 1970 K1/White-Ortiz-Bolelli passed significantly farther from the Sun (its *q* is larger) than these two, and its nodal longitude (Ω) is smaller. Not knowing what else to do with it, Marsden assigned it to its own group, Population IIa. Also unique, Comet 2011 W3/Lovejoy (discovered after Marsden's death) passes much *closer* to the Sun and has an even smaller Ω.

Sekanina realized that dwarf Kreutz sungrazers, detected by the Solar and Heliospheric Observatory (SOHO) and other solar satellites, fragment along their entire orbits, not only at perihelion. With computational assistance from Paul Chodas and Rainer Kracht, he applied the idea of cascades of non-tidal fragmentation to all sungrazer comets, presented in a virtual torrent of papers over the last quarter-century.

A Modern Synthesis

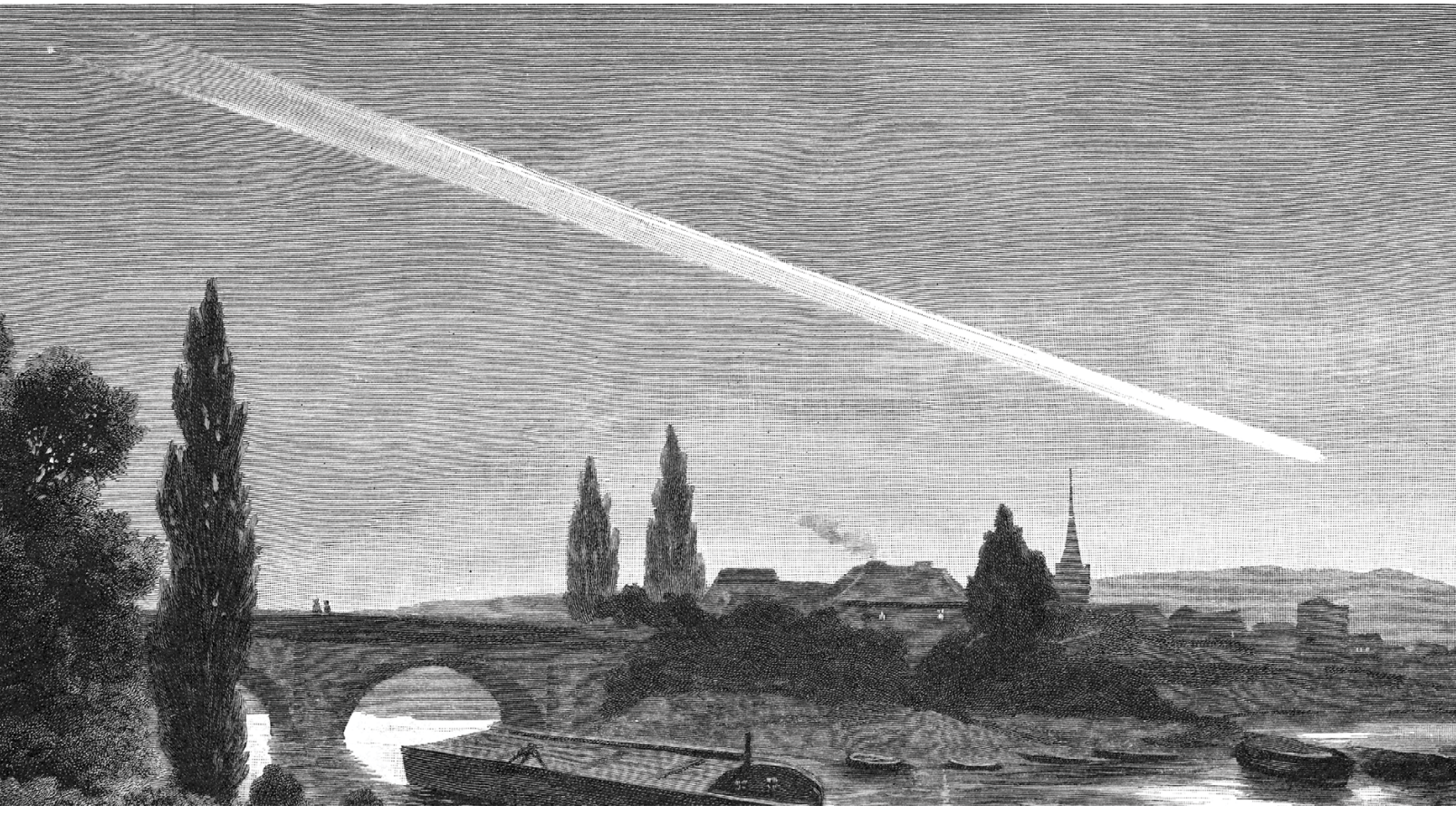
It takes some tricky reverse engineering to find out which offspring belong to which parents, sleuthing the Who's Who of the sungrazer family tree. With the help of a great deal of computing power, the sungrazer origin story has clarified remarkably. Sekanina has articulated a convincing theory of sungrazer origins whose elements, he writes, "fit together as nicely as the final pair of pieces in a puzzle." In a recent breakthrough article, Sekanina has offered an original theory

LEAH TISCIONE / S&T; SOURCE: *CAMBRIDGE DICTIONARY OF ASTRONOMY*

Nineteenth-Century Great Comets

Designation	Name	Perihelion date	*q* (au)	ω	Ω	i
C/1843 D1	Great March Comet	Feb. 27, 1843	0.00553	82.64°	3.53°	144.35°
C/1880 C1	Great Southern Comet	Jan. 28, 1880	0.00537	86.69°	8.45°	144.76°
C/1882 R1	Great September Comet	Sept. 17, 1882	0.00775	69.61°	347.69°	142.01°
C/1887 B1	Great Southern Comet	Jan. 11, 1887	0.00483	83.51°	4.59°	144.38°

With the exception of C/1882 R1, these comets are the original Population I sungrazers. Data from JPL SSD Small-Body Database.



GRANGER

▲ **GREAT MARCH COMET OF 1843** Shown here with its immensely long tail over London, C/1843 D1 was then regarded as the most brilliant comet of the century, with its astounding tail the subject of many paintings and woodcuts. The tail, according to one historian, reached "the extravagant length of 200 millions of miles," resembling "a 'road' through the constellations."

about the Kreutz family tree that is the result of several lines of evidence coming together over the past decade, overturning some earlier assumptions that had hindered progress.

Most crucially, it was widely believed that sungrazing comets fragment only at perihelion. While they often do, Sekanina has presented a more complex tapestry of ideas, the key points of which I've simplified here: (1) The progenitor comet was a lobed, rotating contact binary like Comet 67P/Churyumov-Gerasimenko or the trans-Neptunian object Arrokoth; (2) contact binaries are known to experience stress and material fatigue, rendering them vulnerable to fragmentation anywhere in their orbits, even when they're farthest from the Sun at *aphelion*; and (3) a separation velocity of only a few meters per second will shift the two lobes of the binary into

Population II and III Sungrazers

Designation	Name	Perihelion date	*q* (au)	ω	Ω	i
C/1882 R1	Great September Comet	Sept. 17, 1882	0.00775	69.61°	347.69°	142.01°
C/1965 S1	Ikeya-Seki	Oct. 21, 1965	0.00778	69.05°	346.99°	141.86°
C/1970 K1	White-Ortiz-Bolelli	May 14, 1970	0.00884	61.10°	336.82°	138.95°
C/2011 W3	Lovejoy	Dec. 16, 2011	0.00555	53.51°	326.37°	134.36°

Comets 1882 R1 and 1965 S1 are the representatives of Population II sungrazers. Because of their differences, however, C/1970 K1 was assigned to Population IIa and C/2011 W3 to Population III. Data from JPL SSD Small-Body Database.

different orbits. Depending upon the orientation of a contact binary's rotation axis, these detached fragments (called Lobe I and Lobe II) will thereafter move in different orbital planes, significantly changing the lobes' arrival times at perihelion.

This celestial ballet seems to explain why misfit C/1882 R1 stands out from C/1843 D1 and the rest in our first table: They are from the same ancient progenitor, just from different parts of its body. The Kreutz family is much larger and more branched than we'd thought.

Similarly, Sekanina assigns C/2011 W3 in our second table to Population III (along with its associated dwarf sungrazers). Indeed, each new sungrazer that comes our way seems to slip through the net of the original two-group scheme. We can see this by charting the paths of sungrazers through history based on Sekanina's most recent research, tracing their cometary phylogeny to see how they are related — some closely, some more distantly — in the diagram at right. Says Sekanina: "A major advantage of the contact-binary model is its pyramidal structure that organically explains any progression of populations derived from either of the two lobes as the corollary of its recurring (cascading) fragmentation."

Now it is easy to appreciate the inadequacy of the two-population scheme, especially with C/1970 K1 and C/2011 W3 striking out on their own paths. The "maverick" Comet Pereyra (C/1963 R1) also looks like a fish out of water — not really *in* Population I, but rather superimposed on it. It may be a fragment of the Comet of 1041 (a sibling of the Comet of 1106).

To appreciate how the story has been pieced together, let's backtrack to the primitive beginnings of these Kreutz sungrazers, all the way to the postulated great granddaddy of them all, and trace it forward to our time using Sekanina's latest findings as the backbone of our narrative.

The Great Progenitor: Aristotle's Comet, 372 BC

Our first stop is the 4th century BC. Imagine you are the young Aristotle. It is a "clear and frosty" winter evening in the year 372. You look to the west just after sunset and see a "great comet" of astonishing brightness. In your *Meteorologica*, composed 20 years after the event, you write, "Its light stretched across a third of the sky in a great band, as it were, and so was called a path. This comet receded as high as Orion's belt, and there disappeared." Later writers, quoting earlier sources now lost, have given vivid descriptions of this comet. Diodorus Siculus in the 1st century BC wrote:

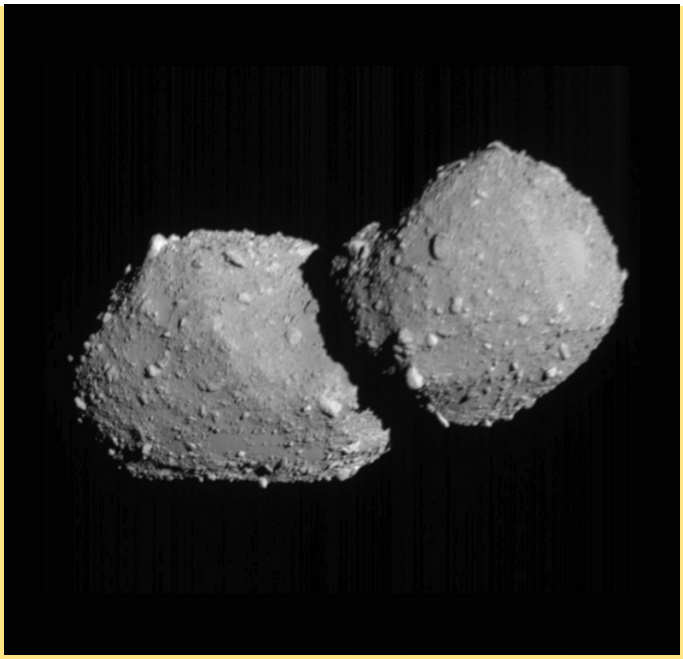
> *[T]here was seen in the heavens during the course of many nights a great blazing torch which was named from its shape a flaming beam. . . . This torch had such brilliancy . . . and its light such strength that it cast shadows on the earth similar to those cast by the moon.*

New research supports the view that this magnificently bright comet might have been the sungrazers' ancient progenitor. One thing is certain: It was real, huge, and had doubtless visited us before.

COMET IKEYA-SEKI: NOAO / SCIENCE PHOTO LIBRARY; TORIFUNE: JAXA / THE UNIVERSITY OF TOKYO / CHIBA INSTITUTE OF TECHNOLOGY / INSTITUTE OF SCIENCE TOKYO / AIST / PARIS OBSERVATORY / IAC



▲ **COMET IKEYA-SEKI (C/1965 S1)** This sungrazer, independently discovered by veteran comet hunters Kaoru Ikeya and Tsutomu Seki, was likely a fragment of the Chinese Comet of 1138, itself a descendant of the second lobe of Aristotle's comet.



▲ **98943 TORIFUNE** This recent addition to the growing list of contact binaries seems to strengthen the hypothesis that Aristotle's comet may have been a contact binary that split into two lobes, fathering the great sungrazer family of comets through the centuries. This image was captured in July 2026 by the Japanese robotic spacecraft Hayabusa 2.

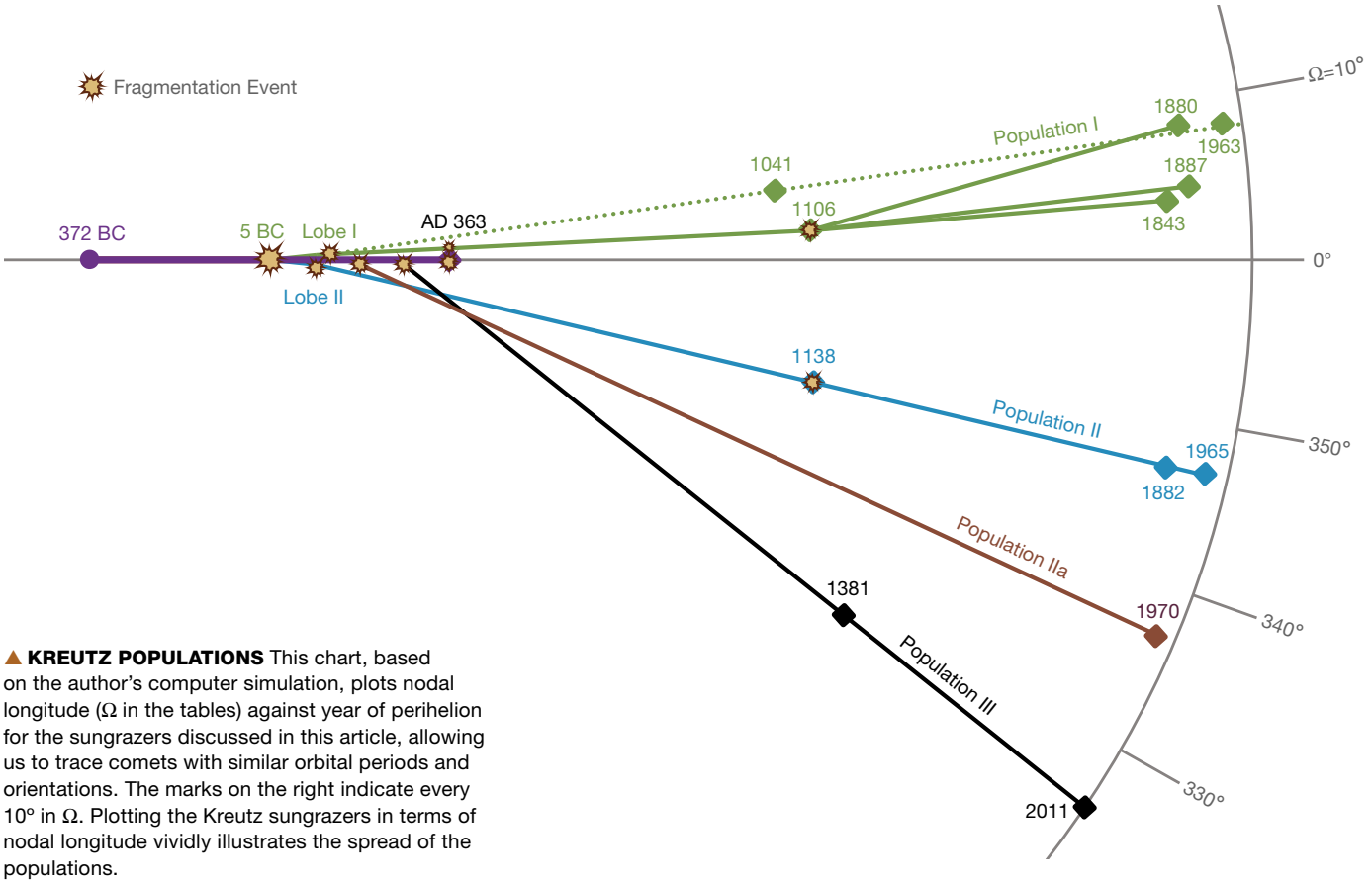


CHART: BEATRIZ INGLESSIS / *S&T*; SOURCE: THE AUTHOR; SCHWASSMANN-WACHMANN: NASA / ESA / H. WEAVER (APL / JHU) / M. MUTCHLER AND Z. LEVAY (STSCI); ARROKOTH: NASA / JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY / SOUTHWEST RESEARCH INSTITUTE / ROMAN TKACHENKO

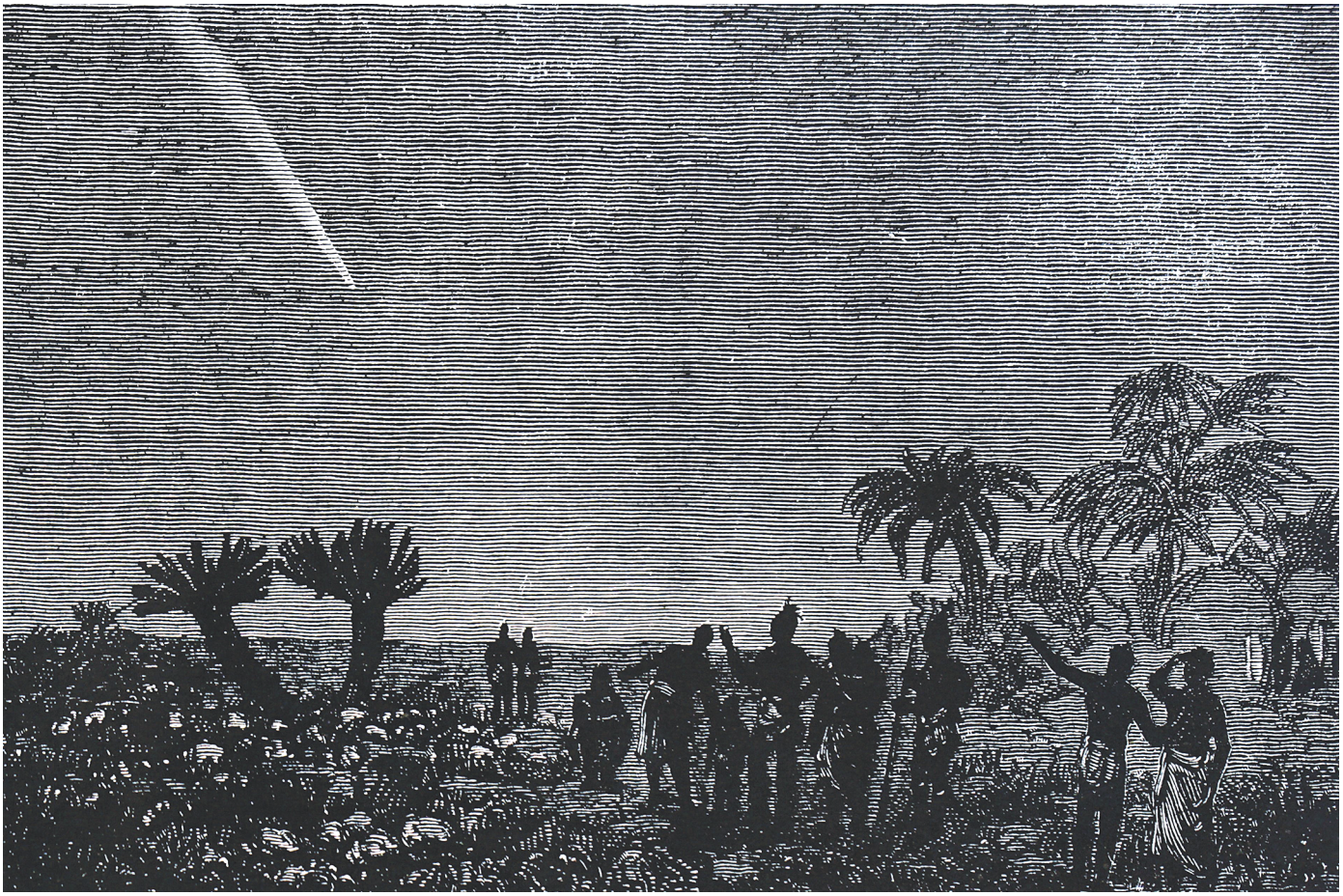
▲ **KREUTZ POPULATIONS** This chart, based on the author's computer simulation, plots nodal longitude (Ω in the tables) against year of perihelion for the sungrazers discussed in this article, allowing us to trace comets with similar orbital periods and orientations. The marks on the right indicate every 10° in Ω. Plotting the Kreutz sungrazers in terms of nodal longitude vividly illustrates the spread of the populations.



▲ **COMET 73P/SCHWASSMANN-WACHMANN 3** The disintegration of this bright comet in the spring of 2006 offers a vivid example of cascading fragmentation that likely happened to Aristotle's comet and some of its descendants.



▲ **486958 ARROKOTH** Photographed by the interplanetary probe New Horizons on January 1, 2019, this little trans-Neptunian object is a good example of a body made by sticking two lobes together. The relatively recent discovery of such contact binaries was an important factor in the development of Zdenek Sekanina's sungrazer theory.



▲ **GREAT SEPTEMBER COMET OF 1882** Depicted here over South Africa, C/1882 R1 was one of the brightest comets ever seen. Its astonishing brilliancy, according to accounts, made it visible even close to the Sun. Its bright daylight visibility extended over three days: "All over the world, whenever the sky was clear . . . it was obvious to ordinary vision."

After One Orbit: The Daylight Comets of AD 363

More than 700 years pass until Ammianus Marcellinus, the foremost Roman historian of the 4th century AD, records that in the fall of AD 363 "in broad daylight comets were seen." It's rare enough to see a single bright comet near the Sun in broad daylight, and unprecedented to see more than one at the same time. The arrival time is consistent with the expected return of Aristotle's comet, now evidently fragmented like the aging Roman Empire would soon be.

Ammianus's description fits the scenario advocated by Sekanina, in which the progenitor broke up at large heliocentric distance into two lobes. These lobes each split into additional fragments, the largest pieces of which are called Fragments I and II. All these pieces arrived days apart in our neighborhood, where they fragmented again.

After Two Orbits: Two Great 12th-Century Comets

After the AD 363 apparition, we wait for the next full revolution of the comet fragments. Now, 742 years have elapsed, and we are in the early 12th century, just after the First Crusade to Jerusalem. It is early February 1106, and a truly remarkable comet lights up the sky around the world. Recent detailed orbital computations have suggested that X/1106 C1 was the largest mass of Fragment I.

The comet was first seen in Belgium in broad daylight. Observers in Japan estimated its tail to be 100° in length and white in color. The Welsh *Chronicle of the Princes* reported for 1106: "In that year there was seen a star wonderful to behold, throwing out behind it a beam of light of the thickness of a pillar in size and of exceeding brightness. . . ."

Other observers also marveled. A Muslim text from the time says that

> *. . . a star appeared in the heavens with locks of hair like a rainbow. It went from the west to the middle of the heavens and it was seen close to the Sun before its appearance during the night. It continued appearing a number of nights, then disappeared.*

Until recently, the existence of Fragment II was a mystery; researchers knew of no second spectacular sungrazer like the Great Comet of 1106. But Sekanina has identified the long-missing largest piece of Fragment II as the Chinese Comet of 1138, passing perihelion about three decades after X/1106 C1.

WORLD HISTORY ARCHIVE / ALAMY

After Three Orbits: The Giant 19th-Century Sungrazers and Their Kin

The 1106 comet likely split apart at perihelion. When its largest (or perhaps entire) mass arrives 737 years later, the world is very different. It is spring of 1843: England's Victorian Age is dawning, and Napoleon III will soon make himself Emperor of the French.

After a tight loop around the Sun, our returning visitor blossoms into one of the most splendid comets ever seen, the Great March Comet of 1843 (C/1843 D1).

Forty years later, pieces of Fragment I — the Great Southern Comet of 1880 (C/1880 C1) and the Great Southern Comet of 1887 (C/1887 B1), nicknamed the "headless wonder" when its unfortunate head disintegrated hours after perihelion — arrive for Kreutz's investigation.

Meanwhile, the Chinese Comet of 1138 (from Fragment II) has itself fathered two brilliant offspring. The first recorded was the Great September Comet of 1882 (C/1882 R1), possibly the brightest of all the sungrazers in the last 200 years and probably the largest surviving mass of Fragment II of Aristotle's comet. The other was Comet Ikeya-Seki (C/1965 S1), perhaps the greatest comet of the 20th century.

Other down-line descendants of Lobe II became Comet White-Ortiz-Bolleli (C/1970 K1) and (with greater uncertainty) C/2011 W3, the breathtaking Comet Lovejoy.

New Discoveries

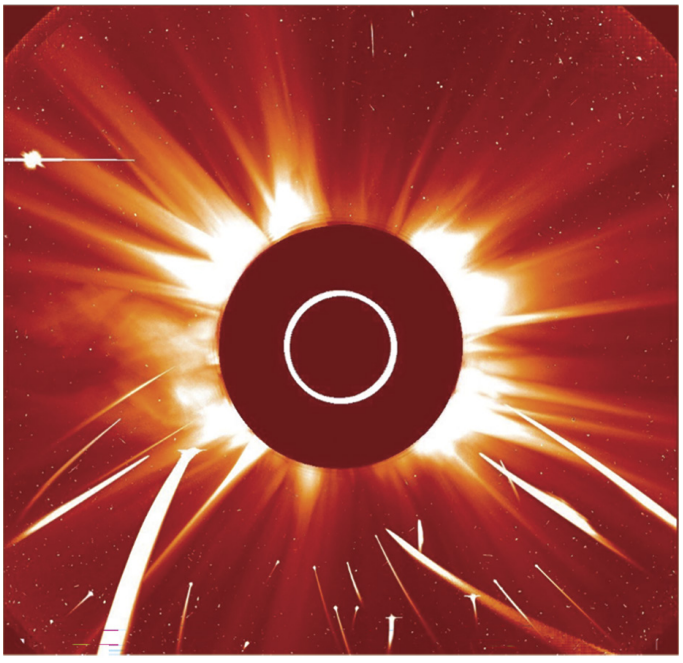
The big picture of the Kreutz system has now come into focus: First Aristotle's comet appears, and its two lobes separate after half a revolution about the Sun. Its remains arrive in AD 363 as many comets. Each lobe has broken into great fragments, spawning two 12th-century comets, which further split into their modern descendants. But the story continues.

Not included on the graph are the great number of dwarf sungrazers detected by spacecraft, most especially SOHO, including as many as 4,500 members of the Kreutz family. The enormous numbers of these boulder-sized objects not seen from Earth reveal at least nine populations of Kreutz sungrazers. Their existence bolsters the case of continuous and ongoing fragmentation of these objects and the likely return of future sungrazers.

Indeed, it's plain from these studies that there will be more sungrazers visible from Earth, as evidenced for example by the recent arrival of C/2024 S1 (ATLAS). This Population II sungrazer, arriving only 13 years after Lovejoy, may be a fragment of the Great Chinese Comet of 1138.

Images taken last January from the Atacama Desert in Chile revealed the inbounding of yet another Kreutz sungrazer, Comet 2026 A1/MAPS, holding the record for pre-perihelion detection of 81.4 days. But careening too near the Sun is a risky business for even the hardiest sungrazer, and C/2026 A1 sadly disappeared into the solar shredder.

Nevertheless, this object's obituary holds great interest for comet astronomers. By the best evidence, it had an immensely long orbital period of about 1,670 years, making it a rare oldie. It is thus possible, when all the computations have been done, that Comet MAPS may prove to be a sibling to Pereyra on the family tree.



ESA / NASA / R. PICKARD

▲ **FLIRTING WITH DISASTER** This composite of SOHO images shows some of the Sun-skirting objects identified by participants in the Sungrazer Project.

Intriguingly, C/2026 A1's orbital period implies an earlier perihelion of AD 360, matching Marcellinus's AD 363 daylight comets, supporting the case that they were indeed Kreutz sungrazers. Three dwarf sungrazers also followed Comet MAPS's path days later, providing more evidence for non-tidal fragmentation. Sekanina and his colleague Malgorzata Krolikowska regard Comet MAPS as an outlying fragment — a second-generation descendant of Aristotle's comet, like the Great Comet of 1106.

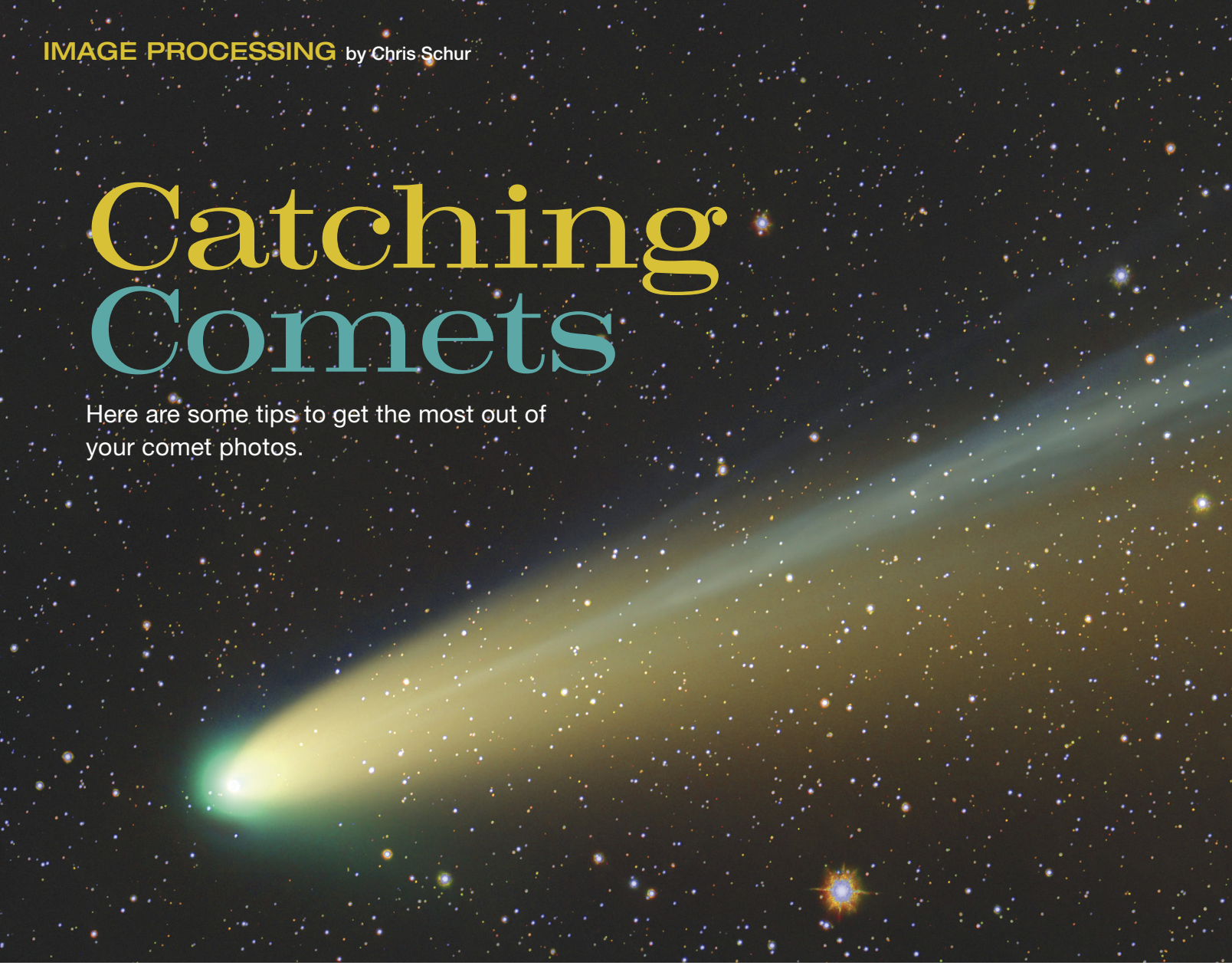
There is so much more to learn about the Kreutz family tree, and certainly more sungrazers to watch for. They are out there, on their way in. And each arrival will bring still more great new puzzles to solve!

■ **DOUGLAS MACDOUGAL** wishes to thank Zdenek Sekanina for his generous input to this article. Any errors or omissions in the narrative are the author's. MacDougal enjoys cometary dynamics and writes about the history of astronomy and mathematics from his home in Portland, Oregon. He is the author of *Newton's Gravity: An Introductory Guide to the Mechanics of the Universe* (Springer, 2012) and the forthcoming Springer book, *Ancient Skies: A First Look at Early Astronomy*. He can be found at **www.douglasmacdougal.com**.

GET INVOLVED: You can help professional scientists identify dwarf sungrazing comets for the Sungrazer Project by visiting **sungrazer.nrl.navy.mil**.

Catching Comets

Here are some tips to get the most out of your comet photos.



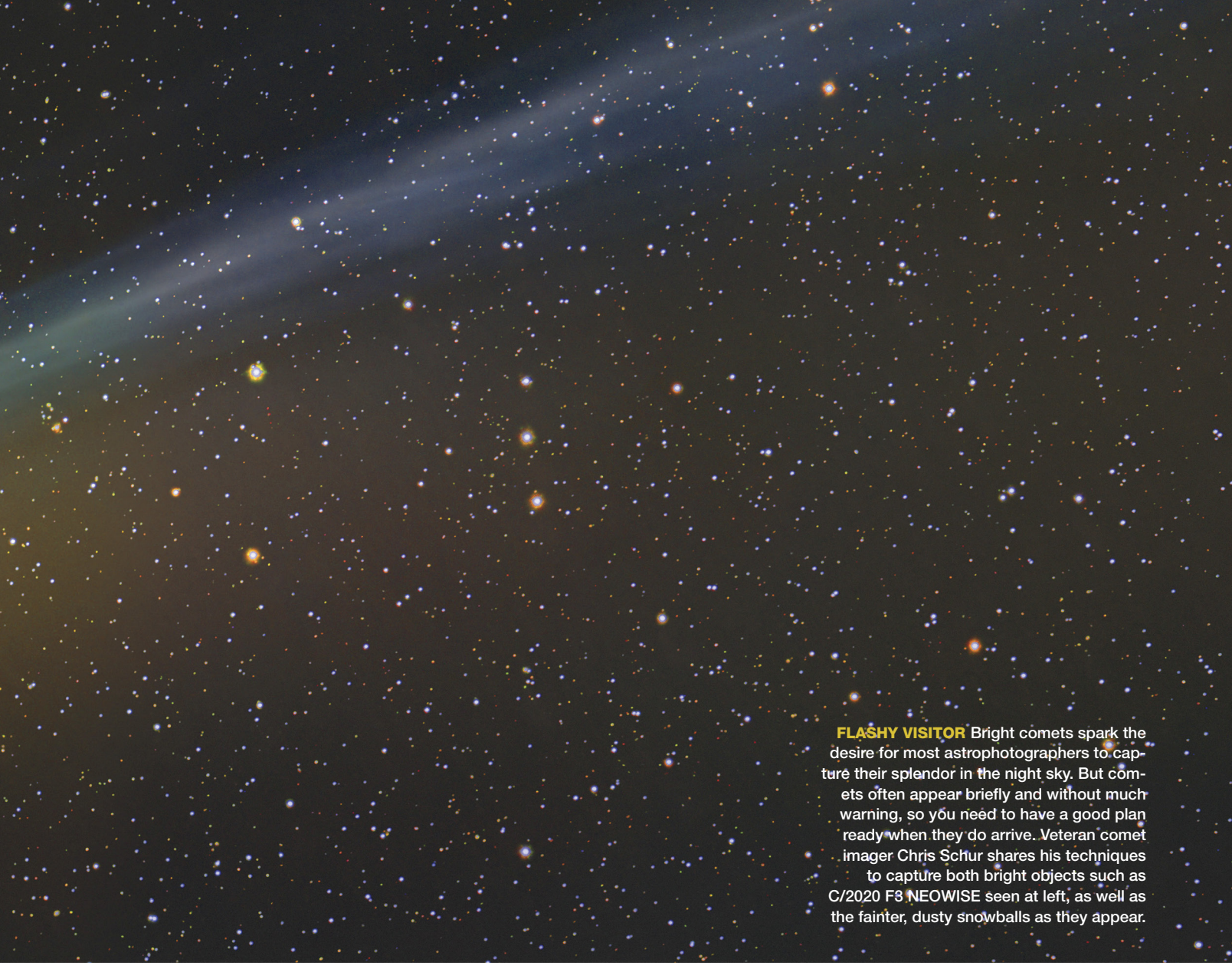
Each time a bright, naked-eye comet appears in the sky, it ignites a special desire in astrophotographers to capture the beauty of this new celestial visitor. However, successful comet imaging is a very different affair than capturing nebulae, star clusters, and galaxies. Comets are moving targets, and their very appearance can often change over short timespans, which isn't something that deep-sky imagers typically encounter. But using innovative techniques in comet imaging can be highly rewarding. Here are some shooting guidelines and processing tips that will greatly improve your chances of acquiring a well-composed, high-quality image worthy of your effort.

A Good Plan

How fast the comet moves may limit the maximum time allowed for each subframe without the comet trailing, unless you're guiding on the comet itself and are willing to accept star trails in the background. However, I find that the best images freeze the comet's motion against a field of sharp, round stars. This requires determining how much the comet moves during each subframe beforehand so that trailing can be limited to only a few pixels. A bigger question is whether or not to use guiding for your subframes at all. While you could limit the exposure to say, 30 seconds, this approach comes with its own challenges. First, the amount of camera sensor-correlated noise in each subframe will add up, creating string-like artifacts in the final stack. Second, if you're removing the stars during subsequent processing, doing so for dozens of short subframes will turn into a real nightmare due to the amount of time required to perform the action on each image. Your best bet is to just use a guidescope or off-axis guider to track on the stars, which will result in far less frustration when processing later. Comets near the Sun at dusk or dawn also dictate your guiding options. Sometimes there's simply not enough time to set up and guide on a faint star when the comet is very low on the horizon and setting fast.

Being aware of the comet's position in its orbit around the Sun is very important as well. The brightness of a comet

ALL IMAGES ARE COURTESY OF THE AUTHOR



FLASHY VISITOR Bright comets spark the desire for most astrophotographers to capture their splendor in the night sky. But comets often appear briefly and without much warning, so you need to have a good plan ready when they do arrive. Veteran comet imager Chris Schur shares his techniques to capture both bright objects such as C/2020 F8 NEOWISE seen at left, as well as the fainter, dusty snowballs as they appear.

