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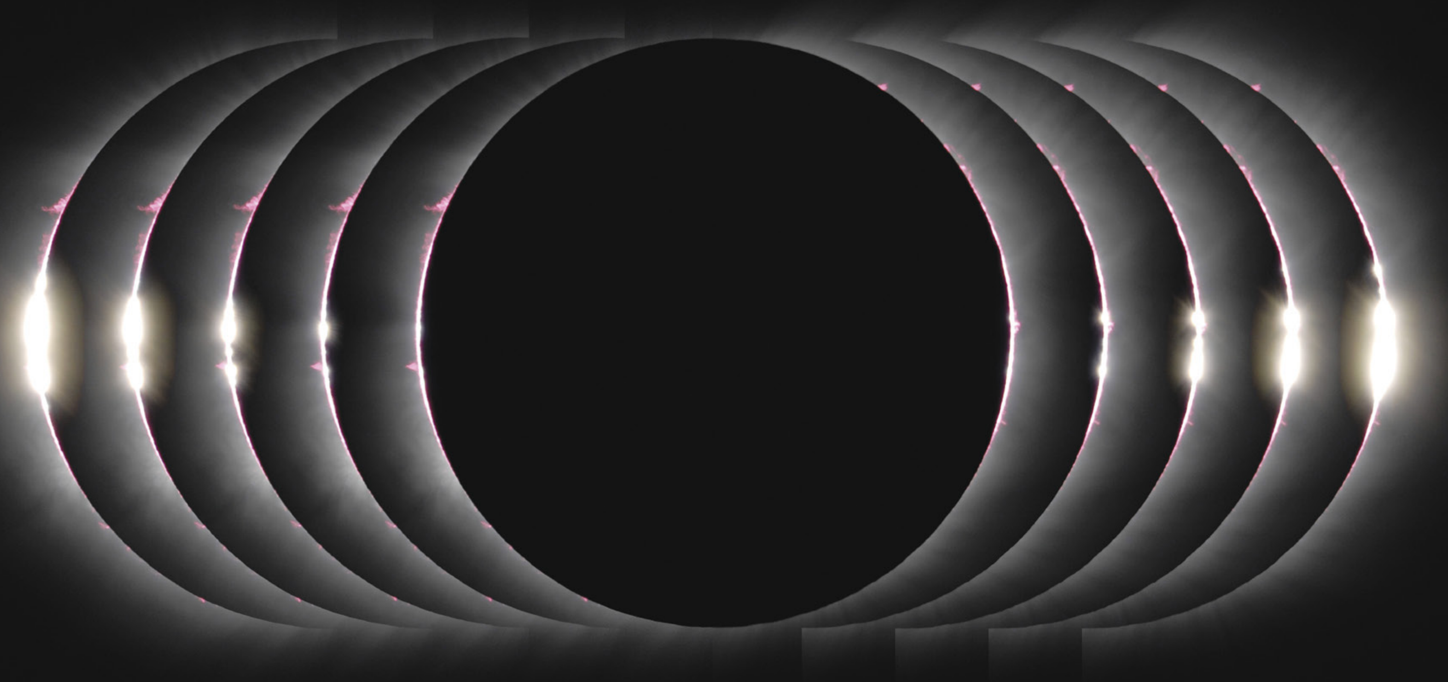
SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

JANUARY 2024

Totality in 2024



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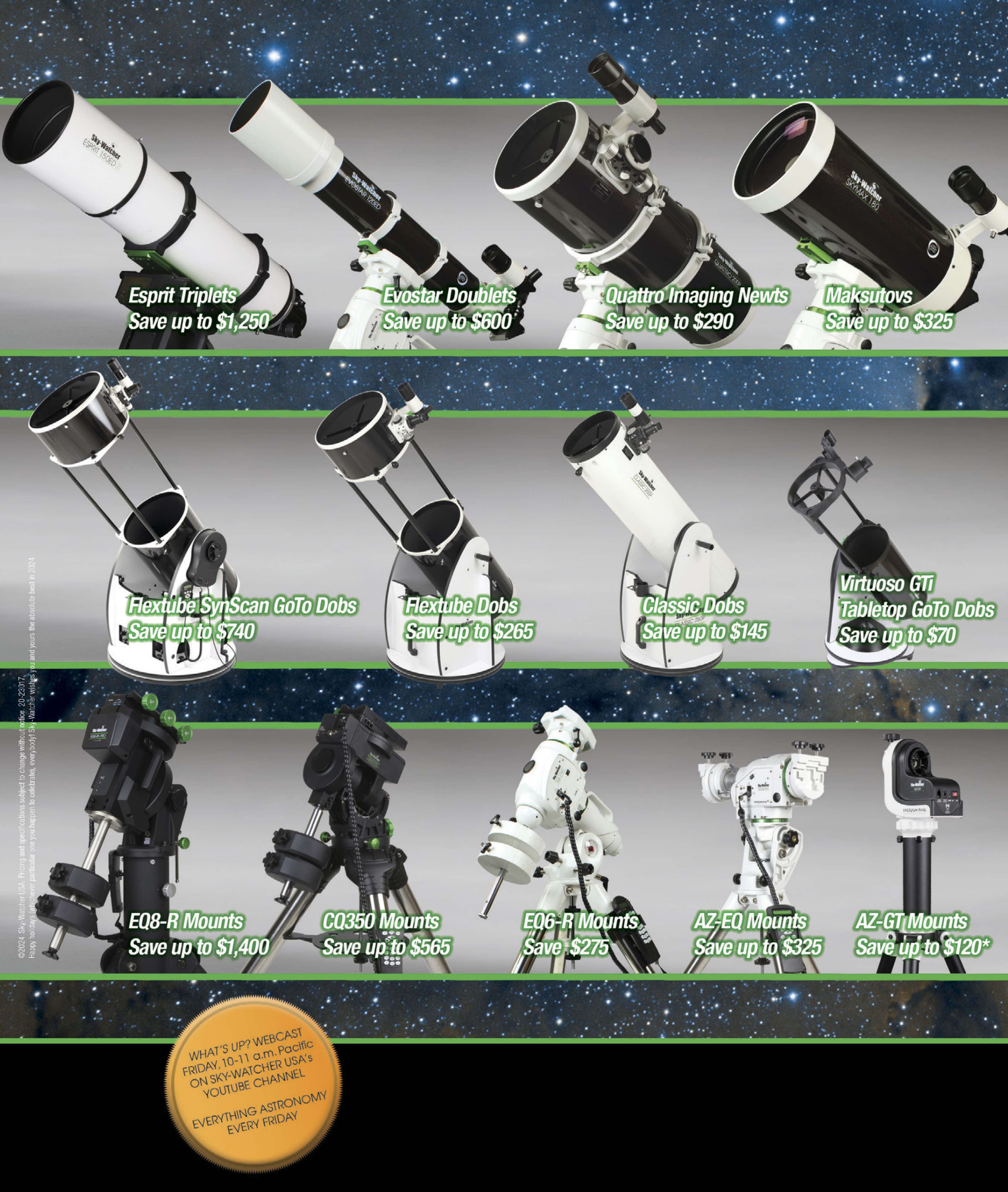

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PROMO PALOOZA!

SKY-WATCHER IS ROLLING OUT SPECIALS ALL THROUGH NOVEMBER ON ALL OF YOUR FAVORITE GEAR

At Sky-Watcher we're gearing up for all of the holidays** by putting our gear on sale to make your life a little easier for the season. And just so it won't be too overwhelming, we're easing out our sales over November, starting with:

November 6 - Sky-Watcher Optical Tubes
From our flagship Esprit Super Apo triplets to our Evostar and Evolux doublets to our industry-leading Maksutov and Newtonian reflectors, you can save up to 30%* on our optical tubes. Whether you're an imager or a visual enthusiast, you're practically guaranteed to find the right fit and price.

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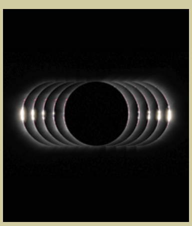

Image sequence from the March 2006 total solar eclipse
CREDIT: FRED ESPENAK

ONLINE

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Helping Hands

AT *S&T*, we rely to the nth degree on our contributing editors, those writers who aren't on staff but pen many of our stories. In this issue alone, they've written two of the five feature articles and eight of the columns. This month we've had some changes regarding this deeply valued group that I'd like to share with you.

First, a huge thank you to Fred Schaaf for all his years as an *S&T* columnist. For 31 years, beginning in 1993 with Stars & Planets, he wrote various observing columns, among them Guide to the Evening Sky (1997–2004); Sun, Moon & Planets (2004–2020); and Northern Hemisphere's Sky (2004–2016). That last one morphed first into Under the Stars in 2017 and then into Evenings with the Stars, which wrapped up last month. All told, since his first contribution to *S&T* in 1977, Fred has authored more than 860 articles for the magazine.

With this issue, three new names appear on the contributing editors list at right. First, we're extremely pleased to welcome back Stephen James O'Meara. Steve began working for *S&T* in 1979 and was a staff editor through 1995 and then a contributing editor until 2007. As many *S&T* readers know, Steve is one of the most talented visual observers out there, with several major "firsts." One of those was determining Uranus's rotational period, which Contributing Editor Tom Dobbins deems "perhaps the last great planetary discovery by a visual observer" (see page 53). Starting with this issue, Steve offers a new monthly column on naked-eye stargazing entitled Stories in the Stars (page 45).

We also welcome Scott Harrington, whose Focal Point appears on page 84. A talented young amateur astronomer, Scott has produced multiple observing articles for us, from "Star-Forming Regions in Faraway Galaxies" (*S&T:* May 2021, p. 22) to December's Going Deep, "IC 10 — The Hidden Dwarf."

Finally, we welcome Jonathan Nally. Jonathan was editor in chief of *Australian Sky & Telescope*, our sister magazine Down Under, which sadly ceased publication in recent months. He now joins us with a monthly Southern Hemisphere sky chart and observing notes on page 44. (Planetary Almanac moves to page 54.) Jonathan will also soon launch a monthly online column on Southern Hemisphere observing — watch our website for further details.

David Grinspoon, as you'll know if you read his most recent column in November, has paused Cosmic Relief, which we've run since 2009. We hope David can resume writing for us in the future, but for now he's too busy with his new position as NASA's new Senior Scientist for Astrobiology Strategy.

Lastly, a shout-out to Senior Contributing Editor Roger Sinnott, the mastermind behind the 2024 Skygazer's Almanac that comes bundled with this issue.

In short, we simply couldn't do without our contributing editors. A final collective thanks to all 32 of them.

Peter

Editor in Chief

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Williamina Fleming discovered IC 418 in 1891.

Following in Fleming's Footsteps

Thank you for Steve Gottlieb's "Williamina Fleming's Deep-Sky Discoveries" (*S&T:* Aug. 2023, p. 20). I began reading thinking it was a historical astronomy article only to realize it was a twofer that combined history with an observing piece. Very nice. And very topical for me since I recently completed the Astronomical League's Planetary Nebula Observing Program list. Searching for these tiny fuzzies really ramped up my observing skills like star-hopping and the use of filters. As difficult as it is to observe these small objects, it must have been tedious work for Fleming to sort through the plates and spectra of more than 10,000 stars while working for low pay and almost no recognition. To me, they will always be known as Fleming's Hydrogen Star and Fleming's Triangular Wisp.

Loren Reimers • Springfield, Oregon

Early-Morning Observing

Thanks for reviving my interest in astronomy with the September issue. In searching for the Moon at the swimming pool in the early-morning hours, I also saw Jupiter for the first time in several years. I've been an amateur astronomer for many years, but I was sidetracked by moving and hurricanes. It was like seeing an old friend. And I had my daybreak swim while watching the Moon and the sunrise. I can't drive at night now, but I never thought about dawn viewing before. Now I can just walk downstairs to the pool and see the sky sights, too!

Alice Mack
Fort Myers, Florida

A Career in Planetary Exploration

David Grinspoon's "Long Time Coming" (*S&T:* Sep. 2023, p. 12) about the benefits of a long career in planetary exploration struck a chord with me. If you are lucky enough to work on a space mission in any role, you will join a creative team involved with spacecraft that return data from places we have never seen before. It never gets old.

When I arrived at the NASA Jet Propulsion Laboratory's Image Processing Lab in 1969 as a young computer engineer, the Mariner 6 and 7 spacecraft had just flown by Mars, returning closeup images of the planet.

When Mariner 9 orbited Mars, we developed the software used to produce the first photomosaic globe of Mars. In 1976, I led the team processing the first images ever taken on the surface of another planet for the Viking mission. Then came cascades of images from the two Voyagers and the Galileo and Cassini orbital missions to the outer planets. Twenty years after Viking, I drank from the fountain of youth, working on the Mars Pathfinder mission, again processing images from the surface of Mars.

Now retired from Caltech's Infrared Processing and Analysis Center, I'm on a NASA Review Board for the Near-Earth Object Surveyor mission. I enjoy watching folks I hired back in the day continuing to communicate the mysteries of the universe for all.

It has been a great ride, and I'd recommend considering a career in planetary exploration to anybody.

William Green
Reseda, California

Speeding Spiral

I enjoyed Ken Croswell's "Dawn of the Milky Way" (*S&T:* Aug. 2023, p. 34), but I have a few questions.

First, he discusses evidence for an increase in the galaxy rotation speed from 40 km/s to 140 km/s, but he doesn't provide any explanation or state that astrophysicists are still searching for an explanation. Was this increase due to a transfer of angular momentum from galaxies that collided with the Milky Way? Was it due to the movement of baryonic matter and/or dark matter toward its rotational axis?

Second, I'm confused by the two graphs on pages 39 and 40. Both graphs have similar variables, but the plotted points are different, and there is no explanation for this difference. The graph on page 40 includes lower iron abundances and higher alpha-to-iron ratios. Also, does the red line on the graph on page 39 separate stars in the thin disk from stars in the thick disk? And what do the colors on the graph on page 39 represent?

Dan Crowe
Sterling, Virginia

X-RAY: NASA / CXC / SAO; OPTICAL: NASA / ESA / AURA / STSCI

Monica Young replies: *Regarding the spin-up: The author did not want to go into an attempted explanation of the past spin-up of the Milky Way because there are a few competing scenarios, with no good evidence for any of them as of yet. In fact, it could be as simple as several blobs coming together with a net angular momentum in one direction or the other, but it's difficult to find the "archaeological" evidence to back this up. However, the author did want to mention that the Milky Way sped up, because it's spinning fast today and so must have spun up at some point in its past.*

Regarding the plots, I agree that we should have given a better description for the populations of stars being plotted. The second graph is showing a selection of stars from the first one. The plot on page 39 shows stars from across the Milky Way, including some in the thin disk and some in the thick disk. The red line separates points that are "high-alpha" (thick disk) from those that are "low-alpha" (thin disk). The color represents the density of stars. The plot on page 40 shows a selection of those stars with high alpha-to-iron ratios, signifying that they are in the thick disk.

Carving Pillars in Space

I have been wondering about something for quite some time. Photos of dust and gas pillars appear to be spreading from a point source, similar to the way smoke rises from a fire. While I know there is no "up" in space, it still appears to me that the gas and dust is rising from some point to form the columns. What drives this phenomenon? Why is it forming the columns and not just spreading evenly?

Dennis Dibala
Wallis, Texas

Monica Young replies: *These photos of pillars in space are interestingly misleading. In reality, these dust and gas clouds started out roughly spherical (or ovoid) in shape and were then eroded away by the intense ultraviolet radiation and stellar winds that come from newborn stars. The denser middles take longer to dissipate, hence the pillar-like shapes. So rather than thinking of the pillars as rising from somewhere, you might instead think of them as forms that are being sculpted out of what was initially a much larger cloud.*

FOR THE RECORD

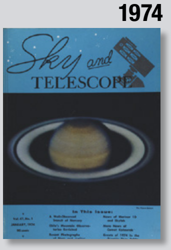
- "A Planetary Imaging Primer" (*S&T:* Nov. 2023, p. 28) erroneously implies that water vapor produces atmospheric dispersion. In fact, all the elements within our atmosphere contribute to atmospheric dispersion.
- "Raising the Bar" (*S&T:* July 2023, p. 74) and "Howdy, Neighbor" (*S&T:* Sep. 2023, p. 79) were created using data from Telescope Live.

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

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

1949

1974



1999

January 1949

Big Eye "Dr. Ira S. Bowen, director of Mount Wilson and Palomar Observatories, has announced that the 200-inch telescope might not be in working order until next fall. In figuring the mirror, a zone 18 inches wide at the edge was allowed to remain 20 millionths of an inch too high, and the support system has not been able to introduce the desired correction of the figure. In addition, the edge of the mirror has been found to respond to temperature changes more quickly than the center. It is expected to install a set of small fans and to insulate the mirror's outer edge with aluminum foil. Thereafter, if the supports are still unable to correct the raised zone, the mirror will have to be taken out of the telescope for refiguring . . . Dr. Bowen pointed out that the 100-inch telescope on Mount Wilson did not work acceptably for a year and a half, and he is undiscouraged by this recent turn of events."

Aluminum foil, plus mild refiguring by optician Don Hendrix, did the trick. Regular observations with the 200-inch began in November 1949.

January 1974

Redshifts "Are the quasistellar radio sources really at the immense distances implied by their optically observed redshifts? Yes, say most astronomers, [but] the assumption would be unsafe if there existed a physically connected close pair of quasars whose components had very different redshifts. . . .

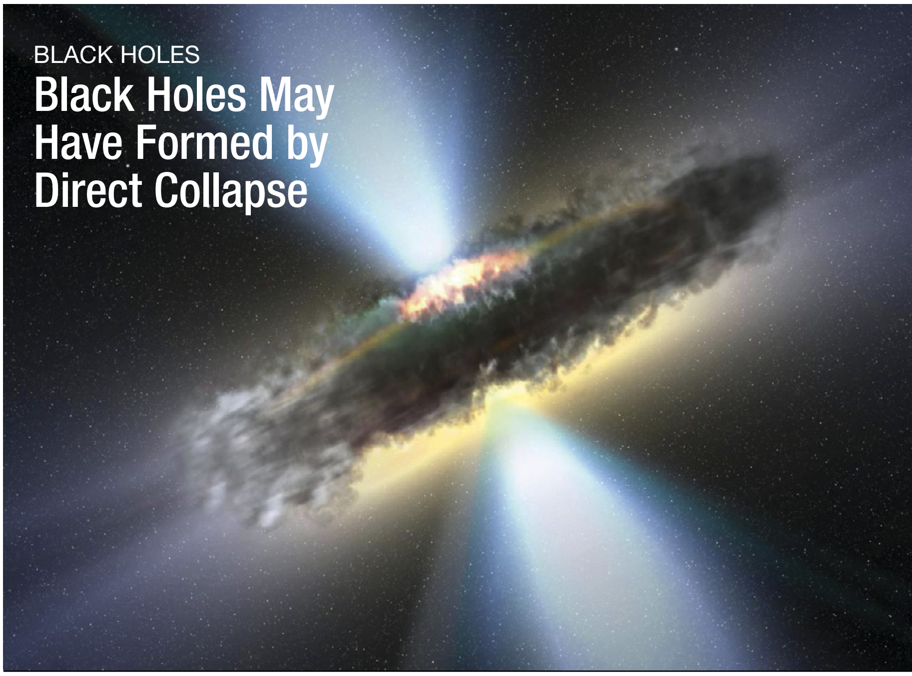
"The radio source 4C-11.50 in the constellation Serpens [is one such pair] separated by only five seconds of arc. At Lick Observatory, both components were studied with the 120-inch reflector by E. J. Wampler and his collaborators. . . . The redshifts for the brighter and fainter members of the pair are very unequal: $z = 0.4359$ and 1.901, respectively. [They write,] 'We believe that these observations add support to noncosmological theories of redshifts.'"

Back then, some astronomers still wondered if quasars' extreme redshifts were artifacts of antimatter, gravitational wells, or even wormholes — but not anymore.

January 1999

Andromeda Galaxy "The census of our galactic neighborhood has just grown a bit more complete with the discovery of another satellite galaxy to M31. Designated Andromeda V, this very dim, dwarf spheroidal galaxy is 8° northeast of M31 at roughly the same distance from Earth (2.6 million light-years). . . . Taft E. Armandroff, James E. Davies, and George H. Jacoby (Kitt Peak National Observatory) found the object in September 1997 by digitally enhancing the Second Palomar Observatory Sky Survey plates [and confirmed it] with Kitt Peak's 4-meter reflector in Arizona, which resolved the galaxy into individual stars . . ."

The list of M31's satellites, mostly dwarf spheroidal galaxies, has now reached Andromeda XXXIII.



BLACK HOLES

Black Holes May Have Formed by Direct Collapse

ASTRONOMERS HAVE SPOTTED a supermassive black hole in the early universe that might have formed in the implosion of a gargantuan gas cloud.

The black hole's host galaxy, UHZ1, was spotted in James Webb Space Telescope (JWST) observations of galaxies in the early universe. Ákos Bogdán (Center for Astrophysics, Harvard & Smithsonian) and others followed up on these galaxies using the Chandra X-ray Observatory. One of the galaxies, appearing to us from a mere 460 million years into cosmic history (at a redshift of 10.3), boasts the classic X-ray signature of a gigantic black hole shrouded in gas. Based on the Chandra

◀ This artist's impression shows a supermassive black hole girthed by dusty gas. The origins of these objects are still under debate.

SOLAR SYSTEM

Osiris-REX Completes Sample Return from Asteroid Bennu

AFTER A JOURNEY of seven years and 7.1 billion kilometers (4.4 billion miles), NASA's Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer (Osiris-REX) spacecraft has accomplished its primary mission: It has brought back material grabbed from the rubble-pile asteroid 101955 Bennu (*S&T:* Feb. 2021, p. 8).

On September 24th, four hours prior to touchdown, a coffee table–size capsule separated from the spacecraft while it was still more than 100,000 km away. The capsule came in hot at 12 kilometers per second (28,000 mph) over the U.S. Department of Defense's Utah Test and Training Range before landing at a gentler 18 km/hr (11 mph) at 8:52 a.m. local time. Teams sent in via helicopter searched a 58-by-14-km reentry area, and by 9:07 a.m., the team had located the sample. The accomplishment is NASA's first asteroid sample brought to Earth for study.

The samples next made their way to the Astromaterials Research & Exploration Science facility at NASA's Johnson Space Center for study, evaluation, and eventual sharing with international partners. Scientists will not only weigh the collected rocks but also begin detailed investigations into the solar system's early history.

With the capsule safely on the ground, the mothership now has an encore mission, with a new name: Osiris-APEX. The spacecraft is headed toward the near-Earth asteroid 99942 Apophis. It should reach the asteroid in 2029, just before the asteroid swings by Earth in a close approach.

■ DAVID DICKINSON

▲ The just-arrived capsule from Osiris-REX, with a sample of asteroid Bennu inside, awaits recovery on the Department of Defense's Utah Test and Training Range.

IN BRIEF

Asteroid Bennu Has Layers

The asteroid 101955 Bennu is a so-called "rubble pile," but close-up observations show it is far from a random accumulation. Scientists analyzing data from NASA's Osiris-REX report evidence in the December *Icarus* that underneath Bennu's rough surface, there's an inner shell of finer particles that's 1–4 meters (3–14 feet) thick. The first clue came from the spacecraft's high-resolution images of the asteroid, which revealed a texture contrast between smaller and larger craters. Additional data from other Osiris-REX instruments confirmed the difference. Edward B. Bierhaus (Lockheed Martin Space) and colleagues conclude that the asteroid has a subsurface layer of particles finer than those on the surface. Microimpacts may serve to shake smaller grains down between larger surface rocks. These findings will help provide context for the sample recently acquired from Bennu's surface.

■ JEFF HECHT

ARTIST'S CONCEPT OF DIRECT-COLLAPSE BLACK HOLE: ESA / V. BECKMANN (NASA GSFC); LANDING PHOTO OF CAPSULE: NASA / KEEGAN BARBER data, the astronomers think the black hole has a mass somewhere around 40 million Suns.

Meanwhile, the galaxy itself, while fairly normal compared with its peers at that time, has a mass of some 100 million Suns. That puts the galaxy on a level with the black hole it holds — in stark contrast with the modern universe, where black holes are usually 0.1% as massive as their host galaxies.

This too-big-for-its-galactic-britches black hole has the team excited — in fact, they set out hoping to find exactly this kind of object.

Astronomers debate how the first supermassive black holes formed (*S&T:* Jan. 2017, p. 25). In one scenario, stars collapsed, then grew at a breakneck pace by scarfing down gas and slamming into one another. In another, big, pristine clouds of gas collapsed more or less directly into black holes of tens of thousands of solar masses. They then kept growing at a less hasty pace.

However, the direct-collapse scenario suffers from a fragile convergence of factors. The gas can't be contaminated by heavy elements made by stars, yet it has to be heated by nearby stars so that it doesn't collapse too early. One solution is that the black hole forms in a satellite next to a protogalaxy brimming with young suns.

Priyamvada Natarajan (Yale) and others had previously predicted that the satellite cloud holding the direct-collapse black hole would merge with the larger galaxy soon after the black hole's formation, creating an over-massive black-hole galaxy, or OBG. In this scenario, the black hole's mass would roughly match that of the new host galaxy. These objects should exist between 350 and 550 million years after the Big Bang — smack-dab when UHZ1 is.

Bogdán, Natarajan, and Andy Goulding (Princeton) and collaborators make the case that UHZ1 is an OBG hosting a direct-collapse black hole in three studies posted to the arXiv preprint server.

Xiaohui Fan (University of Arizona), who was not involved in the trio of papers, thinks this and similar results are among the most exciting finds from JWST. If follow-up X-ray observations confirm this black hole's mass, then the direct-collapse scenario would be a "very natural explanation."

■ **CAMILLE M. CARLISLE**

COSMOLOGY

Galaxies Outline Bubble 1 Billion Light-Years Wide in Space

ASTRONOMERS MAPPING precise galactic distances have found thousands of galaxies outlining a spherical shell that spans 1 billion light-years.

Given the name Hoʻoleilana ("sent murmurs of awakening"), the structure lies about 820 million light-years away, well outside the Laniakea Supercluster that encompasses the Milky Way Galaxy as well as the Local Group that we're part of (*S&T:* Dec. 2014, p. 16).

R. Brent Tully (University of Hawaii) and colleagues happened on the structure while mapping 55,877 galaxies in the local universe as part of a project known as Cosmicflows-4. The structure had been previously discovered by Maret Einasto (University of Tartu, Estonia) and colleagues in 2016, as reported in *Astronomy & Astrophysics*, but now Tully's team proposes a unique origin in the Sept. 10th *Astrophysical Journal*.

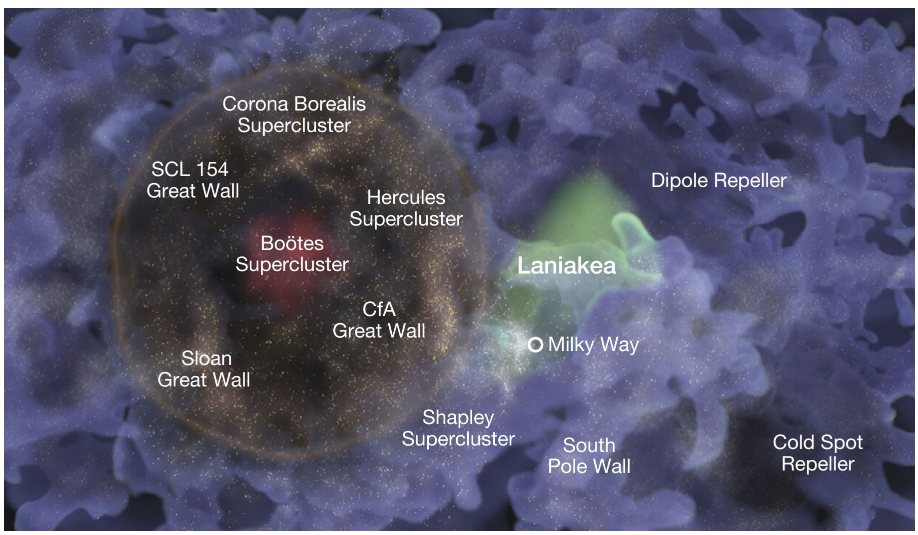
It's possible the sphere-shape collection of galaxies came together due to the gravitational mingling of matter. However, Tully and colleagues suggest instead that this spherical structure might be the echo of huge sound waves that sloshed around the early universe.

Known as *baryon acoustic oscillations* (BAO), these waves permeated the plasma that filled the early universe. Eventually, ions and electrons combined to form neutral gas, but the effect of the sloshing remained, imprinting itself on the large-scale spread of galaxies. Tully's team thinks that Hoʻoleilana might be a single ripple, frozen in space.

Some disagree, arguing that BAO ripples would have overlapped, making a single one difficult to distinguish. Previous studies have only found evidence of BAOs on a statistical basis, by studying huge populations of galaxies.

The only way to discern a single such ripple, Tully and colleagues argue, is if the mass at the center of the ripple (in this case, the Boötes Supercluster) were exceptionally dense. The BAO scenario could be tested by "weighing" this supercluster to see if it contains enough mass to engender a ripple of its own.

■ **MONICA YOUNG**



▲ This artist's concept shows the giant spherical shell named Hoʻoleilana (orange), with individual galaxies depicted as luminous specks. The Milky Way is within the green region at right, while the distribution of background galaxies in the cosmic web is shown in purple.

FRÉDÉRIC DURILLON (ANIMEA STUDIO) / DANIEL POMARÈDE (IRFU / CEA UNIVERSITY PARIS-SACLAY)

COSMOLOGY

Data Reveal Dark Matter Clumps Between Galaxies

A TEAM OF JAPANESE astronomers has mapped the distribution of dark matter on an unprecedentedly small scale. Their findings back up the idea that dark matter particles are "cold," that is, slow-moving with respect to the speed of light.

The team, led by Kaiki Taro Inoue (Kindai University, Japan), has made inroads by using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile to observe radio waves that left a distant quasar 11 billion years ago. The team's findings are published in the September 10th *Astrophysical Journal*.

The gravity of a massive foreground galaxy bends the quasar's light as it passes by, creating four separate images of the quasar in an effect known as *gravitational lensing*. However, the positions and shapes of the quartet of images don't match up with predictions based on the gravitational pull of the foreground galaxy alone.

Based on the precision of the new ALMA observations, the team concluded that additional dark matter clumps in intergalactic space further skew the quasar's light en route to Earth. The clumps are about 1.1 arcsecond across; if the clumps are near the foreground galaxy, that corresponds to 30,000 light-years across. These observations mark the first time that dark matter's distribution has been mapped on such a small scale.

The gravitational lensing effect due to the line-of-sight structures is consistent with cold dark matter models, the researchers say, indicating that dark matter particles are heavy and slow-moving (as opposed to lighter and speedier particles such as neutrinos).

"The work appears to be very thorough," says Kyle Oman (Durham University, UK), who was not involved in the research. "It adds a little bit more weight to an already well-established cosmological model."

At the same time, the data are also consistent with the alternative idea of modified gravity. In this scenario, rather than rely on the effects of mysterious dark matter, gravity itself is variable. According to Hongsheng Zhao (University of St. Andrews, UK), who was also not involved in the research, the mismatched lensed quasar images "could also be explained by line-of-sight dwarf galaxies [and] modified gravity."

For their part, Inoue and his colleagues are currently making further observations in the hope of adding more data to their gravitational lensing model. This work — both present and future — could prove an important piece of the dark matter puzzle.

■ **COLIN STUART**

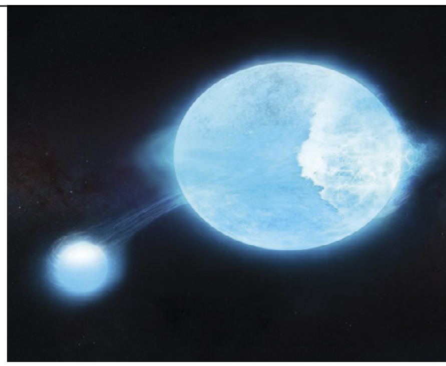
STARS

Surf's Up: Waves Might Be Breaking on This Star

HUMONGOUS WAVES of plasma might be breaking on the sloshing surface of a massive star. According to Morgan MacLeod and Abraham Loeb (both at Center for Astrophysics, Harvard & Smithsonian), these waves could reach heights of more than 4 million kilometers (2.5 million miles) before crashing back onto the blue giant star, releasing incredible amounts of tidal energy in the process.

The giant star has 35 times the Sun's mass and is located in the Large Magellanic Cloud. Identified as MACHO 80.7443.1718, it and its smaller companion brighten and dim again by 0.4 magnitude every 32.8 days. The pair is classified as a *heartbeat star*, an unusual type of binary system with highly elliptical orbits that raise enormous tidal deformations at closest approach.

However, MACHO 80.7443.1718 is an extreme example of that class. Its brightness variations are much larger



▲ This artist's impression shows a giant blue star and its smaller companion, whose close passes create changes in brightness that look like heartbeats.

MELISSA WEISS (CENTER FOR ASTROPHYSICS, HARVARD & SMITHSONIAN)

than in regular heartbeat systems; it rotates unusually fast (once every 4.4 days), which should in turn give the star a highly *oblate* shape (wider in the middle); and the orbital period is slowly decaying by 11 seconds per year.

MacLeod and Loeb carried out detailed 3D hydrodynamical computer simulations of the binary, published August 10th in *Nature Astronomy*. They show that during closest approach, the companion star raises huge tidal waves on the diluted surface of the blue giant. The waves, three times as high as the Sun's diameter, subsequently break like ocean waves on a beach before devolving into a sea foam-like turbulence.

When the waves crash down on the bigger star's surface, they accelerate its rotation, explaining its fast spin rate. Moreover, part of the foam ends up in an extended, tenuous atmosphere, which shows up in the star's spectrum as bright emission lines. The crashing waves dissipate energy at a rate 100 times higher than the Sun radiates — and that neatly matches that of the observed orbital decay.

Edward Guinan (Villanova University), who was not involved in what he calls an "intriguing study," cautions that the conclusions are mostly inferred from calculations and simulations. "There is really no 'hard' observational evidence for the proposed huge clashing waves," he notes. However, 20 similar systems offer opportunities for additional study of what MacLeod calls a "brief and transformative moment in a long stellar lifetime."

■ **GOVERT SCHILLING**

EXOPLANETS

Webb, Hubble Hint at Ocean Worlds

WITH RECENT OBSERVATIONS, astronomers have found signatures hinting at water-rich compositions for two planets between Earth and Neptune in size — but other scenarios can't be ruled out just yet.

By their average density, *sub-Neptunes* have compositions unlike rocky Earth but also unlike fluffy Neptune. These worlds could be made almost entirely of different phases of water, or they could just as easily be dense cores wrapped in thick blankets of hydrogen.

To distinguish between scenarios, astronomers can take a spectrum as a planet passes in front of its star. Molecules in the upper atmosphere absorb light, changing the planet's apparent size, at particular wavelengths.

Nikku Madhusudhan (University of Cambridge, UK) and colleagues announce in an upcoming issue of *Astrophysical Journal Letters* that James Webb Space Telescope spectra reveal methane and carbon dioxide in the upper atmosphere of K2-18b, a habitable-zone planet. (Starlight can't penetrate the atmosphere's depths, so the lower atmosphere is still beyond the reach of direct measurement.) But the researchers did not see ammonia, a molecule expected in thick atmospheres. Ammonia's nondetection permits the possibility of a global surface ocean under thin, hydrogen-rich air.

But Raymond Pierrehumbert (University of Oxford, UK), who was not involved in the study, isn't convinced. The absence, he says, might instead indicate an aspect of ammonia chemistry or atmospheric mixing that we still don't understand.

Elsewhere in the galaxy, the atmosphere of hotter and fluffier GJ 9827d shows signs of water vapor in observations taken by the Hubble Space Telescope. Publishing the data in the September 10th *Astrophysical Journal Letters*, Pierre-Alexis Roy, Björn Benneke (both at University of Montreal), and colleagues make the case that GJ 9827d is another candidate water world — albeit a steamy one.

The detection is uncertain, though, due to the limited range of wavelengths Hubble covers. In fact, in 2019, astronomers thought Hubble had spotted water vapor in K2-18b's upper atmosphere; however, Madhusudhan's analysis of JWST infrared data revealed that the signal actually came from methane; the same might be true for GJ 9827d. Additional JWST observations are already planned for both worlds as well as a few other sub-Neptunes.

"In the end, the main goal is not to find some methane, or to find some water vapor," Benneke says. "What we really want to do is to distinguish between those two scenarios . . . [that is] what Webb can eventually deliver."

■ ELISE CUTTS

See the Webb and Hubble spectra at https://is.gd/WaterWorlds.

▲ This artist's concept, based on science data, shows what exoplanet K2-18b could look like.

NASA / CSA / ESA / J. OLMSTEAD (STSCI) / N. MADHUSUDHAN (CAMBRIDGE UNIVERSITY)

IN BRIEF

Japan, India Launch X-ray, Solar Telescopes

In an ambitious mission pairing, Japan launched a new X-ray observatory and an innovative lunar lander on September 6th. The X-Ray Imaging and Spectroscopy Mission (XRISM) carries a *microcalorimeter*, jointly developed by Japan's space agency and NASA. The instrument precisely measures the energies of incoming X-rays, shedding light on the hot gas spiraling around black holes, flying outward from supernovae, and drifting within galaxy clusters. XRISM is the fourth mission to attempt to bring such an instrument into orbit — and will hopefully be the first one to report success. The Smart Lander for Investigating Moon (SLIM) mission accompanied XRISM on the launchpad. It's now headed for the Moon, with a landing expected in early 2024. Its primary objective is to demonstrate a pinpoint landing, with an accuracy of 100 meters (300 feet). Meanwhile, on September 2nd, India launched the Aditya-L1 mission, which carries a suite of seven instruments to study the Sun's photosphere, chromosphere, and corona. Three of these instruments will also carry out in situ studies of solar wind particles and magnetic fields at the spacecraft's position at the Earth-Sun L_1 Lagrange point. Aditya will also for the first time resolve the solar disk at near-UV wavelengths.

■ DAVID DICKINSON

NASA Panel's UAP Report

NASA has announced the results of an independent study commissioned to determine how the agency can contribute to understanding *unidentified anomalous phenomena* (UAPs). The panel in charge of this study was not commissioned to evaluate existing reports of UAPs, though they did note that there was no evidence to suggest such phenomena are extraterrestrial in origin. Instead, the goal was to determine how NASA can help evaluate future UAP reports. The agency's Earth-observing satellites lack the resolution to resolve individual events but can help monitor background conditions. Commercial satellites, on the other hand, offer resolution from several meters to under a meter. However, they are not looking everywhere all the time, so any detections would require some serendipity. The panel also suggests NASA could help provide a framework for civilians to report UAPs. Once scientific data are collected, the panel then advocates either following up on individual reports or, perhaps more profitably, searching for unusual events that deviate from expected conditions. While NASA is still reviewing the panel's report, it has already created a new position to oversee the study of UAPs, appointing Mark McInerney as director of UAP research.

■ MONICA YOUNG

M78
A Hotbed of Stellar Activity

Spend some time these winter nights exploring an object of remarkable complexity.

While planning a foray into the marvelous constellation Orion, **M78** (NGC 2068) probably isn't the first nebula that comes to mind. Heck, sometimes it doesn't come to mind at all — it's a daunting task having to compete with the incredible M42 complex, the Flame Nebula near Alnitak, and the dim-but-famous Horsehead Nebula. Also, even though M78 is the brightest reflection nebula in the sky, it wasn't until 2021 that I finally saw what makes it so special.

Before getting into that, we might ask what distinguishes a reflection nebula from other types of nebulae. *Reflection* nebulae, as their name implies, are clouds of gas and dust that simply reflect (and scatter) light from nearby stars.

▲ **REFLECTION SPLENDOR** This remarkable image by Jarett Trezzo highlights M78 and its associated reflection nebulae. Note the lack of stars in the immediate vicinity of the nebulae and how there are just about as many dark regions as there are bright ones. M78 exhibits the typical blue color of reflection nebulae. North is up here and in all sketches.

ALL SKETCHES BY HOWARD BANICH

Emission nebulae, on the other hand, shine because a highly luminous O or B star (or clump of stars) photoionizes the hydrogen in the cloud, which then radiates the characteristic red color so often seen in images. Reflection nebulae, instead, are more often tinted blue since that wavelength is more efficiently scattered than red light (think of our daytime sky).

If you've never seen a reflection nebula, M78 is a good place to start, not only because it's the brightest of its class but also because it's so easy to find. Imagine a 2°-long isosceles triangle pointed northeastward with Alnilam and Alnitak — the two easternmost stars in Orion's Belt — forming the base and you'll find M78 near the triangle's apex. Or, using Alnitak and Mintaka — the westernmost Belt star — imagine a right triangle with M78 as far from Alnitak as Mintaka is. You could also just use the Go To function of your scope if it has that feature, but try the M78-Belt-stars triangles technique (referring to the chart below) at some point to get a feel for its location.

