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SEPTEMBER 2026

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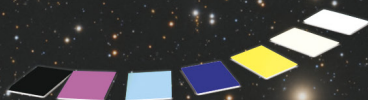
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THE ESSENTIAL GUIDE TO ASTRONOMY

September 2026

VOL. 152, NO. 3

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Illustration of the Nancy Grace Roman Space Telescope

IMAGE: NASA GSFC

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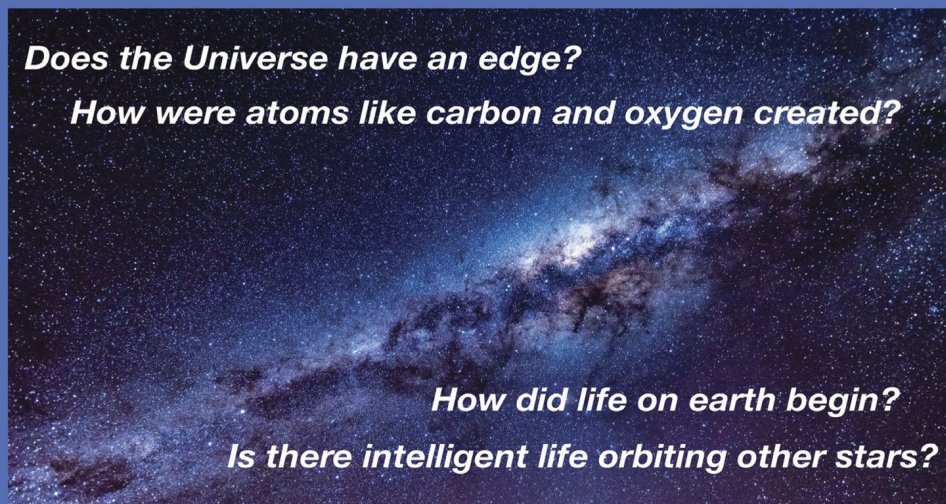


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A Legendary Lady

I'M SURE THIS MONTH'S cover story on the Nancy Grace Roman Space Telescope by Contributing Editor Govert Schilling (page 26) will prove illuminating to many readers. Roman is NASA's next flagship astrophysics mission; you might have heard it mentioned before now. It's a Big Deal: It promises to advance our understanding of everything from exoplanets to cosmic evolution.

But until recently, I didn't know much about Nancy Grace Roman, the woman. When NASA announced in 2020 that they would name the mission after their first chief of astronomy, I felt I had to rectify this lacuna. What I've learned since then has revealed a pioneer of 20th-century astronomy.

Born in 1925 in Tennessee, Roman spent her childhood moving around the country, going wherever her geophysicist father's work took the family. She expressed an early interest in astronomy, founding her school's club in sixth grade. Like many girls and women at the time, she was discouraged from pursuing a science career, but she persisted and earned a PhD in astronomy from the University of Chicago in 1949. Although she enjoyed teaching, she saw no future in academia: At the time, there was only one tenured female astronomer (Cecilia Payne-Gaschewskina) in the whole of the U.S. Roman moved to government labs and, in 1959, joined NASA just six months after the agency's founding.



▲ Nancy Grace Roman was a true pioneer.

The following year, Roman was appointed NASA's Chief of Astronomy; it's in that capacity that she cemented her career. Her main role was to secure grant funding for projects. After listening to scientists' goals, she took it upon herself to push for a long-dreamed-of space-based telescope. She steered the mission concept through myriad congressional meetings until Congress gave the green light in 1978. It launched in 1990 as the Hubble Space Telescope.

Planners said Hubble would operate for about 15 years — in fact, one of Roman's taglines when rustling up political support was that “for the price of one night at the movies each year, each American would receive 15 years of exciting discoveries.” The telescope has surpassed her prognosis: Some 36 years later, it's still wowing the world with its superlative images. Her unflagging support led Hubble Chief Scientist Ed Weiler to dub her the “Mother of Hubble.”

And now, a cutting-edge space telescope will sail through the heavens bearing her name. As I pen this reflection, NASA is aiming to launch Roman's telescope in September. I'm sure we'll all be waiting with bated breath for the first images. As we do so, let's celebrate the remarkable scientist it pays homage to.

Dimm
Editor in Chief

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Subscription Rates:

U.S. and possessions: \$59.46 per year
Canada: \$75.38 (including GST)
All other countries: \$91.29, by expedited delivery
All prices are in U.S. dollars.

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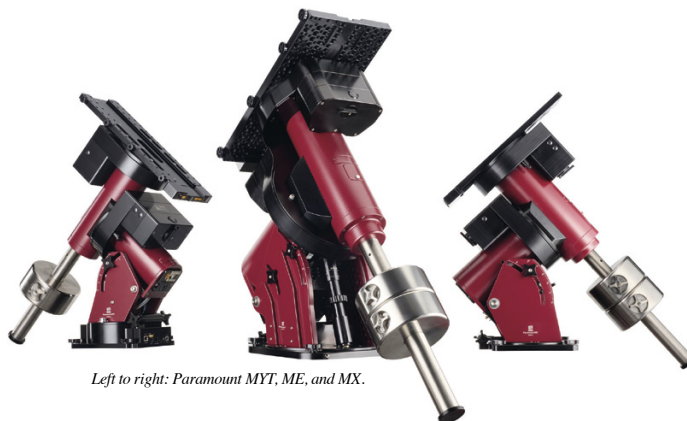


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Tiny Astronomers

I thought I'd let you know how much I enjoyed seeing South Africa's amazing little astronomers — the nocturnal dung beetle *Scarabaeus satyrus* — featured in Javier Barbazano's "Animal Navigators" (S&T: June 2026, p. 20). I see them at work many a night when I'm out with my telescope.

If my dog is indiscreet enough to leave a pile of dung-beetle takeaways on the sand, that night the little creatures arrive in droves and in no time at all are heading out of the combat zone with their balls of dung. (They are brutal little beasts and will happily smash each other up to swipe a dung ball!)

It's one of the coolest astronomy experiences to see them clamber on top of their balls and do a 360° spin to get a snapshot of their celestial cues . . . and then roll their little balls off in a straight line.

It never ceases to boggle my brain that within their tiny heads lies a complex sky compass that employs such seriously sophisticated celestial navigation skills. (I try not to think about being upstaged by a dung beetle when I am struggling to hop my way through a handful of stars to locate an object.)

In fact, it was a tremendous article. All those star-navigating animals are simply incredible, but I confess, I lost my heart to Nick the seal sitting on his chair and looking at the night sky!

Susan Young
Limpopo, South Africa

Dare to Be Different

The planetary system from Ana Georgescu's "Planetary System Breaks the Rules" (S&T: June 2026, p. 11) could be an example of captured planets. After LHS 1903 left its birth cluster, it could have encountered four brown dwarfs or rocky orbs and trapped them in its orbit. This explanation would be simple to test for any professor with access to an orbital simulator.

It would also be interesting to slam a couple of hot Jupiters together and see what happens to the hydrogen. It's possible that this fun experiment could explain the creation of protoplanetary disks and why the spin of many worlds are out of whack with the rotation of their disks.

Chris Bogardus
Cullowhee, North Carolina

“ Monica Young replies: *An interesting suggestion — I love it when a news story like this one gets readers thinking!*

Regarding the capture of other worlds, this seems unlikely. The planets were detected via their transits, so they all orbit in the same plane, meaning they were born with the star.

But the creation of a debris disk from the collision of planetary bodies is right on target (S&T: Aug. 2026, p. 34). Protoplanetary disks form when the stellar nebula gas is still present and being accreted onto giant planets. Debris disks represent the next stage, when the gas has dissipated, but lots of not-quite-planets are still roaming around. Planetsimal collisions are what create the debris in these disks. In fact, we briefly mention the collision of two ice giants in this news story:

skyandtelescope.org/planets-collide.

(Scroll down to see the mention of the study by Kenworthy et al.) Astronomers think that such massive collisions shape planets, potentially explaining Venus's retrograde rotation, Uranus's extreme tilt, and even Saturn's (probably young) rings.

Telescopic Twins

Stephen James O'Meara's column "Delightful Telescopic Asterisms" (S&T: June 2026, p. 12) struck a chord with me. In the first paragraph, his comment about skywatchers embarking on a journey of celestial discovery with the "sails of their imagination open" made me chuckle. Because in December 2019, I discovered the "False Sailboat" asterism from my backyard in Houston, Texas — and yes, I saw sails.

I input NGC 225 into my Celestron C8 Schmidt-Cassegrain's Go To mount. It gave me a field that I merrily spent about 15 minutes sketching. In my defense, doubting this was any sort of cluster, I had gone back and synced the scope on nearby Beta (β) Cassiopeiae. But it still insisted that it had found NGC 225. Using a software chart later, I discovered that the star field was not around NGC 225 after all. The field I saw was 1½° to the northwest.

The asterism is centered on emission nebula Sharpless 2-177. The nebula is thought to be ionized by my "deck house" star, 9.3-magnitude SAO 11241. The brightest star in the asterism is the bowsprit, 7.4-magnitude HD 2654. An arc of stars leads from there to the stern, 8.7-magnitude HD 2928. The top of the mast is 9.7-magnitude TYC 04019-2409-1.



▲ Less words, more dung beetles. (Technically, the grammatically correct thing to say would be "fewer words," but we shan't dwell.)

NGC 225 has fainter stars, is smaller, and looks less like a sailboat, so I like to think my C8 got it right!

Craig Lamison
Houston, Texas

The Binocular Struggle

I love Mathew Wedel's articles on binocular observing. I have Celestron 15×70 binoculars, which I love for quick viewing because I don't have to drag out my scopes. I'm amazed at how powerful and clear they are, and I get the best views of the Orion Nebula and Pleiades with them. But unfortunately, my hands aren't steady enough for viewing planets and smaller objects. Could you recommend a good tripod and adapter for my binoculars? I bought a cheap tripod on Amazon that looked sturdy and had good reviews, but I don't find it very steady. Thanks



in advance and keep those articles coming. We have started a small group for binocular viewing in the Tucson Amateur Astronomy Association.

Jeff Collins
Marana, Arizona

“ Mathew Wedel replies: You pose an interesting question. There are lots of ways to steady big binoculars — you can see some DIY ideas on the websites of Rob Nabholz (homebuiltastronomy.com) and Gary Seronik (garyseronik.com). But I've noodled around with them a bit and always found them unsatisfying. For me, binoculars are all about freedom. If I have to put them on a tripod or even steady them against a monopod, I might as well haul out a rich-field scope.

Like you, I love my 15×70s, and I agree, they can get tiring!

My usual solution is to have some lightweight 7×35s standing by. I use the smaller glass for wide-field scanning and finding interesting targets, then grab the 15×70s to go deep for a couple of minutes and set them down again as soon as my arms start complaining. I also started weightlifting, and it's really improved my steadiness and stamina while using binoculars.

These are the things that have worked best for me. I don't know what will be the best option for you, but I wish you good luck in your quest. And thank you for the kind words! I love hearing from readers.

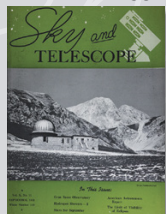
FOR THE RECORD

● May's lunar libration diagram (S&T: May 2026, p. 42) and planet chart (S&T: May 2026, p. 47) were incorrect. Corrected versions can be found at skyandtelescope.org/errata.

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75, 50 & 25 YEARS AGO by Sabrina Garvin

1951



September 1951

Tiny Scope “It was [Donald O'Toole's] desire to discover just what an extremely small glass would reveal that prompted him to construct an instrument for himself last summer. The telescope . . . was made entirely from available parts, and in less than one hour's time. The objective was a two-element achromatic 35-mm. projection lens, with a diameter of 1” and a focal length of about 3½”. At f/3.5, the lens was not usable, and it was consequently diaphragmed down to ½”, and therefore worked at f/7.

“The ocular was a 1/6” focus single biconvex lens mounted in a standard 1¼” tube. The resulting telescope approximated a magnification of 20×, or 40× per inch of aperture. The definition was satisfactory at the center and poor at the edges—a result [of the] ocular . . .

“Amazing as it may seem, this telescope outperformed my best expectations.”

1976



2001



September 1976

Touchdown! “The clock read 5:12:07 a.m. inside the Jet Propulsion Laboratory's Viking control center in Pasadena, California. There, on July 20th, the word ENABLET appeared on the television monitor in front of Richard Bender. To him, it meant that the three terminal-descent engines of the Viking 1 lander had shut down — it also meant that the spacecraft had successfully touched down on the surface of Mars . . .

“Within 90 minutes, two crisply detailed and incredible photographs of the surface were being examined by members of the lander imaging team and others throughout the center. In the days to come, Viking would continue to reveal a Mars full of colorful landscapes and geologic enigmas. It was an awesome scientific achievement.”

September 2001

Russian Rebound “With the disintegration of the Soviet Union in 1991, [the All-Union Astronomical-

Geodetical Society (VAGO)] lost its 'all-union' status, and the activity of some of its branches ceased. A black period for astronomy began. . . . Under such adverse conditions, it might seem that amateur astronomy in Russia would slowly wither away.

“Under the chaotic economic conditions that still prevail . . . most Russians still struggle for their daily bread, and there is little money for hobbies. But despite these difficulties, we see many hopeful developments. Some former VAGO branches have survived . . . and since 1995 many new amateur groups have formed. . . .

“Thanks to the Internet, amateurs across our vast country are communicating and forging bonds. . . . Dobsonian reflectors, star parties, and Messier marathons — all foreign to us not too many years ago — are becoming increasingly popular. . . .

“It is once again a time for astronomy and planetariums to flourish in Russia.”



The Gemini North telescope on Maunakea, Hawai'i, captured the interstellar comet 3I/ATLAS on November 26, 2025.

SOLAR SYSTEM

The Cold, Ancient Origins of Interstellar Comet 3I/ATLAS

WHEN ASTRONOMERS FIRST spotted the interstellar comet 3I/ATLAS, they had only months to collect observations before the comet retreated beyond view. Now, those data are telling a story: This comet started its journey a long time ago, forming far from its star and crisscrossing the galaxy for some 10 to 12 billion years before arriving in our solar system.

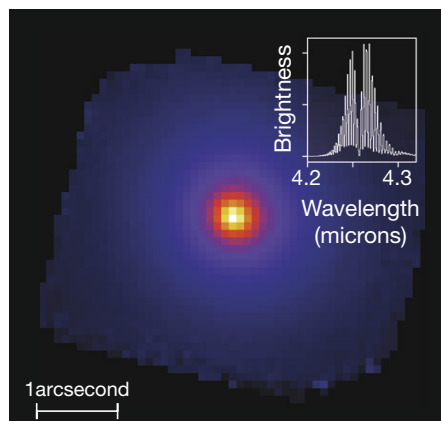
Ready and Waiting

Comet 3I/ATLAS first popped into view near Jupiter's orbit, coming in at 58 km/s (130,000 mph). Its speedy and unbound orbit placed its origin far beyond the Oort Cloud, the reservoir of small, icy rocks that surrounds our Sun and from which most long-period comets originate.

Ordinary comets, hailing from those chemically inert outer reaches, retain a fossil-like record of our 4.6-billion-year-old solar system's earliest years, noted Martin Cordiner (NASA Goddard Space Flight Center) at a March 17th

colloquium at the Harvard-Smithsonian Center for Astrophysics. The same should be true of comets that coalesced around other stars. "Interstellar comets coming from different stars give us the opportunity to reach out across space and time through the galaxy to study close-up . . . the planet-forming regions of other star systems," he said.

That promise led Cordiner and colleagues to propose for James Webb Space Telescope (JWST) investigations



of any new interstellar comets as they were discovered. The moment arrived on July 1, 2025.

"I came back from a canoeing trip in Maine to a lot of emails," Cordiner said with a laugh. "I couldn't believe the day had come."

By early August that year, JWST had captured an image and spectrum of 3I/ATLAS. The Hubble Space Telescope and myriad ground-based observatories gathered additional data.

Thanks in part to the comet's large size (about 1.3 kilometers, or 0.8 miles, across), it was becoming far brighter than the first two interstellar visitors. It reached 9th magnitude by the time it arrived at *perihelion*, passing 1.36 au from the Sun on October 30, 2025.

By then, astronomers knew that the interstellar comet was quite different from its solar system siblings. "When I loaded up [JWST's August] spectrum, I was just blown away," Cordiner said. "Look at that carbon-dioxide feature at 4.3 microns — just through the roof. And so little water."

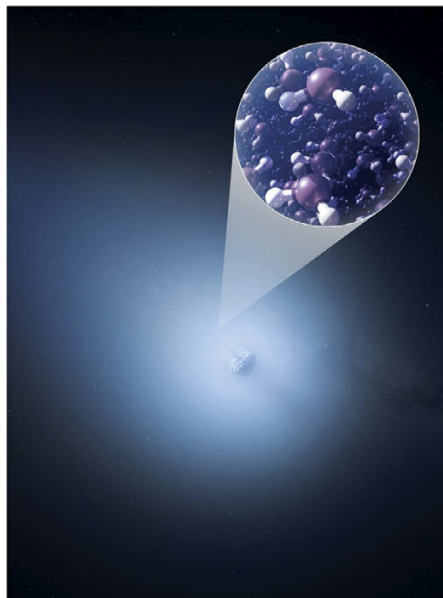
The low amount of water, which normally dominates cometary comae, was partly due to distance. At the time JWST observed it, 3I/ATLAS was still far enough from the Sun, at 3.3 astronomical units, that carbon-dioxide ice was vaporizing faster than water ice was.

Indeed, there was more water vapor when JWST observed the comet again after perihelion, in late December. The new spectra also showed clear fingerprints of organic molecules such as methane, methanol, and ethane. (There was nickel vapor, too, which Cordiner couldn't explain: "That's a question for another day.")

Cold, Ancient Origins

Most intriguingly, those spectra revealed water molecules with a heavy hydrogen isotope known as *deuterium*. Unlike regular hydrogen, which only has a proton in its nucleus, deuterium has a neutron as well. Deuterium joins with oxygen to make semi-heavy water

◀ The James Webb Space Telescope mapped emission from carbon dioxide in the comet's coma (the spectrum is inset).



▲ This artist's impression compares the semi-heavy water content of the interstellar comet 3I/ATLAS (left) and Earth (right). Insets illustrate the relative abundance of water molecules that have incorporated a deuterium atom, showing that 3I/ATLAS contains more than 30 times such molecules compared to Earth's oceans.

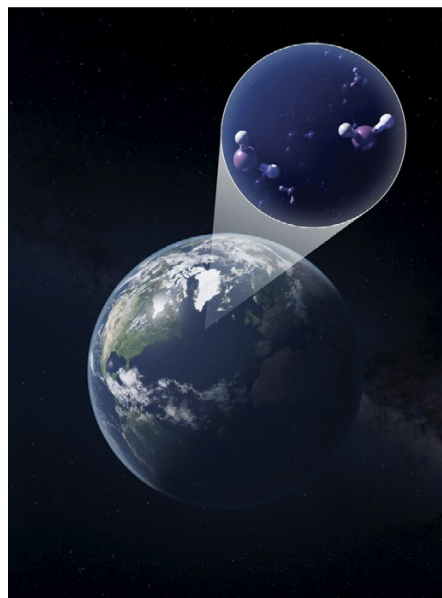
molecules (DHO) under the right chemical conditions.

The team only detected the deuterium because there was so much of it — entirely unexpected, were this a solar system comet. Luis E. Salazar Manzano (University of Michigan, Ann Arbor) and colleagues (including Cordiner) likewise found excessive deuterium in data collected by the Atacama Large Millimeter/submillimeter Array (ALMA). Those researchers found 30 times more heavy water in 3I/ATLAS than the typical solar system comet — and more than 40 times more than what's found in Earth's oceans, Salazar Manzano and colleagues reported April 23rd in *Nature Astronomy*.

Not only does 3I/ATLAS's deuterium chemistry not match typical solar system comets, it also doesn't match the environments around nearby infant stars where planets may still be forming. "So this is something new and different," Cordiner says.

The kind of chemistry that makes lots of deuterium requires intense cold — colder than about 30 kelvin (−410°F), says Salazar Manzano.

But a second condition also encourages the abundance of deuterium, Cordiner explained: 3I/ATLAS was likely



born in an environment where few elements were heavier than hydrogen.

An unexpectedly low amount of "heavy carbon" (^{13}C instead of ^{12}C) in the comet's coma supports that conclusion. Moderate-mass stars push heavy carbon out into interstellar space, so a low amount of that element suggests the comet formed before those stars had a chance to exist. Cordiner suggested the comet formed around a star in the Milky Way's initial burst of high-mass star formation, back when there were few heavier elements to go around.

Cordiner cautioned that the chemical models that lead to this conclusion contain many uncertainties. Nevertheless, the evidence seems to be converging on a story about the interstellar comet's origins: 3I/ATLAS formed in the outskirts of a star system in the young Milky Way, some 10 to 12 billion years ago. A gravitational nudge, perhaps from a giant planet, ejected the icy rock from its home, and it's been ping-ponging through our galaxy ever since.

Analysis of this interstellar object isn't finished yet. The mounds of data astronomers collected during the comet's brief visit will continue to test and revise this story.

■ MONICA YOUNG

IN BRIEF

Wisps of Atmosphere Around a Plutino

A team of Japanese professional and amateur astronomers has unexpectedly found an atmosphere clinging to a world sharing an orbit similar to Pluto's. It's the first time astronomers have spotted an atmosphere on a *trans-Neptunian object* (TNO) besides Pluto. Most TNOs have small masses and therefore weak gravity, and they reside in frigid temperatures where gases freeze. But the plutino 2002 XV₉₃ appears to buck the trend, despite measuring only about 550 kilometers (340 miles) across. In January 2024, the astronomers watched from locations across Japan as 2002 XV₉₃ passed in front of a distant star. In most such *occultations*, the star's light disappears abruptly, but this time the star's light dimmed and brightened again more gradually, suggesting the light passed through a thin atmosphere. Reporting May 4th in *Nature Astronomy*, the team concludes the worldlet hosts a thin atmosphere with a surface pressure of 100 to 200 nanobars — roughly 100 times more diffuse than Pluto's thin atmosphere. The gases could have been released by either cryovolcanic activity or a recent impact. David Jewitt (UCLA), who applauded the discovery, adds, "Neither explanation seems particularly likely, although neither can be ruled out with the existing data." The team plans more occultation observations to better understand these findings.