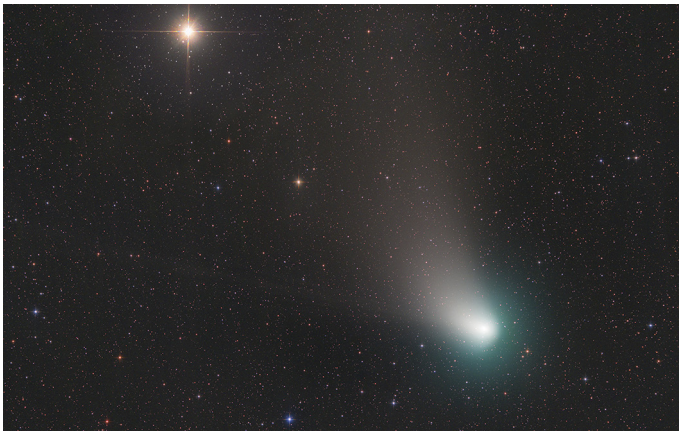
on each night is determined by several factors, including its heliocentric distance, or how close it is to the Sun, and its geocentric distance, or how close it is to Earth, as well as the volatility of the comet's nucleus. Plan on taking the majority of your images in a moonless sky when the comet is near maximum brightness. Other times to consider are near orbital plane crossing to search for dusty antitails, post perihelion for maximum tail growth, and any serendipitous conjunctions with background deep-sky objects.

Many comet imagers today use a color camera because of its ease of use and straightforward image processing. On the other hand, if you want to capture the very best comet images, a monochrome camera with a set of LRGB filters often yields better results. This is due to a clear luminance (L) exposure passing about three times the signal of color-filtered subframes, yielding far more image detail and depth. This advantage is offset, however, by the extra time needed to take separate color frames afterward to yield a final color image. Complicating matters is the fact that the comet's wispy dust and ion tails are constantly changing and moving. If you spend too much time acquiring the separate color frames, these features may become blurred in your stacked result. I find I can sometimes only stack about 10 minutes or so when there are knots in an ion tail moving downstream.

Composition Is Key

The difference between a good comet photo and a great one is arguably its composition. A common mistake is to center the comet's head in the camera frame and miss out on the full tail. The best approach is to position the tail diagonally across the middle of the frame, with the comet's head in one corner and the tail's end in the opposite corner. A simple 5-minute test shot before you start your subframe sets is handy for determining just how much offset to use. Also, consider framing the comet with a nearby deep-sky object to enhance the artistic composition. A rich star cluster, swirling galaxy, or perhaps a striking diffuse nebula in the same field will greatly improve the appearance of the image.





Wide-field photos that include the horizon are most spectacular if the comet is big and bright enough. If you're shooting with an equatorially aligned tracking platform, be sure to rotate the camera to align the edge of the frame with the horizon. Another popular wide-field imaging technique is to record a sequence showing the comet rising or setting. You can take a series of exposures at timed intervals of roughly 10 minutes apart and then combine them all with layers in *Adobe Photoshop* (**photoshop.adobe.com**) using the ***Lighten*** layer-blending mode. The result is a time lapse of the comet as it moves over a distant horizon or foreground feature. Try to avoid having any bright light sources within the frame, which can overpower the scene and shift the focus away from the primary subject.

Processing Techniques

Deep-sky imagers are familiar with the typical image-processing drill: calibrate, debayer (if you've used a color camera), align, stack, and apply nonlinear stretching. With comet photography, it's a bit more complex. An important consideration is whether you want the final result to show the comet appearing stationary in a field of trailed stars, or make

◀ **COMPOSITIONAL CONSIDERATION** Most newcomers to comet photography make the mistake of centering the comet's head in the camera frame *(upper left)*. To take advantage of the entire field of view, offset the coma in order to include as much of the tail as possible *(left)*. These examples show C/2022 E3 (ZTF) on the night of February 20 and February 8, 2023, respectively.



ATTRACTIVE JUXTAPOSITION Catching a comet as it passes near a deep-sky object greatly enhances the aesthetics of an image. Be sure to compose the shot so that both objects are balanced in the frame, like this example showing C/2025 R2 Swan with M16, the Eagle Nebula, in Serpens on the evening of October 17, 2025.

the icy visitor surrounded by a field of trailed stars. The old-fashioned way is the former, to emulate a single-frame film shot with subframes registered on the comet and allowing the stars to trail. This works well for comets that are much brighter than the stars in the background. Colorful star trails provide an excellent backdrop for a bright comet and imply its motion, and it's easy to accomplish this during processing. After calibrating all your subframes, perform a one-star alignment using the comet nucleus as reference point. The frames are then stacked with an average combine method. Follow this with some denoising and gradient removal and you're finished.

Creating a picture with both a stationary comet and pinpoint stars requires much more effort, but the results are well worth it. The key is to create two versions of the subframes and process them separately before combining the result.

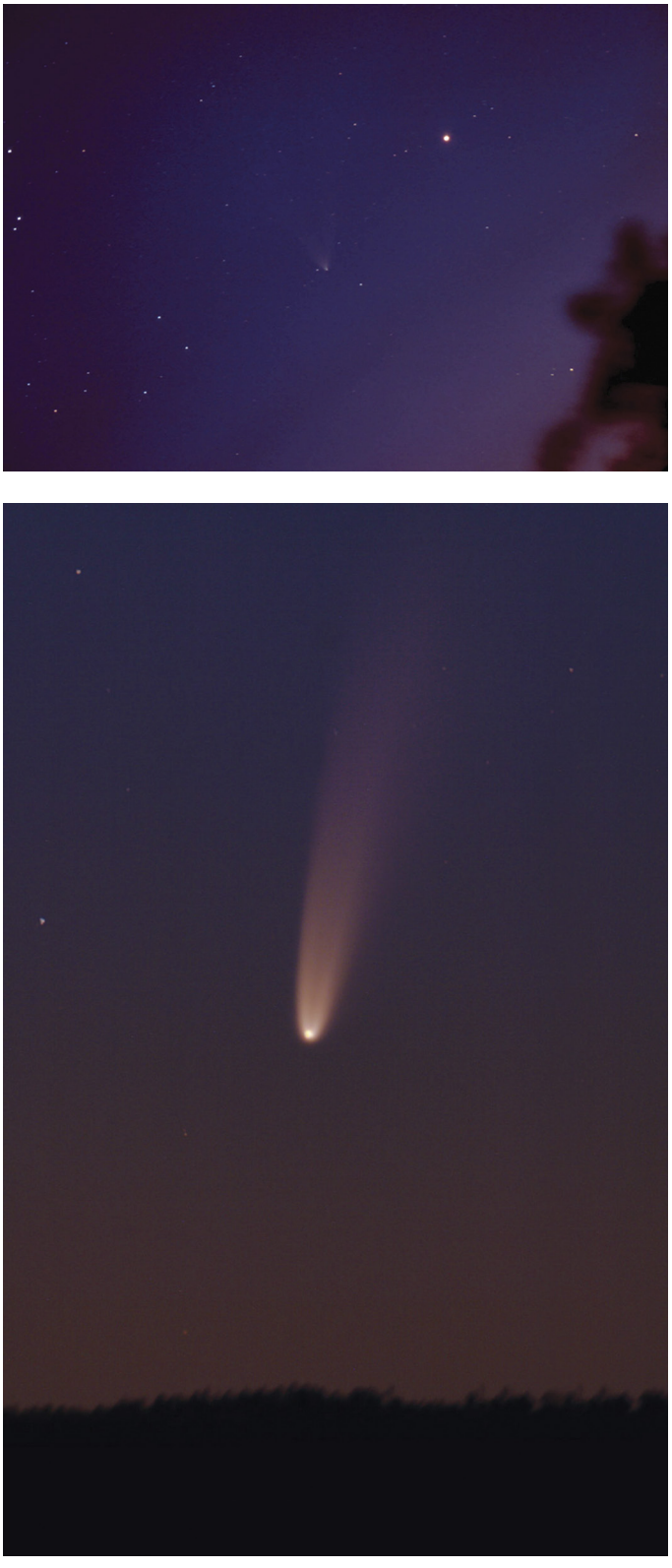
Start by registering the subframes on the background stars. Stack them with either a median combine or sigma-reject average, which is available in most any astronomical image-processing software (*Photoshop* doesn't have an equivalent feature). This results in a dim, trailed comet but nice round stars and sharp background objects like star clusters, nebulae, and galaxies. Use a nonlinear stretch to bring out these objects to the desired level and save it as a new image. Here you can perform additional processing to enhance any background objects should they appear in the field.

Create a second stack by registering on the comet and then removing the stars from all the subframes before stacking. There are several star-removal programs that operate as standalone or plug-ins for *PixInsight* (**pixinsight.com**) and even *Siril* (**siril.org**). These include *StarXterminator* (**rc-astro.com**) and *StarNet2* (**starnetastro.com**). *StarXterminator* is also available as a plug-in for *Photoshop*, but requires you to stretch the image first, and it's generally best to perform these actions on linear images before stretching. Again, use a median or sigma-reject average to erase the trails of stars. This yields an isolated comet with a few star residuals seen faintly in the background. Once again, apply a gradient correction followed by some noise reduction to the linear image. Now perform a nonlinear stretch to reveal the faintest extent of its coma and tails. You can then combine this with the comet-only image by simply adding the two images together. (In *Photoshop*, it's best to paste the comet image over the star field result and change the layer-blending mode to ***Lighten*** or ***Screen***). To add any deep-sky objects back in, you can layer over the star-aligned image again, and using masks, put them back in their place using the layer-blending mode.

Additional Enhancements

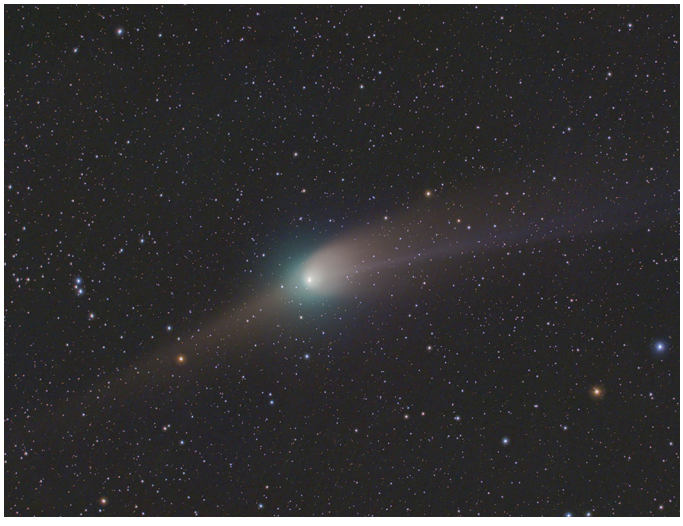
Here are several special techniques that you can use to process your comet images. Most of them can be performed in *Photoshop* or other astronomy-specific image-processing programs.

Arcsineh Stretch. The typical approach used for processing deep-sky images generally compresses the histogram to display details in both the bright and faint parts of a picture.



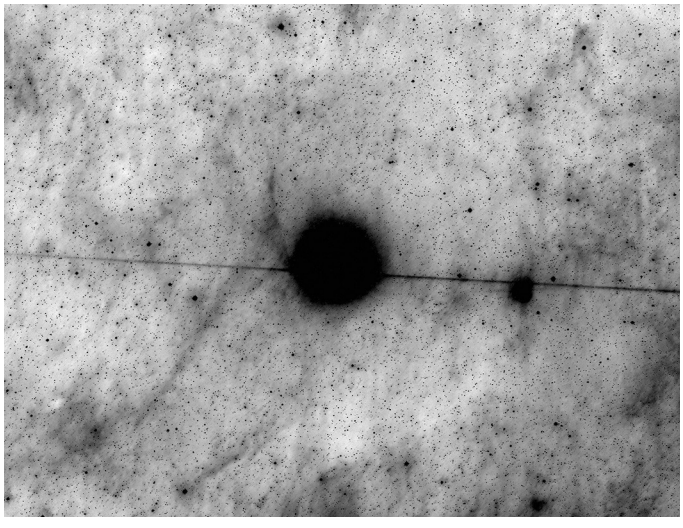
▲ **MIND THE HORIZON** Plan wide-field shots that include the foreground to be parallel to the edges of the frame. Add a ball-head mount to your setup when shooting with camera lenses on tracking mounts to avoid odd compositions like the example of C/2002 F1 (Utsunomiya) at top. The image above shows C/2020 F3 NEOWISE standing tall over the horizon on the evening of July 7, 2020.





▲ **TO TRAIL OR NOT TO TRAIL** Imaging fainter comets often requires stacking many short exposures. You can combine the results either by registering and stacking the subframes on the comet nucleus and allowing the stars to appear as trails, like this example of C/2007 N3 Lulin, at left, back in 2009. The other option is to "freeze" the comet's motion against the background stars, as seen in the picture of C/2022 E3 (ZTF) at right.





▲ **NEGATIVE BENEFIT** An inverted comet photo can be significantly stretched to better reveal faint details such as the dust trail of 10P/Tempel and any surrounding nebulosity.



MULTI-FRAME MOSAICS The long tails of some comets are often best imaged as a panorama of several frames stitched together. Plan on including about 20% overlap between fields to ensure there are enough stars to register each panel together. This result is a four-panel mosaic totaling 50 minutes of Comet Tsuchinshan-ATLAS recorded with a Sigma 135-mm lens and ZWO ASI2600MC camera on the evening of October 20, 2024.

For really bright comets, this strategy doesn't work well as it tends to blow out the core where some very interesting features reside. A better solution is to do a preliminary stretch using the ***ArcsinhStretch*** process in *PixInsight* (found in the pulldown menu ***PROCESS > Intensity Transformations > ArcsinhStretch***). The process is called ***Asinh Transformation*** in *Siril*. This tool rapidly brightens the low end of the histogram but does very little to the highlight regions. It preserves the comet's core and yet still brings out faint tail extensions. Both color and monochrome images can benefit from this process.

Dust & Scratches filter. One shortcut I prefer to obtain starless color data for enhancement with a luminance (unfiltered) result is to apply *Photoshop*'s ***Dust & Scratches*** filter after stacking to quickly remove the trailed stars. It's found in the pulldown menu at ***Filter > Noise > Dust & Scratches***. This removes a lot of noise and slightly blurs the image. Adding the luminance image as a new layer — by pasting the L image over this result and changing the layer-blending mode to ***Luminosity*** — restores sharpness and adds detail while requiring a lot less time than the star-removal path.

Median combine. This popular technique comet imagers often use has fallen a bit out of favor lately due to the newer star-removal software. Use the median combine process to stack comet-aligned images. This results in a stack with the star trails being minimized and can clearly show the full extent of the comet's tail and its faintest features. Because there are still a lot of faint star residuals, this is more of a quick test to evaluate a night's work.

Rotational filtering. You've likely seen professional images of comet heads where the internal rays and fountains of jets appear very clearly near the nucleus. This takes a special process to accomplish, called a Larson-Sekanina filter, which is found in *PixInsight* as well as the program *MaxIm DL* (**diffractionlimited.com**). It works by subtracting a copy of the coma that's rotated from the original image and aligned on the comet's pseudo-nucleus. While this process does indeed reveal hidden jets within the coma, it also introduces a lot of artifacts, making interpretation quite difficult. An alternative is to use a high-pass filter layer in *Photoshop* (***Filter > Other > High Pass***), then reset the black and white points using the Levels tool (***Image Adjustments > Levels***).



Screen mask boost. This old *Photoshop* technique is useful for enhancing very dim comet tails, antitails, and delicate knots within them. Here we open our stretched RGB or Luminance data and duplicate it to create a new layer (***Image > Copy*** followed by ***Image > Paste***). Set the layer-blending mode to ***Screen***, and a grayscale luminance mask is extracted from the original image. Click the ***Create Mask*** icon on the bottom of the Layers window while selecting the copied layer and then paste it on the mask. To finish this, blur the duplicate image to remove any noise with a Gaussian blur filter (***Filter > Blur > Gaussian Blur***), specifying a radius of two or three pixels. The combined effect is a substantial boost in brightness with the mask accentuating the body of the comet, rather than the star background. Set the transparency to a low value so as to not overdo it (I usually set for somewhere between 10% and 30%).

Inverted display. Converting your comet image to grayscale and inverting it to a negative image can reveal the faintest features. This is accomplished in *Photoshop* by choosing ***Image > Mode > Grayscale***, then ***Image > Adjustments > Invert***. Next, open ***Image > Adjustments > Levels*** and move the black-point (left) slider toward the right to set the background to a light gray rather than pure white. This type of image is often paired with one that's normally processed for comparison, to show the faintest features such as antitails or debris trails along the comet's orbital path.

Display and Presentation

Your masterpiece is almost ready to share. Make sure you crop off any non-overlapping edges, rotate the image to have north up, and flip any mirror-reversed images so they're correctly displayed. Be sure not to set the background too dark, as this will hide the faint details that you've worked so hard to bring out in your final portrait. I can't stress this too much here! A medium-dark-gray background with a brightness around 10% to 15% is best. Images can be shared not only on social media or via email, but don't forget to send them to websites such as *Sky & Telescope*'s online gallery (**skyandtelescope.org/gallery**) or Spaceweather.com. Also consider joining the International Comet Quarterly on Facebook (**tinyurl.com/ICQcomet**).

Spending the extra time and effort to hone your comet imaging skills has lots of positive implications. Many less obvious features in comets are found by amateurs paying close attention to the fine details they image in the coma and tail. Your deep-sky imaging will also benefit from the new techniques that you develop for comets in the process. Be prepared so that when the next bright comet comes along, you'll be ready for the action!

■ **CHRIS SCHUR** has been photographing comets for more than five decades. To see more of his work, visit his website at **www.schursastrophotography.com**.

Why This *Winter Wonderland?*

The extravagance of the night sky right now arises in part from our perspective on the galaxy at this time of year.

An arctic cold front has swept the skies clean, and above the snow-decked evergreens the evening sky is aflame. Brilliant Sirius twinkles fiercely in the southeast, while high above it shine the red and blue supergiants Betelgeuse and Rigel, on opposite sides of Orion's three-star belt. Extending this starry path, we find orange Aldebaran sparkling near the beautiful Pleiades star cluster. Capella gleams yellow at the zenith. Meanwhile, more subtle sights, such as the Orion Nebula and its dark neighbor, the Horsehead Nebula, await those who seek them.

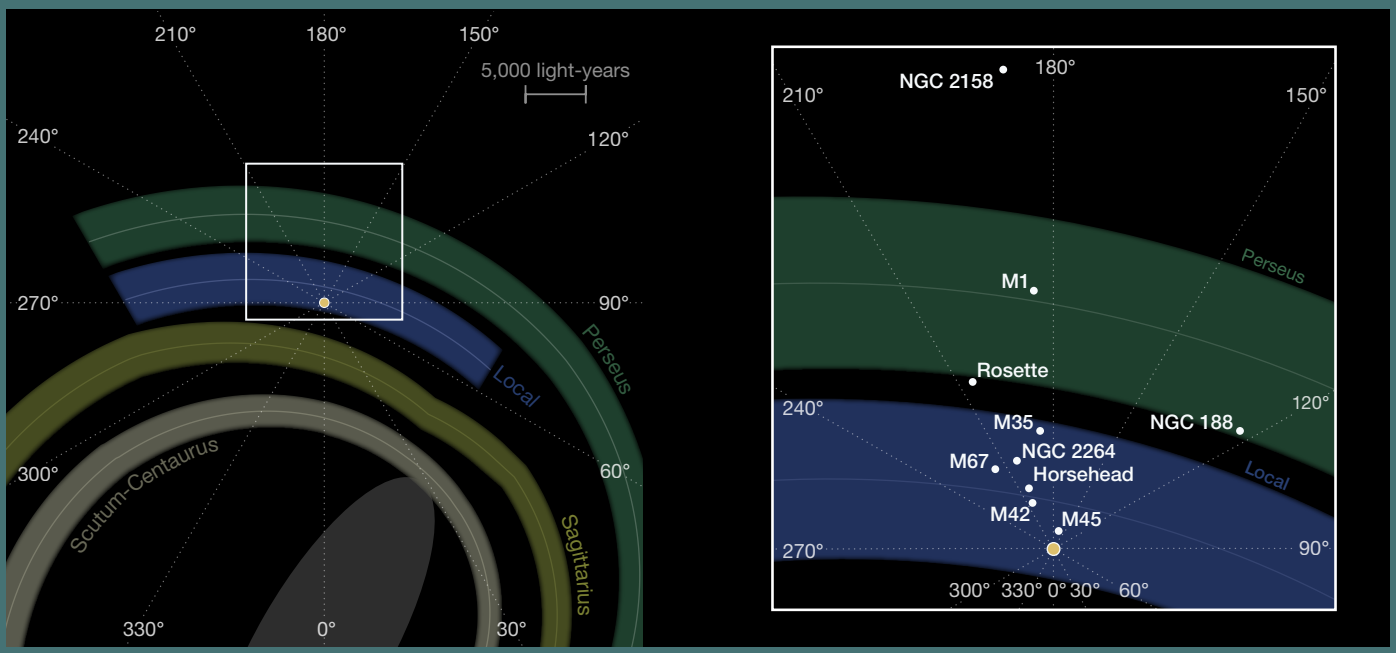
At mid-northern latitudes, winter is a spectacular celestial season for stargazers. Why does the winter night sky outperform the other seasons? Part of the answer comes down to the structure of our galaxy.

Galactic Geography

The Milky Way is a giant barred-spiral galaxy. Spiral arms are flashy: They create new stars and house stars of all masses, including the short-lived ones with the most mass. These massive stars are also among the most luminous.

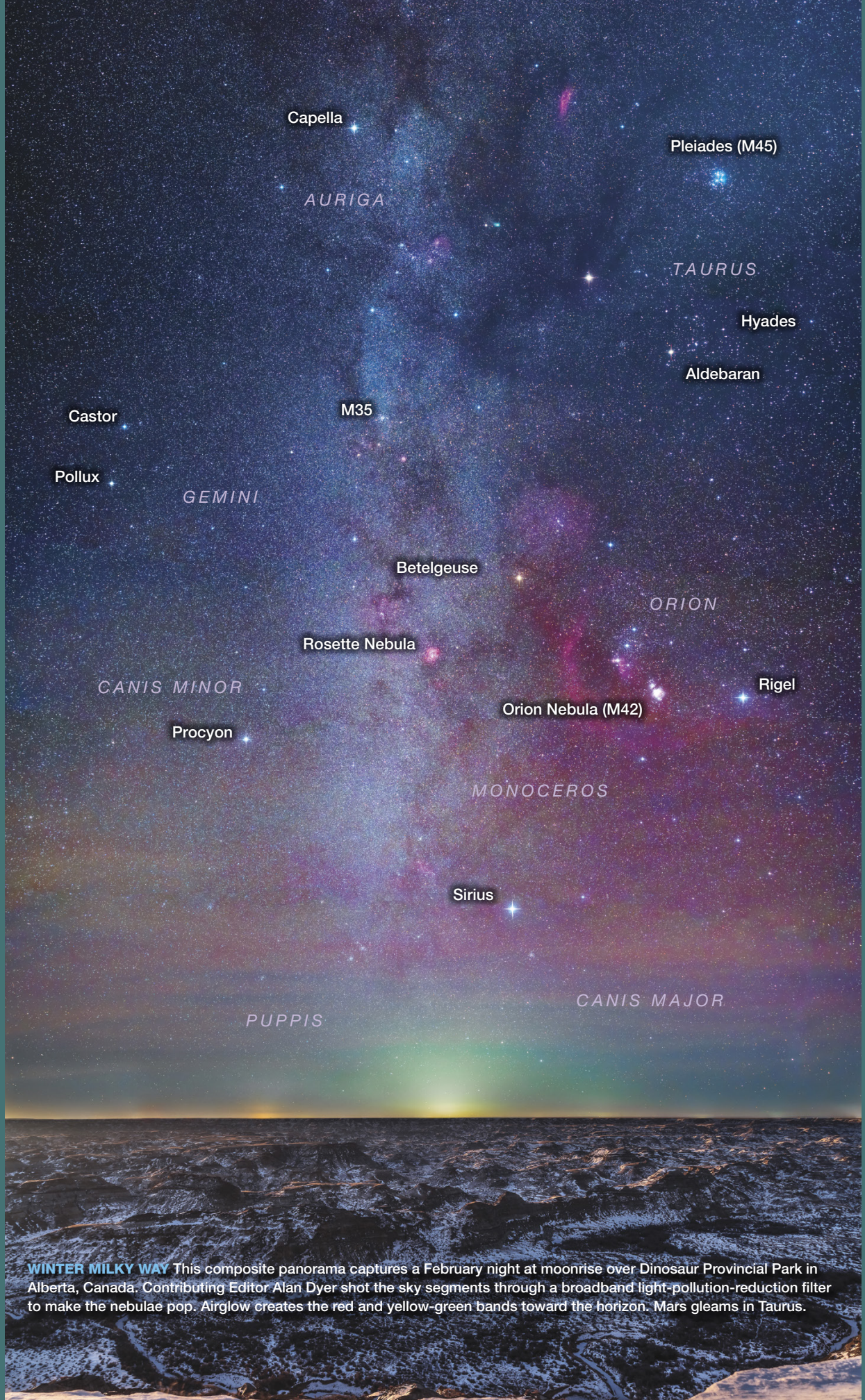
We're fortunate to reside in a spiral arm ourselves (*S&T:* Nov. 2019, p. 16). Known as the Local Arm, this structure puts us in an ideal spot to witness stellar treasures. The Local Arm is about 4,000 light-years wide from its inner side — the edge nearer the galactic center — to its outer side. We lie toward the inner side. The Scorpius-Centaurus Association, the closest clump of young, massive stars to Earth, is near the Local Arm's inner edge, which is only about 800 light-years from us.

This location partially explains why winter is prime time for stargazing. During winter, Earth is on the opposite side of the Sun from the galactic center. At night, we look away from the Sun, so we also look away from the galactic center and therefore straight into the depths of the Local Arm, where brilliant constellations abound — including the brightest one of all.



▲ **GALACTIC GLANCE** We live inside a spiral arm, and when we look along the galactic plane into space, we see objects at vastly different distances within the disk. Shown in the inset are January deep-sky objects mentioned in the text. Some lie in our Local Arm, while others lie beyond. Most of the stars discussed lie too close to the Sun to plot visibly on the map. The coordinates are galactic longitude, and the Sun's location is the orange circle.

BEATRIZ INGLESSIS / *S&T*; SOURCE: Y. XU ET AL. / *ASTRONOMY & ASTROPHYSICS* 2021



WINTER MILKY WAY This composite panorama captures a February night at moonrise over Dinosaur Provincial Park in Alberta, Canada. Contributing Editor Alan Dyer shot the sky segments through a broadband light-pollution-reduction filter to make the nebulae pop. Airglow creates the red and yellow-green bands toward the horizon. Mars gleams in Taurus.



▲ **THE PLEIADES** Messier 45's clutch of young stars is a favorite target for naked-eye and binocular observing.

Brilliant Orion

You can thank the fertility of the Local Arm for most of Orion's splendors. Orion, the Hunter, is one of the rare constellations that boasts two 1st-magnitude stars, ruddy Betelgeuse and blue-tinged Rigel. Orion also possesses five 2nd-magnitude stars. These five are hot, massive, and blue. Like Betelgeuse and Rigel, they were born in just the past several million years.

In turn, Orion continues to boost the Local Arm's star-making power. Its eponymous nebula, 1,350 light-years from Earth, has spawned thousands of new stars. The constellation's eerie Horsehead Nebula, which looks like the black knight in a cosmic chess game, also creates new stars, albeit in much smaller numbers. Doppler shifts of different parts of the Horsehead's gas reveal that the entire nebula is rotating, as if the horse is trying to peer toward Earth.

Southwest of the Orion and Horsehead nebulae shines Rigel, the most luminous star within 1,000 light-years of Earth. Rigel's powerful light even illuminates interstellar gas and dust in another constellation: the haunting Witch Head Nebula in Eridanus, dozens of light-years from the star (*S&T:* Apr. 2007, p. 26).

Orion is so vigorous that it's home to several stars that are spectral type *O*. Of the seven main spectral types, *O*-type stars are the hottest and rarest. For the other main spectral types, it's easy to find bright examples across the sky, such as blue-white Rigel (type *B*), white Sirius (type *A*), yellow-white Procyon (type *F*), yellow Capella (type *G*), orange Aldebaran (type *K*), and red Betelgeuse (type *M*). But spectral type *O*? The brightest specimens are only 2nd-magnitude.

Born at least 16 times as massive as the Sun, *O*-type stars are rare for two reasons. First, the galaxy gives birth to few stars this massive. Second, in order to balance the great inward gravitational pull of their own weight, these stars must generate an equal and opposite outward pressure. They do so by burning their nuclear fuel at a furious pace, creating tremendous light and heat whose outward push keeps the stars stable — at least for a short time. But within just 10 million years of their birth, they run out of fuel and die, most in titanic supernova explosions. For comparison, our Sun will live more than 10 *billion* years in all.

The Hunter is chockful of *O* stars, another sign of its recent fertility. Alnitak, the easternmost star in the Belt of Orion, consists of an *O*-type star coupled with a dimmer *B* star. Mintaka, the westernmost star, is also a system with an *O* star. Lambda (λ) Orionis, marking Orion's head, is type *O* as well. So is Iota (ι) Orionis, in the Sword of Orion. And two other *O* stars in the sky used to inhabit this constellation: AE Aurigae, north of Orion, and Mu (μ) Columbae, south of Orion. They likely arose in the Orion Nebula but flung each other away in a gravitational encounter.

The Belt of Orion leads you to a bright star elsewhere: aging Aldebaran.

Taurus and Auriga

Draw a line through the three stars of the Belt of Orion from east to west, and you will reach the vicinity of the brightest star in Taurus, the Bull: Aldebaran. This orange giant is older than the Sun, so unlike the youthful brilliance of Orion, Aldebaran's beauty actually says nothing about the Local Arm. Like clouds and waves, individual spiral arms may come and go, and Aldebaran probably formed long before the Local Arm did. A 2018 study of Aldebaran's internal oscillations found that the star is only about 16% more massive than the Sun and was probably born 6 or 7 billion years ago.

In its youth, Aldebaran was a yellow-white *F* star, converting hydrogen into helium at its core. But when the core ran out of hydrogen, the star began burning the fuel in a layer around the core. This transition made the star expand, cooling its surface and boosting its brightness. Today, Aldebaran is an orange *K*-type giant and the most luminous star within 100 light-years of Earth. In the distant future, our Sun will resemble it.

Aldebaran currently lies 67 light-years from us, located farther from the galactic center than we are. But it hasn't always been that way. The truth is, both stars' distances from the galactic center change as they go around the Milky Way. In fact, the Sun's distance from the galactic center varies by about 3,000 light-years; during most of the Sun's galactic orbit, our star is farther out than it is now. Aldebaran is the opposite: It spends most of its life closer to the galactic center. If that were the case now, then Aldebaran would be on the other side of us, and the star would appear in our summer sky. Aldebaran's actual position thus illustrates another reason behind the brilliance of the winter night sky: pure luck.

Also by luck, Aldebaran looks as though it's part of the closest star cluster to Earth. But no: The Hyades cluster is

KPNO / NOIRLAB / NSF / AURA / TAD DENTON / ADAM BLOCK

153 light-years from us, more than twice as far as Aldebaran and only a tenth as old. So the star and the cluster have nothing to do with each other.

Taurus houses the Pleiades cluster (M45), which looks stunning through binoculars. At 120 million years old, it is sufficiently young that some of its short-lived *B*-type stars still shine. A 2025 study found that the Pleiades is part of an enormous complex of young stars sprinkled across 2,000 light-years of the Local Arm. The Pleiades itself is 444 light-years from us, nearly three times farther than the Hyades.

Taurus's second-brightest star is blue *B*-type Elnath, marking the tip of one of the Bull's horns. Elnath joins Taurus to Auriga, the Charioteer, home of the bright star Capella. Both Taurus and Auriga sport interstellar clouds of gas and dust about 450 light-years from Earth that give birth to new stars. But unlike the Orion Nebula, which has spawned stars large and small, the Taurus-Auriga clouds produce only stars with less than a few solar masses. The best-known of these stellar infants is T Tauri (*S&T:* Feb. 2021, p. 12).

In Auriga, just 4¼° east of Elnath, lies the *galactic anticenter.* Although this sounds like something out of science fiction, it's an actual location in the sky: the spot where you gaze outward through the Milky Way's vast disk of stars, exactly opposite the galactic center. Here you peer toward the outer edge of the Local Arm as well as at the one beyond, the Perseus Arm.

In fact, if you traveled back in time 2,000 years and took your binoculars with you, you might glimpse a dim supergiant star 1° northwest of Zeta (ζ) Tauri, the tip of Taurus's other horn. Back then that dim supergiant was one of the most luminous stars in the Milky Way, shining in the Perseus Arm. After the star exploded, the flash from its death reached Earth in 1054. Today the Crab Nebula (M1) marks this massive star's remains, 6,500 light-years from us.

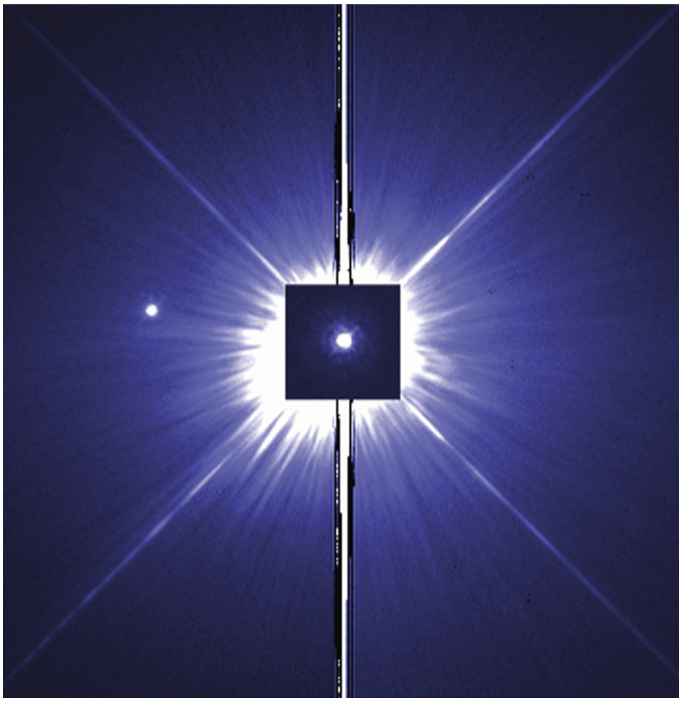
Other intriguing sights await when we follow the Belt of Orion the other way.

Sirius and Procyon

Draw a line through the Belt of Orion from west to east and you'll reach Sirius, the brightest star in the night. Sirius is a white *A*-type main-sequence star emitting more light than the Sun, but the chief reason it looks so bright is because it's only 8.6 light-years away — just twice the distance of Alpha (α) Centauri, the nearest star system to Earth.

Sirius shines in Canis Major, the Great Dog. Two other bright stars in this constellation — Adhara and Mirzam — are more distant, lying respectively 405 and 490 light-years from Earth. Or at least, they do now. But a mere 4.4 million years ago, they were only 30 light-years away, each shining nearly as brightly in our sky as Venus. Both are massive *B*-type stars that, unlike Sirius, will someday explode as supernovae.

Today, despite their distance, Adhara and Mirzam play a major role in ionizing — that is, stripping the electrons off of — hydrogen atoms in the Local Interstellar Cloud. This is a piece of diffuse flotsam cast our way more than



▲ **TAGALONG** This ultraviolet Hubble Space Telescope image reveals the white dwarf companion (dot at left) of the nearby star Procyon (bright star occulted in center).

1 million years ago when a massive star exploded in the Scorpius-Centaurus Association, near the Local Arm's inner edge. Normally, neutral hydrogen atoms in interstellar space would absorb the two stars' extreme-ultraviolet radiation long before it reached the Local Interstellar Cloud. But a long tunnel largely empty of interstellar material extends through this part of space, enabling the photons to travel farther.

If we leap northeast across the plane of the Milky Way's disk, we find that Sirius has a partner in spirit: Procyon, the brightest star in Canis Minor, the Lesser Dog. Like Sirius, Procyon is also one of our nearest neighbors, 11.4 light-years from Earth. Furthermore, each star has a white dwarf companion. Sirius B was the second white dwarf astronomers ever discovered, after 40 Eridani B (*S&T:* Dec. 2022, p. 28). Procyon B is more obscure; its mass and dimness betrayed its white-dwarf nature long ago, but observers first obtained the star's spectrum by using the Hubble Space Telescope.

The white dwarfs tug on their bright companions, revealing how massive the stars in each system are. These masses, together with the stars' temperatures and luminosities, then indicate the stellar ages. Sirius is the younger system, born only 230 or 240 million years ago, as dinosaurs were emerging on Earth. In contrast, a 2015 study found that Procyon formed 2.7 billion years ago, back when our planet's air lacked oxygen.

Jewels of Gemini

Like Aldebaran, Sirius and Procyon would be in our summer sky if they happened to lie a little closer to the galactic

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center. Ditto for Pollux and Castor, the two brightest stars in Gemini, the Twins, which shine above Procyon in our winter sky. Orange Pollux is 34 light-years from Earth, half the distance of Aldebaran, and the closest giant star to us. Castor is 51 light-years from us, a sextuple system consisting of two white *A*-type stars, each with a red dwarf companion, plus two additional red dwarfs that whirl around each other while slowly orbiting the other four stars.

Gemini also sports the distant open cluster M35, which is 2,900 light-years from Earth and visible in binoculars. Whereas we're near the Local Arm's inner edge, M35 resides near the arm's outer edge. The cluster is about the same age as the Pleiades and lies along the galactic plane.

Just half a degree from M35 sits a rich open cluster named NGC 2158. Too small and faint for small scopes, it looks far more compact and notably more yellow than M35's diffuse gathering of bluish stars. But though the two clusters lie close together on the sky, NGC 2158 is actually four times farther away, putting it 12,000 light-years from Earth. The cluster shines beyond both the Local Arm and the Perseus Arm; it may reside in a still more remote spiral arm, known as the Outer Arm, or in no arm at all.

NGC 2158 owes its golden color to both its greater distance and its greater age. Because of the greater distance, there's more interstellar dust between us and the cluster to scatter away its blue light. Because of its greater age, its massive blue stars have perished, and many of its other members have matured into yellow, orange, and red giants.

Unlike NGC 2158, most open clusters, such as the Pleiades and the Hyades, are younger than 1 billion years. That's because various forces and processes usually doom these objects. For example, gravitational tugs from *giant molecular clouds* — huge conglomerations of interstellar gas and dust that can be millions of times more massive than the Sun — tear these star clusters apart. So can the galaxy's tides: The galactic disk pulls harder on cluster stars that are nearer the disk than it does stars on the other side, luring them away. In addition, as stars inside a cluster orbit its center and encounter one another, a massive star's gravity can kick a lesser one out of the nest.

But NGC 2158 has survived for 2 billion years. How? Probably because it had the wisdom to reside far from the galactic center. There, giant molecular clouds are scarce and galactic tides are weaker. Furthermore, some open clusters have endured even longer. For example, M67 in Cancer is 4 billion years old, while NGC 188, in Cepheus, is 6 to 8 billion years old. Both clusters also inhabit the outer galaxy, though they're not nearly as far from the galactic center as NGC 2158 is.