Even moderate light pollution reduces M78's visibility, so you need a dark sky to fully appreciate it. That's true of most nebulae but especially so of the reflection variety, as no deep-sky filter will noticeably improve their visibility. Before outdoor LED lighting became prevalent, a broadband filter could help a little, although the contrast gain was minimal even then.

Discovery

First discovered by Pierre Méchain in early 1780, fellow French astronomer Charles Messier confirmed the nebula later that year. Here are Messier's notes from December 17, 1780:

> *Cluster of stars, with much nebulosity in Orion & on the same parallel as the star Delta in the belt, which has served to determine its position; the cluster follows the star on the hour wire at 3d 41′, & the cluster is above the star by 27′7″. M. Méchain had seen this cluster at the beginning of 1780, & reported: "On the left side of Orion; 2 to 3 minutes in diameter, one can see two fairly bright nuclei, surrounded by nebulosity (diam. 3′).*

Three years (and two days) later, William Herschel wrote:

> *1783, Dec. 19 (Sw. 59). Two large stars, well defined, within a nebulous glare of light resembling that in Orion's sword. There are also three very small stars just visible in the nebulous part which seem to be component particles thereof. I think there is a faint ray near ½ deg long towards the east and another towards the south east less extended, but I am not quite so well assured of the reality of these latter phenomena as I could wish, and would rather ascribe them to some deception. At least I shall suspend my judgement till I have seen it again in very fine weather, tho' the night is far from bad.*

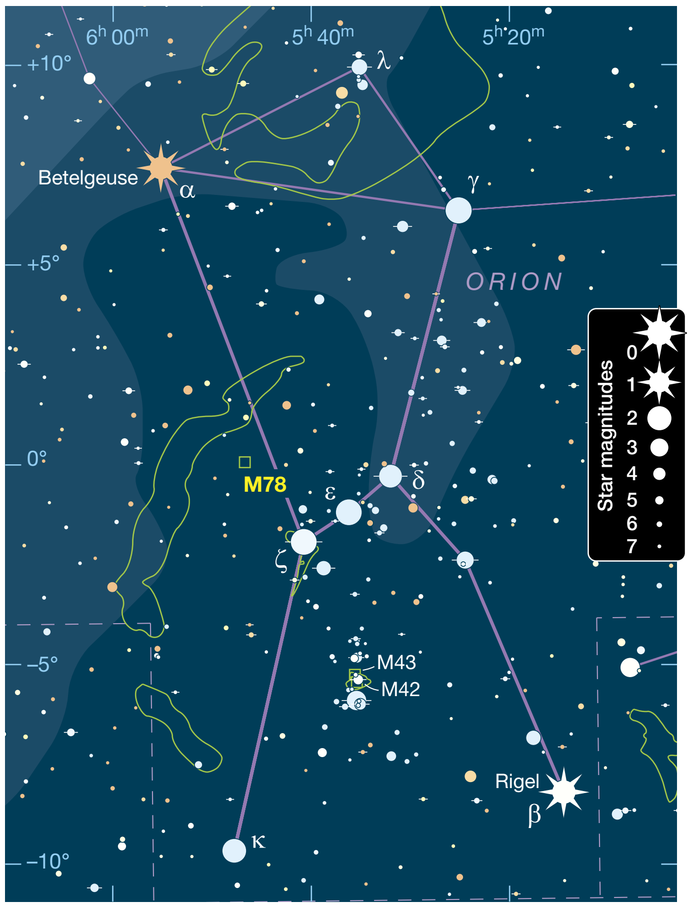
I'm surprised Herschel didn't see more nebulosity. The Moon was a waning crescent when he made his observation, so the night was probably quite dark at the time.

Active Star Formation

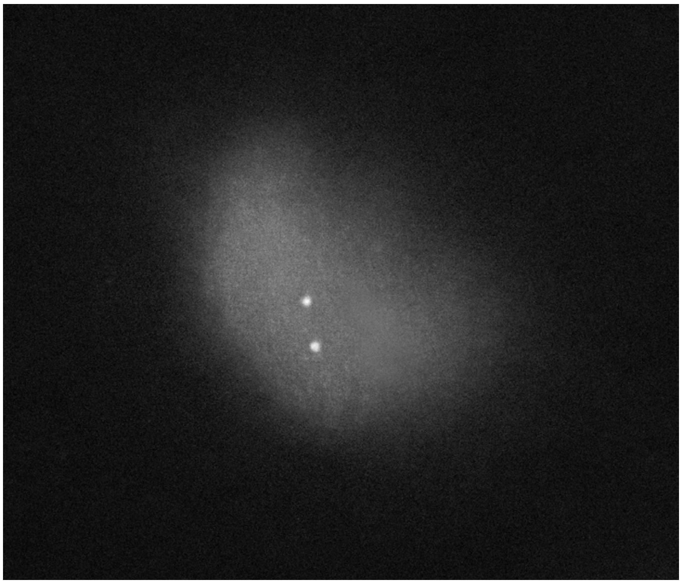
M78 is part of the Orion B molecular cloud. This nebular complex, at a distance of approximately 1,350 light-years, is one of the nearest star-forming regions. The Orion B cloud counts among its components the combination emission-and-reflection nebulae NGC 2023 (near the Horsehead Nebula) and NGC 2024 (also known as the Flame Nebula) some 2° southwest of M78. Orion B's elongated form is nearly at a right angle to the Orion A molecular cloud (which includes M42) several degrees farther to the south. So, when you think of star-forming regions in Orion, there's way more going on than just M42.

M78 belongs to a group of objects that includes the reflection nebulae **NGC 2064**, **NGC 2067**, and **NGC 2071**. To me, in photos and during visual observations with my 28-inch f/4 scope, they all appear to be part of the same nebula that's overlain by dark nebulosity.

All these reflection nebulae are made up of spinning grains of interstellar gas and dust. I've never imagined interstellar dust grains spinning around, but why wouldn't they? Most everything else in space does. The universe is a dynamic place, especially around the young stars forming within these nebulae.



▲ **IN THE HEART OF ORION** The Belt stars act as a handy guide to the location of M78. You can make triangles using the central star of Orion's Belt plus either of the other two on each side.



▲ **HUMBLE BEGINNINGS** This sketch represents how I saw M78 through my 8-inch f/4 Dobsonian in 1984 at 41×. This is an enlargement of a tiny sketch from my observing notebook and shows a typical view through a suburban sky.

Furthermore, it seems that about 6 million years ago a cataclysmic event (perhaps a supernova?) in the region compressed the preexisting interstellar dust and gas into the nebulae we see today, kick-starting an intense bout of star formation. That same supernova may be one of several that carved out the Orion-Eridanus Superbubble, which includes all the nebulae in Orion. Amazingly, researchers estimate that between 10 to 20 supernovae have gone off in this area over the past 10 to 15 million years. Two regions, LDN 1622 and IC 2118, must have been on the near side of the blasts — because they're moving towards us.

Intense star formation means there are abundant Young Stellar Objects (YSOs) and Herbig-Haro objects (HH) in and around M78. I haven't seen any of the HH objects, but I've detected oodles of YSOs. T Tauri stars are a type of YSO (see sidebar below) and are fascinating because they're pre-main-sequence stars in the early stages of their formation. Quite a few are visible in the M78 region.

First Forays

My first peek at M78 was in January 1984 with my 8-inch f/4 Dobsonian on a very cold and clear suburban night. I was able to see only the nebula itself and two of its embedded stars, but I was excited nonetheless:

> *A new one! North of (Orion's) belt, this (is a) small but surprisingly bright diffuse nebula. 41× didn't bring out much detail, although it seemed to contain two stars within it.*

My sketch (at left) definitely shows the two stars, which I think are the same pair that Méchain, Messier, and Herschel saw. And also, like them, I detected none of the other NGC nebulae surrounding M78. Further observations with the 8-inch showed similar views, but they were all from suburban locations, too. I'll bet that an 8-inch under a dark and transparent sky will reveal considerably more nebulosity and stars, though.

Through the years, I was able to see M78 and its family of three NGC nebulae with larger scopes under so-so conditions. But it wasn't until March 2021 that I got a high-quality look with my 28-inch.

This was during the same observing trip to eastern Oregon that resulted in all-time memorable views of the Cygnus Loop (*S&T:* Sept. 2021, p. 28) and NGC 4565 (*S&T:* May 2023, p. 20) — as well as several other targets — during absolutely epic conditions. Although M78 wasn't on my observing list for that trip, I ended up spending several hours over two nights sketching what I saw. Wow, did I ever come away with an eyeful!

Newly formed stars — what are the different types?

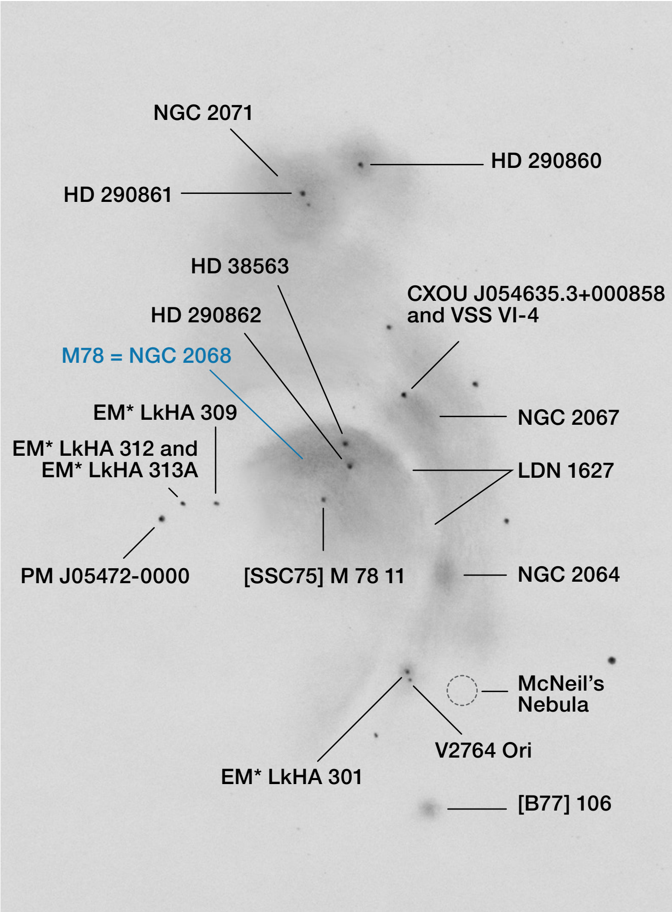
"Young Stellar Objects" is an overall term used to describe various stars in the early stages of formation. They're broadly divided into two categories: *protostars* and *pre-main sequence stars*. These are further subdivided into five classes, but the main idea is that they represent young stars at different stages of development. Astronomers categorize YSOs based on the nature of their mid-infrared spectrum.

Protostars are still accreting mass from their local environment and are very young. This initial phase of star formation lasts about half a million years; it begins when a dense part of a molecular cloud contracts under self-gravity and ends when infalling material from its parent cloud is depleted. The end result is a pre-main-sequence star.

T Tauri stars are older protostars that are continuing their evolution toward the main sequence. They're less than 10 million years old, variable, and are lighter than 3 solar masses. Most T Tauri stars are in binary systems and about half have circumstellar disks where planets may form.

Herbig-Haro objects aren't stars per se but are bright patches of emission nebulae arising from collimated outflows from a YSO, which are aligned with the rotational axis of the forming star. These outflows rush into the surrounding molecular cloud, creating an emission nebula at each end. Several nebulae can form this way as the axis of the YSO rotates.

STUPENDOUS SKY, STUPENDOUS VIEW Finally I got a great view under a dark and transparent sky! This sketch shows what I saw with my 28-inch scope in March 2021 over two nights. I used magnifications from 155× to 408× and was surprised by how well the features shown above stood up to magnification. I didn't use narrowband filters as reflection nebulae don't respond to them — but I tried an old broadband filter anyway. It didn't help.



▲ **LABELED NEGATIVE OF THE SKETCH** Note that nearly every star is a type of youthful star! Some sources place NGC 2064 within the outer reaches of NGC 2068, but its actual location is as shown.

My notes from the first night read:

Two main clumps of nebulosity with an irregular arc of clumpy nebula arcing around the brightest of the main areas. With the curved dark lane highlighting the pervasive background glow — which seems rather patchy — this is a lovely sight! 155×, 408×, 21.81 SQM [Sky Quality Meter]

On the second night I noticed two small nebulous glows along the southern end of M78's extended nebulosity. I didn't know their designations at the time, so I wondered if one of those two knots might be **McNeil's Nebula**, a variable nebula that American amateur Jay McNeil discovered photographically in 2004. His object is reminiscent of a smaller version of Hubble's Variable Nebula (NGC 2261). The illuminating star for McNeil's Nebula is the protostar **V1647 Orionis**, which, at magnitude 18.1, is very difficult to see.

After returning home, I looked up the location of McNeil's Nebula and quickly confirmed that I hadn't seen it. Evidently, no one has since 2018, but at least I know where to look for it now. However, I did see quite a bit more of M78 and its surroundings, and they proved to be plenty interesting.

The Main Nebula and Friends

M78 is the largest and brightest region of nebulosity, and it's what the three pioneering observers referred to above saw. However, the first part of Messier's description doesn't really match modern views of M78. Not only is there no star cluster here, but there's also a noticeable *lack* of them around M78. This has me wondering why he described it as a "*cluster of stars*." Where Messier quotes Méchain, though, is spot on, and Herschel's precise notes confirm he was seeing M78, too.

Although my 28-inch sketch (on page 15) shows exactly what I saw, let's go through some of the highlights. Notice the sharp but slightly uneven northern boundary M78 makes with the curved dark nebula **LDN 1627**. I saw one definite notch and perhaps glimpsed another. To paraphrase Herschel, "*I am not quite so well assured of* [its] *reality*," but I did have the impression that the northern border of NGC 2068 was somewhat serrated.

The two lights illuminating M78, which I first saw with my 8-inch scope, stand out as equally bright and conjured a pair of stellar eyes within a ghostly face. The northernmost star, 10.8-magnitude **HD 38563**, is a close double that I saw as a single object, while the southern star, **HD 290862**, is a YSO and is slightly brighter at magnitude 10.4. The third star that Herschel mentioned, just south of the brightest part of M78, is 13th-magnitude **[SSC75] M 78 11**.

The three seemingly nondescript stars trailing off to the southeast from M 78 11 turn out to be rather interesting. In descending order of brightness, we have the high-proper-motion star **PM J05472-0000**; the T Tauri star **EM* LkHA 309**; and a close double comprising a YSO, **EM* LkHA 312**, and a T Tauri star, **EM* LkHA 313A**, that I saw as a single object. Don't dismiss stars in this region at first glance — many turn out to be fascinating once you dig into their true natures.

To my eye, LDN 1627 — as the dark backbone of this area — helps define the northern and northwestern edges of M78, while in the opposite directions its bright nebulosity gradually fades to the south and east. The dark nebula is as visually important as the bright portions, and I imagine it's brightly illuminated all along its far side. In fact, it doesn't disappear completely, because the entire area is dappled with a subtle mix of dark and barely detectable bright nebulae, with the most noticeable part straggling off to the south.

The Northern Area

NGC 2071 connects to the northern reaches of M78 by the subtle and uneven glow of background nebulosity that suffuses this area. It gives the strong impression that all the brighter nebulae are part of the same complex and separated by dark nebulae. The brightest part of NGC 2071 is punctuated by the star **HD 290861**, a 10th-magnitude YSO.

The nebula surrounding HD 290861 is roughly circular, colorless, but with noticeably irregular edges. It gradually dims the farther it gets from the star until it joins the background glow to its south and northwest, where it brightens again around the star **HD 290860** (also 10th magnitude). The edges of the nebula abruptly dim into the background glow of this region.

Two More NGCs

NGC 2067 is the elongated bright nebula on the northwestern side of LDN 1627, which follows the curve both to the west and south of M78. The brightest portion of NGC 2067 is near its northern end. A roughly 10th-magnitude object pokes through the most prominent part of the nebula as it trails southward down the visual length of NGC 2067. That object is in fact a close double consisting of a YSO, **CXOU J054635.3+000858**, and a star of uncertain type cataloged as **VSS VI-4**.

Following the curve of NGC 2067 southward we come to NGC 2064, a subtle knot that's easy to miss at first glance, but with averted vision it appears more substantial. It's right about here where LDN 1627 becomes indistinct, and the western side of M78 begins to merge with NGC 2064. Keep following the overall curve to find a wide double comprising a pair of T Tauri stars. I saw a faint halo around the easternmost component, 14.6-magnitude **EM* LkHA 301**. Its wide companion, **V2764 Orionis**, is almost the same magnitude at 14.4. By the way, the location of McNeil's Nebula is just west of this young stellar pair.

Infrared Star Cluster

Continuing along the overall curved outline of this region southward, I came to a small knot of nebulosity, **[B77] 106**. Although I only noticed the fairly bright glow of the nebula, there's a T Tauri star embedded within. YSOs are everywhere!

Infrared observations confirm that a star cluster is developing within M78 and its associated nebulosities, and as I've noted here, we can even see some of these new stars visually. Although M78 isn't the flashiest nebula in Orion, it and its surroundings give us a rare inside look into the usually hidden and beautiful arena of star formation. To my mind, that elevates M78 into one of the great sights anywhere in the sky. It's one I won't overlook again.

■ Contributing Editor **HOWARD BANICH** is grateful to have had at least one great view of M78. You can reach him at **hbanich@gmail.com**. Read about the evolution of his scope collection at **https://is.gd/banich_scopes**.

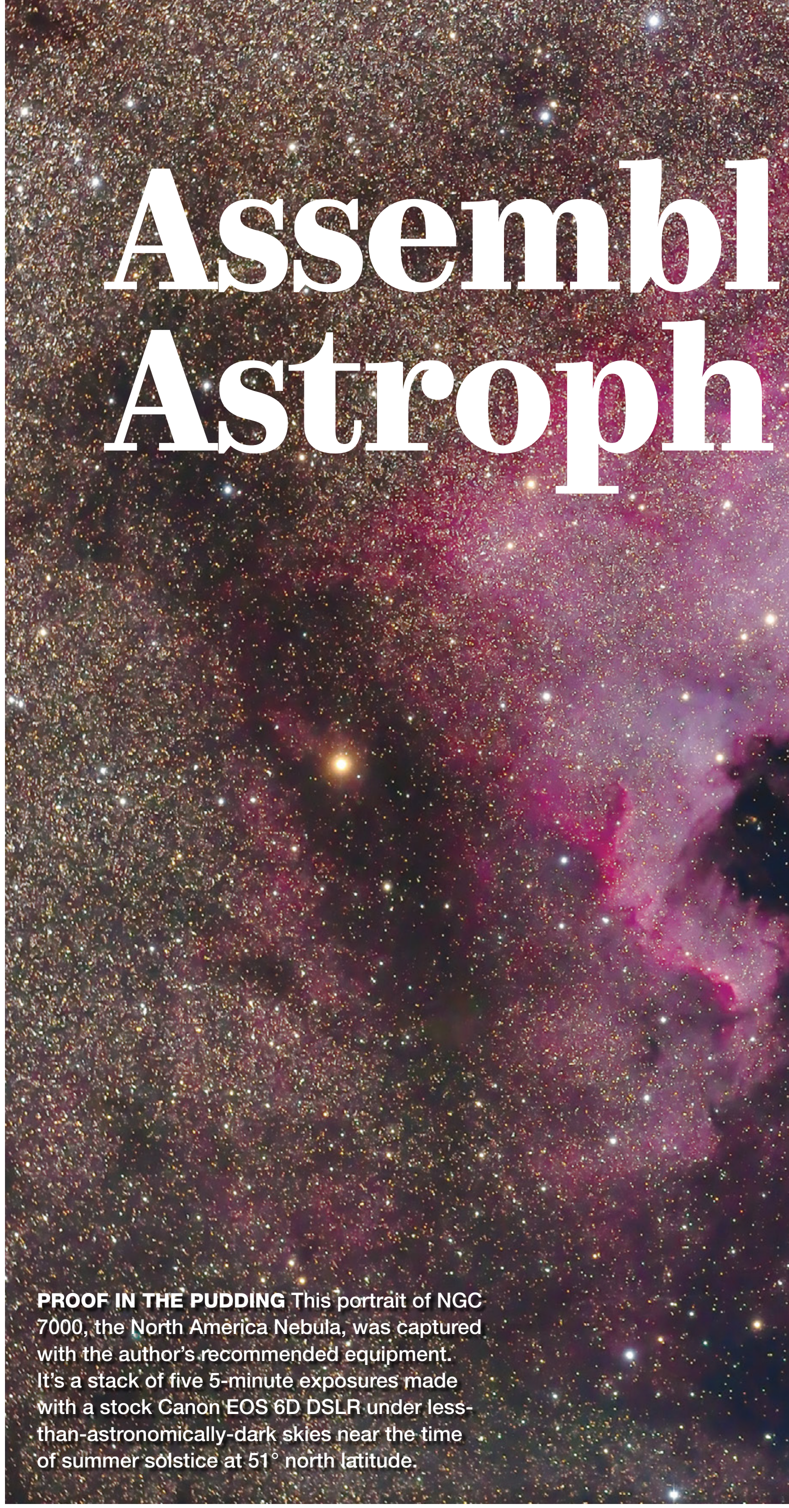
In and Around M78

Object	Type	Mag(v)	Size	RA	Dec.
M78	Reflection nebula	—	8′ × 6′	$05^h 46.7^m$	+00° 05′
NGC 2064	Reflection nebula	—	1′ × 1′	$05^h 46.3^m$	+00° 00′
NGC 2067	Reflection nebula	—	8′ × 3′	$05^h 46.5^m$	+00° 08′
NGC 2071	Reflection nebula	—	7′ × 5′	$05^h 47.1^m$	+00° 18′
McNeil's Nebula	Variable nebula	15–16	1′	$05^h 46.2^m$	–00° 06′
V1647 Orionis	Star	18.1	—	$05^h 46.2^m$	–00° 06′
LDN 1627	Dark nebula	—	6′ × 2′	$05^h 46.4^m$	+00° 03′
HD 38563	Double star	10.8	—	$05^h 46.7^m$	+00° 05′
HD 290862	Young Stellar Object	10.4	—	$05^h 46.7^m$	+00° 05′
[SSC75] M 78 11	Star	13.1	—	$05^h 46.7^m$	+00° 03′
PM J05472-0000	Star	10.9	—	$05^h 47.3^m$	–00° 02′
EM* LkHA 309	T Tauri star	14.7	—	$05^h 47.1^m$	+00° 01′
EM* LkHA 312	Young Stellar Object	15.1	—	$05^h 47.2^m$	+00° 00′
EM* LkHA 313A	T Tauri star	—	—	$05^h 47.2^m$	+00° 00′
HD 290861	Young Stellar Object	10.0	—	$05^h 47.1^m$	+00° 18′
HD 290860	Star	9.9	—	$05^h 47.0^m$	+00° 20′
CXOU J054635.3+000858	Young Stellar Object	—	—	$05^h 46.6^m$	+00° 09′
VSS VI-4	Star	—	—	$05^h 46.6^m$	+00° 09′
EM* LkHA 301	T Tauri star	14.6	—	$05^h 46.3^m$	–00° 05′
V2764 Orionis	T Tauri star	14.4	—	$05^h 46.3^m$	–00° 06′
[B77] 106	Nebula	—	—	$05^h 46.1^m$	–00° 12′

Magnitude for McNeil's Nebula is given for when the target is detectable. 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.

Assembl
Astroph

Alan Dyer gives his recommendations for a first-class imaging rig for anyone aspiring to begin deep-sky photography.



PROOF IN THE PUDDING This portrait of NGC 7000, the North America Nebula, was captured with the author's recommended equipment. It's a stack of five 5-minute exposures made with a stock Canon EOS 6D DSLR under less-than-astronomically-dark skies near the time of summer solstice at 51° north latitude.

If you want to capture great images of star clusters, nebulae, and galaxies, there's a bewildering amount of gear to choose from these days. So let me provide some guidance. People often ask, "What would you buy?" Well, this is the kit I *did* buy and which I can personally recommend to beginners. The combination could also be ideal for an experienced astrophotographer wishing to downsize to a smaller, lighter system.

Choice Criteria

The goal of this buying guide is to help you assemble a portable imaging system capable of publication-quality images of deep-sky objects, at a less-than-astronomical price. The approximate cost of my suggested system adds up to $3,500, not including a camera and some accessories. I realize that might be a bit pricey for many just starting out, so I also include some lower-cost alternatives.

I haven't recommended any of the robotic "smart" scopes now on the market. They fall within my proposed price range and can deliver initially gratifying images with turnkey operation — no assembly required. However, I consider the images they produce to be less than publication quality. In addition, while they might be the latest in high-tech, today's smart scopes aren't upgradable, should you aspire to take better images later. Instead, I suggest a more conventional system with components that can be upgraded in stages, yet without any parts at risk of being rendered obsolete or redundant. What you buy now to get started will still be useful years later, even if you graduate to a larger, more advanced setup. The one exception is the camera, for reasons I'll describe later.

In assembling my recommended rig I've followed three personal philosophies:

- **Buy nice or buy twice.** Low-cost gear might save money in the short-term, but scrimping in the wrong places often results in poor photos and the need to toss the ill-chosen gear and buy again.
- **Favor an integrated system.** Those with technical skills revel in the challenge of getting hardware and software from disparate suppliers to work together. Not me. I like my stuff to work straight "out of the box."
- **Keep it simple.** The more gadgets, cables, and software you accumulate, the more that can go wrong. Plus, you'll need to invest additional time to master each piece of equipment.

I've also adhered to two axioms I think are universally accepted by astrophotographers:

- **Invest most in the mount.** The mount is literally the foundation of any astrophoto system. As your ambitions grow, you'll acquire new telescopes and cameras, but a well-chosen mount can remain the core of any astrophoto system.
- **Start with a small apochromatic refractor.** A good apochromat can produce first-class images that are sharp across a large camera sensor. An apo lens is also free of false color halos, unlike lower-cost achromats. And unlike fast, entry-level Newtonian reflectors, quality refractors are essentially maintenance-free.

The recommendation of a small refractor often surprises newcomers, who naturally assume the bigger the telescope,

ing an oto System

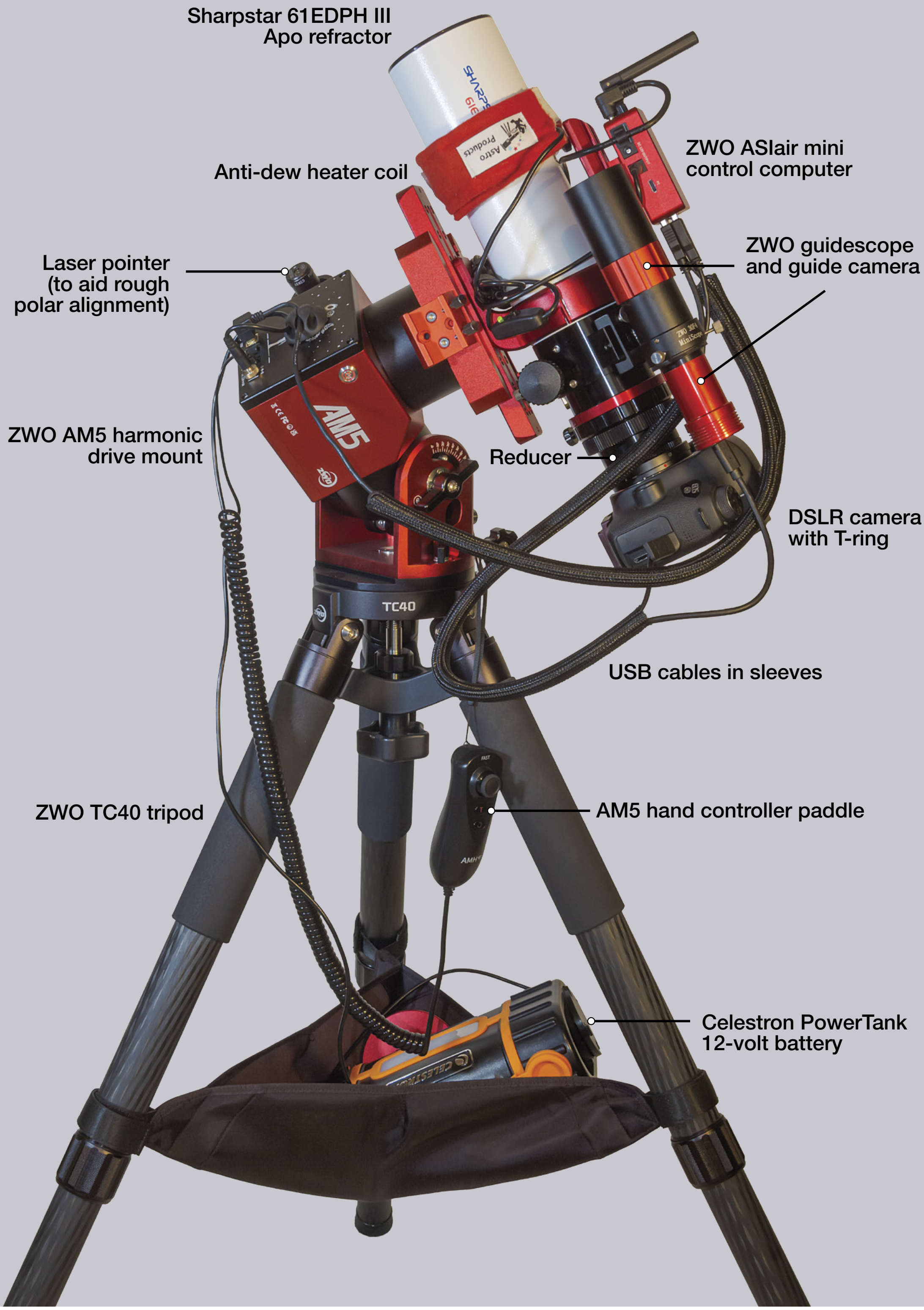
the better the images. For planetary imaging that can be the case, but not for deep-sky photography.

The Mount — $1,800 to $2,300

For the all-important mount I've selected the popular ZWO AM5 (*S&T:* April 2023, p. 64), one of the new strain-wave models. When bundled with ZWO's sturdy yet lightweight TC-40 carbon-fiber tripod at a cost of $2,298, this is the costliest part of the rig by far.

However, this new type of mount is both light and compact yet can handle larger payloads than a traditional

AN EXCELLENT STARTER SYSTEM The author's recommended system shown in detail, with its various components assembled and ready for imaging. Key elements are from one supplier, ZWO, to ensure compatibility, but the optics come from Sharpstar. The camera is a Canon EOS 6D, a decade-old but very capable full-frame DSLR, available on the used market at bargain prices.



mount with worm-and-wheel gears or belt drives, and without the need for a bulky counterweight. It's possible to carry the AM5 with a small telescope out to the yard all assembled, or to pack the components into a small car with lots of room to spare.

While other brands (such as iOptron, PegasusAstro, and Sharpstar) also offer strain-wave-driven mounts in the $1,800 to $3,000 price range, I chose the AM5 for its price, its compatibility with ZWO's other hardware and mobile apps, and its simple polar-alignment routine. The AM5 can easily handle telescopes up to a 130-mm refractor or a 200-mm Schmidt-Cassegrain, so there's plenty of room to grow.

Of course, no sooner had I purchased my AM5 when ZWO announced an even smaller and less expensive mount. Its AM3 sells for about $1,800, bundled with the same tripod. For our entry-level system, the AM3 is probably the better choice, bringing the total system cost down to about $3,000. But for the extra $500 you do get a greater payload capacity: 12.7 kg (28 lb) for the AM5 versus 8.2 kg for the AM3, making the AM5 more future-proof.

The Optics — $750

For my suggested starter system, I've elected to keep the telescope as small, light, and affordable as possible without compromising image quality. I've chosen the Sharpstar 61EDPH III ($549), a 61-mm triplet-lens apochromatic refractor.

With its matching 0.75× f/4.4 Full-Frame Focal Reducer lens ($199) — an essential accessory for deep-sky imaging — the total cost comes to about $750. That's a good price for such a quality combination when you consider that other 60-mm triplets with flattener lenses sell for up to twice as much. While some good doublet 60-mm apos are available at lower cost, not all have a reducer lens, an option I prefer for the faster photographic speed. As a bonus, the Sharpstar 61 can also be used visually with any 2-inch star diagonal and eyepiece, unlike some dedicated astrographic refractors.

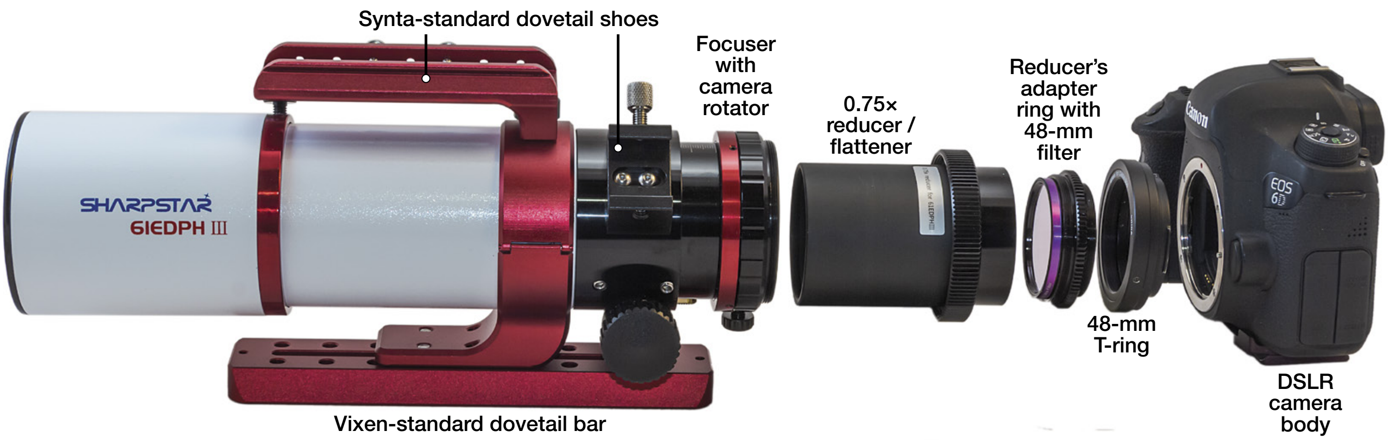
Paired with its reducer, the Sharpstar's focal length is 270 mm, which is long enough to record large targets well. Its f-ratio of f/4.4 is fast enough to keep exposures short at low ISO settings, which helps to keep camera noise at bay. The field of view with a full-frame camera is a generous 7.6° by 5°, providing impressive star-filled images. Adding the $199 1× Full-Frame Flattener lens turns the little Sharpstar into a 360-mm f/5.9 instrument with a 5.8° by 3.6° field — a good option for many smaller targets. Even with a houseful of larger refractors, I often turn to this scope for a night's shoot.

Guiding and Control — $450

While it's possible to shoot and stack dozens of short (less than 1 minute long) unguided sub-frames, I find the results are often underexposed, noisier, and less detailed when compared to compiling fewer multi-minute images. That's especially true of older DSLRs, whose sensors are much noisier in low light and so cannot tolerate underexposure.

However, keeping stars pinpoint in exposures longer than a minute requires autoguiding to compensate for a mount's tracking errors. One of the most affordable solutions is ZWO's ASI120MM Mini, its lowest-cost guide camera, mated to its f/4 Mini Guidescope, for a package price of $248. Although its aperture is only 30-mm, I've never found this setup unable to find and lock onto a guide star.

To control the autoguider, I recommend the newest version of ZWO's popular imaging computer, the ASIair Mini, for $199. The ASIair Mini sets up a local Wi-Fi network you connect to with your smartphone or tablet using the *ASIair* app (free for iOS and Android). A mobile device is much easier to operate and power in the field than the laptop computer most other autoguiders require. So far in several months of use, the system has yielded a 100% success rate. Except when clouds interfered, not one frame has suffered from misguided or trailed stars, though admittedly, a short-focal-length apo is quite forgiving of such errors.



▲ **ATTACHING A DSLR** The Sharpstar's 0.75× Reducer screws into the focuser's rotator and has an adapter ring that accepts 48-mm filters. Mounting a DSLR camera requires a user-supplied 48-mm T-ring for the camera mount (Canon EF in this case).

◀ MANY SHORT VERSUS FEWER LONG EXPOSURES This comparison shows a stack of twenty 30-second unguided exposures (left) with a stack of two 5-minute guided exposures (right). Each totals 10 minutes of exposure time. All images were taken with the Canon 6D (above) at ISO 800 and processed identically except for the short exposures having to be boosted in brightness. The short-exposure stack exhibits much more noise and banding artifacts as well as lower contrast.

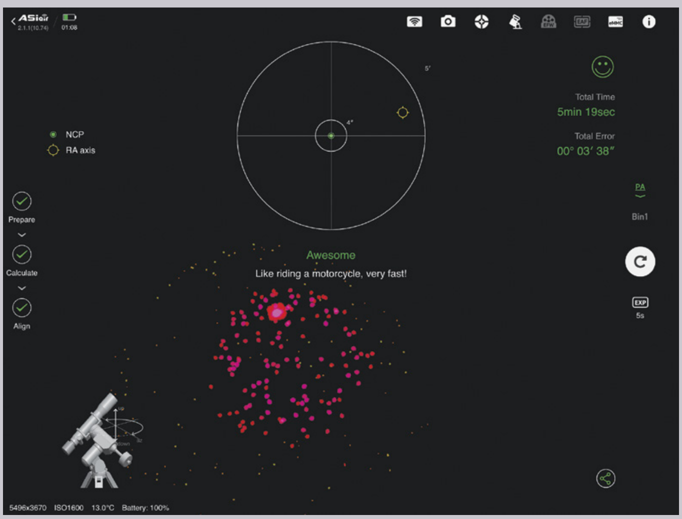
If all it did was autoguide, the ASIair Mini would still be worth buying. But it does much more. It can also control an imaging camera, Go To mount (most brands are supported), focuser, and filter wheel through multiple USB connections. A key reason I recommend ZWO's AM5 mount (or its smaller AM3), however, is the seamless integration with the ASIair computer. The ASIair controls the mount with plug-and-play ease and reliability. Ditto the autoguider camera, though it must be a ZWO model.

While it's easy to use the *ASIair* app at the telescope, once the system is set up you can retreat indoors to operate your gear wirelessly and monitor incoming images with your phone or tablet. That's a huge convenience.

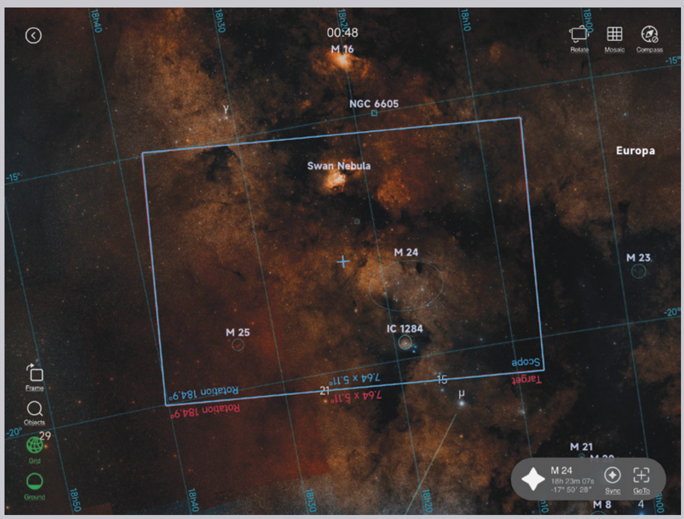
Camera Choices — $0 to $400

To keep costs down, I suggest using the camera you likely

STEPS TO USING THE ASIAIR The *ASIair* app controls the ZWO autoguider (inset), mount, and main camera. It takes a night or two to learn but becomes easy to use with a touch-friendly interface.



▲ **Step 1:** Polar Align — Using images taken with the main camera, the app shows how to adjust the mount to align it. Getting within 3 to 5 arc-minutes of the pole is sufficient to produce round stars in your astrophotos with the Sharpstar telescope.



▲ **Step 2:** Go To Target — Use either the built-in star chart or list of targets to slew the mount. Once there, it takes short plate-solving exposures to fine-tune the pointing.

already own. Almost any DSLR or mirrorless camera made in the last 15 years can do a good job capturing deep-sky objects.

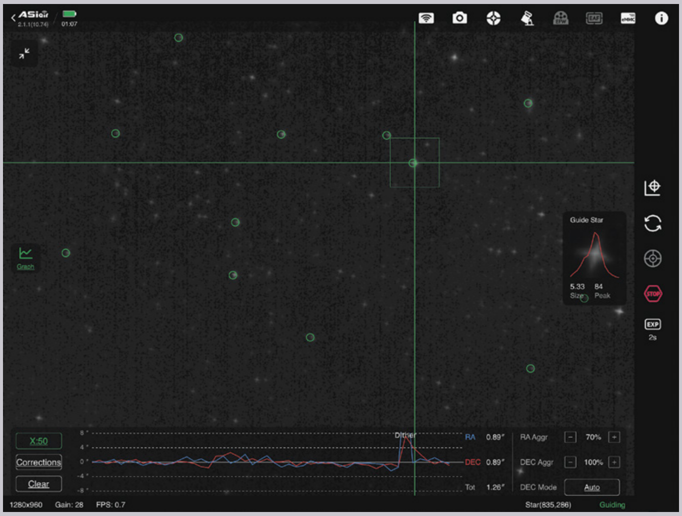
However, for your camera to work with an ASIair control computer it has to be a Canon, Nikon, or Sony, with many models supported. ZWO lists the compatible cameras at its web page for the ASIair.