■ COLIN STUART

SpaceX Booster to Hit Moon in August

As of press time, a SpaceX Falcon 9 upper stage is expected to strike the Moon on August 5th. Bill Gray (Project Pluto) announced his prediction on April 29th. The booster was part of SpaceX's January 15, 2025, launch that sent Firefly Aerospace's Blue Ghost and ispace's Hakuto-R landers to the Moon. "This object has spent almost all of its time at distances similar to that of the Moon," Gray says. "Generally speaking, such objects are very poorly tracked." He predicts the booster, which is nearly the size of a semi-truck trailer, will impact the Moon at 2:44 a.m. EDT (6:44 UT), striking Einstein Crater on the illuminated side of a waning gibbous Moon. The impact is not likely to be visible. Though the impact poses no danger, it highlights the growing issue of debris in cislunar space.

■ DAVID DICKINSON

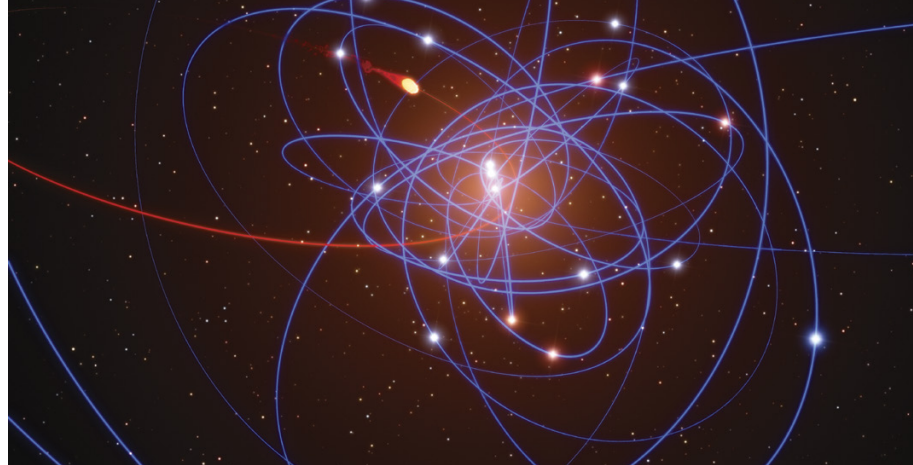
MILKY WAY

What's Feeding Our Supermassive Black Hole?

ASTRONOMERS HAVE IDENTIFIED the likely source of gas that's slowly flowing into the maw of the Milky Way's central black hole, Sagittarius A* (Sgr A*). In the March *Astronomy & Astrophysics*, a team led by Stefan Gillessen (Max Planck Institute for Extraterrestrial Physics, Germany) reports that a chain of gas clouds detected near the supermassive black hole might come from a pair of interacting stars.

Over the past decade or so, several teams have spotted compact clouds of dust and gas, naming them G1, G2, and so on. In 2014, G2 achieved notoriety when it survived passing within 100 astronomical units of Sgr A*, rather than becoming the black hole's latest meal (*S&T*: Jan. 2015, p. 16). But the origins of G2 and other clouds like it remained a mystery.

G1, G2, and G3 all travel on similar orbits, so Gillessen's team suspected they could be part of a continuous stream of gas with a common source.



▲ This simulated view shows the G2 gas cloud (just above center, orbit shown in red), which elongated during its close pass by the black hole. Stellar orbits are shown in blue.

The team used the Very Large Telescope to track the orbits of the G clouds as well as stars near the black hole.

The researchers found that the clouds' motions most closely match the orbit of IRS 16SW, a pair of massive stars 0.3 light-year from Sgr A*. They orbit each other so closely that their atmospheres partially overlap. Each star emits strong winds of particles into thin, surrounding gas, forming bow shocks. These shocks could break into dusty clumps every 10 to 20 years, the researchers conclude. Those clumps then end up in elongated orbits with close approaches to Sgr A*, appearing

as G clouds. IRS 16SW is thus the likely origin of G1, G2, and G3 — and a significant food source for the black hole.

Jordi Miralda-Escudé (University of Barcelona, Spain), who wasn't involved in the research, previously proposed that the clouds came from the disruption of a young star's gaseous disk. Now, he's willing to change his stance, especially since simulations have also shown that G clouds, once created, can survive for some time. "[That's why] I think I agree with the conclusion of the present paper," he concludes. "It's a very impressive new result!"

■ JAN HATTENBACH

SOLAR SYSTEM

How Jupiter's Ganymede Melted Its Core

GANYMEDE IS THE ONLY moon in the solar system known to generate its own magnetic field, which emanates from a molten core. A new study suggests that the core appeared relatively recently.

Planets generate magnetic fields in electrically conductive molten layers, such as Earth's outer iron core. But Ganymede shouldn't have formed with a metal core, much less a core that would stay molten for 4.6 billion years.

As planetesimals gather into a single object, the energy from their accretion converts into heat. Radioactive atoms incorporated into the planet add further heat as they decay. At the same time, the newborn planets' surfaces lose heat

through radiation, with smaller worlds cooling more quickly.

Ganymede is bigger than Mercury, yet unlike the planet, it's not easy to understand how the moon formed with a metal core. It came together too gently and slowly — likely after most of the solar system's radioactive aluminum-26 had decayed, limiting how warm the moon's interior could become. Accretion energy by itself wouldn't have

provided enough heat to melt the moon's rocks. Without melting the rock, metal wouldn't separate out and sink to make a molten core.

◀ The JunoCam imager snapped this photo of Ganymede during Juno's June 7, 2021, flyby of the icy moon.



Now, in a study in the May 8th *Science Advances*, postdoctoral researcher Kevin Trinh (Caltech) and colleagues suggest that Ganymede's metal core wasn't present from birth. Rather, it might have come along later — and might still be forming now.

In Trinh's simulations, Ganymede missed out on aluminum-26 but incorporated other, slower-decaying radioactive isotopes. It's big enough that the radioactive heat can't entirely escape, so the temperature within slowly builds. At a critical moment 2.4 billion years after the moon's formation, the deep interior heats up enough that the rocky mixture sweats droplets of iron sulfide. Those drops percolate downward through pores in the still-solid rock. Within a few tens of millions of years, they form a molten metal core, generating Ganymede's magnetic field. Even today that core is likely still forming, drop by drop.

■ EMILY LAKDAWALLA

EXOPLANETS

Nearby Super-Earth Has Bare, Dark Surface

THE SURFACE OF the bare rocky exoplanet LHS 3844b appears to be old and dark, akin to the surface of our Moon, new observations show.

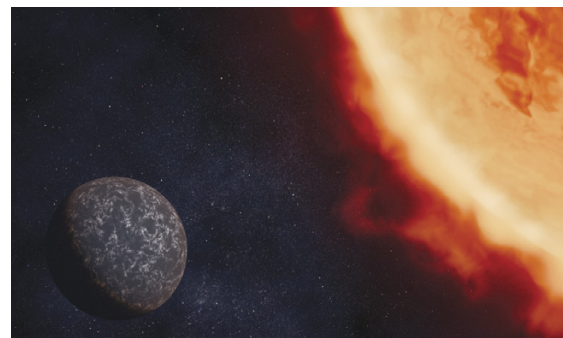
LHS 3844b is 30% larger than Earth and whips around its red dwarf star every 11 hours. Astronomers had already ruled out the possibility of a thick atmosphere around the planet back in 2019, using data from the Spitzer Space Telescope. Now, James Webb Space Telescope observations have shown the world is completely bare. There aren't even wisps of gases indicating recent geological activity. The observations, published May 4th in *Nature Astronomy*, are one of the first to enable "exoplanet geology."

LHS 3844b is more than 48 light-years from Earth; astronomers can't see its surface directly. Instead, they collected data from the planet by watching

as it passed behind its star. By comparing the star's light during the eclipse to the combined light of both the star and planet before and after the eclipse, Sebastian Zieba (Center for Astrophysics, Harvard & Smithsonian) and colleagues isolated the emission that's coming from the planet's permanently star-facing side.

Comparing against lab data of various rock types, they concluded the planet's surface is dark and low in silicates (the type of minerals that make up most of Earth's crust).

Instead, the emission from LHS 3844b's hot dayside surface matches that of basalt or igneous mantle rock — the remains of ancient volcanoes. It could also be rich in olivine, a dark-green mineral in Earth's upper mantle found in low-silicate rocks. Without an atmosphere, that



▲ An artist's illustration showing the dark, space-weathered powder that might cover the surface of the exoplanet LHS 3844b.

surface was peppered over eons with impacts from micrometeorites as well as charged particles coming from its star. Those mini-strikes turned the surface into a fine, dark powder, similar to the Moon's regolith.

The team is analyzing additional eclipses of LHS 3844b as well as observations throughout the planet's orbit to better understand the planet's geology.

■ ARIELLE FROMMER

STARS

Catching the Earliest Stars in the Universe

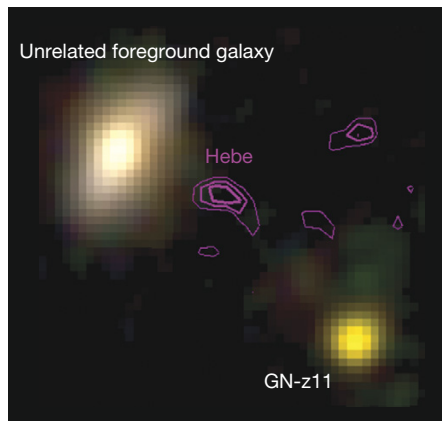
NEW OBSERVATIONS FROM the James Webb Space Telescope might have caught the signature of the universe's first stars.

Within a few hundred million years after the Big Bang, these bright behemoths formed out of the primordial brew of hydrogen and helium that filled the newborn universe. Using the sensitive Near-Infrared Spectrograph on the James Webb Space Telescope, Roberto Maiolino (University of Cambridge, UK) and his colleagues claim to have found this first generation of stars, termed Population III (or Pop III for short), in a cloud of gas observed as it was 400 million years after the Big Bang.

The small, irregular cloud lies some 10,000 light-years from the much

brighter early galaxy GN-z11, close enough that it's within the larger galaxy's halo. The team first spotted this cloud in Webb observations taken in 2024. Now, they've followed up for a deeper look.

From the cloud itself, JWST detected only emission from ionized helium and excited hydrogen (the latter is referred to as Balmer emission). The team has nicknamed the object Hebe, short for Helium Balmer Emitter. In Greek mythology, Hebe is the goddess of youth.



► This image shows the location of Hebe in purple contours, near the early galaxy GN-z11. The image is taken at near-infrared wavelengths, and the purple contours show emission from ionized helium atoms.

In three papers posted on the astronomy arXiv preprint server (one of them now published in the May 20th *Astrophysical Journal Letters*), the team argues that only hot, massive stars could have ionized the cloud's helium. And since Hebe's gas contains no heavy elements, the stars must have formed from the same pristine material, making them Pop III stars, the team concludes.

We see the ionized gas rather than the stars themselves, Maiolino explains, because the extreme ultraviolet radiation that Pop III stars produce is entirely absorbed by the surrounding gas.

Simon Glover (Heidelberg University, Germany), who was not involved in the studies, says he was "interested but skeptical" when he heard the team's claim. "I would say right now that the Pop III interpretation is probably the most plausible one," he says, "but I don't think it's completely settled."

The team is more confident, writing, "Hebe represents one of the most convincing pieces of evidence for Population III stars in the early universe."

■ GOVERT SCHILLING

EARLY UNIVERSE Brown Dwarfs Masqueraded as Early Galaxy Candidates

THE RECENT IDENTIFICATION of very early galaxy candidates — only 100 to 200 million years after the Big Bang — has puzzled astronomers. It's unclear how galaxies could come together so fast. Now, new data from the James Webb Space Telescope suggest two of these objects are not galaxies at all but rather ultra-cold brown dwarfs in our own Milky Way.

The objects were first identified as early galaxy candidates because they appear in Webb's longer-wavelength filters but "drop out" of shorter ones. The hydrogen gas that pervades the universe (and galaxies themselves) absorbs light shorter than 91.2 nanometers, and the wavelength of this absorption is *red-shifted* (that is, shifted to longer wavelengths) with distance. An extremely distant galaxy would therefore only

► BD1 (marked) "drops out" of three JWST short-wavelength near-infrared filters (at left).

appear in the longest-wavelength filters that JWST has.

But distant objects aren't the only ones to drop out in this way. For example, closer dusty star-forming galaxies can drop out at shorter wavelengths in the same way. So when early galaxy candidates were spotted in a Webb survey of the Bullet Cluster, Maruša Bradač (University of Ljubljana, Slovenia) led a team that analyzed new spectra and images (also using Webb).

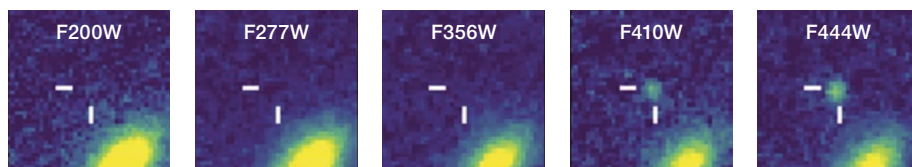
To their surprise, the new images showed the two objects moving across the sky. This *proper motion* indicates without a doubt that the objects reside here, within our own galaxy. The spectra reveal that both objects are brown dwarfs, between roughly 1,000 and 3,000 light-years away. (Though at similar distances, their different motions and brightnesses suggest they're not physically associated.) The results were

posted April 26th to the astronomy arXiv preprint server.

These brown dwarfs, now named Bullet-BD1 and Bullet-BD2, were able to masquerade as distant galaxies in part because they're unusually cold, with surface temperatures of 350 and 410 kelvin (about 170°F and 280°F), respectively. Brown dwarfs cool off over time, so Bradač's team concludes that these objects are likely quite old.

Marco Castellano (Astronomical Observatory of Rome), who wasn't involved in the research, says the findings are compelling, adding they "highlight an important source of contamination in searches for the earliest galaxies." But Pablo Pérez-González (Spanish National Research Council, Madrid), who was also not involved in the study, says other early-galaxy candidates remain viable.

■ DEEPA JAIN



TELESCOPES Questar Ceases Operations

THE MANUFACTURER OF the once highly coveted Questar telescope has closed after serving the astronomical community for 76 years.

The Questar Corporation of New Hope, Pennsylvania, was the manufacturer of the highly sought-after 3.5-inch Maksutov-Cassegrain, known simply as the Questar. The telescope, later referred to as the Standard model, was considered by many to be the Rolls-Royce of precision, compact telescopes. Now, the company has sent its employees home for the final time on May 4th.

Lawrence Braymer founded Questar in 1950, after reading an article in the *Journal of the Optical Society of America* by Soviet optician Dimitri D. Maksutov about his new lens design. Braymer saw this new design as the basis for a compact, rugged, yet easy-to-use

telescope. Released in 1954, the Questar was crafted with care and marketed as a premium instrument for the discerning enthusiast, eventually becoming a collector's item sought after by amateurs and even celebrities. Famous folk such as Wernher von Braun, Arthur C. Clarke, and Johnny Carson were proud owners of Questar telescopes. Charles Bronson is seen using one in the 1972 movie *The Mechanic*. Even Al Nagler, founder of Tele Vue Optics, owned a 3.5-inch Questar.

Over the years, Questar improved on the Standard model and offered other variants of the design, including the Field model (without a mount), the Duplex (with a removable equatorial base), and larger instruments, including 7-inch and 12-inch models. But it was the Standard model that achieved cult status — today it often commands a higher price on the used market than it did at the time of purchase.

Questar effectively stopped manufacturing new telescopes early in 2024, when their primary optics supplier, Cumberland Optical, shut down. Since then, they've focused on servicing instruments. Now the company, including its website, has ceased operations completely.

■ SEAN WALKER



Dazzling Phenomena

This optical effect could subdue an object's apparent brightness.



IN APRIL last year, I joined a group of deep-sky aficionados at Jimi Lowrey's home observatory in Fort Davis, Texas. While I waited my turn to look through his custom-built, 48-inch f/4 Dobsonian reflector, I spent the time admiring the zodiacal light, splendid in the west. Jupiter was hugging the southern edge of the light cone's core, and the longer I looked the more perplexed I became. I expected to see the zodiacal cone and Jupiter as two separate entities, each in their full glory. But this wasn't the case. What I saw was that the width of the outer zodiacal light was greater on the northern side than on the southern, where Jupiter was shining at magnitude -2.

Usually, the zodiacal light is seen as a tapered cone of dim light that appears just after evening twilight in the west in spring and just before morning twilight in the east in autumn (see page 48). Its diffuseness is centered on the ecliptic, as most of the interplanetary matter that causes it lies near the plane of our solar system. But careful observation with averted vision will show that it can have a sharply defined visual axis centered on a bright inner cone of diffuse light (about

▲ **HUBBLE COMPETITOR** According to the author, the view of 8th-magnitude M104, the Sombrero Galaxy, in Virgo as viewed through a 48-inch Dobsonian reflector rivaled the Hubble Space Telescope image shown above. Note how the glow of the galaxy's bulge is slightly more apparent to the north where the nucleus is visible. But he found the opposite was true visually. North is up and the field is 9.6' wide.

20° in width), which itself is surrounded by a much dimmer outer sheath. It's difficult to say exactly how wide the dim sheath extends, but it can be about as broad as the zodiacal light is high.

At first, I thought that the asymmetry I saw was a natural occurrence — the way dust is distributed along its path. Then I blocked Jupiter with my thumb and saw the cone's symmetry restored, with the outer sheath appearing as wide to the south as it did to the north. I suspect the culprit, in part, was caused by *dazzling* — an optical effect created by glare from Jupiter, which subdued the zodiacal light's outer sheath along its entire vertical extent. Still, I didn't expect Jupiter's influence to have such a far-reaching impression. The diminution of light around the planet may have caused a gap in the outer sheath that my brain

corrected by extending the effect. Then again, I had to wonder if this was not a personal phenomenon.

For instance, I know that my eyes are extremely sensitive to a bright sky, which I find almost blinding. My wife, Deborah Carter, on the other hand, doesn't appear to be that bothered by bright light at all. In his 1966 book *Eye and Brain: The Psychology of Seeing*, Richard L. Gregory notes, "The simplest of the visual sensations is brightness. It is impossible to describe the sensation." He goes on to say that "brightness is a function not only of the intensity of light falling on a given region of the retina at a certain time; but also of the intensity of the light that the retina has been subject to in the recent past, and of the intensities of light falling on other regions of the retina."

This dazzling effect didn't stop with Jupiter. Later that evening, we pointed the scope at M104, the Sombrero Galaxy. The view is almost impossible to describe — the detail was just as crisp and fine as the Hubble image at left. The galaxy's distinct core seemed to shine nearly as brightly as Jupiter seen with the unaided eye. And, like the zodiacal light, the galaxy's sharp core was surrounded by a highly luminous bulge and outer sheath, completely encircled by an infinite number of tiny clumps of dust. These clumps traced out M104's tight spiral structure, while the dust running along the outer edge of the disk wrapped around it like rope circles.

Given that the galaxy is inclined so that we see its northern face, one might expect to see more bulge to the north than the south. But what I saw was just the opposite. Did the galaxy's bright core create a dazzling effect? In photos, we see what I'd expect us to see — the northern bulge having a greater radius than the southern. The difference is slight, though noticeable.

Given that light dazzle may be a very personal experience, I wonder if you too can see this effect on similar objects. Only by observing will you ever know.

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

PRISTINE SKIES The Milky Way arches over the dome of the 2-meter Himalayan Chandra Telescope (right) at the Indian Astronomical Observatory in Hanle. The observatory perches some 4,500 meters (15,000 ft) above sea level, north of the westernmost part of the Himalayas.

The Hanle Dark

Threatened by light pollution, astronomers joined forces with residents to protect the night sky and transform the local economy.

Imagine strolling under pristine night skies, conducting sky tours for visitors, and teaching them how to capture stunning photos of the Milky Way. This is the life of Tsering Dolker and 24 other youth in the Himalayan village of Hanle, located in the territory of Ladakh, India. They are the guardians of the night sky.

Hanle, also spelled Anley or Anle, is a cluster of six ham-

lets nestled in the remote Changthang plateau of Ladakh. Ladakh sits in the northernmost part of India, with China to the east and Pakistan to the west. It is sandwiched between the towering Himalayas and the Karakoram range, making it a cold desert sustained only by the River Indus.

For centuries, Hanle's people, primarily pastoral nomads, lived a life dictated by the harsh rhythms of the high-altitude



Sky Reserve

desert, their existence intertwined with their herds and farming in the vast, empty landscapes. But above them, an immense resource glittered every night: a sky so clear and pristine, crowded with stars, that visiting city folk struggle to identify the constellations amid the abundance of stars.

This glittering Bortle 1 sky — the highest dark-sky rating on a nine-point scale — is now the cornerstone of an ambitious project, which is transforming the region's economy and redefining the connection between science and livelihood: the Hanle Dark Sky Reserve (HDSR).

Genesis of the Reserve

The story of HDSR begins with the Indian Astronomical Observatory. Established more than two decades ago, it is located on Hanle's Mount Digpa-ratsa Ri at an elevation of 4,500 meters (15,000 feet) and is operated by the Indian Institute of Astrophysics (IIA). Several professional telescopes operate here, drawn to Hanle for its stable atmospheric conditions and minimal light pollution. The site offers around 270 clear nights every year.

Hanle became a tourist destination not only for the astro-



▲ **REMOTE OBSERVATORY** Hanle sits in a corner of the Indian union territory of Ladakh, which borders Pakistan and China. It is one of the highest regions in the world.

nomical paradise it is but also for the region's unique wildlife and the nearby Umling La pass, which was the world's highest motorable pass until last year. Visitors to the observatory often requested to look through the telescopes, unaware that they are solely used for research purposes. With a steady increase in tourism, a fraction of villagers started running homestays for tourists.

But the increased tourism brought with it an unwelcome glow, putting Hanle's pristine skies under silent threat. Dorje Angchuk, the engineer-in-charge at the observatory, witnessed the growing problem firsthand. Headlights from passing vehicles began saturating the sensitive cameras of the telescopes, jeopardizing scientific research.

"We should do something to protect the observatory," Angchuk recalls thinking. Many of the observatory's instruments had already moved here from light-polluted sites; they couldn't simply relocate again. Astronomers needed a sustainable solution, one that involved the local community.

Drawing inspiration from preservation efforts around the world, the IIA put together a proposal around 2020 and submitted it to the union territory (UT) government of Ladakh in 2021, requesting a 40-kilometer-wide (25-mile-wide) region centered on the observatory be declared a dark-sky reserve.