Between Sirius and Procyon on the sky is the dim constellation Monoceros, the Unicorn, which sports distant gems

◀ **DISTANT NEIGHBORS** The young cluster M35 (left) appears next to the much older NGC 2158 (right) in the sky. But the latter is actually four times farther away and much older, too: Its bright, bluish stars have all died, so its leading lights are now aging yellow, orange, and red giants.

M35 AND NGC 2158: MARK GERMANI; NGC 2244: NASA / ESA / STSCI / DSS, IMAGE PROCESSING BY JOSEPH DEPASQUALE (STSCI)



▲ **CELESTIAL FLOWER** The Rosette Nebula, lit from within by the cluster NGC 2244, spans some 100 light-years and lies nearly 5,000 light-years from Earth in the outer Milky Way.

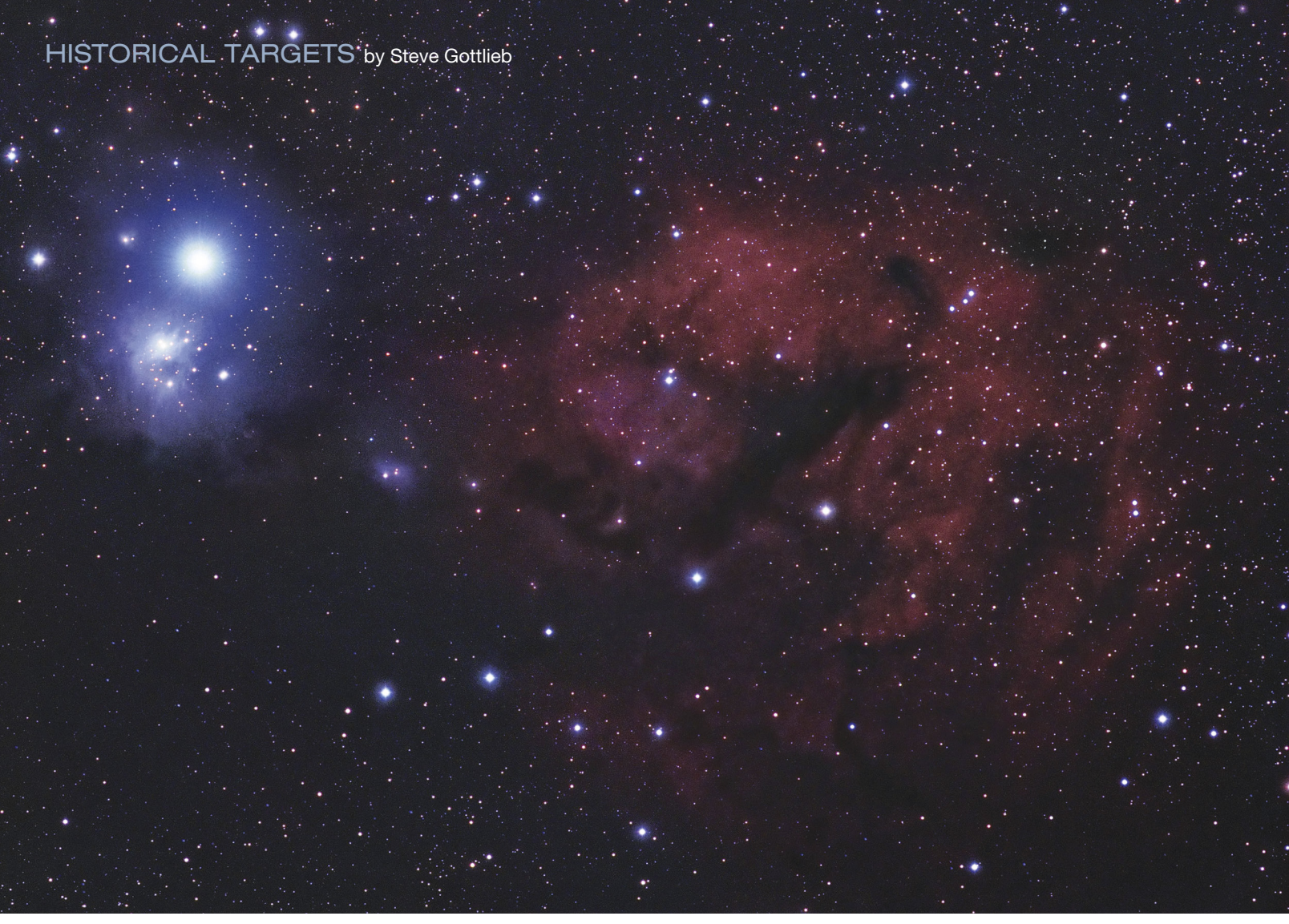
in the Local and Perseus Arms. One such gem is a scattered group of stars called the Christmas Tree Cluster, NGC 2264. It glimmers nicely in binoculars (*S&T:* Feb. 2022, p. 43). Data from the Gaia spacecraft indicate that NGC 2264 is 2,350 light-years from Earth, placing the cluster near the midsection of the Local Arm. With an age of only 1 million years, NGC 2264 bears 5th-magnitude 15 Monocerotis, a rare *O*-type star. Near it is the elusive Cone Nebula, a dark pillar of gas and dust reminiscent of the Horsehead Nebula in Orion.

Twice as far, some 4,700 light-years from Earth, is the Rosette Nebula. Beautiful in images, it's a difficult target for small scopes. It has spawned — and is lit up by — another young star cluster, NGC 2244, which is 1 to 2 million years old. Both reside on the inner edge of the Perseus Arm.

Many a happy life arises from a combination of a well-executed plan and pure luck. The winter night sky is similar: It owes its many sights to both the beautiful spiral structure of our galaxy as well as coincidence. Orion exemplifies the former, and nearby stars such as Sirius and Procyon the latter. Yes, it's cold, but winter nights are long — indeed, it's cold in part *because* the nights are long — but those long nights give us the chance to appreciate the many celestial spectacles at this time of year.

■ Contributing Editor **KEN CROSWELL** is the author of eight books, including *The Alchemy of the Heavens* and *See the Stars*. He wrote "A Stargazer's Guide to the Milky Way," which appeared in the August 2025 issue.

 by Steve Gottlieb



Exploring the First *Index Catalogue*

This sequel to the *NGC* list includes some of the finest visual discoveries of the late 19th century.

It took 35 years, nine trips to the Southern Hemisphere, and telescope apertures ranging from 3 to 30 inches. But in October 2017, I finally completed an observing program that had once seemed almost impossible: visually documenting the roughly 7,200 unique objects in the *New General Catalogue of Nebulae and Clusters of Stars* (*NGC*) that John Louis Emil Dreyer of Armagh Observatory published in 1888. I viewed my final quarry — NGC 2932 in Vela — from the OzSky Star Safari site, a working sheep-and-cattle station in the Southern Tablelands of New South Wales, Australia.

My friends jokingly asked, "Since you've observed *everything,* are you going to retire now?" After pursuing a few shorter lists, I thought, why not pick up where the *NGC* ended? That meant tackling the first *Index Catalogue*, or *IC I*, which includes 1,529 nonstellar objects discovered primarily visually between 1888 and 1894. Like the better-known *NGC*, *IC I* also contains a number of overlooked gems, as well as historical curiosities and galaxies whose identities have puzzled researchers for decades.

Two astronomers dominate the *IC I*. French observer Stéphane Javelle discovered about 800 faint galaxies using the massive 30-inch refractor (La Grande Lunette) at Nice

▲ **CLUSTER AND REFLECTION NEBULA** IC 348, shining at upper left, is an open cluster embedded in the bluish reflection nebulosity called vdB 19 in the constellation of Perseus. It's a young, star-forming region estimated to be about 2 million years old, and it lies about 1,000 light-years from Earth. The bright, bluish-white star above it is Omicron (o) Persei. And just below the cluster is the dark, dust-laden region designated Barnard 4. The faint, red emission nebula visible at right is known as LBN 749 and is part of the Perseus Molecular Cloud.

JIM THOMMES

▶ **CELESTIAL NAVIGATION** Use this and the other accompanying finder charts to help you home in on the *IC I* objects highlighted in this article. You can also refer to the text for detailed star-hopping instructions. All the charts have north up and east to the left.

Observatory in southern France. American comet hunter Lewis Swift added roughly 300 discoveries with the 16-inch Clark refractor at Warner Observatory in Rochester, New York. In contrast, the second catalog (*IC II*), published in 1908, comprises mainly photographic discoveries. However, as we shall see, other astronomers contributed, too.

For many of the faintest *IC I* galaxies, I relied on my 24-inch f/3.7 reflector. One especially challenging target — Abell 1783, a nearly billion-light-year-distant galaxy cluster with 18 ICs — required a look through Jimi Lowrey's 48-inch reflector in West Texas. I finished up with IC 1493 (also designated PGC 1458643), a small, 16th-magnitude smudge in Pegasus. Coincidentally, the setting was also a cattle ranch in Northern California, exactly eight years to the day after completing the *NGC* list.

Let's explore a baker's dozen of *IC I* objects that were discovered visually and are accessible to observers with a 10-inch or smaller telescope.

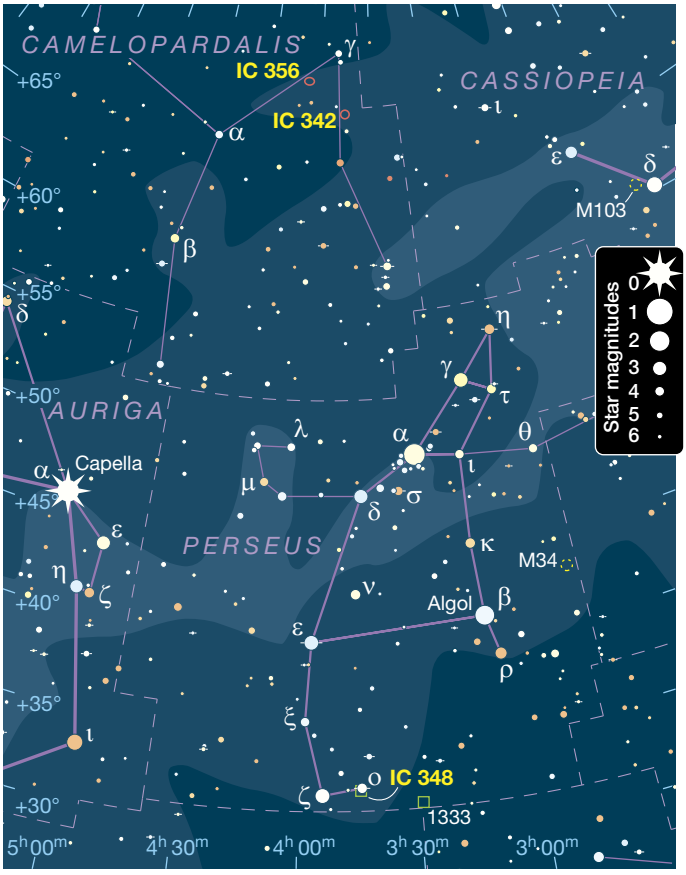
Winter Targets

American astronomer Truman Henry Safford found **IC 348**, a combination of open cluster and reflection nebula, on December 1, 1866, with the 18.5-inch Clark refractor at Dearborn Observatory (then in Chicago). His observation, along with dozens of other discoveries, wasn't published for more than two decades, so it missed being included in the *NGC*.

You'll easily identify IC 348 just 8′ south-southeast of the 3.9-magnitude star Omicron (o) Persei. Viewed through a friend's 5.5-inch refractor at 54×, I found a collection of 10 stars encased in the nebulous glow of the reflection nebula vdB 19. Barnard 4, a very large, dust-filled starless region, lies immediately south of the cluster. In an 8-inch reflector at 71×, vdB 19 appeared as an irregular, nebulous haze stretching mainly northwest-southeast from the 8.5-magnitude star HD 281159, the cluster's brightest member.

This young stellar group resides at the eastern end of the Perseus Molecular Cloud (with the reflection nebula NGC 1333 forming the western core). The complex is the most active star-forming region within 1,000 light-years of the Sun. With an age of 5 million years, IC 348 contains 400 to 500 stars, including 40 to 50 brown dwarfs, some with masses less than one-hundredth the Sun's mass. A 2025 study using the James Webb Space Telescope detected tiny, free-floating brown dwarfs in IC 348 as small as twice the mass of Jupiter (see page 10 in this issue).

Legendary American astronomer Edward Emerson Barnard discovered the spiral galaxy **IC 356** on August 23, 1889. He called it a "very cometary-looking nebula" and checked its position several times that night and even the next, hoping to detect some motion. A year later, British amateur William Frederick Denning independently found the galaxy



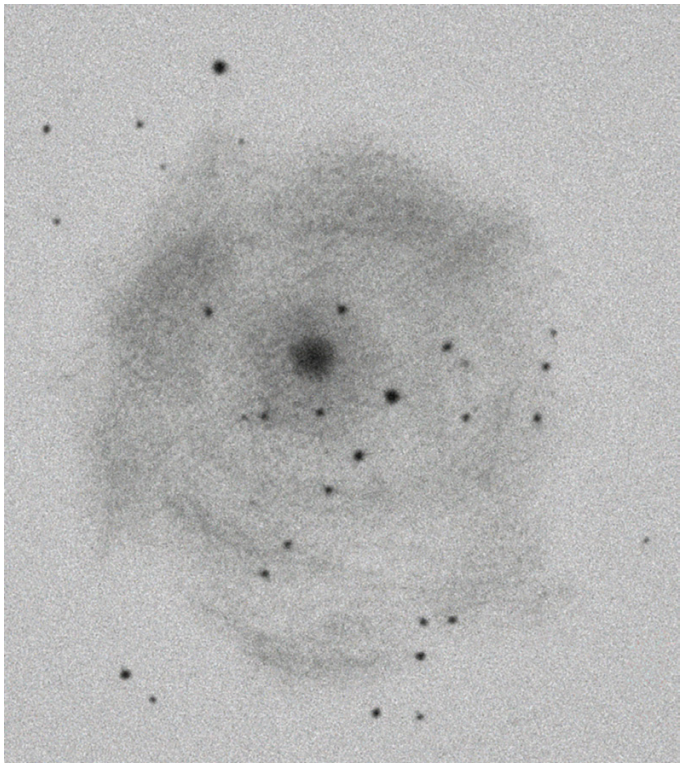
Beyond *Index Catalogue I*

In 1894, Lewis Swift shipped his 16-inch refractor from New York to Southern California, where he continued his search for nebulae at the newly constructed Lowe Observatory on Echo Mountain. Here, the skies were darker and 9° farther south. Between 1895 and 1898, he reported 288 discoveries, but many of his positions were poor, and several objects later proved to be duplicates or couldn't be identified.

The indefatigable observer Stéphane Javelle continued to scan the sky for tiny, faint fuzzies. From 1895 to 1904 he published 807 additional discoveries that appeared in the second *Index Catalogue* (*IC II*). He continued observing until 1911, making another 400 discoveries recorded in a preliminary monograph that never appeared in the *Annals of the Nice Observatory*. After allowing for duplicate and lost objects, Javelle's lifetime total approaches 1,770 confirmed deep-sky discoveries — likely surpassing John Herschel and ranking second only to William Herschel among visual discoverers.



▲ **FACE-ON PINWHEEL** IC 342, also known as Caldwell 5, lies 3¼° south of 4.6-magnitude Gamma (γ) Camelopardalis. The 8th-magnitude, 21′-wide spiral is about 11 million light-years from Earth. Despite its sprawling size and actual brightness, the object's location behind dense gas and dust near the galactic plane make it rather challenging to observe, hence its nickname Hidden Galaxy. You can try to spot it with a small scope at low powers under a dark sky.



▲ **DARK-SKY VIEW** *S&T* Contributing Editor Howard Banich used his 28-inch reflector at various magnifications for this sketch of IC 342. He notes it's a good representation of how the object looks through a dark but relatively poor-transparency sky. At 131×, all he could see was the galaxy's star-like core. "Its low-surface-brightness spiral arms were best seen at 253×, but still quite subtle," he says. "Averted vision made the arms stand out rather well."

A Roundup of *IC I* Targets

Object	Type	Constellation	Mag	Size	RA	Dec.
IC 348	Open cluster/ reflection nebula	Perseus	7.3	10′	$03^h\ 44.6^m$	+32° 10′
IC 356	Galaxy	Camelopardalis	10.5	5.2′ × 3.9′	$04^h\ 07.8^m$	+69° 49′
IC 342	Galaxy	Camelopardalis	8.4	21′ × 21′	$03^h\ 46.8^m$	+68° 06′
IC 749	Galaxy	Ursa Major	12.4	2.3′ × 1.9′	$11^h\ 58.6^m$	+42° 44′
IC 750	Galaxy	Ursa Major	11.9	2.6′ × 1.2′	$11^h\ 58.9^m$	+42° 43′
IC 972	Planetary nebula	Virgo	13.6	43″ × 40″	$14^h\ 04.4^m$	–17° 14′
IC 1029	Galaxy	Boötes	11.3	2.8′ × 0.5′	$14^h\ 32.5^m$	+49° 54′
IC 1257	Globular cluster	Ophiuchus	13.1	1′	$17^h\ 27.1^m$	–07° 06′
IC 1276	Globular cluster	Serpens Cauda	10.3	7′	$18^h\ 10.7^m$	–07° 12′
IC 1295	Planetary nebula	Scutum	12.5	102″ × 87″	$18^h\ 54.6^m$	–08° 50′
IC 1369	Open cluster	Cygnus	8.8	5′	$21^h\ 12.1^m$	+47° 46′
IC 1434	Open cluster	Lacerta	9.0	8′	$22^h\ 10.5^m$	+52° 50′
IC 1459	Galaxy	Grus	10.0	5.2′ × 3.8′	$22^h\ 57.2^m$	–36° 28′

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

PHOTO OF IC 342: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY; SKETCH: HOWARD BANICH

and declared, "there is not another nebula so plain as this remaining to be discovered north of the equator."

But Barnard and Denning may not have been first. Swift replied that he likely discovered the galaxy before 1879 while comet hunting with a 4.5-inch telescope and even marked its position on his copy of Elijah Burritt's popular star atlas.

IC 356 lies 2.1° southeast of 4.6-magnitude Gamma (γ) Camelopardalis, where foreground interstellar dust clouds redden and dim the galaxy's light. American astronomer Halton Arp included this spiral as Arp 213 in his *Atlas of Peculiar Galaxies* due to its intriguing radial dust lane that leads to the nucleus and splits into three branches.

I easily saw the galaxy at 107× in my 8-inch reflector as a large, slightly elongated glow perhaps 2′ across, with a round, brighter core. An 8.5-magnitude star lies only 3′ north, and Denning later suggested that this star had caused earlier observers to overlook the galaxy.

IC 342, located 2.5° southwest of IC 356, lies only 10° from the galactic plane. Barnard's logbook shows that he discovered the galaxy on August 11, 1890, but never announced it (for more of Barnard's lost discoveries, see *S&T:* Nov. 2020, p. 34). Two years later, Denning stumbled across IC 342 while comet hunting with his 10-inch reflector. He published the discovery a few months later and received credit for it in the *IC I*.

At a distance of about 11 million light-years, this face-on spiral sprawls across 21′ of sky, but the so-called Hidden Galaxy is heavily obscured by intervening dust within the Milky Way. Under dark, transparent skies, though, you can spot IC 342 using a small scope. My 8-inch reflector at low power showed a prominent, 12th-magnitude core framed by two stars of similar brightness to the north and northeast and an 11th-magnitude star less than 3′ west. The core is swathed in a tenuous 10′ halo that fills the gaps between numerous superimposed stars.

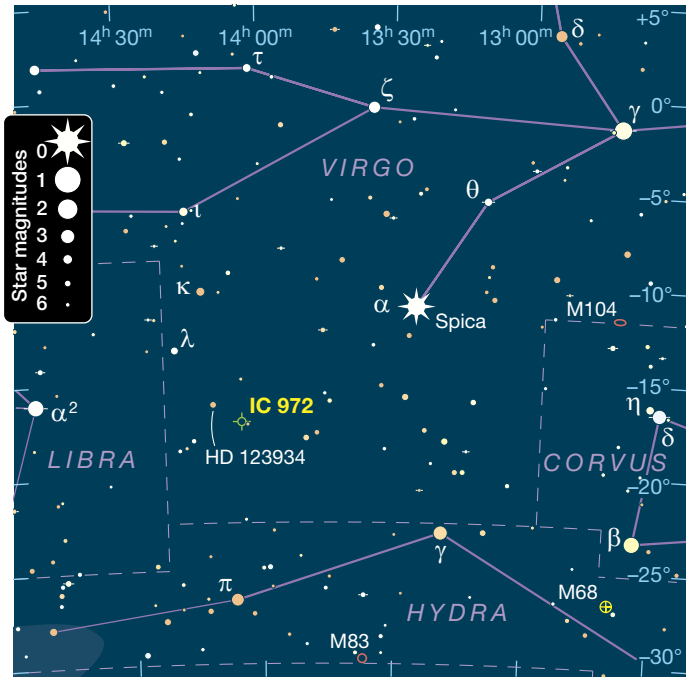
Springtime Targets

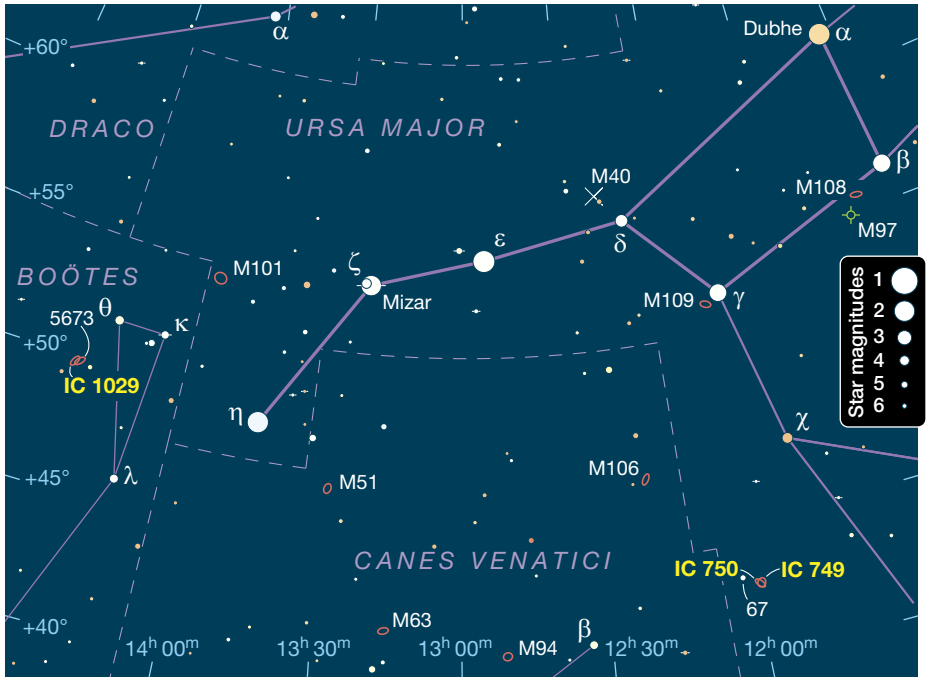
In April 1892, Austrian astronomer Rudolph Ferdinand Spitaler discovered the galaxy pair **IC 749** and **IC 750** at Vienna Observatory. With visual magnitudes of 11.9 and 12.4, respectively, they form the brightest galactic duo in the *IC I* list. William Herschel and his son, John, each swept this region multiple times, discovering several bright galaxies within 2°, yet both overlooked this conspicuous pair.

Only 40′ southwest of the 5.2-magnitude star 67 Ursae Majoris, IC 749 is a patchy, star-forming spiral with loosely wound arms that sparkle with young, blue stellar associations. Less than 4′ east, IC 750 appears sedate and reddish, yet hosts one of the lowest-mass known active galactic nuclei, with an intermediate-mass black hole only 70,000 times the Sun's mass.

The galaxies' visual appearance mirrors their contrasting evolution. Through my 8-inch at 107×, IC 749 appeared faint, roundish, and diffuse, with a low, nearly even surface brightness. IC 750 was an easy spindle, leaning northeast and sporting a bright core.

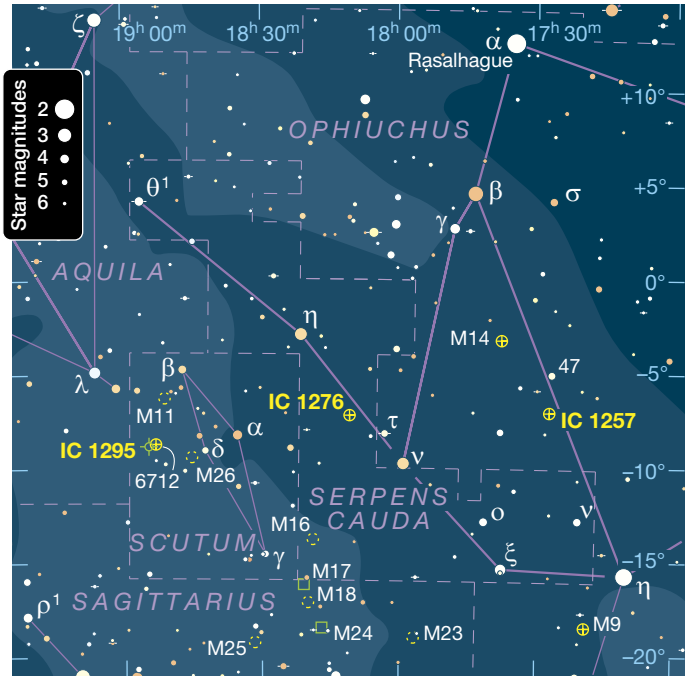
Javelle discovered the planetary nebula **IC 972** on May 25, 1892, and described the object as "faint, round, 20″ in diameter, with a slightly grainy appearance." American astronomer George Abell found IC 972 again in the early 1950s on a *National Geographic Society — Palomar Observatory Sky Survey*

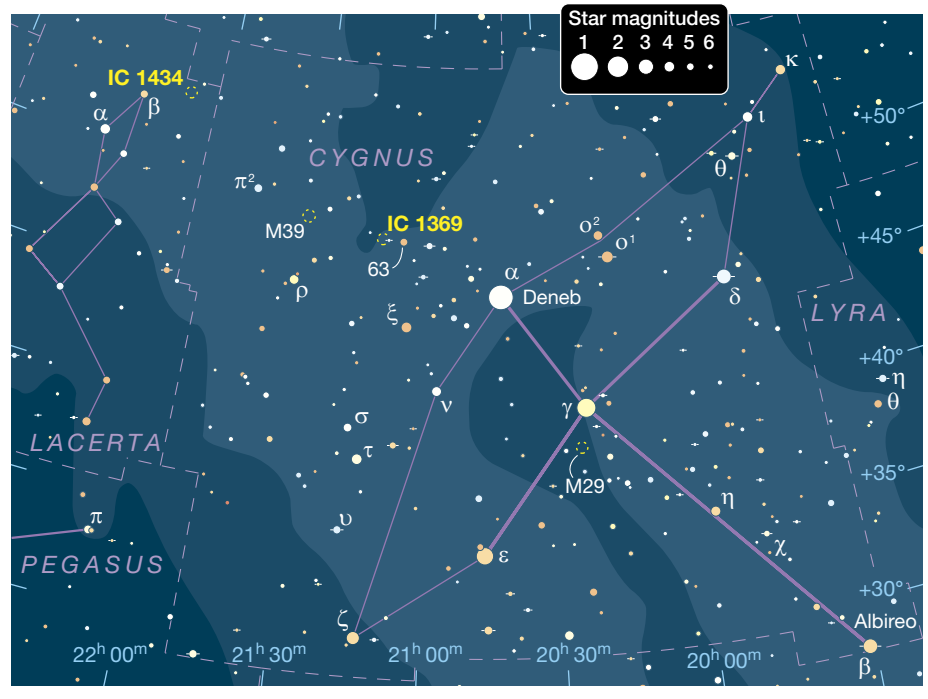




(*POSS*) plate while searching for new planetary nebulae, and he included it in his discovery list as Abell 37, since it wasn't previously recognized as a planetary.

Located in southeastern Virgo — a constellation nearly synonymous with galaxy hunting — IC 972 resides 1.8° southwest of the 4.9-magnitude orange-red star ET Virginis (HD 123934). You can spot it in an 8-inch scope as a small, very faint disk, though you may need an oxygen III (O III) filter to tease it out. At 158× (unfiltered), my 14.5-inch reflector showed an evenly illuminated bubble about 40″ across, and an O III filter noticeably boosted the contrast.





IC 1029 and NGC 5673 form a pair of edge-on spirals in Boötes with a fascinating backstory — IC 1029 is the brighter galaxy, and it was discovered *before* NGC 5673. William Herschel swept the field on May 15, 1787, and recorded a single nebula whose position matches the galaxy identified today as IC 1029. Forty-three years later, John Herschel reexamined the field, expecting to find his father's nebula. He also logged a single object that lay southeast of a 15th-magnitude star, but his position was 9′ farther northwest. Comparing their observations with the sky, it's clear that father and son each discovered a different galaxy in the same field!

When compiling the *NGC*, Dreyer naturally assumed there was a single object there and used John's position — the northwestern spiral — for NGC 5673. Finally in 1887, French astronomer Guillaume Bigourdan took another look and recorded both galaxies. He received credit for IC 1029, although William Herschel made the discovery a century earlier.

To locate IC 1029, steer 2.2° south-southeast of 4th-magnitude Theta (θ) Boötis. Under dark skies, my 8-inch at 107× displayed IC 1029 as a narrow spindle dominated by a small, bright nucleus. I dimly saw NGC 5673 as an elongated, low-surface-brightness glow with a 13th-magnitude star at its northwestern tip.

Summer Targets

While searching for comet C/1888 R1 (a Barnard discovery), Spitaler detected **IC 1257** in Ophiuchus on July 7, 1890. The next night, Barnard also looked for his comet and stumbled upon IC 1257, initially mistaking it for the comet.

For decades, the true nature of IC 1257 remained uncertain. It was cataloged as a diffuse nebula in 1946 and was even listed as an open cluster as late as 1987. Finally, a color-magnitude diagram of its member stars revealed the object as an outer-halo globular cluster reddened by intervening dust. Recent studies place IC 1257 some 86,700 light-years away on the far side of our galaxy, its light significantly dimmed as it threads its way through the galactic bulge.

IC 1257 is situated 2° south of 4.5-magnitude 47 Ophiuchi, but don't expect to see much here. Even in my 18-inch reflector at 246×, it appeared as a faint, unresolved glow about 30″ across with a quasi-stellar nucleus. But *S&T* Contributing Editor Scott Harrington managed to detect IC 1257 using a 5.1-inch reflector at 59×.

Located in Serpens, **IC 1276** is a moderately metal-rich globular 14,000 to 15,000 light-years away. Swift, its discoverer, described it as a very large, extremely faint and diffuse object, with a double star near its western edge. An unusual case of mistaken identity

occurred in 1952, when Soviet astronomers Vera Gaze and Grigory Shajn included IC 1276 in a catalog of diffuse, gaseous nebulae. Around the same time, Abell, then a Caltech graduate student, correctly recognized the object on a *POSS* plate as a previously overlooked globular cluster and cataloged it as Palomar 7. But unlike several remote halo globulars also found by Abell, IC 1276 is a loose, heavily reddened bulge cluster.

Navigate 2.1° northeast of the 4.8-magnitude double star Tau (τ) Ophiuchi (a challenging 1.4″ pair) to reach IC 1276. In a 10-inch scope, the globular will appear much like what Gaze and Shajn reported — a dim, nebulous glow with a few foreground stars superimposed. At 375× in my 24-inch reflector, its halo swelled to 3.5′ in diameter, and up to a dozen stars sparkled over a weakly concentrated halo.

On August 28, 1867, Safford discovered the planetary nebula **IC 1295** in the incredibly rich Scutum Star Cloud. Some sources claim it shines at only 15th magnitude, but this figure is much too faint, being based on old, blue-sensitive photographs. I first observed IC 1295 in 1981 with an 8-inch Celestron Schmidt-Cassegrain and was amazed to easily find it floating in the same gorgeous star field as the globular cluster NGC 6712, only 23′ to the east-southeast.

Later that year, Walter Scott Houston asked readers of his Deep-Sky Wonders column to send in reports of IC 1295, and I was surprised to learn that my 8-inch observation was the smallest aperture submission. The following year, I took another look through a 5-inch reflector and still identified a subtle puff of light just east-northeast of an 11th-magnitude star.

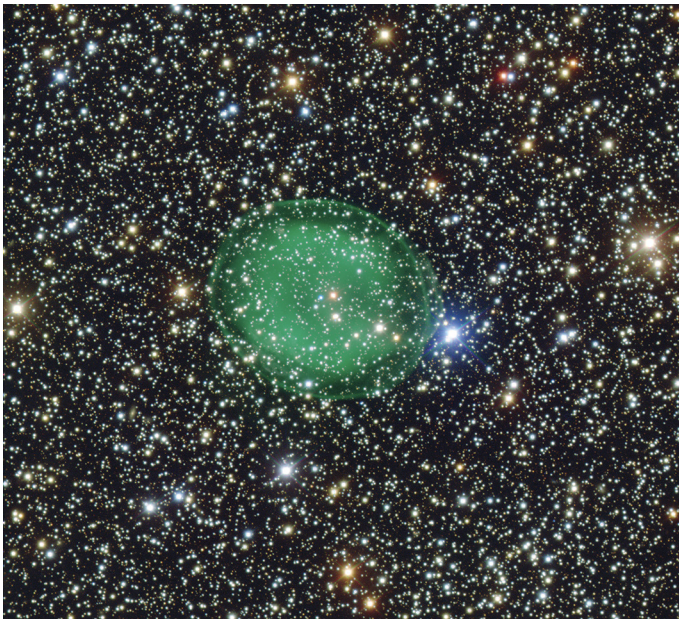
My 18-inch scope at 220× revealed a 1.5′ halo that's slightly bloated west-east. Adding a narrowband filter brightened the rim, particularly along the southern side. At high power, four or five stars appeared within the disk, but the planetary's true central star is a hot, blue-white stellar remnant with a visual magnitude of only 16.8.

IC I Photographic Discoveries

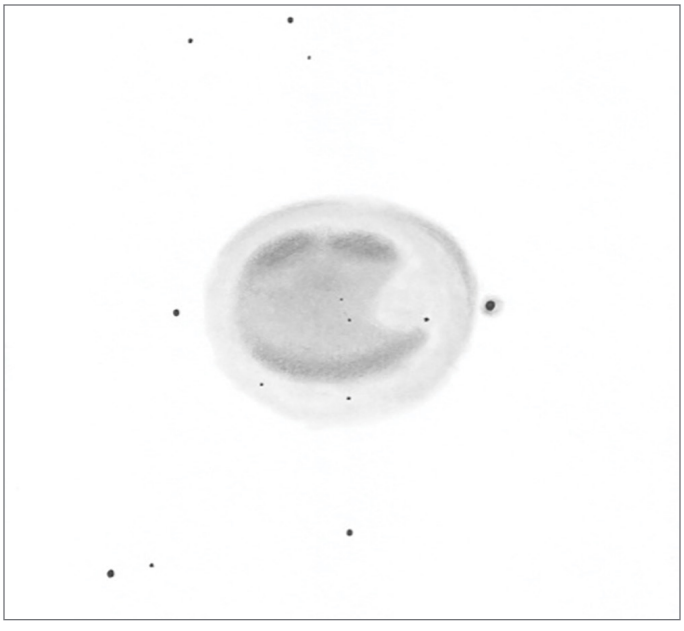
In the early 1890s, pioneering astrophotographers Max Wolf at Heidelberg Observatory and Edward Emerson Barnard at Lick Observatory used 6-inch, wide-field astrographs to capture the Milky Way. While visual discoveries dominate the *IC I*, several well-known emission and reflection nebulae were found photographically: IC 59 and IC 63 (Ghost of Cassiopeia), IC 405 (Flaming Star Nebula), IC 410 (Tadpole Nebula), IC 417 (Spider Nebula), IC 434 (Horsehead Nebula), IC 443 (Jellyfish Nebula), IC 1318 (Gamma Cygni Nebula), and IC 1396 (Elephant's Trunk Nebula). Although they're considered challenging visual targets, various nebula filters such as oxygen III, ultra-high-contrast, or hydrogen-beta, will increase their contrast.

Fall Targets

While sweeping Cygnus with a small comet-seeker in 1891, Danish astronomer Carl Frederick Pechüle discovered the open cluster **IC 1369**. Through Copenhagen Observatory's



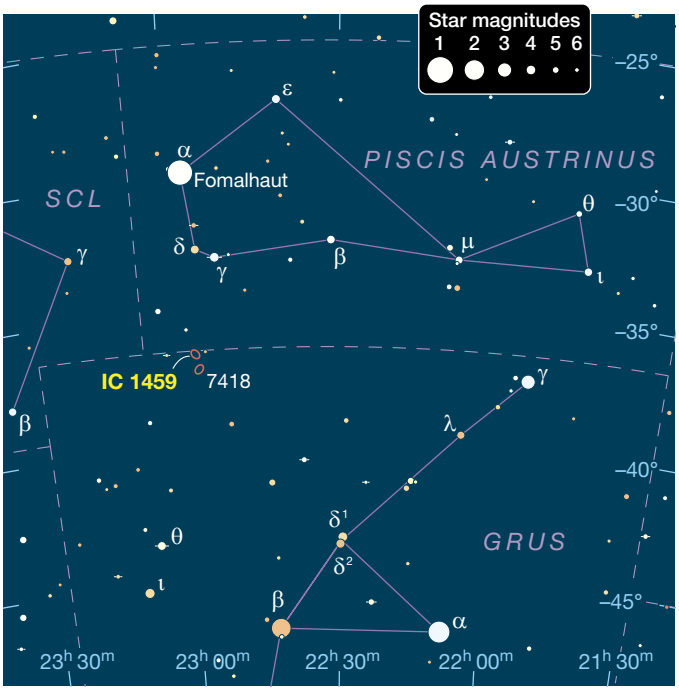
▲ **SCUTUM PLANETARY** This intriguing and detailed image from the European Southern Observatory's Very Large Telescope on Cerro Paranal, Chile, shows the glowing green planetary nebula IC 1295 surrounding a dim and dying star. It's located about 3,300 light-years away in the constellation of Scutum, the Shield.



▲ **A WEALTH OF DETAILS** This was how German observer Uwe Glahn saw IC 1295 through his 27-inch f/4.2 reflector at 293× with an oxygen III filter, under a dark, transparent sky and steady seeing in the Austrian Alps (elevation 2,900 meters, or 9,500 feet). An 11th-magnitude star is visible just west-southwest of the planetary. North is at upper left.