That said, an older-generation cropped-frame camera, such as the entry-level Canon Rebel or T series, can be rather noisy for long-exposure images at ISOs of 1600 or higher. A new camera will exhibit much less digital noise, but that can add $1,000 or much more to the cost. As an affordable alternative, secondhand DSLRs are available at attractive prices as people upgrade to new, mirrorless models. A full-frame DSLR offers larger pixels, which produce lower noise than a cropped-frame model, while the 24- by 36-mm sensor makes full use of the generous field delivered by apo refractors like the Sharpstar.

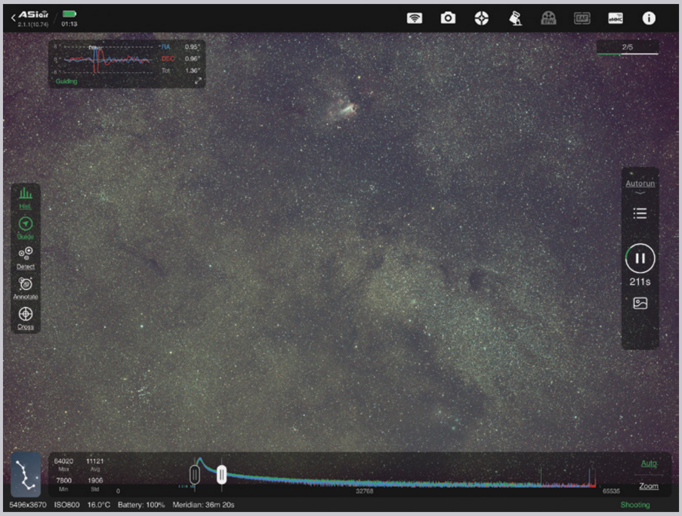
The vintage 20-megapixel Canon 6D has quite low noise even by today's standards. You can purchase a used one in excellent condition for about $400 from re-sellers such as **KEH.com** and **MPB.com**. From firsthand experience I can also recommend the 24-megapixel Nikon D750 or 26-megapixel Canon 6D MkII DSLRs.

All these choices get you a good-performing, full-frame sensor for less than a new mirrorless camera, and much less than the $3,000 on up for a dedicated, full-frame astronomy camera such as ZWO's own ASI2400MC.

▲ **CAMERA MOD AND FILTERS** Shooting with a filter-modified Canon R camera and a narrowband filter records wreaths of faint nebulosity here in central Cygnus. Taken with a Sharpstar 61, this is a stack of eight 8-minute exposures through an IDAS NBZ filter (inset), blended with ten 8-minute unfiltered exposures.



▲ **Step 3:** Get Guiding Going — After a calibration that jogs all four motions, the app starts guiding.



▲ **Step 4:** Start Imaging — The simplest option is ***Autorun***, where you set the number and length of exposures. The ISO speed can also be set under the Camera tab.

To Mod or Not to Mod

The next question is whether you need an astro-modified camera or not. No, you don't. Not to start, at least.

Astro-modified cameras replace the infrared-blocking filter all DSLRs have in front of the sensor with one that still cuts out infrared light but lets through more of the deep, red hydrogen-alpha (Hα) wavelength, allowing the camera to record richer and fainter nebulosity. Canon and Nikon have both offered astronomical camera models in the past, such as the Canon Ra (my personal favorite) and Nikon's D810a. Units appear on the used market rarely and briefly.

Today, one way to get a modified camera is to buy a normal one and send it to one of the several companies who will perform the mod, typically for $200 to $400. Those same companies also sell modified cameras, either new or used, all ready to go. Just be sure it's a model that's supported by the ASIair.

That said, a modified camera is of advantage only for red emission nebulae — a popular class of target to be sure. But Milky Way star fields, star clusters, galaxies, and even bright nebulae record well with unmodified cameras. Learn your craft with one of those before investing in a modified camera, or buying a dedicated cooled-sensor astronomy camera.

While your current camera can serve you well for a year or two, it's the one component you'll likely want to upgrade first, perhaps for one with a larger sensor or offering greater resolution, lower noise, and higher Hα sensitivity.

◀ **PORTABLE POWER** For electricity in the field, the author uses a Celestron PowerTank Pro. It works well for one or two nights of imaging and has both cigarette lighter and 2.1-mm barrel jacks.

Essential Accessories

There are a few accessories you'll need to get everything working together. The first is a power supply. The mount, ASIair, and autoguider camera all require 12 volts. (A DSLR has its own internal battery.) ZWO's mounts don't come with an AC-to-DC adapter, but any 12-volt AC power supply can work at home provided it can output up to 5 amps and has a cable with the 5.5-mm OD, 2.1-mm ID barrel plug that the mount (and most astro-gear) requires.

MILKY WAY STAR FIELDS The Sharpstar 61EDPH III and Reducer covers a full-frame sensor with only minor astigmatism at the extreme corners (shown in the inset). As this framing of nebula M17 and star clusters M24 and M25 in Sagittarius shows, the stock Canon 6D records red nebulae quite well.

For use away from home, a 12-volt lithium battery is essential. There are many brands to choose from, such as Bluetti, Celestron, GoalZero, Jackery, RAVPower, or Yeti. Be sure to budget between $200 to $300 for a battery with enough power to run all your gear for an entire night.

Another crucial accessory is a T-ring to connect your DSLR to the Sharpstar Reducer's M48 threads. You'll need a 48-mm (not 42-mm) T-ring made for your lens mount (about $20). Mirrorless cameras might also need a lens adapter between the T-ring and camera body.

And while the ZWO gear comes with power and USB cables, connecting your camera will require a cable with a USB-A plug on one end and whatever variation of USB plug your camera needs on the other. Older cameras typically had a USB Mini-B or Micro-B connector. Newer cameras all have USB-C ports.

Optional Accessories

While not absolutely necessary, some additional accessories will make your imaging experience much easier. A kit of clamps, ties, and flexible sleeves can help keep the tangle of cables tidy ($20 on Amazon).

Anti-dew heater straps might be required at humid sites. Look for a coil to wrap around a 60-mm lens ($30 to $60) and with the 12-volt barrel-style plug needed to power it through the ASIair.

A focusing mask, such as the slotted Bahtinov mask (named for its Russian inventor Pavel Bahtinov) makes it easy to precisely focus on a bright star. These start at about $35, or you can 3D-print one yourself.

And then there are filters. The best deep-sky images require shooting at a dark site. But even under pristine skies, a filter that blocks most wavelengths except the red Hα and green oxygen III emission lines (called dual-band filters) can make nebulae really pop, provided you have a modified camera. Under light-polluted suburban skies, narrowband filters can make nebula imaging possible, though good results require hours of exposure and skilled processing.

Filter prices vary depending on how narrow their passbands are. Budget $200 to $500 for a 2-inch (48-mm) filter. Or add one to your holiday gift wish list.

Of course, as with any photography pursuit, there's no end of gear you can buy that promises to improve your images. But the kit I've recommended here can serve you for many years to come. Once you've assembled the essential components, the most important accessory is a reliable vehicle for those drives to dark-sky sites.

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

Lower-Cost Options

While there are many good choices for entry-level mounts, these are some models I've used and can recommend.

Sky-Watcher's EQM-35 Mount – $2,300

Substituting Sky-Watcher's entry-level EQM-35 mount for the AM5 saves a considerable $1,000. I own one and used it extensively with the ASIair. The EQM-35 I have has a hand controller with a USB-B port on it, making it easy to connect to the ASIair. The app controls and autoguides the mount quite well. But backlash in the drive gears resulted in trailed stars on a few frames in most image sets, despite autoguiding. I also had to resort to a factory reset of the controller a couple of times when the mount refused to go to targets accurately. The EQM-35 will nicely handle refractors up to 90-mm aperture, so there's modest room to upgrade.

Sky-Watcher's Star Adventurer GTi Mount – $1,950

Choosing the smaller Star Adventurer GTi Go To mount and matching tripod saves another $350 or so. I tested the new GTi with the ASIair and Sharpstar 61EDPH. The ASIair connected to the USB-B port on the GTi and controlled it fine by selecting the AZ-GTi protocol in the ASIair's app. Again, expect to lose some frames to guiding errors. The principal disadvantage of this mount is that a small scope like the Sharpstar 61 is about the largest I would recommend using with it. But for a lowest-cost, portable deep-sky rig with Go To, the combination works very well.

Star Trackers – About $550

If you're looking to get into deep-sky photography and keep to a budget under $1,000, I suggest buying a simple star tracker. I've used and can recommend either Sky-Watcher's Star Adventurer 2i or iOptron's SkyGuider Pro (shown here) — each costs about $550 including a tripod. Use it with your current camera and lenses for tracked (though unguided) images of constellations and the Milky Way. I find a 135-mm lens is about the longest focal length practical for the drive accuracy of these devices. While I've not used one, a popular lens among astrophotographers is the Rokinon/Samyang 135-mm ED, a manual focus f/2 model available for many lens mounts for $450 to $550.

 by John Barentine & Jessica Heim

The Return of Dark Skies?

1 Excellent Dark-sky Site

2 Dark-sky Site

3 Rural Sky

4 Rural/ Suburban Transition

5 Suburban Sky

6 Bright Suburban Sky

7 Suburban/ Urban Transition

Light pollution is spreading across the planet.
But we can stop that.

"They are all up — the innumerable stars," the American poet Nathaniel Parker Willis wrote in 1828. "There they stand, shining in order, like a living hymn." Were he alive today, Willis would struggle to find many stars in the night skies over much of his adopted home of New York. While he didn't live quite long enough to see the introduction of electric light, Willis was struck by the sight of gas lamps "shooting up, bright and star-like" in London during his 1830s sojourn in the United Kingdom.

Fewer people than ever have access to the kind of night skies Willis described in the early 19th century. As the world's population becomes increasingly urbanized, billions of people find themselves awash in city lights at night. A mid-2010s estimate found that some 80% of humanity lived under light-polluted skies; for those in the U.S. and Europe, the figure climbed to 99%. At night, many people around the world now experience a kind of permanent twilight, conditions in which their night skies never approach a natural level of nighttime darkness. Recent observations show night skies brightening by about 10% per year on average, doubling in brightness in a little over seven years. And there is no end in sight.

Or is there? We have solutions that we know work. We just lack the willpower as a society to implement them. Can current worldwide efforts to draw attention to the problem finally drive us toward solving it?

Historical Background

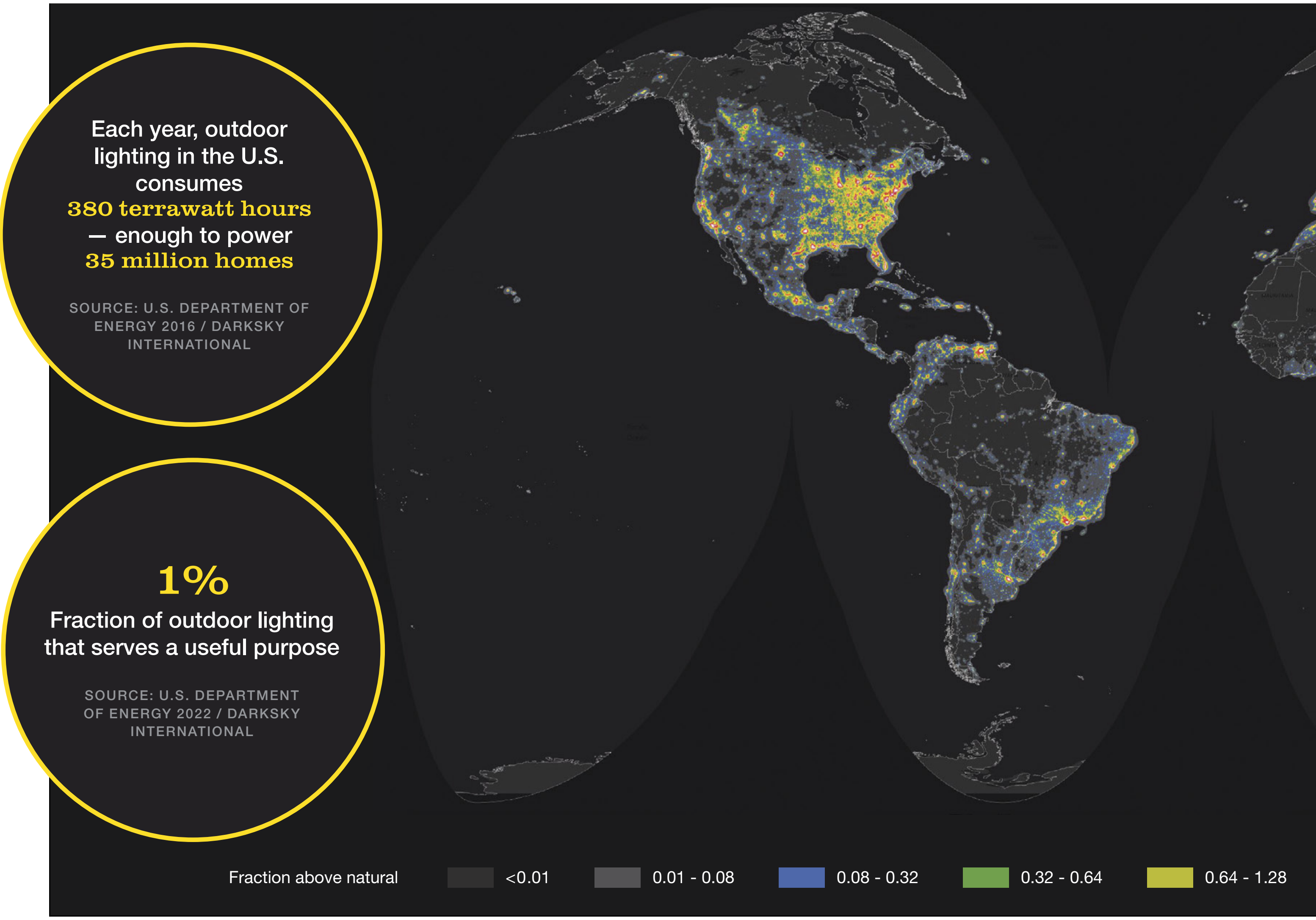
Since time immemorial, the starry night sky has been an integral part of the human experience. The predictable motions of objects in the heavens have been an aid to time-keeping, navigation, and agriculture. In addition, the stars, planets, and Milky Way have long played an essential role in human culture, knowledge systems, and ways of living.

Artificial light at night (ALAN) is a far more recent phenomenon. While experiments with simple gas lighting systems were made in China roughly 2,500 years ago, significant effects were few before the introduction of extensive municipal outdoor lighting systems in the early 19th century. Combined with the poor air quality typical of industrialized European cities of the era, night skies over major observatories were already beginning to brighten around the time photography was introduced to astronomy.

By the 1940s, astronomers were taking steps to escape ALAN's influence on their work. For instance, the UK's Royal Observatory moved its operations out of light-polluted

◀ **FROM DARK SKY TO DOWNTOWN** Under a pristine night sky, the Milky Way's center casts shadows. As light pollution worsens, nebulosity and stars disappear, until maybe a few dozen stars remain. The numbers 1 through 9 are the Bortle scale, which provides observers with a metric to measure the darkness and clarity of the sky overhead at their location (*S&T:* Feb. 2001, p. 126).

ADAPTED FROM MARK BULT / DARKSKY INTERNATIONAL



▲ **NIGHT-SKY BRIGHTNESS** Based on both satellite data and ground-based measurements, this map shows the artificial brightness of the night sky as a ratio to the natural sky brightness. Blue areas qualify as polluted by astronomers' standards. People in yellow areas cannot see the Milky Way in January; in orange areas, June's brighter Milky Way also disappears. In red areas, there is no true night — an artificial twilight reigns, blotting out the stars.

F. FALCHI, P. CINZANO, D. DURISCOE, C. C. M. KYBA, C. D. ELVIDGE, K. BAUGH, B. A. PORTNOV, N. A. RYBNIKOVA, AND R. FURGONI

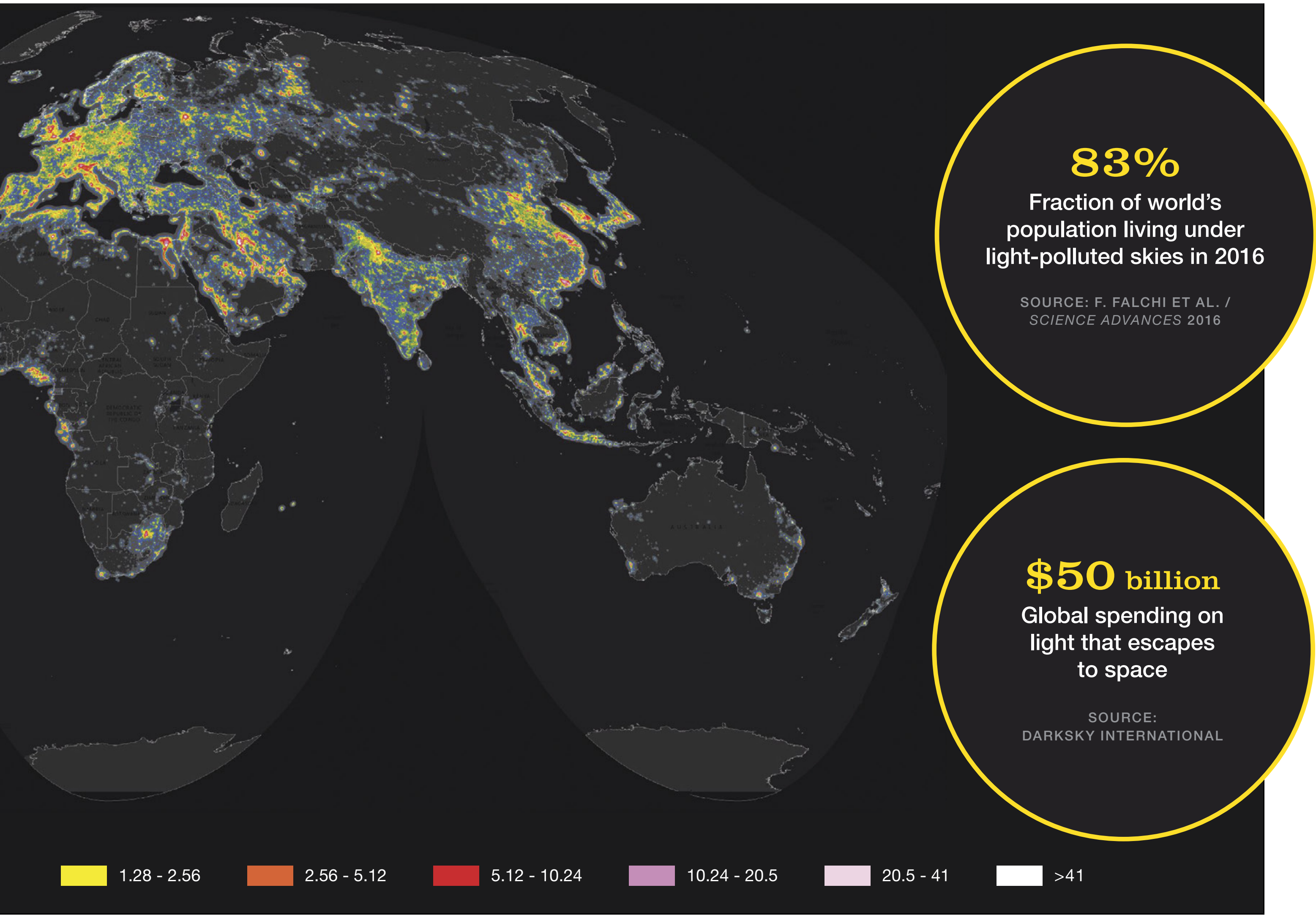
London in 1948, relocating to the grounds of Herstmonceux Castle in east Sussex. And in 1958 the city council of Flagstaff, Arizona, enacted what may be the world's first outdoor lighting law, intending to reduce the impact of lighting on astronomy.

Attention has since spread to a global level. Thirty-five years ago, two astronomers — one professional, one amateur — founded the International Dark-Sky Association, which recently rebranded itself as DarkSky International. From the outset, the organization intended to confront what was already an obviously global problem, not one limited to more technologically advanced countries. Some people began considering a "right to starlight" that international treaties might one day recognize. In 2007, a non-binding resolution sponsored in part by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the International Astronomical Union (IAU) declared that "an unpolluted night sky that allows the enjoyment and contemplation of the firmament should be considered an inalienable right equivalent to all other socio-cultural and environmental rights."

Where We Are Now

Astronomers began studying light pollution systematically in the 1970s, around the time the city of Tucson, Arizona, introduced the first comprehensive policy regulating outdoor lighting in the U.S. As computing power increased in the 1980s, the first sophisticated models of skyglow became available. Today, our most complete and up-to-date view of the issue comes from a combination of satellite remote-sensing observations of Earth at night and the efforts of thousands of citizen-scientists around the world who have contributed observations to the Globe at Night program.

Satellite observations tell us that on average during the early 2010s, the land area of our planet showing indica-



tions of nighttime lights — and the amount of that light — increased by about 2% per year. That's roughly double the rate of global population growth during the same period of time.

Meanwhile, the brightness of the night sky seen from the ground has continued to rise. Ten years of Globe at Night observations show a steep increase: an average of 10% per year at the level of country-size land areas. Much of the light causing this increase seems to be concentrated in and around cities. As the human population becomes increasingly urban, more people than ever are separated from the stars. While on a clear night under pristine skies the unaided eye might see as many as 4,500 stars, an observer in a large city might see 35 or fewer.

But light pollution is about much more than whether we can see the stars at night. We know that artificial light at night has a harmful effect on nearly all plant and animal species studied to date (see page 34). A clear link exists between ALAN exposure and adverse human health outcomes, but the influence of outdoor light sources specifically is largely unknown. And we know that, in at least some cases, racial minorities are exposed to more ALAN. A growing number of Indigenous individuals have also expressed concern about light pollution's impact on their living cultural traditions (see sidebar, page 33).

From an economic perspective, the wasted energy represented by ALAN escaping into the night sky is thought to account for about 1% of the world's greenhouse-gas emissions. And although outdoor lighting is often installed in the belief that its presence discourages crime and enhances personal security, no compelling evidence bears out that conclusion.

How We Got Here

There are several reasons that may explain how and why we use outdoor lighting as we now do. One is that the cost of generating light has plummeted, due to the energy-efficiency gains of white LEDs since their introduction to the international market in the early 2000s. LEDs cost more up front, but thanks to the long-term energy savings, the overall operating cost is much lower compared to earlier lighting technologies, making LEDs appealing to an increasingly large

▶ **GOOD LIGHTING** Carefully designed light fixtures make outdoor spaces pleasant without blotting out the sky. Shown are New Castle Library in Delaware *(left)*, a coworking community center in New York *(center)*, and Jennette's Pier in North Carolina *(right)*.

sector of the economy. However, instead of cutting our energy consumption with the adoption of LEDs, satellite data indicate that we've simply started using more light.

An obsessive focus on energy efficiency has fueled this over-consumption. Some may conflate efficiency with environmental benefits, regardless of the actual amount of electricity used. Lowering the cost of using outdoor lighting prompted both significant public investment in lighting technology and the widespread deployment of LEDs. For example, the U.S. federal government subsidized lighting retrofits in the early 2010s during the recovery from the Great Recession, leading cities to install lighting where it did not previously exist, whether or not there was any particular need for it.

Public policies also haven't kept up with the technology. Lighting ordinances and bylaws prescribing certain numerical thresholds based on older light sources mostly have not been adjusted to account for LEDs' higher light output at the same wattage. Nor have policies considered the increased glare from the shift to bluer wavelengths that LEDs often bring. These omissions have led to many instances of over-lighting relative to international recommendations.

Ongoing and Planned Initiatives

The thing is, we know how to fix this problem. Well-framed and implemented public policies can help preserve dark skies in and around observatory sites, and careful lighting design can measurably reduce skyglow. Efforts to shield and lower roadway lighting in Tucson, for example, have reduced streetlight emissions by about 15%. We can make even more headway if we address other kinds of lighting. In short, we know what works.

So why *isn't* it working? Here, too, there are many potential reasons. There is a persistent perception among the public that light pollution isn't "real" pollution. In the face of many other significant social and environmental issues, a sense of "issue fatigue" sets in, leading to complacency. And we are up against both a deep-seated cultural fear of darkness and the perception of rising crime rates. Meanwhile, we live in a time of hyperpolarized politics that lends itself to us-against-them views coloring almost every topic.

This all sounds like so much doom and gloom. But there are many reasons to be hopeful. Despite the ever-increasing reach of light pollution, amateur and professional astronomers alike continue to engage with the night sky. Backyard telescope enthusiasts share wondrous sights with excited audiences of all ages. Research astronomy continues to amaze with cutting-edge discoveries about black holes, faraway galaxies, and insights into the history of the universe. Casual stargazers enjoy vistas of the Milky Way while camping in places far from city lights, and increasing numbers of remote locales cater to "astrotourists" seeking starry skies.

Attention to the problem of light pollution has never been higher, and there is movement on several fronts, including activism, education and outreach, and public policy. DarkSky International remains the most visible and respected organization advocating for the protection of the night sky.

PHOTOS OF GOOD LIGHTING: JAMES BRIGAGLIANO / DARKSKY INTERNATIONAL (3); RESPONSIBLE LIGHTING INFOGRAPHIC: BEATRIZ INGLESSIS / *S&T*, SOURCE: DARKSKY INTERNATIONAL

Five Principles for Responsible Outdoor Lighting

USEFUL

All light should have a clear purpose. Also consider impacts to the surrounding environment and whether things like reflective paints would accomplish the same goal.

TARGETED

Light should be directed only where needed. Shield and aim beams downward, avoid spillage.

LOW LEVELS

Light should be no brighter than necessary. Use the lowest level required and be mindful of surfaces' reflectivity.

It now leads with the Five Principles for Responsible Outdoor Lighting (see below) and the Responsible Outdoor Lighting at Night Manifesto, providing simple guidance for decision makers, talking points for advocates, and a blueprint for urban planners and lighting designers.

In the United Kingdom, members of the All-Party Parliamentary Group for Dark Skies recently released their policy plan, "Ten Dark Sky Policies for the Government." This is a set of pragmatic policy recommendations that could be enacted by any legislative body, anywhere in the world. Several U.S. state legislatures have also debated or passed bills aiming to reform outdoor-lighting regulation. And the European Union is considering ways it could enact comprehensive light-pollution regulations at the Union level.

There is also now much more non-binding guidance available for governments, non-governmental organizations, and other institutions. This includes the outputs of the recent United Nations Dark and Quiet Skies conferences and guidelines like those published by the U.S. Bureau of Land Management and U.N. Convention on the Conservation of Migratory Species of Wild Animals.

Working on large-scale approaches is key. With more than 22,000 incorporated local governments in the U.S., it is increasingly clear that setting outdoor lighting policies through municipal ordinances and bylaws doesn't scale up well. One idea is to set up regional "light conservation districts" modeled on similar arrangements for conserving water and other natural resources. In this scenario, associations of governments would agree to cap regional light emissions at a rate that grows in proportion to the rate of population change. New lighting installations beyond these limits would require removing light elsewhere in the region in order to meet targets for truly sustainable growth.

In the long term, strategies to meaningfully slow the growth of light consumption might well connect with bigger national and international initiatives. One approach is to tie regulations to existing environmental laws. A model for this is the 2019 expansion of Mexico's General Law of Ecological Balance and Environmental Protection of 1988, which added light pollution to the list of legally declared environmental pollutants in that country. The legislation tasks the Mexican equivalent of the Environmental Protection Agency (EPA) with writing more specific regulations that become obligatory to the country's municipalities.

In the U.S., an equivalent effort might amend or clarify federal legislation like the National Environmental Policy Act (NEPA), which requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions. This would require Environmental Impact Statements and Environmental Assessments prepared under NEPA to explicitly include considerations having to do with outdoor lighting that might adversely affect the environment. The results might well filter down to the states, many of which have their own equivalent laws.

Some in the U.S. dark-sky community dream of a future act of Congress — call it the "Clean Night Skies Act," modeled on the spectacularly successful Clean Air and Clean Water Acts — that would identify artificial light at night as a form of environmental pollu-

CONTROLLED

Light should be on only when it's useful. Use controls such as timers and motion detectors to turn on/off or dim when appropriate.

COLOR

Use warmer-colored lights where possible. Limit the amount of blue-violet light in the spectrum.

tion and task the EPA with writing rules regulating its use.

Absent an act of Congress, the executive branch could take the lead. In 2020, DarkSky International published a letter to the incoming Biden Administration that included a suggested executive order to ensure that outdoor lighting on all federal properties complies with basic dark-sky principles. Specific federal agencies with responsibility for infrastructure, such as the Department of Transportation, could make similar rules for the nation's highways.

The international community may well arrive at these policy goals before the U.S. does. Besides the ongoing "Dark and Quiet Skies" initiative at the U.N. Committee on the Peaceful Uses of Outer Space, an effort is under way to add reducing light pollution to the agenda of the U.N. Development Programme's Sustainable Development Goals (SDGs). The proposed SDG18 ("Sky Quality and Access to Starlight") would formalize the idea of a right to starlight. Others have suggested that new legal interpretations, such as "Earth jurisprudence" and the "rights of nature," may be required to fully affect these changes.

Getting Involved

The history of social movements, whether for civil rights, environmental protection, or to achieve other goals, lends support for the old adage that "slow and steady wins the race." Light pollution is definitely having a moment, as it is increasingly recognized by governments, mass media, and the public. In many respects, it seems as though it is approaching the critical mass at which enough people not only know about the problem but also begin to demand solutions.

Everyone can do something that moves us toward this goal in meaningful ways.

First, get the facts. DarkSky International is a widely respected and trusted source of factual information about light pollution and dark skies. For example, it publishes an annual "State of the Science" report that summarizes the very latest research results in understandable, non-technical language. DarkSky International offers a wealth of advice on outdoor lighting practices and policies. The information can be easily shared with friends, neighbors, and elected officials. And in the belief that there is strength in numbers, the organization connects like-minded people and organizations around the world.

In the world of successful social movements, visibility is key. In addition to learning and sharing reliable information about light pollution, anyone can become engaged in issue advocacy. Speak up at meetings of your local city or town council during the call to the audience. Write a letter to the editor of a newspaper, magazine, or website. Post about light pollution and dark skies on social media. Offer to give presentations to community groups and in schools. Staff a table at events. The more the public hears about these issues, the more it gradually becomes sensitized to both the problem and its solutions. Groups like DarkSky International, the American Astronomical Society, and the International Astronomical Union offer resources that can help.

We also urgently need more information about how light pollution is changing the night sky, both in and near cities as well as in more rural areas. Amateur astronomers and the broader public alike are making important efforts to meet this need through citizen-science programs like Globe at Night. Estimates of night-sky brightness that users have contributed to this program have resulted in peer-reviewed scientific publications, giving us our best and most comprehensive global view of skyglow to date. Purpose-built night-sky brightness monitors are now inexpensive and easy to operate, enabling users to make long-term records of light-pollution impacts almost anywhere in the world. These data can be used to help direct mitigation efforts on local to regional scales and inform public-policy decisions about outdoor lighting regulation. Monitors placed in ecologically sensitive areas also aid land managers in pursuing effective conservation strategies.

Nathaniel Parker Willis's innumerable stars are still up and shining in order, although they are increasingly obscured by our cities. One might ask which will we choose: our light, or starlight? But this is a false choice. The question is not an either/or. Dark skies and a secure nocturnal environment can exist alongside robust economies and safe communities, but that coexistence hinges critically on changing the human relationship to artificial light at night.

The means to turn the tide are in our hands. Will ours be the generation that does it?

JOHN BARENTINE is an astronomer, historian, author, science communicator, and dark-sky consultant. **JESSICA HEIM** is a cultural astronomer whose work focuses on the intersection of culture with Earth, sky, and space environments.

Online Resources

- DarkSky International: **darksky.org**
- DarkSky report "Artificial Light at Night: State of the Science 2023": **zenodo.org/record/8071915**
- American Astronomical Society, "Information on Light Pollution, Radio Interference, and Space Debris": **aas.org/about/governance/light**
- International Astronomical Union, "Controlling Light Pollution": **iau.org/public/themes/light_pollution**
- Astronomical Society of the Pacific, "Dark Skies and Light Pollution: A Resource Guide": **https://is.gd/asp_darkskies**
- Royal Astronomical Society of Canada. "Light Pollution Abatement": **rasc.ca/lpa**

Cultural Astronomy

Cultural astronomy is a field focused on the many ways people have observed and interacted with the night sky across time and place. It delves into the diverse and rich star knowledge that is still held by communities around the world. Working in this highly interdisciplinary area, one quickly becomes aware that Western astronomy is not the only astronomy. There is an incredible wealth of knowledge about the night sky held by these communities.

Many living traditions see the starry sky as a part of the environment that's just as important as the land, air, and water. In these traditions, Earth and sky are intrinsically connected; there is a sense that what happens in the sky and on Earth are related, as expressed in the phrase "as it is above, it is below." In this view, humans are continually in relationship with and participating in diverse aspects of the Earth-sky environment.

Light pollution is an existential threat to these traditions. It is difficult to maintain connections to the sky and the associated teachings if people cannot see these celestial phenomena amid ever-increasing skyglow. In fact, some have likened the impact of light pollution to "an ongoing form of cultural genocide," a form of "slow violence" that gradually, but insidiously, impairs their ability to maintain living knowledge systems that are inextricably connected with the starry skies above. While it may not be the intent of those creating light pollution to hurt anyone, the result is still the same, they argue.

Many Indigenous communities are still dealing with the ramifications of colonization and years of forced suppression of their languages and traditions. But there are increasing native-led efforts to preserve and share their communities' star knowledge. For example, Annette Lee's Native Skywatchers initiative seeks to "revitalize Indigenous star and Earth knowledge" and "to inspire all people to have a rekindling or deepening sense of awe and personal relationship to the cosmos" (**nativeskywatchers.com**), while Wilfred Buck shares night-sky teachings in his book *Kitcikisik (Great Sky): Tellings That Fill the Night Sky* and in other contexts as well (**acakwuskwun.com**).

Astronomy is not something just to read about in a book, view on a screen, or ponder through an eyepiece. It is something to be experienced and lived. Preserving dark skies is essential in order to ensure the survival of a world in which people may still come face to face with the magnificent universe of which we are all a part, and to create a future in which humanity's star knowledge will continue to inspire and enrich future generations.

ANDREY KOZHEKIN / SHUTTERSTOCK.COM

No Creature Comfort

Artificial light at night robs us of more than the stars.

I give a lot of talks about light pollution and its effects on things other than our view of the stars. Everyone working in light pollution generally has a story about dark skies and being inspired by the aurora borealis (or australis) or a first view of the Milky Way. The threat of light pollution to that experience is easy to explain, visceral.

But many people have never experienced the Milky Way firsthand. Those billions of people growing up in cities around the world, often without the personal capital to travel outside the surrounding glow, have no experience with, let alone connection to, the night sky.

One of the ways in which I try to connect with such urban audiences is to talk about the effects of light pollution on things more familiar to them. These include human health — everyone has experience with sleep disrupted by lights, sooner or later — and wildlife that they may know and care about.

It should come as no surprise that anthropogenic light at night (that is, light from human sources) affects living organisms. And yet, it *does* surprise people. It also surprises them that many creatures in the marvelous landscapes surrounding us are falling prey to the effects of nighttime lighting, and that they themselves may suffer the medical consequences of long-term exposure.

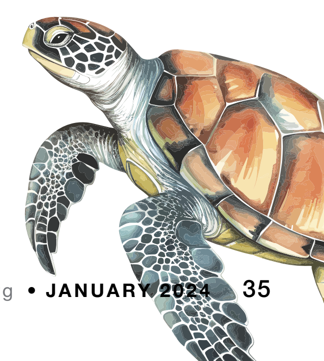
For all of evolutionary history, the major patterns of light and dark were defined by Earth's rotation, the Moon reflecting the Sun's light back at us, and the stars and other glowing phenomena of the sky. Daily, monthly, and seasonal patterns were so predictable that they became the metaphor for predictability — like clockwork.

As a result of this predictability, many events in life are tied to light levels. Birds begin their dawn song when the light levels increase to a certain point. Gerbils come out to search for food when moonlight is low and darkness provides a refuge. Moth-pollinated flowers open as dusk falls. Some plants set seed as daytime shortens. Humans (usually) sleep at night. All of these rhythms are tied to light levels that had billions of years of predictability.

In nature, whenever there are predictably variable resources available in an environment, species will evolve to specialize and divide up those resources. Some birds specialize in looking for food in the highest branches of trees, some in the lowest branches, some on the ground, and some wherever they can (this last group is known as *generalists*). Over the long arc of the history of life on this planet, species have evolved to exploit all the different conditions of darkness — and, in doing so, have come to rely on those conditions for their survival. The darkest nights of the month, the *crepuscular* period between night at day, and the full Sun of noon are all unique conditions to which species have adapted. The generalists may be able to persevere if part of that natural variation is curtailed, but the specialists will not. So it is that light pollution, through simplifying the physical environment and eliminating certain conditions, threatens some species' persistence.

In any given system, although generalists may be numerous in terms of individuals, the number of specialist species can be equal or greater. A world without the species that need the natural patterns of light and darkness would be depauperate indeed.

The effects of light at night on the natural world fall into three main categories: 1) movement, including attraction, disorientation, and resulting fragmentation; 2) disruption of ecologi-



◀ **CAPTIVATED** Thousands of moths swarm around floodlights at the Newcastle United Jets home game at EnergyAustralia Stadium (today, McDonald Jones Stadium) in Newcastle, Australia, on October 1, 2005.

MOTHS AT NIGHT LIGHT: FAIRFAX MEDIA / GETTY IMAGES; MOTH ILLUSTRATIONS: ARTOPHOTODESIGNO STUDIO / SHUTTERSTOCK.COM; SEA TURTLE ILLUSTRATION: TANVIR AHMED SIDDIQUE / SHUTTERSTOCK.COM cal interactions between species; and 3) disruption of those daily, lunar, and seasonal rhythms, which also encompasses the effects light at night has on humans.

Outdoor light that penetrates into bedrooms in a major city can be more than double that of a full Moon — within the same order of magnitude as the melatonin suppression threshold.

Movement and Its Consequences

Influences on animal movement are some of the most well-known effects of light at night, because they can leave dead bodies on the ground. Sea turtles are one familiar example. Female sea turtles normally lay their eggs in nests they excavate on sandy beaches. Once the baby turtles hatch, they emerge from the nest and head for the ocean. Before the advent of electric lighting, the hatchlings simply crawled away from the darkest horizon — which was always the landward dune and vegetation — to find the water.

Coastal and offshore development and lighting have altered these patterns. Lights disorient and misorient the hatchlings, so that they are much less likely to reach the ocean. Recent studies have shown that even skyglow (scattered light in the atmosphere from artificial lighting) can be bright enough to confuse hatchling turtles. Female turtles will also not lay on beaches that are brightly lit, reducing the area of habitat available to them.

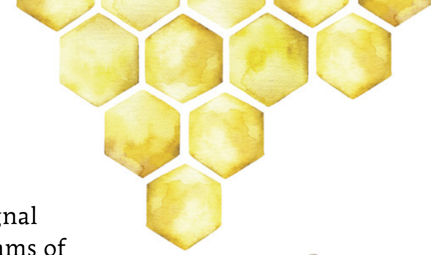
Although some jurisdictions have enacted lighting limitations to protect nesting sea turtles, there remain many tropical beaches around the world where anthropogenic lights threaten these animals.

Other creatures also go toward the light. Many groups of insect species are attracted to lights, so much so that their behavior has been woven into the imagery of language ("like a moth to a flame"). Insects are essential to the functioning of the natural world — think pollination and decomposition — but are in global decline. Some locations have seen upwards of 75% fewer insects in the last three decades, leading to fears of an "insect apocalypse." We suspect light pollution is one of the causes, because lights can draw insects significant distances away from their natural habitats and into areas dangerous for them.

Some insect species flee light instead, while others simply become quiet and do not move at a time when they would normally be active. The degree of such effects is often related to the contrast between the light and the ambient conditions, such that even a dim light in an environment with little light pollution is highly attractive to insects.

Birds, too, are attracted to light, through mechanisms that researchers have not yet fully been able to explain. People have used fire and lights to hunt birds for centuries, and great masses of birds have been recorded at light sources such as lighthouses, lightships, communication towers, buildings, ceilometers (beams of light directed at the sky to measure cloud height), and light displays erected for aesthetic purposes. The annual 9/11 Tribute in Light in New York, for instance, draws around 160,000 birds to its beams in a single night. Very often the species attracted by lights are normally

WILDFLOWERS: NIKIPARONAK / SHUTTERSTOCK.COM; STATS: SOURCE: C. A. HALLMANN ET AL. / *PLOS ONE* 2017



active during the daytime but migrate at night. These birds may die when they collide with lit structures, especially glass windows as day breaks.