Protecting the region's night sky meant removing extraneous artificial light. Initially, some villagers resisted the idea, questioning why they should follow the rules. In meetings

with the villagers, however, advocates pointed out that preventing light pollution would protect Hanle not just astrophotonomically but also economically. Hanle needed something to make it stand out as a unique tourist attraction, with qualities that would keep people coming if, say, another mountain pass were to claim the title of the highest drivable thoroughfare (as recently happened).

Once the community was on board, the village heads of six hamlets signed the international La Palma Declaration, which reaffirms humankind's right to starlight. They also, in a symbolic gesture, granted collective consent to designate Hanle as a dark-sky reserve. From that point on, everyone in Hanle became cautious about the use of light.

By the end of 2022, the UT government of Ladakh created the Hanle Dark Sky Reserve (HDSR). IIA is also working on getting HDSR accredited by international dark-sky agencies.

HDSR is now managed through a memorandum of understanding between the IIA, the UT of Ladakh, and the Ladakh Autonomous Hill Development Council of Leh, which form the reserve's coordination committee.

After the official announcement, the committee provided warm light bulbs, outdoor lamp shades, and black curtains to every house within the HDSR area. It implemented a strict curfew, requiring lights to be switched off after 11 p.m. Instead of streetlights, all roads are equipped with retro-reflectors that reflect vehicles' headlights back to the source with minimal scattering. Using high-beam headlights is prohibited within the HDSR region. The observatory regularly monitors skyglow with a Sky Quality Meter.

Implementation of the light-management plan is ongoing, with materials being distributed every year.

Guardians of the Sky

One innovation planners introduced was the Astronomy Ambassador program, to drive astrotourism in Hanle. A key component of the HDSR project, the program trains young people in the region to guide tourists through the night sky. While some changes initially incited resistance, this program had the villagers' full support.

When HDSR's management opened applications to the program, they received more than 70 applications from local individuals. Of them, 24 were chosen for the first batch.

The initial, week-long training for these ambassadors was intensive, says astrophotographer and telescope maker Ajay Talwar, who volunteered to mentor the ambassadors. Ambassadors learned astronomy basics and were provided with various models of 8-inch Go To telescopes to keep. These telescopes came with a condition, however: They must be used. Those who didn't maintain a logbook or actively use the equipment risked having the telescope reallocated to someone more committed. This accountability fostered a sense of seriousness and purpose.

The ambassadors also received ongoing training. With the support of the Bhabha Atomic Research Centre (which has a telescope at the observatory), the dark-sky reserve has hosted

star parties since 2023 to build a community of astronomy enthusiasts. These events not only have dedicated training sessions for ambassadors, but also allow them to interact with professional and amateur astronomers from across India.

The events attract large crowds. Previously, tourists would simply look up at the sky unguided. But visitors now come to Hanle to interact with the ambassadors. These interactions have helped transform the relationship between Hanle and astronomy into a symbiotic one.

Sudhash Natarajan, a software engineer and a visual observer who has been volunteering at the Bangalore Astronomical Society for seven years and has been a frequent visitor to Hanle since 2021, says that when the ambassadors started, the equipment was new and the scientific concepts were unfamiliar to them. Interacting with tourists put them on the spot: They realized, “‘Uh, if the guests ask some question, I am unable to answer,’” he says. This sparked a genuine desire to understand the science behind the celestial bodies, turning astronomy into a hobby and a passion for many.

“Learning more has made the night sky feel even more alive and meaningful,” Dolker says. “The more I understand, the deeper my sense of wonder and respect grows every night.”

The impact on Hanle has been striking. Over the ambassador program’s first year, villagers came to better appreciate the importance of the night sky. They now routinely turn off

lights at 11 p.m. every night. And if they install new lighting, they direct it downward, so it does not disturb the skies.

Livelihoods in the area have shifted more toward tourism, with many families now running homestays. Natarajan recalls the region before the declaration of the dark-sky reserve. “I have paid for a stay, you know, 1,000 rupees, 1,200 rupees,” he says. “Now, nothing is less than 2,500 rupees.” (That’s about \$30 in USD.) The rising costs reflect the improving local economy as well as the growing demand for clear skies. Its benefits to the community are significant.

Dolker, who also runs a homestay, is one of 18 women out of the current 25 astronomy ambassadors at HDSR. Dolker emphasizes that, through community support, training programs, and stable employment opportunities within tourism, many local women have gathered the confidence to step into roles within the field of amateur astronomy.

The most remarkable outcome, perhaps, has been a case of reverse migration. For years, Angchuk watched as educated young people left Hanle for better opportunities in more urban Leh or beyond. Now, they are coming back. Engineers and other professionals who once built careers outside Ladakh — including one previously employed at a multinational company — are returning to their village, drawn by the new opportunities astrotourism provides.

The ambassador program is open to people from all walks



▲ **CRASH COURSE** Astronomy ambassadors and mentors stand behind the Major Atmospheric Cerenkov Experiment Telescope (MACE) at the first astrotourism training workshop. MACE is one of several telescopes at the Indian Astronomical Observatory.



Adventure Travel

To truly appreciate Hanle, preparation is key. The environment is harsh in this cold, dry, high-altitude desert. Nighttime temperatures in winter can plummet to about -30°C (-20°F), and even during warmer months, nighttime temperatures can fall below zero. The wind can make it feel even colder.

At this high altitude, with the drop in air pressure, the available oxygen is significantly reduced compared to what we breathe at sea level. It is mandatory to undergo acclimatization in Leh for at least two days upon arriving, before traveling to higher-altitude areas like Hanle.

Experts advise visitors to prepare mentally and physically for the conditions. And it helps to arrive with an observing plan, whether a list of deep-sky objects to see or specific celestial targets to image.

▲ **GATHER ROUND** Ambassadors cluster around a telescope at the first training workshop.

of life. Some ambassadors are science graduates, such as Padma Ishey, who grew up in Hanle and now works as an astronomy ambassador at night and a wildlife tour guide during the day. Others come from backgrounds in the arts or business. Notably, the current head lama (monk) of Hanle's historic Buddhist monastery has also been trained as an astronomy ambassador, and the monastery houses a telescope.

Dolker, a 29-year-old arts graduate, finds deep satisfaction in her work. "I became an astro guide because I've always loved the night sky and wanted to share Hanle's beauty with others," she explains. Her typical day ends under the stars, showing visitors celestial objects through her telescope.

Treasury of Ancestral Knowledge

For many of the young ambassadors, the dark-sky reserve has become a means of rediscovery. Their generation knew very little about the stars compared to their elders, who have a

rich vocabulary of traditional names for constellations and celestial lore embedded in songs and stories.

"We are not the first generation to look up," says Angchuk. "Our ancestors learned a lot from the stars. They used to watch them for evening entertainment . . . something truly engrossing."

The ambassador program asked all trainees to meet with village elders to learn about poems, phrases, or songs related to celestial objects. After listening to the elders sing about the Moon and stars and share stories about constellations, Ishey became curious about Hanle's ancestral knowledge of astronomy. He is now involved in a research project focused on cultural astronomy in Hanle.

The developments in Hanle are bridging this gap in other ways as well. Influenced by the reserve's presence, younger generations are now learning about the sky in schools and via awareness programs, creating a new, blended understanding of the universe in which modern scientific knowledge is enriched by ancient cultural wisdom.

Ups Could Be Downs

At only three years old, the HDSR is still a work in progress, Angchuk notes. Hanle experiences harsh winters for roughly four months every year, resulting in a significant drop in tourists. To address this issue, the reserve's management has initiated a plan for the construction of a mini planetarium and a visitor center. The visitor center will have a transparent dome, allowing tourists to enjoy the night sky from indoors.

The success of HDSR comes with challenges. The very popularity that fuels its economy threatens the pristine nature of the place. The influx of visitors has grown exponentially, from a few thousand annually to more than 28,000 in 2024. This surge brings light pollution from vehicles, homestays, and even the military stationed nearby.

Talwar points out the irony. "They want to go there. They want to enjoy. But they don't realize that in the process, they are actually destroying what they want to enjoy."

Cars' high beams frequently disrupt the darkness. Homestay owners, eager to attract guests, sometimes light up their properties, contributing to the creeping skyglow. This light intrudes on the sky, apparent in long-exposure shots and time-lapse videos.

The delicate balance extends to the environment as well. Hanle is situated within a wildlife sanctuary, and increased traffic has led to a few unwanted encounters with wildlife. Furthermore, waste management is a growing concern in the high-altitude desert, where decomposition is incredibly slow.

Awareness is the first line of defense. Ishey stresses the need for both tourists and locals to be better educated about conservation. He believes pre-arrival briefings for tourists are essential. Typically, when tourists call to make bookings, they receive a briefing. However, there are times when people arrive unexpectedly in the village, driving with their high beams on and unaware of wildlife in the area, which leads to problems.

The community is taking steps to mitigate these challenges, promoting eco-friendly stays and training more guides to manage light pollution, but it's an ongoing battle.

"Nothing can be ideal in this world," Angchuk says.

Management is actively working with the villagers, guiding them and seeking their feedback, to ensure they have some level of control in this process. HDSR has established a local coordination committee, which includes all village heads, representatives of homestay owners from each hamlet, and a representative of the astronomy ambassadors, to manage the reserve's day-to-day operations.

Ishey is hopeful that with strict, enforceable policies, the reserve's dark skies can be preserved for many years to come.

Edge of the World

There is no other place in India that offers skies like those in Hanle. The heavens here are dramatically clearer and darker than those over the most populous cities of India, such as New Delhi and Bengaluru, which have heavily light-polluted, Bortle 9 skies.

Many elusive naked-eye phenomena that are difficult to see elsewhere are easy to spot in Hanle's pristine skies. Venus appears so bright that it can occasionally cast faint shadows on the ground. And Talwar speaks of seeing faint phenomena like the zodiacal light and gegenschein with remarkable clarity

every time he visits. These diffuse glows, caused by sunlight scattering off comet and asteroid dust, are often elusive even in other locations known for dark skies (see page 48).

The clarity of the sky allows for detailed observations of objects far beyond the solar system. The air is so thin and clear that the Andromeda Galaxy can span multiple fields of view in a simple pair of binoculars with a 2.5° field of view. "The first time I looked at the Andromeda Galaxy through my binoculars, it was everywhere in my view," says Natarajan.

Observing a galaxy millions of light-years away offers a powerful lesson in humility. "Those experiences make you know your place in the universe, and how small we are," he says. He sees his visits to Hanle not just as a hobby but as a "spiritual visit" that brings a sense of perspective and appreciation for the small things in life.

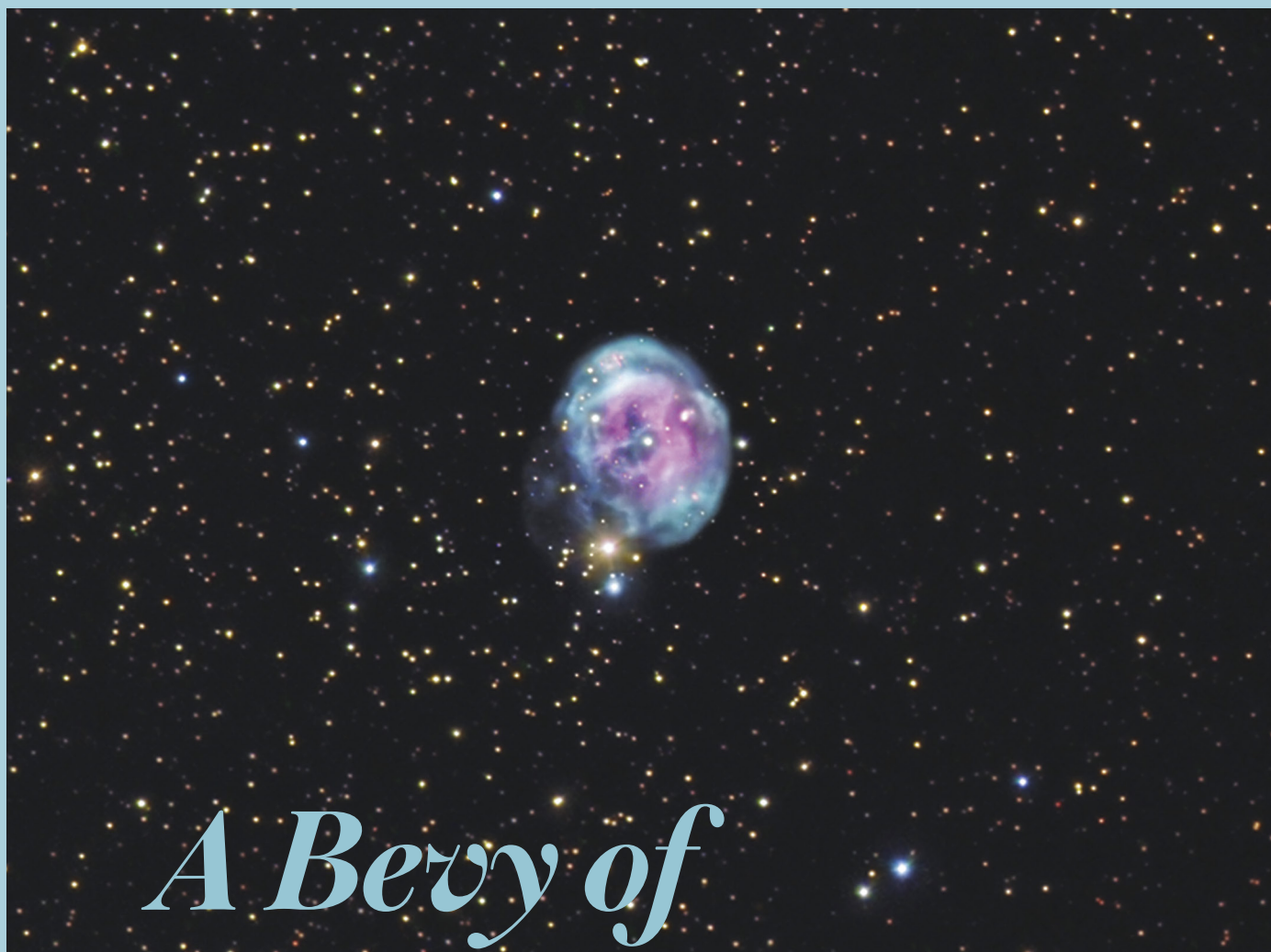
"Most visitors ask things like, 'Is this real? How far is it? And why does it look so clear here?'" says Dolker, filled with pride. "A typical day in Hanle feels like living on the edge of the world — quiet, open, and deeply connected to the sky." For her and Ishey and many others, the sky is no longer just a backdrop but a dynamic, meaningful part of their identity.

■ **SHREEJAYA KARANATHA** is an astronomy communicator based in Udupi, India. Her mind is always in space, which she channels into writing about galaxies, black holes, and beyond.

DORJE ANGCHUK / IAO / IIA



COSMIC VIEW The Moon blazes in the early dawn sky over the Indian Astronomical Observatory, with Mars, Saturn, and Jupiter (from left to right) arrayed in a train to the Moon's upper right.



A Bery of Swan Planetary Nebulae

Explore these glowing clouds of gas shed by dying solar-mass stars.

From my first breathtaking view of M57, the Ring Nebula, and M27, the Dumbbell Nebula, in the mid-1970s, I've been hooked on the fascinating variety of planetary nebulae. Over the past five decades, I've tracked down more than 570 of these glowing shells — a brief, late-life transition between the asymptotic giant branch and the final white dwarf stage. Cygnus, which flies high overhead in early September evenings, contains many intriguing examples, and we'll explore 13 of the Swan's finest.

Let's begin in northern Cygnus with **NGC 7008** (also called the Fetus Nebula), roughly 2,100 light-years away. Discovered by William Herschel in 1787, it lies 7° southwest of 4.1-magnitude Mu (μ) Cephei, known as Herschel's Garnet Star.

Long-exposure imaging uncovers a complex nested structure with an oval outer shell, an irregular kidney-bean-shaped interior, and several condensations. A small nodule on the northwestern side was initially mistaken as a separate planetary nebula (K 4-44). At 11th magnitude, NGC 7008 was faintly visible in my 80-mm finderscope at 25× with a doubly ionized oxygen (O III) filter. Through my 8-inch reflector, the northeastern and southwestern sides were brighter, and the 13.5-magnitude central star was visible in a darker cavity.

▲ **GEMS IN CYGNUS** Join the author on a tour of challenging objects, starting with NGC 7008. The compact, 98"-wide planetary lies about 2,800 light-years away near the Cepheus border. Despite their classification, planetary nebulae have nothing to do with planets — they're actually formed by Sun-like stars toward the end of their lives, shedding their outer layers as the stars cool down to eventually become white dwarfs. Below NGC 7008 is the colorful double star HJ 1606, with a 9.6-magnitude gold primary and an 11.7-magnitude blue secondary. North is up in all images.

With my 18-inch reflector at 452×, NGC 7008 was simply mesmerizing. The oval halo spanned 1.4' × 1.1', leaning to the south-southwest. At the north-northeastern edge was a bright, 25" knot with an irregular surface brightness and a small condensation near its southern end. The planetary brightened in the southwestern quadrant, but weakened on the southeastern side near HJ 1606, a 19"-wide pair of 9.6- and 11.7-magnitude stars.

Shifting south, famed double-star observer Sherburne Wesley Burnham discovered **NGC 7026** in 1873, just 12' north-northwest of the 4.5-magnitude yellow-orange star 63 Cygni. Observing with a 6-inch Clark refractor at his home in Chicago, Burnham reported "a very remarkable and curious double, or elongated planetary (?) nebula." His description may sound odd, but 10.9-magnitude NGC 7026 comprises two compact knots about 6" apart that mimic a fuzzy double star. In a 10-inch scope at high magnification, though, you'll appreciate its Cheeseburger Nebula moniker — twin lobes extend north and south (the Cheeseburger's buns), divided by a thin, dark gap (the burger). Through my 18-inch scope, the buns contained stellar points near their centers.

The Hubble Space Telescope resolves NGC 7026 into a complex shape, with a fast-expanding, ring-like waist, three entangled bipolar lobes, and four pairs of high-speed knots. A hot, central star with Wolf-Rayet-type emission lines powers



◀ **HOURGLASS-SHAPED OUTFLOWS** This view captured by the Hubble Space Telescope reveals NGC 7026's complex structure of glowing clouds of gas and dust. The colors in this composite image have been processed to increase contrast, with starlight shown in green, light from singly ionized nitrogen in red, and light from doubly ionized oxygen in blue.

the nebula, driving high-velocity stellar winds. Outflow speeds exceeding 150 km/s have been measured in its bipolar lobes.

For a far subtler target, first hop 1° east to IC 1369, a small open cluster. **Sh 1-89**, a faint and extended planetary, is only 20' farther east. On deep images it has a butterfly appearance,

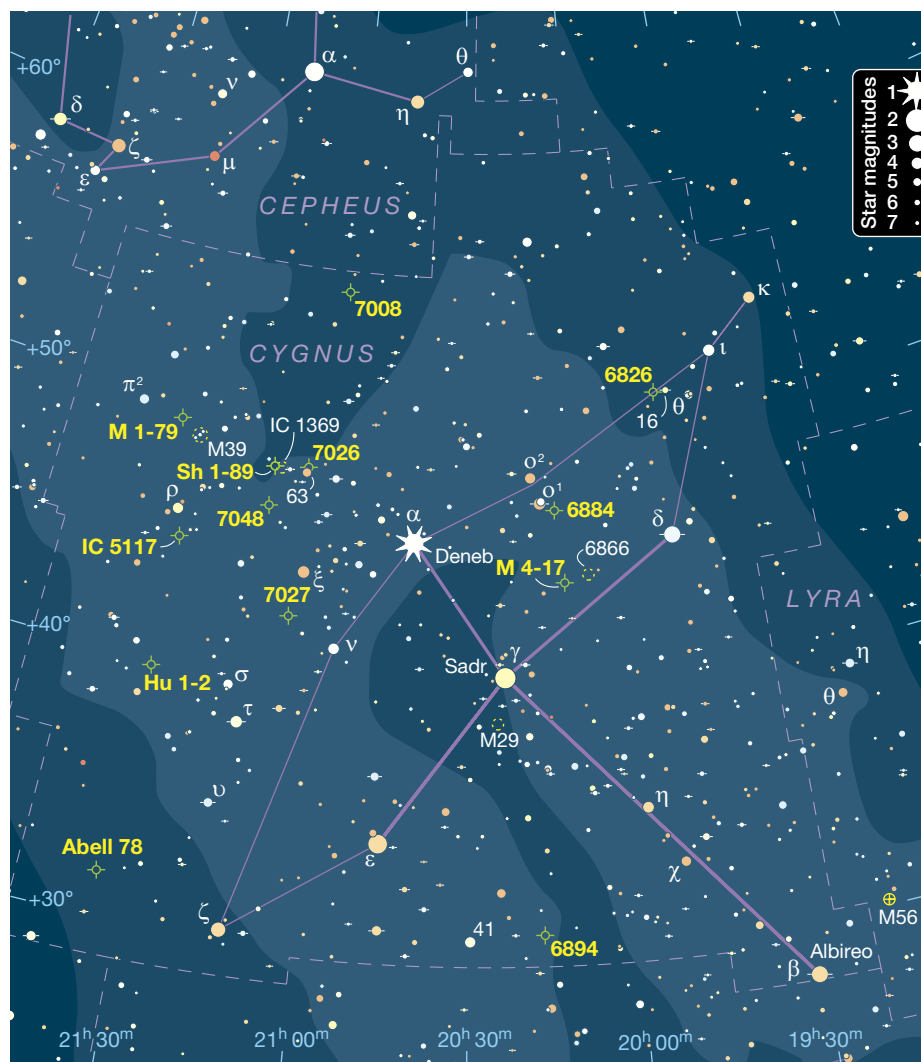
believed to have formed from interactions with an unseen binary companion — in fact, astro-imagers have dubbed Sh 1-89 the Moth Nebula. Its outer bipolar lobes span 3.4' to the southwest and northeast. In near-infrared images, the brighter, 1'-long dumbbell-shaped central region becomes an almost edge-on torus.