PHOTO OF IC 1295: ESO; SKETCH: UWE GLAHN





▲ **GIANT ELLIPTICAL** Located in the southern constellation of Grus, the Crane, IC 1459 lies approximately 95 million light-years from Earth. A supermassive black hole of roughly 350 million to 2.5 billion solar masses is believed to lurk in the galaxy's center.

11-inch refractor, he first noticed a nebulous object in the field that turned out to be a star cluster. A 2020 study identified 143 likely cluster members down to 19th magnitude and established a distance between 10,700 and 11,000 light-years, placing IC 1369 in the Milky Way's Perseus Arm, very close to the galactic plane.

Shifting just 1° east of the 4.5-magnitude yellow-orange star 63 Cygni brings you to IC 1369. Through my 8-inch, numerous faint stars sparkled against a backdrop of unresolved haze. I once ran across the cluster in my 18-inch scope while I targeted the dark nebula Barnard 361, a fairly large dust patch about 20′ to its south. Viewed at 215×, IC 1369 resolved into roughly two dozen stars packed into a boxy, 4′ region.

While hunting for red stars in September 1893, the Reverend Thomas Espin, a skilled British amateur, came across **IC 1434** about 2° west-northwest of 4.4-magnitude Beta (β) Lacertae. Using a 17.3-inch reflector, Espin described a "remarkable cluster with six distinct radiating branches. Stars from [magnitude] 12 to 15."

At 200× in my 8-inch, I resolved a rich collection of about 50 stars, highlighted by a triangle of 10th-magnitude stars on its southern edge. Numerous stars formed four long strings, and the cluster merged into a breathtaking region of the Milky Way. Through my 14.5-inch at 158×, the number of stars tripled and additional stellar chains emerged.

The cluster's very existence was questioned in 2008 when a photometric study concluded that IC 1434 is merely a chance alignment of unrelated stars at different distances. However, a color-magnitude analysis published three years later confirmed it as a genuine open cluster with an age of about 800 million years and a distance of 8,500 light-years.

On the evening of December 13, 1889, Barnard attempted to recover the periodic comet 5D/Brorsen, previously seen in 1879. Although Barnard's search with the Lick Observatory 12-inch refractor was unsuccessful, he stumbled upon **IC 1459**, which he described as "small, about ½′ in diameter, cometary and rather bright, with a 12m [12th-magnitude] nucleus."

IC 1459 is the dominant member of the 1.5°-long Grus Chain, which contains eight *NGC* and *IC* members (see *S&T:* Oct. 2026, p. 58). This giant elliptical galaxy shows clear evidence of past tidal interactions and mergers, including a nuclear dust lane, a counter-rotating core, and a disturbed halo threaded with shells.

Starting from 4.2-magnitude Delta (δ) Piscis Austrini, maneuver 3.9° due south to find IC 1459. In my 8-inch reflector at 107×, it appeared as a bright, round glow at least 1.5′ across with a sharply concentrated, intense core. John Herschel, who discovered the galaxy NGC 7418 a bit more than ½° due south, surprisingly missed IC 1459, which was likely just outside his sweeping pattern. How many members of the chain can you spot?

I hope this tour inspires you to explore more of the first *Index Catalogue*. You don't need to spend years chasing all 1,529 entries — the catalog holds plenty of rewarding targets worth seeking out for yourself.

■ Contributing Editor **STEVE GOTTLIEB** has been hunting deep-sky objects from Northern California for nearly 50 years. For the discovery history, physical data, and his visual notes on the *NGC* and *IC I* objects, visit **deepskygottlieb.com**. The searchable database includes observations of more than 25,000 objects.

ROLF WAHL OLSEN

SKY AT A GLANCE
January 2027



2 EARTH passes through perihelion, its closest point to the Sun for 2027, at around 10:30 p.m. EST.

3–4 ALL NIGHT: The Quadrantid meteor shower is expected to peak around 10:30 p.m. and is best viewed after midnight. The thin waning crescent Moon won't hamper viewing. Page 48 has further details.

4 DAWN: Face southeast to see the rising Moon leading Antares, the burning heart of Scorpius, less than 2° to its left. Turn to page 46 for more on this and other events listed here.

8 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:34 p.m. PST (see page 48).

11 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:23 p.m. EST.

14 DUSK: Look to the southwest for the waxing crescent Moon as it passes roughly 7° above Saturn.

18 MORNING: Face west-northwest to view the Pleiades glittering some 1° lower right of the waxing gibbous Moon as they both set.

21 DUSK: Castor and Pollux, the twin beacons of Gemini, and the nearly full Moon form an almost vertical 9° line above the eastern horizon.

23 EVENING: In the east-northeast, a very bright Jupiter rises 2¼° upper left of the Moon, with Regulus (Leo's lucida) and Mars trailing close behind.

28 MORNING: In the south-southeast the waning gibbous Moon hangs 3° below Spica, the brightest star in Virgo.

28 EVENING: Algol shines at minimum brightness for roughly two hours centered at 11:19 p.m. PST.

31 DAWN: Look to the southern horizon to see a repeat performance by the Moon and Antares. This time, Scorpius's brightest light glows 5° lower left of the waning crescent.
—MEG THACHER

▲ The Moon illuminates a snowy New England scene. DENNIS DI CICCO



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

MOON PHASES

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

NEW MOON
January 7
20:24 UT

FIRST QUARTER
January 15
20:35 UT

FULL MOON
January 22
12:17 UT

LAST QUARTER
January 29
10:55 UT

DISTANCES

Apogee
406,607 km

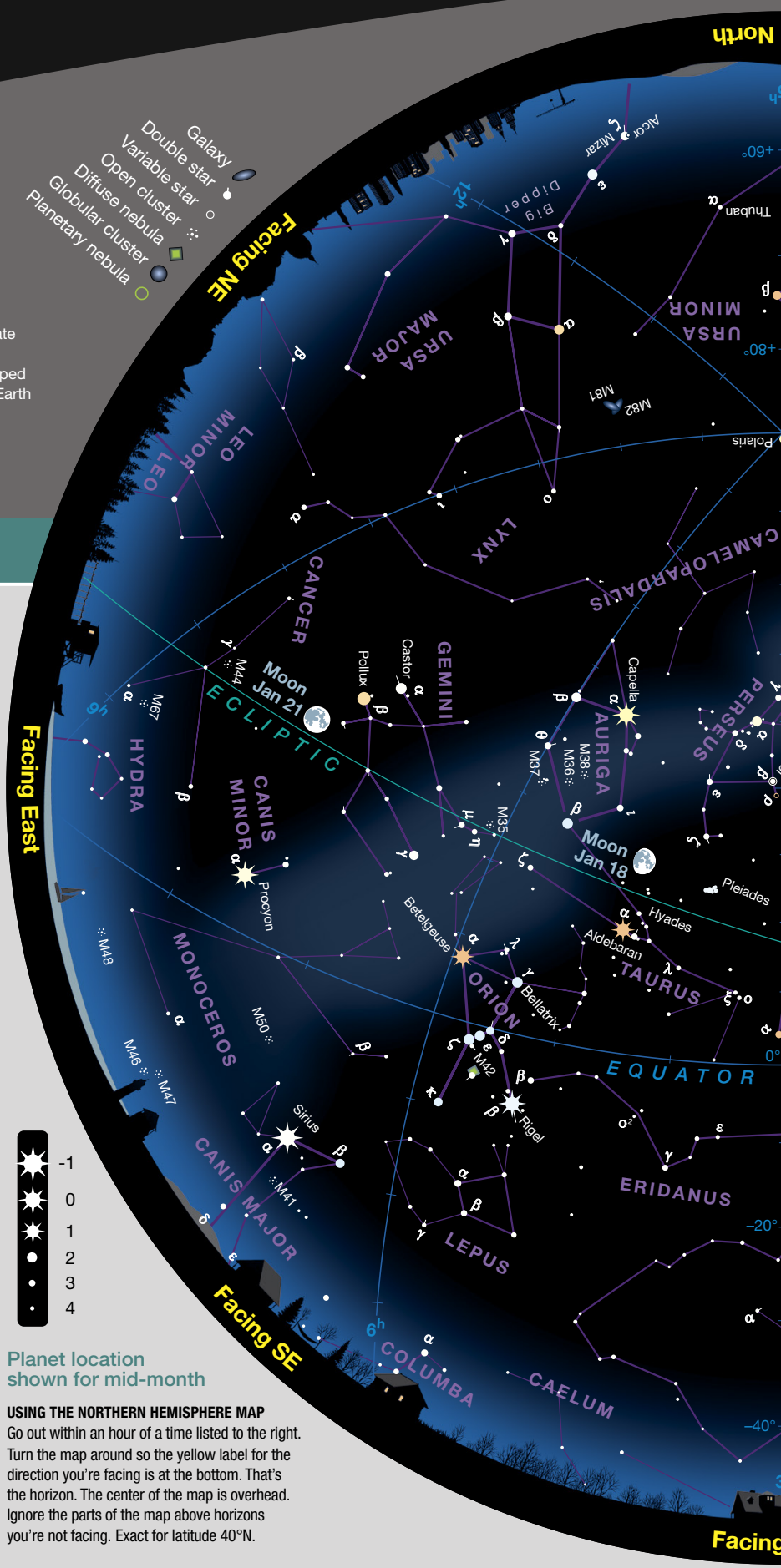
January 7, 8^{h} UT
Diameter 29′ 23″

Perigee
357,283 km

January 21, 22^{h} UT
Diameter 33′ 27″

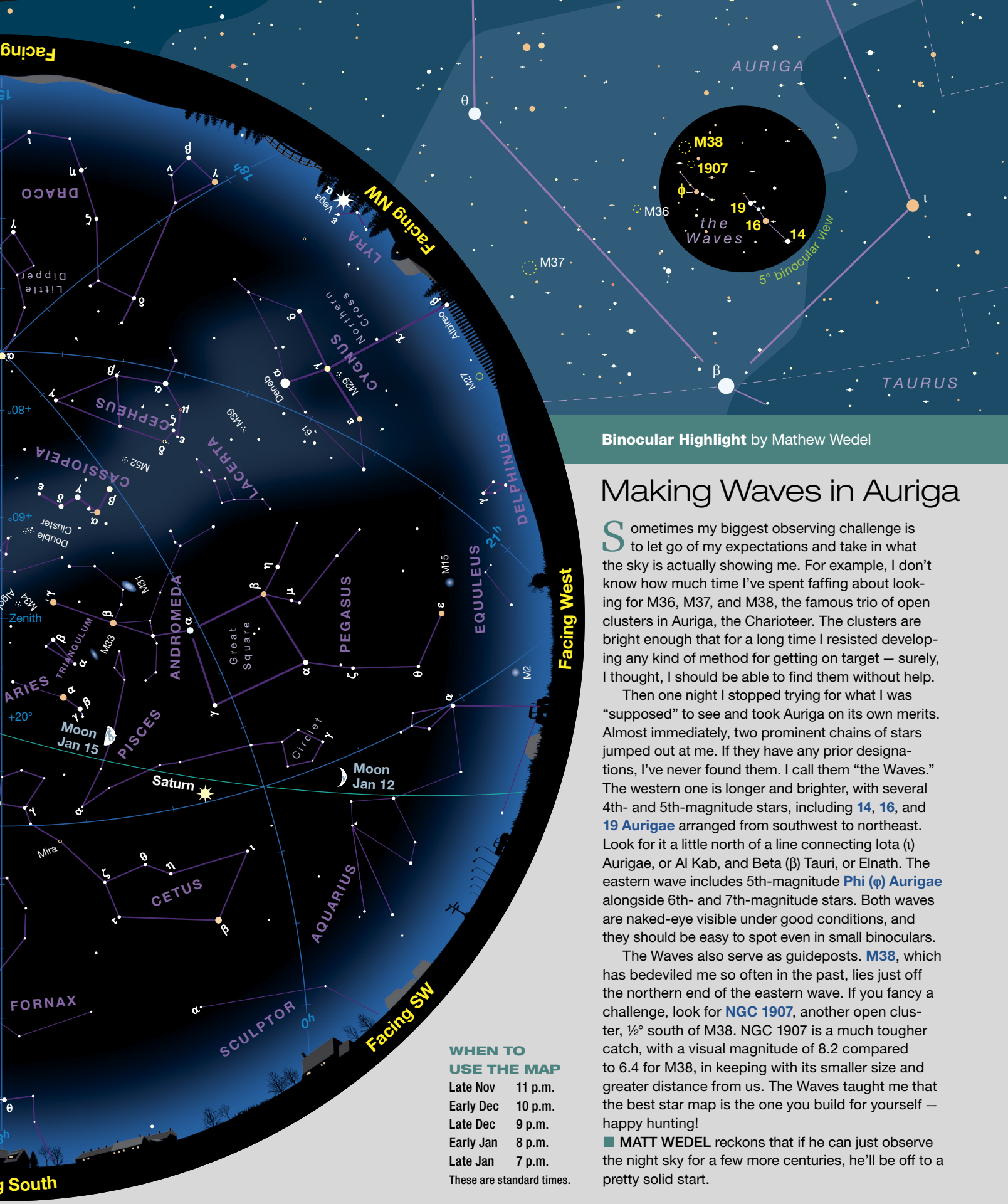
FAVORABLE Llibrations

- Kircher Crater — January 21
- Schomberger Crater — January 22
- Humboldt Crater — January 23
- Ansgarius Crater — January 23



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

Making Waves in Auriga

Sometimes my biggest observing challenge is to let go of my expectations and take in what the sky is actually showing me. For example, I don't know how much time I've spent faffing about looking for M36, M37, and M38, the famous trio of open clusters in Auriga, the Charioteer. The clusters are bright enough that for a long time I resisted developing any kind of method for getting on target — surely, I thought, I should be able to find them without help.

Then one night I stopped trying for what I was "supposed" to see and took Auriga on its own merits. Almost immediately, two prominent chains of stars jumped out at me. If they have any prior designations, I've never found them. I call them "the Waves." The western one is longer and brighter, with several 4th- and 5th-magnitude stars, including **14**, **16**, and **19 Aurigae** arranged from southwest to northeast. Look for it a little north of a line connecting Iota (ι) Aurigae, or Al Kab, and Beta (β) Tauri, or Elnath. The eastern wave includes 5th-magnitude **Phi (φ) Aurigae** alongside 6th- and 7th-magnitude stars. Both waves are naked-eye visible under good conditions, and they should be easy to spot even in small binoculars.

The Waves also serve as guideposts. **M38**, which has bedeviled me so often in the past, lies just off the northern end of the eastern wave. If you fancy a challenge, look for **NGC 1907**, another open cluster, ½° south of M38. NGC 1907 is a much tougher catch, with a visual magnitude of 8.2 compared to 6.4 for M38, in keeping with its smaller size and greater distance from us. The Waves taught me that the best star map is the one you build for yourself — happy hunting!

■ **MATT WEDEL** reckons that if he can just observe the night sky for a few more centuries, he'll be off to a pretty solid start.

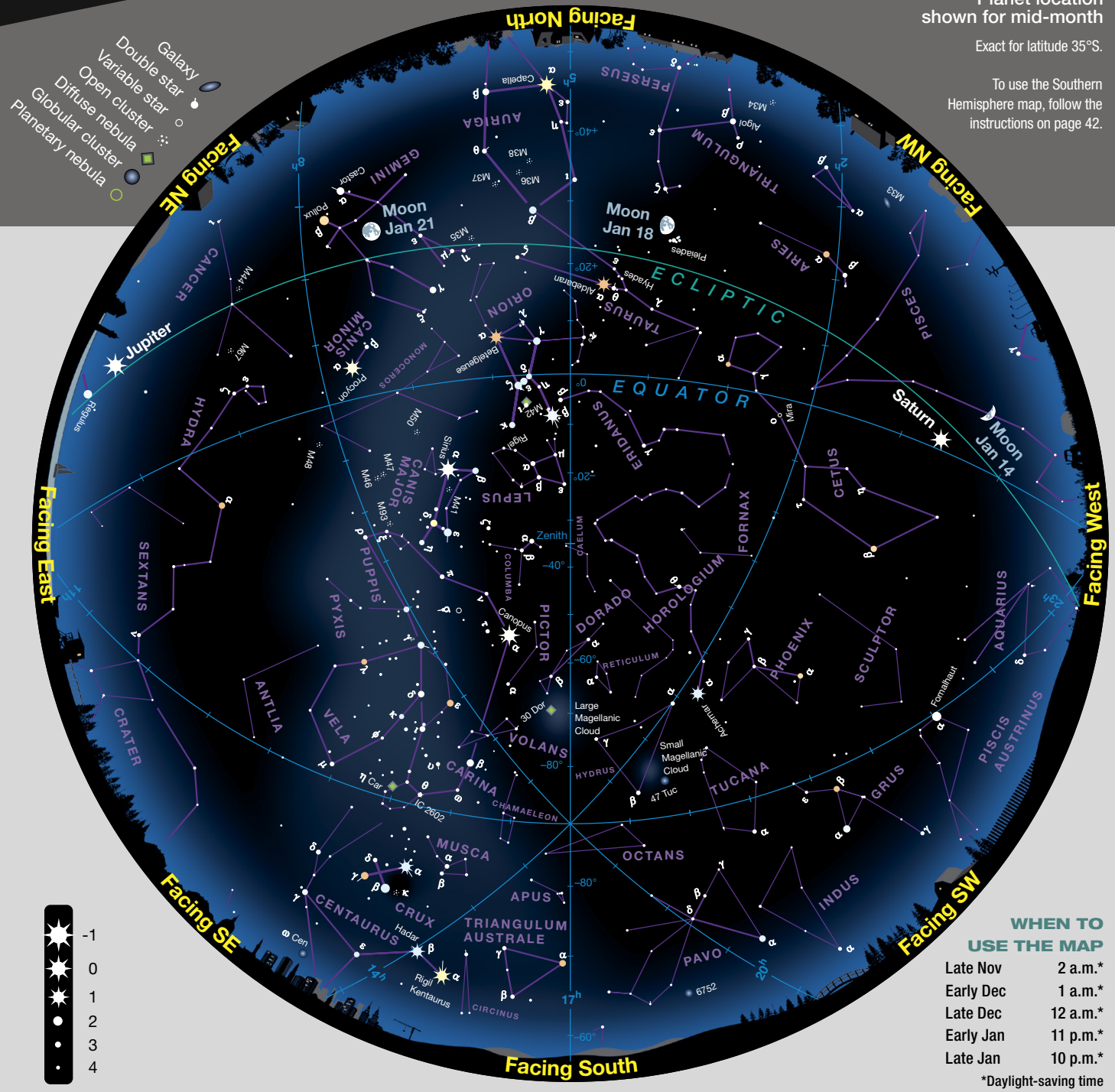
WHEN TO USE THE MAP

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

These are standard times.

Southern Hemisphere Sky Chart

by Jonathan Nally



WHEN TO USE THE MAP

Late Nov	2 a.m.*
Early Dec	1 a.m.*
Late Dec	12 a.m.*
Early Jan	11 p.m.*
Late Jan	10 p.m.*

*Daylight-saving time

GLANCE UPWARDS ON A SUMMER NIGHT in the Southern Hemisphere and you'll be greeted with a panorama that includes some of the sky's brightest stars. In fact, you'll find 10 of the best zigzagging along the meridian at this time of year.

Starting low, face north to view Capella (magnitude +0.1), and slide right to catch Castor (1.6) and Pollux (1.1). Above them arc Aldebaran (+0.9), Betelgeuse (+0.4), and Procyon (+0.4). You'll find Rigel (+0.1) and Sirius (–1.5) farther up. Now hop over the zenith to visit Canopus (–0.7) high in the southeast and Achernar (+0.5) in the southwest. We finish our trek low in the southeast with Acrux (1.3) in the magnificent Southern Cross, and Hadar (+0.6) and Rigil Kentaurus (–0.1) hugging the horizon. That makes a baker's dozen of bright beacons lighting the way across both hemispheres. ■

Mira the Mysterious

Watch Cetus's severed neck reform anew this month.



▲ In this copperplate engraving by William Walker, based on an illustration by Charles Eisen, we see Perseus swooping down from the sky and striking Cetus with his blade. Andromeda throws both arms in the air. The engraving appears in the 1778 volume of *The Copper Plate Magazine or Monthly Treasure for the Admirers of the Imitative Arts* by George Kearsley.

About once a year a magnificent star rises from invisibility to prominence, shining with a bloody luster in the neck of Cetus, the Sea Monster. On paper, the star's magnitude varies between 10.1 and 2.0 every 331.3 days, but its brightness at maximum differs considerably with unknown periodicity. For instance, in December 1906 it outshone 2.5-magnitude Alpha (α) Ceti (Menkar) by half a magnitude; at other times the star is only *just* visible to the unaided eye, even on a dark, moonless night. Now, we expect Mira, Omicron (ο) Ceti, to once again achieve maximum around February 2nd. But there's no way to know how brightly Mira will shine. The star has peaked around 3.0 during the last couple of years, so it may do so again this year. Then again, it's best to expect the unexpected. So it's wise to start watching with the unaided eye now, in January, as Mira brightens.

In his 1914 book *The Stars Night by Night*, Joseph H. Elgie believed the 1906–1907 maximum would "become famous in the annals of astronomy." He was right. The star achieved a brightness of magnitude 2.0 in early December, about a week before the predicted date. Elgie's first sighting of the star was through his bedroom window, where he saw a "big star, ruddy and portentous of aspect. . . . I used to lie with my head on the pillow, looking and wondering—wondering what this midnight apparition could possibly be. Then, in some way, it flashed upon me that it must be Mira." Of the star's appearance, he says, "It is strange-looking as a new star, and pulsates with red and yellow light."

Seeing Mira at maximum for the first time can indeed be strange and wonderful. Classically, the star lies in the middle of the Sea Monster's serpentine neck. So at minimum, when the star is invisible to the eye, its absence severs the mythical creature's head from its body. Its reappearance restores the serpent's outline. And this behavior leads us to a lesser-known mythology.

In the second decade of the 1st century AD, Roman poet Marcus Manilius wrote *Astronomica*, a hexameter poem in five books on the topic of astrology. In it, he offers a gruesome rendition of Perseus's attempt to rescue Andromeda, the Chained Maiden, from being swallowed by the massive Sea Monster. In a 1992 Loeb Classical Library edition of the work, we see Perseus defeating Cetus, not by holding up the severed head of the Gorgon Medusa (as is the case in many versions), but by repeatedly stabbing the creature with a blade stained with Medusa's blood.

In the tale, Perseus flies upward "with a flutter of winged sandals" and attacks his foe from above. When mighty Cetus rises to meet him, supported by the coils of its flanks, the warrior mocks the creature by flying ever higher, still stabbing from above. No matter how much the beast strains toward Perseus, snapping its toothy jaws and spewing bloody seawater at the Hero — with some of the spray shooting to the starry heavens — it cannot reach him and eventually succumbs to the monster hunter's blows: "At last, its frame riddled with stabs . . . the beast sinks, returns once more to the surface, and covers the mighty ocean with its massive corpse."

Gory as it is, we now have a choice to look upon ruddy Mira at maximum as the Bleeding Star — the fatal wound that sank the leviathan. After death, Cetus rose to the surface of the sea, where we see it preserved among the winter skies — frozen, if you like, as if locked in the black ice of night.

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

THE TRUSTEES OF THE BRITISH MUSEUM / CC BY-NC-SA 4.0

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

Five Planets on Display

Venus, Mars, and Jupiter brighten the morning sky while Saturn and Mercury linger at dusk.

SUNDAY, JANUARY 3

Welcome to 2027! And just like the tail end of 2026, this new year begins with most of the celestial action taking place in the morning sky. **Venus**, **Mars**, and **Jupiter** — the three brightest planets — are nicely positioned for some predawn observing. The most eye-catching of all is Venus, the reigning Morning Star, which is a –4.6-magnitude beacon hovering some 20° above the southeastern horizon before astronomical twilight begins. On this morning Venus is joined by a lovely waning crescent **Moon** (16% illuminated) some 9° lower right of the planet.

Today marks Venus's greatest elongation for the current apparition (47° west of the Sun), though it was somewhat higher at dawn in mid-December. Nonetheless, in many ways this occasion signals the beginning of the end for the Venus morning show. It slowly sinks sunward until August, when it has its conjunction with the Sun. Venus won't be gone for long, though — it returns to claim its title as the Evening Star in mid-September.

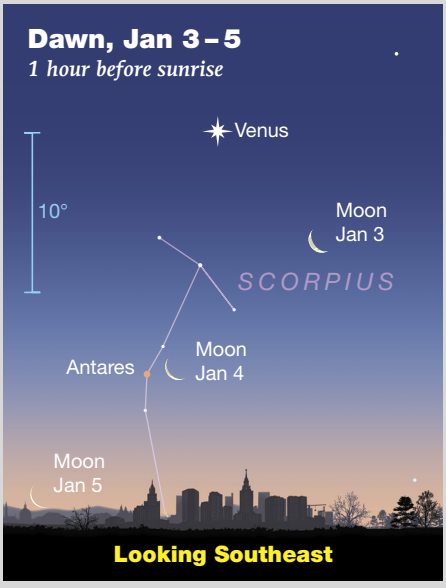
MONDAY, JANUARY 4

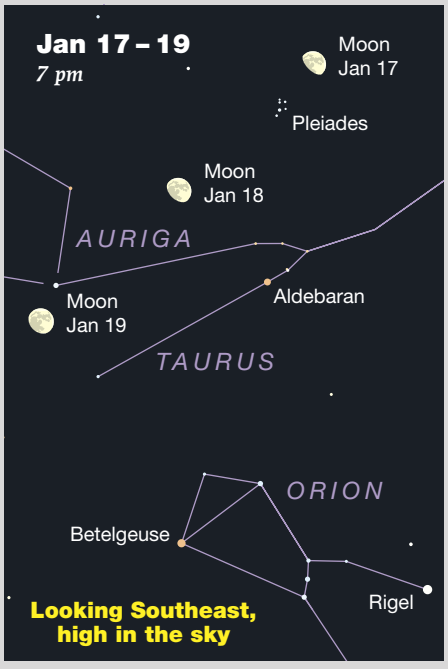
The morning after its visit with Venus, the **Moon** has its closest encounter with a bright star this month when it sits alongside **Antares**, Alpha (α) Scorpii. The narrow (about 10% illuminated) lunar crescent is west of the star, which means it's still approaching as dawn arrives. As a result, how close the pair gets before twilight overwhelms the star's light depends on how far west you are. This morning, the bright limb of the Moon is a bit more than 2° from Antares for observers on the East Coast, while the gap narrows to less than 1° for those enjoying the view from the West Coast. But if you're a New Yorker, don't feel your Los Angeles brethren are benefiting from some kind of cosmic favoritism — the advantage is reversed on those occasions when the Moon stands east of its dancing partner.

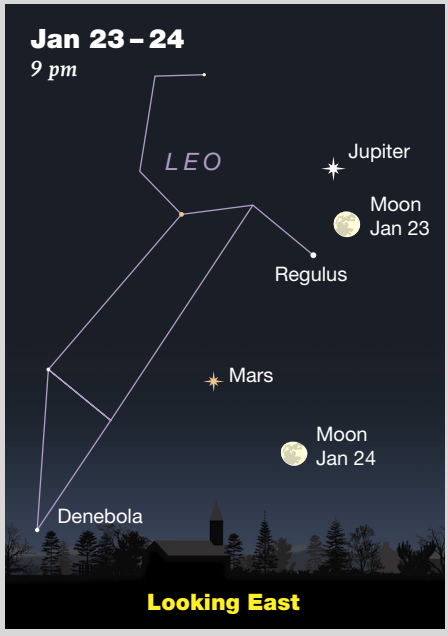
TUESDAY, JANUARY 19

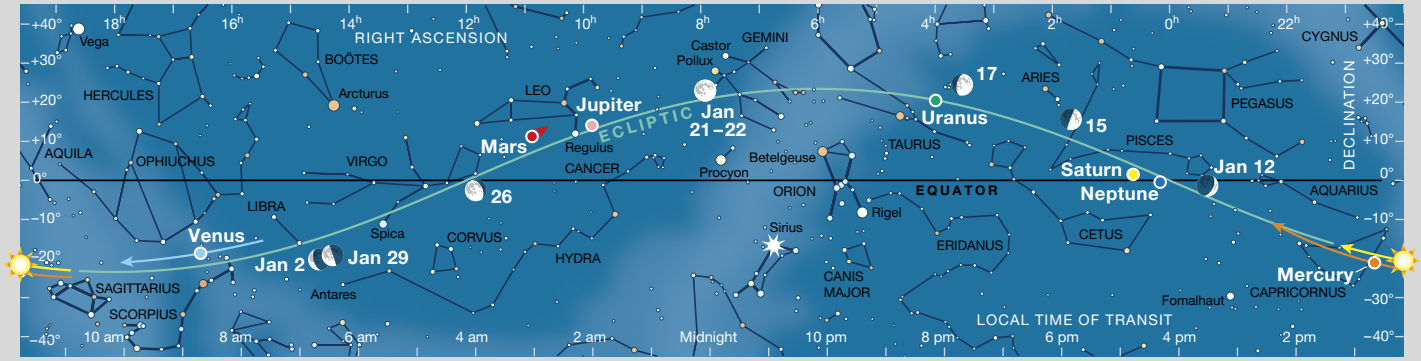
After a few quiet months, the evening sky is starting to look a little more interesting. **Saturn** is well past the meridian by sundown, and now it's joined by **Mercury** as the little planet begins the first of four dusk appearances in 2027. The one starting today is the second-best of the bunch — May's is slightly better for observers at mid-northern latitudes.

As twilight begins to fade this evening, cast your gaze low toward the west-southwest to catch Mercury. Unless you have exceptionally transparent









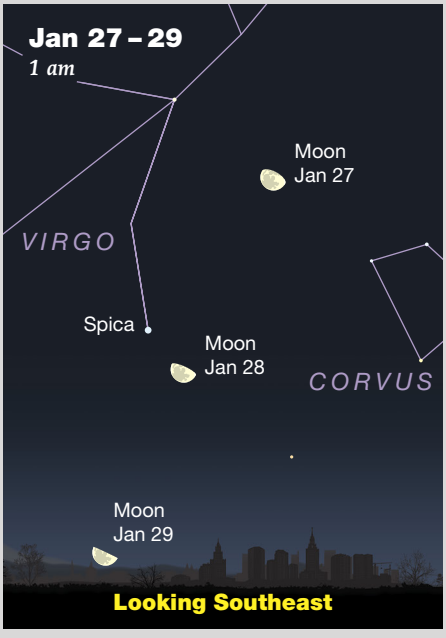
▲ The Sun and planets are positioned for mid-January; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit"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

skies, you'll likely need to resort to binoculars to fish the planet out from the atmospheric muck usually found near the horizon. Mercury presently shines brightly at magnitude –1.0, so it has that in its favor. But if you don't succeed today, don't fret — the planet's visibility gradually improves from here on. Mercury reaches its greatest dusk altitude on February 3rd, after which it begins to sink lower with each passing day.

SATURDAY, JANUARY 23

This evening features the month's most striking conjunction when the **Moon** and **Jupiter** rise together in the east-northeast at roughly 7 p.m. local time. The lunar disk is 96% illuminated and 36 hours past full. That combination — a just-post-full Moon in close proximity to a planet — indicates that the planet in question must be near opposition. And indeed, Jupiter hits that mark on February 10th, just 2½ weeks from today. This evening the big planet shines at magnitude –2.5 (only 0.1 magnitude shy of its opposition peak) from its perch 2¼° upper left of the brilliant Moon. That's close enough for the two objects to fit together in the same binocular field. Normally you wouldn't bother using optics to see the Moon and Jupiter paired together, but if you do, you can probably add two or three Jovian moons to the picture. As the diagram on page 51 illustrates, **Ganymede** and **Callisto** flank the planet's disk and you might even catch **Europa** too, situated between Jupiter and Ganymede. The satellites look like 5th- or 6th-magnitude stars strung out along the planet's equatorial plane.

Continue watching the Moon's progress as the night of the 23rd transitions into the morning of the 24th, and you can enjoy a second conjunction when the lunar disk slowly approaches **Regulus**, Alpha Leonis. The pair are at their closest at around 3 a.m. EST, when the Moon sits 1½° lower right of the star. Unfortunately, 1.4-magnitude Regulus doesn't match up to a bright Moon as well as Jupiter does, so this conjunction is a bit less compelling than the earlier one. Finally, as the first blush of twilight colors the sky, the Moon is below Regulus and between Jupiter and **Mars**. At magnitude –0.7, the Red Planet is obviously dimmer than its planetary neighbor, but it's also much, much brighter than Leo's leading light. Like Jupiter, Mars is on its way to opposition, which occurs on February 19th.



◀ 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.

WEDNESDAY, JANUARY 27

The **Moon** has one last item on its January agenda: a meeting with **Spica**, Virgo's alpha star. The two are closest as they rise in the east-southeast very late in the evening. Indeed, depending on how far west you are, the Moon might not clear the horizon until after midnight and the 27th has become the 28th. Now a 61%-illuminated waning gibbous, the Moon is positioned a hair less than 3° lower right of the 1.0-magnitude star, though the separation between them increases gradually as they climb higher. This is perhaps the least interesting of the conjunctions we've highlighted for this month, but it's still worth checking out — especially if you're up late observing Mars and Jupiter in your scope as they cross the meridian.

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

January's Quiet Fireworks

Quads kick off the year with flash and sparkle.



▶ Framed by bare branches, a bright Quadrantid meteor slices the eastern sky before dawn on January 3, 2025. The shower is a potpourri of faint meteors mixed with occasional fireballs. For the best experience, observe as far from city lights as possible. Particles from the shower's parent asteroid, 2003 EH1, strike the atmosphere at medium speed, around 41 km/s (90,000 mph).

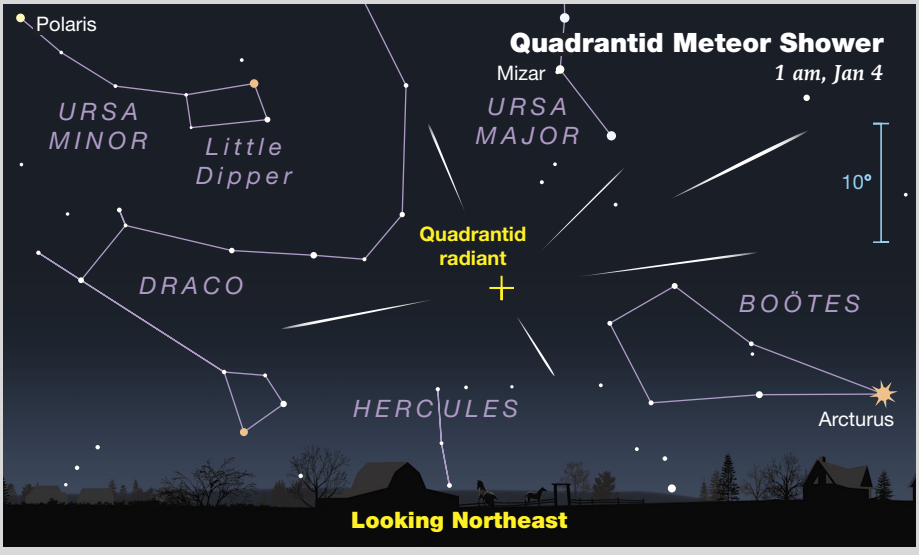
If you missed the fireworks, a quieter but no less exciting cosmic display ushers in the New Year — the annual Quadrantid meteor shower. The shower can be a challenge because its parsimonious peak lasts just six to eight hours. If the *radiant*, the point in the sky where the meteors appear to originate, is well-placed at the same time it's dark at your location, you might spy up to 60 to 200 meteors per hour, including a fair number of fireballs. If the timing is off, your reward for getting out of bed on a cold January morning will be reduced to around 25 meteors per hour.

The annual shower peaks on the night of January 3th around 10:30 p.m. EST (3:30 UT on January 4th), and the radiant (below the Big Dipper's handle) reaches 20° altitude around 1 a.m. local time. While European and western Asian observers are ideally situated for peak viewing, conditions are good for eastern North America and less so for the western half of the continent.

Given that there's practically no Moon — the waning crescent doesn't rise until the start of dawn — I think watching the shower even off-peak is worth a brief bout with frozen toes, especially for viewers living in the northern U.S. and Canada where the radiant is circumpolar. From Duluth, Minnesota, for instance, the streaming point stands 10° high in the northeast around 11 p.m., very close to the predicted maximum. The later it gets, the higher the radiant climbs, peaking around 60° altitude at the start of dawn. Theoretically that means more meteors, but there's a trade-off because the shower's peak is now in the rearview mirror (see *S&T:* Dec. 2026, p. 48), at least for U.S. observers.

While the northern horizon masks a fair number of shower members early on, the radiant's low altitude increases the chances of seeing *earthgrazers*. These are meteoroids that strike the atmosphere tangentially and flare for great lengths across the sky. I recommend finding as dark a site as possible for watching the shower. The Quads are dimmer on average than Perseids or Geminids but have a penchant for producing fireballs. Weather permitting, I'll dress warmly and watch from the shore of a frozen lake with an unobstructed vista to the north. After an hour or two of soaking in the silent splendor, returning to the warmth of my home will feel like going to heaven.

These January sparklers originate from near-Earth object 2003 EH1, an asteroid that may once have been a comet. It's about 3 kilometers (2 miles) across and orbits the Sun every 5.5 years. Some 500 years ago the asteroid released a batch of debris that left a narrow trail of pebbles and dust in its path. The track's slenderness coupled with the fact that Earth intersects the path at a steep 72° angle means we blast straight through it in a matter of hours. Were we to pass through at a shallower angle, the encounter and hence the shower would last longer. Whether you see lots of meteors or just a few, I can't think of a better astronomical start to the year than catching a cosmic fireworks show.



▲ The Quadrantids stream from the obsolete constellation Quadrans Muralis, the Mural Quadrant, which once occupied the space between northern Boötes and Draco below the Big Dipper's handle. Meteors fly from this point all over the sky during the shower's peak the night of January 3-4. Observers may see anywhere from about 25 meteors per hour to more than 100, depending upon location. With a declination of +50°, the radiant is circumpolar for observers north of latitude 40° north.