Research with weather radar, which is sensitive enough to detect individual birds, has shown that birds are indeed attracted to lighted areas from even kilometer-scale distances and that anthropogenic light influences the distribution of birds across the landscape during their migration. In these cases, the birds aren't choosing their stopover habitats because the locations are the highest quality but because they're lured by lights. As a consequence, migrating birds are exposed to the excess dangers associated with urban conditions.

A major consequence of animals changing their movement patterns in response to lights can be the fragmentation of landscapes into smaller pieces. Lights themselves can create a barrier to movement, acting alone or in concert with other features such as roads. In aquatic environments, for example, bridge lights can prevent young salmon from migrating downstream, even without a physical barrier in their way. Young salmon naturally move during darkness, and when under lights they will hunker down like it's daytime. Some species of bats commuting from their roosts will avoid lighted areas and consequently must fly around them. Researchers think these behaviors are attempts to avoid being seen by predators.

In other instances, nocturnally active species avoid lights to reduce contact with humans. Several studies show that mountain lions keep to the darkest parts of the landscapes they are in and will avoid areas with lights. For this reason, controlling lights and creating dark pathways of approach is important for the design of wildlife-crossing structures for roadways.

Physiology: A Matter of Timing

Artificial light also serves as a signal that affects the timing and rhythms of organisms, resulting in a wide number of physiological and behavioral changes. It is here where research on human health and on other species overlaps.

Nearly every organism that lives on Earth's surface (as opposed to in the abyss of the ocean or deep in caves) has intrinsic daily rhythms that are kept synchronized by light. Exposure to light at night, even at relatively low levels, can upset those rhythms. Researchers have extensively investigated this for humans, often using mice as a model organism. Exposure to light at night has been associated with a whole suite of diseases, most notably breast, prostate, and several other cancers, as well as diabetes, obesity, sleep disorders, depression, and stress.

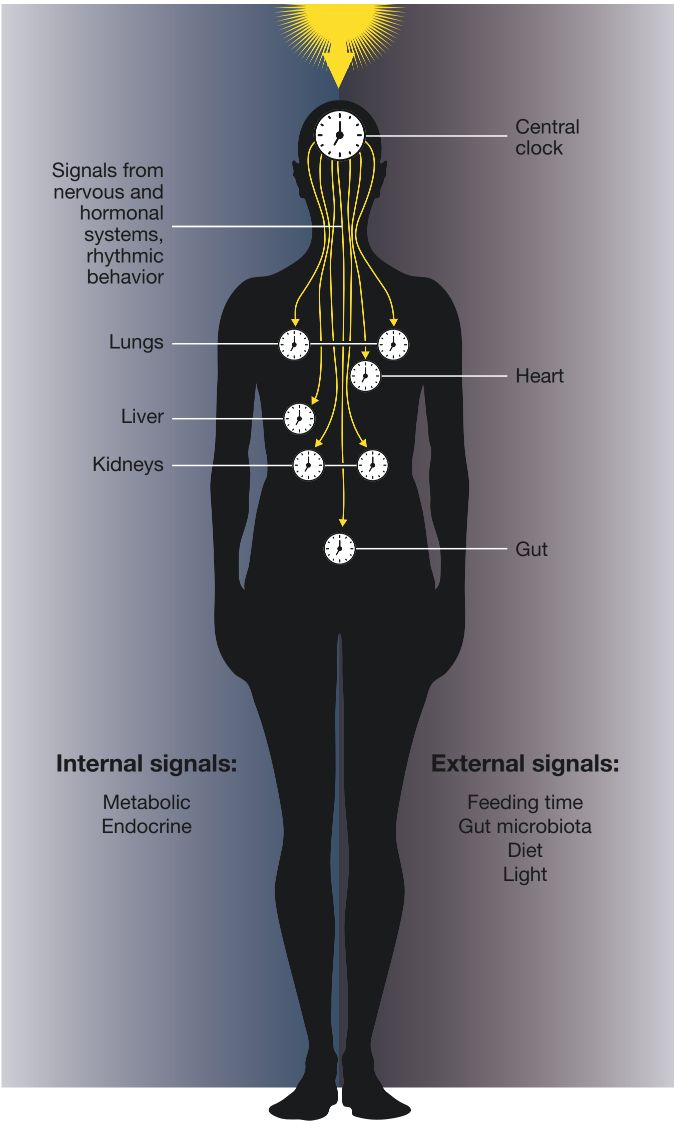
For breast cancer, researchers think nighttime light exposure prompts disease by suppressing the production of the hormone melatonin. Melatonin serves many roles in regulating systems in the body, suppresses cancerous growth, and is produced only in the dark. Large studies consistently connect outdoor nighttime lighting levels measured by satellites with

▼ **SOYBEANS** This drone photo of a soybean field in Fairview, Alabama, shows how the crop's behavior changes when exposed to artificial light at night. Under normal conditions, the soybeans mature, die, and dry out (brown areas), after which they're harvested. But near the streetlight, the plants stay green. Note the long brown strip inside the green area: This is where the pole's shadow blocked light from reaching the plants, enabling them to mature naturally.

HONEYCOMB: ALEKSA__CH / SHUTTERSTOCK.COM; BEE: BELENOVA_ART / SHUTTERSTOCK.COM; SOYBEANS: BEN TANKERSLEY / ALABAMA COOPERATIVE EXTENSION SYSTEM elevated rates of breast cancer. Of course, much of the light that humans are exposed to at night is self-directed (indoor lighting, devices, computers, televisions), but outdoor lighting is still highly correlated with risk.

My own preliminary research with my students indicates that outdoor light that penetrates into bedrooms in a major city can be more than double that of a full Moon — within the same order of magnitude as the melatonin suppression threshold (about 5 lux, similar to civil twilight). Individuals vary enormously in their sensitivity to light at night, though, with some people being up to 50 times more sensitive than others.

The association between increased outdoor light and sleep disruption is quite strong. In a recent study, my colleagues and I showed that light at night is a significant influence even when considering other stressors like noise, air pollution, and lack of green space. Sleep disruption is associated with cardiovascular disease, diabetes, and cancer. But because our study was based on survey results, we could not conclusively tie the effects to melatonin suppression.



▲ **CIRCADIAN RHYTHM** Light exposure sets the master clock in the brain. The brain in turn sets clocks in various organs via nervous and hormonal signals. External and internal factors influence these peripheral clocks, too: Internal signals include metabolic and endocrine sources (such as body temperature and hormones), and external signals include light, feeding time, gut microbiota, and diet composition.

BEATRIZ INGLESSIS / S&T, SOURCE: K. SU ET AL. / BRAIN, BEHAVIOR & IMMUNITY—HEALTH 2022

Wildlife species can be up to 1,000 times more sensitive to melatonin suppression by light than humans, so they must be experiencing the adverse effects of light at night in their most basic inner workings. Birds are one example.

Lights, as a signal of seasonal timing, induce birds to lay eggs. This was noted first in London in the 1920s, where starlings were ready to breed earlier when they lived close to streetlights. Poultry growers harnessed this technique, stimulating decades of research on the timing and types of light to maximize not only egg production but growth for human consumption. To this day, the industry uses lights to keep the billions of hens around the world laying as desired.

Even plants react to artificial lighting. Under normal circumstances, soybeans set seed when the number of daylit hours dwindles. Once they set seed, they die and can be harvested. But under streetlights and in fields affected by lights, soybeans never set seed — they don't know that summer has ended, because the artificial lights make it seem as though the daylight levels remain the same.

Humans also can exhibit seasonal and monthly patterns in response to the light environment. At high latitudes, humans show a seasonal pattern of melatonin production, with more produced during the winter and less during the summer. Urban residents, however, who are exposed to more artificial light at night, do not show this pattern. Recently, researchers have also shown that human sleep in the absence of electric light shows a monthly pattern that tracks the illumination from the Moon. A similar but smaller lunar influence was found in the sleep patterns of a nearby village that did have electric lights, and it was still detectable in college students in a highly urbanized North American city. Whether the lunar patterns' weakening results from illumination in the urban environment remains to be proven, but the patterns' presence indicates how much human sleep is influenced by the environment.

Spectrum Matters

The effects of light pollution are amplified or reduced by the light's color. Outdoor lighting often involves broad-spectrum white lights, which emit a wide range of wavelengths. This light triggers both humans' daytime (color) and nighttime (monochromatic) vision. But other species form images using light at wavelengths outside the sensitivity of human vision. Many non-human species, including some insects, spiders, birds, reptiles, amphibians, and mammal species, see very short wavelengths in the ultraviolet range, while humans generally do not because we filter these wavelengths out in our corneas. Insects in particular are attracted to ultraviolet light, making them vulnerable to lamps that emit in this range.

116 minutes
Time before civil dawn when robins began singing in a light-polluted town

48 minutes
Time before civil dawn when robins began singing in a rural area

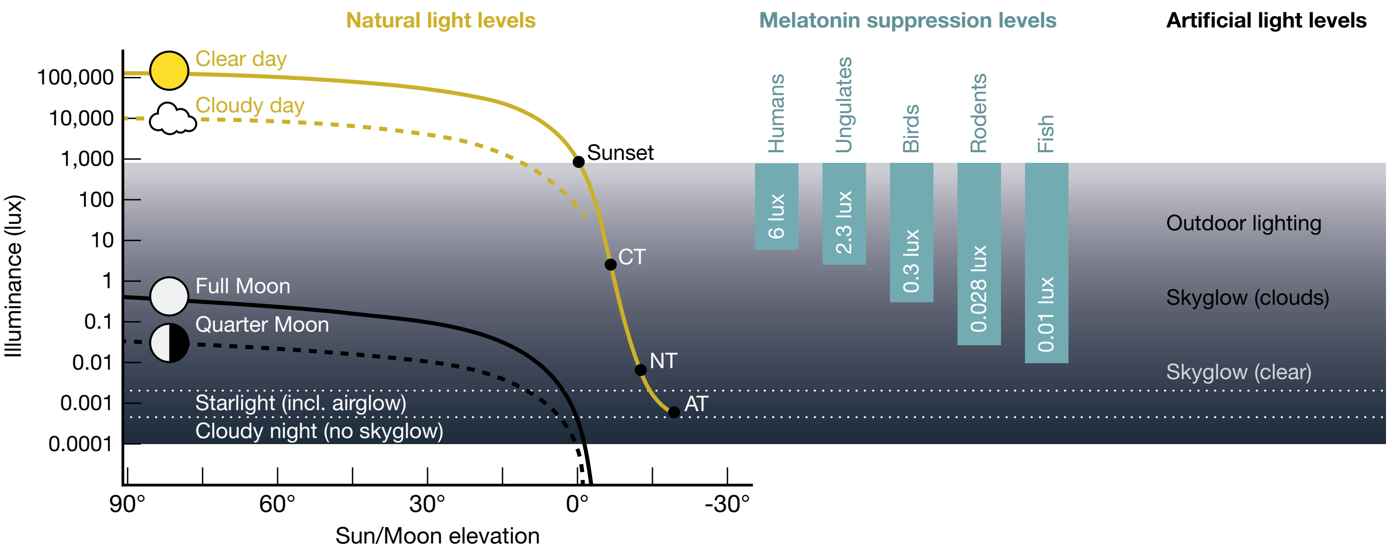
9 minutes
Time before civil dawn when robins began singing in a dark-sky area

I recently compiled and digitized visual sensitivity information for a wide array of terrestrial wildlife species, pulling from published studies dating from the middle of the 20th century to today. I was looking for similarities in the degree to which different groups of animals respond to different light colors, to find out which areas of the spectrum we should avoid. It was not a new idea: Estimates of the degree to which moths are attracted to short (ultraviolet, violet, and blue) and long (red and yellow) wavelengths have been around since the 1960s, and several research groups have suggested using color to mitigate the ecological and health effects of light pollution.

After compiling results from 175 measurements scattered across nearly as many studies, I found considerable variation. But on average, the light sensitivity of terrestrial species' eyes follows a double-peaked wave: We have one peak of sensitivity to ultraviolet light, relatively high sensitivity to blue, another peak in response to green light, declining sensitivity to yellow, and then lowest sensitivity to red. Importantly, the peak sensitivity of human color vision is offset to longer wavelengths from the peak sensitivity of most other species, suggesting that the use of lights that are yellow and red instead of white could provide visibility for humans while reducing their apparency to other species.

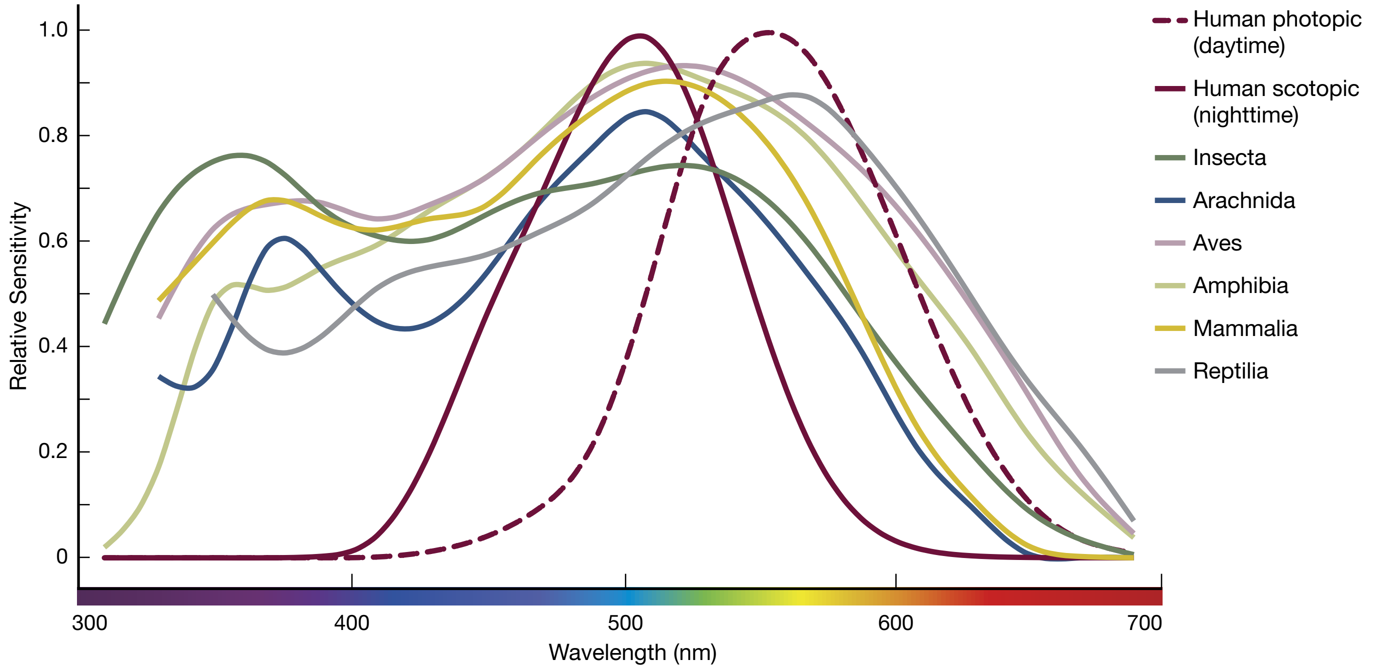
The lower effect of amber and red will come as no surprise to amateur and professional astronomers, who have long relied on red-hued lights to preserve their night vision. But the benefits go far beyond detecting faint fuzzies in telescopes. Light that is more visible to a given species should have a larger impact on behaviors that arise from its visual perception. With this new database, I could calculate the likely effect of lights with different color compositions for groups of organisms — birds, mammals, amphibians, reptiles, insects, and spiders. To do this, I used a technique my colleagues and I had previously developed to compare the light from different real-world sources based on their *correlated color temperature* (CCT), which describes the proportions of different wavelengths in the light.

Those calculations predicted greater effects for lights at higher color temperatures (bluer) and lower effects for lower color temperatures (more yellow and red). The predicted effect was more pronounced for some groups (mammals, insects, spiders) than for others, but it held true across all groups. For example, light-loving insects tend to be more



▲ **LIGHT AND MELATONIN** Natural light levels change throughout the day and month (left). When light levels rise to a certain threshold, animals stop producing the key hormone melatonin (center, minimum light levels shown). But typical artificial light at night (right) can exceed these thresholds. Human sensitivity to light varies widely — on average, 25 lux will suppress melatonin production by 50%, but some people are sensitive to much less, while others can handle 10 times more. CT = civil twilight, NT = nautical twilight, and AT = astronomical twilight.

ROBIN: MIS VECTOR / SHUTTERSTOCK.COM; STATS: SOURCE: M. W. MILLER / *THE CONDOR* 2006; MELATONIN GRAPH: BEATRIZ INGLESSIS / *S&T*, SOURCE: M. GRUBISIC ET AL. / *SUSTAINABILITY* 2019, A. J. K. PHILLIPS ET AL. / *PNAS* 2019



▲ **SEEING THE LIGHT** Each class in the animal kingdom (six shown here) reacts in its own way to different wavelengths, although there are a lot of similarities. These average sensitivities have a similar peak to those of humans' day and night vision, but we are far less sensitive to short wavelengths than other animals are.

attracted to shorter wavelengths, and horses and related species shouldn't be disturbed by red light at night because it's at the edge of what they can see. This would also apply to most insect groups and some species of rodents, as well as bats.

The prospect of using color to reduce lights' impacts comes with some conspicuous exceptions and challenges. Bioluminescent species such as fireflies are often sensitive to the very yellow to amber wavelengths that are less harmful to other species. For these groups, which communicate using light, it is far better to avoid exposing them to stray light altogether. The other challenge is that some species are sensitive to light no matter where it is on the spectrum, so spectrum is not a "get out of jail free" card that allows indiscriminate use of light without adverse effects.

My work looked at color vision, which uses photoreceptors called cones; we also have rods, for dim light. But our eyes, as well as those of other species, also have daylight detectors that set our circadian rhythms yet don't contribute to vision. These photoreceptors are most sensitive to blue light, very close to the color of the blue sky, because before artificial light we only encountered bright bluish light during the day. The deleterious effect on our internal clocks — which govern our sleep patterns — gives another reason to avoid blue light at night.

Takeaways

We can conclude a few things from the research covered here. To minimize the impact on wildlife, plants, and even ourselves, we need to control both light levels and light colors in nighttime environments. We should avoid shorter wavelengths (ultraviolet through blue) in favor of yellow and red, to enable us to see at night while reducing adverse effects on other species.

But the best solution is to reduce light overall and direct it only where it is needed, when it is needed. From a technical perspective, this means shielding lights to make them "full cut-off," so that no light escapes upward, and directed, so that light falls on its target and not in nearby habitats.

For color, I recommend lights with a CCT less than 2200K, which looks like warm candlelight. Such lights are increasingly available from manufacturers who recognize the growing market potential, as awareness of the impacts of light pollution grows.

Once the harms of disrupting darkness are explained, people tend to intuitively understand them and are open to supporting better lighting. When I give presentations, I hear stories about sleep lost from a neighbor's light and hear wonder at the nuanced patterns of activity in response to light at night. Some places we should not light at all, but great strides could be made by simply lighting better — in a way that is less wasteful and aware of the natural rhythms of life on Earth.

■ **TRAVIS LONGCORE** is an adjunct professor at the UCLA Institute of the Environment and Sustainability and co-chair of the Environmental Science and Engineering (D.Env.) Program.

FURTHER READING: Catherine Rich and Travis Longcore, eds. *Ecological Consequences of Artificial Night Lighting*. Island Press. 2006.

BEATRIZ INGLESSIS / S&T, SOURCE: THE AUTHOR

2 **EARTH** is at perihelion, its closest point to the Sun for 2024, at a distance of 91.4 million miles (around 3% closer than at aphelion in July).

3 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 11:12 p.m. EST (8:12 p.m. PST; see page 50).

4 **MORNING:** The brief Quadrantid meteor shower peaks in the small hours of the morning. The waning crescent Moon shouldn't hamper viewing too much. Go to page 50 for further details.

5 **MORNING:** The Moon, two days past last quarter, trails Spica by some 4° as they rise together in the east-southeast. Turn to page 46 for more on this and other events listed here.

6 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 8:01 p.m. EST.

8 **DAWN:** Face southeast to see the waning crescent Moon very near Antares (see page 48). Venus blazes upper left of the pair.

9 **DAWN:** The thin lunar crescent, Venus, and Mercury form a triangle above the southeastern horizon before sunrise.

14 **DUSK:** The waxing crescent Moon sits some 7° upper left of Saturn in the southwest. Watch as the duo sinks toward the horizon in deepening twilight.

18 **DUSK:** Look high in the south to see the Moon, a day past first quarter, about 3° upper left of Jupiter.

20 **DUSK:** The waxing gibbous Moon is in Taurus where it gleams some 5° lower left of the Pleiades. Face southeast to take in this sight.

23 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 9:57 p.m. PST.

24 **DUSK:** The almost-full Moon is in Gemini where it hangs above the eastern horizon, 3½° below Pollux.

26 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 9:46 p.m. EST.

27 **DAWN:** Look low in the southeast to see Mars and Mercury ¼° apart — you'll need binoculars to tease them out of the brightening sky. Venus shines upper right of the pair.

27 **EVENING:** The waning gibbous Moon rises in the east-northeast trailing Leo's lucida, Regulus, by some 4½°. Follow the pair as they climb higher during the night.

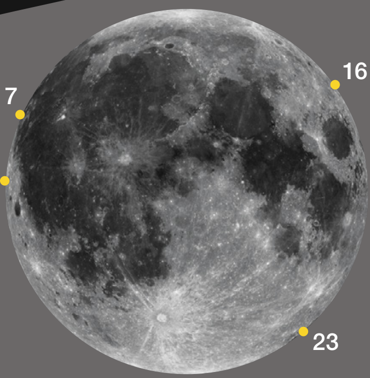
31 **EVENING:** Face east-southeast to see the Moon, a few days shy of last quarter, a bit less than 1½° upper left of Spica in Virgo.
—**DIANA HANNIKAINEN**

▲ The northern lights illuminate the skies above Metsähovi Radio Observatory in southern Finland. MERJA TORNIKOSKI

JANUARY 2024 OBSERVING

Lunar Almanac

Northern Hemisphere Sky Chart



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

MOON PHASES

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

LAST QUARTER

January 4
03:30 UT

NEW MOON

January 11
11:57 UT

FIRST QUARTER

January 18
03:52 UT

FULL MOON

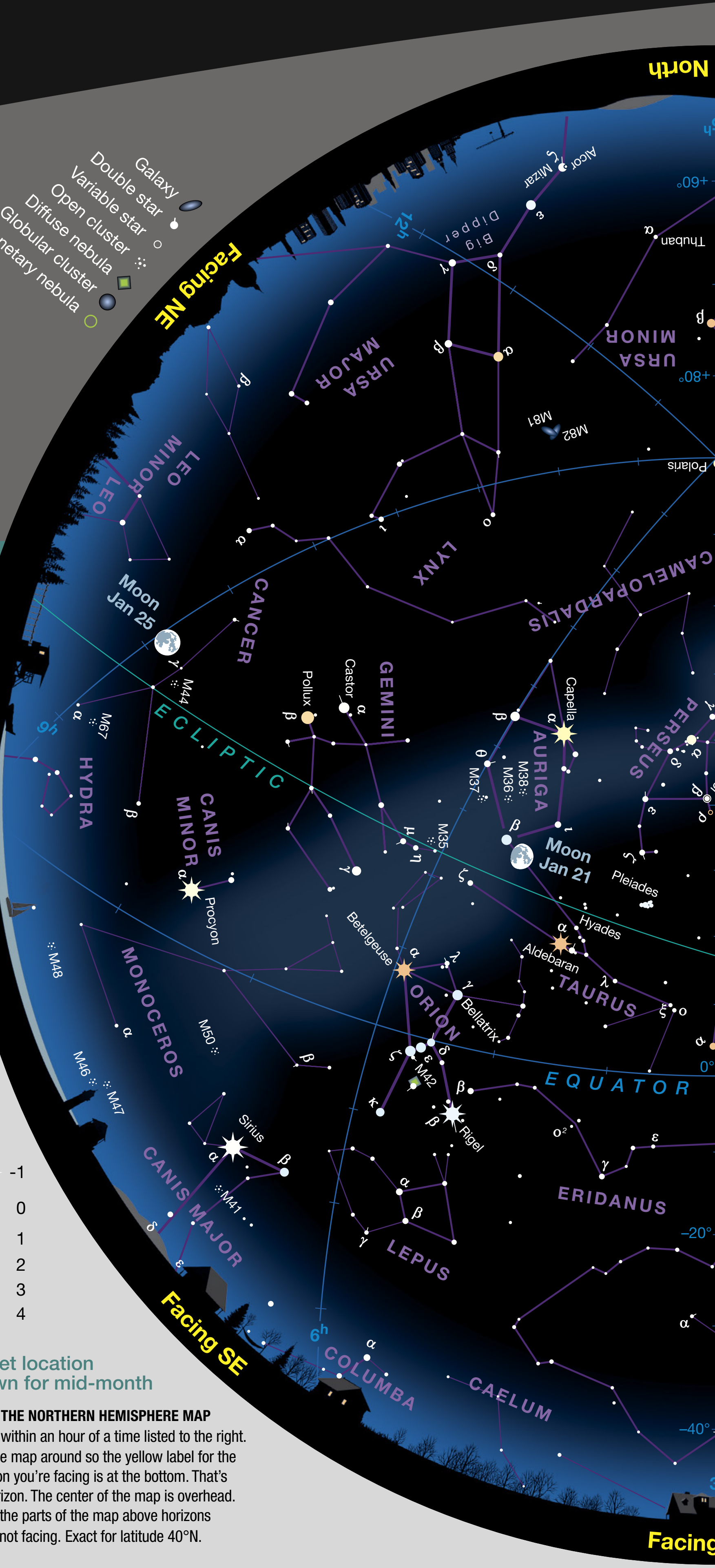
January 25
17:54 UT

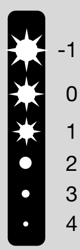
DISTANCES

Apogee	January 1, 15h UT
404,909 km	Diameter 29′ 31″
Perigee	January 13, 11h UT
362,267 km	Diameter 32′ 59″
Apogee	January 29, 8h UT
405,777 km	Diameter 29′ 27″

FAVORABLE LIBRATIONS

• Schluter Crater	January 5
• Lacus Veris	January 7
• Hahn Crater	January 16
• Mare Australe	January 23

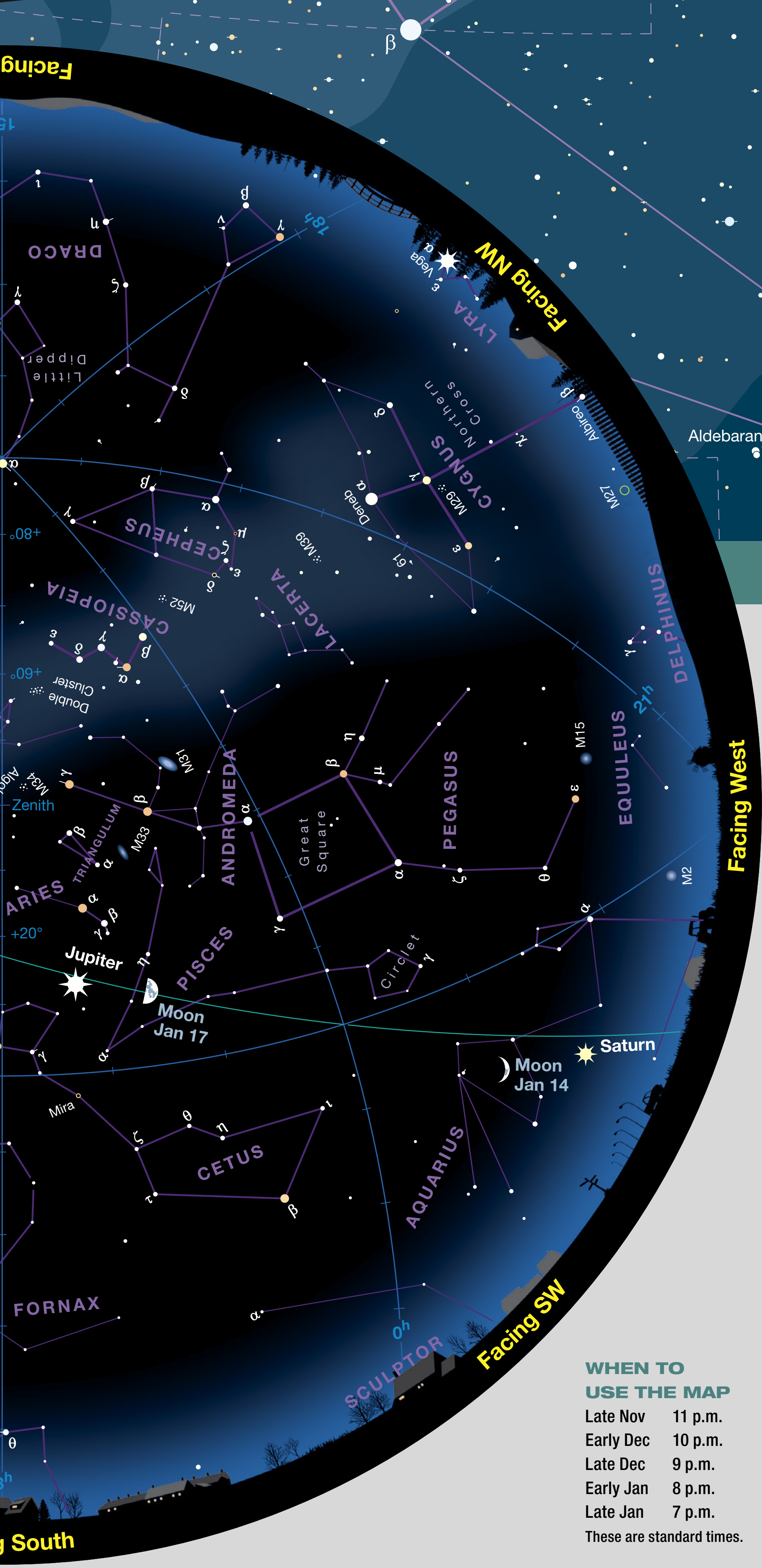




Planet location shown for mid-month

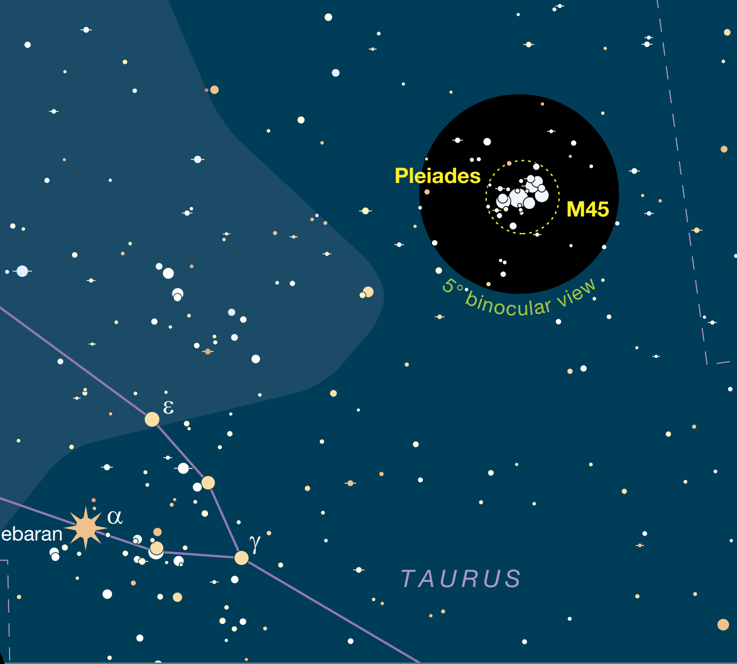
USING THE NORTHERN HEMISPHERE MAP

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.



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.



Binocular Highlight by Mathew Wedel

Starry Messenger

Our target this month probably has a better claim to being a "binocular highlight" than anything else in the northern sky. It's the **Pleiades** (M45), the crown jewel of the constellation Taurus, the Bull.

Let's address the celestial elephant in the room: There's not a lot to say about the Pleiades that hasn't been said before. This conspicuous, naked-eye open cluster has captivated people for thousands of years, and cultures around the globe left records in which they acknowledged, named, and revered the Pleiades.

But set all that aside for a moment and approach the Pleiades with fresh eyes. Try to see the cluster as our ancestors must have, looking skyward as they followed mammoth herds across the steppes, braved the vast expanses of the Pacific in dugout canoes, built massive open-air observatories of soil and stone, and — eventually — employed the first telescopes.

If you can, find a quiet spot, take a few minutes to mentally unplug, and let the rest of the busy, interconnected world recede into the background. Try not to *observe* the Pleiades so much as *discover* them. Galileo was pleasantly surprised to see the Pleiades as a swarm of stars in his simple, 30× refracting telescope, and he plotted no fewer than 36 of them in *Sidereus nuncius* (*Starry Messenger*). How many can you count with your binoculars? Can you detect the elusive, dusty reflection nebula in which the cluster is entangled? What details hover at the edge of vision, only coalescing with time, dark adaptation, and patient study?

Imagine you had just chanced upon this wonder for the first time. What stories would you tell about it, and with whom would you share them?

■ **MATT WEDEL** discovered the Pleiades in his binoculars in the spring of 2008, and he still hasn't quite recovered.

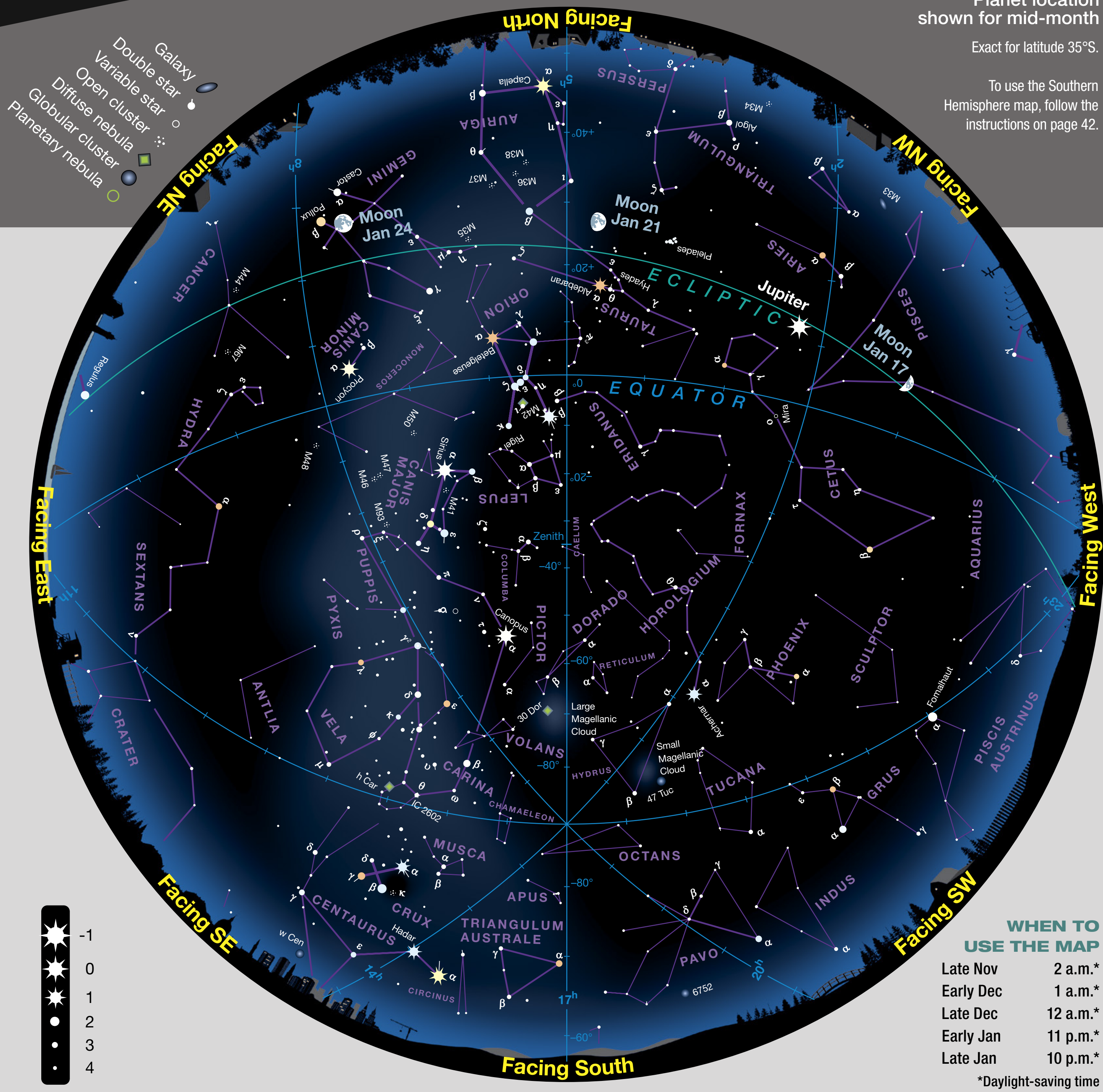
Southern Hemisphere Sky Chart

by Jonathan Nally

Planet location shown for mid-month

Exact for latitude 35°S.

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



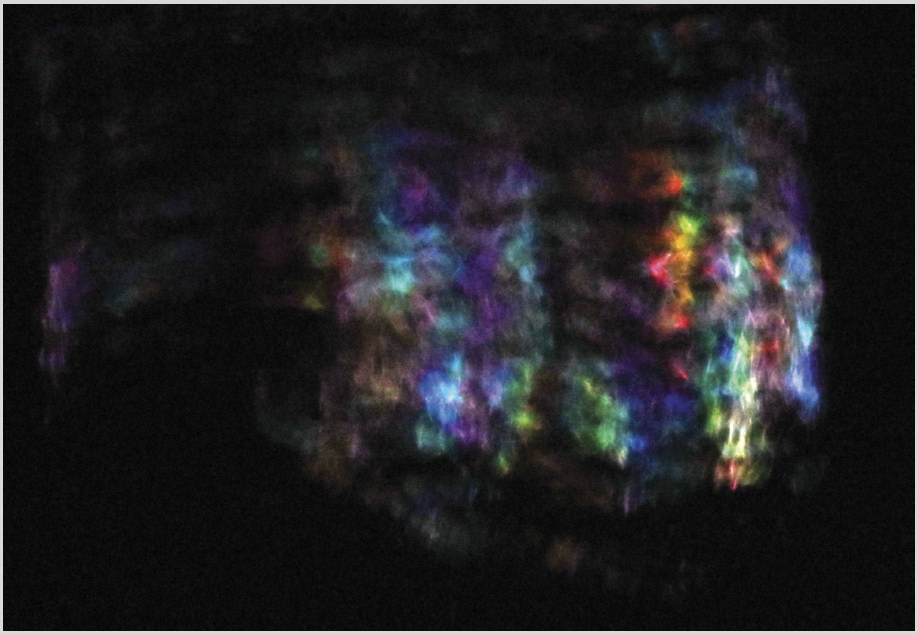
WHEN TO USE THE MAP

Late 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

DEEP IN JANUARY'S southern sky are two celestial showpieces — the **Large and Small Magellanic Clouds** (LMC and SMC, respectively). Easily visible from dark locations as two foggy expanses, they're a bit harder for city dwellers to discern. Each is a small galaxy orbiting our own Milky Way, with the LMC about 160,000 light-years away and the SMC around 200,000 light-years distant.

The LMC is a marvelous sight and contains many fine telescopic objects, especially the huge region of ionized gas known as the Tarantula Nebula (plotted on our chart as **30 Dor**). Famously, the first bright supernova for almost 400 years was spotted there in February 1987 and became known as SN 1987A. The SMC is a splendid sight, too — while there, look for the naked-eye globular cluster **47 Tuc** nearby. ■



STEPHEN JAMES O'MEARA

◀ **SCINTILLATING SPECTACLE** This long-exposure photo captured in November 2018 with a 400-mm telephoto lens reveals the coruscations of Sirius as reflected on the surface waters of the Okavango Delta in Botswana.

Scintillating Sirius

Watch the brightest star in the night sky perform kaleidoscopic feats on dark winter nights.

How many of us, I wonder, can recall a cold winter's night when Sirius rose above a snowy landscape sparkling like fire-fused crystal? The star's original Greek name (Seirios) has a plethora of radiant meanings: glowing, sparkling, flaming, scorching, and flamboyant, to list but a few. Watching Sirius scintillate is arguably one of the most animated, colorful sights in the night sky.