As far as I'm aware, Jack Marling, founder of the astronomical filter company Lumicon, and I made the first-ever visual observations of 14.5-magnitude Sh 1-89 on August 11, 1985, through his 17.5-inch reflector and my 13.1-inch Dobsonian. When I examined the field at 79×, it initially appeared empty. Adding an O III filter did the trick — a ghostly glow materialized intermittently with averted vision. More recently, I revisited Sh 1-89 with my 24-inch f/3.7

The Swan's Finest Planetaries

Object	Alternate Designation	Mag	Size	RA	Dec.
NGC 7008	PN G093.4+05.4	11.0	98" × 75"	21 ^h 00.5 ^m	+54° 33'
NGC 7026	PN G089.0+00.3	10.9	29" × 13"	21 ^h 06.3 ^m	+47° 51'
Sh 1-89	PN G089.8-00.6	14.5	60" × 28"	21 ^h 14.1 ^m	+47° 46'
NGC 7048	PN G088.7-01.6	12.1	62" × 60"	21 ^h 14.2 ^m	+46° 17'
M 1-79	PN G093.3-02.4	13.3	39" × 27"	21 ^h 37.0 ^m	+48° 56'
IC 5117	PN G089.8-05.1	11.5	2.5"	21 ^h 32.5 ^m	+44° 36'
Hu 1-2	PN G086.5-08.8	11.8	5"	21 ^h 33.1 ^m	+39° 38'
NGC 7027	PN G084.9-03.4	8.5	18" × 11"	21 ^h 07.0 ^m	+42° 14'
Abell 78	PN G081.2-14.9	13.4	113" × 88"	21 ^h 35.5 ^m	+31° 42'
NGC 6894	PN G069.4-02.6	12.5	44"	20 ^h 16.4 ^m	+30° 34'
M 4-17	PN G079.6+05.8	14.6	23" × 21"	20 ^h 09.0 ^m	+43° 44'
NGC 6884	PN G082.1+07.0	11.0	6" × 5"	20 ^h 10.4 ^m	+46° 28'
NGC 6826	PN G083.5+12.7	8.8	31" × 27"	19 ^h 44.8 ^m	+50° 32'

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



◀ **EXPLORING THE CELESTIAL SWAN** The constellation Cygnus is also known as the Northern Cross, owing to its distinctive asterism. It soars virtually overhead at mid-northern latitudes during the summer months. Use this chart to help you navigate during your star-hopping. North is up and east is to the left on this map; the stars are plotted down to magnitude 7.

one) is on the northwestern side.

To locate 13.3-magnitude **M 1-79**, start at M39, a large, naked-eye open cluster, and nudge your telescope about 1° to the northeast. German-American astronomer Rudolph Minkowski discovered M 1-79 around 1946 during a search for new planetaries at Mount Wilson Observatory. Minkowski's survey, which lasted two years, used objective-prism plates taken with a 10-inch Cooke triplet astrograph. The central part of M 1-79 is an elongated, barrel-shaped ring, or torus, with brighter knots midway along the northern and southern edges. Outside is a faint, bipolar structure from an earlier mass-loss episode, with pincer-like lobes to the northwest and southeast.

In a 6- or 8-inch telescope, you'll find a roundish disk just east of a 13th-magnitude star, and a nebula filter should improve the view. Through my 18-inch at 228×, I easily saw M 1-79 in a dense star field as an east-west oval about 35" × 25", with a 14.5-magnitude star at the eastern tip. Inserting a nar-

rowband filter, the surface brightness was irregular, dimming on the ends of the major axis.

Now we're heading 4.4° south-southwest to the young, compact planetary **IC 5117**, though an easier path might be to start at 4.0-magnitude Rho (ρ) Cygni and shift 1° to the south-southwest. Harvard astronomer Williamina Fleming (*S&T*: Aug. 2023, p. 20) discovered IC 5117 in 1905 on objective-prism plates of the Henry Draper Memorial project. High-resolution Hubble images display a tiny oval disk less than 2" across, with two minuscule pairs of hollow bipolar shells.

At low power in my 8-inch scope, 11.5-magnitude IC 5117 was starlike, forming a double with a brighter, 10th-magnitude star just 22" northeast. But when I inserted an O III filter, IC 5117 became noticeably brighter than the star. It remained stellar in appearance up to 325×, though distinctly blue-gray. In my 14.5-inch at 660×, IC 5117 shone with a light-blue color and was barely nonstellar, at most 2" in diameter. Interestingly, a *real* double star (Espin 1339) of magnitudes 11.1 and 12.2 that matched IC 5117 and its neighbor in terms of angular separation and position angle lies only 3.5' to the northeast.

telescope at 200× using a narrowband filter. The nebula's soft oval was about 45" long, angling from southeast to northwest. A 14.5-magnitude star was attached at the southeastern tip, and the northwestern end was slightly brighter.

Sliding 1.5° due south of Sh 1-89 — or alternatively, 2.9° northeast of 3.7-magnitude Xi (ξ) Cygni — we encounter 12th-magnitude **NGC 7048** in a field teeming with faint stars. This planetary eluded the systematic sweeps of both William Herschel and his son, John. Instead, it marked the very first discovery of French astronomer Édouard Jean-Marie Stephan in 1866 using a Foucault 31.5-inch silvered-glass reflector. The distance to NGC 7048 is about 5,800 light-years, making its 60" disk to be about 1.7 light-years across.

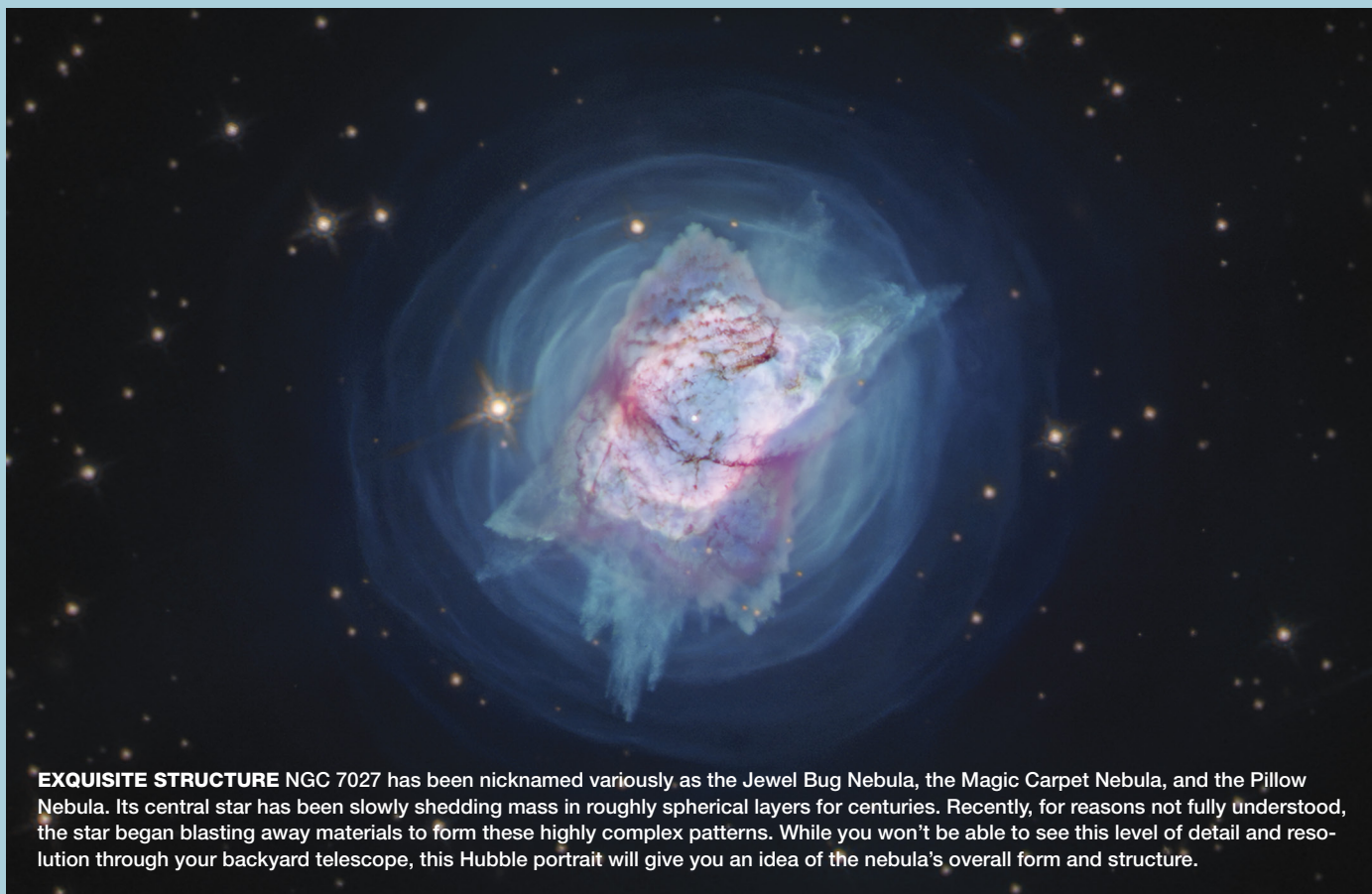
Most online descriptions of NGC 7048 involve using 10-inch or larger telescopes, but former *S&T* Contributing Editor Sue French reported that it was easily seen in her 105-mm (4.1-inch) refractor using an O III filter. Through my 18-inch at 280×, the planetary's fairly bright shell was enhanced along parts of the rim, particularly the western edge, creating a subtle ring. A 10.5-magnitude star lies just off the southern end, and a faint interior star (not the central



▲ **TARGET FOR SHARP EYES** The tiny, bipolar-lobed planetary Sh 1-89 lies about 6,400 light-years away. American astronomer Stewart Sharpless originally included it in his 1953 catalog of emission nebulae but later dropped it from his second catalog when it was reclassified as a planetary.



▲ **SOAP BUBBLE NEBULA** NGC 7048's roughly 60"-wide disk appears slightly enhanced along its western and eastern edges. The object's low surface brightness at optical and infrared wavelengths indicates that it's highly evolved. The 8.3-magnitude star at lower right is TYC 3589-4082-1.



EXQUISITE STRUCTURE NGC 7027 has been nicknamed variously as the Jewel Bug Nebula, the Magic Carpet Nebula, and the Pillow Nebula. Its central star has been slowly shedding mass in roughly spherical layers for centuries. Recently, for reasons not fully understood, the star began blasting away materials to form these highly complex patterns. While you won't be able to see this level of detail and resolution through your backyard telescope, this Hubble portrait will give you an idea of the nebula's overall form and structure.

From this teensy object, we swing 5° due south — or 3° east-northeast of 4.2-magnitude Sigma (σ) Cygni — to the tight, highly energetic planetary **Hu 1-2**. Milton Humason, who famously started his career at Mount Wilson Observatory as a mule driver and janitor, identified this compact planetary in 1920 on a spectrogram made with a 10-inch refractor and an objective prism. A month later, Edwin Hubble visually observed the object as a small disk through the observatory's 60-inch reflector. On deep narrowband images, a central hourglass structure less than 10" in diameter is seen embedded in an oval shell. Two high-velocity bipolar knots — called FLIERs (fast low-ionization emission regions) — flank the central region.

I first viewed 11.8-magnitude Hu 1-2 in 1981 through an 8-inch Schmidt-Cassegrain telescope at home in the bright skies of the San Francisco Bay Area. Even in those conditions, I could detect a slightly fuzzy, 12th-magnitude "star" at 100× using an early nebula filter (the Daystar 300), and doubling the magnification revealed a tiny disk. From a dark site, Hu 1-2 was clearly bipolar in my 18-inch at 450×, with two triangular lobes and a narrow waist. At 800×, the planetary had an uneven surface brightness, and I could see two extremely faint "wings" sprouting from the lobes.

Few planetaries rival **NGC 7027** in brightness or in professional scrutiny. Astronomers consider NGC 7027 the prototype of a very young, rapidly evolving planetary with



◀ **SMOULDERING STAR** American astronomer George O. Abell found Abell 78 in 1955 on Palomar Observatory survey plates. Its central star is considered a "reborn" star — that is, after it exhausted its hydrogen fuel, it started to burn helium in its core. The object's faint outer halo is predominantly hydrogen; its bright, inner elliptical ring is rich in helium.

an expansion age of only 600 to 1,000 years. Its heavily obscured, 16th-magnitude central star is one of the hottest known, at roughly 200,000 kelvin. The star's intense ultraviolet radiation produces a high-excitation spectrum that includes the extreme ultraviolet line of quintuply ionized neon (Ne VI).

Édouard Stephan discovered NGC 7027 in 1878. A year later, the famous British amateur Reverend Thomas Webb stumbled upon it and assumed it was a new discovery. Webb's announcement kicked off a flurry of both visual and spectroscopic interest that continues today.

To find this blue-green gem, point your scope at 3.9-magnitude Nu (ν) Cygni and steer 2° to the east-northeast. I easily saw the 8.5-magnitude object in my 80-mm finder at 12× as a pinprick and confirmed it when I blinked with an O III filter. Through my 18-inch reflector at 175×, NGC 7027 was a colorful oval with a very high surface brightness. Increasing to 450×, the planetary spanned about 18" × 12" with two unusual lobes encased in a thin outer envelope. The larger northwestern lobe sported a quasi-stellar knot at its western edge, and a smaller, fainter lobe jutted out to the southeast. In excellent seeing, I peered into the eyepiece at 807× and wow! The irregular lobes seemed three-dimensional, with the dust-divided southeastern lobe appearing to trail behind in space.

From the brightest, we turn to one of the faintest planetaries on our tour, **Abell 78**, which, at magnitude 13.4, requires a dark sky. It lies in the southeastern corner of Cygnus, 5° east-northeast of 3.2-magnitude Zeta (ζ) Cygni. I found the best view in my 14.5-inch at 87×, producing a 4.2-mm exit pupil, as well as an O III filter. The nebula's low-surface-brightness disk spanned 1.5' in diameter, and the 13th-magnitude central star is slightly offset to the north of center.

Abell 78 belongs to the exclusive "born-again" planetary club. After initially evolving toward the white dwarf stage, its central star experienced a late *helium flash*, a brief episode of helium fusion in the star's core that ejected fresh, helium-rich material into the older, hydrogen-rich nebula. This born-again event, which occurred about a thousand years ago, briefly sent the star toward giant dimensions before reheating and then resuming its descent back toward the white dwarf track.

Discovered by William Herschel in 1784, **NGC 6894** is a slightly oval ring with a thin circular shell and a dim outer halo. Forty-five years later, John Herschel compared it to M57, and called it "a most curious object, resembling much the annular nebula in Lyra, but rounder, smaller (not above half the diameter) and far fainter." NGC 6894 lies within



▲ **COSMIC FLOWER** To the north and west of NGC 6894 are filamentary clouds of hydrogen ionized by the nebula's central star. They are believed to have come from the planetary's halo and may have collided with the interstellar medium and aligned with the galactic magnetic field.

the Cygnus dark rift in the southern part of the constellation, 2.8° west of the 4.0-magnitude star 41 Cygni. This 12.5-magnitude, smoky ring appeared weakly annular in my 10-inch scope equipped with an O III filter. Through my 18-inch reflector at 280×, I saw a striking, 40" doughnut with a darker hole about 25" across. Using 700×, the rim was clumpy, and a faint star was pinned to the inside edge on the northwestern side.

A series of glowing, parallel filaments are adjacent to its northwestern side, and their origin is a bit of a mystery. In a 1997 study, astronomers Noam Soker and Daniel Zucker proposed that this material was stripped from the outer halo of NGC 6894 and is ionized by the central star. The filaments may have interacted with the Milky Way's magnetic field, aligning roughly parallel to local field lines.

Now let's head to the western arm of Cygnus where **M 4-17** is positioned 1° east-southeast of the open cluster NGC 6866. Deep optical images feature a well-defined ring nearly 25" in diameter and faint bipolar lobes. Infrared spectroscopy indicates that M 4-17 is one of several planetaries with complex, carbon-based molecules within its expanding shell. This surprising result demonstrates that despite the central star's high ultraviolet radiation, polyatomic molecules can survive even in this hostile environment and enrich the interstellar medium.

I first examined M 4-17 in 1985 with my 13.1-inch Dob at 166×. Unfiltered, I was pleased to identify its small disk in a rich star field. Through my 24-inch scope at 502×, M 4-17 was a touch out-of-round, and its southwestern rim was slightly enhanced. Don't be discouraged by these apertures — experienced observers have spotted 14.6-magnitude M 4-17 through 8-inch and smaller scopes using an O III filter.

About 5° west-northwest of Alpha (α) Cygni, or Deneb, is the colorful triple star Omicron¹ (ο¹) Cygni — an excellent binocular target with a 3.9-magnitude golden primary and 4.8- and 7.0-magnitude blue and white companions, respectively. Shift your gaze about 40' southwest to find the teeny, 11th-magnitude planetary **NGC 6884** in a rich star field. Hubble images display a warped elliptical ring with bipolar S-shaped outflows, suggesting precessing jets or binary interactions.

NGC 6884 was discovered twice — both times with visual spectroscopy. Edward Charles Pickering, director of Harvard College Observatory, identified it first in 1883, but he made a digit error in reporting the object's coordinates. When British astronomer Ralph Copeland found it again the following year at the private Dun Echt observatory in Scotland, he claimed it was new and received credit for the discovery.

I could identify NGC 6884 in my 80-mm finder by blinking with an O III filter, which produced a dramatic contrast gain. Through my 14.5-inch scope at 140×, the planetary was slightly nonstellar and surrounded by numerous stars. At 264×, I could clearly resolve a small blue disk about 5" across.

Our last stop is the star-party trick **NGC 6826**, commonly known as the Blinking Planetary. It lies 29' east of the 6th-magnitude double star 16 Cygni. Use averted vision



▲ **GREEN EYE IN THE SKY** NGC 6826, also called the Blinking Planetary, lies about 4,250 light-years away. The nebula's hot, dense white dwarf central star produces fast winds that push the surrounding gas into the outer, older material, creating a bright-rimmed, oval-shaped interior bubble. Note the two ruby-red blobs of glowing gas called FLIERS (fast low-ionization emission regions) shown in this Hubble image. They propagate along the planetary's long axis at supersonic speeds.

and NGC 6826's halo brightens, swelling to prominence. Then stare at its 10.4-magnitude central star and the halo fades significantly. Deep narrowband imaging reveals a pair of FLIERS enriched with singly ionized nitrogen (N II) embedded near the ends of the 30" disk, along with an inner elliptical rim.

At magnitude 8.8, NGC 6826 was visible in my 10×50 binoculars, but only as a faint stellar object. A 4-inch to 8-inch telescope is ideal to see the blinking effect — in large scopes the halo is generally visible continuously. Through my 18-inch at 500×, the slightly oval 30" × 25" disk was tilted to the east-southeast, and a small, darker annulus surrounded the central star. Using my 24-inch with a hydrogen-beta (Hβ) filter, the east-southeastern FLIER was just visible as a very small knot. Switching to an O III filter, I was surprised to see that the main body was surrounded by a dim, 2'-wide outer halo.

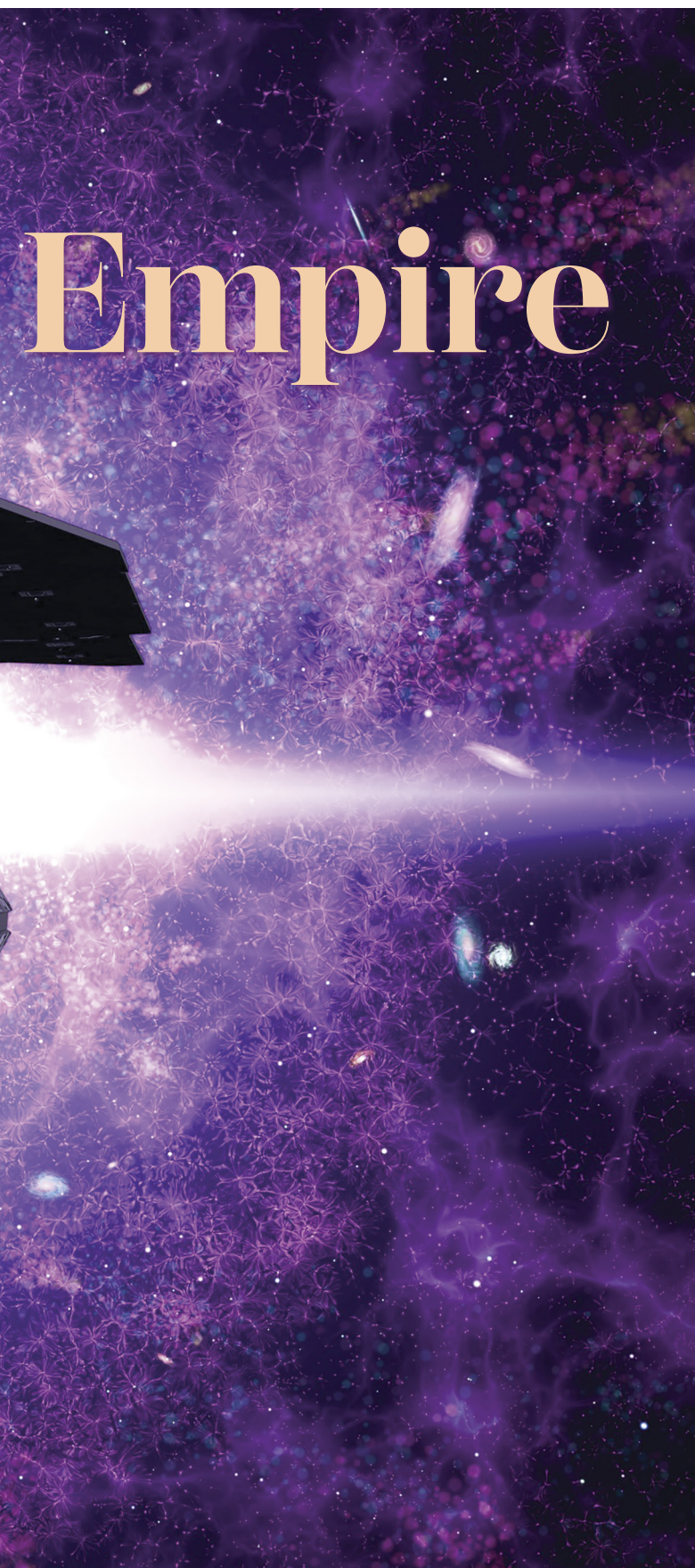
Each of these Swan planetary nebulae has a distinct charm, from nearly stellar sparks to disks that transform into smoke rings and delicate halos on the edge of visibility. To detect low-contrast features and tiny details, though, may require patience, the right filter, and dark, steady skies. For the dedicated observer, it's well worth the effort.