BOB KING

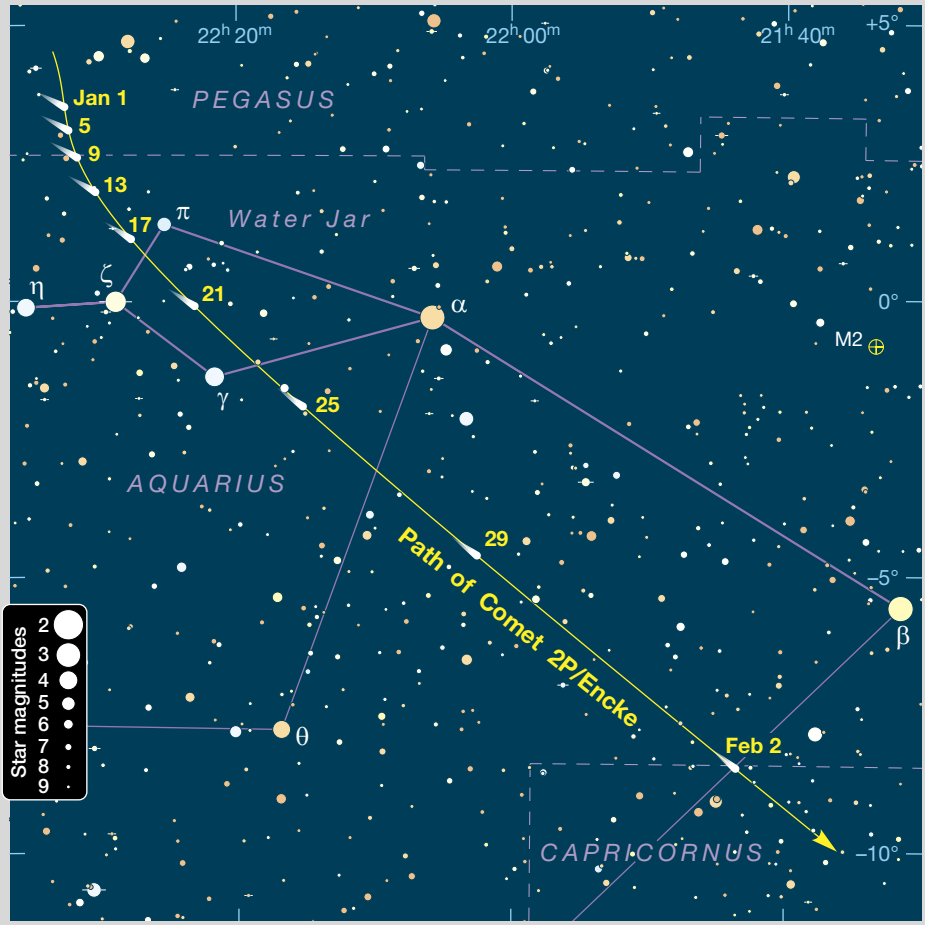
"Old Faithful" Comet Encke Pays a Visit

EVERY 3.3 YEARS Comet 2P/Encke travels from the vicinity of Jupiter into the inner solar system. When the geometry is favorable, as it is for the current apparition, this frequent flyer briefly enlivens the night sky. Closest approach to Earth occurs on February 3rd at around 90 million kilometers (56 million miles), followed by perihelion a week later on February 10th. Predictions call for the comet to crest at around 6th magnitude. Unfortunately, during this time it's lost in the solar glare. Prior to that, in late January we'll see it in binoculars glowing around magnitude 7.5 low in the western sky during late evening twilight.

Although Comet 311P/PanSTARRS has the shortest known orbital period (3.2 years), 2P/Encke is a close second and a far more familiar face. On January 1st it's a dim, 11th-magnitude smudge in southern Pegasus. The comet should then brighten quickly. By January 25th it may glow at 9th magnitude near the Water Jar asterism in northern Aquarius and stand 12° high in the western sky at the end of astronomical twilight from latitude 40° north. Observers with 4- to 6-inch telescopes will likely corral it at this time.

Although Encke continues sinking westward, it brightens and exhibits a small, increasingly compact coma and weak, pencil-like gas tail pointing east. Northern Hemisphere skywatchers will likely get their last views of the comet around January 30th. After perihelion it barrels across Capricornus and relocates to the morning sky. Unfortunately, Encke's southerly declination dashes hopes of post-perihelion observation from northern latitudes. Prospects are more sanguine for Southern Hemisphere observers, where the comet returns to view low in the east during early dawn about February 12th, at around magnitude 6.7. Thereafter, Encke rapidly ascends the eastern sky and fades.

I find that Encke's comet is slow to "turn on" during the early part of a run, but once it does it quickly becomes an easy sight in modest telescopes and makes an excellent target for astrophotography with a smart telescope. Make sure you have an observing location with an unobstructed view to the west to maximize your viewing opportunities.

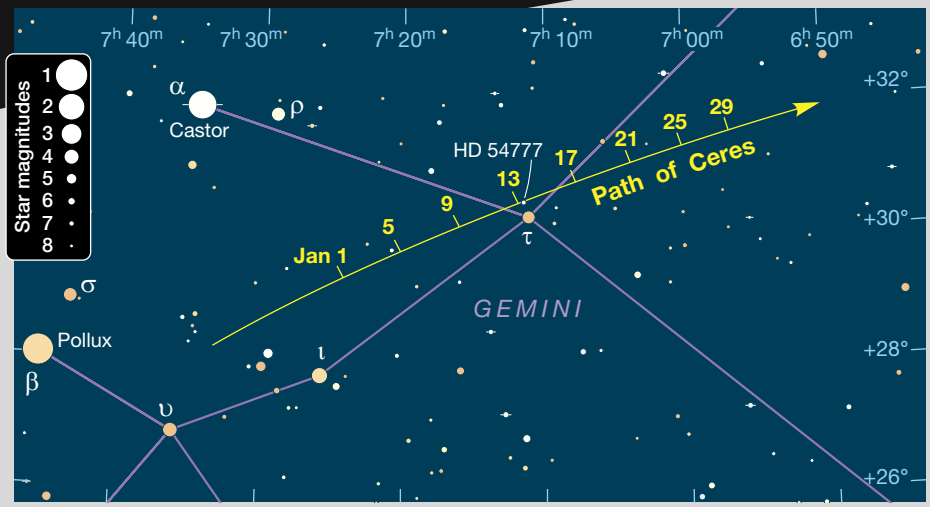


▲ Named for Johann Encke, the 19th-century German astronomer who first calculated the comet's orbit, 2P/Encke starts the month as a faint puff in Pegasus. Its brightness should increase by several magnitudes as it scoots southwest across Aquarius. To see it best, start in late twilight, when the comet stands highest in the western sky.

Ceres with the Naked Eye?

DON'T FORGET TO eat your carrots: They may provide just the edge you'll need to spot Ceres with nothing but your eyeballs. Ceres was the first asteroid discovered and the only dwarf planet in the inner solar system. When it comes to opposition on January 7th, the dual-personality orb practically gleams at magnitude 6.8, about as bright as it ever gets. Its closest approach to Earth occurs on January 9th, at 243 million kilometers (151 million miles) from Earth.

Good fortune is on our side during the current opposition, at least for Northern Hemisphere observers. Ceres is located around declination +30°, and the thin, waxing crescent Moon won't interfere. Sounds like the makings of a doable challenge, as long as you can find a dark-sky location and allow your eyes at least 45 minutes to fully dark-adapt.



▲ The largest asteroid in the main belt and a dwarf planet, Ceres wends its way westward in Gemini in retrograde motion during its favorable opposition. Italian astronomer Giuseppe Piazzi discovered Ceres — the first known asteroid — with a 75-mm refractor on January 1, 1801. Appropriately, Ceres became the first dwarf planet to receive a visit from a spacecraft. NASA's Dawn spacecraft entered orbit around it more than 200 years later in March 2015.

If naked-eye-limiting challenges aren't for you, a pair of 35-mm binoculars makes tracking Ceres a breeze even in compromised skies. The dwarf planet sets up shop in northern Gemini this winter, inching slowly westward during January. On the night of January 12–13, Ceres lies just ¼° north-northeast of 4.4-magnitude Tau (τ) Geminorum. That same night it passes about 30″ north of 7.2-magnitude HD 54777 around 1:30 a.m. EST. It's possible to detect the dwarf planet's westerly motion after just 10 or 15 minutes using medium to high magnification.

Around opposition Ceres' disk measures 0.8″ across. That's tiny, but possibly just big enough to discern as a disk in a telescope. Many of us have routinely seen the minute disks of Jupiter's Galilean satellites, including Europa at 1.0″. Give Ceres a try. Use your highest magnification on a night when the seeing calms, and you just might succeed.

Minima of Algol

Dec.	UT	Jan.	UT
2	22:55	3	11:56
5	19:44	6	8:45
8	16:33	9	5:34
11	13:22	12	2:23
14	10:11	14	23:13
17	7:00	17	20:02
20	3:50	20	16:51
23	0:39	23	13:41
25	21:28	26	10:30
28	18:17	29	7:19
31	15:06		

These geocentric predictions are from the recent heliocentric elements Min. = JD 2457675.72 + 2.867343E (where E is any integer) as listed in the AAVSO Variable Star Index. For a comparison-star chart and more info see **skyandtelescope.org/algol**.



▲ Perseus is conveniently positioned at the zenith during evening hours in January. Every 2.87 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Estimate its brightness with respect to the comparison stars, whose magnitudes are shown in this chart without the decimal point (e.g., *29* = 2.9).

Action at Jupiter

JUPITER IS UP nearly the entire night this month, rising around 8:30 p.m. on the 1st and earlier each day until the 31st, when it rises right at dusk. It sets after dawn, which means the big planet is available to play the main character at star parties or a supporting role at a meteor shower event. It will also appear large in your telescope or binoculars, growing to 45″ by the end of the month.

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

Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Daylight Time is UT minus 4 hours.)

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

January 1: 7:40, 17:36; **2**: 3:31, 13:27, 23:23; **3**: 9:18, 19:14; **4**: 5:09, 15:05; **5**: 1:01, 10:56, 20:52; **6**: 6:48, 16:43; **7**: 2:39, 12:35, 22:30; **8**: 8:26,

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

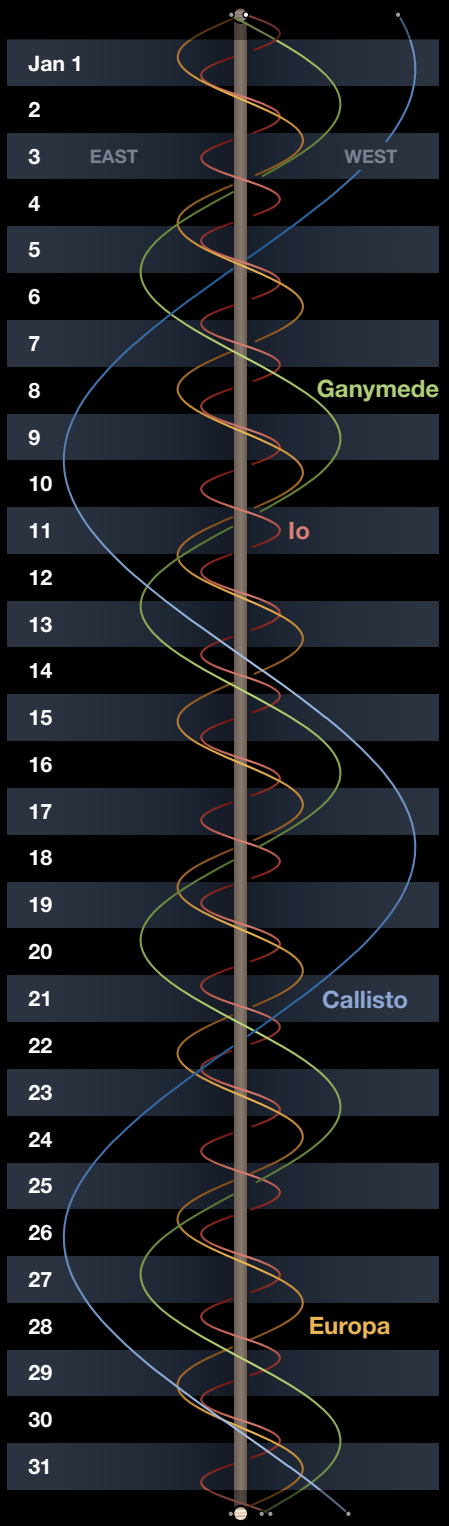
These times assume that the spot will be centered at System II longitude 97° on January 1st. If the Red Spot has moved elsewhere, it will transit 1²⁄₃ minutes earlier for each degree less than 97° and 1²⁄₃ minutes later for each degree more.

Phenomena of Jupiter's Moons, January 2027

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

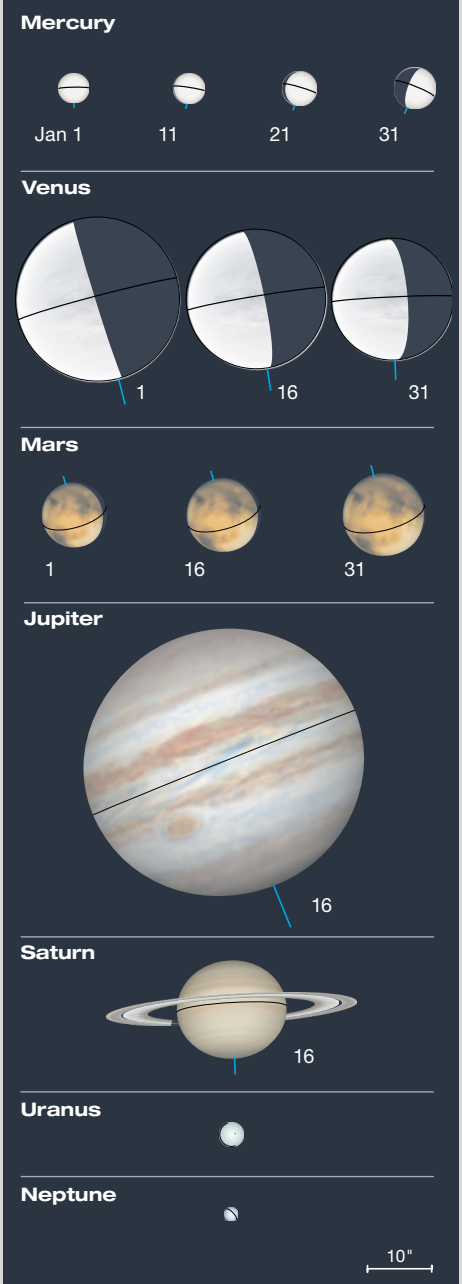
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede,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

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dusk starting on the 19th • **Venus** visible at dawn • **Mars** and **Jupiter** rise in the late evening and visible till dawn • **Saturn** visible at dusk and sets late night.



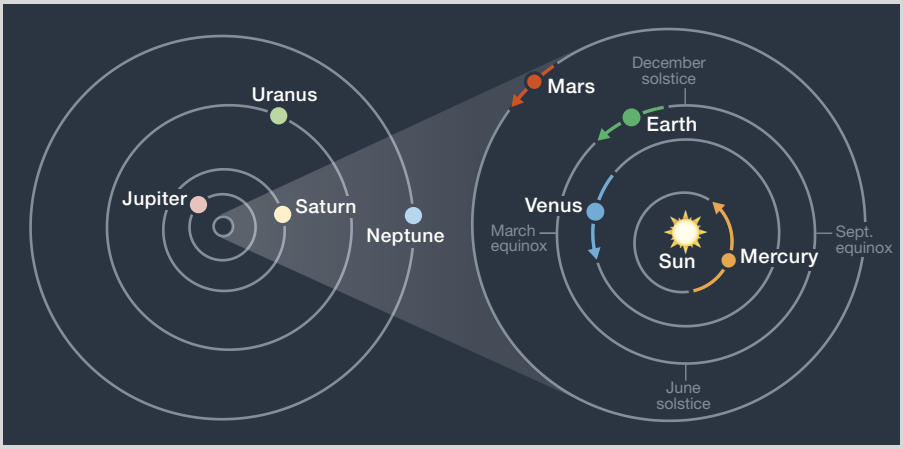
▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

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

January Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 43.3^m$	–23° 04′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 51.7^m$	–17° 36′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$18^h\ 42.0^m$	–24° 48′	2° Mo	–1.3	4.7″	100%	1.440
	11	$19^h\ 53.1^m$	–23° 03′	6° Ev	–1.1	4.8″	98%	1.389
	21	$21^h\ 02.7^m$	–18° 43′	12° Ev	–1.0	5.3″	91%	1.265
	31	$22^h\ 02.2^m$	–12° 25′	18° Ev	–0.8	6.4″	67%	1.046
Venus	1	$15^h\ 26.4^m$	–15° 16′	47° Mo	–4.6	25.5″	49%	0.653
	11	$16^h\ 08.3^m$	–17° 35′	47° Mo	–4.5	22.9″	54%	0.729
	21	$16^h\ 53.3^m$	–19° 31′	46° Mo	–4.4	20.7″	59%	0.805
	31	$17^h\ 40.8^m$	–20° 49′	45° Mo	–4.3	19.0″	63%	0.880
Mars	1	$10^h\ 49.2^m$	+11° 03′	120° Mo	–0.1	10.2″	93%	0.914
	16	$10^h\ 51.4^m$	+11° 23′	135° Mo	–0.5	11.6″	95%	0.804
	31	$10^h\ 42.5^m$	+12° 46′	153° Mo	–0.9	13.0″	98%	0.722
Jupiter	1	$9^h\ 54.5^m$	+13° 42′	134° Mo	–2.4	42.8″	100%	4.607
	31	$9^h\ 43.1^m$	+14° 48′	167° Mo	–2.5	45.0″	100%	4.379
Saturn	1	$0^h\ 33.1^m$	+0° 54′	88° Ev	+0.8	17.7″	100%	9.389
	31	$0^h\ 39.7^m$	+1° 44′	59° Ev	+0.9	16.9″	100%	9.862
Uranus	16	$3^h\ 57.8^m$	+20° 20′	126° Ev	+5.6	3.7″	100%	18.823
Neptune	16	$0^h\ 07.9^m$	–0° 38′	66° Ev	+7.9	2.3″	100%	30.257

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



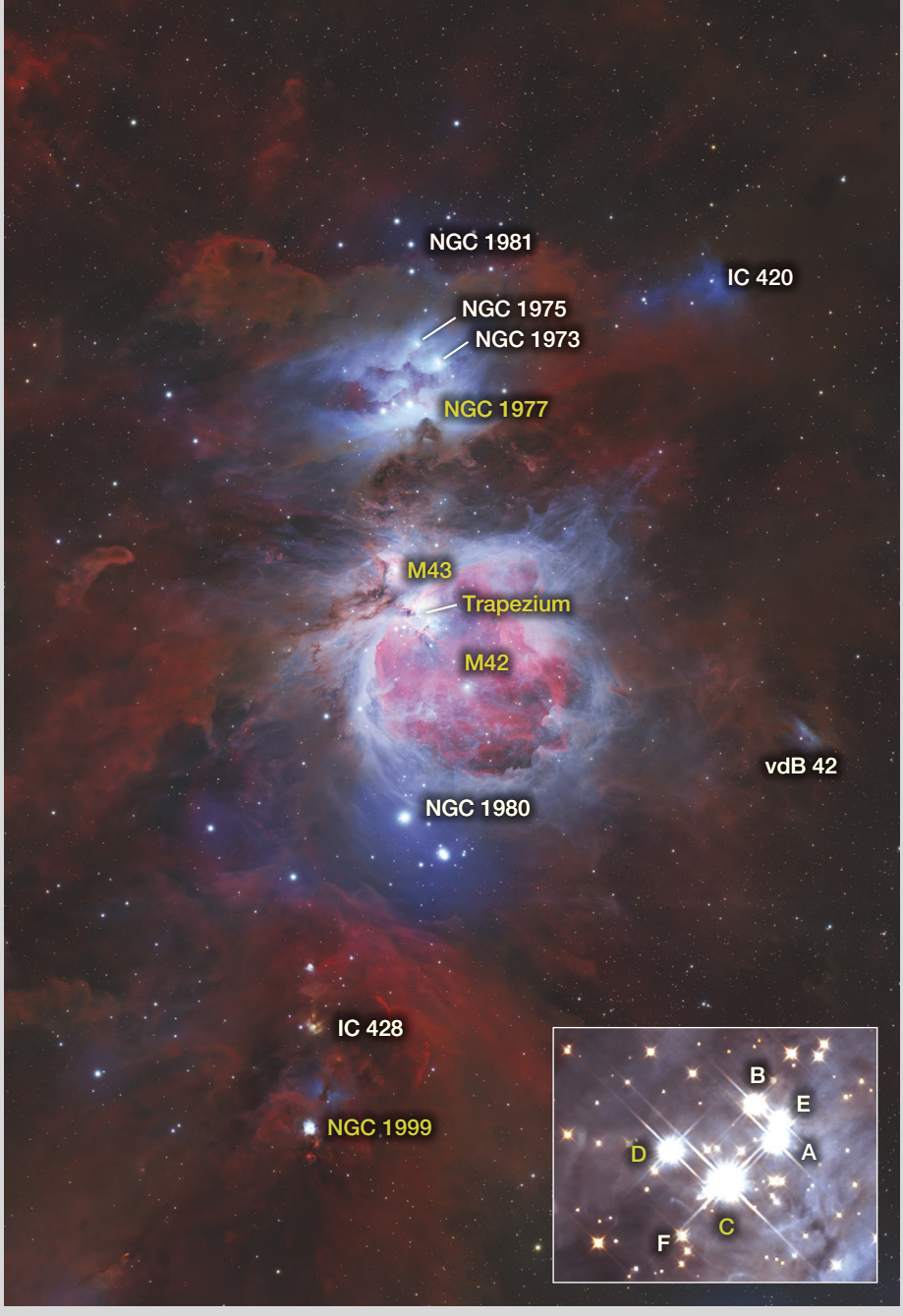
The Orion Molecular Cloud

Track down these bright and dark nebulae across the celestial Hunter's domain.

We live in an extraordinary place within a pretty typical spiral galaxy, the Milky Way. We're inhabitants of the so-called Local Arm (see page 28), and in a direction away from the galactic center lies a vast cloud of interstellar material that's slowly forming newborn stars. Known as the *Orion Molecular Cloud*, this complex contains many of the bright stars and gas clouds we see spread over the constellation Orion and related environs in our night sky. The Milky Way's disk of stars stretches over an impressive 120,000 light-years. Just around 1,000 to 1,500 light-years from us are the hotspots of this immense Orion stellar nursery, and they offer a wonderland for telescopic observers during the winter months in the Northern Hemisphere.

As deep, wide-field images of Orion show, the entire region around this constellation is wrapped in subtle shades of nebulosity (*S&T:* April 2026, p. 78). These are mostly reddish glows from hydrogen emission but also are rich in scattered, bluish reflection nebulosity and the tiny, opaque dust grains of dark nebulae. It's a nebula hunter's paradise!

The star of the show, of course, is **M42**, the Orion Nebula, and its attendant parts. It's visible to the unaided eye as a hazy glow tucked within the so-called Sword of Orion, below the three bright Belt stars — Delta (δ), Epsilon (ε), and Zeta (ζ) Orionis. The Orion Nebula is the brightest emission nebula for northern-sky observers, and only

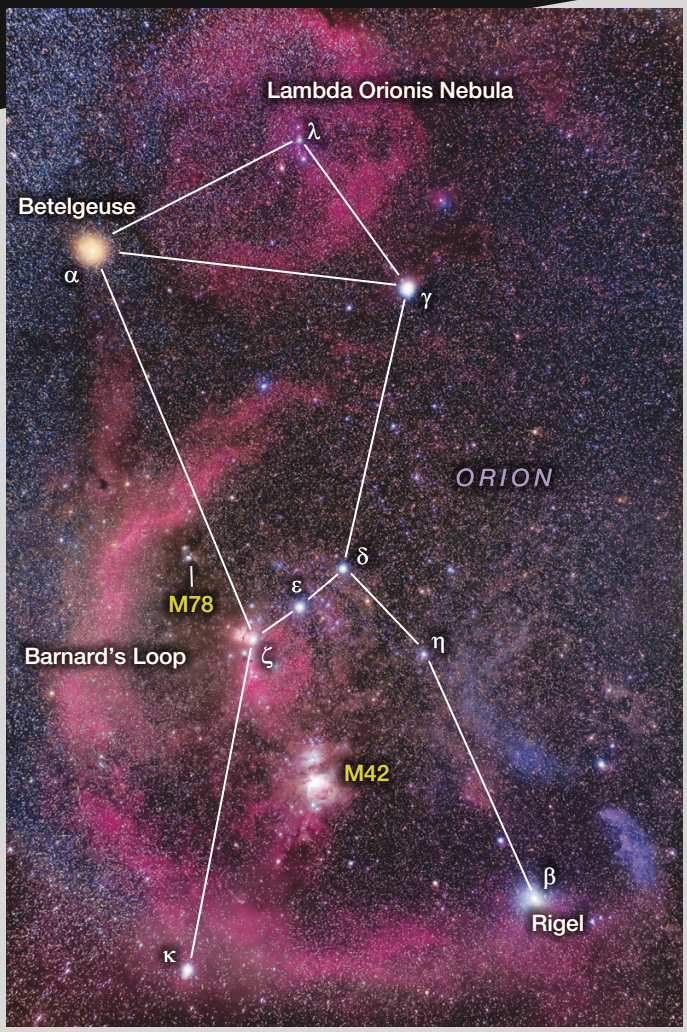


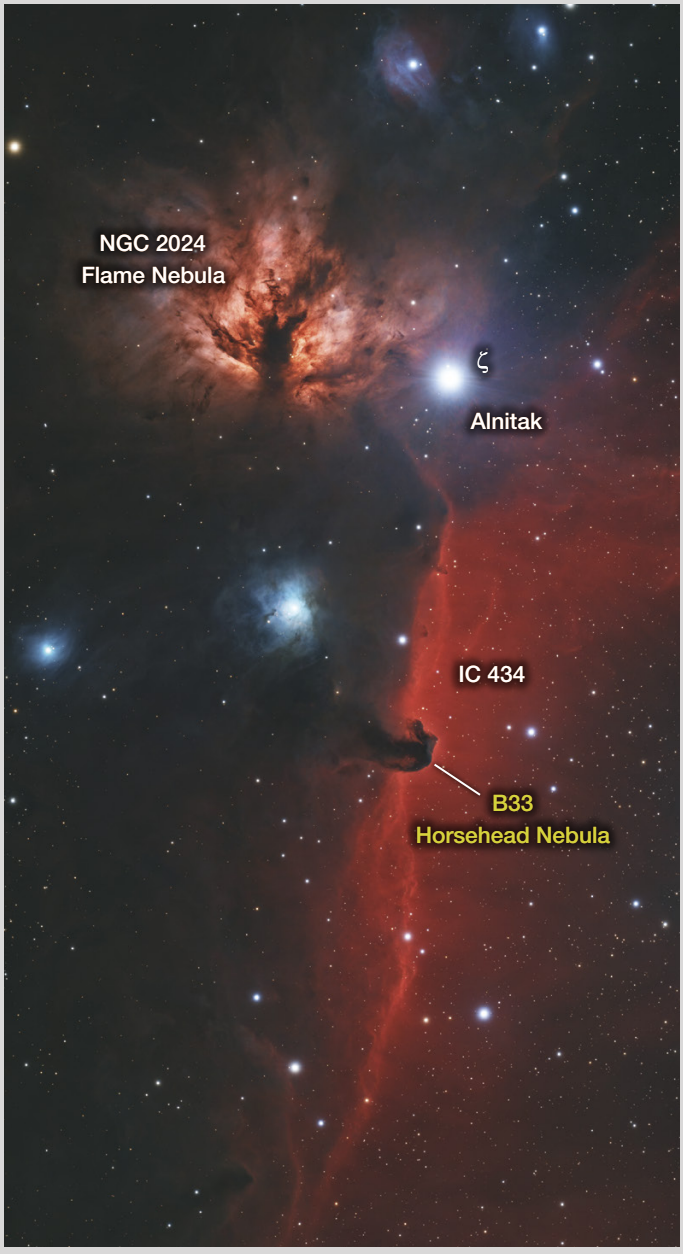
ORION NEBULA: MARIO BAUTISTA; TRAPEZIUM: K. L. LUHMAN (HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS) / G. SCHNEIDER, E. YOUNG, G. RIEKE, A. COTERA, H. CHEN, M. RIEKE, R. THOMPSON (STEWARD OBSERVATORY, UNIVERSITY OF ARIZONA) / NASA / ESA

▲ **NEBULA WONDERLAND** The crown jewel of the celestial Hunter is the Orion Nebula. This 42nd object in Charles Messier famous catalog is the brightest and most conspicuous emission nebula in the northern sky and offers a wealth of details in backyard telescopes. Use it as a jumping-off point to explore the other deep-sky objects in the area. *Inset:* A close-up view of Theta^1 (θ^1) Orionis, also known as the Trapezium. The system's brightest component is C at magnitude 5.1. The field measures approximately 55″ wide. North is up in all images.

exceeded (by far!) in size and brightness by the Carina Nebula in the southern sky. The Orion Nebula consists of a bright, central geometric pattern of nebulosity surrounding the multiple star Theta^1 (θ^1) Orionis, known as the **Trapezium**. Galileo discovered the complexity of the Trapezium group when he observed the Orion Nebula in 1617. The overall brightness of M42 is in the range of a 4th-magnitude star.

The gauzy light of the Orion Nebula, with its reasonably high surface brightness, shows up very well in small telescopes. A 4-inch aperture reveals M42's prominent core containing the dazzling, small stars of the Trapezium cluster, surrounded by nebulous, wing-like extensions that spread out like a flower's petals spanning 66′ across. An 8-inch scope at moderate magnifications reveals nearly the full extent of





▲ **MAJESTIC HUNTER** Orion is one of the most recognizable constellations in the sky, owing to its distinctive pattern. Use this wide-field portrait to help as you navigate its rich, nebula-studded field. You can also refer to the text for additional star-hopping instructions.

▶ **DARK HORSE** Popularly known as the Horsehead Nebula, Barnard 33 is a dense cloud of gas and dust that towers in front of the reddish emission nebula IC 434.

ORION CONSTELLATION: ALAN DYER; HORSEHEAD NEBULA: MARIO BAUTISTA

the nebula, with its almost bird-like body extending outward and southward. A bright knot of nebulosity with its own Messier designation, **M43**, forms the shape of a comma and lies just to the north.

The Orion Nebula represents a complex blend of emission nebulosity, bluish reflection nebulosity, dark dust clouds, and associations of young stars. The ionized region we see as the glowing cloud is roughly centered on Theta[1] Orionis C, one of the Trapezium stars. This star lies on the side of a cavity formed by several massive, hot, young stars that are bathing the area in intense radiation. The glow of the Orion Nebula lies within a concave bay of high-density material, and the gas velocities within this area reach greater than 50 km/s.

Just 30′ north of M43 lies a hotspot of nebulosity that make up NGC 1973, NGC 1975, and **NGC 1977**, together known as the Running Man Nebula. Still a short hop north of this nebulous grouping is the sparse open cluster NGC 1981. Less than 1° west of the Running Man lies a dim, isolated patch of reflection nebulosity, IC 420. South of M42 is another sparse open cluster, NGC 1980. Barely 1° due west of the Orion Nebula lies another detached cloud, the reflection nebula van den Bergh 42 (*S&T:* Jan. 2026, p. 14). And about 45′ south-southeast of the entire complex is yet another hotspot, the reflection nebula IC 428.

Dark nebulae are also present, and the most conspicuous such feature is the so-called "Fish's Mouth," the prominent, dusky area northeast of the Trapezium, as well as several areas of dark nebulosity intertwined with M42's wings and prominently visible on the eastern edge of M43.

The multilayered, complex character of the many objects in this area underscores its rich nature as a star-forming region. Large telescopes show some color in M42 and also remarkable areas of definition, as well as exposing large swaths of much fainter nebulosity that aren't visible in small scopes. The Orion Nebula represents one of the great deep-sky objects in the entire sky, and I encourage you to explore it at length, to note details, and even to make sketches of what you see, which will refine and sharpen your observing techniques.

Not far from the Orion Nebula, just ½° south of 1.8-magnitude Zeta Orionis, or Alnitak — the easternmost of Orion's three Belt stars — is one of the most notable dark nebulae in the entire sky. Cataloged as Barnard 33, it's widely known as the **Horsehead Nebula** due to its distinctive equine shape. This dusky figure is a challenging object among deep-sky observers, being somewhat notoriously difficult to see visually and certainly requiring a very dark sky. It's a far easier target for astro-imagers, however.

As American astronomer Edward Emerson Barnard first uncovered a century ago, dark nebulae are hard to see. They're composed of obscuring dust clouds and are typically visible only because they're backlit by other objects or bright nebulous clouds, or appear as a conspicuous lack of stars. In the case of the Horsehead, a faint curtain of emission nebulosity, IC 434, glows behind the horse's silhouette, rendering its equine head dimly visible. The Horsehead lies some 1,400 light-years away and measures some 6′ by 4′ in extent. Some observers who spot the Horsehead for the first time are surprised by its relatively small angular size, after seeing many close-up images of it published in popular literature.

Decades ago, Walter Scott Houston reported seeing the Horsehead in a 5-inch refractor. Such an observation could be made only from a very dark, rural sky. Typically, a 10-inch or larger scope is required to spot the nebula, and then only on dark, moonless nights. It's far easier to see this tough object than it was years ago, due to the proliferation of large reflectors in recent years, and also with the aid of nebula filters and image-intensifying devices, which make the Horsehead relatively easy to see in a medium to large backyard scope.

Aside from emission and dark nebulae, Orion also presents one of the brightest examples of a reflection nebula in the sky in **M78**, which is located 2½° northeast of Alnitak (*S&T:* Jan. 2024, p. 12). Glowing at magnitude 8.0 and spanning some 8′ by 6′, M78 should be observed by any deep-sky watcher who wanders into Orion. The double star HD 38563, with components at magnitudes 10.4 and 11.5 and lying 2.1′ apart, illuminates the surrounding gas and dust as a bluish cloud. A 6-inch scope shows M78 as a ghostly smudge of pale light floating around the two stars embedded within, while a larger scope in the 10- to 12-inch range reveals significantly more detail and shows an uneven illumination over the face of the reflection nebula.

Other sprawling nebulae characterize areas of Orion. Glowing by emission, Barnard's Loop is yet another type of gas cloud — a supernova remnant. This immense nebula, which arcs more than 10° over a significant portion of the entire constellation of Orion, resulted from the explosion of a massive star some 2 million years ago. Barnard discovered the loop in photographs in 1894, and it now bears his name. For visual observers, Barnard's Loop is quite challenging, with only its brightest parts visible as slight enhancements in a low-power field. Imaging Barnard's Loop, however, is relatively easy using wide-field telescopes and lenses equipped with a hydrogen-alpha filter or astro-modified camera body.

Another expansive, dim nebula lies around the "head" of Orion. Like Barnard's Loop, the Lambda Orionis Nebula is very faint visually but prominent in deep, wide-field portraits of the constellation. Named for Lambda (λ) Orionis, the 5.6-magnitude star that ionizes the surrounding gas, this huge nebula is also cataloged as Sharpless 2–264 and covers some 390′ across its face.

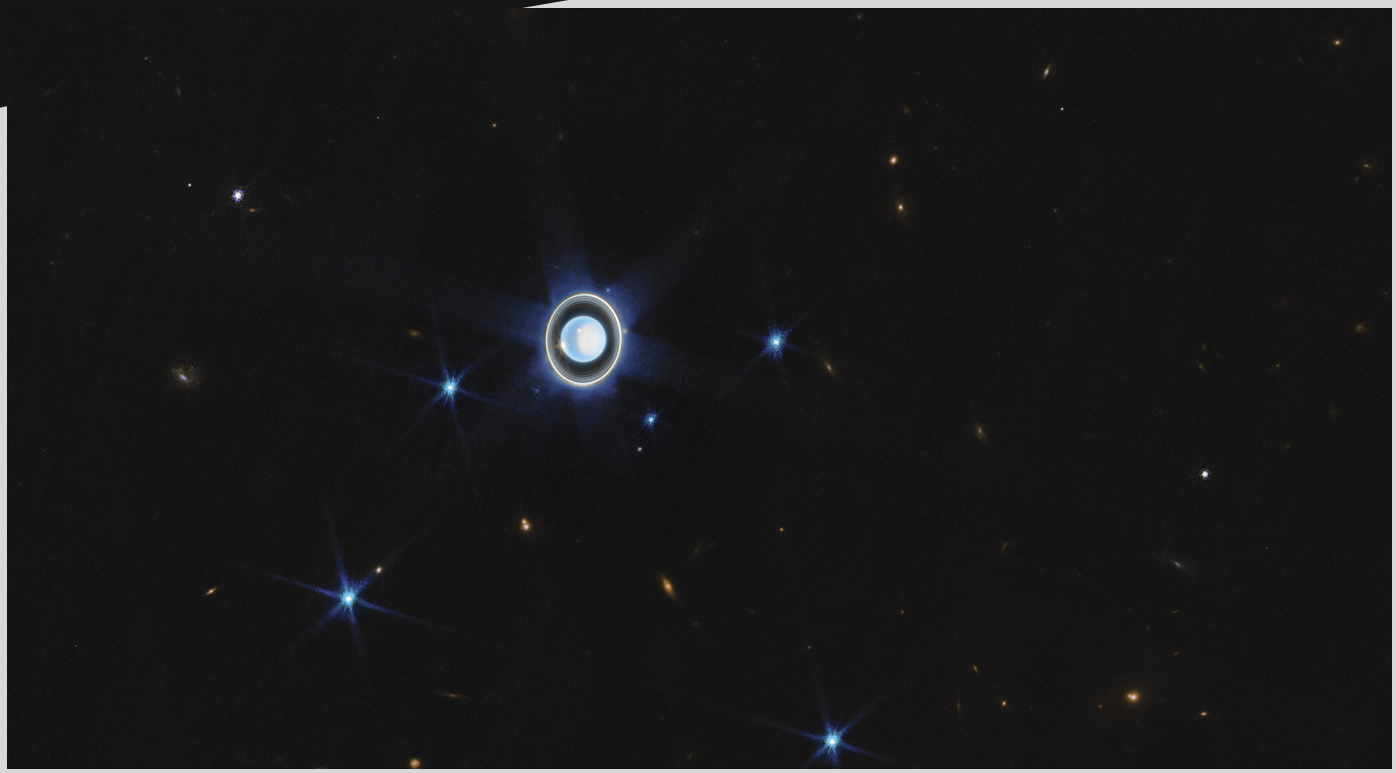
In a region peppered with notable gas clouds, one more nebula worthy of close inspection is **NGC 1999**, an oddball reflection nebula surrounding the variable star V380 Orionis, which flickers between magnitudes 10.2 and 10.7. This strange nebula lies about 1° south-southeast of M42 and contains a wedge-shaped chunk of dark nebulosity that gives rise to its nickname "The Keyhole." Give it a try the next clear night.

DAVID J. EICHER is editor emeritus of *Astronomy* magazine and author of 26 books on science and history.