Sirius resides in the constellation Canis Major, the Great Dog, and is a white-hot star with almost twice the mass of our Sun. It's only 8.6 light-years distant, so its status as the brightest star in the entire heavens is largely linked to its proximity. When seen on high from the Southern Hemisphere, this brilliant beacon shines with a steady, pure light. But from mid-northern latitudes, Sirius sails much lower in the sky, where it can twinkle with rapid flashes of kaleidoscopic color — especially as it rises or sets. Aware that Sirius was not alone in its colorful tantrums, Greek polymath Eratosthenes grouped all such stars as *seirioi* (the plural of seirios) "due to the quivering motions of their light."

Early astronomers wondered if these rapid changes arose from internal paroxysms of the star. Of course, we now know they're related to turbulence in Earth's atmosphere, but that doesn't diminish the visual magic performed by Sirius, whose colorful coruscations are unrivaled. American astronomer Garrett P. Serviss captured the essence of scintillating Sirius in his 1908 book, *Astronomy with the Naked Eye*:

> *[Sirius] has a hundred moods, according to the state of the atmosphere. Sometimes, when the air is still, the star burns with a steady white light, unflickering, like a core of electric fire; then, as invisible atmospheric waves flow over it, its rays spread and leap and flutter, breaking into keen prismatic darts that almost cause the eye to wince. By turns it flames, it sparkles, it glows, it blazes, it flares, it flashes, it contracts to a point of intensest brilliance or expands into a coruscating spectrum.*

Indeed, early Arab skywatchers knew Sirius as the star "of a thousand colors." And while that interpretation leans toward the fantastic, mid-19th-century experiments by French physicist Charles Montigny using a scintillometer revealed that Sirius can have nearly 70 color changes in a second — even when the star is about 30° above the horizon. But the show is so much more intense when Sirius is lower in the sky, as it appears on this month's Northern Hemisphere sky chart, where it's plotted with an altitude of only about 10°.

The drama begins when the star's light enters our atmosphere. Moving air cells provoke the incoming light to pulse into and out of focus (causing light rays to rapidly converge and diverge, respectively) or to disperse (so that each ray of light follows a slightly different path according to its color). This creates an ever-shifting kaleidoscopic effect of spectral wonder.

The twinkling of starlight is not the same for all stars. White suns like Sirius show all possible color variations, while stars of warmer hues have scintillations that lack cooler hues. You can see this for yourself by watching Orion's red supergiant Betelgeuse as it rises.

These colorful effects can be enhanced anytime with the use of binoculars, especially when the star is defocused into a disk, across which dances an eternal ballet of fleeting hues. No matter how you view it, twinkling adds a dimension of life to an otherwise static celestial landscape. And it's always there for you to enjoy — all you have to do is look up.

■ Contributing Editor **STEPHEN JAMES O'MEARA** still vividly recalls seeing Sirius scintillate over a snowy Cambridge landscape on his way to Midnight Mass in 1962.

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

Planets Dance at Dawn

Venus, Mercury, and Mars adorn the morning sky.

FRIDAY, JANUARY 5

The **Moon** encounters **Spica** on a monthly basis throughout the year, but some of those meetings are more visually rewarding than others. For instance, there are several that are simply unobservable because they happen in the autumn months when the star is lost in the Sun's glare. Strike those off the list. And then there are some where the Moon may not get especially close to Spica. Call those interesting but perhaps not worth more than a glance. And then there are a few in which the two objects have a separation of 5° or less — close enough to occupy the same binocular field. Those are the ones to get excited about.

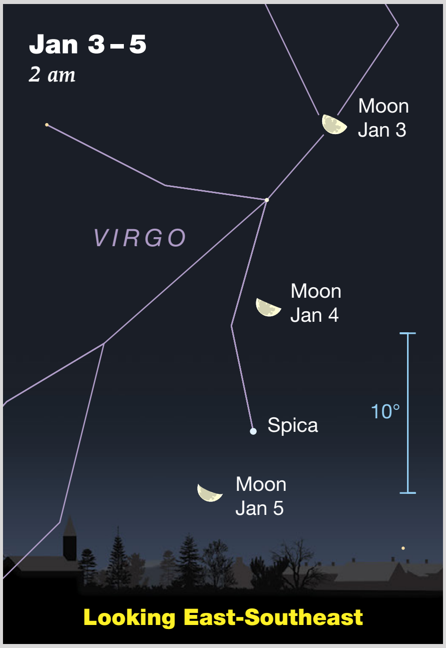
As it happens, 2024 is a banner year for Spica-and-Moon conjunctions, starting this morning when they rise in the wee hours with about 4° separating them. The waning lunar crescent trails the star and clears the east-southeastern horizon around 1:30 a.m. local time. By the time twilight seriously brightens the sky, the Moon's eastward motion puts it an additional 2° farther from Spica. But as enjoyable as this particular conjunction is, you ain't seen nothin' yet! On two occasions this year, the Moon will glide right up to Spica and eclipse the star! One occultation happens in July and another in November. Watch this space for more on those.

MONDAY, JANUARY 8

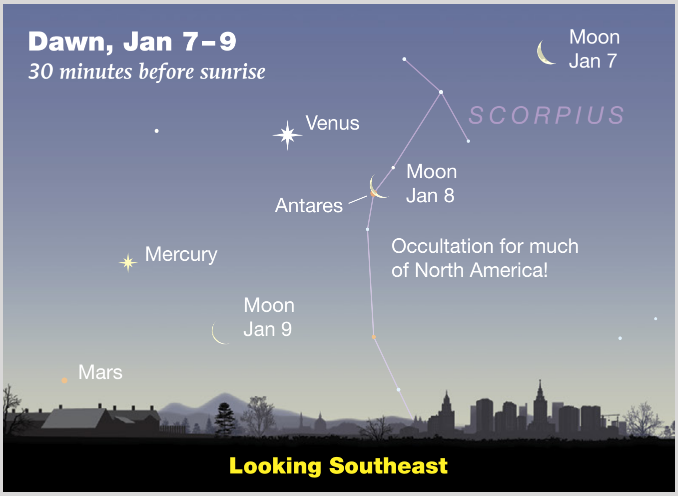
If you don't want to wait until July to see the **Moon** cover a bright star, well, you might not have to. As noted in Celestial Calendar (page 48), observers across much of the western U.S. and Canada will get to see the 26½-day-old waning lunar crescent occult **Antares**. Since Bob King details that event in his column, we won't dwell on it here. Instead, let's take in the big-picture perspective and appreciate a truly wonderful gathering at dawn.

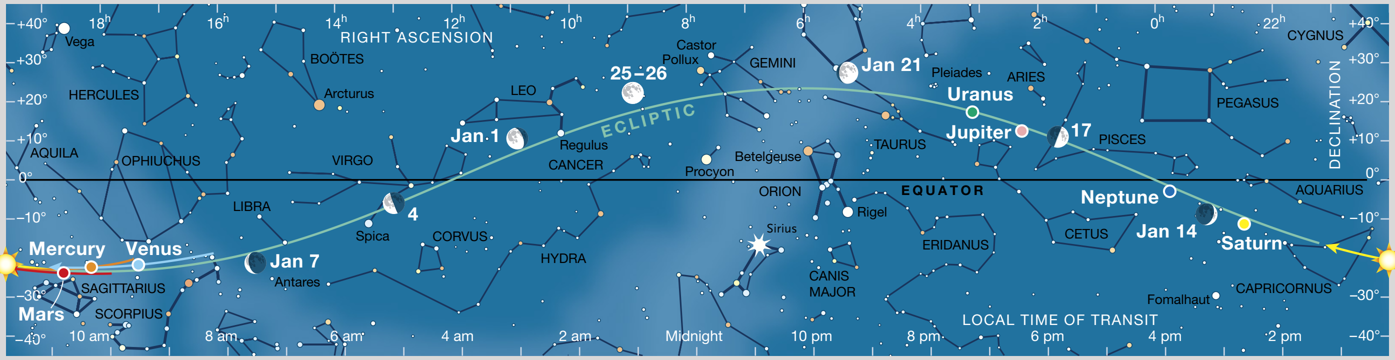
At around 6 a.m., cast your gaze to the southeastern horizon and soak up the sight of the Moon forming a large right triangle with brilliant **Venus** (gleaming at magnitude –4.0) and **Mercury** (holding its own at magnitude –0.2). Both planets are currently putting on quite a show. Venus is as favorably positioned as it will be in the morning sky all year for Northern Hemisphere observers, while Mercury is enjoying the first of three excellent 2024 dawn appearances. Indeed, this morning it's only one day removed from its highest dawn altitude during this apparition.

If the weather doesn't cooperate, you have an excellent second opportunity to view this collection of solar system wonders in a slightly different configuration. On the following morning (the 9th), the trio arranges itself into a second right triangle, but this time the Moon is lower, thinner, and closer to Mercury. If we include Antares in our geometry, then our shape is a 12°-wide box instead.



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

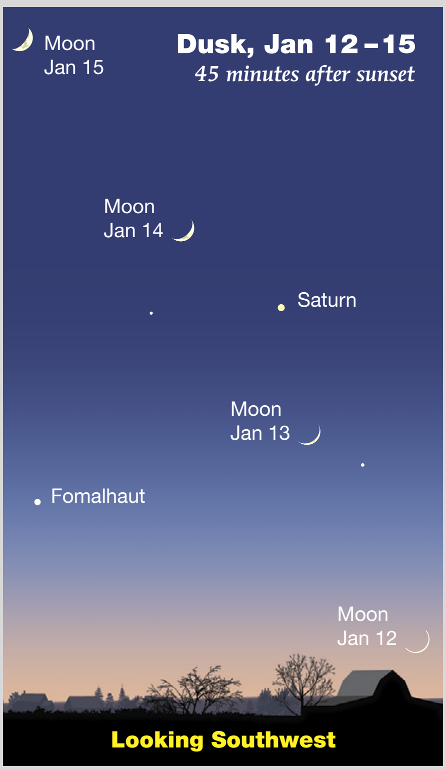




▲ The Sun and planets are positioned for mid-January; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit"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

THURSDAY, JANUARY 18

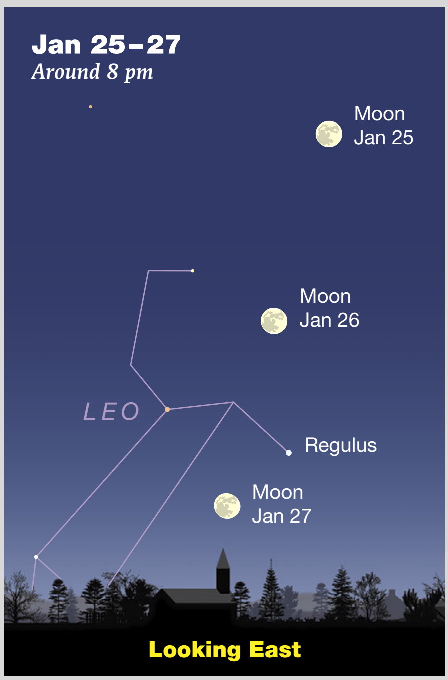
The best conjunction that's not in the morning sky this month occurs when the **Moon** meets up with **Jupiter** this evening. The two will be close together and high in the south as darkness falls. The earlier you look and/or the farther east you are, the closer they'll appear. For observers on the East Coast, the gap between the pair will be less than 3°, but by the time twilight fades on the West Coast, the Moon will be an additional 1½° farther from the planet. You'll have no trouble spotting Jupiter well before full darkness arrives — it shines brightly at magnitude –2.5. Big Jove is well past opposition (which occurred back in early November) and is now a prime, early-evening target for telescope enthusiasts. Meanwhile, the Moon is a waning gibbous just one day past first-quarter phase.



SATURDAY, JANUARY 27

This is a date worth circling on your calendar since there are treats to be enjoyed in both the predawn sky and in the evening. Let's begin with the morning stuff.

Set an early alarm and you'll be rewarded with the opportunity to see two planets just a hair away from each other. The duo in question is **Mercury** and **Mars** — two planets briefly meeting as they head in opposite directions. Mercury shines at magnitude –0.2 as it sinks lower each day. Meanwhile, Mars is just now emerging from the Sun's glare as a 1.3-magnitude ember. The Red Planet is just beginning an apparition that culminates in January 2025 when it reaches opposition once again. However, this dawn conjunction will be a tricky one to see. You'll need an unobstructed horizon towards the east-southeast *and* binoculars or a small telescope. Optics will not only help fish the pair out of brightening twilight but also make it much easier to see dim Mars next to gleaming Mercury. And they're *close* — just ¼° (half a Moon diameter) separates them.



While you're up, shift your gaze toward the western horizon and take a moment to appreciate the first part of a two-part event. At dawn, the waning gibbous Moon is positioned some 4½° right of **Regulus**, the brightest star in the constellation Leo, the Lion. It's a fine sight, but what makes it really interesting is what happens roughly 14 hours later. Part two of this event occurs in the evening when the Moon and Regulus rise in the east-northeast. Now, in a neat bit of celestial symmetry, the Moon sits roughly 4½° to the lower left of the star.

■ Although not a "morning person," even Consulting Editor **GARY SERONIK** will be up at dawn this month.

◀ The waxing Moon parts from Antares after occulting the star on August 24, 2023. That event signified the start of a five-year-long series of Antares occultations that will present multiple opportunities for amateur astronomers to spot its close companion. David Sharp, of Marana, Arizona, captured this image with an iPhone 13 and a 17.5-inch f/4.5 Dobsonian telescope. "Seeing was excellent, and Antares B was on display," he writes. "It was a neat blue color and quite the contrast to Antares as the pair emerged from behind the Moon."

A Morning Antares Occultation

Scorpius returns to the dawn sky only to have its heart stolen by the Moon.

On August 24, 2023, members of my local astronomy club had a wonderful time watching a waxing gibbous Moon occult Antares, the 1st-magnitude heart of Scorpius, the Scorpion. We set up our telescopes at a local dog park, but due to the instantaneous nature of lunar occultations, only the person at the eyepiece at the split second the star was covered would get to see it. Recognizing this, a few of us brought along binoculars so members of the public could watch, too. That summer event was the inaugural kickoff of a five-year-long series of Antares occultations that concludes on August 27, 2028.

While it's exciting to see a bright star suddenly disappear behind the Moon's dark limb, I was entranced more by its reappearance on the sunlit edge about an hour later. Antares easily held its own against the powerful lunar glare and resembled a shimmering fire opal.

It all happens again on the morning of January 8th, but this time the Moon is a waning crescent, just 10.5% illuminated. That means disappearance occurs at the bright limb and reappearance at the dark limb. Observers across much of the U.S. (except in the Eastern time zone, where the Sun will still be above the horizon), Canada, and parts of Mexico can watch events unfold. For those in the Midwest, the Moon covers Antares around sunrise. Slightly farther west, in the Mountain time zone, immersion occurs in twilight. Telescopic observers there might be able to see the star reappear approximately 30 to 45 minutes after sunrise if sky conditions are crystal clear.

The best locations are along the West Coast, where Antares disappears before the start of astronomical twilight (though at a low altitude) and reappears as the sky begins to brighten. The moment of egress provides a unique opportunity to spot the star's companion, Antares B. The 5.4-magnitude secondary is notoriously difficult to glimpse thanks to the overwhelming glare of the primary, Antares A, just 2.7″ away. Unfortunately, from mid-northern latitudes Antares never climbs very high, compounding the challenge. As the pair re-emerge, the fainter secondary star will pop out first because it lies nearly due west of the primary. You'll get to see it on its own for about five seconds before brilliant Antares A reappears. I observed this occurrence once years ago, and it remains one of my top-10 best astronomical sights.

A telescope gives the best view of the occultation, but Antares is bright enough that tripod-mounted binoculars will also work well. Last August, I was able to spot the star without any kind of optical aid until about two minutes before the Moon's dark limb covered it. Since immersion occurs at the bright edge this time, I doubt you'll be able see it happen naked-eye, though the star's reappearance should be obvious.

Antares is a red supergiant 550 light-years distant and with a diameter between 680 and 800 times that of the Sun. So, it's close enough and large enough that it will take slightly more than an instant to disappear and reappear. While this is probably not detectable visually, you might be able to record the interval with a telescope and planetary camera set to its highest possible frame rate.

Catch Comet 62P/Tsuchinshan

THE CURRENT APPARITION of Comet 62P/Tsuchinshan is a favorable one, with the icy object well placed for viewing from midnight until dawn as it crosses from Leo into eastern Virgo during January, as shown in the chart below.

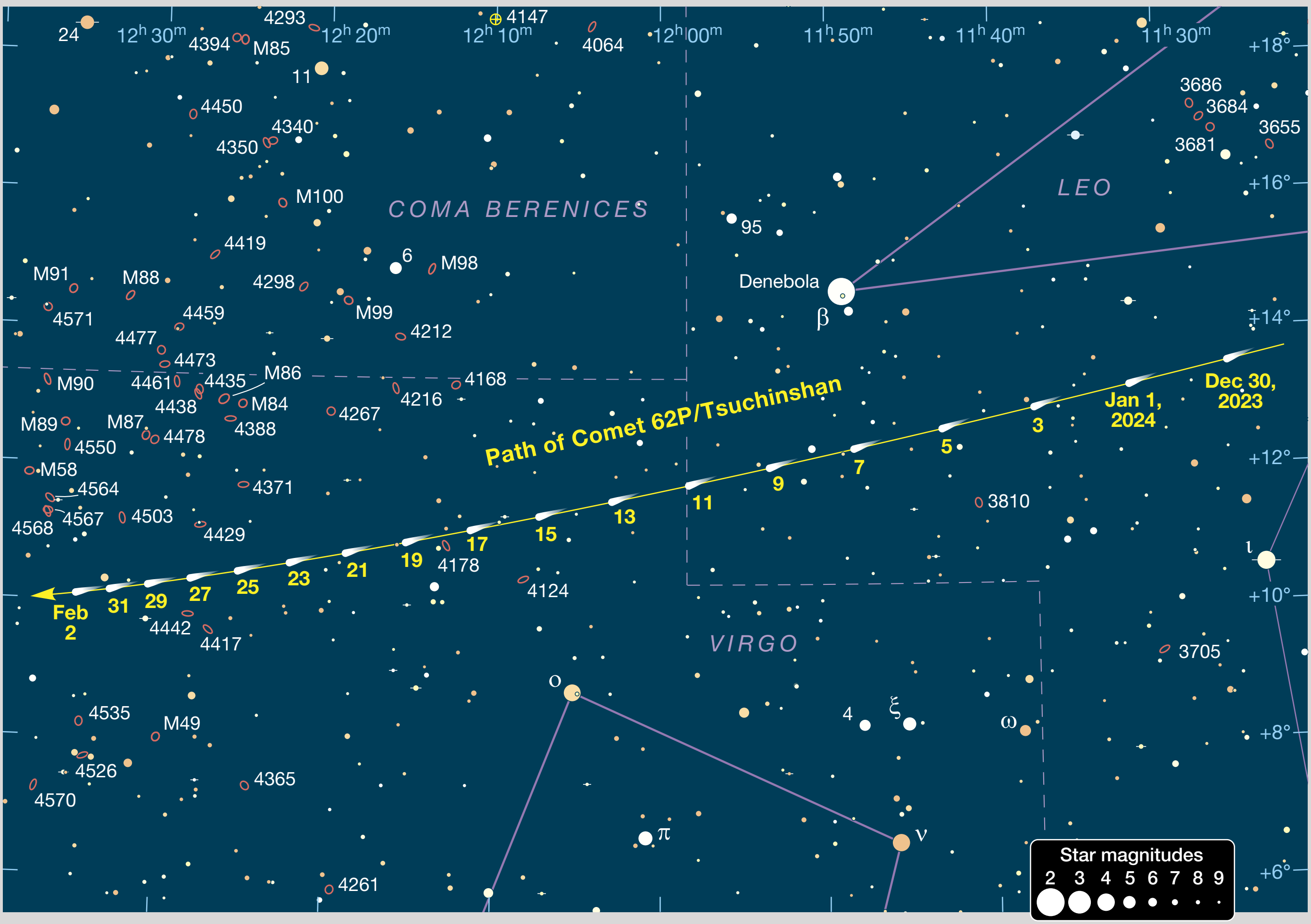
The comet is unusual in at least one regard — it's named after a place rather than a person. It was discovered on January 1, 1965, at Purple Mountain Observatory in Nanjing, China — the name "Tsuchinshan" meaning "Purple Mountain" in Mandarin Chinese.

Early this month the comet should be close to its peak brightness of magnitude 7, having passed perihelion on December 25th. A pair of 50-mm binoculars should suffice to coax it into view a few degrees south of Denebola — Beta (β) Leonis — in Leo's tail. The best observing window in January occurs during the Moonless stretch from roughly the 5th to the 22nd.

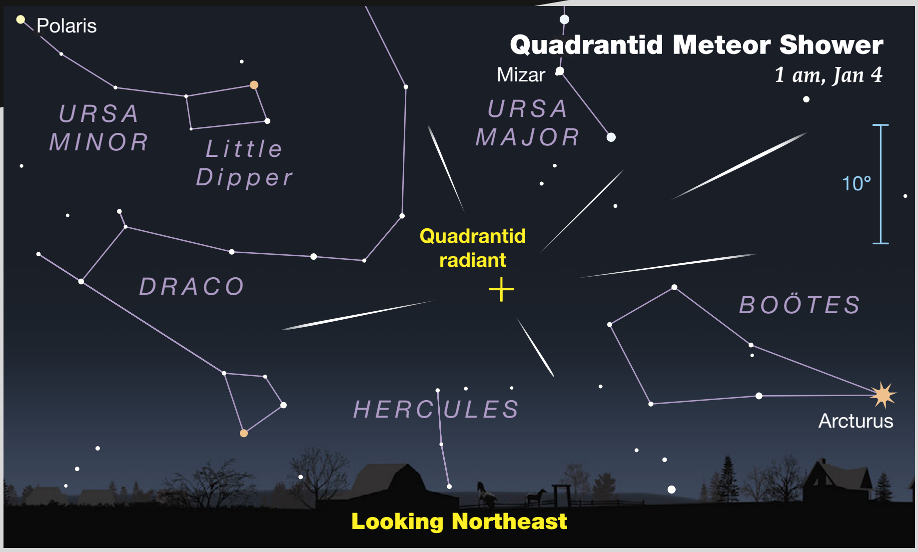
Observers with 6-inch or larger telescopes should see a bright, round coma and possibly a short tail pointing east. By month's end the comet will have faded about one magnitude. From mid- to late-January, 62P/Tsuchinshan sashays across the Virgo Galaxy Cluster, creating several opportunities for astrophotographers to frame the fuzzy visitor with a variety of galaxies.

The comet cycles around the Sun every 6.2 years and this time swings closest to Earth on January 29th, at a distance of less than 75 million kilometers (47 million miles). Recent close encounters with Jupiter have reduced its perihelion distance from 1.5 a.u. to 1.3 a.u., which could spark more activity than usual this apparition.

▲ Comet 62P/Tsuchinshan glides by a pair of galaxies in Virgo on December 13, 2017, during its last apparition. On that passage, the comet brightened to around magnitude 9 and developed a short tail.



DAMIAN PEACH



The Quads Are Back

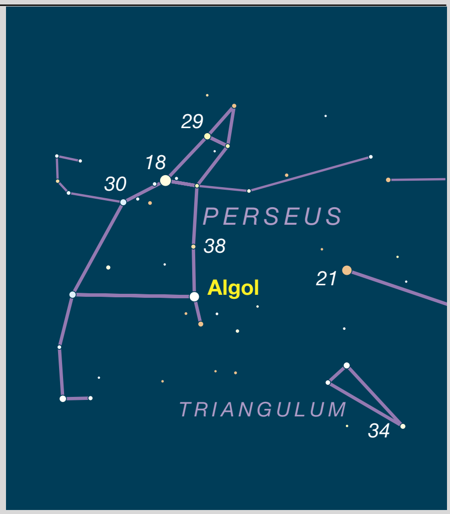
THE ANNUAL QUADRANTID meteor shower will share the sky with the last-quarter Moon when the display reaches its maximum during the early-morning hours of January 4th. While this will lower the potential number of meteors visible, the extra light won't ruin the event. It helps that the Moon is in Virgo more than 60° from the shower radiant in northern Boötes, the location of the defunct constellation Quadrans Muralis for which the shower is named.

The Quads have multiple parent bodies, with asteroid 2003 EH1, Comet 96P/Machholz, and possibly other comets all contributing to the shower's dusty flux. The debris stream is narrow, so we zip through it quickly — the reason the shower's peak lasts only about six hours. This year that occurs around 9 UT (4 a.m. EST) — a favorable time for the eastern half of North America, where the radiant will be high in the northeastern sky.

Minima of Algol

Dec.	UT	Jan.	UT
3	15:11	1	7:23
6	12:00	4	4:12
9	8:49	7	1:01
12	5:38	9	21:50
15	2:27	12	18:40
17	23:17	15	15:29
20	20:06	18	12:18
23	16:55	21	9:08
26	13:44	24	5:57
29	10:33	27	2:46
		29	23:36

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



▲ Perseus is conveniently 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. Use this chart to estimate its brightness in respect to comparison stars of magnitude 2.1 (Gamma Andromedae) and 3.4 (Alpha Trianguli).

Action at Jupiter

AS JANUARY OPENS, Jupiter is nicely positioned for early-evening viewing. On the 1st it transits the meridian at about 7:30 p.m. local time. But make haste. By month's end it hits that mark almost two hours earlier and in bright twilight — a sure sign the current apparition is winding down. During the course of the month, Jupiter's disk shrinks perceptibly from 44.0″ down to 39.8″ as the planet dims very slightly from magnitude –2.6 to –2.4.

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

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. (Eastern Standard Time is UT minus 5 hours.)

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

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

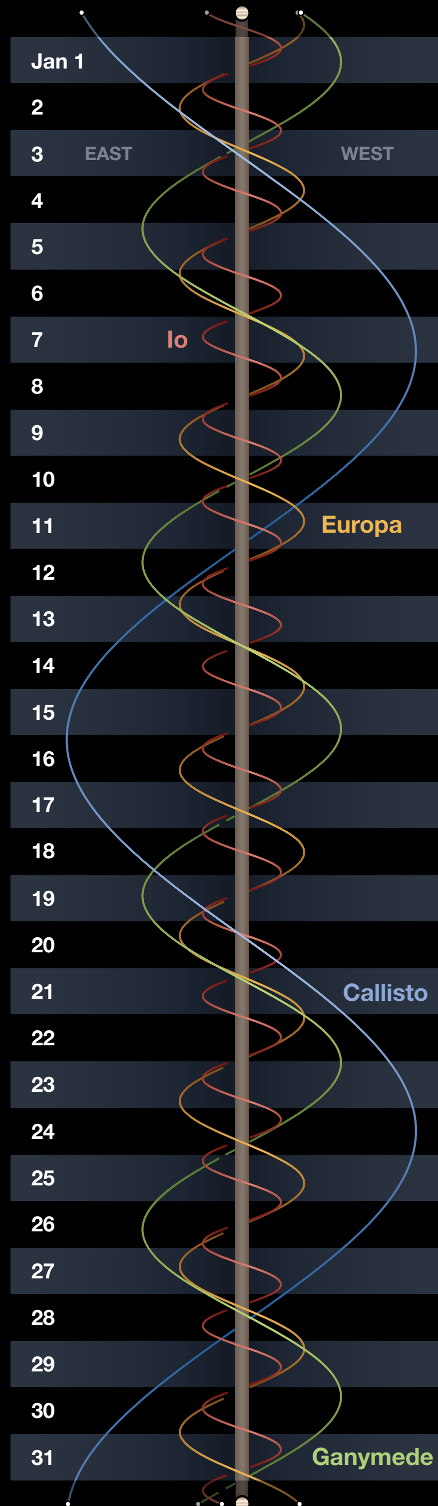
These times assume that the spot will be centered at System II longitude 49° on January 1st. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 49° and 1⅔ minutes later for each degree more than 49°.

Phenomena of Jupiter's Moons, January 2024

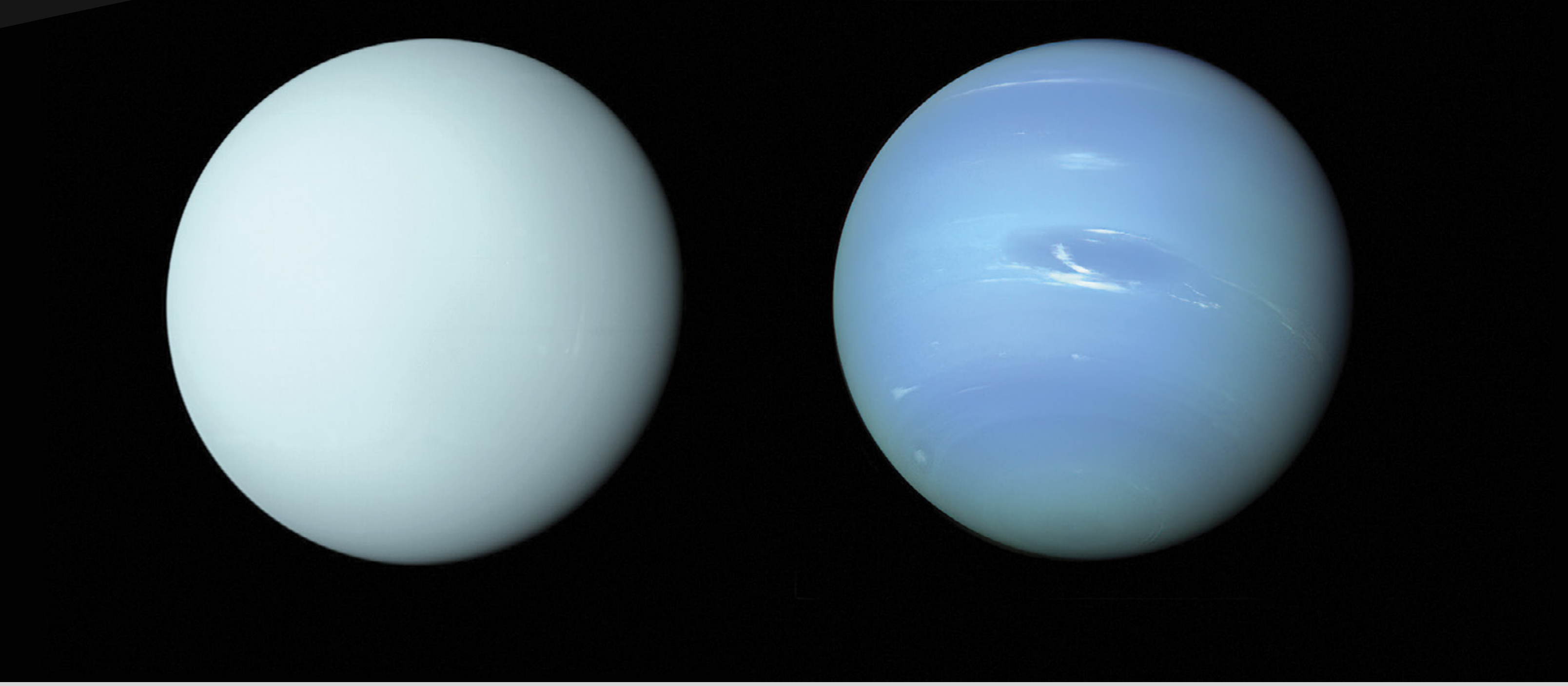
Jan. 1	14:10	II.Oc.D
	15:24	I.Oc.D
	16:31	II.Oc.R
	16:39	II.Ec.D
	18:46	I.Ec.R
	19:01	II.Ec.R
Jan. 2	12:37	I.Tr.I
	13:51	I.Sh.I
	14:47	I.Tr.E
	16:00	I.Sh.E
Jan. 3	7:00	III.Oc.D
	8:52	III.Oc.R
	8:53	II.Tr.I
	9:51	I.Oc.D
	11:12	II.Tr.E
	11:18	II.Sh.I
	12:05	III.Ec.D
	13:15	I.Ec.R
	13:37	II.Sh.E
	13:46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

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

Jupiter's Moons



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



Observing the Ice Giants

Turn your attention to our solar system's neglected outer planets.

Uranus and Neptune are often referred to as "the distant twins" because they are very similar in diameter and mass. If Earth were reduced to the size of an orange, the two ice giants would be a pair of basketballs.

Despite their impressive sizes, these planets' sheer remoteness makes them challenging targets for even the largest telescopes. Uranus's apparent diameter never exceeds 3.7″ — 13× smaller than Jupiter and 5× smaller than Saturn when both are at opposition. Viewing Uranus through a telescope is comparable to observing a pea across the distance of five football fields. Neptune's disk is smaller still, measuring only 2.3″ in apparent diameter, and requires a 4-inch (100-mm) or larger telescope to be clearly discerned.

The *luminance* (apparent brightness per arcsecond) of both planets is low because solar illumination is so feeble at their vast distances. The cloudtops of Uranus appear almost 12× dimmer than Jupiter's, while Neptune's are 2.6× dimmer still. High noon on Neptune would seem like gloomy twilight to us because the intensity of sunlight we are accustomed to is reduced by a factor of 900.

Through a telescope, the lack of contrast between the tiny discs of Uranus and Neptune and the background sky is further diminished by limb darkening produced by their dense atmospheres. This poses an additional challenge to observers by making it difficult to determine whether the planet is even in focus. To overcome this problem, focus on a nearby star of comparable brightness, then point the telescope back at the planet.

Observers often struggle to perceive color in the excessively dim light of these remote worlds. A 6- or 8-inch scope is required to discern the subtly different hues displayed by Uranus and Neptune. The leaden gray globe of Neptune is tinted with an icy azure blue. Uranus appears paler and less blue, with a color that is often described as cyan, aquamarine, or seafoam green. This difference in hue is downright striking in images taken by the Voyager spacecraft during their flybys of the ice giants in the late 1980s (see images above).

▲ These Voyager II spacecraft images of Uranus (left) and Neptune (right) were carefully processed to accurately show the subtle difference in the color of these distant worlds.

NASA / JPL-CALTECH / SEAN WALKER

Both planets have deep, frigid atmospheres of almost identical structure and composition: hydrogen and helium with traces of methane, water vapor, hydrogen sulfide, and ammonia. Why their appearance differs perceptibly is a longstanding mystery that astronomers may have only solved very recently.

The ultimate source of the difference seems to arise from a deeper mystery. Uranus radiates hardly any heat at all, but Neptune radiates 2.6× more energy than it receives from the Sun. As a result, atmospheric circulation on Uranus is sluggish, while Neptune's internal heat drives weather of unimaginable violence. The Voyager 2 spacecraft clocked winds of 1,900 kilometers per hour (1,200 mph) on Neptune compared to 900 km per hour on Uranus — the fiercest in the entire solar system.

Methane strongly absorbs red light and is responsible for the overall cool colors of both ice giants. The uppermost layers of their atmospheres also contain a haze of photochemical smog produced by the interaction of solar ultraviolet radiation with methane and other hydrocarbons. Last year a team of researchers led by Patrick Irwin, Professor of Planetary Physics at the University of Oxford, postulated that on both planets, methane can freeze onto these aerosol particles, causing them to fall as snow. Because Neptune's atmosphere is so turbulent, it's far more efficient than the comparatively quiescent atmosphere of Uranus at transporting methane upward into the haze layers in order to produce these haze-thinning snowfalls. The presence of thicker atmospheric hazes on Uranus appears to be responsible for its paler hue.

Uranus is usually almost featureless in visible light, although bright storms are glimpsed on rare occasions. In 1870, British amateur T. H. Buffham detected "two round bright spots" using a 9-inch reflector and was able to follow their motion on two nights. In 1884, French astronomers Henri Perrotin and Charles Trépied and British astronomer Norman Lockyear independently reported an elongated bright spot near the planet's equator.

The appearance of two brilliant spots in 1981 that persisted for several weeks enabled the eagle-eyed observer Stephen James O'Meara to accurately determine the planet's rotation period using Harvard Observatory's 9-inch Clark refractor, perhaps the last great planetary discovery by a visual observer (*S&T:* Sept. 2012, p. 54). It's noteworthy that in the four decades following that feat O'Meara has never managed to make out any Uranian features of comparable prominence even with far more powerful instruments. Low expectations are the key to happiness when observing Uranus, but I always hope to be surprised by one of these rare events whenever I point a telescope in its direction.

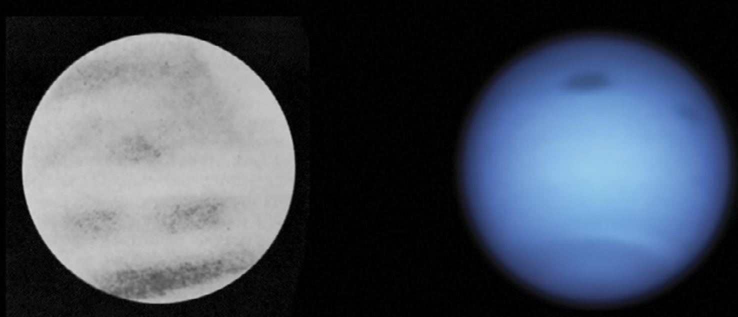
Neptune would be a rewarding target if it were only as distant as Jupiter. In contrast to the bland appearance of Uranus, Neptune's dynamic atmosphere has dusky belts resembling those of Jupiter and Saturn as well as huge dark storms rivaling Jupiter's Great Red Spot that persist for weeks. A handful of observers wielding large telescopes have caught sight of hints of these features.

While observing through the 26-inch Clark refractor of the U.S. Naval Observatory on several nights of superb seeing in 1899, astronomer Thomas Jefferson Jackson See described Neptune as "marbled and spotted" with "extremely faint" and "granular" bands. In 1959, Brazilian astronomer Ronaldo Rogério de Freitas Mourão detected a dusky spot near the center of Neptune's disc using an 18-inch refractor.

Are any features on Neptune visible through more modest instruments? There is one compelling piece of evidence that they are. In 1950, Lowell Observatory astronomer Charles F. Capen observed Neptune using a 12½-inch reflector at a magnification of 432×. His sketch depicts faint atmospheric banding and at least one prominent dusky spot. I find it uncannily similar to Voyager 2 and recent Hubble Space Telescope images of the planet.

Uranus reached opposition on November 13th, so this month it's well placed for observation in the constellation Aries. Almost four months removed from its September 19th opposition, Neptune is still visible early in the evening in the constellation Pisces. Why not take advantage of the opportunity to train your telescope on these distant worlds?

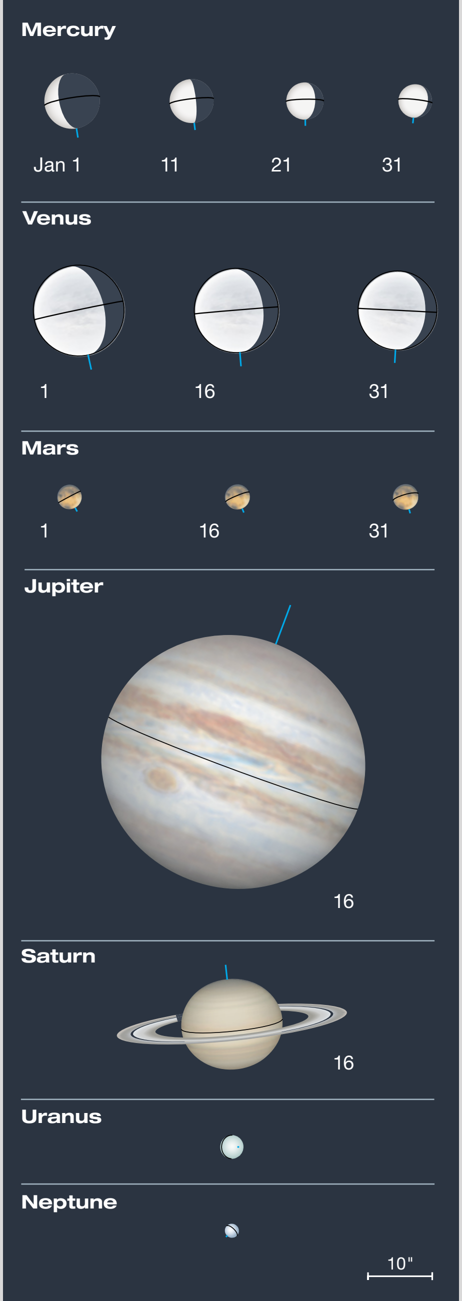
■ Contributing Editor **TOM DOBBINS** has never seen features on Neptune, but he glimpsed a diffuse bright spot on Uranus in 1995 through Lick Observatory's 36-inch refractor.



Features depicted in Charles F. Capen's 1950 sketch of Neptune (left) resemble those captured by the Hubble Space Telescope in 2022 (right). The Hubble image records a large dark storm at top, a smaller storm to its lower right, and a dusky polar region.