Good luck!

■ Contributing Editor **STEVE GOTTLIEB** has been hunting deep-sky objects from northern California for 48 years. You can explore his observations of nearly 25,000 objects at deepskygottlieb.com.

The Start of the Roman





Empire

The Nancy Grace Roman Space Telescope, poised for launch this month, is set to revolutionize the study of everything from exoplanets to cosmology.

This fall, a SpaceX Falcon Heavy rocket will blast off from NASA's Kennedy Space Center in Florida to start a new chapter in cosmic exploration. The rocket's cargo is the Nancy Grace Roman Space Telescope, a powerful instrument that promises to detect at least 100,000 new exoplanets, study billions of stars and galaxies, and shed new light on the evolution of the universe.

"Roman will provide us with an unprecedented, high-resolution panoramic view of the universe," says mission office head Kristen McQuinn (Space Telescope Science Institute). "I expect a Nobel Prize to be awarded for its results."

On Time

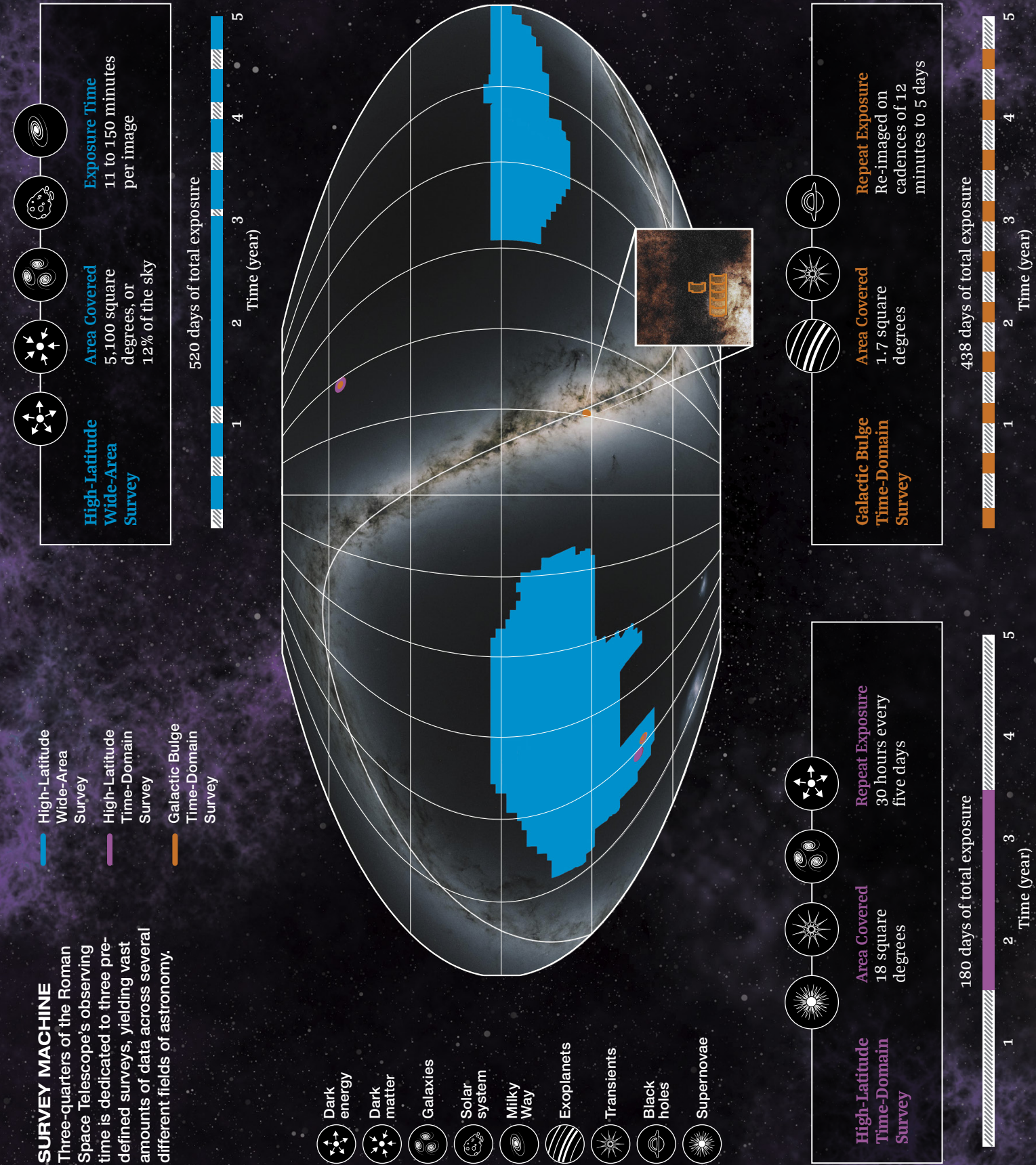
The story of Roman began more than 15 years ago, when the National Research Council published its 2010 decadal recommendations for astronomy and astrophysics. That report suggested astronomers should build the Wide-Field Infrared Survey Telescope (WFIRST), based on earlier plans for what was called the Joint Dark Energy Mission (JDEM).

Originally, planners envisioned WFIRST would sport a 1.3-meter-diameter primary mirror and just one science instrument, an imaging spectrometer. However, things changed in 2012 when the National Reconnaissance Office — an organization within the Department of Defense that builds intelligence satellites — donated a 2.4-meter mirror to NASA. The larger mirror provided more sensitivity and better angular resolution. The donation also offered the opportunity to add a second science instrument: a coronagraph that can block a star's light to directly detect the star's planets.

In early 2016, after much of the design work had already been carried out, NASA officially approved WFIRST for development, with launch planned for 2024. In May 2020, the mission was named after Nancy Grace Roman (1925–2018), NASA's first Chief of Astronomy, who is commonly known as the "Mother of Hubble" for her pivotal role in realizing the Hubble Space Telescope.

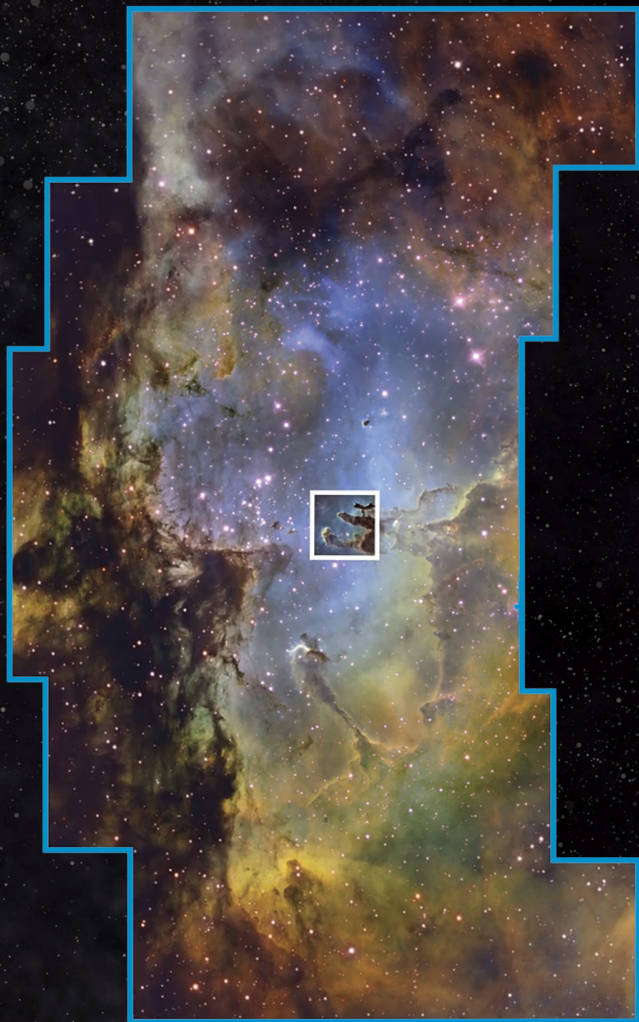
There have been many challenges along the way, says Roman's deputy senior project scientist Jeffrey Kruk (NASA Goddard Space Flight Center). Funding for the new space telescope has repeatedly been under threat. "I've lost count of how often the project has been proposed for termination," he says. Even last year, when the hardware was all but completed, the White House suggested slicing Roman's funding in half (*S&T*: Aug. 2026, p. 22). "You can't help but worry," *(Continued on page 30)*

◀ **THE EMPIRE** An artist's impression showcases the Nancy Grace Roman Space Telescope mapping the infrared universe.



A WIDER VIEW

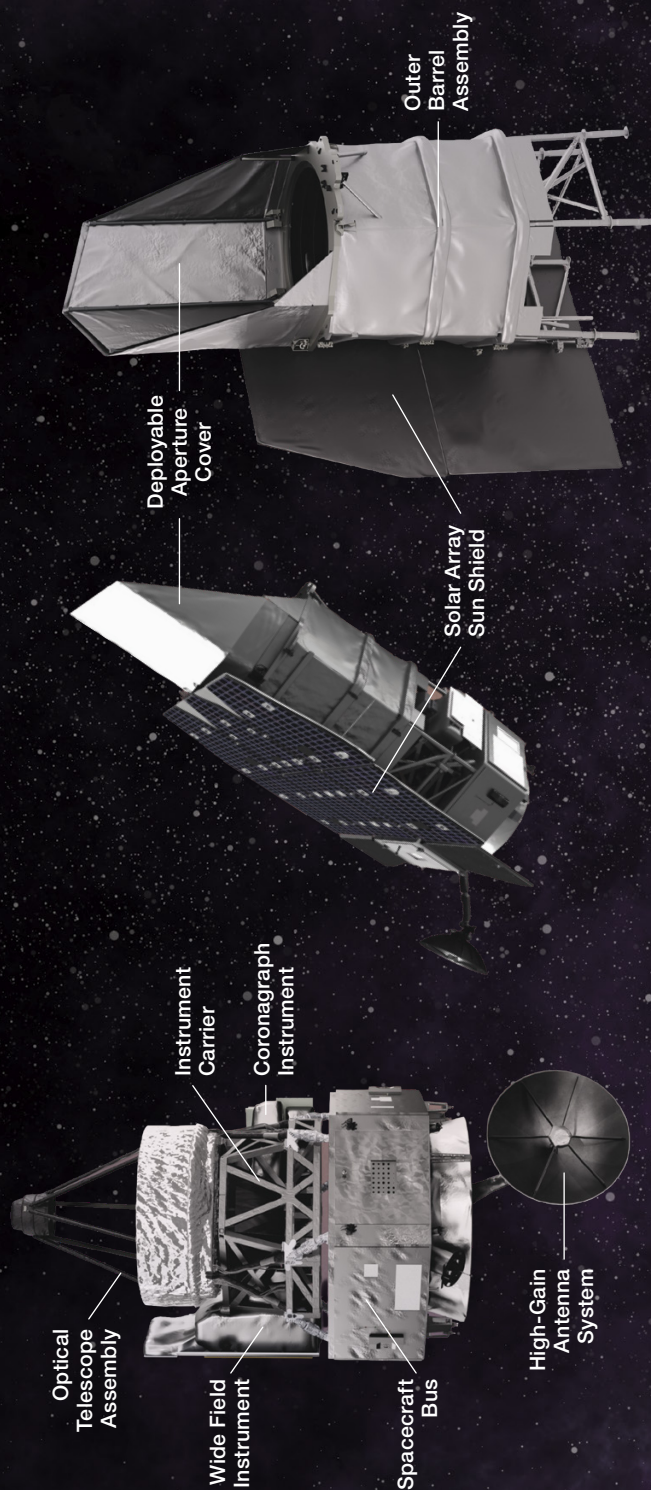
A single Roman field of view, outlined in blue, covers an area 100 times greater than that covered in a single image from the Hubble Space Telescope (white outline at center). Here, Hubble sees the Pillars of Creation, while Roman's field also includes the surrounding nebula.



PIECES OF A WHOLE

At right is a diagram of the inner portion of the Nancy Grace Roman Space Telescope, including the Wide Field and Coronagraph instruments.

This payload fits inside the Outer Barrel Assembly, shown at far right. The aperture cover and solar array/sunshield will shade and power the observatory.



(Continued from page 27)

Kruk says, “but on every occasion in the past, Congress eventually came through and gave us money. After so many times, you learn to just go ahead.”

The result: The launch is now planned for early September, some eight months before the latest Congressional goal of no later than May 2027. “Despite delays due to the pandemic, the team has been able to get ahead of the original pre-COVID schedule,” says McQuinn. “It’s incredible.”

Powerful Instrument

According to McQuinn, Roman is a relatively simple spacecraft, especially when compared to the James Webb Space Telescope (JWST) and its 344 potential points of failure. Nevertheless, it’s an extremely powerful instrument. Its primary mirror is as large as Hubble’s, so it will match Hubble’s sensitivity and angular resolution. But Roman’s field of view is about 100 times larger: 0.28 square degree, or some 40% larger than the apparent area of the full Moon.

“Hubble and Webb provide us with a small keyhole to peer through to get an impression of the room behind,” explains McQuinn. “In contrast, Roman will swing open the door, so we can see the entire room.” During its planned five-year lifetime, the new telescope will survey the sky about 1,000 times faster than Hubble can, partly due to its higher slew speed. According to McQuinn, “Every 10 months, Roman will be able to collect 1,000 years’ worth of Hubble observations.”

The space telescope’s Wide Field Instrument (WFI) provides imaging and spectroscopy using an array of 18 mercury-cadmium-telluride (HgCdTe) sensors, which are sensitive to both visible and near-infrared wavelengths. One wideband and seven narrowband filters enable observations between 0.48 and 2.3 microns. The instrument boasts more than 300 million pixels, each one smaller than the width of a human hair and offering a resolution of 0.11 arcsecond.



▲ **NANCY GRACE ROMAN** Shown here at the NASA Goddard Space Flight Center in 1972, the new observatory’s namesake was NASA’s first Chief of Astronomy.

Roman’s second science instrument, the Coronagraph Instrument (CGI), is basically a technology demonstrator for NASA’s proposed Habitable Worlds Observatory. Much like what noise-canceling headphones do for sound, the CGI cancels out 99.9999999% of a star’s light to reveal faint things around it. With this instrument, Roman may be able to see Jupiter-like planets in Jupiter-like orbits around Sun-like stars (S&T: Sept. 2024, p. 34).

The European and Japanese space agencies (ESA and JAXA, respectively) are partners in the CGI program, and they will also help keep track of the mission and downlink data to the ground. Roman will produce 4 petabytes of data per year, about as much as 1 million HD movies. The data will be almost continuously downlinked at hundreds of megabits per second to large antennas around the world.

Survey Machine

Hubble and JWST operate mainly in guest-observer mode, carrying out astronomers’ observing proposals on topics ranging from our own solar system and stars in the Milky Way to other galaxies and cosmology. With Roman, just a quarter of the available observing time is set apart for such guest observations. All of the remaining time is devoted to large, predefined survey programs, which will yield vast amounts of data for astronomers to analyze and study in detail. Unlike with Hubble and JWST, all Roman observations will become publicly available immediately.

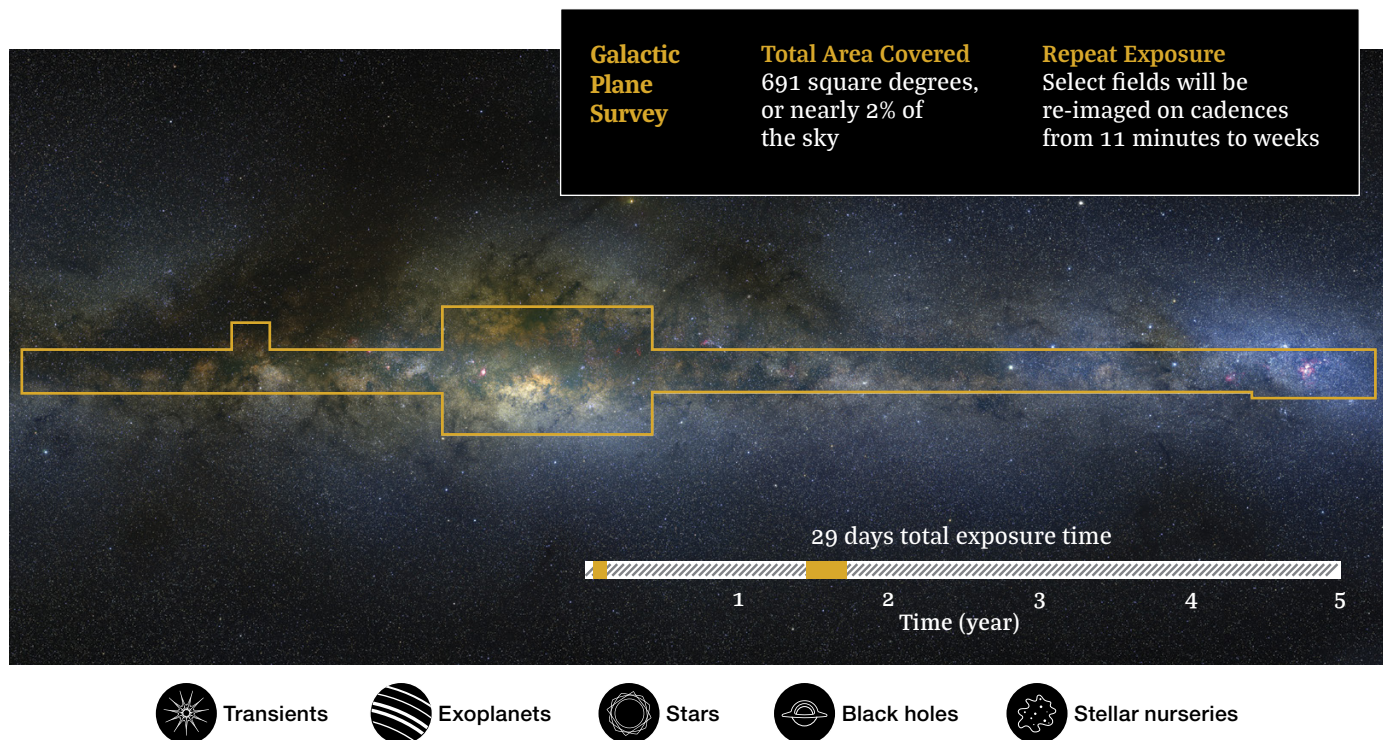
“Roman is a community-driven mission,” says McQuinn, “with three core surveys, each focusing on a particular science driver.” Planners have designed those surveys with input from astronomers worldwide. According to McQuinn, “for many scientific purposes, the survey programs are more than sufficient.” Different astronomical communities will certainly compete for their own observing time, but “this pie is big enough for everyone to share,” she says.

Roman’s High-Latitude Wide-Area Survey will observe two large swaths of sky on either side of the star-dense band of the Milky Way. The survey’s main goal is to investigate the nature of dark matter and dark energy by studying the shapes and spatial distribution of billions of galaxies. The gravity of intervening matter distorts galaxy shapes, and both dark matter and dark energy help determine the evolution of the universe’s large-scale structure.

In contrast, the High-Latitude Time-Domain Survey will focus on two smaller patches of sky to discover distant supernovae and other short-lived phenomena (or *transients*).

The third core survey is the Galactic Bulge Time-Domain Survey, which will meticulously monitor six small fields, gazing in the direction of the Milky Way’s core. Apart from enabling the discovery of countless exoplanets, this survey will also allow astronomers to study neutron stars, white dwarfs, and stellar-mass black holes in our galaxy.

Finally, there’s the Galactic Plane Survey. Although it’s not a core survey program, the Roman science team selected this proposal early on from the community to kick off the



▲ **GALACTIC PLANE SURVEY** The astronomy community will have the opportunity to propose observations outside of Roman's core surveys. One that's already selected is the Galactic Plane Survey, shown here.

guest-observer program. During the first two years after launch, this survey will produce detailed views of the stellar plane of the Milky Way, measuring the brightness and position of billions of stars — more than ESA's Gaia mission did and with a higher precision, too. According to Gaia's Anthony Brown (Leiden Observatory, The Netherlands), combining Gaia data with the new Roman measurements will yield precise values for stellar *proper motions*, the slow movements of stars across the sky.

Worlds Unnumbered

Through its time-domain surveys, the Roman Space Telescope is expected to discover around 100,000 new exoplanets, finding them at farther distances than previous planet hunters have. It'll use three different techniques to do so, picking out different types of planets in the process.

Most of these worlds will be found using the *transit* method championed by NASA's Kepler space telescope, in which planets create tiny periodic dips in the brightness of their parent stars. Watching for transits tends to turn up large planets in tight orbits (e.g., Neptune-size worlds in orbits smaller than Mercury's orbit around the Sun). Roman's discoveries will add to our knowledge about such tight planetary systems, which are weird but common.

But Roman will also use a technique called *gravitational microlensing* to find planets much farther away from their parent stars. Those discoveries will likely include Earth-like worlds in the habitable zone, the region around a star where temperatures allow the existence of liquid water on such a

planet's surface. Using this method, the telescope should find analogs for every planet in our solar system.

Microlensing occurs when one star by chance passes in front of another, more distant star. The foreground star's gravity acts as a magnifying lens, temporarily brightening the background star. If the foreground star has a planetary system, the gravity of each planet produces an additional, even-more-short-lived spike in brightness. Using precise photometry of the microlensing event, astronomers can estimate the planet's mass and orbital radius, explains Lisa Kaltenegger (Cornell University).

By keeping an eye on hundreds of millions of stars in the Milky Way's central bulge, Roman might discover more than 2,000 exoplanets through microlensing. "While we can't follow up microlensing planets to study their atmosphere and their nature, having a statistical sample of what kind of planets are out there will be extremely interesting," says Kaltenegger. The microlensing technique could also uncover rogue planets with no parent star. It could also find stealth stellar-mass black holes that roam our galaxy.

Roman will also directly image planets with its coronagraph, studying giant planets that orbit their stars at large distances; in the same way, it can image earlier stages of planet formation, when disks of gas and dust surround the stars. To accomplish those feats, the instrument will suppress the host star's glare by a factor of at least 100 million. Using a complex series of masks and prisms as well as small deformable mirrors to actively control the shape of the light's wavefront, the coronagraph is expected to be hundreds of times more effective than earlier versions, such as the one on JWST.