Selected Showpieces in Orion

Object	Type	Mag	Size	RA	Dec.
M42	Emission/reflection nebula	4.0	66′ × 60′	$05^h\ 35.3^m$	−05° 23′
Trapezium C, D	Multiple star	5.1, 6.4	13.8″ sep.	$05^h\ 35.3^m$	−05° 23′
M43	Emission/reflection nebula	9.0	20′ × 15′	$05^h\ 35.5^m$	−05° 16′
NGC 1977	Emission/reflection nebula	6.3	20′ × 10′	$05^h\ 35.3^m$	−04° 51′
Horsehead Nebula	Dark nebula	—	6′ × 4′	$05^h\ 41.0^m$	−02° 28′
M78	Reflection nebula	8.0	8′ × 6′	$05^h\ 46.8^m$	+00° 05′
NGC 1999	Emission/reflection nebula	9.5	2′ × 2′	$05^h\ 36.4^m$	−06° 43′

Angular sizes and separation 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.



Targeting a Different Set of Rings

Here's a worthy challenge for planetary imagers with large scopes.

You may have observed Uranus, the seventh planet, many times. It's occasionally bright enough for sharp-eyed observers to spot without optical aid. Indeed, a few months ago it glowed at magnitude 5.6 for several weeks around the time of its opposition last November 25th. Through any size telescope, the planet appears as a 3.8″-wide, bluish-green disk that's generally featureless, though on very rare occasions it can sport a bright storm or two (*S&T:* July 2025, p. 52). But nobody putting their eye to an eyepiece has ever seen its rings. The planet's discoverer, German-English astronomer William Herschel, claimed he had detected them in 1789, though most agree this was highly unlikely.

The rings (we now know of 13 distinct ones) were discovered by accident on March 10, 1977, by James L. Elliot, Edward W. Dunham, and Jessica Mink aboard the Kuiper Airborne Observatory. They were observing Uranus as it occulted a star in hopes of learning more about the planet's atmosphere. Their data showed that the star unexpectedly dimmed five times before and an equal number after the planet hid it from view. The only explanation was that Uranus is surrounded by a ring system. The closest ring to the planet is about 25,000 km (15,500 miles) above its atmosphere, and the farthest is roughly 85,000 km away.

Can you see the rings visually? The short answer is *no*. Although there may be some ice mixed in, the particles in the rings are mostly dark material. And I mean they're just about as dark as it gets — the rings reflect a scant 2% of the light that falls on them. Compare that number to the reflectivity of Uranus, which is pretty much the same as Earth's, at 30%.

The other problem is that, from an angular-measurement standpoint, the rings are just 1.9″ to 6.4″ from the planet's limb. In other words, Uranus's cloud tops reflect 15 times more light than the rings, which aren't that far away from it.

▲ The rings of Uranus show up well in this infrared-light composite taken with the James Webb Space Telescope on February 6, 2023.

But they *are* within reach of amateurs, and a few have managed to catch them in recent years. While your eye can't register the ring system, many of you own cameras that certainly have the sensitivity to do so. Not on their own, of course, but coupled with at least an 11-inch telescope. The main consideration is reducing the brightness of Uranus as much as possible without dimming the rings themselves.

To do that, most astro-imagers shoot through a near-infrared filter, one that passes wavelengths between 700 and 1,400 nanometers. The most

NASA / ESA / CSA / STScI / JOSEPH DEPASQUALE

popular ones for sale block wavelengths below 685 or 720 nanometers. Some planetary imagers have had success using a deep-red filter such as a Wratten #29, which blocks all wavelengths shorter than 620 nm.

Another filter that some amateur astronomers use is a methane-band (CH_4) filter, which has a central wavelength of 889 nm. This filter is quite restrictive — it passes only a narrow range (between 8 nm and 20 nm) of infrared wavelengths, so if you plan to use one, step up to at least a 14-inch scope. All these filters subdue the bluish-green color of Uranus' atmosphere, and that makes the rings stand out more.

In addition to the filters mentioned above, you'll need a camera sensitive to the near-infrared. Fortunately, the detectors in most CMOS cameras available today can record wavelengths as long as 1,100 nm. Note that color detectors are at a distinct disadvantage here, as many camera manufacturers have installed an infrared-cutoff filter to block longer wavelengths and ensure good color balance in photos. Monochrome detectors are best suited for this job. It's also important that you operate the camera at its highest bit-depth mode, for example 16-bit versus 8-bit, to ensure your camera records every photon it can.

While it's true that some amateurs have produced images of the rings through 11-inch instruments, your chance of success goes up dramatically if you use a 14-inch or larger scope, which collects about 60% more light than an 11-inch. Remember, the rings themselves are super dark, and the filter will be cutting the light down (a lot) from everything else in the field of view. That said, Uranus's disk will still be quite bright — essentially overexposed and larger than a properly focused shot would be — and the image will need some processing to pull out the rings. Finally, as always, make sure your telescope's collimation is absolutely perfect.

Of course, I always stress the need to pick a night with excellent seeing (atmospheric steadiness). In this case, however, you get a bit of a break because the longer wavelengths you're after aren't affected as much by our atmosphere as those toward the blue end of the spectrum. Be aware, however, that most amateur images of the rings have been produced under steady skies.

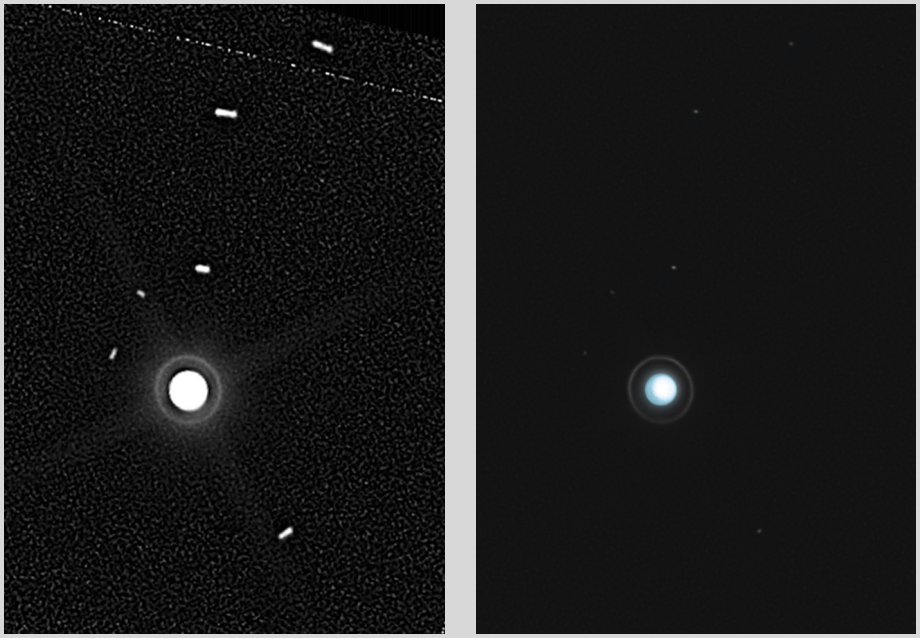
If this challenge gets you fired up to try, relax. There's no need to rush. That's because, from our vantage point on Earth, Uranus's rings are slowly opening up to our view. The most face-on views will come during 2028, so any of the next five or six years will provide excellent opportunities around the times that the planet reaches opposition. And, just so you know, opposition in 2028 will occur December 3rd.

Regarding the imaging itself, you know your setup best. You could choose to shoot a series of exposures or videos — software like *AutoStakkert!4* (**autostakkert.com**) will select the best-quality frames, aligning and stacking them into an image that you can then process in another program, such as *LuckyStackWorker* (**tinyurl.com/lsworker**). Plan on recording many videos and stacking those results together as the rings are really, really faint.

As mentioned earlier, you should aim to overexpose the disk of Uranus. That's not a bad thing. In fact, taking longer exposures that blow out the disk will almost certainly be necessary to collect enough signal to record the rings. Try some different settings and pick the one that looks best. Then, once you've captured your data, process them to achieve the correct planet-to-rings balance.

When Uranus's rings were discovered, I would've placed real money against any amateur astronomer ever being able to image them. But digital technology has improved tremendously in the half century since. Advanced astro-imagers like Anthony Wesley and Tom Williams have shown that it can indeed be done. And if you're one of our lucky readers with a large telescope, this challenge is for you. Good luck!

■ **MICHAEL E. BAKICH** observes the night sky from his backyard observatory in Tucson, Arizona.



▲ *Left:* Using a home-built, 24-inch Dobsonian on a tracking platform, UK amateur Tom Williams captured the rings of Uranus by shooting several videos with a Player One Uranus-M video camera equipped with a Sightron 720-nm near-IR filter. Overexposing the planet's disk permitted enough light from the rings to be clearly visible. The curved arcs surrounding the planet are five of its moons as well as a background star. *Right:* Combining the overexposed image with a properly exposed shot of the planet through the same near-IR filter and additional color data shows both the rings as well as the planet's bright polar region.

TOM WILLIAMS (2)



▲ SKY QUALITY MONITOR

Lunaticoastro introduces Lanternfish, a compact device that measures sky brightness. The Lanternfish (starting at $199 USD) features a calibrated light sensor with an 18° field of view that's paired with a custom optical filter that passes between 380 and 740 nanometers for visual-wavelength sky measurements. Simply aim the sensor end at the area you'd like to measure, press the button, and immediately the device shows its readings in magnitudes per square arcsecond (MPSAS) on its OLED display. The device is also programmable to take measurements at timed intervals and saves them on its internal memory. The Lanternfish includes built-in Wi-Fi for the initial setup and also to export its readings in CSV format. The device includes an internal, USB-rechargeable battery that lasts several nights. A kit option with a telescope-mounting bracket that connects to most quick-release finder shoes is also available for $228.

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▲ 90-MM SMARTSCOPE

Dwarflab announces the Draco smart telescope (starting at $1,399). The system includes two lenses: a 90-mm f/3.8 Cassegrain telephoto and a 2.96-mm f/1.9 wide-angle lens. The larger optic is paired with an OmniVision OV50Q40 CMOS color sensor that produces a 12-megapixel image in deep-sky mode, while the wide-angle lens is paired with an OV50E40 sensor of similar specs and output. The telephoto also includes an off-axis OS04C1B autoguiding sensor to ensure round stars in exposures as long as 5 minutes. The main sensor in the Draco is motorized and will de-rotate fields when imaging in alt-azimuth mode. Equatorial mode is also supported. The Draco is built into a compact alt-azimuth Go To mount that weighs only 5.5 kg (12 pounds) and connects to tripods with either standard ¼- or ⅜-inch male studs. Users control the device with a smartphone or tablet through the DWARFLAB app connected via Wi-Fi. Images and videos are saved on 128GB of onboard memory. A built-in, rechargeable lithium-ion battery powers the device for up to five hours. Each purchase includes a USB-C charging cable and a carrying case.

Dwarflab
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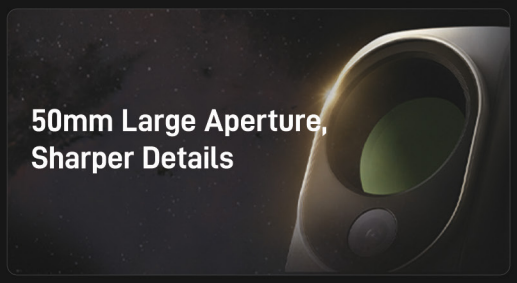






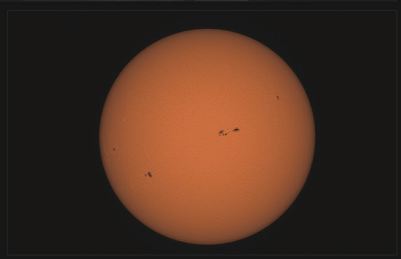
One Tap to the Cosmos











The Very Big Picture

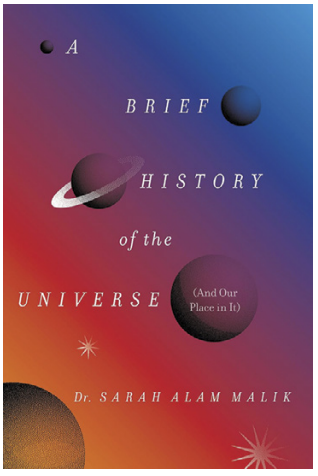
A BRIEF HISTORY OF THE UNIVERSE (AND OUR PLACE IN IT)

Sarah Alam Malik
William Morrow, 2026
256 pages, ISBN 978-0063476523
$28.00, hardcover.

THE QUEST TO UNDERSTAND the cosmos is an ambitious one, to say the least, cutting across centuries and cultures. In her debut book *A Brief History of the Universe (And Our Place in It)*, Sarah Alam Malik seeks to provide readers with a sense of this journey and how we are all part of it. What started off as letters to her young children about the privilege of exploration grew into a sprawling historical examination of the discoveries that have shaped how we see the universe. She explains, "it remains a marvel of human existence that we can comprehend worlds far removed from our own — from the fiery demise of faraway suns to the baffling complexities of the subatomic. Our partaking in a much grander and more mysterious reality may be among the greatest privileges life has to offer."

Writing about the evolution of the universe is a massive undertaking, and though Malik presents the book as "brief," it's quite thoughtful. Anyone interested in the history of astronomy or the cosmos will find this a worthwhile read. While not comprehensive, it provides a compelling survey of the topic and functions as an accessible introduction.

The book is organized into four non-chronological sections. "Our Cosmic Contemplations" covers big ideas and movements such as the ancient cosmos, the Copernican Revolution (the shift from an Earth-centered model to a Sun-centered one), and the Scientific Revolution. "Our Cosmic Conquests" examines theories about space and time, gravity, laws of matter, subatomic particles, and dark matter. "Our Search for Cosmic Company" addresses the question of whether there is other life in the cosmos and how this question has been explored in the past and present. And "Our Future in the Cosmos" contemplates humanity's future role in exploring the universe, along with planetary concerns such as supervolcanoes, artificial intelligence, and biological technology.



The book is less about the history of the universe itself, and more about the discoveries that have shaped our understanding of the universe thus far — a small but important distinction. In the first section, Malik introduces the universe by writing about how the stars acted initially as navigation aids, backdrops for myths and deities, and prompts for farming schedules. She then takes the reader on a survey of Babylonian astronomy, the Ancient Greeks, and the Islamic Golden Age, before moving on to the Copernican and Scientific Revolutions, for the most part listing scientists and discussing their contributions.

But Malik hits her stride in the middle two sections, where she delves into the more advanced scientific theories. Perhaps this is not surprising, since she has worked on the Large Hadron Collider as a particle physicist and dark matter expert. Her explanations are simple and direct, making astronomical concepts easy to understand. Her descriptions about the end of the universe are almost poetic: "Ultimately, this would mean that galaxies are torn apart, stars are violently ejected from their stellar families, planets disintegrate and even atoms are shredded into their most elementary constituents. This cataclysmic vision has been termed the 'Big Rip,' an end where all cosmic structures are irrevocably dismantled into their fundamental components."

The book draws from a variety of disciplines that all circle back to what makes up our universe, humanity's place in it, and how we interact with the cosmos. The author clearly displays the myriad parts all working together, adding to the grand design of the universe. We are not the first to wonder about the stars or dream of exploring further; we are simply the latest in our line of ancestry, a small pocket of time on a nearly unfathomable timeline that will stretch out long after we're gone. In the same way that we look out into the sky and peer into galaxies and deep time, Malik turns that lens back on humanity and our place within the cosmos, while situating us in the bigger picture. "We are storytellers, in search of the greatest story of them all," she writes, "even if we may be a mere footnote in it."

■ **JAIME HERNDON** is a science writer and editor. Her writing can be found on *Undark*, *Science* magazine, *Mercury* magazine, *American Scientist*, and *Earth Island Journal*. When she's not working or dreaming of space, she loves reading and spending time with her son outside.

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The Horsehead and Flame Nebula
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Chasing Mar



GREEN GLOW This artist's impression depicts how the aurora might appear in the sky above the Perseverance rover on Mars. The level of green approximates what a smartphone would see if the auroral event were 10 times as intense as the one scientists observed in March 2024.

ALEX MCDOUGALL-PAGE, UNIVERSITY OF STRATHCLYDE / ASTROLLCAREERS

tian Aurorae

Persistence and serendipity helped planetary scientists discover green aurorae on the Red Planet.

The recent solar maximum has brought spectacular auroral displays to another generation of skywatchers. Light shows of green and red have bedazzled Earth's skies. But all that space weather has affected other parts of the solar system, too. The Space Age has revealed that a dozen worlds beyond Earth also display different kinds of aurora: potentially all of the terrestrial planets, all of the gas giants, and the giants' five largest moons.

A planet's aurora is the visible manifestation of the interaction between the planet and its space environment. A major influence on this environment is the *solar wind*, the gale of charged particles (such as electrons and protons) streaming through the solar system from our star. Space-weather processes energize these and other charged particles, and the particles then plunge into the planet's atmosphere, losing all of their energy in collisions with the gases there. The collisions transfer energy to the electrons attached to the gases' atoms and molecules. When these electrons decay back to lower-energy states, they emit the extra energy as light.

It's this light that makes up the auroral glow. The precise energies the electrons emit dictate the aurora's colors, and these in turn depend on which elements and compounds the upper atmosphere is made of.

But aurorae are more than their color palettes. Their features and behaviors all reflect the planet's particular magnetic conditions.

For example, on Earth, Jupiter, and Saturn, the planets' strong global magnetic fields have distinct north and south poles, and these fields concentrate incoming particles in ovals around the magnetic poles. On Earth, we call these lit-up ovals the *northern* and *southern lights*. In fact, it's the interactions between Earth's magnetic field and the solar wind that energize the particles to such high levels.

On other worlds, the situation can be more complicated. What if the magnetic field is highly tilted, patchy, or nonexistent? What if no known mechanisms exist to energize particles to the necessary levels?

We faced some of these situations on Mars. Yet we now know that the Red Planet has its own zoo of aurorae, including a type we should have expected but didn't find until the Sun's outbursts lit up the Martian sky.

Aurora on a Planet with No Magnetic Field?

The case of Mars is especially interesting, as we know it lacks the strong, global dipole field capable of energizing particles and guiding their trajectories into the atmosphere. Only weak, localized *crustal fields* exist, like those on Earth's seafloor. These are locked into ancient lava flows, primarily in the southern hemisphere.

Given the lack of a global field, scientists' expectations for aurorae on Mars were low. But observations by the European Space Agency's Mars Express orbiter reported in 2005 proved the pessimism wrong: The orbiter's Spectroscopy for the Investigation of the Characteristics of the Atmosphere of Mars (SPICAM) instrument detected small, transient patches of ultraviolet aurora, usually around the stronger of the planet's crustal fields.

SPICAM recorded just 19 events over 10 years. The low number didn't necessarily mean aurorae were rare, however; the instrument could only look at certain places and times, and those didn't always overlap with good aurora-viewing (or aurora-making) conditions.

We were able to take a closer look with NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft. The orbiter arrived at Mars in 2014 carrying the Imaging Ultraviolet Spectrograph (IUVS), which was designed to be more capable than SPICAM, with higher sensitivity and greater flexibility to target observations. MAVEN extensively studied Mars's nightside over its 11-year lifetime and, through hundreds of detections, confirmed that SPICAM's crustal-fields aurorae do exist.

Coupled with MAVEN's thorough measurements of various particles and fields, the results demonstrated that even the planet's weak magnetic fields could interact with the solar wind's field to cause energized electrons surrounding Mars to rain down deeper into the atmosphere in specific places. More recently, the Emirates Mars Mission has expanded the menagerie of these *electron aurorae* since its arrival at the planet in 2021 (*S&T:* Feb. 2024, p. 12).

The biggest auroral surprise at Mars shouldn't have been a surprise at all: a global aurora. A solar storm early in MAVEN's mission flabbergasted the team, however, lighting up the nightside in ultraviolet for days. We soon realized that with no global magnetosphere present, what could prevent super-speedy solar energetic particles from hitting the atmosphere anywhere the magnetized solar wind might deposit them? Nothing! The lack of a strong global magnetic field allowed the particle storm to strike the planet absolutely everywhere.

Over the course of its mission, MAVEN observed more than 30 of these global events. These *solar-storm aurorae* likely occur when energetic protons from the Sun smash into the atmosphere, with some contribution from energetic solar electrons.

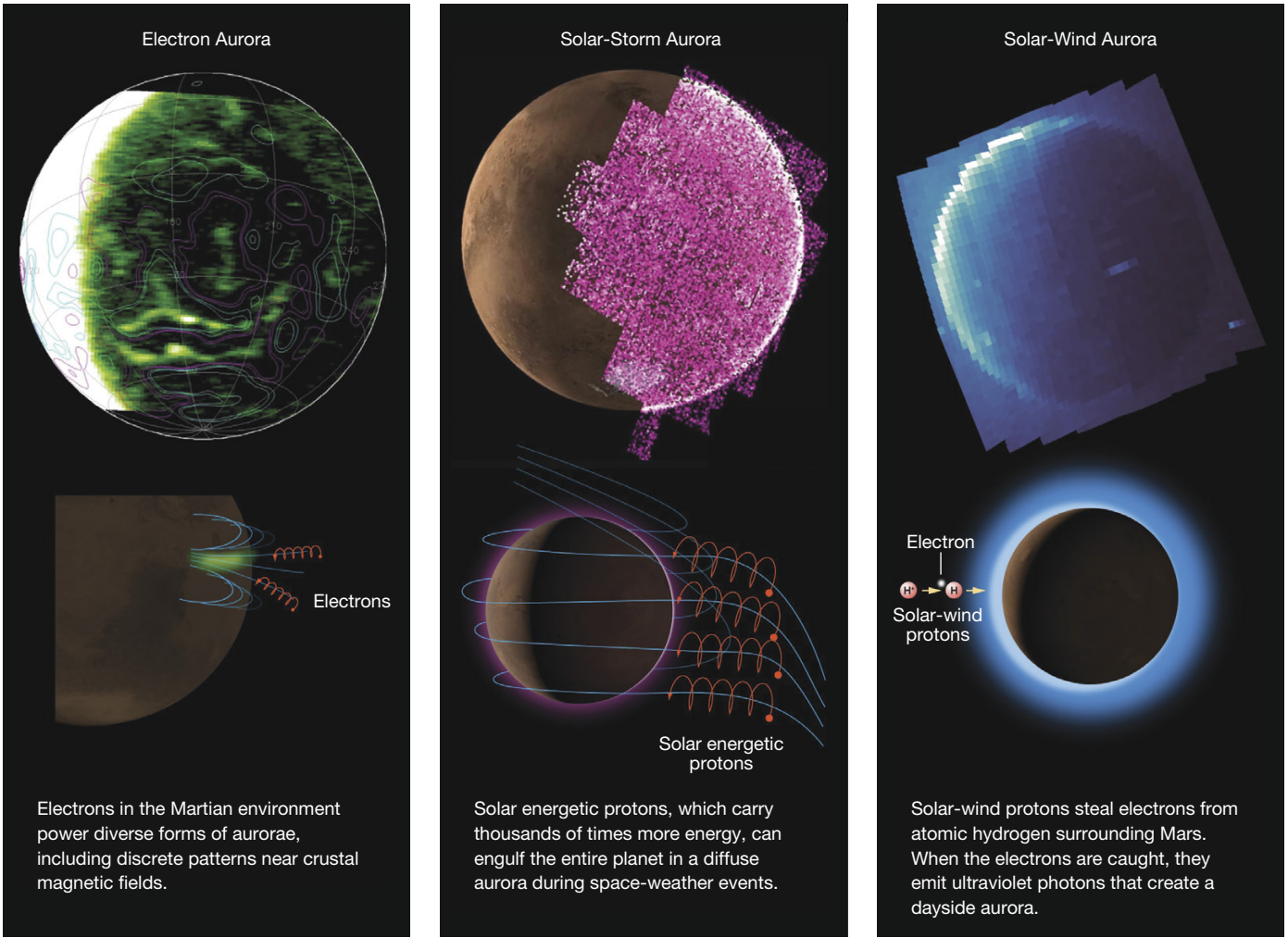
MAVEN's auroral revelations continued, with the discovery of a less intense *solar-wind aurora*. If the solar-storm aurora is a downpour, then the solar-wind aurora is a drizzle. Akin to its brighter cousin, this phenomenon occurs when lower-energy protons carried by the solar wind bombard Mars's dayside and cause intermittent brightenings.

All three of these ultraviolet spectacles are sufficiently different from terrestrial aurorae that they require new technical terms to avoid confusion. Many Mars researchers have taken to referring to the three types based on the kind of precipitating particles that cause them: *electron aurora*, *solar-energetic-proton aurora*, and *solar-wind proton aurora*. Although these names won't win any poetry awards, hopefully they'll enable us to avoid the confusion in auroral studies for other worlds, where types are identified by things like their location, shape, timing, particles, emission wavelength, or some combination of these.

Green Aurorae at Mars?

The instruments used to discover aurorae on Mars did not operate at visible wavelengths. Yet throughout these discoveries of ultraviolet aurorae, planetary scientists and the interested public have wondered whether there would also be visible emissions. And would that light be bright enough to see with the naked eye, should an astronaut get the chance?

On Earth, the distinct auroral hues of green and red are due to the atomic oxygen in our atmosphere, with blues, more red, and purple coming from molecular nitrogen (*S&T:* Oct. 2023, p. 74). But Mars's atmosphere is made almost entirely of carbon dioxide (CO_2). Could an atmosphere dominated by carbon dioxide create visible-light aurorae, as does Earth's nitrogen-oxygen atmosphere?



▲ **MARTIAN MENAGERIE** The Red Planet's complex magnetic environment means its aurorae look nothing like those on Earth. Some are patchy, tied to local magnetic fields locked into the crust *(left)*. Others are a global, diffuse glow triggered by energetic solar particles raining into the atmosphere, either as an intense storm that can cover the sky *(center)* or a drizzly daytime glow *(right)*. All three images were taken at ultraviolet wavelengths and show the same orientation. The green features in the left panel aren't the same as the visible-light aurora discussed in the article, although both types are emissions from atomic oxygen.

NASA / MAVEN / LASP / UAE SPACE AGENCY / EMM / ANIL RAO (3)

In the 2005 SPICAM discovery paper, the answer came quickly: in theory, yes. Emission from CO_2 molecules dominates the planet's glow, but SPICAM (and later, IUVS) saw ultraviolet emission from atomic oxygen as well. Statistical quantum mechanics and observational work both tell us that the atmosphere's oxygen atoms are some 16.5 times more likely to emit the "oxygen green line" at 557.7 nanometers — exactly the wavelength that lights up Earth's night sky — than they are the ultraviolet photons we'd detected.

Thus there was little doubt that green aurorae should occur along with the ultraviolet phenomena we'd observed. In principle, any camera or spectrometer at Mars operating at green wavelengths could detect such an aurora, if the light show were bright enough.

But researchers didn't think any of the orbiting instruments could see green aurorae: Nearly all of them were designed to operate in the daytime and lacked the sensitivity to see dim nighttime emissions, which would be fainter by orders of magnitude than the daytime surface. The orbiters also likely didn't have enough observing time available to catch an auroral flash, given their higher priorities, and are also unable to react to events in real time.

The Curiosity and Perseverance rovers stood a better chance. Their instruments potentially had the sensitivity to operate at night, too.

Knowing where and when to look became the larger question for scientists. Which type of ultraviolet aurora was most likely to be accompanied by a green glow that rover instruments could detect?

Martian-electron aurorae should include green emission, but this kind of aurora is sporadic, patchy, and usually geographically limited to places with strong crustal fields. Neither rover is anywhere near such locations.

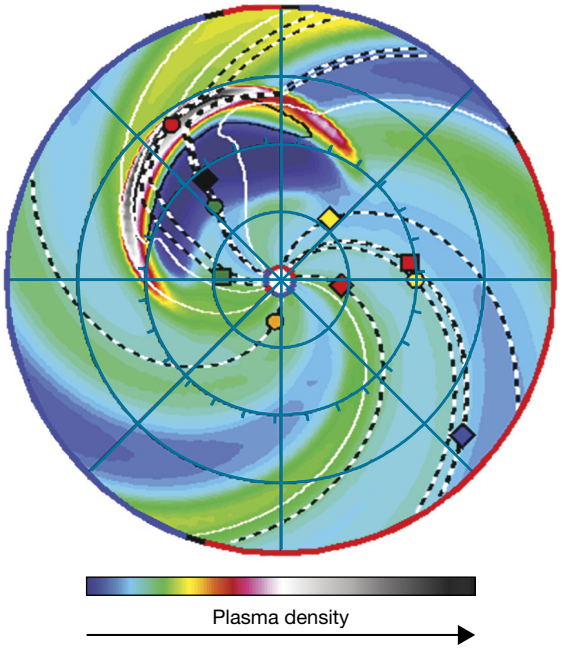
A solar-storm aurora therefore offered the best opportunity. Answers to "where" and "when" were straightforward: anywhere, and right after major solar storms.

Unfortunately, solar activity was unusually low in the 2010s, and it fell even lower due to solar minimum in 2019. But as the Sun's activity began to increase, so too did NASA's ability to monitor it — and to predict the arrival of aurora-sparking space weather at Mars.

The Search from Below

Mission scientists with NASA's Perseverance rover developed a dedicated strategy to capture the green aurora. Their theoretical estimates suggested two instruments on board would be sensitive enough to do the job: the SuperCam spectrometer and the Mastcam-Z stereo cameras. Together, these two instruments could spectrally identify the 557.7-nm emission line and simultaneously image the Martian night sky, hopefully seeing it illuminated by a soft green glow.

When the Sun releases a *coronal mass ejection* (CME), the giant cloud of plasma takes about three days to reach Mars. As the CME travels, it accelerates particles in front of it and creates a shock front, which can give the particles a further boost. These energized particles then precipitate into the Martian nightside atmosphere.



▲ **INCOMING** This space-weather prediction for March 18, 2024, shows a huge plasma bubble (dark blue) plowing through the interplanetary solar wind, creating a shock front of much higher plasma density (red-gray arc) that hits Mars (red dot). The Sun is the white dot at center. Colored round dots are planets, while squares and diamonds are spacecraft.

NASA GSFC MOON TO MARS SPACE WEATHER ANALYSIS OFFICE

NASA's Moon to Mars Space Weather Analysis Office detects CME events and models their potential impact on human and robotic missions. By using the office's estimates, the rover team planned when to observe in order to maximize the likelihood of capturing an aurora. Perseverance receives commands several times per week, so by closely monitoring the solar-storm models — pronounced "obsessively refreshing the website every few hours for two years" — the team would have enough time to jump into action.

What scientists still didn't know, however, was exactly how intense a solar storm needed to be in order to produce visible aurorae. Researchers made some early attempts at detection when smaller CMEs hit Mars. These first searches proved unsuccessful, though, with no discernible green glow in the sky. So the team decided to focus on more powerful events instead.

On Friday, March 15, 2024, the space-weather office logged a powerful new CME and posted a prediction for its path through the solar system. A solar flare accompanied the CME, too. The event caused some chatter among U.S. and European researchers operating Mars satellites and rovers. The CME was expected to reach Mars on Monday, luckily at a time when the rover was experiencing nighttime. Operators uploaded commands to Perseverance just before finishing work for the weekend.

Projections suggested this would be the most intense event since the hunt for green aurorae had started. Now, it all came

down to timing. How accurate was the model? Had the scientists selected the best time to observe?

Three days later, the answers came. On Monday, March 18th, the rover sent its data back to Earth via orbiter relays. Scientists were blown away: SuperCam's spectrum clearly showed a distinct peak at 557.7 nm, precisely as theory predicted. The Mastcam-Z images required some careful processing, but researchers eventually identified a green signal of similar intensity there as well. A second detection followed shortly after in May 2024.

We had finally discovered green aurorae on Mars. The prediction from nearly 20 years earlier had come true.

These aurorae are somewhat reminiscent of those we see on Earth, albeit fainter and without the detailed structure of terrestrial phenomena. (Our global magnetic field guides particles' paths to create such structures.) Imagine looking up at the Martian night sky, the rocky horizon black against the stars. As the solar storm arrives, a uniform green glow starts emerging all around you, eerily backlighting the nearby hills.

The aurora appears brightest near the horizon, where the line of sight through the emitting atmospheric layer is thickest. The longest line of sight is of course *at* the horizon, but Mars's dusty atmosphere obscures most of the light at this angle. Therefore, this global, diffuse green aurora appears as a glowing ring low in the sky, gradually decreasing towards the zenith where the line of sight through the emitting layer is thinnest.

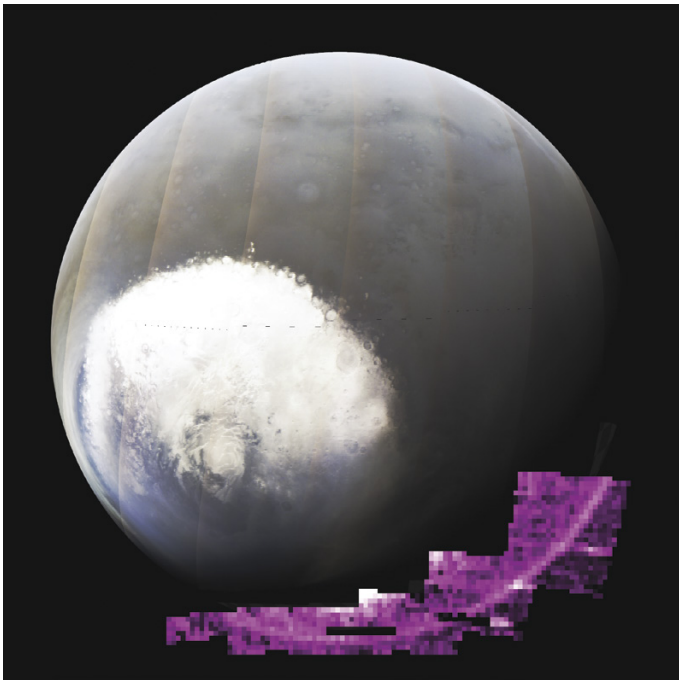
This is exactly what Mastcam-Z imaged in the Martian sky on two different nights. On the night the rover first detected the aurora, the sky softly glowed with a yellow-green color. The camera intentionally captured the edge of the nearby mountain ridge to show its contrast against the illuminated sky. Some stars are visible as diagonal streaks in the images, since Mastcam-Z collected light for two minutes in order for the weak aurora to become apparent.

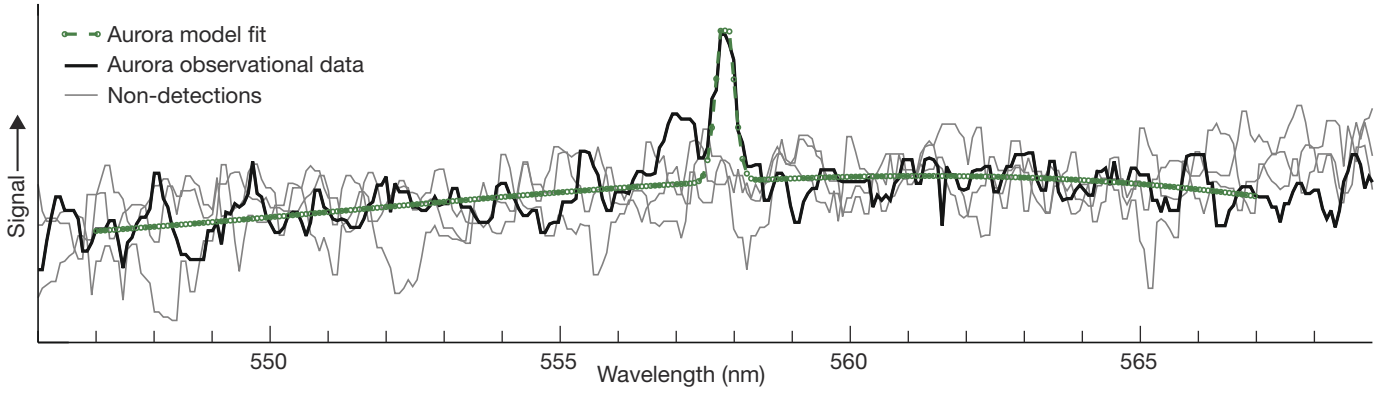
The May aurora was about half as intense as the earlier one in March. Mastcam-Z's image from May is also slightly green in color, but with a much colder hue. This color difference between March and May is due to the moon Phobos being in the sky in the March image, adding a lot of reflected sunlight to the night sky. Images with no aurora or moons appear gray in color.

While Perseverance was observing the Martian sky from below, MAVEN's IUVS instrument detected a global ultraviolet aurora from orbit, visible against the thin dark crescent of the planet. All the lines of evidence converged.

These auroral events would have been invisible to an astronaut on the Martian surface: The intensity of these green emissions were at most roughly one-third of the level that humans would be able to distinguish.

It's possible that Perseverance just missed a brighter display in May 2024, though. The Sun had entered a period of unusually high activity and released a barrage of solar flares and CMEs in a matter of weeks, many directed toward Earth and Mars. MAVEN's powerful suite of instruments captured the





◀▼ **BINGO** Working together, scientists on the MAVEN orbiter and Perseverance rover teams caught a solar-storm aurora on March 18, 2024. The image shows the ultraviolet glow (pink) superimposed on a Mars image, along with its simultaneous dayside image. The spectrum is an average of 75 spectra taken by the rover, revealing the bump in emission at the telltale green wavelength of 557.7 nm. Spectra from observations with no aurora are shown in gray for comparison.

SOLAR STORM: NASA / MAVEN / IUVS; SPECTRUM: ELISE W. KNUTSEN ET AL. / *SCIENCE ADVANCES* 2025

entire space-weather maelstrom at Mars. In ultraviolet, the planet put on a spectacular auroral show.

The rover observed twice during this period, but it just missed the storm's peak. As any aurora chaser will tell you, an hour can be the difference between awe and disappointment. If Percy had looked two days earlier or just hours later, it might have captured an unprecedented light show at Mars, likely visible even to the human eye.

But on Mars, a brighter aurora can be a more dangerous one. The atmosphere is so thin that it provides little protection against space radiation. The Curiosity rover's RAD instrument, designed to measure potentially harmful radiation at the surface, measured the equivalent of 30 chest X-rays of radiation during the largest May 2024 storm. *The New York Times* declared "Mars Got Cooked."

In other words, a Mars astronaut might have seen the aurora — but they would have had to hurry to safe shelter instead of enjoying the show. This would be true for any visible aurora created by a downpour of solar-storm particles. Those made by electrons interacting with crustal fields, on the other hand, would likely be safe because of the particles' lower energies.

We can therefore also use Martian aurorae as a means of measuring radiation hazards through remote sensing — another good reason to send cameras to the Red Planet before we send people.

What's Next?