DRAWING: CHARLES CAPEN; NEPTUNE PHOTO: NASA / ESA / STSCI / M. H. WONG / L. A. SROMOVSKY / P. M. FRY

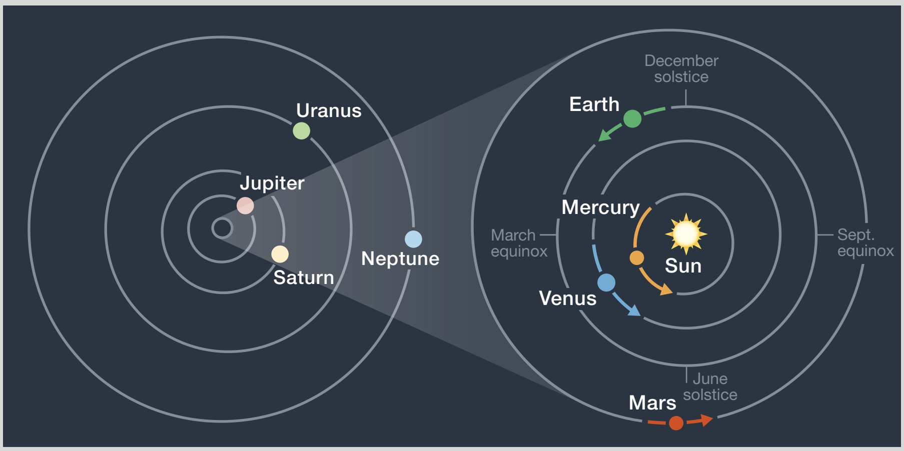
PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dawn until the 27th • **Venus** visible at dawn all month • **Mars** is lost in the Sun's glare this month • **Jupiter** transits at dusk and sets after midnight • **Saturn** visible at dusk and sets in the early evening.



January Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h 42.3^m$	–23° 05′	—	–26.8	32′ 32″	—	0.983
	31	$20^h 50.8^m$	–17° 40′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$17^h 25.8^m$	–20° 08′	18° Mo	+0.5	8.6″	27%	0.778
	11	$17^h 45.1^m$	–21° 33′	23° Mo	–0.3	6.8″	60%	0.982
	21	$18^h 34.5^m$	–22° 52′	22° Mo	–0.2	5.8″	78%	1.156
	31	$19^h 35.0^m$	–22° 36′	18° Mo	–0.3	5.2″	87%	1.281
Venus	1	$16^h 02.4^m$	–18° 42′	37° Mo	–4.0	14.1″	78%	1.182
	11	$16^h 53.5^m$	–20° 57′	35° Mo	–4.0	13.4″	81%	1.243
	21	$17^h 46.0^m$	–22° 14′	33° Mo	–4.0	12.8″	83%	1.302
	31	$18^h 39.3^m$	–22° 26′	31° Mo	–3.9	12.3″	86%	1.357
Mars	1	$17^h 46.8^m$	–23° 57′	13° Mo	+1.4	3.9″	99%	2.424
	16	$18^h 35.8^m$	–23° 53′	17° Mo	+1.4	3.9″	99%	2.375
	31	$19^h 25.1^m$	–22° 50′	21° Mo	+1.3	4.0″	99%	2.323
Jupiter	1	$2^h 13.4^m$	+12° 09′	116° Ev	–2.6	44.0″	99%	4.481
	31	$2^h 19.4^m$	+12° 49′	87° Ev	–2.4	39.8″	99%	4.952
Saturn	1	$22^h 21.9^m$	–11° 57′	53° Ev	+0.9	16.1″	100%	10.295
	31	$22^h 33.5^m$	–10° 49′	26° Ev	+1.0	15.7″	100%	10.607
Uranus	16	$3^h 05.8^m$	+17° 08′	114° Ev	+5.7	3.7″	100%	19.193
Neptune	16	$23^h 43.7^m$	–3° 06′	60° Ev	+7.9	2.2″	100%	30.383

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



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

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

▲**TAKE A DIVE** Begin with the brilliant star Rigel, in Orion, as you wade into the flowing waters of the river Eridanus. Only the uppermost portion of this southern constellation is visible from mid-northern latitudes, but it contains several rewarding sights for suburban backyard telescopes.

ALAN DYER

A River Runs Through It

The seemingly barren region southwest of Orion flows with interesting targets.

Woe is me. Although I reside in a small city (pop. 100,000) in southern British Columbia, the local light pollution is just plain awful. And because I live on the city's north side, my south sky is astro-abysmal. Another thing: I live near latitude 49° North, so my telescopes can't probe very far below the celestial equator.

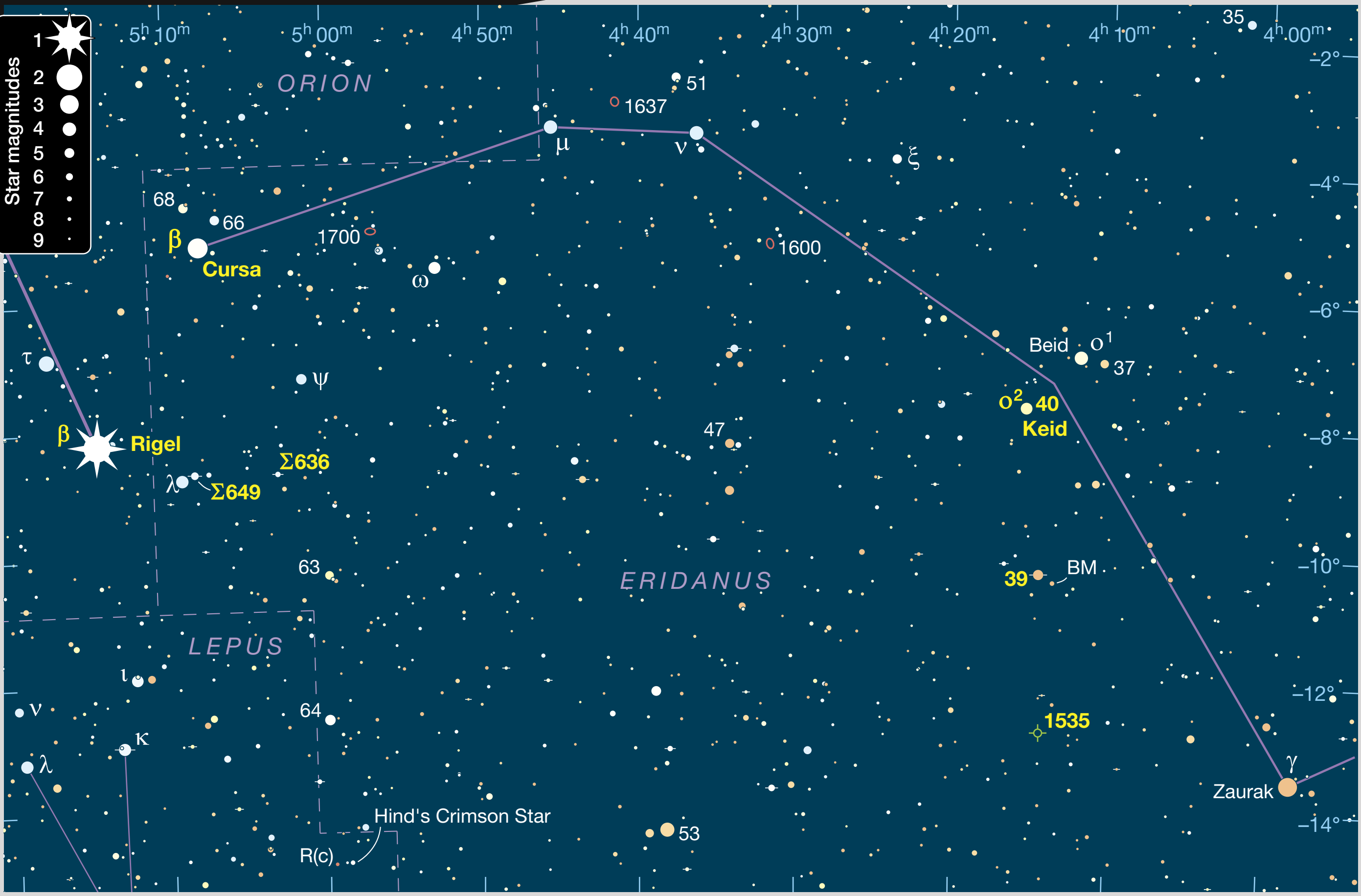
Unsurprisingly, one constellation not high on my observing list is low-lying Eridanus, the River. This issue's Northern Hemisphere star map (pages 42 and 43) plots the headwaters of Eridanus at 2.8-magnitude Beta (β) Eridani, or Cursa, 3.5° northwest of +0.3-magnitude **Rigel**, in Orion. From Cursa, the great river meanders westward just below the celestial equator, then turns in a huge semicircle to flow briefly eastward before curving southwestward and dropping to the horizon.

Eridanus's star pattern is attractively sinuous but mostly faint. Gazing southward from my suburban yard on January evenings, I can barely trace only the topmost part of the constellation. Even so, I've plumbed the river's depths using my 4.7-inch (120-mm) f/7.5 apochromatic refractor and 8-inch (200-mm) f/6 Newtonian reflector. And several objects in upper Eridanus are definitely worth a look.

Taking the Plunge

Cursa, the modest marker noted earlier, is hardly attention-grabbing. Fortunately, gleaming Rigel makes a surefire signpost to the streaming waters of Eridanus. But before you dive in, examine Rigel carefully with your telescope. The blazing, blue-white jewel harbors a 6.8-magnitude companion 9.4″ to the south-southwest. My little refractor can resolve the strikingly unequal binary at 100×, and my larger reflector does so effortlessly at 135×. Both magnifications are produced by a 9-mm eyepiece.

From Rigel, a 1½° hop southwestward arrives at 4.3-magnitude Lambda



▲**WINDING RIVER** Eridanus flows in a sinuous fashion east and southeast away from Orion and toward the south horizon. This month's tour will guide you to several colorful double stars, including an exotic triple system that features tandem red and white dwarf stars. At the south end of the fishing expedition is a prize catch — the bright planetary nebula NGC 1535.

(λ) Eridani. Lambda is a stepping stone to a double called **Struve 649** (Σ649), 13′ to the west-northwest. The pure-white primary of Σ649 is magnitude 5.8, and the distinctly reddish-orange secondary sun 21.3″ northeast is magnitude 9.0. From Σ649, a 13′ nudge due west captures a much tighter binary designated **Σ636**. Its 7.1- and 8.5-magnitude pinpoints, just 3.7″ apart, resolve faintly yet cleanly in my refractor at 100×. The compact components of Σ636 are pristine in the reflector.

A meandering star-hop gets us to the next fishing hole on my Eridanus angling trip. First, we hop northward back to Cursa. At Cursa, we head west 3¾° to 4.3-magnitude Omega (ω), then go northwest almost 3° to 4.0-magnitude Mu (μ), then west again for 2¼° to 3.9-magnitude Nu (ν), and finally 7° southwest to 4.0-magntiude Omicron^1 (ο^1) Eridani. The total trip westward to Omicron^1 is about 14°, but you'll find the route easy to follow in an optical finder. If your sky is better than mine, you can star-hop the whole way using your bare eyes and a red-dot (or similar) aiming device.

Observe Omicron^1 Eridani in a finderscope, or in a wide-field telescope at low magnification, and you'll discover it's flanked by 5.4-magnitude 37 Eridani, ⅓° roughly westward, and 4.4-magnitude Omicron^2 Eridani, a bit more than 1° to the southeast. The threesome forms a shallow triangle that resembles the constellation Aries. In Arabic star lore, the two Omicrons were named Beid (the Eggs) and Keid (the Egg Shells). According to legend, the eggy Beid and Keid belonged to a couple of lanky ostriches — one relaxing on the riverbank, the other standing knee-deep in the water slaking its thirst. Celestial mythology is never short of tall tales.

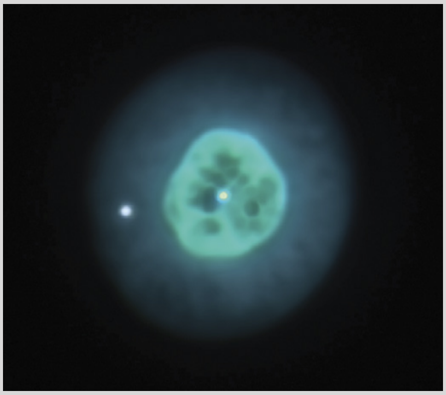
Astronomers know Omicron^2 as **40 Eridani**. Just 16.3 light-years away, 40 Eridani displays significant proper motion across the sky, shifting approximately 4″ per year. Moreover, 40 Eridani is an exotic multiple system. The yellowy primary, **40 Eri A**, sports a wide, 9.3-magnitude attendant, **40 Eri B**, 82.7″ eastward. That 9.3-magnitude dot is actually the combined light of two stars: a 9.5-magnitude white dwarf, 40 Eri B, and an 11.2-magnitude red dwarf, **40 Eri C**. Currently, the red and white siblings stand 7.9″ apart — essentially their greatest separation in over two centuries. The diminutive duo is perfect in my reflector at 135×. In my apochromat at 200×, the white dwarf shines easily through the city murk (it's the most accessible white dwarf for backyard scopes), while the feeble red dwarf is dim but definite.

Fuzzy Fishing

My next fish, 5.0-magnitude **39 Eridani**, shows plainly in finderscopes a tad more than 2½° south and slightly west of the tandem dwarfs. Orangey 39 Eri harbors an 8.5-magnitude pure-white star 6.4″ to the southeast. The tightly spaced pair is a snap in both scopes, again using my preferred 9-mm ocular. By the way, 7th-magnitude BM Eridani, a deeply orange, long-period variable star, sits ¼° southwest of 39 Eri. The warm-hued suns are unrelated: 39 Eri resides 230 light-years from Earth, whereas BM Eri is nearly six times farther away.

A 2½° drop south from 39 Eri rewards us with the planetary nebula **NGC 1535** — maybe! Essentially a teeny, fuzzy disk, NGC 1535 is easy to miss if you're a star-hopper. My advice for hooking this cosmic small fry is to center 39 Eridani in your scope at low magnification, then descend slowly and look for two starry landmarks. The first is a solitary 8th-magnitude star. The second, ½° farther along and a bit westward, is a 10′-wide triangle formed by three 9th-magnitude stars. NGC 1535 lies south-southeast of the solitary star and east of the triangle. Those helpers, plus the planetary, share a low-power field.

Boasting a magnitude of 9.6 and a diameter of 20″, NGC 1535 is actually a moderately prominent planetary nebula. But because this healthy specimen lies nearly 13° below the celestial equator, it climbs less than 29° above my south horizon. The lower portion of anyone's night sky frequently exhibits turbulent seeing. In my case, the low south is also horribly light-polluted. Fishing for fuzzies in a murky gray sky is, to put it politely, a challenge. Thankfully, NGC 1535 isn't terribly diffuse, and its luminous, bluish disk can pierce the pollution.



▲ **NOT A REAL PLANET** This relatively bright planetary nebula, NGC 1535, has nothing to do with planets. The name "planetary" was coined by 18th-century astronomer William Herschel, who commented that the tiny, round nebulae he viewed in his telescope resembled distant planets. The Neptune-like aqua hue of NGC 1535, evident in this image, is apparent in mid-size amateur scopes. However, the nebula's central star is difficult to detect in small, city-based instruments.

ADAM BLOCK

Admittedly, NGC 1535 can be hard to detect in my refractor. At around 50×, it materializes as a teeny disk, provided my south sky isn't too hazy or turbulent. The 8th-magnitude landmark star noted above helps me achieve sharp focus when I play around with different eyepieces. At 100×, the planetary is larger and much more distinct than in the 50× view, though any additional magnification beyond 100× doesn't really help.

What *does* help is threading an Ultra-High Contrast (UHC) filter into the eyepiece barrel. By blocking certain unwanted wavelengths of light, a UHC increases contrast between nebula and sky. Our tiny spherical planetary, NGC 1535, really pops with the aid of the filter. And if you have a doubly ionized oxygen (O III) filter, try it. An O III delivers even stronger contrast. It's important to remember, though, that while greatly darkening the sky, these narrowband filters also slightly attenuate the nebula. I find the O III view a bit too dim in my 120-mm refractor.

Seeing Is Believing

NGC 1535 is substantially more impressive in my 8-inch reflector than in the smaller refractor. My trusty 9-mm eyepiece yields a well-defined disk that seems (perhaps in my imagination!) subtly greenish-blue. Intriguingly, the almost azure disk is somewhat brighter at its center — possibly a blurry hint of the nebula's 12.2-magnitude central star. And I don't need to apply either a UHC or O III filter for a satisfying view — NGC 1535 is bright enough in the 8-inch to be appreciated in its purest light.

The bottom line for the top of Eridanus is that this selection of little fish deserves a place on your January hit list. Special mention goes to the pint-sized planetary NGC 1535, which I consider to be a prize catch considering the blanched and turbulent state of my sorry southern sky.

■ Contributing Editor **KEN HEWITT-WHITE** first reeled in NGC 1535 40 years ago while scanning the low south with an 8-inch Schmidt-Cassegrain telescope from a motel balcony. Fortunately, nobody called the police.

Eridanus Catches

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Rigel	Double star	+0.3, 6.8	9.4″	5^h 14.5^m	–08° 12′
Σ649	Double star	5.8, 9.0	21.3″	5^h 08.3^m	–08° 40′
Σ636	Double star	7.1, 8.5	3.7″	5^h 03.0^m	–08° 40′
40 Eri AB	Double star	4.4, 9.3	82.7″	4^h 15.3^m	–07° 39′
40 Eri BC	Double star	9.5, 11.2	7.9″	4^h 15.3^m	–07° 39′
39 Eri	Double star	5.0, 8.5	6.4″	4^h 14.4^m	–10° 15′
NGC 1535	Planetary nebula	9.6	20″	4^h 14.3^m	–12° 44′

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

Eclipse Soundscapes

The much-anticipated April 2024 total solar eclipse is soon upon us — and scientists are looking for your help.

If you've ever witnessed a total solar eclipse, you'll likely never forget the sight — or the emotions as you watched our Moon slowly cover the bright solar disk and darkness sweep across the land. But humans aren't the only creatures to react to solar eclipses. Animals do, too.

One of the earliest records of animal behavior during an eclipse dates back to 1544, when (the commentator tells us) "birds ceased singing." Later anecdotes report that nocturnal insects started chirping and diurnal animals fell silent as darkness deepened. In 1932, the Boston Society of Natural History coordinated the first modern scientific experiment focused on studying how the natural world reacts to a total solar eclipse. They advertised in a local newspaper — and hundreds of volunteers, from the general public to game wardens and naturalists, stepped forward to record their observations during the eclipse in August that year.

William Morton Wheeler and his colleagues collated 498 personal observations from these early citizen scientists and published them in 1935 in the *Proceedings of the American Academy of Arts and Sciences*. In their paper, they listed detailed visual and acoustic observations of the behavior of birds (wild and domesticated), mammals, insects, fish, reptiles, and plants. The study is peppered with gems such as "Crickets became very noisy during the darker period" and "The golden carp left the depth of the pool and started surface feeding as they do every evening."

Eclipse Soundscapes Project. NASA and collaborators are reviving this historical experiment for the upcoming solar eclipse in April. The team worked with the National Park Service for the August 2017 eclipse to determine the best equipment for recording biological sounds. And now they're turning to you for help: They're looking for your multisensory observations.

The relatively recent field of *soundscape ecology* studies the acoustic properties of environments and the creatures (human and not) that inhabit them. As their dates are known well in advance, eclipses provide a great opportunity to research how the natural world reacts to quick changes in the environment, such as the "nightfall" of totality.

There are so many great things about this project. To begin with, everyone — literally everyone — can participate, for there's neither prior experience required nor skills necessary. The project also gives people who are blind or low vision the opportunity to contribute by tapping into their nonvisual senses.

There are many ways you can lend a hand. The project website describes the different roles involved (go to **eclipsesoundscapes.org**). For example, you can participate as an "observer" and collect sensory data (sounds, sights, etc.) during the eclipse. There's no equipment required, which makes it fun and easy. In addition, you don't need to be along the eclipse path to participate.

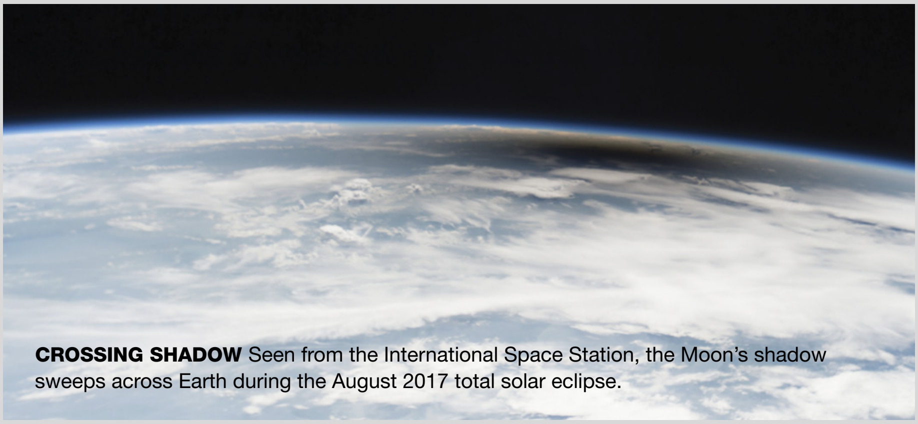
If you're a numbers-and-graphs person, maybe you want to focus on analyzing the post-eclipse data instead. For this role as well there are no geographical requirements. You will have to do a bit of training, though, but that's online and it's free.

Of course, you can always do both!

Everyone is welcome. In case we haven't stressed it enough, we'll say it again: There's room for *everyone* in this project. Eclipse Soundscapes is an excellent project for group leaders (such as in scout programs or science clubs) or teachers to get involved in and inspire their young protégés. It's a perfect setting to open up the wonders of natural phenomena and illustrate how science works, from observation to data collecting to analysis. Park staff and scientists can also use this opportunity to engage their community and rustle up enthusiasm not only about eclipses but also about science in general — and in the process make everybody more aware of their environment. But obviously, if you want to do it on your own, you can.

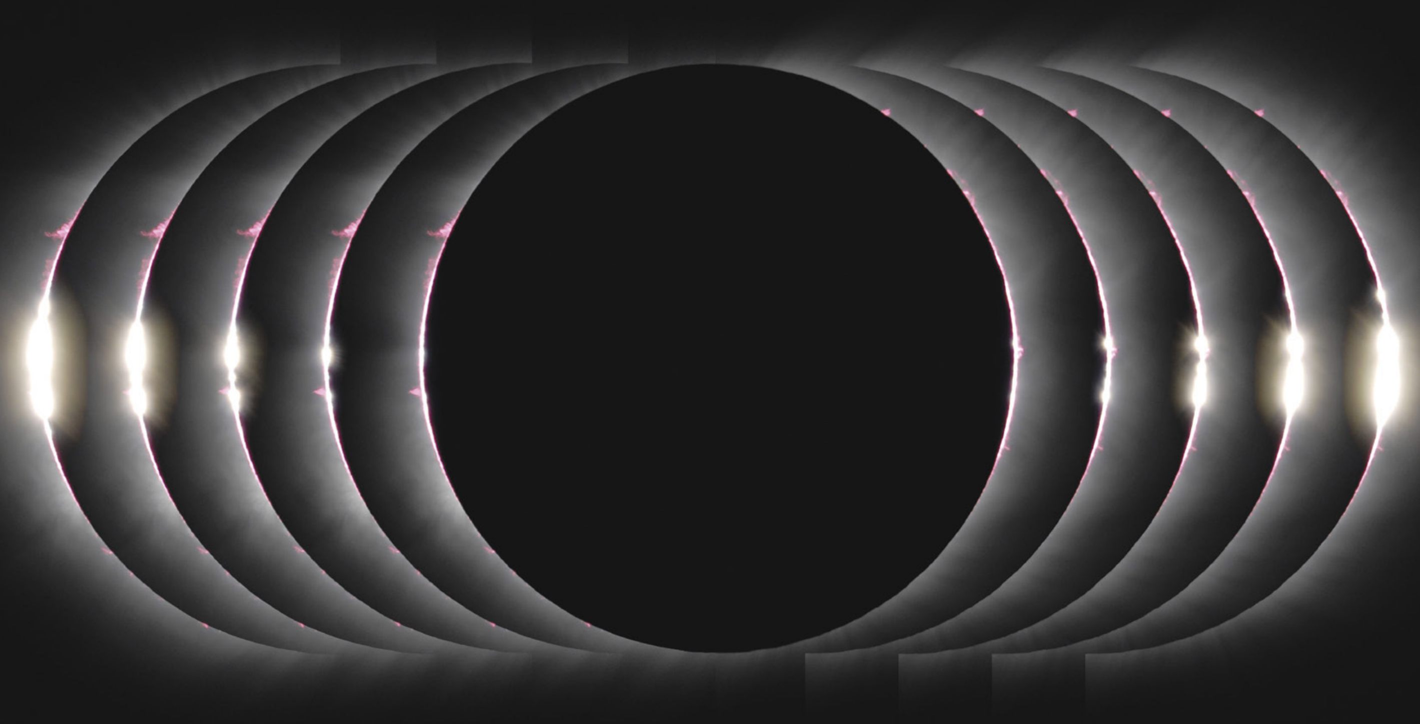
Head to the project website and find the role that suits you. Get ready to listen to the "sounds" of the eclipse.

■ Observing Editor **DIANA HANNIKAINEN** is counting the days to the April eclipse.



CROSSING SHADOW Seen from the International Space Station, the Moon's shadow sweeps across Earth during the August 2017 total solar eclipse.

NASA



Understanding Saros Cycles

Let Babylonian astronomy prepare you for April's total solar eclipse.

It is a remarkable coincidence that the Moon's size and distance combine exactly right for it to just cover the Sun's disk during a total solar eclipse. If the Moon were only about one-eighth of its distance farther away, all solar eclipses would be annular like last October's when the Sun displayed a brilliant ring at mid-eclipse. As it is, annular eclipses happen only when the Moon is near *apogee* — the point in its elliptical orbit when it's farthest from Earth and appears too small to completely cover the Sun.

But total solar eclipses are of a distinctly higher dramatic order, as anyone who has seen one will attest. As the Moon's leading edge slowly slides over the disk of the Sun, the temperature drops and shadows harden. If you're in the right place, you see the Moon's shadow racing across the landscape toward you. The sky darkens to an eerie twilight. A brilliant corona rings the blackened Sun. Bright stars and planets appear. And even though we understand exactly what is happening, we still experience a sense of awe and wonder. Earlier peoples feared it.

If we go back in time — as far back as the first half of the 7th century BC — we discover that Mesopotamian astronomers made cuneiform records of eclipse observations on clay tablets, now known as the *Astronomical Diaries*. Reports from Assyrian and Babylonian scholars to the Assyrian court show that they worked hard to predict

▲ **SIGHTING THE SAROS** This eclipse sequence was captured during totality on March 29, 2006. That event was eclipse number 29 in saros cycle 139. Number 30 in that cycle is the upcoming eclipse on April 8, 2024. Because both events are from the same saros cycle, their paths are remarkably similar, though offset by roughly 120° of longitude.

FRED ESPENAK

eclipses. Accurate forecasts gave order to their cosmos and allowed time for priests to prepare the appropriate rituals to counter eclipse omens, or even to install a substitute king until the perceived danger passed. Babylonian eclipse predictions were surprisingly accurate, though the required mathematical competence was an evolving effort. By the last three centuries BC, however, Babylonian astronomers had created sophisticated mathematical algorithms for predicting portentous appearances of the Moon and planets.

From Saros to Exeligmos

Most eclipse chasers have heard of the *saros*. Discovered early in the flowering of Babylonian computational astronomy, it's an eclipse recurrence cycle of about 18 years, or 6,585$^{1}/_{3}$ days. That extra fraction of a day means that Earth's surface shifts about 120° westward from its position during the previous solar eclipse in the series. For example, the moment of greatest eclipse along the track of the March 29, 2006, eclipse was in Africa at a longitude of 16.7° east. That eclipse path parallels the track for the April 8, 2024, event, which has greatest eclipse at a longitude of 104.1° west, over Mexico. The extra third of a day shifts the consecutive eclipses in saros cycle 139 by a longitude of 120.8° (16.7° + 104.1°), all the way west from Africa to Mexico. That 120° longitudinal shift means the fourth eclipse in the sequence will return to the longitude of the first.

We can illustrate the remarkable regularity of the saros cycle by looking at a subset of six lunar eclipses in lunar saros series 45 dating from 595 BC to 504 BC, around when scholars believe the Babylonians discovered the saros. The Moon's proximity to the center of the Earth's shadow in each 18-year event is shown by the value of gamma (γ) in the table presented below: The closer gamma is to zero, the closer the Moon is to the center of Earth's shadow. The final column shows the separation (in days) from the previous eclipse.

Saros 45 Eclipse Sample

Eclipse Date	Gamma (γ)	Days between successive saroi
November 27, 595 BC	.0011	—
December 8, 577 BC	.0020	6585.370
December 19, 559 BC	.0037	6585.369
December 29, 541 BC	.0093	6585.367
January 10, 522 BC	.0175	6585.364
January 20, 504 BC	.0327	6585.359

▲ **WRITTEN IN STONE** This tablet stored in the British Museum in London dates from about 500 BC. Babylonian scholar-priests recorded celestial events meticulously for many centuries. The vertical divisions in the tablet correspond to an eclipse recurrence cycle of 18 years.

The deviation from an integer number of 6,585 days only slightly exceeds one-third of a day. You can imagine the comforting sense of order the discovery of the saros must have conveyed to the ancient Babylonians in an otherwise chaotic world controlled by arbitrary gods and demons.

Yet, despite the regularity of this cycle, the nagging third-of-a-day excess hinted at a deeper truth. The extra fraction practically begged to be tripled. Astute reckoners, the Babylonians realized that three saroi would form an integer number of days: 19,756, which is 54 years and about 32 days. This must have appeared as a divine coincidence to them and reinforced the idea of a great cosmic wheel that brings events back to where they started. This three-saroi period came to be called *exeligmos*, which means "turning of the wheel." It was known throughout the Greco-Roman world; evidence of the exeligmos was even found on the Antikythera mechanism discovered in the sunken wreck of a Hellenistic cargo ship (*S&T:* Nov. 2023, p. 22).

A modern example of exeligmos in action from saros cycle 145 will be familiar to older readers. On July 20, 1963, the Moon's shadow raced from Japan to Alaska, across northern Canada, then through Maine and out to sea. Its path was strikingly parallel to the track of the so-called Great American Eclipse of August 21, 2017. It streaked across the Pacific, through Oregon and America's heartland, shifted slightly south from its 1963 predecessor. The next exeligmos eclipse in the series occurs on September 23, 2071. The path for that one is again shifted south and crosses northern Mexico and passes through several countries as it clips the top of South America.

Odds and Evens

Eclipses of the Moon or Sun occur at and near where the Moon's tilted orbital plane crosses the plane of the ecliptic. The two crossing points are called the *nodes*. At its ascending node, the Moon is moving upward in its orbit and emerges above the ecliptic plane, while at its descending node it passes below the ecliptic plane. Saros series are conveniently organized by these nodes — ascending-node solar eclipses have odd saros numbers, and descending-node events have even numbers.

The much-anticipated April 8, 2024, eclipse belongs to saros 139 and, as it's an odd-numbered cycle, is an ascending node event. Ascending-node eclipses for a given saros series begin in the north polar region with a positive gamma whose value decreases as the eclipse paths drift southward (usually by several hundred kilometers each time), until the series concludes centuries later in the south polar region.

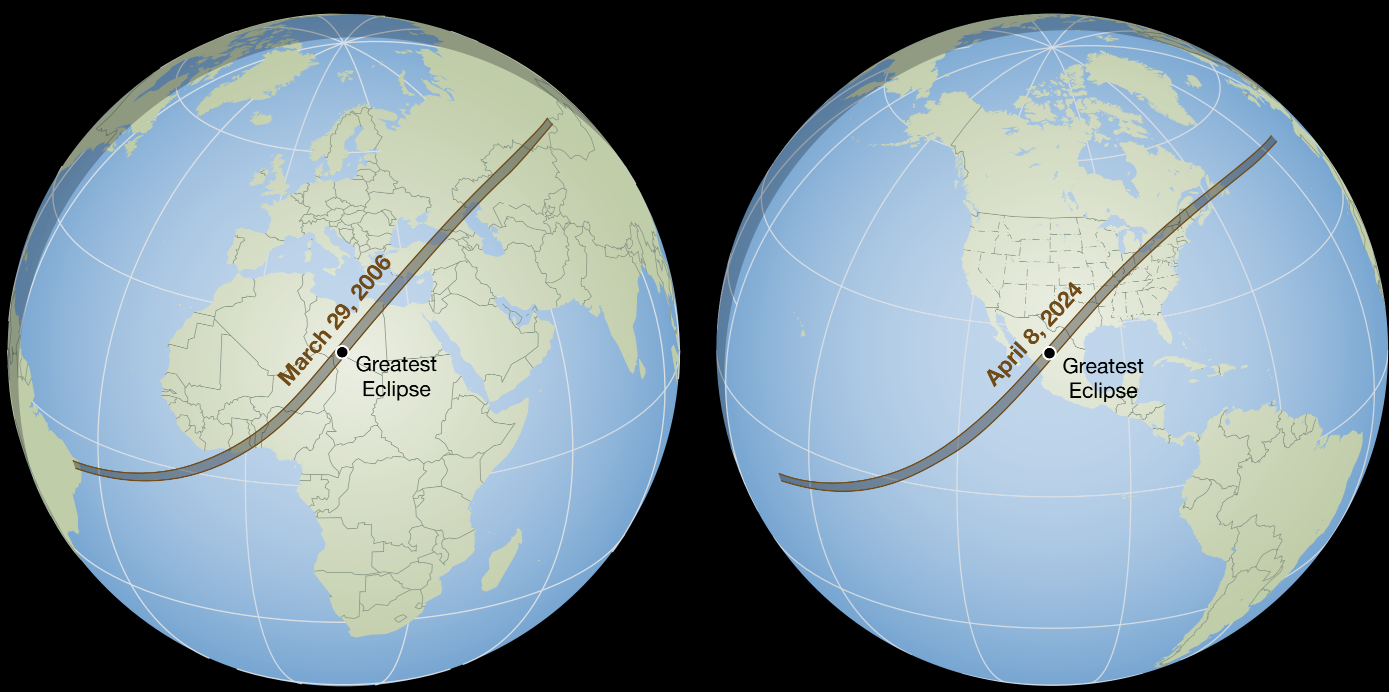
Conversely, the recent annular eclipse of October 14, 2023, belongs to even-numbered saros 134 and is therefore from a descending-node series. Such eclipses begin in the south polar region and progress northward until the series ends in the north polar region, all the while their gamma values increasing from negative to positive.

Lunar eclipses have saros numbers, too, however, the rules are reversed — even-numbered saroi refer to ascending-node events, and descending-node eclipses are odd.

The periodic rhythms of each saros last 12 to 15 centuries and contain 70 or more eclipses. Although such a span is insignificant on geological time scales, a single saros cycle covers a vast stretch of human history — the world at the beginning of a saros is absolutely nothing like the one when the series concludes. Consider that the April 8, 2024, solar eclipse belongs to saros series 139, which began on May 17,

▲ **SUPER RED MOON** The Moon's progress through the northern portion of Earth's umbral shadow during the January 20, 2019, lunar eclipse is portrayed in this sequence of images. The lunar eclipse belongs to lunar saros cycle 134, whose even number indicates it was an ascending-node event.

SUPER RED MOON: GARY SERONIK; GLOBES: LEAH TISCIONE / *S&T*



▲ **SIMILAR PATHS** The moment of greatest eclipse on March 29, 2006 (left globe), occurred over Africa at longitude 16.7° East. Moving ahead one saros cycle, the Moon's shadow at greatest eclipse on April 8, 2024 (right globe), will darken central Mexico at longitude 104.1° West, evidencing the westward shift in longitude over the course of one 18-year saros cycle of solar eclipses.

1501, and will end on July 3, 2763 — lasting almost 13 centuries from start to finish. What will our world look like when the saros concludes in the 28th century? Obviously, no one can say, but we can at least grasp the mechanism behind what makes a saros begin and last so long.

Ever-shifting Nodes

The reason for this centuries-long procession lies in the slow shift of the Moon's nodes. Under the influence of gravitational perturbations mainly from the Sun and Earth, the *nodal line* (the intersection of the two orbital planes) slowly rotates clockwise. As the Moon moves counterclockwise along its orbital path, the plane on which it travels drifts slowly in the opposite direction, like a platter dropped on a table wobbling around in exceedingly slow motion. As the orbital plane rotates, the nodal line slowly shifts, performing one full revolution every 18.6 years in what is called the *nodal* or *draconic cycle*.

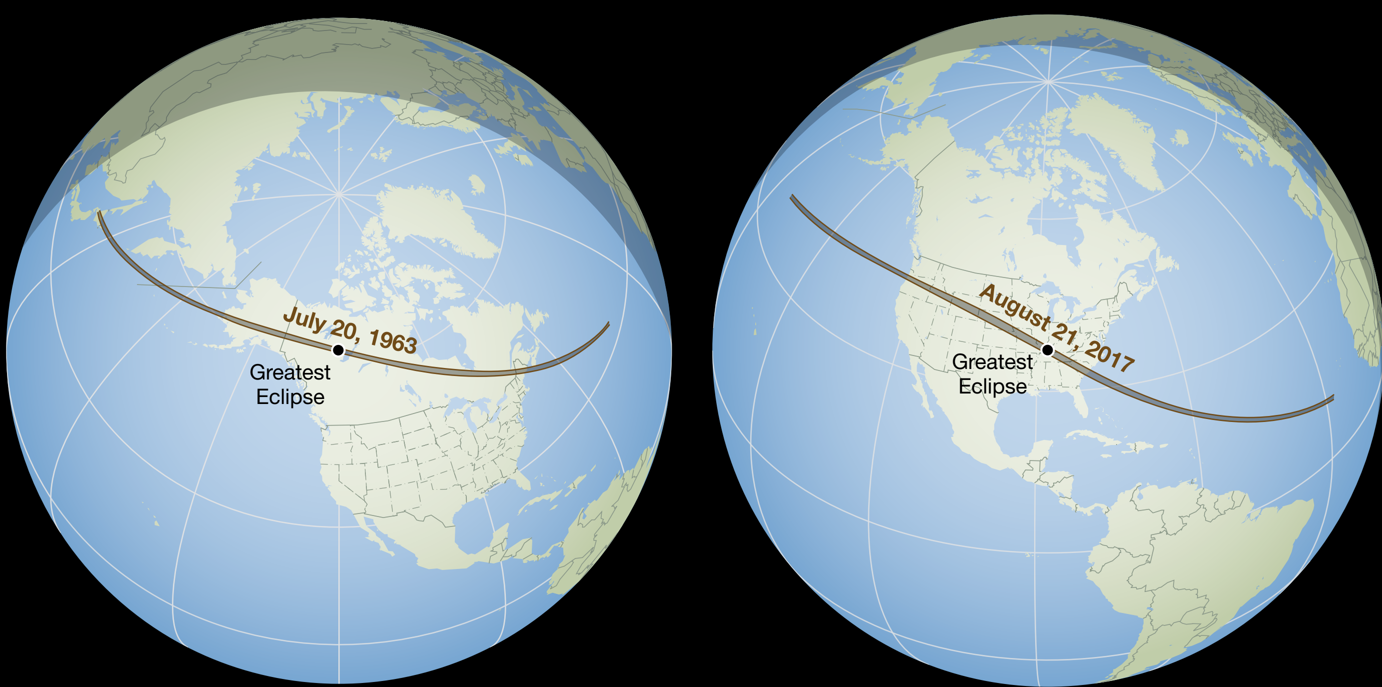
Because of this westward movement of the nodes, most of the time the eastward-moving Moon will be out of sync with the position of the nodes as it reaches *syzygy* (when the lunar phase is new or full). In other words, when the Moon passes through either a descending or ascending node, its phase won't necessarily be full or new — the only phases during which an eclipse is possible. But occasionally the Moon will arrive at (or near) a nodal point when it happens to be aligned with Earth and the Sun, at which time there's

A Saros by Any Other Name

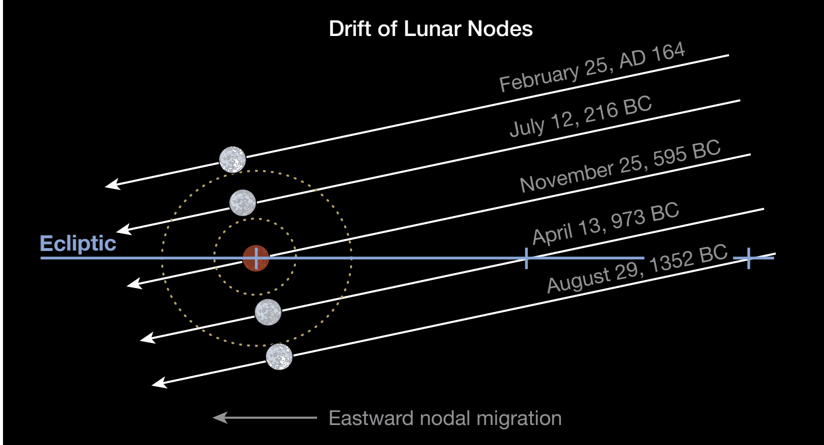
The saros numbering system was devised by Dutch astronomer George van den Bergh, who in the 1950s drew from a massive 1887 catalog by Austrian astronomer and mathematician Theodor von Oppolzer of more than 13,000 solar and lunar eclipses. The numbering follows the order in which each series peaks (when the gamma value is as close to zero as it gets), so there are many series in progress at the same time. Solar saros 0 began May 23, 2956 BC, while lunar saros 1 began March 14, 2571 BC.