As a result, the coronagraph is sensitive not only to young gas giants, which still glow with the heat of their formation,

but also older Jupiter-like worlds that merely reflect light. By detecting gas giants in wide orbits, Roman's coronagraph will complete our picture of what planetary systems look like, says Kaltenegger. "Is our solar system 'standard,' or is it very different from most systems?" she asks. "Adding the outer planets with longer periods to the population of inner planets we have already found will help us answer that question."

A much more powerful coronagraph will fly on the Habitable World Observatory, a proposed future space telescope that will search for signs of life in the atmospheres of Earth-like planets. "Roman provides a test bed for the next-generation instrument we plan to fly on HWO," says Kaltenegger. "Roman will enable the future."

Cosmological Conundrums

While Roman will yield many new exoplanet discoveries, most scientists expect the mission's biggest breakthroughs to come in cosmology.

By far the biggest puzzle on scientists' minds is the composition of the universe. Over the past decades, astronomers have found convincing evidence for the existence of large amounts of both dark matter, which holds galaxies and clusters together, and dark energy, the driving force for the observed accelerating expansion of space. However, no one has a clue as to the true nature of these cosmic components.

Yet another riddle is that different observational probes of the current expansion rate yield different results — a mismatch known as the *Hubble tension* (S&T: Mar. 2022, p. 14). Moreover, recent data from large ground-based surveys suggest that dark energy may vary over time, contrary to popular cosmological models. Intriguingly, JWST observations hint that the newborn universe might have evolved much faster than theorists expected, with numerous large, massive galaxies and black holes already showing up a few hundred million years after the Big Bang.

To better understand cosmic evolution, Roman will map the 3D distribution of gravitating matter (85% of which is

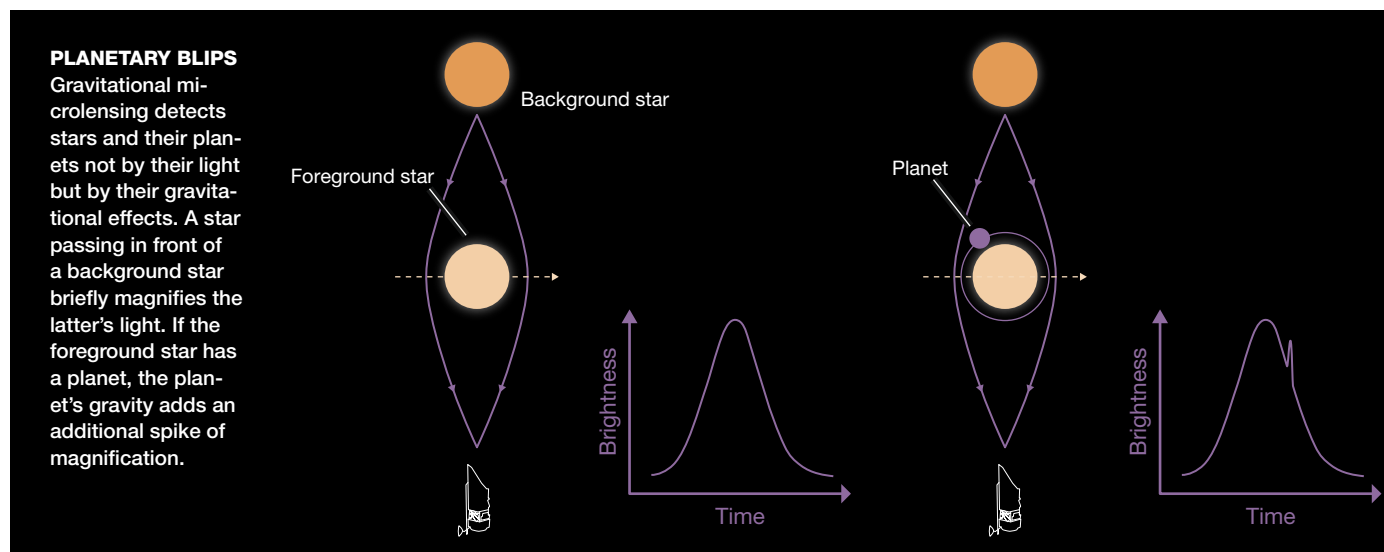
dark) to trace the universe's expansion history over billions of years. The avalanche of new data will constrain cosmological models and may ultimately weave a self-consistent picture that doesn't have as many loose ends as our current understanding — something that could indeed result in a future Nobel Prize, as McQuinn predicts.

There are a number of ways in which cosmologists hope to address these nagging issues. First, observations of Type Ia supernovae can help astronomers map out the universe's early expansion history. These white dwarf explosions serve as *standard candles*, burning with a known brightness so that astronomers can use them to determine distances. (The 1998 discovery of dark energy relied on this type of supernova, albeit those were much closer than the ones Roman will find.)

Another probe of the evolution of cosmic expansion — and thus the possible evolution of dark energy — is provided by *baryon acoustic oscillations* (BAOs). These are statistical patterns in galaxies' distribution, imprints of the sound waves that sloshed in the primordial matter filling the newborn universe (S&T: Mar. 2026, p. 34). The patterns grow as the universe grows, explains Henk Hoekstra (Leiden University, The Netherlands). "They're like expanding fingerprints," he says. "BAOs constitute a very clean probe of the expansion history of the universe."

Precisely mapping the distribution of galaxies at a wide range of distances and look-back times does double duty: Those data also track the growth of cosmic structure, enabling astronomers to measure the opposing effects of dark matter, which tries to pull everything together, and dark energy, which tends to push things apart.

Finally, there's yet another powerful way to probe dark matter: by investigating the images of distant galaxies. The subtle, light-bending effects of intervening matter slightly distort galaxies' apparent shapes in a phenomenon known as *weak gravitational lensing* (S&T: Sept. 2016, p. 34). Statistical studies of billions of galaxies' images thus reveal the distribution of matter — both visible and dark.



Complementary Projects

Existing facilities are already collecting cosmological observations, including ESA's Euclid space telescope, which launched in July 2023, and the Vera C. Rubin Observatory in Chile, whose Legacy Survey of Space and Time is expected to commence this year. But Roman won't duplicate their work; according to Hoekstra, Euclid's cosmology coordinator, the various programs are complementary.

Euclid's 1.2-meter primary mirror is half as wide as Roman's, so its images aren't as sharp and sensitive as Roman's. "But Euclid's survey covers a much larger part of the sky," says Hoekstra, "so it provides better statistics." That capability is especially important for weak-lensing studies. "Moreover, we're already flying. We expect to present our first cosmological results in late 2026 or early 2027."

As for Rubin, its giant 8.4-meter mirror can detect much fainter objects, but as a ground-based observatory, its images suffer from atmospheric blurring and airglow, and its 3.2-gigapixel camera mainly observes in the visible part of the spectrum. With Roman's razor-sharp near-infrared observations, astronomers will be able to study galaxy shapes, distant supernovae, and other transient phenomena at larger distances, as the universe's expansion shifts remote objects' visible light to longer wavelengths.

Although Roman is less sensitive than JWST, which is a near-infrared powerhouse, Roman's wider field of view may help to unravel the evolution of the mysterious *little red dots* that JWST discovered (*S&T*: May 2024, p. 20). These appear to be gas-shrouded black holes, though other possible explanations exist, too. "Little red dots are plentiful in the early universe," says Sangeeta Malhotra (NASA Goddard Space Flight Center). "We've also found a handful of them at lower redshifts, but we'd like to know what happens in between." Astronomers expect Roman to find little red dots at a variety of distances, shedding light on their evolution.

Malhotra also thinks Roman could help cosmologists to better understand the origin and evolution of the first galaxies at cosmic dawn. A dedicated deep and wide spectroscopic study of very distant galaxies, which she has proposed together with Anton Koekemoer (Space Telescope Science Institute) and others, could reveal the growth of star-forming galaxies and the way in which they contribute to the early heating of intergalactic gas. "However, this would take up a lot of observing time," she says, "and it's not in the plan yet."

Imagine This

For image specialists like Joseph DePasquale (Space Telescope Science Institute), the sheer volume of data generated by Roman poses wholly new challenges.

"Processing images of this scale requires a fundamental rethink of our approach," he says. When working with Hubble or JWST data, specialists deal with issues like blips from cosmic particles or internal reflections on a case-by-case basis. Now, they must find a way to address such artifacts across Roman's vast field of view.



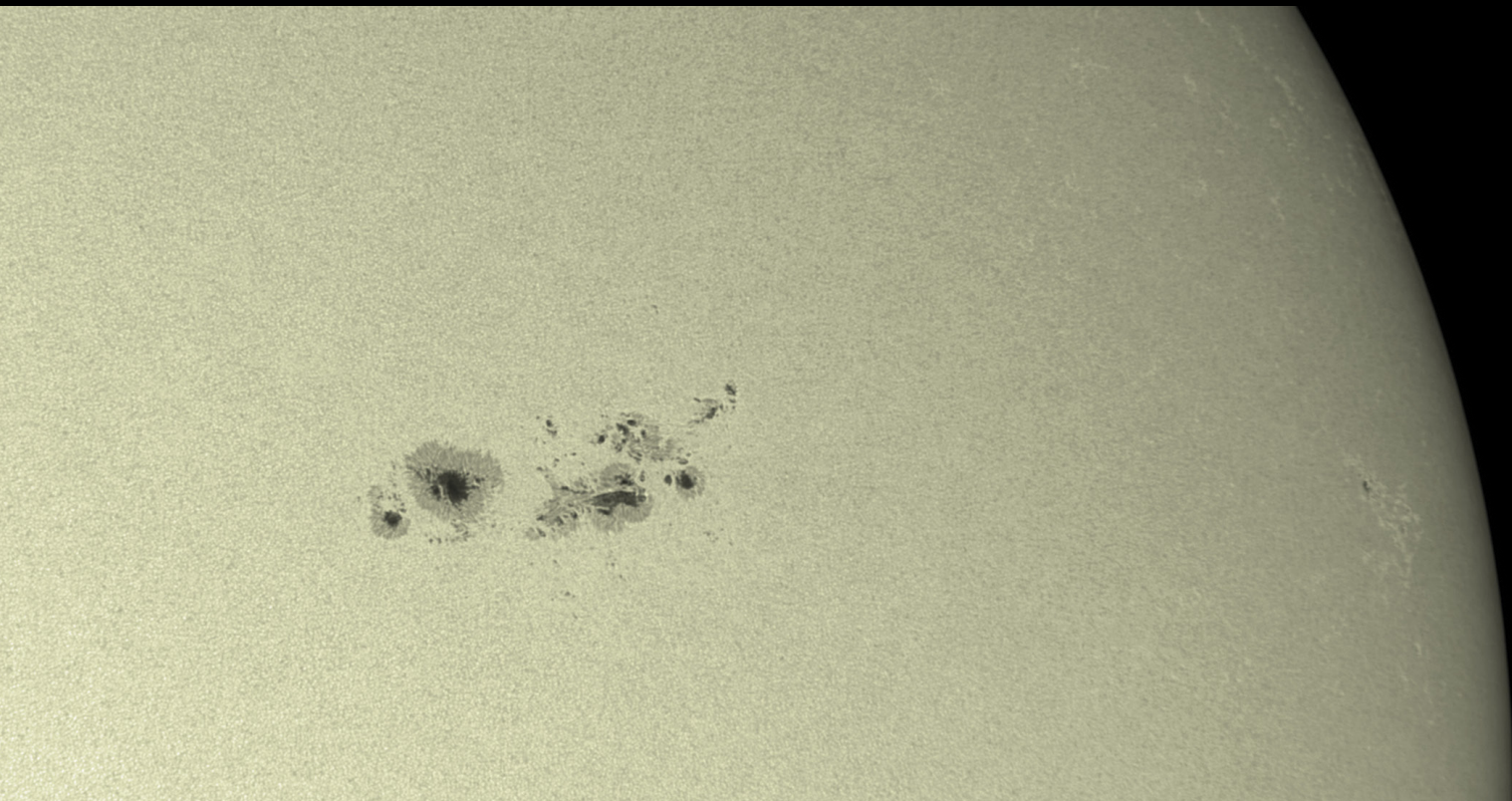
▲ **FINAL INTEGRATION** In the months prior to launch, technicians worked to connect the inner and outer parts of the Roman Space Telescope in the clean room at the NASA Goddard Space Flight Center.

DePasquale is confident that the resulting images will be nothing less than spectacular. "I am most excited by the possibility of revisiting areas made famous by Hubble and Webb, but seeing them in an entirely new context," he says. "Because of the much larger field of view, we can for example capture the iconic Pillars of Creation within the Eagle Nebula while simultaneously revealing their entire surrounding environment in exquisite detail."

NASA will release Roman's first-light images shortly after the observatory completes a three-month-long commissioning phase, which will start as soon as the new space telescope has reached its destination. It will loop around the L₂ Lagrange point, 1.5 million kilometers (930,000 miles) behind Earth relative to the Sun, where Earth's and the Sun's gravity are in equilibrium. "You should expect to see the first images in December," says Kruk.

Since all Roman data will immediately become publicly available, citizen-science image processors will also have unlimited access to the cosmic vistas collected by the new space telescope. As McQuinn says, "These telescopes aren't just for scientists. The Nancy Grace Roman Space Telescope is for all humanity."

■ After writing Dutch coffee-table books on both Hubble and Webb, *S&T* Contributing Editor GOVERT SCHILLING looks forward to working on a visually stunning book about the Nancy Grace Roman Space Telescope.



Observing the Sun in the 21st Century

Focusing on our nearest star has never been easier.



The night sky has always been what draws me to astronomy — galaxies, nebulae, the planets, the stars. I'm sure the same is true for many readers. The Sun, however, is also a star. It provides the energy that makes life on our planet possible, and it's the only star we can study up close. Other stars appear little more than pinpricks of light in our telescopes, or slightly bloated points when we image them with a camera. By contrast, we orbit our own home star and observe it from a uniquely close perspective. This provides not only stunning, dynamic views of an active celestial body, but it also yields a wealth of information for those interested in the study of stars themselves. Today, there are many options for safely focusing on our nearest stellar neighbor. Let's take a look at the current state of the art.

The Blazing Photosphere

The foremost consideration when observing the Sun is that it's intensely bright and hot — to begin with, it's not safe to stare at it with the unaided eye without any proper filter protection. And if you use any optical aid, even the slightest magnification or increase in light-gathering power can permanently damage your eyes or camera. This is the fundamental challenge of solar observing — that is, reducing its light and heat to a safe level.

White-light views of the Sun show the *photosphere*, the lowest layer of the Sun's atmosphere, its visible "surface." They reveal *sunspots* in fantastic detail. Sunspots are dark, cooler regions where strong magnetic fields penetrate the photosphere and inhibit convection. Under steady sky conditions, you'll see the photosphere is made up primarily of *solar granulation* — hot, rising convection cells of plasma surrounded by darker lanes of cooler plasma sinking back down into the photosphere. They last only some 10 minutes or so before cooling and darkening. Also visible are *faculae* — bright, speckled regions seen between granulation that are produced by concentrations of magnetic fields. Another prominent white-light feature is *limb darkening*, in which the Sun appears darker at the edges. This is because as you view the center of the Sun's disk you're looking deep into the hot glowing atmosphere, but as you approach the limb you're seeing higher, cooler layers of the photosphere.

The easiest and safest way to observe the photosphere is by adding a front-aperture filter to your telescope that attenuates

most of the light before it enters the instrument. These are available in both glass and polymer forms, often appearing shiny — they're mirror-like on the front of the scope because they reflect 99.999% of the Sun's energy back into the sky. Some of these filters produce a yellow or orange image of the Sun, others purely white, and there are options to fit camera lenses as well as telescopes through a variety of dealers.

Front-Mounted Filters

An often-preferred approach to observing the photosphere is to use a filter in front of the telescope's objective. My favorite type incorporates AstroSolar Safety Film, a thin polymer sheet with a metallic coating produced by Baader Planetarium (baader-planetarium.com). Filters made from this material are widely available and are made to fit over small-aperture scopes. You can also buy larger sheets of the material to make your own filter. The film produces a colorless view of the Sun. One important caveat here is that Baader makes two versions of this film, one for visual (optical density 5.0) and one for photography (optical density 3.8). The photographic film passes too much light to be used safely for visual observing, so make sure you have the right one for the right use!

In my experience, this film produces sharper images than many front-mounted glass filters, which are often not of the highest optical quality.



◀ **PHOTOSPHERE VS. CHROMOSPHERE** Sunspots take on a very different appearance at certain wavelengths. The view at top shows the dark sunspot group AR 3354 with the spots' dark umbra surrounded by lighter penumbra in the white-light view. The same group reveals that several fibrils connect the spots in the chromosphere view below. Note the bright faculae near the solar limb in the white-light view, while the limb in the chromosphere displays short spicules and a prominence.

▶ **MULTI-WAVELENGTH PLATFORM** Stephen Ramsden uses several Sky-Watcher HelioStar telescopes to show off of our nearest star at this year's Northeast Astronomy Forum & Space Expo. Each scope uses an internal Fabry-Pérot etalon to isolate a narrow sliver of the spectrum to reveal dynamic features in the Sun's chromosphere.



▲ **WHITE-LIGHT GATEWAY** Front-mounted solar filters, like this example from Baader Planetarium (left) using optical-quality polymer film, are the most affordable entry into solar observing by making a telescope you already own safe for solar viewing. These filters are sold in sizes for telescopes of up to 280 mm and produce a view of the photosphere revealing sunspots, plages, and granulation (right).

One note about these white-light glass or polymer filters: They must always be placed over the front aperture of your telescope. Light concentrated near the focal plane of your instrument will melt, crack, or simply vaporize a filter that isn't designed for the intense heat and destroy your vision.

You can further enhance contrast of the white-light view by adding a *continuum filter* in the barrel of your eyepiece or camera in addition to the full-aperture filter. A continuum filter passes a narrow region of the spectrum centered at 540 nanometers (green) improving the visibility of fine detail and helps bring out the structure of sunspots, including the inner dark *umbra* and surrounding lighter *penumbra*.

Front-aperture solar filters are the most cost-effective way to turn most telescopes into an amazing white-light solar telescope. A more specialized approach is to use an optical device called a *Herschel Wedge*. This special prism is placed near the focal plane of a refractor where you'd usually place a star diagonal. This prism passes much of the Sun's energy through its back, and the heat is dispersed with a metal screen or ceramic diffuser. The remaining light is reflected toward the eyepiece, where additional neutral-density and polarizing filters further attenuate the light to safe levels. Herschel wedges are designed exclusively for use with small- to mid-sized refracting telescopes as they concentrate the Sun's unfiltered energy near the focus point. (See our reviews of two Herschel Wedges in *S&T*: Mar. 2023, p. 68, and Feb. 2025, p.70.)



A Higher Level: The Chromosphere

Above the photosphere is the next observable layer of the solar atmosphere called the *chromosphere*. This region is some 3,000 to 5,000 km (1,900 to 3,100 miles) thick and appears about 1% larger than the photosphere. The chromosphere is much more visually dynamic than the photosphere though it requires more specialized tools to observe. The most common approach is with a type of filter that passes a fraction of a single wavelength of the Sun's light centered in 656.28 nm, the emission line of hydrogen alpha ($H\alpha$). The view of the Sun in $H\alpha$ reveals a tremendous wealth of detail compared to white light.

Along the limb, dramatic *prominences* of cool, dense plasma are often seen suspended by magnetic fields, towering tens of thousands of kilometers or more above the solar surface.

Short, bright, spikelike *spicules* are also visible just along the solar limb. Long, sinuous dark *filaments* (which are simply prominences seen against the brighter disk) often trace magnetic fields millions of kilometers around the disk. Sunspots take on a very different appearance in $H\alpha$, with occasional bright flares blazing forth from the frothy plages that surround the spots. There are also small, dark, thread-like structures called *fibrils*.

◀ **UNIQUE DIAGONAL** Another option for attaining safe and sharp views of the photosphere is a device called a Herschel Wedge. These operate much like a star diagonal and redirect a small amount of sunlight toward your eyepiece or camera while diverting the rest of the Sun's energy through the rear of the device. Herschel Wedges should only be used with small refractors and are not safe for use with catadioptrics.

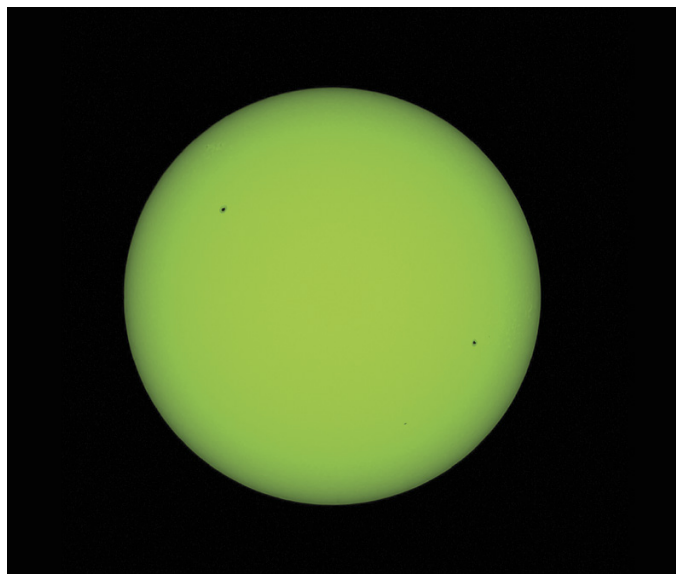
that connect active regions within sunspot groups. All these features are highly dynamic and can change appearance over the course of just minutes.

Isolating such a small bandpass of light requires a more complex approach than a simple glass filter. It's best accomplished with device known as a *Fabry-Pérot etalon*, which is made of two highly reflective plates that are placed very close together. Light bounces between these plates and reflects most of the unwanted wavelengths. An additional blocking filter is required at the focal plane to further restrict the view to the specific wavelength of interest.

There are currently two types of etalons for H α observing: passive, air-spaced etalons and solid-spaced, electrically heated filters. The difference is that heated units are more thermally stable and will stay on-band despite ambient temperature changes, whereas air-spaced etalons often require adjustments as conditions change. Electronically regulated etalons can also be made to pass a narrower slice of the spectrum, as small as 0.3 angstrom (0.03 nm).

Companies, including Baader Planetarium and Daystar Filters (daystarfilters.com), offer thermally regulated etalons that are safe for use without additional filtration for refractors of up to about 80 mm in size. Larger apertures require an additional energy rejection filter (ERF) placed over the telescope's objective lens for safe operation. You can use a solid-spaced etalon with any refractor, but it requires a high focal ratio of at least f/30 to ensure light rays are nearly parallel when they reach the device.