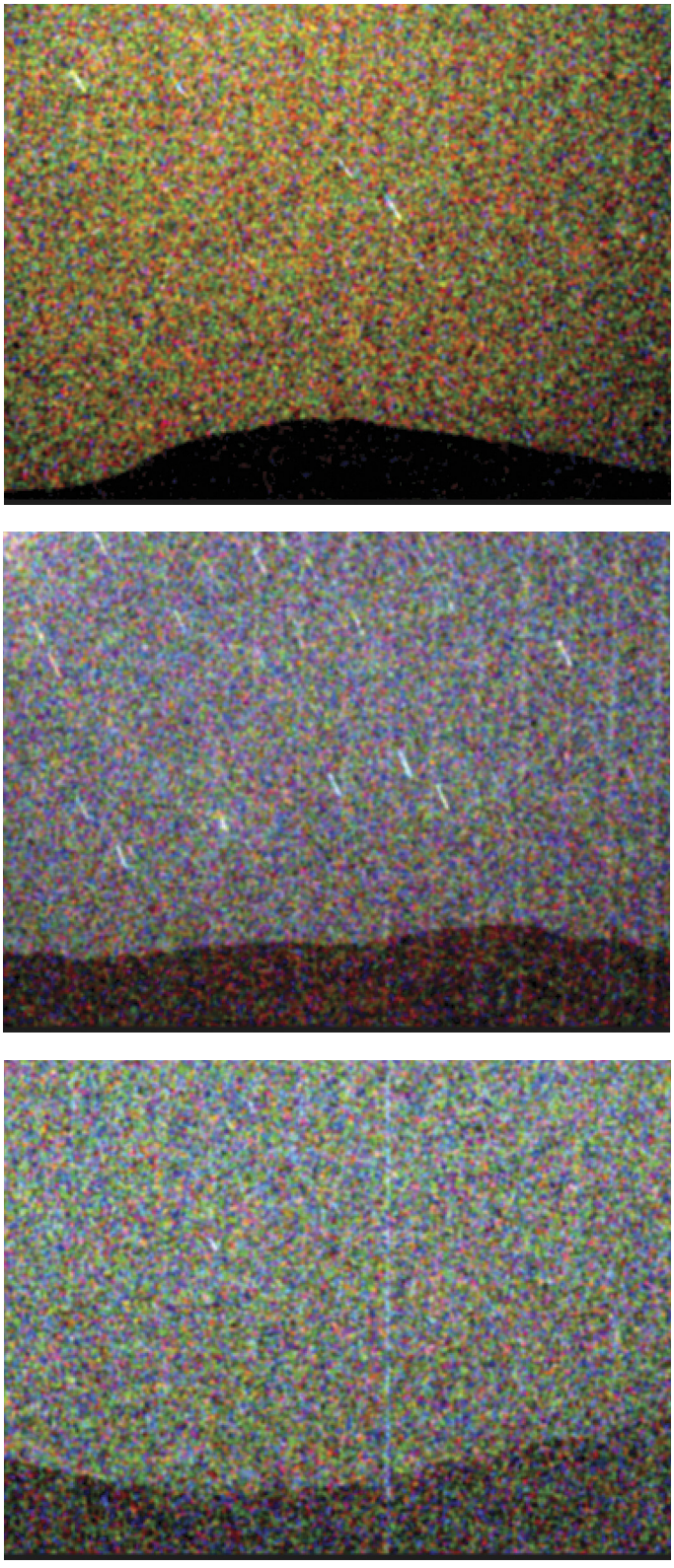
Recent bursts of solar activity have shown the world that decent auroral pictures only take a smartphone. Given advances in imaging technology and that we now know the Red Planet has visible-light aurora, it makes sense to ask, "What's next for aurora science on Mars?"

Well, we might have to wait for significant developments.

The Escape and Plasma Acceleration and Dynamics Explorers (ESCAPADE) mission, launched in November 2025 for a 2027 arrival at Mars (*S&T:* Mar. 2026, p. 10), will use twin satellites to study the planet's response to space weather. Each craft carries a student-built camera sensitive to visible and infrared wavelengths. The cameras might be able to see aurorae, but it's not a high science priority.

Meanwhile, space agencies are taking a deeper look at Martian space weather. A recent NASA workshop invited mission concepts for a satellite that would sit just upstream from Mars in the solar wind and monitor conditions. It could carry an imager to study the dayside "drizzle" aurora. But we'd need an orbiter or lander to see the nightside aurora. Whoever gets a good camera there first will probably get quite a show!

■ **NICK SCHNEIDER** is a planetary scientist at the University of Colorado and leads the MAVEN IUVS team that has discovered multiple types of aurorae at Mars. **ELISE W. KNUTSEN** is an atmospheric physicist and mission manager of the future space-weather CENSSAT-1 satellite at the University of Oslo, Norway. She led the discovery of visible Martian aurorae.



▲ **FAINT GLOW** These images from the stereo camera instrument on Perseverance show the sky on three Martian nights: March 18, 2024, with a yellow-green tinge from the combined effect of the aurora and Phobos's glare *(top)*; April 2, 2024, when there was no space-weather event *(center)*; and May 18, 2024, with the green aurora unsullied by moonlight *(bottom)*.

MASTCAM-Z / NASA / JPL-CALTECH / ASU / MSSS (3)

Dark Skies Are Calling

Dark skies. What might those words conjure in your mind? Since you're reading this magazine, you're most likely an astronomy enthusiast. (I'm assuming here.) And as an astronomer, you're probably thinking of your dream observing site, far from city lights, where the Milky Way arcs overhead. In fact, the location you're picturing is so dark and the stars so numerous that it might take a while for you to identify the constellations — the brighter stars that make up the familiar patterns we all love are awash in a sea of starlight, like in this shot by my colleague Sean Walker, taken in Botswana.

Sadly, we're losing our dark skies to light pollution. Fast. Currently, around 80% of the world's population lives under artificial *skyglow*, which is the brightening of the night sky due to artificial lights — and that's increasing by 10% every year. A whopping 99% of Americans and Europeans don't have ready access to a naturally dark sky.

Dark skies aren't only important to astronomers, though. Increasingly, studies show light pollution's insidious effects on wildlife. The quintessential example is turtle hatchlings on the Florida coast, which become disoriented by artificial lights and, instead of heading out to the ocean, they end up squashed by passing cars on littoral roads. Migrating birds can also drop out of the sky from sheer exhaustion as bright city lights lure them into endless flight patterns.

Light pollution affects human health, too. The stress of living with constant lighting takes a toll on our physical and mental well-being. Our circadian rhythm gets messed up, which causes more problems than just a bad night's sleep: Disrupting our body's internal clock can increase our susceptibility to everything from depression and obesity to certain kinds of cancer.

All this might sound apocalyptic — and it is for the birds and the turtles and all the other living creatures out there affected by our perceived need for lighting. But thankfully there is a phenomenal organization, DarkSky International, spearheading efforts to mitigate the spread of light pollution. Their website, **darksky.org**, outlines these efforts and, more importantly, provides tips on what *you* can do to help out.

Preserving dark skies is very important to us here at *Sky & Telescope*. In fact, we frequently cover the subject in our pages (see, e.g., *S&T:* Jan. 2024, p. 26 and p. 34; *S&T:* Nov. 2025, p. 11; *S&T:* Oct. 2026, p. 84). But we're not in it "just" for the astronomy (or for our health). When we lose sight of the night sky, we sever a visceral connection to our cultures, to our past, and to letting our imaginations soar. Let's not lose all that.

—DIANA HANNIKAINEN



Photograph by
Sean Walker

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MANY NEW SCOPE owners go through this particular rite of passage. You're gifted with or buy your first telescope, which usually comes with one or two eyepieces. At some point you try a friend's eyepiece and are gobsmacked to learn that a great deal of your instrument's performance is helped or hindered by the eyepiece it's paired with.

The quality of your eyepieces matters just as much as the quality of your scope: Even a fine telescope needs a good eyepiece to show what it's fully capable of. This is why there are companies that specialize in eyepieces and offer a wide variety of optical designs. Many of us spend years purchasing and trading up to improve our ocular collections and may even buy a special case just for storing and displaying them (*S&T:* Feb. 2025, p. 68).

Sky-Watcher, a company known for its telescopes and mounts, recently unveiled a series of wide-field eyepieces of their own. We borrowed a set to see how they perform.

The Emerald series of telescope oculars currently includes a 9-mm model with a 1¼-inch barrel ($215) and a pair of 2-inch-format siblings, the 16 mm ($295) and 22 mm ($310), which are threaded to accept filters. All three use a seven-element design to produce an 82° apparent field of view. The 9-mm weighs in at 0.16 kg (0.36 pound), while the 16- and 22-mm models tip the scale at 0.54 and 0.59 kg, respectively.

Each eyepiece comes with rubber end caps as well as an individual carrying case with fitted foam for storage and transport. The 9-mm has a rubber eye guard that folds back on itself, but the two larger models have more rigid eye guards that are a bit deeper. There's a metallic, green ring around each eyepiece noting its focal length. These rings are loose and spin around the eyepiece barrels.



◀ Sky-Watcher's new line of 82° Emerald eyepieces consists of a 9-mm, 1¼-inch model (center) as well as 16-mm and 22-mm focal lengths with 2-inch barrels (left and right, respectively).

ALL IMAGES ARE BY THE AUTHOR

Under the Stars

I tested the Emeralds using four different telescopes, two of which were specifically Maksutov-Cassegrain designs, which have fewer optical aberrations that would compromise my eyepiece evaluation. My best views were through Sky-Watcher's 8-inch f/10 SkyMax 200 DX and the company's smaller 127-mm SkyMax. I studied the Moon extensively with these, using all three eyepieces to look for distortions along the edges of the field. Both the 16-mm and 22-mm eyepieces displayed clear views of the Moon in the center

of the field, free of any color fringing. The pair also appeared to be parfocal to each other. When moving the Moon to the edge of the field, a razor-thin, blue edge appeared all the way around the circumference of the field. If I jogged my eye around off axis, there was also a wider, noticeably yellow ring around the edges of the field. This known optical phenomenon, often referred to as a *ring of fire*, occurs in some wide-angle ocular designs and is caused by light focusing at different positions within the exit pupil. The effect was only visible while observing the Moon.

The 9-mm Emerald performed the best on the Moon with both of the Mak-Cass telescopes. While the model's 8-mm eye relief is much shorter than its larger siblings', the yellow ring was much less pronounced when looking off axis, but it was still noticeable. The blue line around the edge was likewise present in the two larger models but was considerably thinner.

This brings me to the subject of *eye relief*. The quoted distance varies considerably between models. The 9-mm eyepiece is stated to have 8 mm of eye relief, while the 16-mm and 22-mm are listed at 14 mm and 18 mm, respectively. While 14 mm and 18 mm seem generous, the eye guards on the two larger models are quite deep, which prevented me from really enjoying the entire field of view without having to move my head around. This of course is when that yellow ring would make an appearance.

On star fields, the eyepieces showed very little change in the stars as they drifted across the field. There was no color distortion at all with any of them, but the 22-mm did display some slight flaring out of stars as they approached the edge that wasn't visible in the other eyepieces. It only became noticeable in the last quarter of the field near the edge, and it was slight. Even with this distortion, there was no color separation that I could see. I also observed Saturn with the smaller Mak-Cass, and it was clean and sharp over most of the field. It was only when nearing the very edge that I noticed some additional glare surrounding the planet.



▶ The 9-mm model features an eyecup that can be folded down to better take in the entire field of view.

Reflectors and Refractors

I also used the Emerald eyepieces with a 6-inch f/4 Newtonian reflector to observe M45 (the Pleiades cluster), Vega, and the Moon. When viewing through the 16- and 22-mm on the bright cluster, stars began showing some radial flaring about halfway from the center of the field to the edge due to coma inherent in this telescope design. It was quite strong near the edge of the field of view, with brighter stars having red and blue highlights on the side of their comet-like heads facing the center of the view. On Vega, this was especially obvious as it was of course dazzlingly bright. The 9-mm was again the best eyepiece in this scenario. The distortion was only about half as strong, and I had to look much closer to the edge of the field before it became apparent.

But notably, there was no color separation at all in this eyepiece. Vega stayed brilliant white, even as it began to pull apart at the edges of the field. An f/4 mirror is a tough test — Newtonians with longer focal ratios will show much less edge distortion when paired with these eyepieces. Observers with short-focal-ratio reflectors generally have better views with eyepieces when fitted with a coma corrector specifically for visual use.

The two larger Emeralds rendered the Moon sharply in the center of the field, though they exhibited the same blue ring along the very edge of the field if I moved the Moon there, along with a bit of that yellow band again. The clarity of the Moon was a bit less sharp, too, at the edges as you'd expect with an uncorrected Newtonian primary. With the 9-mm eyepiece the Moon filled the entire field, and the thin blue band is always there, as is the yellow ring. I didn't need to shift my head around this time to see it, but it wasn't overpowering. The center, however, is clean and without any discoloration.



Each Emerald eyepiece comes with two rubber end caps and a foam-lined case with a carrying strap.



▲ Each eyepiece seated squarely in all of the star diagonals used on a variety of scopes.

In addition, I also observed with the Emerald eyepieces while reviewing the Stellarvue SVX180T-2 180-mm f/7 refractor (*S&T:* Oct. 2026, p. 72). On star fields, all three eyepieces showed sharp, pinpoint stars in the center of the field. Observing the Pleiades, brighter stars began to grow tails about halfway from the center to the edge of the field. I then slewed over to Aldebaran in Taurus's head to use as a bright-star test. I could see the same elongation and some slight blue flaring when the star got closer to the edge.

The pair of 2-inch Emeralds fully contained the Moon within the field when paired with the big refractor. There was again the yellow ring when I moved the Moon to the edge of the field, as well as the thin blue ring along the edge. The 9-mm eyepiece, however, really stood out on the refractor, though not in a good way. With the full view being occupied by a bright gibbous Moon, the yellow band was especially deep and bright, to the point of distraction. The effect faded in the center, but I'd say fully half the distance from the edge toward the middle had this strong, brownish yellow gradient.

While not marketed as planetary eyepieces, Saturn was an irresistible target with the 7-inch refractor and, paired with the Emeralds, the ringed planet put on a good show (though it required adding a Barlow lens to really pull out details). I could see the rings, the Cassini division, the planet's shadow, and a few of its attendant moons easily in the 9-mm. Often at low power in wide-field eyepieces I've seen Saturn produce far too much glare to make out fine details, but even the 22-mm Emerald rendered tiny Saturn and its rings crisp and well defined in the big refractor.

I thought I'd try another light-scatter test, and so I also observed with the 9-mm in Sky-Watcher's 76-mm Heliostar (*S&T:* Dec. 2025, p. 68). Several eyepieces I've paired with this scope show a hazy red sky around the Sun, which is typically caused by both internal reflections and optical coatings that aren't optimized for the narrow hydrogen-alpha wavelength produced by these specialized scopes. The 9-mm Emerald yielded a nice, dark sky background, and chromospheric details across the solar disk were sharp and contrasty.

The Verdict

All three Emerald eyepieces performed well, with only the 22-mm showing just a bit of optical infidelity when stars got too close to the edge of the field. The 9-mm seemed to add the least objectional distortions or edge color in every test, except for the Moon in some cases. It has just 8 mm of eye relief, considerably less than either of the two larger models. However, its eye guard is shallower than the others in the series, allowing your eye to be closer in and comfortably take in its full 82° field of view.

The Emerald series is a distinct step up from the generic models that often come with a new scope, though the eyepieces work better with some optical designs than they do with others. Users with long-focal-ratio instruments, such as Schmidt-Cassegrains and Maksutov-Cassegrains, will likely be very pleased with the eyepieces' performance.



▲ *Left:* The eyecups on the 16- and 22-mm models are thicker than that of the 9-mm and can't be folded down, which prevents viewers (particularly those who must observe wearing glasses) from taking in the entire 82° apparent field at once. *Right:* Each eyepiece is threaded to accept standard visual filters.

■ Contributing Editor **RICHARD S. WRIGHT, JR.** can sometimes be found behind an eyepiece at the Grand Canyon Star Party in Arizona.



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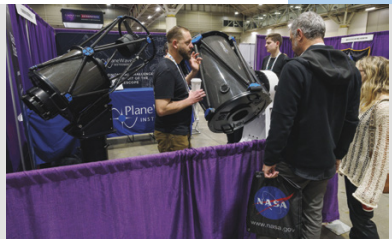




Reverse Aperture Fever

This ATM's projects are increasing in size but narrowing in aperture.

WHEN ASTRONOMERS REACH for more focal length, it often comes with an increase in aperture. But Minnesota amateur telescope maker Zach Resler thinks differently, having just ordered his smallest objective yet, with an unusual twist: a single-element, 1-inch (25.4-mm) lens having an 8.2-foot (2.5-meter) focal length, or f/98.

Single-lens refractors, or singlets, have serious optical shortfalls, *chromatic aberration* being the biggest example.



◀ Zach Resler stands next to his 6-inch f/5.33 hypochromatic refractor. Its design is based on an optical configuration first proposed by ATM John Wall. It uses a very slow singlet as an objective, with a small refractor near the middle of its focal length for viewing.

Glass bends blue light more than red, meaning the colors each come to a slightly different focus. This causes colored fringes in the resulting images. An *achromatic* lens, consisting of two or more elements made of different glass materials, reduces this aberration and produces nearly color-fringe-free images. Refractors of the 17th and 18th centuries were very long (typically f/20 in ratio of focal length to aperture) to minimize this and other problems; for a given design and aperture, a higher focal ratio means shallower light angles and milder aberrations.

Zach discovered the hobby in 2022, getting a small scope after seeing photos of the great conjunction of Jupiter and Saturn in December 2020. Then a freshman in high school, he ran into the telescope-making world online via the Cloudy Nights forum (**cloudynights.com**). There he read about the Fraunhofer and other historical, long-focus refractor designs and wondered what he could make out of parts he already had.

For his first project, he removed the crown element of a stray 60-mm refractor and ground the rear surface flat to form a plano-convex lens. For grit, he raided his childhood sandbox, letting the sand settle and separated it by grain size in flooded cooking tins. He rotated through three bricks as he ground the back face of the lens flat, only deciding "good enough" when it registered flat against a straightedge. Experiments with polishing agents involved toothpaste, automotive polishing compound, and powdered grit scraped off of sandpaper.

To mount the instrument, Zach improvised something resembling the masts that towering aerial telescopes had used in the past. He anchored a telescoping pool skimmer pole into a heavy, five-gallon bucket filled with gravel, and tied a rope on both ends of the optical tube to create a rudimentary alt-azimuth mount.

With a negative lens as the eyepiece, this scope started out as a Galilean design; it later became a slightly better Keplerian when he swapped the eyepiece for a Huygens from the 60-mm refractor. Behind a single lens, Zach's view was mush. The scope's shiny, metallic interior, a now-uncoated lens back surface, and microscopic digs from grinding didn't help either. The Moon appeared as a featureless smear, and stars were spiky kaleidoscopes of color, Zach recalls. Even the extremely long f/17 focal ratio wasn't enough for the 60-mm singlet to perform, so he experimented with reducing the aperture. It was at 12-mm aperture, or around f/85, that the view became coherent.

By drastically reducing the aperture, he was able to remove most of the muddiness. "The Moon was fuzzy, but I could see distinct craters," Zach says. "Jupiter was a tan circle flanked by four dots, Saturn was oblong with a line through it, and the stars were terrible, with huge red, blue, and green spikes." And he was happy — with only parts he had sitting around, he managed to fashion a scope in the style of the 1600s. The colors were fun, and he



▲ This unusually long refractor consists of two lens assemblies spanned by three aluminum rail extrusions 80 inches (2 meters) long. The objective of the small refractor helps the system produce markedly better views than the bare singlet would alone.

ALL PHOTOS ARE COURTESY OF ZACH RESLER



▶ Resler's first 60-mm f/17 refractor, an optical design straight out of the late 17th century, is seen mounted with materials close at hand: a bucket full of garden rocks, a pool skimmer pole, and a piece of rope.

enjoyed showing off the views to people.

It wasn't until the optics supplier Surplus Shed (**surplusshed.com**) restocked a specific, long-focus singlet that Zach could start his next ambitious scope, starting with a 6-inch f/27 plano-convex lens for a *hypochromatic* refractor. This optical system reduces, but doesn't completely eliminate, chromatic aberration. The late inventor John Wall — better known for devising the ubiquitous Crayford focuser — created the unique design, which utilizes a large, simple singlet lens paired with a smaller refractor downstream. The resulting telescope is only useful for low-magnification stargazing but may serve as a template for building large-aperture refractors inexpensively that have unusually wide, bright views.

Zach read on the forum about someone's success doing this with a similar f/17 lens from Surplus Shed, so he reasoned the f/27 lens would perform better. He ordered a secondhand, 80-mm f/5 refractor and found a good deal on some 80-inch-long aluminum rail extrusions to use for the optical truss assembly.

Zach also used an Ender 3 Pro 3D printer to fabricate the structural rings and lens cells. Mounting the scope is no small task, but he lucked into acquiring an old Criterion pier with an adjustable wedge. A classic, plumbing-pipe mount with a small counterweight formed the head. When a friend recently cajoled him into dragging the scope out for the August 28th partial lunar eclipse, he was ready.

The view was a little fuzzy — a Cheshire collimating eyepiece had proved inadequate for aligning the optics in the field, so Zach spent an afternoon getting all the optical elements to come into agreement. The subsequent views were an improvement on his prior refractors, with deep-sky objects appearing quite bright. His back-of-the-napkin math suggests an effective focal length of around 800 mm for the system, though this may still change as he fine-tunes the lens spacing.

Zach's ongoing project is even longer. He ordered a 1-inch lens from Thorlabs (**thorlabs.com/optics**) with a focal length of 2,500 mm for maximum "mast-mounted ancient astronomer absurdity." For this and future projects — he hopes to later build a 2.8-inch f/70 — Zach is now searching for long-focal-length Huygens eyepieces. "They're usually garbage," he says affectionately, "but they get along well with the slowness of these telescopes."

■ Contributing Editor **JONATHAN KISSNER** is already searching for long-focus singlet lenses.



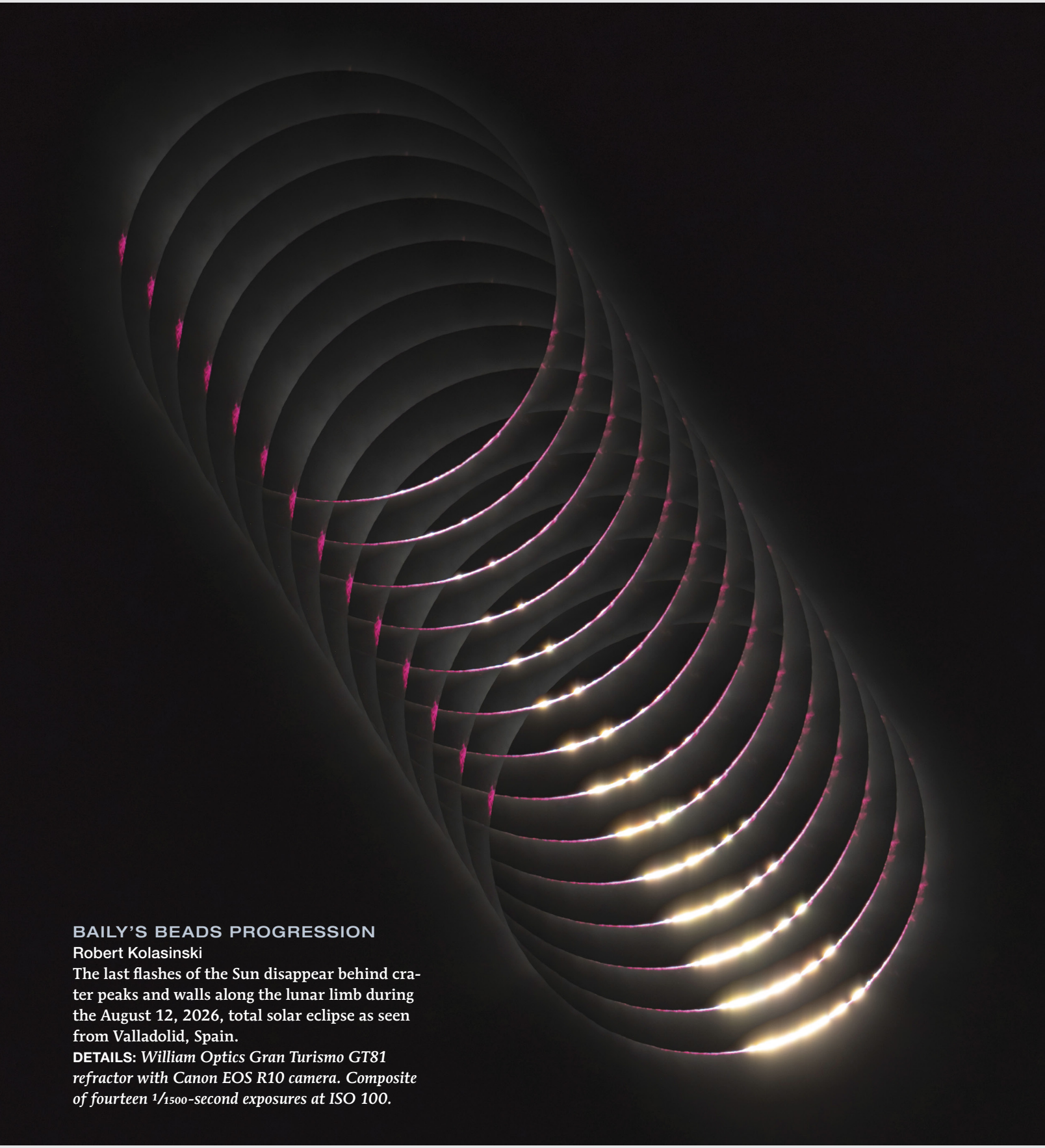
▲ Concentric rings are visible in the singlet objective of the hypochromat. These "zones," or departures from the desired figure of the lens, refract light rays incorrectly, worsening an image. This has been one of Resler's biggest barriers to truly testing this design.



▲ A close-up view of Resler's 3D-printed lens cell for holding the objective lens, complete with spring-tensioned bolts for collimating the optics. He also printed the structural rings that support the optical truss assembly and the small refractor at the scope's rear end.



▲ Resler's secondhand refractor (an 80-mm air-spaced f/5) came missing an element spacer. The spacing was prescribed as a few thousandths of an inch, and he was able to match this neatly enough with some ultrathin packing tape.



BAILY'S BEADS PROGRESSION

Robert Kolasinski

The last flashes of the Sun disappear behind crater peaks and walls along the lunar limb during the August 12, 2026, total solar eclipse as seen from Valladolid, Spain.

DETAILS: *William Optics Gran Turismo GT81 refractor with Canon EOS R10 camera. Composite of fourteen 1/1500-second exposures at ISO 100.*



◁ FIERY ATMOSPHERE

Philipp Salzgeber

Loops and streamers within the solar corona appear unusually reddened due to its low altitude as seen from Villalmanzo, Spain, during last August's total solar eclipse.

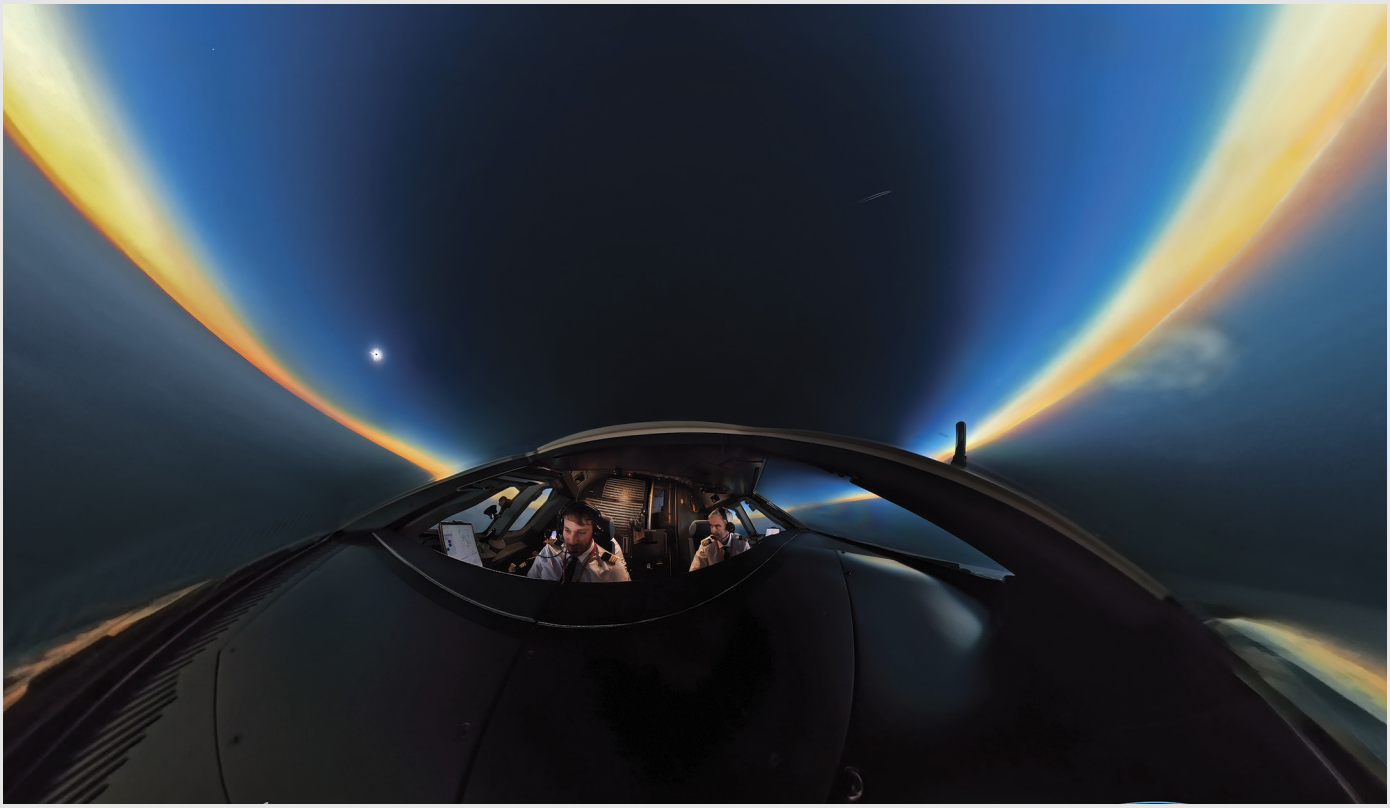
DETAILS: *Nikon Z6 camera with 180-to-600-mm zoom lens and 1.4× teleconverter. High-dynamic-range composite of several bracketed exposures ranging from 1/500 to 2 seconds at ISO 100.*

▽ SHADOW CHASING

Juan Carlos Casado

The Airbus A321XLR specially chartered flight IB1473 avoided the risk of clouds, permitting several astronomers and photographers aboard to record the August 12, 2026, total solar eclipse above Spain. Another flight is just visible in the upper right of the frame.

DETAILS: *Insta360 X5 action camera mounted in front of the pilot. Stack of 50 video frames.*





DESERT PERSEIDS

Osama Fathi

Several bright meteors streak across the sky above the photographer standing among sand dunes in Egypt's Western Desert during the Perseid meteor shower on August 12, 2026.

DETAILS: *Nikon Z6 camera with 14-to-24-mm lens and Sony α7 III with 16-to-35-mm zoom lens. Composite of several 15-second exposures at ISO 3200.*



◁ STELLAR SHOCK FRONTS

Gerald Rhemann and Michael Jäger

Planetary nebula NGC 7293, the Helix Nebula, displays its eye-like appearance in this deep color image. In addition, outer shells are visible where previous ejections collided with the surrounding interstellar medium.

DETAILS: *AstroSysteme Austria ASA N12 astrograph with ZWO ASI6200MM Pro camera. Total exposure: 51 minutes through LRGB filters.*

▽ PARTIAL PEEK-A-BOO

Tom Polakis

The 96% eclipsed Moon shines among the stars of Aquarius on the evening of August 27, 2026, shortly before clouds enveloped the scene.

DETAILS: *William Optics Gran Turismo GT71 f/5.9 refractor with Canon EOS R6 camera. Total exposure: 1 second at ISO 800.*



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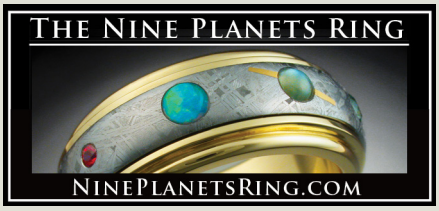

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WINTER STAR PARTY
Scout Key, FL
scas.org/winter-star-party

March 31–April 3
MIDSOUTH STARGAZE
French Camp, MS
rainwaterobservatory.org/events

April 10–11
NORTHEAST ASTRONOMY FORUM
Suffern, NY
neafexpo.com

May 2–9
TEXAS STAR PARTY
Fort Davis, TX
texasstarparty.org

May 8
ASTRONOMY DAY
Everywhere!
astronomyday.astroleague.org

May 29–June 5
GRAND CANYON STAR PARTY
Grand Canyon, AZ
https://is.gd/GrandCanyonStarParty

June 3–6
CHERRY SPRINGS STAR PARTY
Cherry Springs State Park, PA
tinyurl.com/cssp2027

June 30–July 4
ROCKY MOUNTAIN STAR STARE
Gardner, CO
rmss.org

July 6–11
OREGON STAR PARTY
Indian Trail Spring, OR
oregonstarparty.org

August 1–6
NEBRASKA STAR PARTY
Valentine, NE
nebraskastarparty.org

August 3–7
WASHINGTON STATE STAR PARTY
Jameson Lake, WA
washingtonstatestarparty.com

August 5–8
STELLAFANE CONVENTION
Springfield, VT
stellafane.org

September 2–6
ALMOST HEAVEN STAR PARTY
Spruce Knob, WV
ahsp.org

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ASTRONOMY DAY
Everywhere!
astronomyday.astroleague.org

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

LUCA PFEIFFER / NPS

One of Those Nights

Freezing temperatures, a clear night, and an avid amateur astronomer — what could possibly go wrong?

EVERY ASTRONOMER has one of those ill-fated nights when staying at home would have been much smarter than plying the skies with a telescope. Mine came one January several years ago.

I'm a retired Royal Canadian Air Force officer based in North Bay in Central Ontario. The skies in the region are marvelous: exceptionally dark, phenomenally clear, a boon for an amateur astronomer. North Bay, however, gets some serious winter weather.

On my night the wind was in full force. The mercury barely poked its head above –25°C (–13°F). Common sense told me to remain indoors, all warm and toasty. But astronomers don't always listen to common sense. The night was promising to be spectacular, and I couldn't resist heading out.

Bundling up in nine layers of clothing, I loaded my trusty 6-inch f/6 Edmund Scientific Newtonian into my car and drove to the far side of the base. I set up and for the next hour lingered over the most beautiful sky I'd seen in a long time. The Pleiades leaped through my eyepiece, while Orion took on a 3D appearance. It was all so magnificent I wasn't even aware of the cold.

At one point, the glare of headlights from a bus interrupted my session. While I waited for it to pass, I mused over what to view next. I gazed up at Gemini and decided to hunt for 5th-magnitude 64 Geminorum, which forms a rough equilateral triangle with Castor and Pollux.

I was having trouble finding it in the eyepiece, so I knelt behind the scope and carefully sighted along the tube towards the star. And then it happened.



LEAH TISCIONE / S&T

Over the previous hour, much of the moisture from my breath had accumulated on my moustache and, as I deftly aligned the telescope, the right half of my moustache brushed against the metal mirror cell — and instantly froze to the cell! I hadn't realized this had occurred until I tried to stand up and found the telescope firmly attached to my face.

Eighty pounds of telescope and mount was hanging from my upper lip.

I mumbled an expletive.

Regaining my composure, I yanked with all my might. A thick tuft came out. Through welling tears I could see some strands that used to be on my face clinging to the mirror cell.

Suddenly, my observing site exploded with light and a voice called out, "Move away from the rocket launcher! Keep your hands where I can see them!"

Rocket launcher? Out of the sea of light, I could discern a figure cautiously approaching, pistol drawn and pointed at me. He was a military policeman.

While I'd been sorting out my moustache, the bus driver had reported a suspicious person, lurking about the back of the base. The MPs dispatched two patrol vehicles, their lights off to achieve maximum surprise. They certainly surprised me. I almost wet myself.

A bit incensed and smarting from the moustache affair, I blurted, "This isn't a (expletive deleted) rocket launcher! It's a telescope."

The MP looked at the "weapon," then at me, then back again. After scrutinizing the "launcher," he reholstered his pistol and snuffed the searchlights out.

Although now stone-blind from the glare of the searchlights, I made a valiant attempt to show our military's finest Jupiter, the Orion Nebula, and M31.

As they left, I knew the "jig" was up. My night vision had been blasted to smithereens, half my moustache was missing, and the temperature had sunk to –30°C. Fate was telling me to pack up my toys for the night.

I took the hint and did just that.

■ While in the RCAF, **DOUG NEWMAN** served at 22 Wing/Canadian Forces Base North Bay and NORAD.

PLAYS WELL WITH OTHERS

OFFICIAL TELESCOPE COMPANY OF MENSA SMART CHOICE AMERICAN MENSA

SKY-WATCHER'S NEW SYNLINK UNIVERSAL ASTROIMAGING CONTROLLER MAKES IT EASY TO USE YOUR GEAR ...NO MATTER WHERE IT COMES FROM

Imaging rigs rarely come from a single manufacturer, and SynLink was built with that in mind. This single unit mounts directly to your scope and automatically recognizes cameras, mounts, focusers, filter wheels, rotators, and flat panels across a wide range of brands — no proprietary ecosystem required. Configure your optics, connect your equipment, and you're ready to image: guided polar alignment, autofocus, and plate-solved GoTo are all managed from one app, available on iOS, Android, Windows, and Mac.

Hardware

- Up to 10 Amp DC input current with reversed-polarity protection.
- Four DC output outlets. 7 Amp per outlet, up to 10 Amp total output.
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- 2.4G/5G Wi-Fi connection.

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- Mulitiple platform support: Android, iOS, Macintosh, and Windows.
- Equipment auto-connect.
- Focus wizard / Polar alignment wizard.
- Major brand equipment support, including cameras, mounts, focusers, filter wheels, rotators, flat panels, and more.

So if you want a controller that plays nice with the equipment you already have, check out the QR code below for SynLink's complete list of specifications, or connect with your nearest authorized Sky-Watcher dealer.



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SynLink doesn't care whose logo is on your gear -- it just wants to help you image with it.