The origin of the term "saros" is controversial. The Sumerian sign šár meant "universe" and also the number 3,600, according to antiquities scholar Otto Neugebauer, but the term was not then associated with eclipses. That didn't occur until 1691 when Edmond Halley adopted the name for the 18-year eclipse interval long known to the Babylonians. Rightly or wrongly, it's been linked ever since.

GLOBES: LEAH TISCIONE / *S&T*



▲ **EXELIGMOS SHIFT** Compare the path of the July 20, 1963, solar eclipse (left globe) from Alaska through northern Canada and Maine, with that of the August 21, 2017, event (right globe) through Oregon and America's heartland. The second was shifted slightly south from its predecessor.



MIGRATING NODES Five sample tracks of the Moon through its descending node in lunar saros 45, each separated by almost 380 years, or 7 exeligmos cycles. Note how the slow, eastward migration of the node (indicated by the blue tick marks) causes the Moon to cut successively more northerly slices into Earth's shadow. The full 85-eclipse series ends about 1,500 years after the Moon first entered the southern penumbra in 1352 BC. (The Moon's 5° orbital tilt is exaggerated for clarity.)

an eclipse. This occurs most famously after 223 months (of about 29.53 days each), which coincidentally corresponds to 242 *draconic months* (of about 27.21 days each). The result is the 6,585⅓-day saros match-up discovered long ago by keen-eyed Babylonian astronomers.

But there's a subtler movement of the nodes that's only apparent when one stacks all the eclipses of a saros together. If one could flip through them like an animated cartoon, the node would appear to shift eastward along the ecliptic path by almost half a degree with each eclipse in the saros cycle. As a result, over the 85 eclipses in saros 45, for example, the Moon's position at the moment of eclipse ventures very slowly upward as the node migrates, as shown in the diagram above.

A lunar eclipse through the Moon's descending node starts as the Moon slices through the lowest part of the penumbra. In succeeding eclipses, as the node nudges east, it inches up until the Moon reaches the umbra for a group of total eclipses. Gamma approaches zero as the Moon cuts through the center of Earth's umbral shadow. As the node continues to shift eastward over the centuries, the intersections with Earth's shadow cuts northward of the ecliptic into positive gamma territory. Then, about 1,500 years after the Moon first touched the southern half of the penumbra at the start of the saros cycle, it departs the northern penumbra, and the party is over for this series.

April's Eclipse in Context

The April 8, 2024, total solar eclipse belongs to saros cycle series 139, a 13-century-long family of 71 ascending-node eclipses that began in May 1501 — around the time young Copernicus was studying law in Italy while his heart lay with Ptolemy's astronomy. The sequence won't end until July 2763, which means we're not yet at the mid-point of this cycle. We can discern some near-term trends by looking at the six solar eclipses bracketing April's totality in the table below.

The saros interval of 18 years, 11 days, and about 8 hours between eclipses presents itself clearly. The April 8th event is one of three exeligmos eclipses in our sample — the other two being March 7, 1970, and May 11, 2078. The time of maximum eclipse for all three is remarkably similar, occurring at 17:39, 18:18, and 17:57 UT, respectively.

During this one-century snapshot of saros 139, the Moon's distance from the ascending node decreases by less than ½° each time, falling to under 4° for the April eclipse.

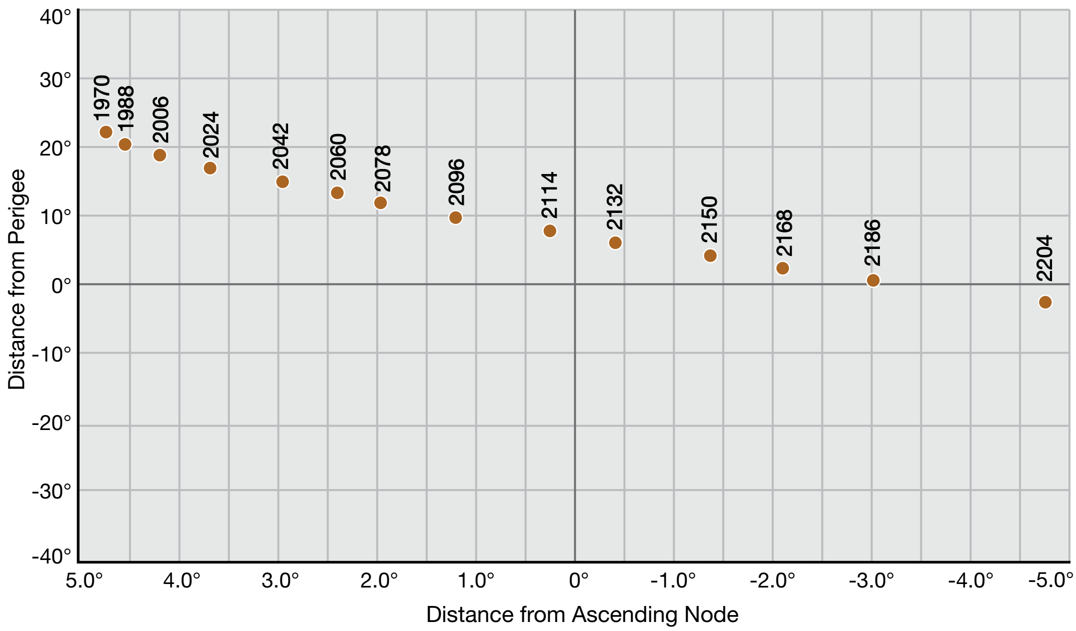
Saros 139 Eclipse Sample

Eclipse Date	Time	Lunar Longitude	Ascending node	Lunar perigee	Moon's offset from node	Moon's offset from perigee	Gamma (γ)
March 7, 1970	17:38:30	347°	342.26°	324.8°	4.74°	22.2°	0.4473
March 18, 1988	1:58:56	357.8°	353.3°	337.13°	4.5°	20.67°	0.4188
March 29, 2006	10:12:23	8.4°	4.28°	349.53°	4.12°	18.87°	0.3843
April 8, 2024	**18:18:29**	**19.0°**	**15.3°**	**1.85°**	**3.7°**	**17.15°**	**0.3431**
April 20, 2042	2:17:30	29.3°	26.34°	14.14°	2.96°	15.16°	0.2956
April 30, 2060	10:10:00	39.8°	37.38°	26.37°	2.42°	13.43°	0.2422
May 11, 2078	17:56:55	50.4°	48.43°	38.54°	1.97°	11.86°	0.1838

BEATRIZ INGLESSIS / *S&T*

▶ LOOKING FORWARD This graph looks into the future for saros 139, the cycle that includes the April 8, 2024, eclipse. Each orange dot in this sample represents consecutive solar eclipses in the series. The 2186 event has the greatest totality since it occurs when the Moon is very nearly exactly at perigee when it occurs.

Lunar Distance from Node and Perigee for Saros 139 Solar Eclipses



Gamma decreases, too, with the Moon's nodal distance, signaling the steady southward shift of the Moon's shadow track on Earth's surface. Gamma is +0.3431 for the April 2024 eclipse and will be closest to zero (+0.0525) for the eclipse of June 3, 2114, when the center of the Moon's shadow passes over Saudi Arabia. Gamma then turns negative for the subsequent southward-heading eclipses in the series. In the last eclipse of saros 139, on July 3, 2763 (gamma of –1.5132), the Moon's shadow just nicks the daylight edge of Antarctica, then mostly in its wintertime darkness.

The Babylonians were aware of the apsides of the lunar orbit — *perigee* (when it is closest to Earth) and *apogee* (when it is farthest) — and when they coincided with the nodes. The apsides have their own motion, too, completing a clockwise revolution in 8.85 years. The Moon will be reasonably close to its perigee for the April eclipse, having sailed past that mark the previous evening. Being close to perigee signals a longer-duration event since the lunar disk will be larger compared to when it's near apogee. Luckily for totality-lovers, the Moon will be only 359,781 km from Earth when it passes in front of the Sun on April 8th.

Compare that with the annular eclipse on October 14, 2023. It occurred half a year earlier at the opposite (descending) node and belonged to even-numbered saros 134. During annularity, the Moon was at a distance of 397,017 km and close to apogee, which occurred four days earlier.

A Perfect Eclipse?

The decreasing angular separation of the Moon both from the node and perigee with each eclipse in our saros 139 sample suggests they will converge in a few more cycles. As a matter of mathematical and astronomical curiosity, I plotted the closeness of the perigee with the closeness of the nodes over the course of a century on this saros cycle, as shown in the graph at upper right.

As I suspected, there is indeed an upcoming saros 139 solar eclipse in which new Moon and perigee nearly coincide: July 16, 2186. On that date, perigee occurs within an hour of totality. Lucky observers will get to enjoy 7 minutes and 29 seconds of totality! In fact, it's the longest eclipse in the entire 1,262 years of saros 139. By contrast, our April eclipse will have a respectable (but not exceptional) maximum of 4 minutes and 28 seconds.

That 2186 event gets the prize for the best eclipse in this series! Sadly, I don't expect to be around to see it. All the more reason to look forward to viewing its April saros cousin.

■ **DOUGLAS MACDOUGAL** enjoys using mathematics to explore the mysteries of early astronomy and the curious motions of our universe. You can read his blog at **douglasmacdougal.com**.

▲ SAFETY FIRST The author's grandchildren look skyward from eastern Oregon with safe eclipse glasses during the August 21, 2017, solar eclipse. Many readers are planning (and hoping) to witness a repeat performance this April.

GRAPH: BEATRIZ INGLESSIS / S&T; ECLIPSE SAFETY: DOUGLAS MACDOUGAL

Two Tiny Cameras from QHYCCD

We test a pair of monochrome cameras created for solar system imagers.

◀ The QHY5III200M and QHY5III678M monochrome planetary cameras offer high-resolution detectors designed to fit directly into 1¼-inch focusers.

QHY5III200M

U.S. Price: $309

QHY5III678M

U.S. Price: $349

qhyccd.com

What We Like

Small, extremely sensitive pixels

Lightning-fast downloads

Internal memory prevents dropped frames

What We Don't Like

QHY5III678M requires more frames to produce smooth results

Difficult to keep dust off sensors when installing filters

IT SEEMS LIKE EVERY month or so, QHYCCD announces a new planetary camera. This Chinese manufacturer specializes in astronomical models for both deep-sky and planetary imaging that are often at the cutting edge. The company is also constantly developing new cameras with the latest detectors. I've reviewed a few over the years (most recently in the May 2021 issue, p. 30), and I've been pleased with the quality of images they produce.

So my interest was piqued when the manufacturer announced the QHY5III678M, a camera with a sensor having unusually small yet highly sensitive pixels. We borrowed one in the late spring of 2023 to see how well it performs. In addition, QHYCCD also sent along a QHY5III200M for comparative purposes.

Both cameras appear identical except for the labelling on the side denoting the model designation. Each is housed in Version 2 of the QHY5III camera body, which is no bigger than a low-power, 1¼-inch eyepiece. In fact, these 7.94 × 3.18-centimeter (3⅛ × 1¼-inch) cameras are designed to fit into a standard 1¼-inch focuser and reach focus with most any telescope.

The real difference between the two models resides in their detectors. Within the QHY5III200M is a SmartSens SC2210 CMOS sensor with a 1,920 × 1,080 array of 4-micron-square pixels. The QHY5III678M, on the other hand, contains a Sony IMX678 CMOS sensor boasting a 3,856 × 2,180 array of 2-micron-square pixels — about 4× as many pixels as the 200M, though yielding nearly the exact same field of view with a given telescope. Both are 12-bit sensors with options to record video or FIT still frames in either 8-bit or 12-bit (converted to 16-bit) mode.

QHY recently redesigned the 5III-series body to permit replacement of the chamber window in front of the detector. Both cameras come with a clear glass window installed within a removable cell. In addition, there's also an IR850 coated glass window replacement that permits near-IR imaging. A thin, threaded ring is included to accommodate the replacement filter's thicker glass. The front of the cell accepts standard 1.25-inch filters. One note about changing the optical window: Be very careful not to get dust directly on the CMOS sensor when switching the window for the IR850 filter. It can be difficult to get dust completely off the sensor. I recommend changing the filter indoors in a dust-free environment.

▶ The detectors in the 678M (top) and the 200M (bottom) may appear identical, but the 678M's 2-micron pixels are half the size of those in the 200M's array. Each imaging chip is mounted precisely 8 mm (0.3 inches) behind its replaceable chamber window.

Several additional adapters and spacers are included to permit attaching C- and CS-mount video lenses that enable the cameras to funtion as all-sky cameras. Also included is a very flexible 2-meter

ALL PHOTOS COURTESY OF THE AUTHOR

▲ Each camera includes a near-infrared pass filter (center) that replaces the chamber window. Two thin spacers at left are meant to compensate for the different focus point when using the IR850 window paired with tiny C-mount or CS-mount lenses. A pair of 1¼-inch adapter rings are also included for each type of lens mount as well as a replacement spanner ring to secure the filter. At right is the included parfocalizing ring.

USB 3.2 Gen1 Type-C cable and an autoguider cable.

The rear of each camera body contains a USB-C cable port, a red LED status indicator light, and a 6-pin ST-4-compatible autoguiding port that permits either camera to function as an autoguider.

A link to download the drivers and *SharpCap* control software from the manufacturer's website is provided with each camera. Both installed on my PC laptop without a hitch. *SharpCap* provides adequate camera control, though I preferred the third-party free program *FireCapture* (**firecapture.de**), which QHY also recommends. The camera outputs several file formats, including AVI and SER video, as well as individual FIT, TIF, PNG, or JPG frames, all of which are compatible with most popular image-stacking programs.

QHY5III200M

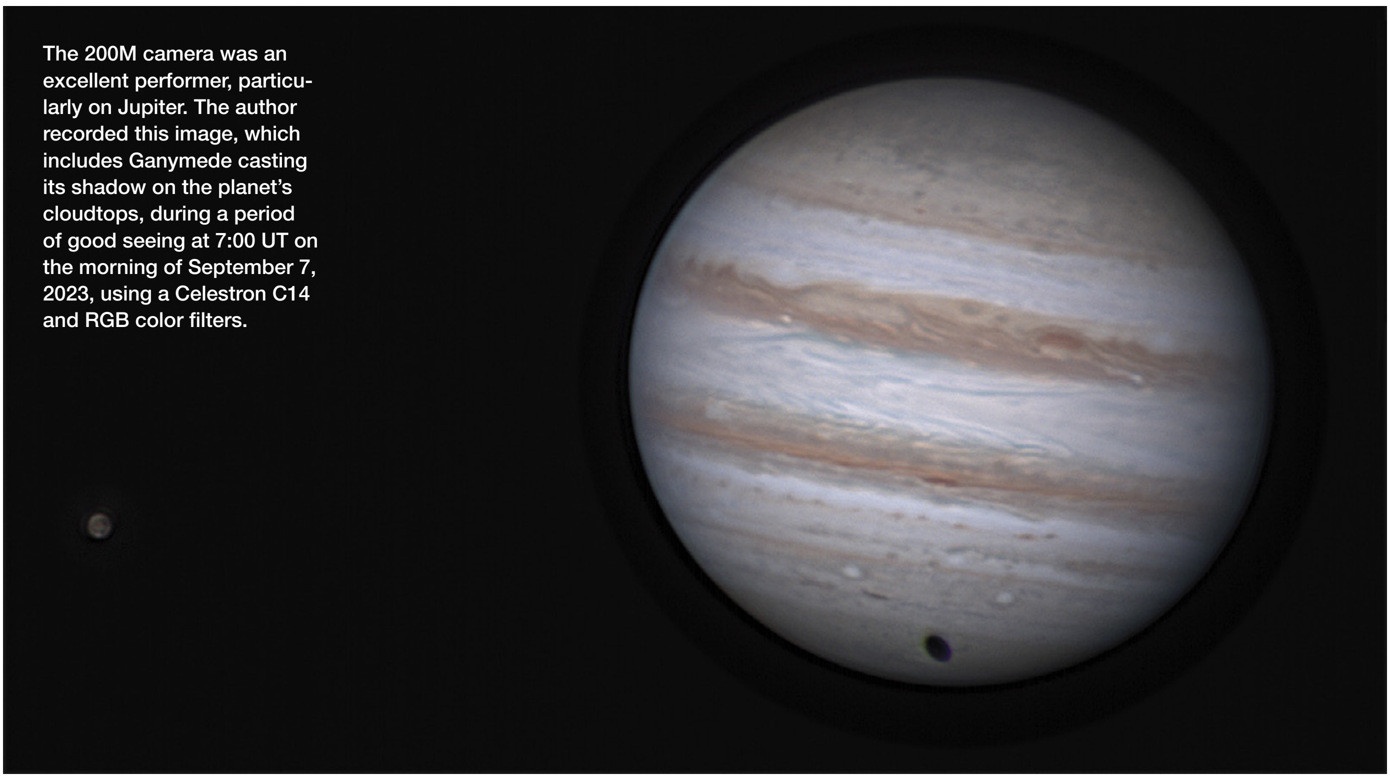
I tested both cameras by targeting Venus, Jupiter, and Saturn as well as using them for closeups of lunar craters and sunspot groups. The 200M is capable of streaming up to 96 full-resolution frames per second (FPS) in 8-bit mode, and many more FPS when using a region of interest (ROI) crop of the sensor — most helpful when targeting the planets.

When I received the camera last spring, Jupiter and Saturn were still emerging from morning twilight, but Venus was headed toward a particularly good elongation in the evening sky. For my testing I used a 12½-inch

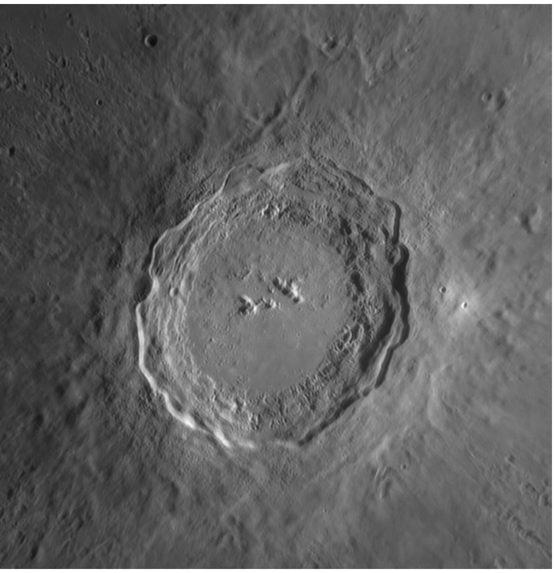
▶ The back of each camera contains a 6-pin autoguiding port, a USB-C connection, and an LED status indicator light.

Newtonian and 4× Tele Vue PowerMate to achieve a focal ratio of f/20. At this image scale, the camera had no problem recording 209 FPS through my retinue of R, G, B, UV, and near-IR filters using an ROI of 640 × 480 pixels. While this high frame rate was expected at visible wavelengths given the camera's advertised high sensitivity of 92% at 500 nanometers, I was especially pleased with its ultraviolet sensitivity. At the 350-nanometer passband of my Baader Planetarium U-Venus filter, the SC2210 detector in the 200M boasts a quantum efficiency of 80%. With older cameras, I was lucky to achieve 15 to 30 FPS and had to customize my optical train in order to pass as much ultraviolet light as possible.

Of course, Venus has the highest surface brightness of all the planets, so lightning-fast frame rates aren't unex-



The 200M camera was an excellent performer, particularly on Jupiter. The author recorded this image, which includes Ganymede casting its shadow on the planet's cloudtops, during a period of good seeing at 7:00 UT on the morning of September 7, 2023, using a Celestron C14 and RGB color filters.



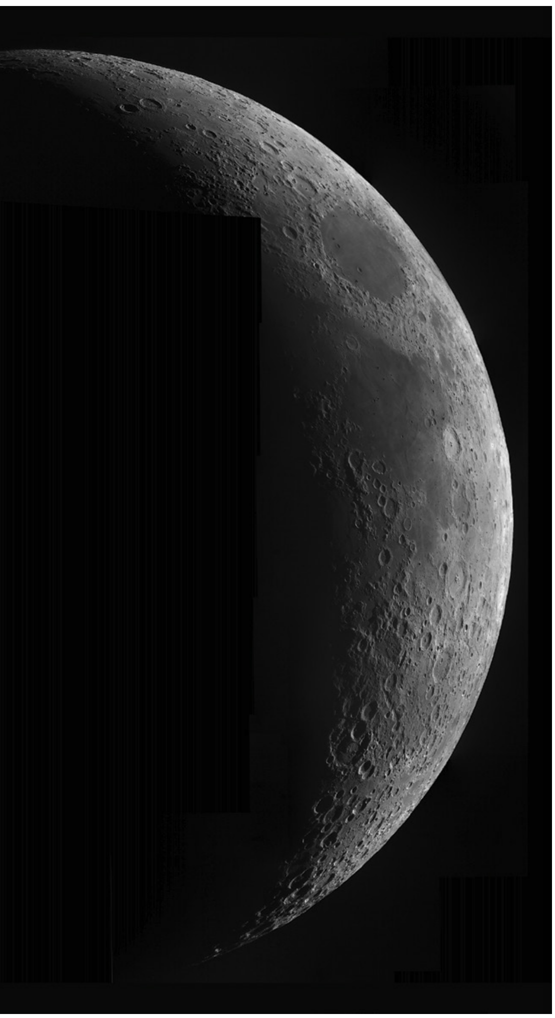
▲ The 200M is also no slouch when it comes to lunar close-ups. This detailed, 2-panel mosaic of the crater Copernicus was recorded through a green filter on the same evening as the photo of Jupiter seen on page 67.

pected. When I turned to Jupiter and Saturn, they also yielded high frame rates, as did the Moon and Sun (through a proper solar filter). Recording videos with the full frame of the 200M was useful when including nearby Galilean moons in images of Jupiter. The onboard 512 megabytes of DDR RAM acting as a frame buffer was particularly useful then. While operating the camera using *FireCapture*, the software's status bar showed buffered frames downloading for 10 seconds or so after the recording had been completed, and I never lost any data because of dropped frames.

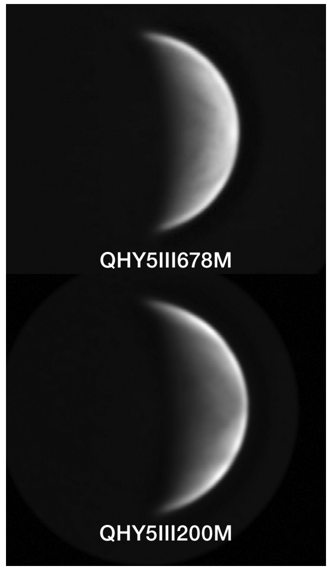
I briefly used the 200M as an autoguider when supernova SN 2023ixf appeared in M101 late last May. *PHD2* software had no problem detecting the camera and got busy guiding without a hitch.

QHY5III678M: Tiny Pixels, and Lots of Them

As mentioned earlier, both cameras have very similar field coverage. But due to the smaller pixels in the 678M the camera produces an *image scale* twice that of the 200M. Those little pixels cover a smaller area of the sky and so produce an effect similar to using a higher-magnification eyepiece. This translates to extremely high resolution when imaging with the 678M at prime focus of the Schmidt-Cassegrains popular with planetary imagers. You often may not need additional focal extenders in the optical path to produce high-resolution



◀ The small pixels within the 678M combined with its relatively wide field make the camera attractive for lunar imagers seeking to create high-resolution lunar photos. The author recorded this 11-panel mosaic on the evening of June 23, 2023, at the prime focus of his 12.5-inch Newtonian reflector through the camera's included IR850 near-infrared-filtered chamber window. He still missed a spot.



◀ Both cameras are very sensitive to wavelengths beyond the visible spectrum, as noted in the text. These images show Venus recorded on June 22, 2023, about 24 hours apart through a Baader Planetarium Venus filter centered at 350 nanometers in the ultraviolet. Both photos were captured at a frame rate of 209 frames per second through the author's 12.5-inch Newtonian reflector operating at f/20.

close-ups of the Moon, planets, or the Sun. For example, the 678M is an excellent match for my Celestron C14 at prime focus in average seeing.

The 678M also claims even greater quantum efficiency than the 200M, though it peaks at around 650 nanometers. The camera's 8.4-megapixel sensor produces up to 43 FPS when operating in 8-bit mode, and 22 FPS in 16-bit mode. Both generate a lot of data! 16-bit-mode is generally more useful for deep-sky imaging, so I'd recommend activating it and output FIT-format images when targeting nebulae, galaxies, and star clusters. In those cases, you would record exposures many seconds (or even minutes) long, rendering the camera's frame rate irrelevant. However, none of the cameras in the QHY5III series includes thermoelectric cooling, so the long exposures are generally noisier than those captured with a cooled deep-sky camera, particularly on hot summer nights.

In contrast, the targets for high-resolution planetary imaging (as well as solar and lunar photography) are bright by comparison. As such, they are well-exposed in fraction-of-a-second exposures, so they don't benefit greatly when recorded with a greater bit depth. In these cases, speed is more important than bit depth.

The little pixels in the 678M paired with its generous field make the Moon a particularly attractive target. Its expansive detector produces a wide field at an impressively high image scale, eliminating the need to mosaic several frames in order to capture the largest craters when shooting with my Newtonian and Schmidt-Cassegrain.

Under the typical seeing conditions at my New Hampshire location, I often didn't need any additional Barlow or projection to produce good detail on Jupiter using a Celestron C14 at its Cassegrain focus, unless the atmosphere was extremely steady, allowing me to crank up the magnification. Nor did I need anything but the 678M camera in my 12.5-inch Newtonian reflector's focuser to capture a fairly large image of Venus on August 13, just half a day after inferior conjunction, when the planet was a 57″ crescent (seen at right).

I had two particularly notable observations with the 678M. The first was most likely due to those tiny pixels. I found I needed to stack a lot more images of my targets to get a smooth result that held up to sharpening compared to the 200M and other planetary cameras I've used. Images taken with the camera become "noisy" when applying the same wavelet settings in *RegiStax 6* that I would use with the same target, scope, and number of frames. For example, I often stacked about 33% of 5,800 frames when targeting Jupiter with the 200M camera on my C14 to achieve a good result after sharpening. Using the 678M in the same scope at

▲ The 2-micron-square pixels in the 678M camera make resolving the planets easy even when imaging at relatively short focal lengths. This shot of Venus was captured at prime focus on the author's 12.5-inch f/5 Newtonian reflector less than 12 hours after the planet passed through inferior conjunction on August 13, 2023.

an identical image scale and frame rate, I needed about 40% of the frames to achieve a comparable result.

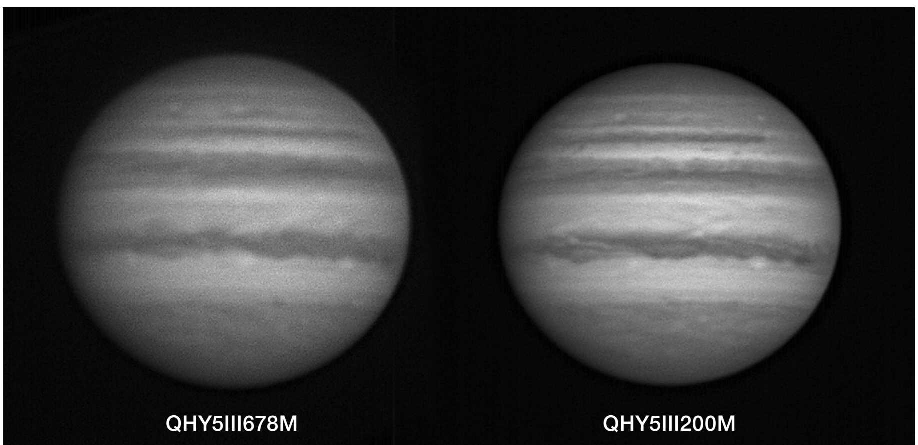
The other thing to be aware of when considering the 678M is that its 8.4-megapixel detector generates massive files when working at full resolution. Each video can be dozens of gigabytes. And that onboard 512-megabyte image buffer did some heavy-duty lifting as I attempted several lunar mosaics. When imaging with the camera connected to my aging SurfacePro laptop, I had to wait a good 15 seconds or more before starting another video

Both cameras are smaller than the typical 1¼-inch eyepiece.

as the buffer released its backlog of frames. Be sure you have a computer with a large hard drive and a fast write speed. Solid-state drives are highly recommended for planetary imaging. Also, plan on investing in a multi-terabyte portable drive in order to move and/or store your videos.

A welcome option with such tiny pixels is the ability to bin the chip 2×, meaning the control software groups 4 pixels together to effectively function as a single, larger pixel. This allows the 678M to perform just like the 200M in most respects, producing a 2-megapixel video as opposed to one with four times the pixels. It's like having the ability to reduce the image scale by half when the seeing degrades, but without having to swap Barlows or even change focus.

Both the QHY5III200M and the QHY5III678M are excellent cameras for imaging the Sun, Moon, and planets. Although they offer similar fields of view, the 678M is particularly attractive for lunar imagers, and its binning capability makes it versatile for imagers who use a wide variety of telescopes and focal lengths. The 200M is a fine performer, especially if your focus is exclusively with the major planets, or if you're looking for a camera that functions as both an imager and autoguider. The QHY5III body is one of the most compact designs available today and will work in most any guidescope or off-axis guider.



Although both cameras performed admirably on each chosen target, images taken with the 678M get noisy quickly when sharpened compared to those from the 200M. This pair of Jupiter images was recorded through the same telescope and blue filter. Each utilizes the same number of frames, though the 678M result at left is noticeably grainier than that with the 200M. A simple remedy is to stack a higher percentage of frames.

■ Associate Editor **SEAN WALKER** often targets solar system bodies from his backyard observatory in Litchfield, New Hampshire.

Brian's Bicycle Dob

Innovation abounds in this unusual build.

◀ Brian Wingert's "Bicycle Dob" is easy to assemble and a joy to use.

CREATIVITY OFTEN RUNS IN FAMILIES. So I wasn't particularly surprised when Lauren Wingert, whom I've covered multiple times in this column, introduced me to her brother Brian, who has built an innovative telescope of his own. Brian Wingert is a general contractor and the scope repair tech for the Seattle Astronomical Society's lending library, so he knows his way around tools and telescopes. When he found a 12½-inch mirror set from a Meade Starfinder on Craigslist, he suddenly had a new project.

Brian says, "I wanted to do a good job but also keep the costs in line. And while I have repaired a number of scopes, I'd never actually built one and didn't really have a clue." That's how new ideas happen, and Brian came up with a few.

The biggest hurdle to begin with was the idea of cutting circles. Brian admits that he's no good at it, and he lost sleep thinking about cutting radii. But he saw a photo of an ultra-lightweight scope that used a bicycle rim for the secondary ring, and that set him off down the path you see here. Brian wanted stiffness and durability rather than extreme portability, so he went with two bike rims separated by oak slats and black ABS plastic.

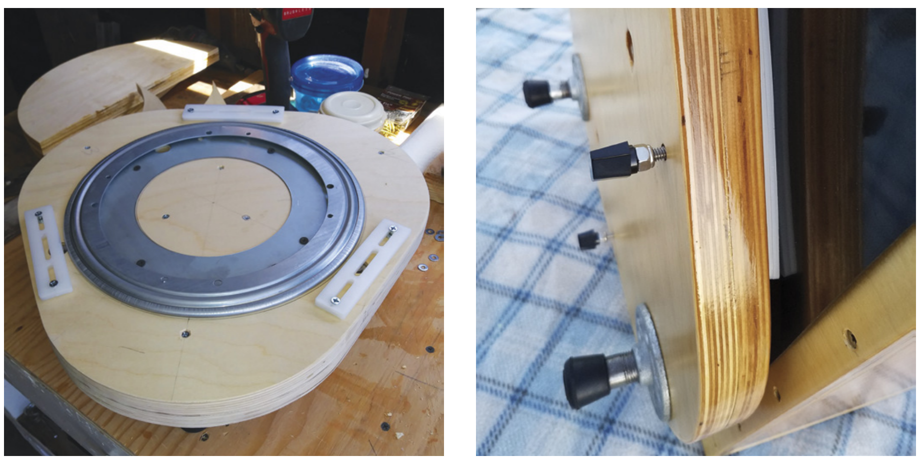
Then he started thinking about the trusses. He reports, "I didn't relish the idea of fooling around with strut lengths over and over 'til I got them right. Boom: Tripod legs are adjustable. And I had two leftover tripods collecting dust in a corner. Who cares what the distance needs to be? I would just loosen the clamps and slide the secondary cage up or down as needed."

Experimentation taught him that the tripod legs had to be attached to the corners of the mirror box in order to leave room for the altitude bearings, and he needed to use two bolts on each or the secondary cage would flex way too much. The legs fit into wide brackets that allow easy placement of the secondary cage and hold them snug when tightened down.

The mirror box and rocker box are of relatively straightforward Dobsonian design, made of plywood. Brian found 16-inch half-circles at Home Depot to use for the altitude bearings, eliminating the need for him to cut a radius. He did have to glue two half-inch pieces together to get inch-thick bearings, but that was easy. Rather than cut matching circles for the bearings to sit in, he did the Dobson trick of using inner boards with simple angled cuts and Teflon pads at the contact points.

Then came the ground board. Again, Brian had no interest in cutting circles, so he bought a Lazy-Susan bearing plate and installed that on a plywood trefoil (double thickness for strength). But Lazy-Susan bearings are almost frictionless, so Brian needed a way to increase the friction to match that of the altitude bearings.

That led to brakes made of nylon spacers from a bypass door's floor-bracket kit. A three-prong T-Nut holds a flat-head machine screw that pushes the brake pad against the bottom of the rocker box. Brian used a sheet of ABS plastic on the bottom of the rocker box for the bearing surface, but he quickly realized that the bumpy texture resulted in a rough, sandpapery, fingernails-on-chalkboard feeling and sound. So he flipped the ABS over to use the smooth



▲ *Left:* The Lazy-Susan bearing plate provided such smooth motion that Brian needed brakes to increase the friction. *Right:* Wingnuts accessible from the sides turn screws that put pressure on the nylon pads, pressing them against the rocker box to fine-tune the azimuth friction.

BRIAN AND SCOPE: JERRY OLTION; LAZY SUSAN PLATE AND BRAKES: BRIAN WINGERT (2)

▲ The battery box rests in the mirror box handle cutout and doubles as a weight box for balancing the scope.

side, and that was, in his words, "Mo betta." Using all three brakes, the motion can go from freewheeling to locked tight for transport.

Brian had one final trick up his sleeve: He installed fans to cool the mirror, so he made a battery box that hung from the handhold in the mirror box. But that's not all it is, because the battery box can also hold counterweights that balance the scope when Brian adds a heavy eyepiece.

How do all these different ideas work together? I had the opportunity to see for myself, meeting Brian for a night of observing at a dark site near Lauren's home. And I have to say, I was mightily impressed. The scope is solid as a rock on its tripod-leg struts, and the brakes are adjustable to yield whisper-smooth motion in azimuth that perfectly matches the equally smooth motion in altitude. It's easy to collimate, and the optics give excellent views. We had a blast observing with it, and that's the ultimate goal with any scope.

For more information, contact Brian at **brian@raincityhome.com**.

■ Contributing Editor **JERRY OLTION** hasn't yet seen it all, but he's seen some pretty cool stuff.

SHARE YOUR INNOVATION
Do you have a telescope or ATM observing accessory that *S&T* readers would enjoy knowing about? Email your projects to Jerry Oltion at **j.oltion@gmail.com**.

JERRY OLTION

What Do Binocular Numbers Mean?

▲ **DOUBLE-BARRELED DELIGHTS** Binoculars come in many shapes and sizes — some of which are ideal for viewing the night sky, others less so. Which ones work best for you depends largely on two main specifications: the magnification and the diameter of the front lenses. That information is usually printed somewhere on the binoculars themselves.

ALL IMAGES COURTESY OF THE AUTHOR

BINOCULARS ARE ONE OF THE MOST useful tools for exploring the wonders of the night sky. They're also one of the most comfortable — almost everyone finds viewing with both eyes more natural than with just one. But I've noticed that most enthusiasts go through three distinct phases as they gain experience under the stars.

First, curious beginners often reach for binos simply because there's already a pair lying around the house, often purchased for birdwatching or sporting events. Impressed (hopefully!), their interest in astronomy grows, and eventually they enter a second phase in which the binoculars are set aside in favor of the greater magnification and light grasp of a telescope. It's only later, in the third phase of an observer's journey, that binoculars are fully appreciated for the unique and valuable capabilities they offer. That's why most veteran skywatchers keep a pair within easy reach even as they explore the deep-sky with a monster Dobsonian.

No matter what phase you're in, it pays to choose binoculars with care. After all, a good pair can (and should) last a lifetime. But what makes one model better than another? Thankfully, the most important specifications are printed right on the instrument itself. And once you understand those numbers, you'll know if a given pair has stellar potential or is strictly for the birds.

Binoculars have two main jobs: to gather light and to present a magnified image to both eyes. Those capabilities are neatly summarized by a set of numbers usually found near one of the eyepieces or in the center of the focus dial. You'll see a pair of digits separated by an "×", such as 7×35, 10×50, or even 20×80. That first number is the magnification — how much bigger something will appear compared to when it's viewed with your eyes alone. So, with 10× binoculars, a bird that's perched in a tree 20 meters (66 feet) away will look as if it's only 2 m distant. You'll be able to see features that would be impossible to perceive without the magnification boost. Expressed using terms astronomers prefer, magnification allows you to *resolve* finer detail — and that's as helpful for a distant star cluster as it is for a backyard bird.

The second number in the set refers to the diameter of the twin front lenses (in millimeters) — the so-called *objective* lenses, or *aperture*. The importance of this spec is easy to appreciate since when it comes to optics, bigger is better. Larger lenses gather more light the same way a bucket left outside gathers more rain than a cup. So, binoculars with 50-mm objectives drink up twice as much light as 35-mm lenses, bearing in mind that light-gathering is a function of *area*. Putting it all together, 10×50 binoculars yield a magnification of 10× and have 50-mm-diameter objective lenses.

But when it comes to astronomy, how do we know if one model will be better than another? For example, would 8×56s show us more than 10×50s? One way to compare different models is to calculate a basic performance rating by doing exactly what the numbers suggest — multiplying the second figure by the first. In this scheme

▲ **IT'S ALL IN THE NUMBERS** The most important specifications for a pair of binoculars are its magnification and the size of its light-gathering objective lenses. These figures are printed near the right eyepiece in this example. As explained in the text, they indicate that this particular model magnifies 10×, has 50-mm front lenses, and yields a field of view 6.5° wide.

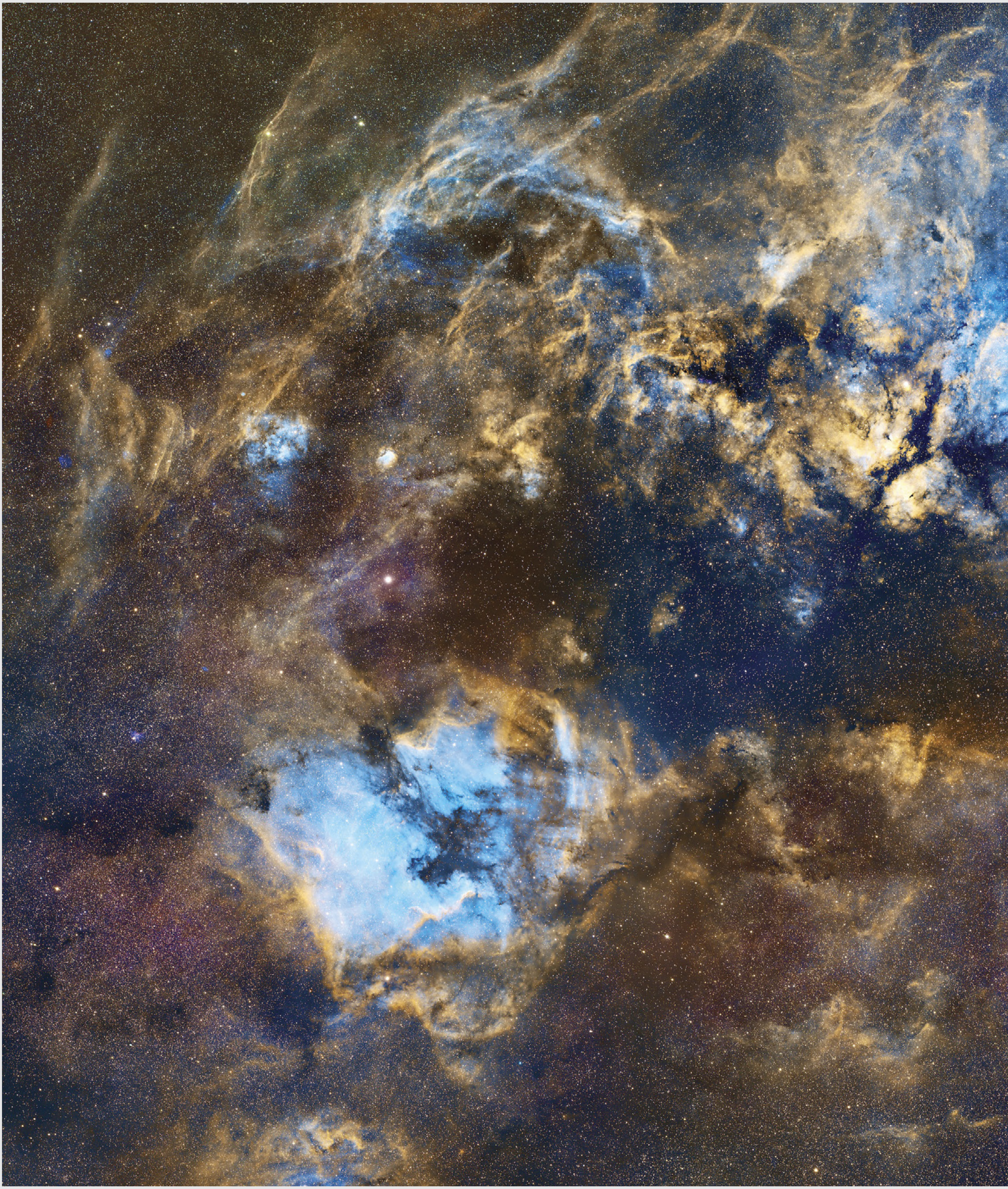
(first proposed by Canadian observer Roy L. Bishop), 8×56s would rate 448, while 10×50s would score 500, indicating slightly better performance despite having smaller objective lenses. This rating system gives you a rough feel for how magnification and aperture interact, and their impact on how different binoculars work under the stars.