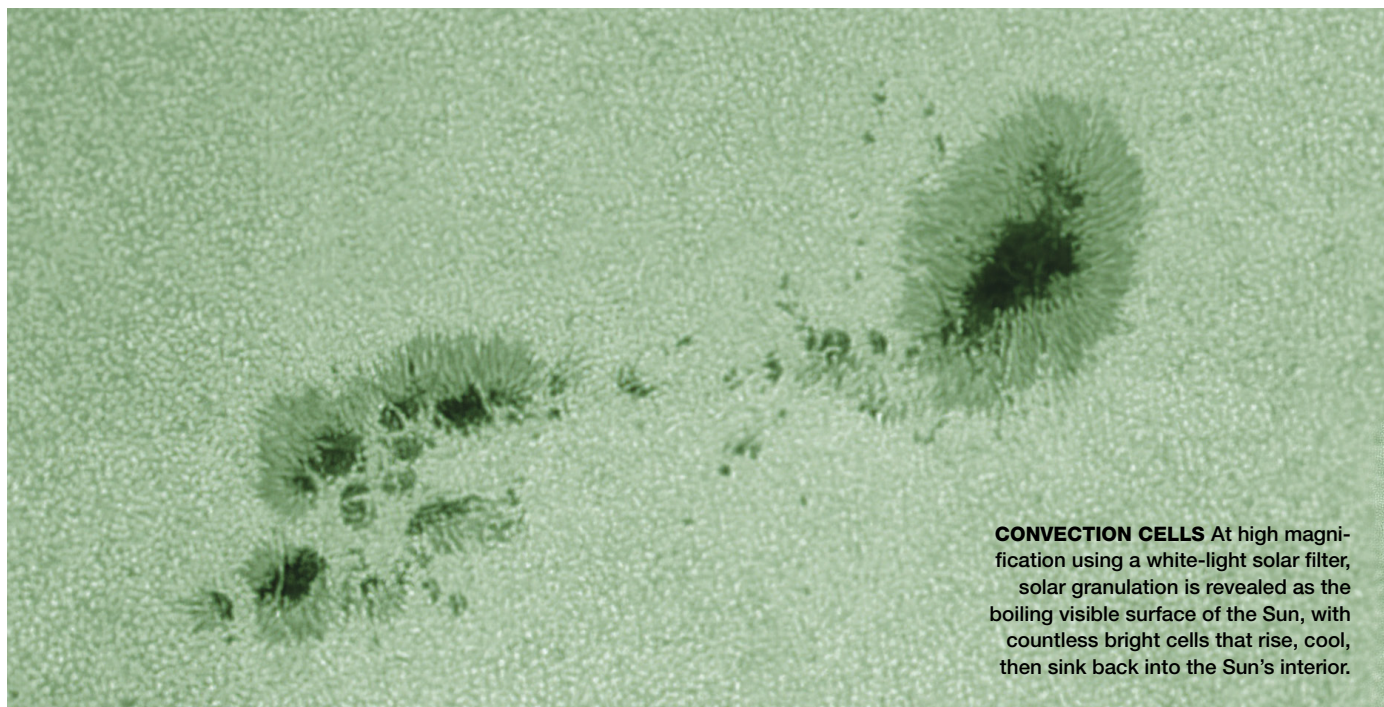
The current best source for air-spaced H α etalons that you can add to your own refractor is Lunt Solar Systems (luntsolarsystems.com). These are placed over the objective lens of your refractor and don't require additional magnifica-



▲ **GREEN CONTINUUM** Adding a continuum filter (a narrowband green filter centered at 540 nanometers) increases contrast of sunspots and granulation when paired with a white-light solar filter.

tion unless desired. They are tuned to the precise wavelength by slightly tilting the etalon.

If your telescope isn't suitable for adding an etalon for solar H α observing, there are lots of dedicated H α telescopes available on the market such as those from Daystar Filters, Lunt Solar Systems, and Sky-Watcher Telescopes (skywatcherusa.com). These systems produce excellent, high-contrast views, though achieving uniform illumination across the solar disk can sometimes be more challenging, as the transmitted wavelength can vary slightly across



CONVECTION CELLS At high magnification using a white-light solar filter, solar granulation is revealed as the boiling visible surface of the Sun, with countless bright cells that rise, cool, then sink back into the Sun's interior.



▲ **SOLAR H α FILTERS** There are two primary types of etalon designs available that reveal the first Balmer line, hydrogen alpha, in your refractor. There are etalons that require electricity (like the Daystar Quantum filter seen above) to ensure the filter is operating at a precise temperature, and air-spaced etalons (top) which are tuned by slightly tilting the device when installed in front of your telescope's objective lens. Air-spaced models require an additional back filter to further block off-band light from reaching the viewer.

the image. For even greater contrast, some instruments can be configured in a “double-stacked” arrangement by placing two etalons in the light path to further narrow the bandpass, but this is at the cost of image brightness. The Sky-Watcher Heliostar telescopes (*S&T*: Dec. 2025, p. 68) offer narrower bandpass than most single-stacked options while maintaining a notably brighter solar image.

Other Notable Wavelengths

White light and H α aren't the only options for solar observing; there are additional wavelengths that probe different layers of the solar atmosphere. The calcium lines — Ca II K (at 393.4 nm) and Ca II H (396.9 nm) — reside in the violet region of the spectrum and reveal a wealth of detail in the lower chromosphere. Both wavelengths are difficult to see visually but are easy to capture with a monochrome camera. Many observers find that their sensitivity to violet light diminishes with age; I could see it readily 20 years ago, but today I can no longer detect it visually.

The view through a CaK filter reveals sunspots and extended bright plage regions surrounding them compared to the view in white light. In addition, faculae, or bright filaments are visible throughout the solar disk. Even promi-

nences are visible through a calcium filter, though they're much fainter than in H α . It's less complicated to safely observe the Sun in calcium light — to image it, at least. Baader Planetarium sells a filter that includes a sheet of its photographic ND 3.8 Astrosolar Safety Film that does the job, and Lunt Solar Systems offers a Calcium Module that produces even higher contrast.

Less common are filters centered on the magnesium and sodium wavelengths. The magnesium I B2 line at 517.28 nm lies in the green, where our eyes are highly sensitive. It produces a bright image with enhanced contrast, showing plages and fine mottling across the solar surface. The sodium D lines at 589.59 nm and 588.99 nm produce a bright, high-contrast view similar to whitelight, with improved visibility of plages and sunspots.

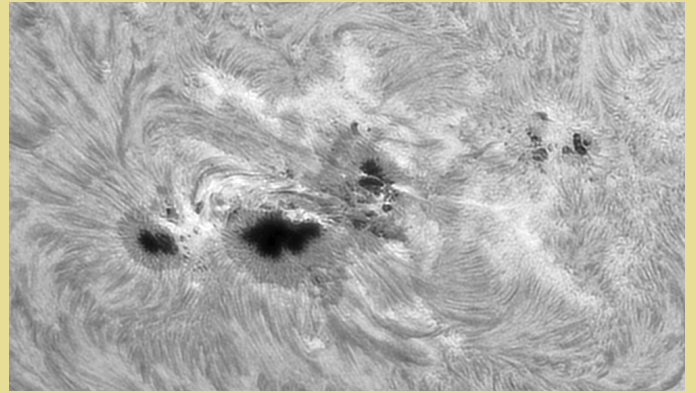
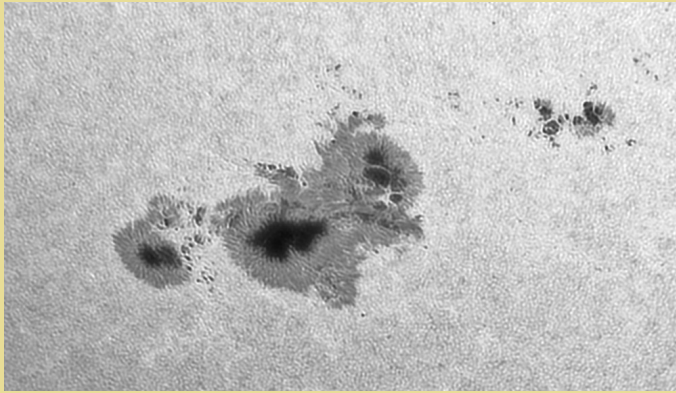
There's one final option for imaging the Sun at any visible wavelength using a special device called a *spectroheliograph*. This instrument uses a diffraction grating that's tunable to any specific spectral line of interest. The trade-off is that it captures only a narrow strip of the solar disk at a time. To build up a complete image, you must either slowly scan the telescope across the Sun or stop tracking and allow the Sun to drift through the field. These devices produce exceptionally detailed, high-contrast images with a passband of 0.01 nanometer, but they are more complex to operate and process than conventional solar imaging systems (*S&T*: Sept. 2025, p. 60). A commercially produced spectroheliograph is available through MLAstro (mlastro.com).

Observing Tips

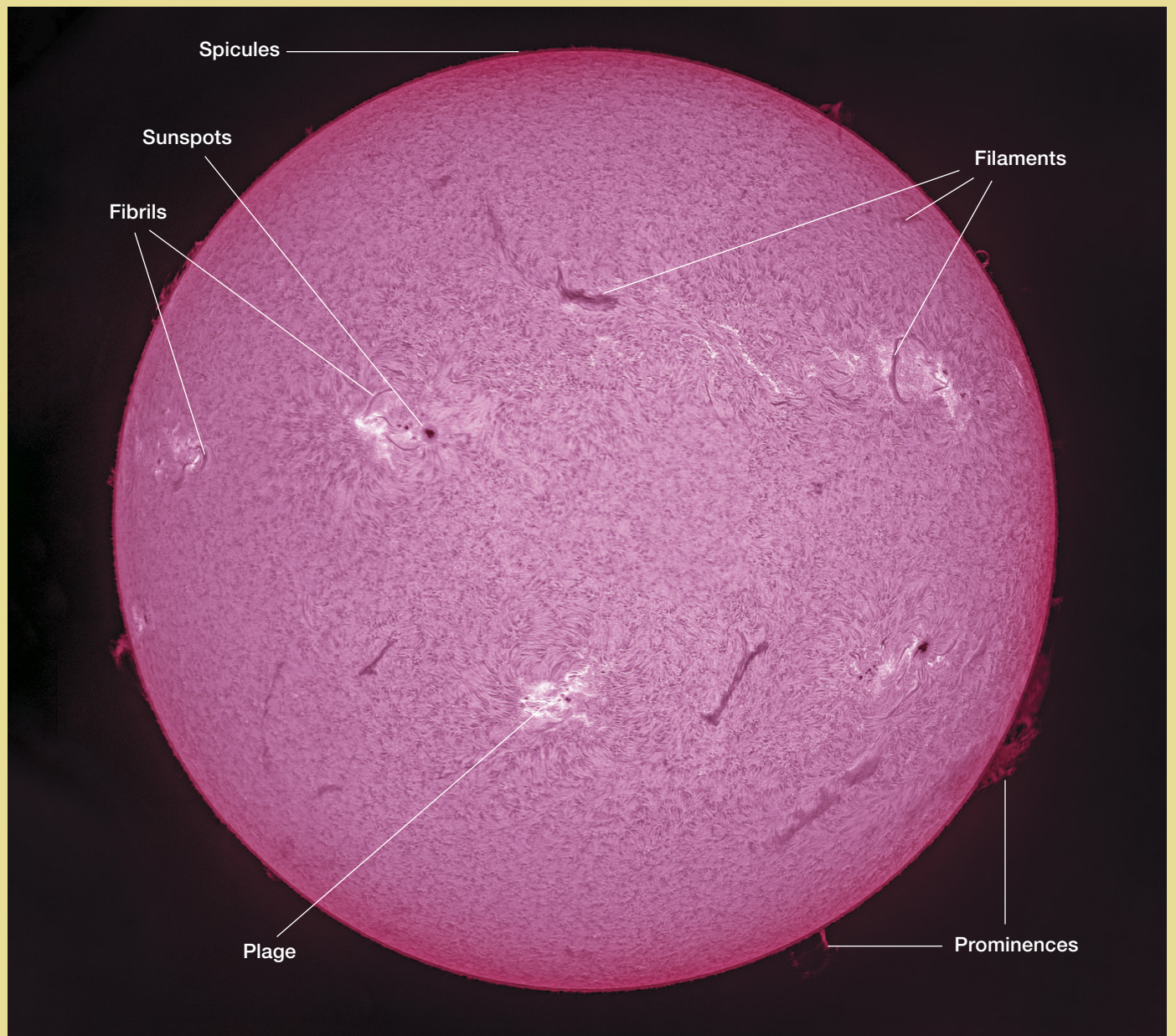
Regardless of whether you're observing or imaging the Sun, the technique is similar when you're out with your telescope. The best seeing conditions are often (though not always) within a few hours after sunrise; as the Sun gets higher, it heats up your surroundings which degrades the local seeing conditions. You can limit some local turbulence by setting up on grass rather than concrete or asphalt, both of which quickly radiate heat. Also, try not to observe directly over buildings and rooftops.

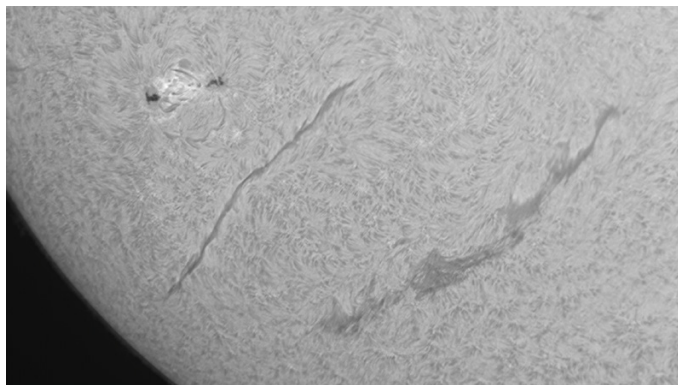
Be sure to shield your eyepiece or camera from direct sunlight as this can interfere with your focusing and viewing — direct light in your eye overwhelms the view in the eyepiece. Shielding your camera can eliminate a source of scattered light in your images, which robs contrast. Sky-Watcher's Heliostar telescopes (seen on page 35) come with a handy clip-on solar shield, which I consider a must-have for every solar observer. If you're imaging with a laptop or tablet, you'd want to shield its screen (and your head) too to see fine details to focus on. I often use a large cardboard box on

► **DYNAMIC CHROMOSPHERE** The view through a refractor fitted with a Fabry-Pérot etalon that passes a fraction of a single wavelength of light centered at 656.28 nanometers (hydrogen alpha) shows the upper region of the chromosphere. In this part of the solar atmosphere, several features not visible in the photosphere are revealed. Bright solar flares occasionally are seen at this wavelength.



▲ **BEYOND SPOTS** Everything outside of the sunspots' umbrae appears different in an $H\alpha$ solar filter compared to white light. Besides the fibrils and plages seen in the left image, solar granularity in the photosphere is hidden by the swirling pattern of the chromosphere network suspended some 2,000 km above seen at right.





▲ **SLAKING FILAMENTS** These massive, dark features are simply prominences seen against the solar disk. Filaments are cooler clouds of plasma suspended anywhere from hundreds to hundreds of thousands of kilometers above the Sun's surface by stable magnetic fields. They can last anywhere from hours to even weeks on end.

a folding table and throw a beach towel over the top to block enough ambient light to operate the camera and computer.

When imaging the Sun, consider using a dedicated monochrome camera. The Sun is essentially colorless in white light, so it won't appear dramatically different between color and monochrome cameras, but the latter sensors will provide slightly higher resolution and sharper detail. And at other wavelengths like calcium and $H\alpha$, a color camera will essentially record nothing on two of the three channels of the detector.

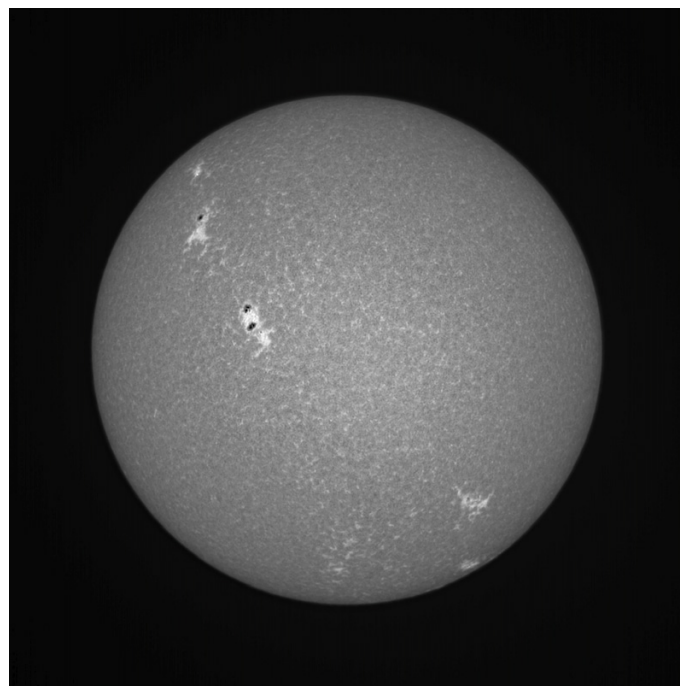
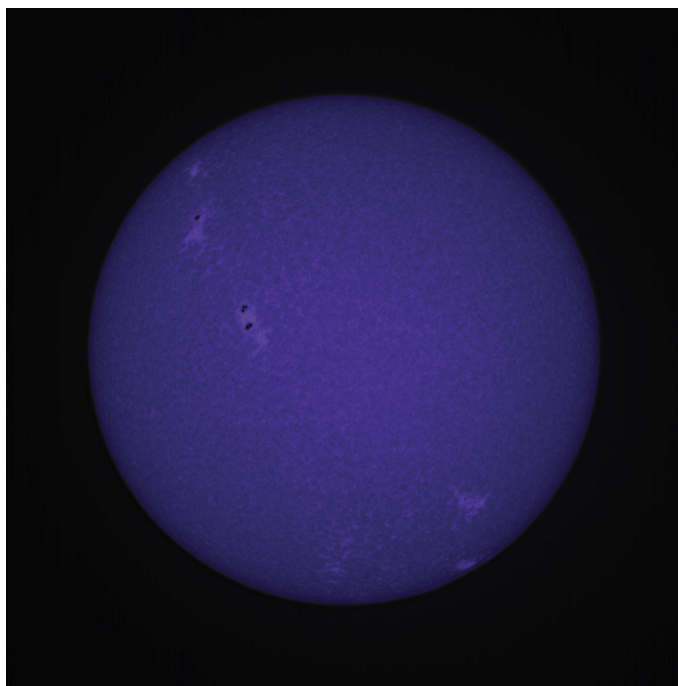
Most full-disk images are bright enough that single exposures often produce excellent results. However, when

working at the long focal lengths required to capture close-up views of sunspots or active regions, it's advantageous to use a high-speed video camera and apply *lucky imaging* techniques, in which you record short videos and process them to find just the sharpest frames or portions of frames to then combine and stack for a final image. A tutorial on solar imaging is on page 60 in the July 2024 issue.

One final caveat: A telescope used for solar observing will stay coolest when pointed directly at the Sun, presenting the smallest possible profile to incoming radiation. A slightly misaligned telescope may concentrate sunlight onto internal surfaces such as tube walls or baffles, potentially causing damage or even posing a hazard to the operator or bystanders. If turned completely to the side, the sunward facing tube will heat up under the hot Sun compared to the shadowed side, creating a temperature imbalance and poor performance of your optics.

The Sun is often overlooked by astronomy enthusiasts, yet it's one of the most dynamic and rewarding targets in the sky. From the subtle texture of the photosphere to the ever-changing drama of the chromosphere, modern tools have made it possible to explore our nearest star in remarkable detail in real time. With proper technique and respect for safety, solar observing can easily become a centerpiece of your astronomical pursuits.

■ Contributing Editor RICHARD S. WRIGHT, JR. considers himself an "indoor boy," but solar astronomy will draw him out into direct sunlight.



▲ **DEEP PURPLE** Other interesting wavelengths for targeting the Sun are the calcium lines in the violet region of the visible spectrum. Located at 393.4 and 396.9 nm (the calcium K and H lines, respectively), these wavelengths are often difficult for older observers to see visually, though are easy to photograph with monochrome cameras. The image at left is the same photo as the monochrome image at right colorized to simulate the visual impression at the eyepiece.

SKY AT A GLANCE

September 2026

1 DUSK: Look to the west-southwest to see Venus about $1\frac{1}{2}^\circ$ lower left of Spica. Turn to page 46 for this and other events listed here.

1 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:53 p.m. PDT (see page 49).

3 MORNING: High in the southeast the almost-last-quarter Moon perches just above the Pleiades. Binoculars will help you enjoy this sight.

4 EVENING: Algol shines at minimum brightness for roughly two hours centered at 9:42 p.m. EDT.

7 DAWN: Face east before sunrise to catch the waning crescent Moon with Pollux some 5° to the upper left. Completing the tableau are Mars a bit farther to the upper right and Jupiter below.

8 DAWN: The thin lunar crescent hangs around $3\frac{1}{2}^\circ$ above Jupiter in the east. Later, the Moon eclipses the planet for much of the U.S. and

almost all of Canada. Go to page 48 for additional details of this daytime occultation.

9 MORNING: For the next two weeks from dark locations at mid-northern latitudes, the soft glow of the zodiacal light should be visible beginning about two hours before sunrise. Look toward the east for a tall, hazy pyramid of pale light (see page 48 for more).

9 DAWN: The Moon, two days shy of new, rises in the east-northeast with Regulus in tow. A bit more than 4° separates the pair.

13 DUSK: Find an unobstructed horizon to the west-southwest to see the waxing crescent Moon with blazing Venus $5\frac{1}{2}^\circ$ to the upper left and Spica $3\frac{1}{2}^\circ$ to the upper right. You'll have to be quick to catch this sight before it sets out of view.

17 DUSK: Antares smolders in the south-southwest $5\frac{1}{2}^\circ$ right of the nearly first-quarter Moon. Follow the duo as they set in the southwest.