WHAT'S UP? WEBCAST FRIDAY, 10-11am Pacific ON SKY-WATCHER USA's YOUTUBE CHANNEL

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Image Credit: @astroryan2

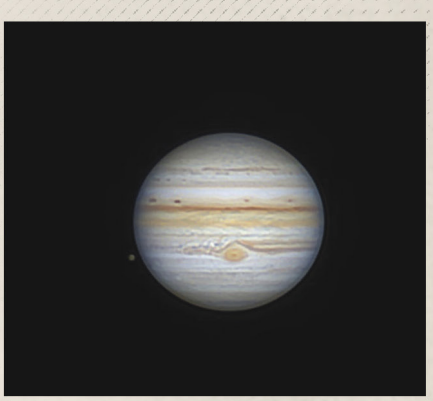

Image Credit: @astrotombr

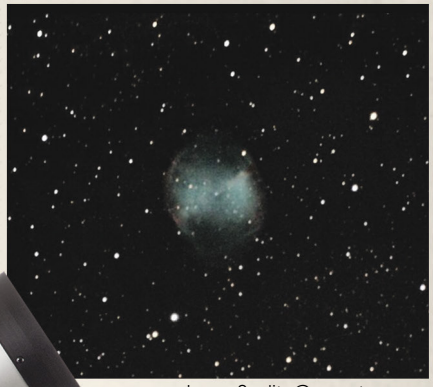

Image Credit: @cv_astronomy



DECEMBER, OVERHEAD

DEC 05	Venus & Moon Conjunction
DEC 13-14	Geminid Meteor Shower
DEC 18	Saturn & Moon Conjunction
DEC 21	December Solstice
DEC 27	Jupiter & Moon Conjunction

The sky changes nightly. Keep up with it.

@CelestronUniverse for celestial events, observing tips, and reminders.

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Skygazer's Almanac 30°s 2027

FOR LATITUDES NEAR 30° SOUTH

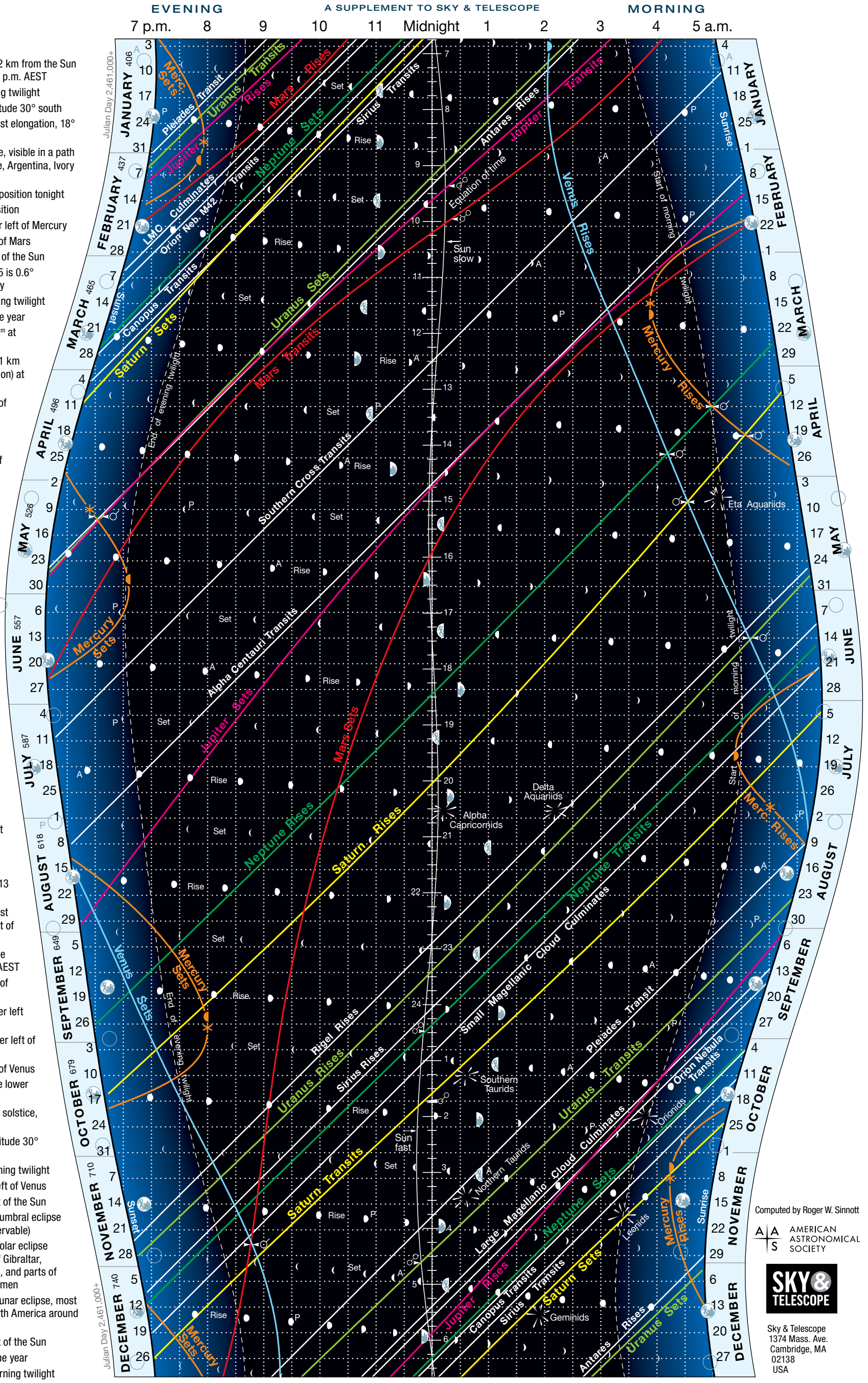
A SUPPLEMENT TO SKY & TELESCOPE

EVENING SKY

- Jan 3 Earth is 147,104,592 km from the Sun (perihelion) at 12:33 p.m. AEST
- Jan 4 Latest end of evening twilight
- Jan 10 Latest sunset at latitude 30° south
- Feb 3 Mercury is at greatest elongation, 18° east of the Sun
- Feb 6 Annular solar eclipse, visible in a path across parts of Chile, Argentina, Ivory Coast, and Ghana
- Feb 10 Jupiter comes to opposition tonight
- Feb 19 Mars reaches opposition
- May 11 Uranus is 1.9° upper left of Mercury
- May 16 Regulus is 1.2° left of Mars
- May 28 Mercury is 23° east of the Sun
- May 31 The star cluster M35 is 0.6° upper left of Mercury
- Jun 8 Earliest end of evening twilight
- Jun 11 Earliest sunset of the year
- Jun 21 Shortest day, 10ʰ 13ᵐ at latitude 30° south
- Jul 5 Earth is 152,100,481 km from the Sun (aphelion) at 3:06 p.m. AEST
- Jul 27 Regulus is 0.4° left of Jupiter
- Aug 24 Spica is 1.9° left of Mars
- Sep 21 Spica is 0.3° right of Mercury
- Sep 23 Spring begins at the equinox, 4:02 p.m. AEST
- Sep 24 Mercury is 26° east of the Sun
- Sep 28 Neptune comes to opposition
- Oct 17 Saturn stands at opposition
- Nov 25 Mars is 0.4° lower right of Venus
- Nov 30 Uranus reaches opposition
- Dec 22 Longest day, 14ʰ 05ᵐ at latitude 30° south; summer begins at the solstice, 12:42 p.m. AEST

MORNING SKY

- Jan 4 Venus is at greatest elongation, 47° west of the Sun
- Feb 21 A deep penumbral eclipse of the Moon, best seen around 1:13 SAST from Africa
- Mar 18 Mercury is at greatest elongation, 28° west of the Sun
- Mar 21 Autumn begins at the equinox, 6:25 a.m. AEST
- Apr 12 Neptune is 1.0° left of Mercury
- Apr 20 Mercury is 0.8° lower left of Saturn
- Apr 25 Neptune is 0.5° upper left of Venus
- May 8 Saturn is 0.6° right of Venus
- Jun 14 Uranus is 0.8° to the lower left of Venus
- Jun 22 Winter begins at the solstice, 12:11 a.m. AEST
- Jul 2 Latest sunrise at latitude 30° south
- Jul 4 Latest onset of morning twilight
- Jul 5 M35 is 0.9° lower left of Venus
- Jul 16 Mercury is 21° west of the Sun
- Jul 19 A very marginal penumbral eclipse of the Moon (unobservable)
- Aug 2 The path of a total solar eclipse crosses the Strait of Gibraltar, northernmost Africa, and parts of Saudi Arabia and Yemen
- Aug 17 A slight penumbral lunar eclipse, most noticeable from South America around 7:14 UT
- Nov 5 Mercury is 19° west of the Sun
- Dec 4 Earliest sunrise of the year
- Dec 9 Earliest onset of morning twilight



Computed by Roger W. Sinnott

AMERICAN ASTRONOMICAL SOCIETY

SKY & TELESCOPE

Sky & Telescope
1374 Mass. Ave.
Cambridge, MA
02138
USA

Conjunction (appulse) · Greatest elongation · Greatest illuminated extent · Opposition · New Moon · First Quarter · Full Moon · Last Quarter · A Apogee · P Perigee · Waxing (moonset) · Waning (moonrise)

Skygazer's Almanac 30°s 2027

FOR LATITUDES NEAR 30° SOUTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time is moonrise?

Welcome to the *Skygazer's Almanac 2027*, a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 30° south — in Australia, southern Africa, and the southern cone of South America.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart, you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 10, 2027.

First find "January" and "10" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 10–11 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 10–11 begins at the black curve at left, which represents the time of sunset. Reading up to the top of the chart, we can estimate that sunset on January 10th occurs at 7:06 p.m. *Local Mean Time*. (All times read from the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Continuing rightward on the dotted line for the 10th, we see that Mercury sets at 7:32 p.m., too soon after sunset for viewing. There's a dashed line crossing the dotted line at 8:40 p.m. This is when evening twilight technically ends (with the Sun 18° below the horizon) and the sky is fully dark.

Note the tiny crescent Moon symbol at about 8:41. The legend at the bottom of the chart tells us the Moon is at its waxing crescent phase, setting. At exactly the same time the dim planet Uranus transits the meridian, meaning it is due north and highest in the sky. Much brighter Jupiter rises at 9:04, as does Mars at 9:57.

At about 10:04 p.m. the Large Magellanic Cloud culminates (another way of saying it transits). The Orion Nebula, Messier 42, transits at 10:17. But Saturn sets at 11:16, a sign it was better viewed earlier in the evening.

The two brightest nighttime stars, Canopus in Carina and Sirius in Canis Major, transit at 11:05 and 11:27, respectively. Transit times of such celestial landmarks help us follow the nightly march of constellations.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 10–11 this is $7^h\ 20^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then lay a ruler through it parallel to the white event lines of stars. See where your ruler intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Also near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due north. On January 10th the Sun runs slow, transiting at 12:07 p.m. This deviation, useful in reading a sundial, is due to the tilt of the Earth's axis and the ellipticity of its orbit.

As the wee hours continue, Uranus sets at 1:53 a.m. Then Antares, a star we usually associate with later seasons of the year, climbs above the southeastern horizon at 2:01. Venus follows at 2:04.

The first hint of dawn — the start of morning twilight — comes at 3:35. The Sun finally peeks above the southeastern horizon at 5:10 on Monday morning, January 11th.

Other Charted Information

Many of the year's most important astronomical events are listed in the chart's left-hand margin. Additional

Local Mean Time Corrections

Adelaide	+16	Melbourne	+20
Brisbane	–13	Perth	+18
Canberra	+4	Sydney	–4
Cape Town	+46	Johannesburg	+8
Durban	–3	Port Elizabeth	+18
Harare	–4	Pretoria	+8
Asunción	–10	Rio de Janeiro	–7
Buenos Aires	+54	Santiago	+43
Montevideo	+45	São Paulo	+6

events are marked on the chart itself.

Conjunctions (close pairings) of two planets are marked by a ☌ symbol on the planets' event lines. Here, the symbol indicates the night when the planets appear closest in the sky (at appulse), not just when they have the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol. For instance, Jupiter reaches opposition on the night of February 10–11 this year.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces left (waxing Moon sets) or right (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk with surface features whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark when their telescopic disks have the greatest illuminated extent in square arcseconds. For example, this occurs for Mercury on the evening of January 29th this year.

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant (point of origin) is highest in the night sky. This often occurs just as morning twilight begins.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a count of days beginning with January 1, 4713 BC. Its first four digits this year are 2461, as indicated just off the chart's upper left margin. To find the last three digits for days in January, add 406 to the date. For instance, on January 10th we have 10 + 406 = 416, so the Julian Day is 2,461,416.

Note that the Julian Day does not change to this value until 12:00 Universal Time (UT). In Australia, 12:00 UT falls during the evening of the same day (at 10 p.m. Australian Eastern Standard Time, AEST). Before that time, subtract 1 from the Julian Day number just obtained.

Rising or Setting Corrections

South Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
10°	0	8	16	24	33	43
15°	0	6	12	19	26	33
20°	0	4	8	13	18	23
25°	0	2	4	7	9	12
30°	0	0	0	0	0	0
35°	0	2	5	7	10	13
40°	0	5	10	16	22	29
45°	1	8	17	26	37	49
50°	1	12	25	39	54	72

Time Corrections

All events on this southern version of the *Skygazer's Almanac* are plotted for an observer at longitude 135° east and latitude 30° south. However, you need not live near McDouall Peak, South Australia, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's south temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in order of decreasing importance.

• **Daylight-saving time ("summer time").** When this is in effect, add one hour to any time read from the chart.

• **Your longitude.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by many minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Australia are 150°E for the eastern states (which use Australian Eastern Standard Time, AEST), and 142.5°E for the central state and territory (an odd value that puts the minute hands of their clocks 30 minutes out of joint with most of the rest of the world).

If your longitude is very close to your standard time-zone meridian, luck is with you and your LMT correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Melbourne, Australia (longitude 145°), is 5° west of its time-zone meridian (150°). So at Melbourne, add 20 minutes to any time obtained from the chart. The result is standard time.

Find your Local Mean Time correction and memorize it; you will use it always. The table at far left below has the corrections, in minutes, for some of the world's major cities.

• **Rising and setting.** Times of rising and setting need correction if your latitude differs from 30° south. This effect depends strongly on a star or planet's declination. The declinations of the Sun and planets are listed each month on the Planetary Almanac page of *Sky & Telescope*.

If your site is *south* of latitude 30°S, an object with a south declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), while one with a north declination spends less time above the horizon. If you are *north* of 30°S, the effect is just the reverse. With these rules in mind, you can gauge the number of minutes for correcting a rise or set time using the table above left.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 135°E. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of central Australia, and two minutes later for each time zone west of there. Observers in southern Africa can simply shift the Moon symbol a third of the way to that for the following date. Those who live in South America can shift the symbol about halfway there.

For reprints (item SGA27S) or to order a similar chart for latitude 40° north or 50° north, go to: shopatsky.com/collections/maps-globes/almanacs

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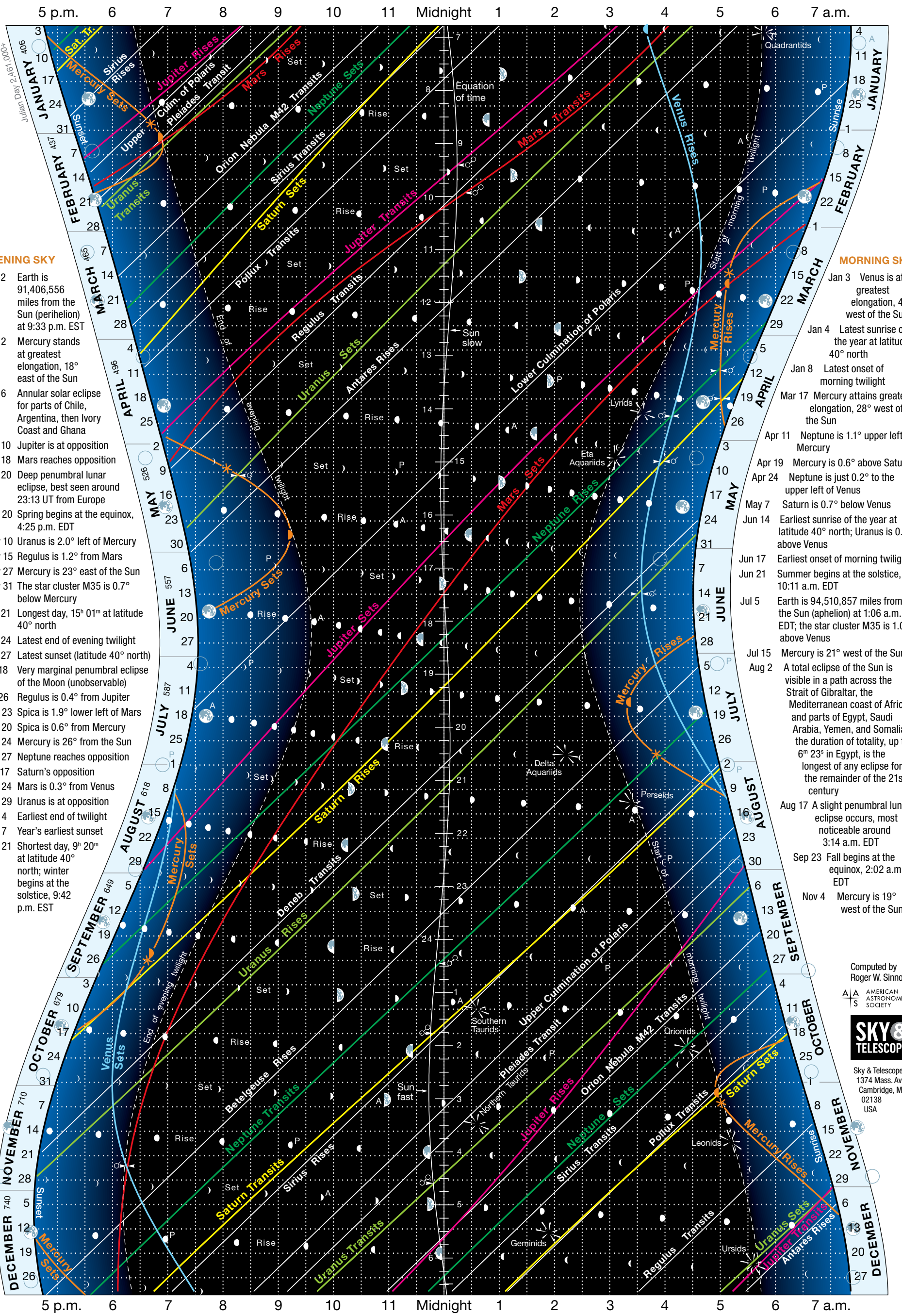
Skygazer's Almanac 40°N 2027

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



EVENING SKY

- Jan 2 Earth is 91,406,556 miles from the Sun (perihelion) at 9:33 p.m. EST
- Feb 2 Mercury stands at greatest elongation, 18° east of the Sun
- Feb 6 Annular solar eclipse for parts of Chile, Argentina, then Ivory Coast and Ghana
- Feb 10 Jupiter is at opposition
- Feb 18 Mars reaches opposition
- Feb 20 Deep penumbral lunar eclipse, best seen around 23:13 UT from Europe
- Mar 20 Spring begins at the equinox, 4:25 p.m. EDT
- May 10 Uranus is 2.0° left of Mercury
- May 15 Regulus is 1.2° from Mars
- May 27 Mercury is 23° east of the Sun
- May 31 The star cluster M35 is 0.7° below Mercury
- Jun 21 Longest day, 15h 01m at latitude 40° north
- Jun 24 Latest end of evening twilight
- Jun 27 Latest sunset (latitude 40° north)
- Jul 18 Very marginal penumbral eclipse of the Moon (unobservable)
- Jul 26 Regulus is 0.4° from Jupiter
- Aug 23 Spica is 1.9° lower left of Mars
- Sep 20 Spica is 0.6° from Mercury
- Sep 24 Mercury is 26° from the Sun
- Sep 27 Neptune reaches opposition
- Oct 17 Saturn's opposition
- Nov 24 Mars is 0.3° from Venus
- Nov 29 Uranus is at opposition
- Dec 4 Earliest end of twilight
- Dec 7 Year's earliest sunset
- Dec 21 Shortest day, 9h 20m at latitude 40° north; winter begins at the solstice, 9:42 p.m. EST

MORNING SKY

- Jan 3 Venus is at greatest elongation, 47° west of the Sun
- Jan 4 Latest sunrise of the year at latitude 40° north
- Jan 8 Latest onset of morning twilight
- Mar 17 Mercury attains greatest elongation, 28° west of the Sun
- Apr 11 Neptune is 1.1° upper left of Mercury
- Apr 19 Mercury is 0.6° above Saturn
- Apr 24 Neptune is just 0.2° to the upper left of Venus
- May 7 Saturn is 0.7° below Venus
- Jun 14 Earliest sunrise of the year at latitude 40° north; Uranus is 0.8° above Venus
- Jun 17 Earliest onset of morning twilight
- Jun 21 Summer begins at the solstice, 10:11 a.m. EDT
- Jul 5 Earth is 94,510,857 miles from the Sun (aphelion) at 1:06 a.m. EDT; the star cluster M35 is 1.0° above Venus
- Jul 15 Mercury is 21° west of the Sun
- Aug 2 A total eclipse of the Sun is visible in a path across the Strait of Gibraltar, the Mediterranean coast of Africa, and parts of Egypt, Saudi Arabia, Yemen, and Somalia; the duration of totality, up to 6m 23s in Egypt, is the longest of any eclipse for the remainder of the 21st century
- Aug 17 A slight penumbral lunar eclipse occurs, most noticeable around 3:14 a.m. EDT
- Sep 23 Fall begins at the equinox, 2:02 a.m. EDT
- Nov 4 Mercury is 19° west of the Sun

Computed by Roger W. Sinnott

AMERICAN ASTRONOMICAL SOCIETY

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Skygazer's Almanac 40°N 2027

FOR LATITUDES NEAR 40° NORTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2027*, a handy chart that answers these and many other questions for every night of the year. It is plotted for skywatchers near latitude 40° north — in the United States, the Mediterranean countries, Japan, and much of China.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 10, 2027.

First find "January" and "10" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 10–11 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 10–11 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 10th occurs at 4:54 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your clock time. More on this later.)

Following the dotted line for the 10th rightward, we see that at 5:14 p.m. Mercury sets, so it is out of view tonight. But Saturn transits the meridian at 5:15 p.m., meaning it is due south and highest in the sky. It will be a fine telescopic target when the sky gets a little darker.

At 6:20 the brightest nighttime star, Sirius, rises in the southeast. Then the dashed line at 6:30 p.m. tells when evening twilight technically ends. This is when the Sun is 18° below the horizon and the sky becomes fully dark.

The bright planet Jupiter rises at 7:41 p.m., and just to the right of its pink line, near 7:46, is a tiny Moon symbol. The legend at the chart's bottom indicates the Moon is at waxing crescent phase.

At 7:47 Polaris, the North Star, reaches upper culmination. It then stands directly above the north celestial pole (by 38′ or r37′ this year), a good time to check the polar alignment of an equatorial telescope mount.

The famous Pleiades star cluster in Taurus transits at 8:27, followed by the Orion Nebula (Messier 42) at 10:15 p.m. The transit times of such celestial landmarks help us keep track of the westward march of the constellations.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 10–11 this is $7^h\ 22^m$. To find the sidereal time at any other time and date on the chart, locate that point and lay a ruler through it parallel to the white event lines of stars. See where your ruler intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 10th the Sun runs slow, transiting at 12:08 p.m. This deviation, important for reading a sundial, is caused by the tilt of the Earth's axis and the ellipticity of its orbit.

The transits of Jupiter (2:30 a.m.) and Mars (3:31) are the best times for telescopic study. As the wee hours continue Antares, a star we normally associate with a later season, rises at 4:43.

The first hint of dawn — start of morning twilight — comes at 5:45. The Sun finally peeks above the horizon at 7:21 a.m. on January 11th.

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are indicated by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest in the sky, not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* necessarily the line for mid-

night). Opposition is marked there by a ☍ symbol, as for Jupiter on the night of February 10–11.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk with surface features whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark their dates of greatest illuminated extent in square arcseconds. For example, this occurs for Mercury on the evening of January 29th this year. (Venus doesn't reach greatest extent in 2027.)

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant is highest in the night sky. This is often just as morning twilight begins.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2461, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 406 to the date. For instance, on the evening of January 10th we have 10 + 406 = 416, so the Julian Day is 2,461,416. For North American observers this number applies all night, because the next Julian Day always begins at 12:00 Universal Time (6:00 a.m. Central Standard Time).

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at longitude 90° west and latitude 40° north, near the population center of North America. However, you need not live near Peoria, Illinois, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
50°	0	7	14	23	32	43
45°	0	3	7	10	14	19
40°	0	0	0	0	0	0
35°	0	3	6	9	12	16
30°	0	5	11	16	23	30
25°	0	8	16	24	32	42

To convert the charted time of an event to your civil (clock) time, the following corrections must be made. They are mentioned in order of decreasing importance:

• **Daylight-saving time.** When this is in effect, add one hour to any time obtained from the chart.

• **Your longitude.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in North America are Eastern Time, 75°W; Central, 90°; Mountain, 105°; and Pacific, 120°. If your longitude is very close to one of these (as is true for New Orleans and Denver), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Washington, DC (longitude 77°), is 2° west of the Eastern Time meridian. So at Washington, add 8 minutes to any time obtained from the chart. The result is Eastern Standard Time.

Find your time adjustment and memorize it. The table below left shows the corrections from local mean to standard time, in minutes, for some major cities.

• **Rising and setting.** These times need correction if your latitude differs from 40° north. This effect depends strongly on a star or planet's declination. (The declinations of the Sun and planets are listed monthly on the Planetary Almanac page of *Sky & Telescope*.)

If your site is *north* of latitude 40°, then an object with a north declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), whereas one with a south declination spends less time above the horizon. At a site *south* of 40°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion affects lunar rising and setting times if your longitude differs from 90° west. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Central Time, and two minutes later for each time zone west of it. European observers can simply shift each rising or setting Moon symbol leftward a quarter of the way toward the one for the previous night.

Local Mean Time Corrections

Atlanta	+38	Los Angeles	–7
Boise	+45	Memphis	0
Boston	–16	Miami	+21
Buffalo	+15	Minneapolis	+13
Chicago	–10	New Orleans	0
Cleveland	+27	New York	–4
Dallas	+27	Philadelphia	+1
Denver	0	Phoenix	+28
Detroit	+32	Pittsburgh	+20
El Paso	+6	St. Louis	+1
Helena	+28	Salt Lake City	+28
Honolulu	+31	San Francisco	+10
Houston	+21	Santa Fe	+4
Indianapolis	+44	Seattle	+9
Jacksonville	+27	Tulsa	+24
Kansas City	+18	Washington	+8
Athens	+25	Lisbon	+36
Baghdad	+3	Madrid	+75
Beijing	+14	New Delhi	+21
Belgrade	–22	Rome	+10
Cairo	–8	Seoul	+32
Istanbul	+4	Tehran	+4
Jerusalem	–21	Tokyo	–19

For reprints (item SGA27W) or to order a similar chart for latitude 50° north or 30° south, go to: shopatsky.com/collections/maps-globes/almanacs

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SKY & TELESCOPE

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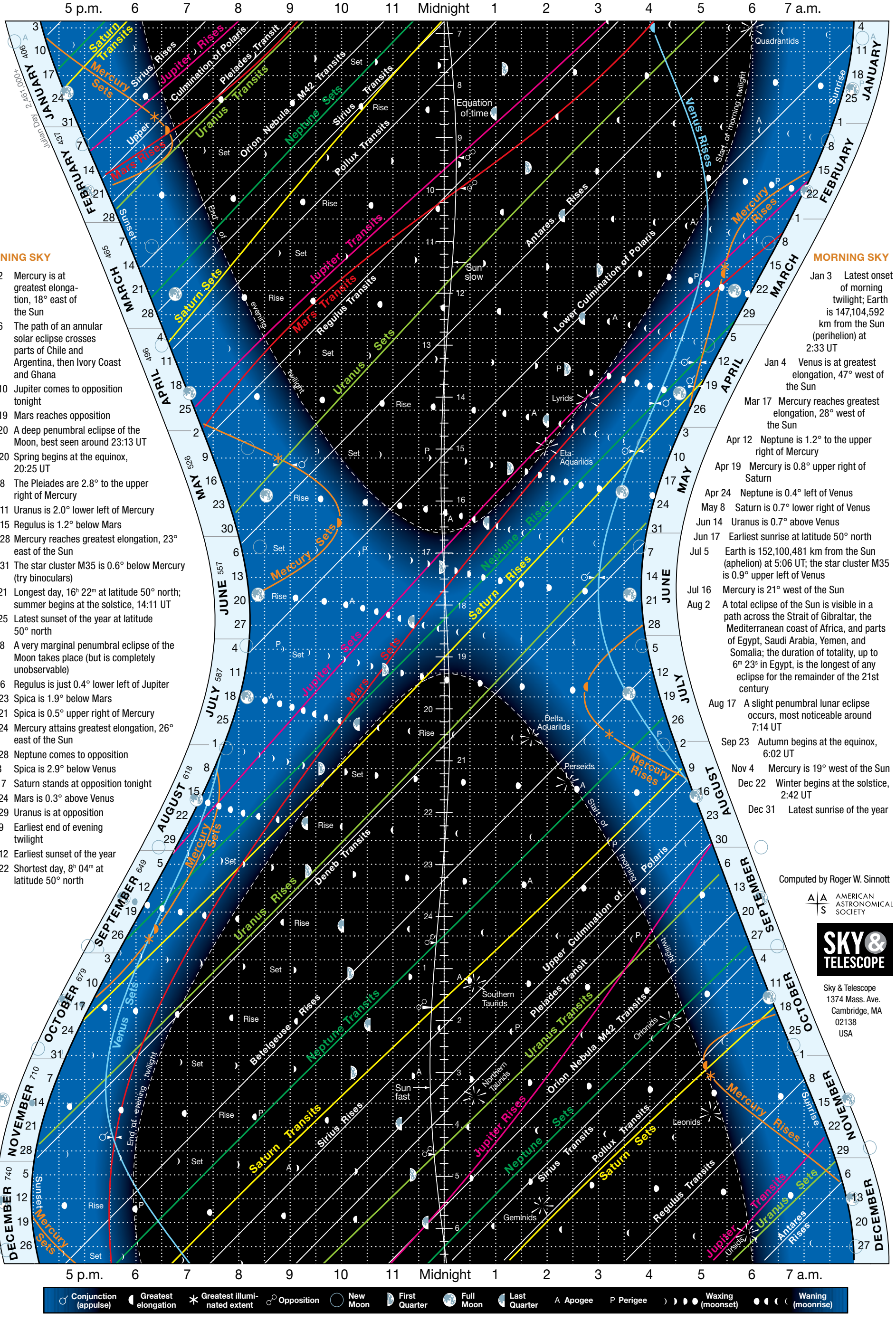
Skygazer's Almanac 50°N 2027

FOR LATITUDES NEAR 50° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



EVENING SKY

- Feb 2 Mercury is at greatest elongation, 18° east of the Sun
- Feb 6 The path of an annular solar eclipse crosses parts of Chile and Argentina, then Ivory Coast and Ghana
- Feb 10 Jupiter comes to opposition tonight
- Feb 19 Mars reaches opposition
- Feb 20 A deep penumbral eclipse of the Moon, best seen around 23:13 UT
- Mar 20 Spring begins at the equinox, 20:25 UT
- May 8 The Pleiades are 2.8° to the upper right of Mercury
- May 11 Uranus is 2.0° lower left of Mercury
- May 15 Regulus is 1.2° below Mars
- May 28 Mercury reaches greatest elongation, 23° east of the Sun
- May 31 The star cluster M35 is 0.6° below Mercury (try binoculars)
- Jun 21 Longest day, 16^{h} 22^{m} at latitude 50° north; summer begins at the solstice, 14:11 UT
- Jun 25 Latest sunset of the year at latitude 50° north
- Jul 18 A very marginal penumbral eclipse of the Moon takes place (but is completely unobservable)
- Jul 26 Regulus is just 0.4° lower left of Jupiter
- Aug 23 Spica is 1.9° below Mars
- Sep 21 Spica is 0.5° upper right of Mercury
- Sep 24 Mercury attains greatest elongation, 26° east of the Sun
- Sep 28 Neptune comes to opposition
- Oct 3 Spica is 2.9° below Venus
- Oct 17 Saturn stands at opposition tonight
- Nov 24 Mars is 0.3° above Venus
- Nov 29 Uranus is at opposition
- Dec 9 Earliest end of evening twilight
- Dec 12 Earliest sunset of the year
- Dec 22 Shortest day, 8^{h} 04^{m} at latitude 50° north

MORNING SKY

- Jan 3 Latest onset of morning twilight; Earth is 147,104,592 km from the Sun (perihelion) at 2:33 UT
- Jan 4 Venus is at greatest elongation, 47° west of the Sun
- Mar 17 Mercury reaches greatest elongation, 28° west of the Sun
- Apr 12 Neptune is 1.2° to the upper right of Mercury
- Apr 19 Mercury is 0.8° upper right of Saturn
- Apr 24 Neptune is 0.4° left of Venus
- May 8 Saturn is 0.7° lower right of Venus
- Jun 14 Uranus is 0.7° above Venus
- Jun 17 Earliest sunrise at latitude 50° north
- Jul 5 Earth is 152,100,481 km from the Sun (aphelion) at 5:06 UT; the star cluster M35 is 0.9° upper left of Venus
- Jul 16 Mercury is 21° west of the Sun
- Aug 2 A total eclipse of the Sun is visible in a path across the Strait of Gibraltar, the Mediterranean coast of Africa, and parts of Egypt, Saudi Arabia, Yemen, and Somalia; the duration of totality, up to 6^{m} 23^{s} in Egypt, is the longest of any eclipse for the remainder of the 21st century
- Aug 17 A slight penumbral lunar eclipse occurs, most noticeable around 7:14 UT
- Sep 23 Autumn begins at the equinox, 6:02 UT
- Nov 4 Mercury is 19° west of the Sun
- Dec 22 Winter begins at the solstice, 2:42 UT
- Dec 31 Latest sunrise of the year

Computed by Roger W. Sinnott

AMERICAN ASTRONOMICAL SOCIETY

SKY & TELESCOPE

Sky & Telescope
1374 Mass. Ave.
Cambridge, MA
02138
USA

Skygazer's Almanac 50°N 2027

FOR LATITUDES NEAR 50° NORTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2027*, a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 50° north — in the United Kingdom, northern Europe, Canada, and Russia.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 10, 2027.

First find "January" and "10" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 10–11 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 10–11 begins at the black curve at left, which represents the time of sunset. Reading up to the top of the chart, we can estimate that sunset on January 10th occurs at 4:19 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Continuing rightward on the dotted line for the 10th, we see that Mercury sets at 4:35 p.m., too soon after sunset to be observed. But Saturn transits at 5:16, meaning it is then due south and highest in the sky. It will be very well placed for telescopic viewing all evening.

A dashed line at 6:16 marks the end of evening twilight, the time when the Sun is 18° below the horizon and the sky is fully dark. Then at 6:46, the brightest nighttime star, Sirius, rises.

Notice the tiny crescent Moon symbol near 7:08. The legend at the chart's bottom tells us the Moon is at waxing crescent phase, and setting.

Polaris, the North Star, reaches upper culmination at 7:48 p.m. This is when Polaris stands directly above the north celestial pole (by 38′ or 37′ this year), a good opportunity to check the polar alignment of a telescope mount.

The Red Planet Mars rises at 8:35 p.m., so we must wait until the predawn hours for it to become well placed for viewing.

Other events on our dotted line include transits of Taurus's Pleiades star cluster at 8:28 and the Orion Nebula (Messier 42) at 10:16. Transit times of such celestial landmarks help us follow the constellations across the sky.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 10–11 this is $7^h\ 21^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then lay a ruler through it parallel to the white event lines of stars. See where your ruler intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 10th the Sun runs slow, transiting at 12:07 p.m. This deviation, important for reading a sundial, is caused by the tilt of the Earth's axis and the ellipticity of its orbit.

In the wee hours before dawn, Jupiter reaches the meridian at 2:32 a.m. and Mars at 3:32. Venus joins them in the sky, rising at 4:14. Then at 5:30 Antares, a star we usually associate with later seasons of the year, rises in the southeast.

The first hint of dawn — the start of morning twilight — comes at 5:59. The

Local Mean Time Corrections

Amsterdam	+40	Manchester	+8
Belfast	+24	Montreal	–6
Berlin	+6	Moscow	+26
Bordeaux	+62	Munich	+14
Bremen	+24	Oslo	+17
Brussels	+44	Ottawa	+3
Bucharest	+16	Paris	+51
Budapest	–16	Prague	+2
Calgary	+36	Quebec	–15
Copenhagen	+10	Regina	+58
Dublin	+25	Reykjavík	+88
Geneva	+35	St. John's	+1
Glasgow	+16	Stockholm	–12
Halifax	+14	Toronto	+18
Hamburg	+20	Vancouver	+12
Helsinki	+20	Vienna	–5
Kyiv	–2	Warsaw	–24
London	0	Winnipeg	+29
Lyon	+41	Zurich	+24

Sun finally peeks above the eastern horizon at 7:56 a.m. on Monday morning, January 11th.

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

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Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark the dates when their disks in telescopes show the greatest illuminated extent in square arcseconds. For example, this is true for Mercury on the evening of January 29th. (Venus does not reach greatest extent in 2027.)

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Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2461, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 406 to the date. For instance, on the evening of January 10th we have 10 + 406 = 416, so the Julian Day is 2,461,416. For European observers this number applies all night long, because the next Julian Day always begins at 12:00 Universal Time (noon Greenwich Mean Time).

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
60°	1	11	23	36	53	80
55°	0	5	10	16	23	32
50°	0	0	0	0	0	0
45°	0	4	8	13	18	24
40°	1	8	15	23	32	43
35°	1	10	20	31	44	68
30°	1	12	25	39	54	72
25°	1	15	30	46	64	84

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at longitude 0° and latitude 50° north, a reasonable compromise for the countries of northern and central Europe. However, you need not be on a boat in the English Channel to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in order of decreasing importance:

• **Daylight-saving time (or "summer time").** When this is in effect, add one hour to any time that you obtain from the chart.

• **Your longitude.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Europe are Greenwich Mean Time (or Universal Time), 0°; Central European Time, 15°E; and Eastern European Time, 30°E. If your longitude is very close to one of these (as is true for London), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Copenhagen (longitude 12.5° east) is 2.5° west of the Central European Time meridian. So at Copenhagen, add 10 minutes to any time obtained from the chart. The result is Central European Standard Time.

Find your local-time correction and memorize it. In the table below at left are the corrections from local to standard time, in minutes, for some major cities.

• **Rising and setting.** Times of rising and setting need correction if your latitude differs from 50° north. This effect depends strongly on a star or planet's declination. (The declinations of the Sun and planets are listed in *Sky & Telescope*.)

If your site is north of latitude 50°, then an object with a north declination stays above the horizon longer than the chart shows (it rises earlier and sets later), while one with a south declination spends less time above the horizon. At a site south of 50°, the effect is just the reverse. Keeping these rules in mind, you can gauge roughly the number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 0°. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Greenwich Mean Time, and two minutes later for each time zone west.

For reprints (item SGA27E) or to order a similar chart for latitude 40° north or 30° south, go to: shopatsky.com/collections/maps-globes/almanacs

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