But can two numbers really tell the whole story? Not entirely. Magnification and aperture mostly define how a given pair will perform, but (as with most things in life) there are inevitable tradeoffs to consider. For example, 20×80s unsurprisingly (with their 1,600 rating!) can show greater detail than 10×50s. However, big binos are a lot heavier and require a tripod to work effectively. So, if portability and ease-of-use are important to you — and many would argue those are the main strengths of binoculars — the lightweight 10×50s are a better choice. In addition, the smaller pair will also show you a bigger slice of the sky. The fact of the matter is that (all other things being equal) as magnification goes up, the field of view goes down. Those hefty 20×80s will show you a circle of sky roughly 2½° across — only one quarter the area that 10×50s will deliver. That's a big difference! It's true that things will appear smaller, fainter, and less detailed in the 10×50s, but you'll be able to take in a much bigger swath of sky, which makes locating your target far easier than with the more powerful pair.

So, what about those other numbers you sometimes see printed on binoculars? It's not unusual to encounter specifications such as "367 feet at 1,000 yards," for example. These figures describe the diameter of the field of view. To put it into English, the numbers in this example tell us that if we look at an office tower that's 1,000 yards away, you'll see 367 feet of its height in your binoculars. Interesting, but for astronomy, not terribly useful since we don't measure the sky in feet or yards. But you can convert to degrees by simply dividing the first number in the set by 52.4. Doing so reveals that the binos we're discussing here have a 7°-wide field of view (367/52.4). Handy. If the numbers are expressed in meters instead of yards, you'd divide the first figure by 17.5 instead. Thankfully, many manufacturers simply give the field size in degrees — no math required.

Of course, there's much more to choosing binoculars than just the basic specifications discussed here. Price, brand, optical and mechanical quality, plus a host of other factors all matter. However, the first and most important decision to make is to figure out which combination of magnification and aperture makes sense for the kind of observing you like to do. And for that, you really can begin your search with just two numbers. ■

◀ **CRUCIAL SPECS** On some binoculars, such as this pair of Nikon Aculons, the magnification, objective-lens diameter, and field of view are displayed between the eyepieces.



DUSTY SWAN
Jorge Restrepo
This colorful narrowband composite image of Cygnus captures several bright emission nebulae, including NGC 7000 (left), NGC 6914 (center), and parts of the Veil Nebula (bottom right).
DETAILS: *ZWO ASI294MM Pro camera with Rokinon 135-mm lens. Total exposure: 27 hours through narrowband filters.*

▷ SEE-THROUGH GALAXY

Warren Keller and Mike Selby

Several distant galaxies are visible through the bluish spiral arms of NGC 578 in Cetus, including PGC 133775 (left) and PGC 810586 (right). Also visible is PGC 810295 at lower right.

DETAILS: *PlaneWave 1000CDK telescope and FLI ProLine 16803 camera. Total exposure: many hours through LRGB filters.*

▽ TWILIGHT MEETING

Jamie Cooper

The waxing crescent Moon and bright Venus shone just above the trees in Northamptonshire, England, on the evening of the summer solstice on June 21, 2023.

DETAILS: *Canon 5D Mark III camera and 300-mm lens. Total exposure: 3.2 seconds at f/6.3, ISO 500.*

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△ FLAMING OUT

Dave Doctor

Interacting spiral galaxies NGC 4568 (lower left) and NGC 4567 to its upper right are beautiful targets in Cetus in their own right. But they gained an added interest when Supernova SN2023ijd exploded in NGC 4568 (seen south of the galaxy's nucleus) in mid-May of 2023. Elliptical galaxy NGC 4564 is also visible in the top of the field.

DETAILS: *Officina Stellare RiDK 400 telescope and SBIG STX-16803 camera. Total exposure: 22 hours through LRGB filters.*

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MISCELLANEOUS

MISCELLANEOUS (cont.)

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Event Calendar

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

February 5–11
WINTER STAR PARTY
Scout Key, FL
scas.org/winter-star-party/?y=2024

April 5–9
TEXAS TOTAL SOLAR ECLIPSE AND STAR PARTY
Fort Davis, TX
texasstarparty.org

April 20–21
NORTHEAST ASTRONOMY FORUM
Suffern, NY
neafexpo.com

May 8–11
MIDSOUTH STARGAZE
French Camp, MS
rainwaterobservatory.org/events

May 18
SPRING ASTRONOMY DAY
Everywhere!
astroleague.org/astronomy-day

June 1–8
GRAND CANYON STAR PARTY
Grand Canyon, AZ
https://is.gd/GrandCanyonStarParty

June 5–9
ROCKY MOUNTAIN STAR STARE
Gardner, CO
https://is.gd/RMSS2024

June 6–9
CHERRY SPRINGS STAR PARTY
Cherry Springs State Park, PA
cherrysprings.org

July 28–August 2
NEBRASKA STAR PARTY
Valentine, NE
nebraskastarparty.org

July 30–August 3
TABLE MOUNTAIN STAR PARTY
Oroville, WA
tmspa.com

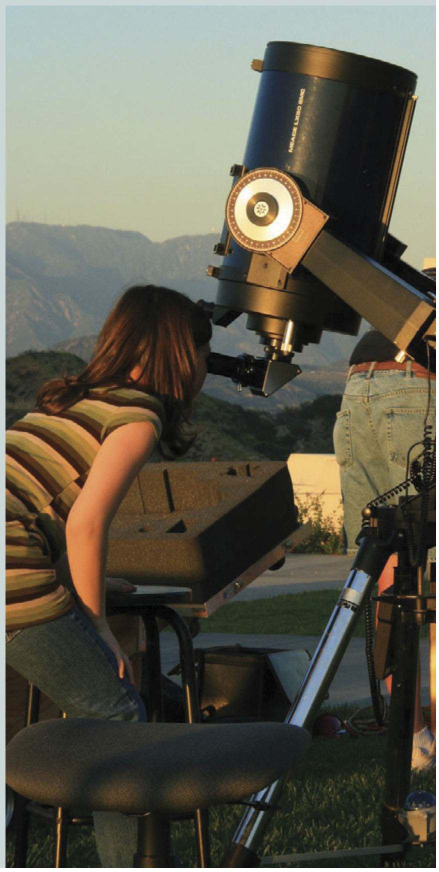
July 30–August 4
OREGON STAR PARTY
Indian Trail Spring, OR
oregonstarparty.org

August 1–4
STELLAFANE CONVENTION
Springfield, VT
stellafane.org

August 30–September 3
THE ALMOST HEAVEN STAR PARTY
Spruce Knob, WV
ahsp.org

October 12
FALL ASTRONOMY DAY
Everywhere!
astroleague.org/astronomy-day

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



A Surprising Second Chance

The universe gave the author a gift that made him reflect on an earlier, uncertain observation.

AT AGE 17, just three years after I fell head over heels into astronomy, I got to see a supernova in Messier 101, the Pinwheel Galaxy. It was my first supernova and, little did I know at the time, an exceptionally bright one. But I'm getting ahead of myself, because I wouldn't know for sure I'd seen it . . . for another 7½ years.

On September 23, 2011, I learned of a Type Ia supernova in M101 (SN 2011fe). The Palomar Transient Factory survey had discovered it a month earlier, and it had reached a peak magnitude of 9.9 in mid-September. Two days after I learned of the supernova, the evening sky was clear, and I went searching for it using my late grandfather's pre-computerized, 10-inch Schmidt-Cassegrain telescope.

My hopes of seeing it were high despite my having only used his telescope off and on for less than two years. That evening, I spent more time observing M101 with the scope than I had any other deep-sky object previously. I got the galaxy into the main field without much trouble, but knowing where to look for the imposter "star" proved to be much harder than I'd anticipated.

I was struggling to line up the few photos I had of the supernova in the galaxy to what I was seeing at the eyepiece — something that I *still* struggle with when it comes to M101. I kept my chin up, however, and sketched the entire field, adding an arrow indicating which point of light I thought was the supernova. A week later, I looked again, but the star I'd arrowed on my drawing didn't seem to have dimmed, as it should have if it were the exploded star. This made me skeptical as to whether I'd truly seen my first supernova.

In early 2019, I stumbled upon *S&T* Contributing Editor Howard Banich's impressive sketch of M101 (*S&T:* June 2013, p. 38). When I noticed he'd labeled it on his drawing, I was reminded of my possible supernova sighting. For fun, I pulled out my old sketch. When I compared the two, I was shocked to find that I *had* drawn the supernova — it just wasn't the star I'd labeled as such!

> It was an emotional experience that nearly brought me to tears.

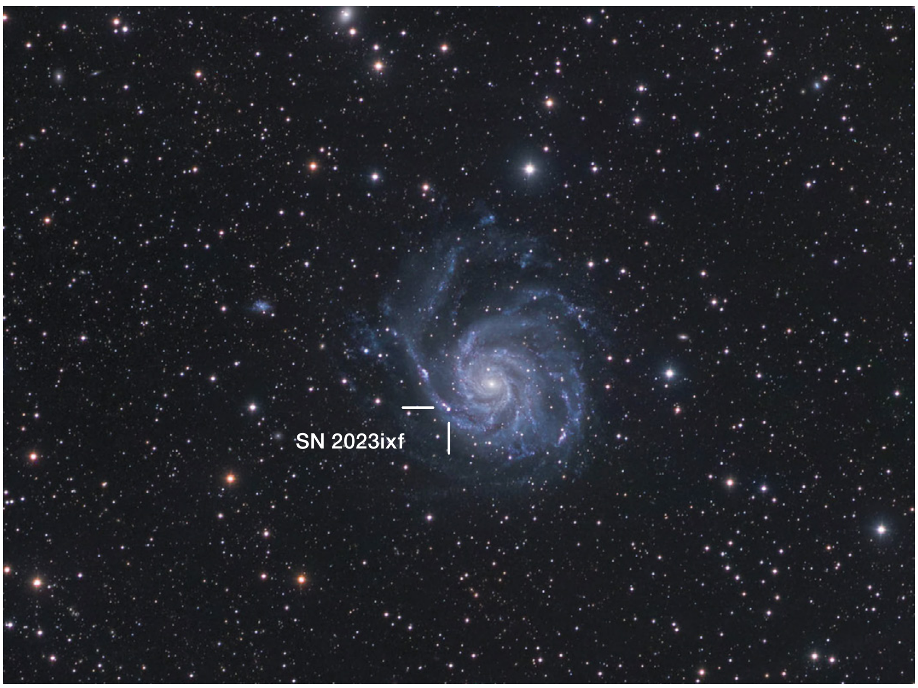
My only regret then was that I hadn't seen the supernova in handheld binoculars. I doubted I'd ever get to accomplish such a feat, too, since supernovae that bright are usually in even brighter galaxies and/or too close to their cores.

At least, that was my feeling up until May 19th of last year, when M101 belched out its fifth recorded supernova.

Within 36 hours of its discovery by Japanese amateur Kōichi Itagaki, I was able to easily spot the new Type II supernova (SN 2023ixf) in the same telescope I'd used the last time. On that night and successive ones, I observed it as well in my 12×60 binoculars, 4.5′ from the galaxy's core.

It was an emotional experience. Getting to see a supernova not only in handheld binoculars but in the same galaxy in which I'd seen my first one a dozen years earlier nearly brought me to tears. It reminded me of just how far I've come and how much better I am at finding things in the vastness of space we call the universe.

■ Contributing Editor **SCOTT HARRINGTON** is no longer losing sleep over the next Milky Way supernova.



▲ Taken with a 4-inch refractor on the night of May 24, 2023, this image of M101 shows the supernova designated SN 2023ixf at peak brightness.

SEAN WALKER / S&T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Skygazer's Almanac 30°S 2024

FOR LATITUDES NEAR 30° SOUTH

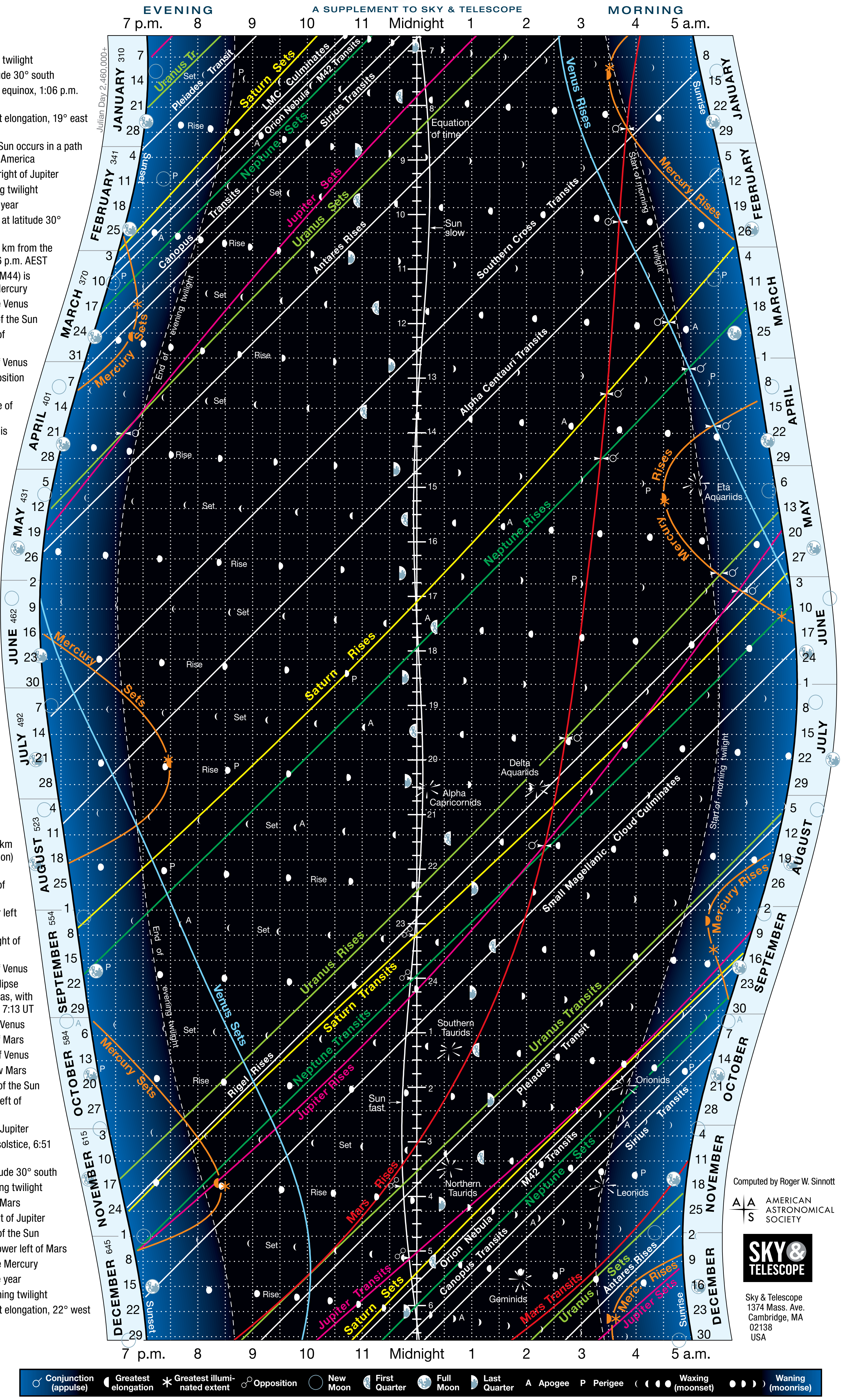
A SUPPLEMENT TO SKY & TELESCOPE

EVENING SKY

Jan 4 Latest end of evening twilight
Jan 10 Latest sunset at latitude 30° south
Mar 20 Autumn begins at the equinox, 1:06 p.m. AEST
Mar 25 Mercury is at greatest elongation, 19° east of the Sun
Apr 8 A total eclipse of the Sun occurs in a path running across North America
Apr 21 Uranus is 0.5° lower right of Jupiter
Jun 7 Earliest end of evening twilight
Jun 10 Earliest sunset of the year
Jun 21 Shortest day, 10ʰ 13ᵐ at latitude 30° south
Jul 5 Earth is 152,099,968 km from the Sun (aphelion) at 3:06 p.m. AEST
Jul 7 The Beehive Cluster (M44) is almost centered on Mercury
Jul 17 Beehive is 0.6° above Venus
Jul 22 Mercury is 27° east of the Sun
Jul 25 Regulus is 2.1° right of Mercury
Aug 5 Regulus is 1.0° left of Venus
Sep 8 Saturn comes to opposition tonight
Sep 17 A slight partial eclipse of the Moon occurs for South America late this evening
Sep 20 Neptune's opposition
Sep 22 Spring begins at the equinox, 10:44 p.m. AEST
Oct 2 An annular eclipse of the Sun follows a path through the southeastern Pacific Ocean and across southern Chile and Argentina
Nov 10 Antares is 2.0° upper left of Mercury
Nov 16 Mercury is 23° east of the Sun
Nov 17 Uranus reaches opposition
Dec 7 Jupiter stands at opposition
Dec 21 Summer begins at the solstice, 7:20 p.m. AEST; longest day, 14ʰ 05ᵐ at latitude 30° south

MORNING SKY

Jan 3 Earth is 147,100,633 km from the Sun (perihelion) at 10:39 a.m. AEST
Jan 13 Mercury is 24° west of the Sun
Jan 28 Mercury is 0.3° lower left of Mars
Feb 23 Mars is 0.6° upper right of Venus
Mar 22 Saturn is 0.4° right of Venus
Mar 25 A penumbral lunar eclipse occurs for the Americas, with shading deepest near 7:13 UT
Apr 4 Neptune is 0.4° from Venus
Apr 11 Saturn is 0.4° right of Mars
Apr 20 Mercury is 1.8° left of Venus
Apr 29 Neptune is 0.3° below Mars
May 10 Mercury is 26° west of the Sun
May 31 Uranus is 1.5° lower left of Mercury
Jun 5 Mercury is 0.8° from Jupiter
Jun 21 Winter begins at the solstice, 6:51 a.m. AEST
Jul 1 Latest sunrise at latitude 30° south
Jul 4 Latest onset of morning twilight
Jul 16 Uranus is 0.5° left of Mars
Aug 15 Mars is 0.3° lower left of Jupiter
Sep 5 Mercury is 18° west of the Sun
Sep 9 Cluster M35 is 0.9° lower left of Mars
Sep 10 Regulus is 0.8° above Mercury
Dec 3 Earliest sunrise of the year
Dec 8 Earliest onset of morning twilight
Dec 25 Mercury is at greatest elongation, 22° west of the Sun



Skygazer's Almanac 30°S 2024

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 2024*, 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 7, 2024.

First find "January" and "7" 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 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 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 7th occurs at 7:05 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 7th, we see that at 8:02 p.m. a line for Uranus crosses it. But the twilight would make it hard to find this dim planet. Evening twilight doesn't truly end until 8:41, when the Sun is 18° below the horizon (note the dashed line).

At 8:42 the Pleiades star cluster transits the meridian, meaning it is due north. Moving to the right, we see that Saturn sets at 9:49, so it has been low in the west up to now.

At about 10:17 the Large Magellanic Cloud culminates (another way of saying it transits). The Great Orion Nebula M42 transits at 10:30, and the two brightest nighttime stars, Canopus and Sirius, transit at 11:18 and 11:40, 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 7–8 this is $7^{h}\,07^{m}$. 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 draw a line through it parallel to the white event lines of stars. See where your line 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 north. On January 7th the Sun runs slow, transiting at 12:06 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.

At 12:42 a.m. the bright planet Jupiter sets. As the wee hours continue, a tiny Moon symbol is centered on the dotted line at 1:36, and the legend at the bottom of the chart tells us it is a waning crescent, just rising. Then at 2:14 Antares, a star we usually associate with later seasons, climbs above the southeastern horizon. It is followed up by brilliant Venus at 2:39.

The first hint of dawn — the start of morning twilight — comes at 3:32. Elusive Mercury rises at 3:34, and Mars at 4:00. The Sun finally peeks above the southeastern horizon at 5:07 a.m. on Monday morning, January 8th.

Other Charted Information

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

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

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 December 7–8 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 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 morning of January 11th 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 running count of days beginning with January 1, 4713 BC. Its first four digits early this year are 2460, as indicated just off the chart's upper left margin. To find the last three digits for days in January, add 310 to the date. For instance, on January 7th we have 310 + 7 = 317, so the Julian Day is 2,460,317.

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 below at left has the corrections, in minutes, for some 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.

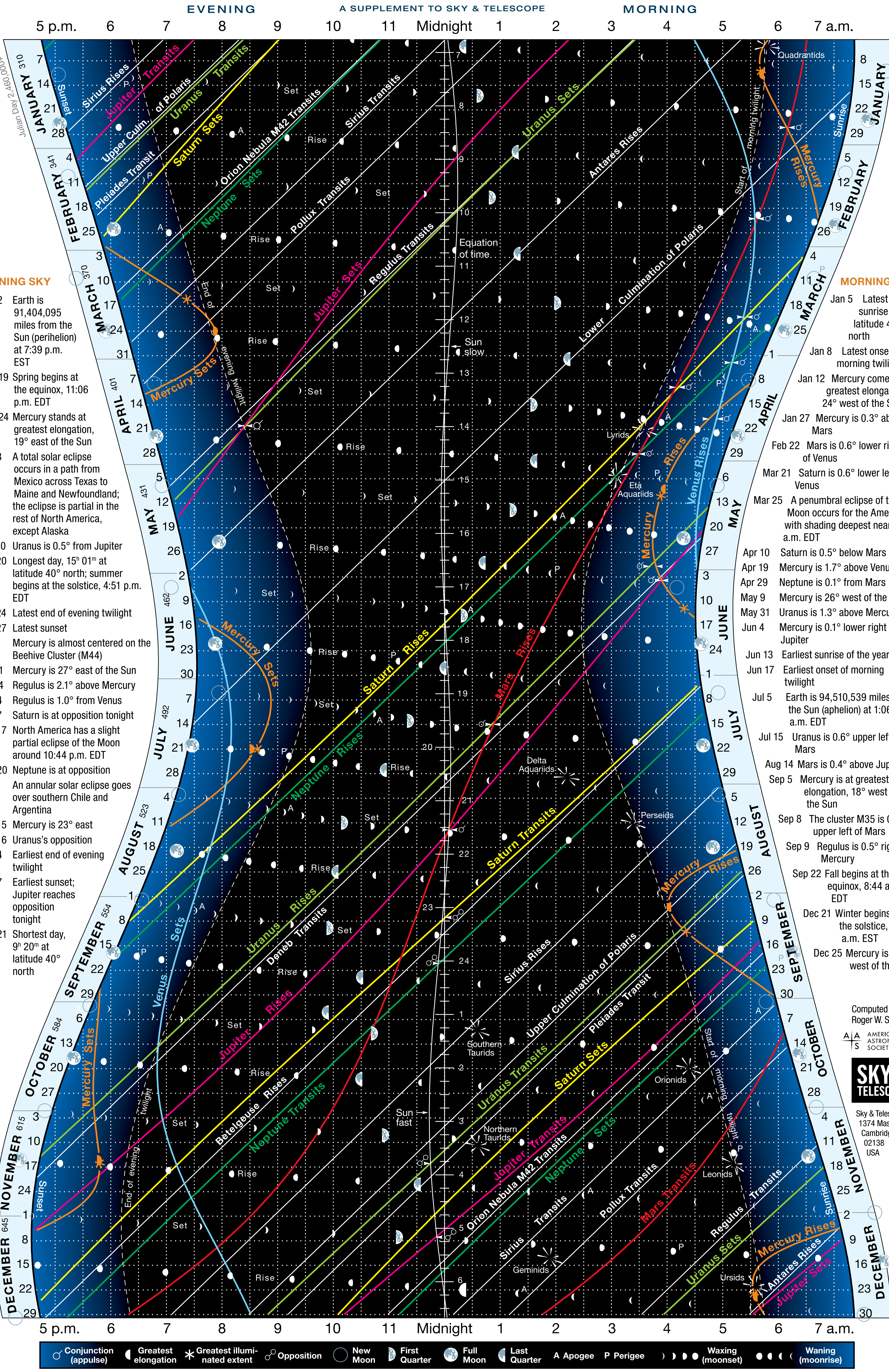
Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 135°E. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of central Australia, and two minutes later for each time zone west of there. Observers 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.

Skygazer's Almanac 2024 is a supplement to *Sky & Telescope* Magazine, 1374 Massachusetts Avenue, Cambridge, MA 02138, USA, skyandtelescope.org.

Skygazer's Almanac 40°N 2024

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



EVENING SKY

- **Jan 2** Earth is 91,404,095 miles from the Sun (perihelion) at 7:39 p.m. EST
- **Mar 19** Spring begins at the equinox, 11:06 p.m. EDT
- **Mar 24** Mercury stands at greatest elongation, 19° east of the Sun
- **Apr 8** A total solar eclipse occurs in a path from Mexico across Texas to Maine and Newfoundland; the eclipse is partial in the rest of North America, except Alaska
- **Apr 20** Uranus is 0.5° from Jupiter
- **Jun 20** Longest day, $15^h 01^m$ at latitude 40° north; summer begins at the solstice, 4:51 p.m. EDT
- **Jun 24** Latest end of evening twilight
- **Jun 27** Latest sunset
- **Jul 6** Mercury is almost centered on the Beehive Cluster (M44)
- **Jul 21** Mercury is 27° east of the Sun
- **Jul 24** Regulus is 2.1° above Mercury
- **Aug 4** Regulus is 1.0° from Venus
- **Sep 7** Saturn is at opposition tonight
- **Sep 17** North America has a slight partial eclipse of the Moon around 10:44 p.m. EDT
- **Sep 20** Neptune is at opposition
- **Oct 2** An annular solar eclipse goes over southern Chile and Argentina
- **Nov 15** Mercury is 23° east
- **Nov 16** Uranus's opposition
- **Dec 4** Earliest end of evening twilight
- **Dec 7** Earliest sunset; Jupiter reaches opposition tonight
- **Dec 21** Shortest day, $9^h 20^m$ at latitude 40° north

MORNING SKY

- **Jan 5** Latest sunrise at latitude 40° north
- **Jan 8** Latest onset of morning twilight
- **Jan 12** Mercury comes to greatest elongation, 24° west of the Sun
- **Jan 27** Mercury is 0.3° above Mars
- **Feb 22** Mars is 0.6° lower right of Venus
- **Mar 21** Saturn is 0.6° lower left of Venus
- **Mar 25** A penumbral eclipse of the Moon occurs for the Americas, with shading deepest near 3:13 a.m. EDT
- **Apr 10** Saturn is 0.5° below Mars
- **Apr 19** Mercury is 1.7° above Venus
- **Apr 29** Neptune is 0.1° from Mars
- **May 9** Mercury is 26° west of the Sun
- **May 31** Uranus is 1.3° above Mercury
- **Jun 4** Mercury is 0.1° lower right of Jupiter
- **Jun 13** Earliest sunrise of the year
- **Jun 17** Earliest onset of morning twilight
- **Jul 5** Earth is 94,510,539 miles from the Sun (aphelion) at 1:06 a.m. EDT
- **Jul 15** Uranus is 0.6° upper left of Mars
- **Aug 14** Mars is 0.4° above Jupiter
- **Sep 5** Mercury is at greatest elongation, 18° west of the Sun
- **Sep 8** The cluster M35 is 0.9° upper left of Mars
- **Sep 9** Regulus is 0.5° right of Mercury
- **Sep 22** Fall begins at the equinox, 8:44 a.m. EDT
- **Dec 21** Winter begins at the solstice, 4:20 a.m. EST
- **Dec 25** Mercury is 22° west of the Sun

Computed by Roger W. Sinnott

American Astronomical Society

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

Skygazer's Almanac 40°N 2024

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 2024*, 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 7, 2024.

First find "January" and "7" 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 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 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 7th occurs at 4:51 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 7th rightward, we see that at 6:27 evening twilight technically ends. This is when the Sun is 18° below the horizon and the sky is fully dark. At 6:33 the bright star Sirius rises, so we know it will be visible most of the night.

The giant planet Jupiter transits the meridian at 7:07, meaning it is due south and "riding high," an excellent time to examine it in a telescope.

At 7:55 Polaris, the North Star, has its upper culmination. It then stands directly above the north celestial pole (by 38′ this year), a good time to check the polar alignment of an equatorial telescope mount.

The famous Pleiades star cluster transits at 8:40 p.m., so it is well placed for viewing in a telescope. At the same time, however, the ringed planet Saturn sets, so we won't be observing it later tonight.

The Great Orion Nebula M42 transits at 10:28, as does Sirius at 11:37. Transit times of celestial landmarks help us keep track of the march of constellations across the night 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 7–8 this is $7^h\,09^m$. To find the sidereal time at any other time and date on the chart, locate that point and draw a line through it parallel to the white event lines of stars. See where your line 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 7th the Sun runs slow, transiting at 12:06 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.

At 1:51 a.m. Jupiter finally sets. The wee hours continue, and at 3:00 the star Regulus transits. At 4:42 the brilliant planet Venus rises. Then a few minutes later a tiny Moon symbol appears on the dotted line, and we can tell from the legend at the bottom of the chart that it is at waning crescent phase, rising.

The elusive planet Mercury rises at 5:40 a.m. That's even before the first hint of dawn — start of morning twilight — at 5:45. For those with an ocean horizon, the red planet Mars comes up at 6:27. The Sun finally peeks above the horizon at 7:22 a.m. on January 8th.

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* the line for midnight). Opposition is marked there by a ☍ symbol, as for the dim planet Neptune on the night of September 20–21.

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 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 March 15th 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 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 2460, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 310 to the date. For instance, on the evening of January 7th we have 310 + 7 = 317, so the Julian Day is 2,460,317. 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 to standard time, in minutes, for some major cities.

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

• **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.

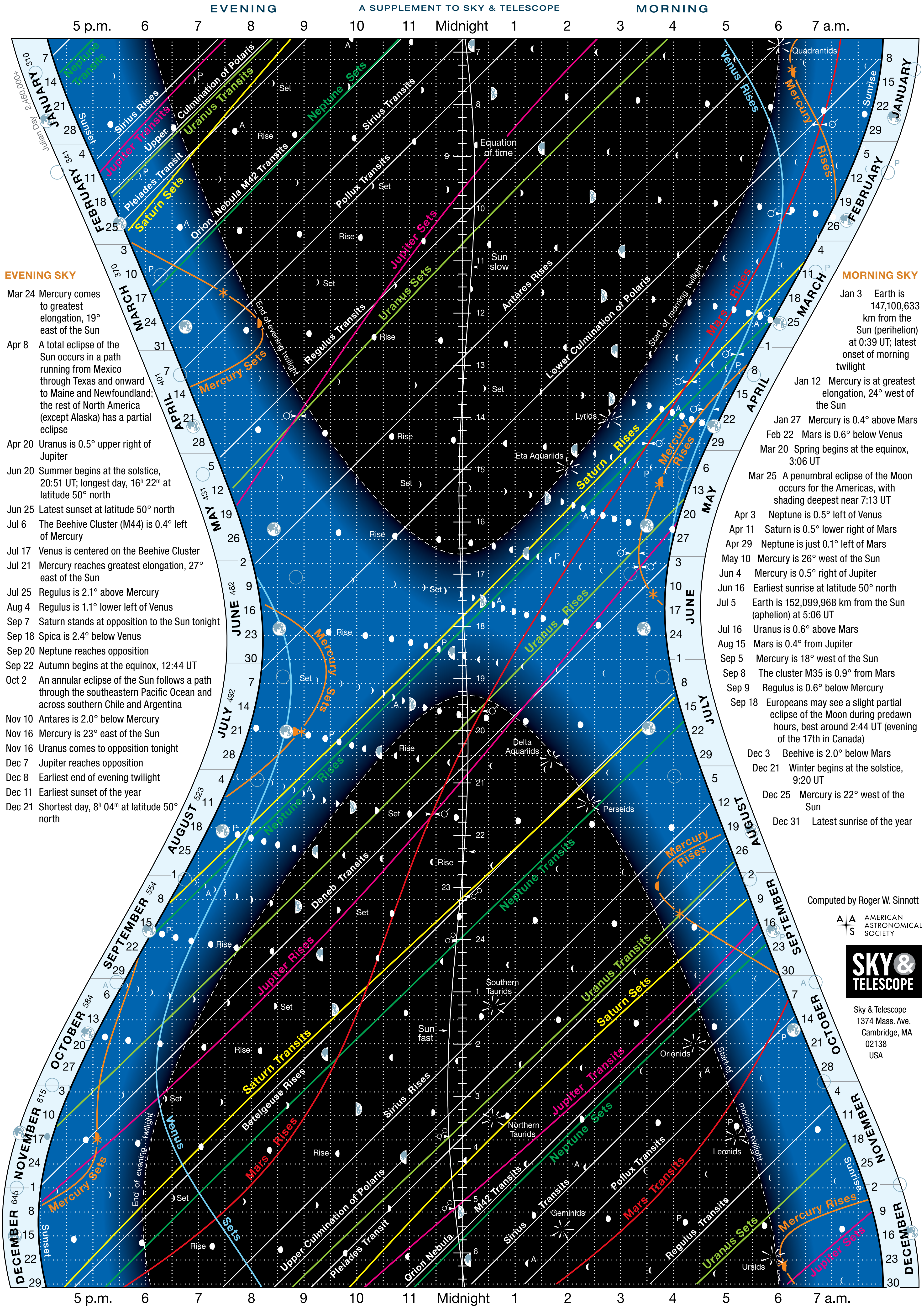
Skygazer's Almanac 2024 is a supplement to *Sky & Telescope* Magazine, 1374 Massachusetts Avenue, Cambridge, MA 02138, USA, skyandtelescope.org.

SKY & TELESCOPE
AMERICAN ASTRONOMICAL SOCIETY

Skygazer's Almanac 50° N 2024

FOR LATITUDES NEAR 50° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



EVENING SKY

- Mar 24 Mercury comes to greatest elongation, 19° east of the Sun
- Apr 8 A total eclipse of the Sun occurs in a path running from Mexico through Texas and onward to Maine and Newfoundland; the rest of North America (except Alaska) has a partial eclipse
- Apr 20 Uranus is 0.5° upper right of Jupiter
- Jun 20 Summer begins at the solstice, 20:51 UT; longest day, $16^h 22^m$ at latitude 50° north
- Jun 25 Latest sunset at latitude 50° north
- Jul 6 The Beehive Cluster (M44) is 0.4° left of Mercury
- Jul 17 Venus is centered on the Beehive Cluster
- Jul 21 Mercury reaches greatest elongation, 27° east of the Sun
- Jul 25 Regulus is 2.1° above Mercury
- Aug 4 Regulus is 1.1° lower left of Venus
- Sep 7 Saturn stands at opposition to the Sun tonight
- Sep 18 Spica is 2.4° below Venus
- Sep 20 Neptune reaches opposition
- Sep 22 Autumn begins at the equinox, 12:44 UT
- Oct 2 An annular eclipse of the Sun follows a path through the southeastern Pacific Ocean and across southern Chile and Argentina
- Nov 10 Antares is 2.0° below Mercury
- Nov 16 Mercury is 23° east of the Sun
- Nov 16 Uranus comes to opposition tonight
- Dec 7 Jupiter reaches opposition
- Dec 8 Earliest end of evening twilight
- Dec 11 Earliest sunset of the year
- Dec 21 Shortest day, $8^h 04^m$ at latitude 50° north

MORNING SKY

- Jan 3 Earth is 147,100,633 km from the Sun (perihelion) at 0:39 UT; latest onset of morning twilight
- Jan 12 Mercury is at greatest elongation, 24° west of the Sun
- Jan 27 Mercury is 0.4° above Mars
- Feb 22 Mars is 0.6° below Venus
- Mar 20 Spring begins at the equinox, 3:06 UT
- Mar 25 A penumbral eclipse of the Moon occurs for the Americas, with shading deepest near 7:13 UT
- Apr 3 Neptune is 0.5° left of Venus
- Apr 11 Saturn is 0.5° lower right of Mars
- Apr 29 Neptune is just 0.1° left of Mars
- May 10 Mercury is 26° west of the Sun
- Jun 4 Mercury is 0.5° right of Jupiter
- Jun 16 Earliest sunrise at latitude 50° north
- Jul 5 Earth is 152,099,968 km from the Sun (aphelion) at 5:06 UT
- Jul 16 Uranus is 0.6° above Mars
- Aug 15 Mars is 0.4° from Jupiter
- Sep 5 Mercury is 18° west of the Sun
- Sep 8 The cluster M35 is 0.9° from Mars
- Sep 9 Regulus is 0.6° below Mercury
- Sep 18 Europeans may see a slight partial eclipse of the Moon during predawn hours, best around 2:44 UT (evening of the 17th in Canada)
- Dec 3 Beehive is 2.0° below Mars
- Dec 21 Winter begins at the solstice, 9:20 UT
- Dec 25 Mercury is 22° west of the Sun
- Dec 31 Latest sunrise of the year

Computed by Roger W. Sinnott

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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 50° N 2024

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 2024*, 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 7, 2024.

First find "January" and "7" 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 7–8 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 7–8 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 7th occurs at 4:15 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 7th, we see a line for Neptune crossing it at 4:37, but twilight is still much too bright to look for that faint planet. The dashed line at 6:13 marks the end of evening twilight, the time when the Sun is 18° below the horizon and the sky is fully dark.

At 6:59 p.m. the brightest nighttime star, Sirius, rises in the southeast. Then at 7:08 the giant planet Jupiter transits the meridian, meaning it is then due south and highest in the sky, the best time to view its cloud belts and four bright moons in a telescope.

Polaris, the North Star, reaches upper culmination near 7:56. This is when Polaris stands directly above the north celestial pole (by 38′ this year), a good opportunity to check the polar alignment of a telescope mount.

The ringed planet Saturn sets at 8:25, so we know it has been visible, low in the west, up to now. The Pleiades star cluster in Taurus transits the meridian at 8:41, followed by the Great Nebula in Orion (10:29) and Sirius (11:38). Transits of celestial landmarks help remind us where the constellations are during the night.

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 7–8 this is $7^h\ 08^m$. 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 draw a line through it parallel to the white event lines of stars. See where your line 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 7th the Sun runs slow, transiting at 12:06 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.

Pollux in Gemini transits at 12:38 a.m., and Regulus in Leo does so at 3:01. As the wee hours continue, note the tiny Moon symbol centered at about 5:10. The legend at the bottom of the chart tells us the Moon is a waning crescent, rising. Just 3 minutes later brilliant Venus also rises (but they happen to be about 7° apart on this occasion).

The first hint of dawn — the start of

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
Lyons	+41	Zurich	+24

morning twilight — comes at 5:59. Elusive Mercury rises at 6:13, followed by Mars at 7:07. The Sun finally peeks above the eastern horizon at 7:57 a.m. on Monday morning, January 8th.

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 marked on the chart by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), 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 visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is indicated there by a ☍ symbol. For instance, Jupiter reaches opposition on the night of December 7–8 this year.

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 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 the dates when their disks in telescopes show the greatest illuminated extent in square arcseconds. For example, Mercury does so on the morning of September 13th.

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

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 early this year are 2460, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 310 to the date. For instance, on the evening of January 7th we have 310 + 7 = 317, so the Julian Day is 2,460,317. 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 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.

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