21 EVENING: Algol shines at minimum brightness for roughly two hours centered at 11:34 p.m. PDT.

22 AUTUMN BEGINS in the Northern Hemisphere at the equinox, at 8:05 p.m. EDT (5:05 p.m. PDT).

24 EVENING: Algol shines at minimum brightness for roughly two hours centered at 11:22 p.m. EDT (8:22 p.m. PDT).

26 EVENING: The full Moon climbs in the east with Saturn a bit less than 6° below.

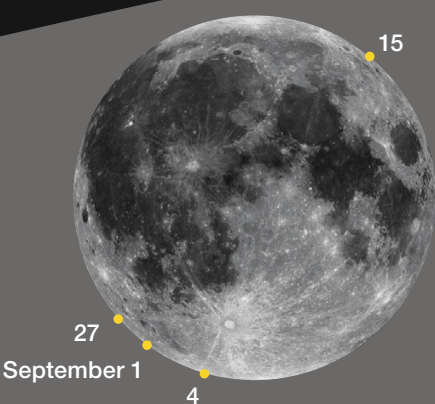
27 EVENING: Algol shines at minimum brightness for roughly two hours centered at 8:11 p.m. EDT.

30 EVENING: Catch the waning gibbous Moon trailing the Pleiades by about $5\frac{1}{2}^\circ$ as they climb in the east-northeast.

—DIANA HANNIKAINEN

▲ The zodiacal light extends high above Horseshoe Lake in central Minnesota in this photo from autumn 2021. Turn to page 48 for tips on how to view this phenomenon. BOB KING

SEPTEMBER 2026 OBSERVING
Lunar Almanac
Northern Hemisphere Sky Chart



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

MOON PHASES

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

**LAST QUARTER**
September 4
07:51 UT

**NEW MOON**
September 11
03:27 UT

**FIRST QUARTER**
September 18
20:44 UT

**FULL MOON**
September 26
16:49 UT

DISTANCES
Perigee
368,259 km
September 6, 21^h UT
Diameter 32' 27"

Apogee
404,220 km
September 19, 03^h UT
Diameter 29' 34"

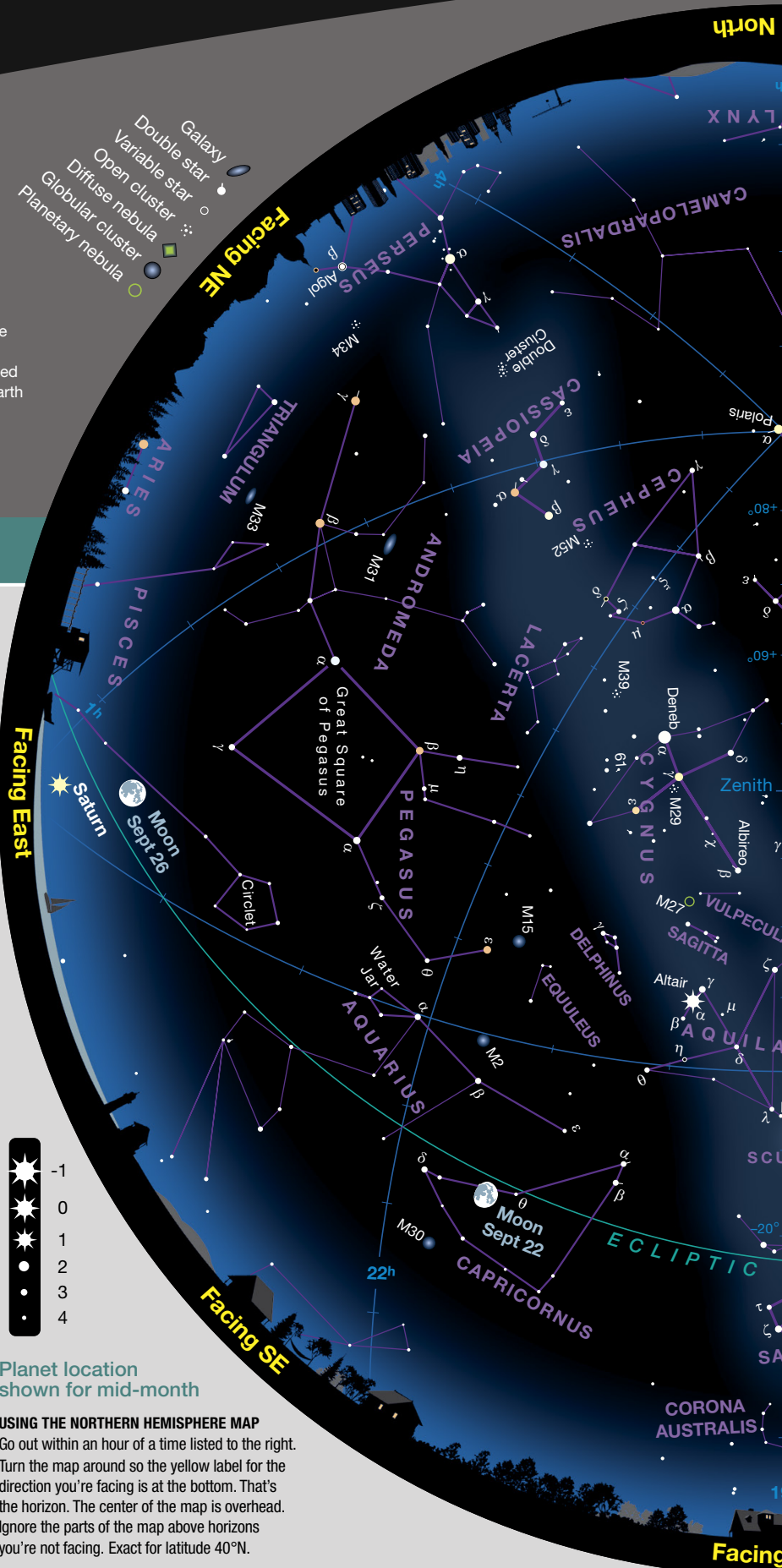
FAVORABLE LIBRATIONS

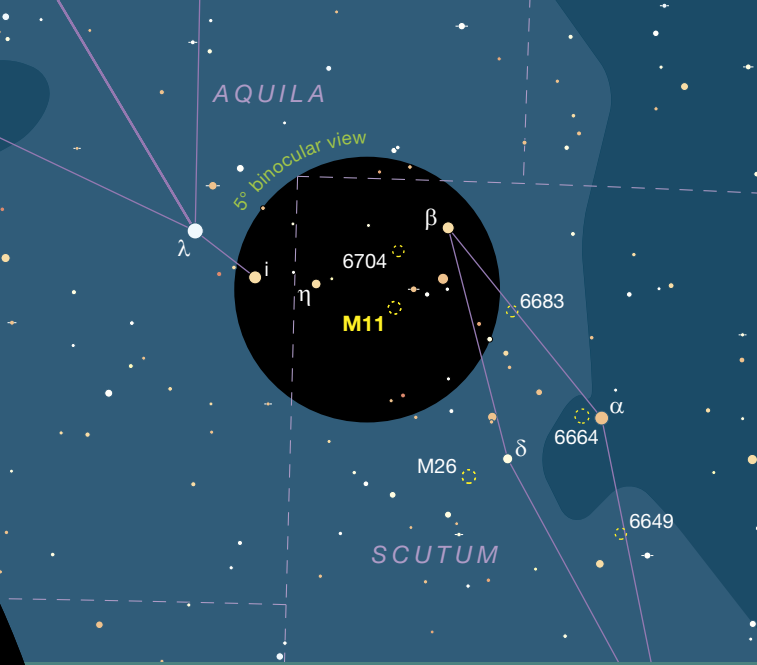
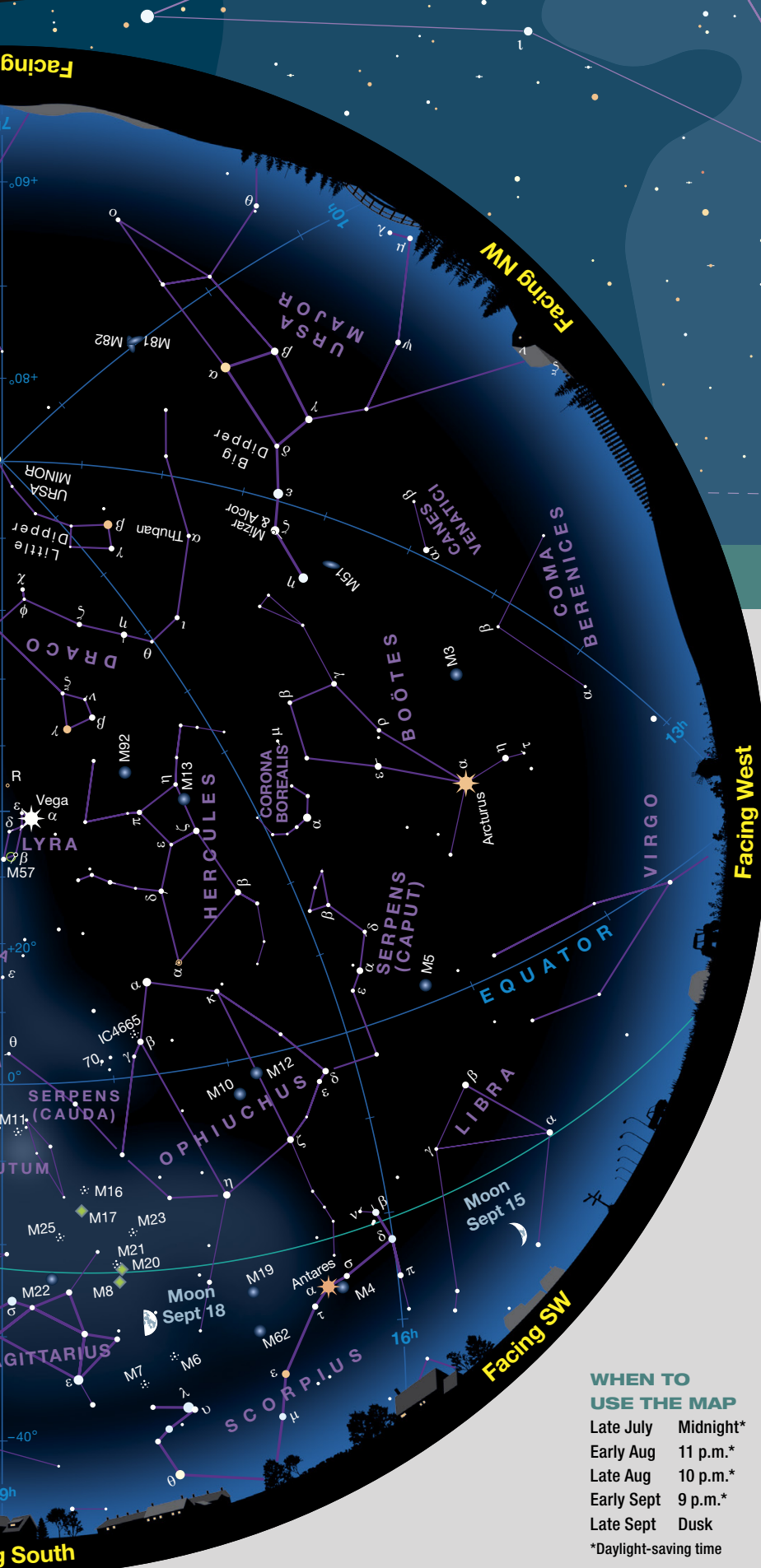
- Andersson Crater
September 1
- Le Gentil Crater
September 4
- Bel'kovich Crater
September 15
- Baade Crater
September 27



Planet location shown for mid-month

USING THE NORTHERN HEMISPHERE MAP
Go out within an hour of a time listed to the right. Turn the map around so the yellow label for the direction you're facing is at the bottom. That's the horizon. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing. Exact for latitude 40°N.





Binocular Highlight by Mathew Wedel

Fly With Ducks

One of my favorite sights this time of year is **M11**, the Wild Duck Cluster, which resides in the constellation Scutum, the Shield. To find it, start at the southern end of neighboring Aquila, the Eagle, and follow the kite-tail arc of Lambda (λ) Aquilae, i Aquilae, and Eta (η) Scuti. M11 is about 1.5° west-southwest of Eta Scuti, forming a wide triangle with Eta and Beta (β) Scuti.

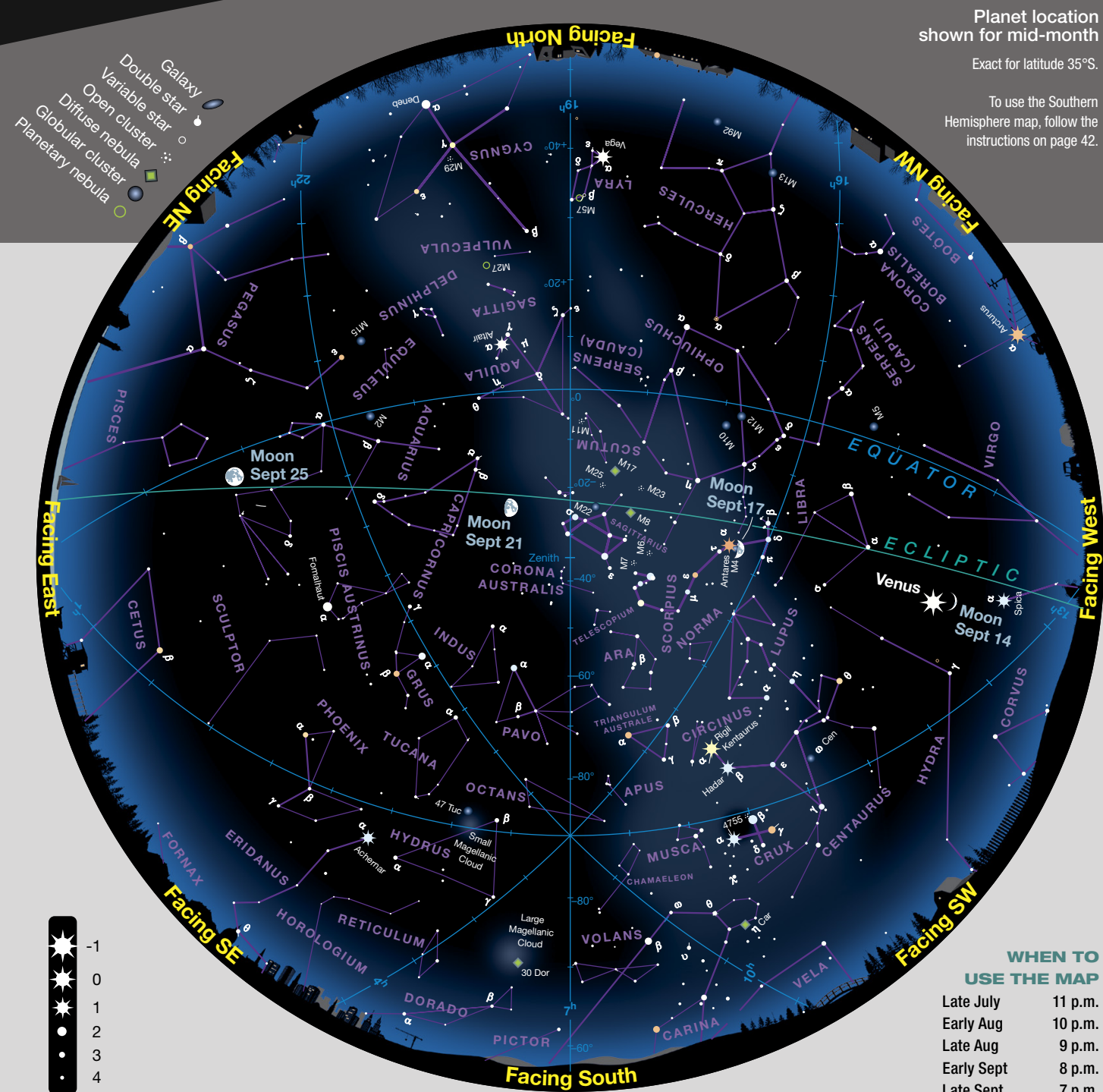
M11 is what I call a “total object,” one worth observing at every magnification. With a visual magnitude of 5.8, the cluster is bright enough to be naked-eye visible under dark skies. For a Messier open cluster, M11 is both very far away — more than 6,000 light-years distant — and very rich, with several hundred member stars. So many stars packed into a small apparent size of 14′ give this open cluster a visual density rivaling that of most globular clusters. In my 7× binoculars, all I see is a bright but unresolved glow. Moving up to 10× doesn’t let me distinguish any stars, but I can start to make out the sharp wedge shape that gives the Wild Duck Cluster its nickname. At 15×, a dense swarm of stars flashes in and out of resolution, especially in averted vision.

My temptation then is to reach for a telescope and pour on the magnification, and in my early years of observing I often did. These days I go in the other direction, grabbing my 7× wide-field binos and cruising the summer Milky Way. Just east of M11, the Scutum Star Cloud sprawls like storm clouds over the Great Plains (at least to this Oklahoma farm boy), and this whole stretch of sky is a riot of clusters, asterisms, and dark nebulae. Take a page from the ducks, and go fly.

MATT WEDEL enjoys California’s dark desert skies but misses his native Oklahoma — especially weather as a spectator sport.

WHEN TO USE THE MAP

Late July	Midnight*
Early Aug	11 p.m.*
Late Aug	10 p.m.*
Early Sept	9 p.m.*
Late Sept	Dusk
*Daylight-saving time	



TELESCOPIUM, the Telescope, is a tiny constellation devised by French astronomer Nicolas Louis de Lacaille in the mid-18th century while observing from the Cape of Good Hope in South Africa. It lacks Beta and Gamma stars, as they were gifted to Sagittarius and Scorpius respectively during a 19th-century reorganization.

The three stars marked on the chart above are, clockwise

from bottom left, Zeta (ζ), Alpha (α), and Epsilon (ϵ) Telescopii. At magnitude 4.1, Zeta has a distinctly orange hue and is located about 122 light-years from us. Bluish Alpha, brightest at magnitude 3.5 and roughly 278 light-years distant, was originally part of Corona Australis. Lacaille later assigned it to Telescopium. Third-brightest is 4.5-magnitude Epsilon, another orange star, residing some 410 light-years away. ■

Lyra the Malleefowl

Watch this endangered bird climb its celestial nesting mound in preparation for egg-laying season.

Look at the Northern Hemisphere Star Chart on pages 42–43, and you will see little Lyra, the Lyre, placed high in the evening sky (see page 53 for a tour of Lyra). Its Alpha (α) star, radiant Vega, which beams down at us at near-perfect +0.0 magnitude, glorifies the constellation. While the Greeks and Romans envisioned this pattern of stars as the musical instrument that Orpheus used to charm the rulers of the Underworld to gain back his deceased bride Eurydice, other Northern Hemisphere cultures associated the area's stars with birds of prey — including an eagle, a vulture, an osprey, a falcon, and a kite. But in southeastern Australia one aboriginal tribe linked the constellation to one of the region's most ecologically important birds, around which they built a practical mythology.

William Edward Stanbridge read “On the Astronomy and Mythology of the Aborigines of Victoria” before the Philosophical Institute of Victoria in Melbourne (prior to the article's publication in the Institute's 1858 *Transactions*) in which he shared the Boorong people's knowledge of the stars. In the speech, he claimed to repeat their stories, “as nearly as language will allow, word for word, as they have repeatedly during some years stated it to me.” Stanbridge also says that the Boorong, who inhabit the Mallee country in the neighborhood of Lake Tyrill, “pride themselves upon knowing more of Astronomy than any other tribe.”

According to the Boorong, the stars and all celestial bodies in *tyrille* (space) emanated from the *Nurrumbunguttias* or old spirits. The previous inhabitants of Earth before humans, they were “translated in various forms to the heavens, before the present race

came into existence.” Among the early constellations was *Neilloan*, in an area of sky including Lyra. To the Boorong, *Neilloan* was a *Loan*, an old word for Malleefowl (*Leipoa ocellata*). This bird species, about the size of a chicken, belongs to the family *Megapodiidae*, which means big footed. Malleefowl are among the most important bird species, due to their role as ecosystem engineers, helping to redistribute nutrients and supporting biodiversity in its habitat. The birds use their powerful feet to build nesting mounds measuring some 4 meters across and 1 meter high, in which the female buries up to 30 large eggs per season.

Malleefowl eggs were a major food source to the Boorong, and *Neilloan* imparted to them knowledge of the bird's nesting and laying habits. Their egg-laying season happens between early spring and mid-summer (roughly September to January). Then, during incubation, the male Malleefowl, also known as the thermometer bird, uses its beak to check the temperature of the compost in the nesting mound, ensuring it maintains a constant incubation temperature of about 33°C (91°F) for its eggs.

As seen from southern Australia, Lyra rises shortly before the Sun in March, when Malleefowl start to dig holes in preparation for nest building. At this time *Neilloan* is only about 10° above the northeastern horizon, and can be imagined as the bird standing upright, with Vega as the powerful digging foot in action. The male will largely build and tend to the nest throughout

► This Malleefowl was spotted in Little Desert National Park in Victoria, Australia, back in 2017.

Southern Hemisphere winter until temperatures begin to rise. When Lyra rests on the northwestern horizon after sunset in October (page 44), the Boorong knew that the eggs were being laid and soon to be collected.

As seen from the Lake Tyrill region, *Neilloan* only achieves a maximum altitude of about 15° during its sojourn across the sky. In the months leading up to October, skywatchers there can envision *Neilloan* walking up its substantial mound, only to sit with it after October, as Stanbridge explains, “When she sits with the setting Sun the *Loan* eggs are in season.”

Imagining *Neilloan* as described above works, but it overlooks how the Boorong actually saw it, namely flying. At first, I thought this curious, because these ground-dwelling birds rarely fly — they do so only to escape danger or to reach a tree roost. As these birds hardly leave their nesting site, it's only logical that humans disrupting their nests would surely cause the birds to fly, which is what the egg collectors would have likely witnessed.

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



Venus has a Grand Dusk Farewell

The Evening Star meets the Moon and Spica before slipping into the Sun's glare.

TUESDAY, SEPTEMBER 1

Venus had a good run. The reigning Evening Star has dominated the twilight sky since January, but now it's nearing the end of its current apparition, with only a couple of notable events left on its calendar. One of those occurs early this evening when Venus partners up with **Spica** for an enjoyable conjunction. The 1st-magnitude star is positioned just $1\frac{1}{2}^\circ$ upper right of the planet, which shines at magnitude -4.6 . The pair sets about 90 minutes after the Sun, so you'll want to catch them early. Try using binoculars roughly 30 minutes after sunset, when Venus is some 10° above the west-southwestern horizon. Locate the brilliant planet first and then see if you can spot Spica. It should be possible to see the star without optical aid later, though by then it's starting to sink into the atmospheric muck that always seems to cling to the horizon at this time of year.

THURSDAY, SEPTEMBER 3

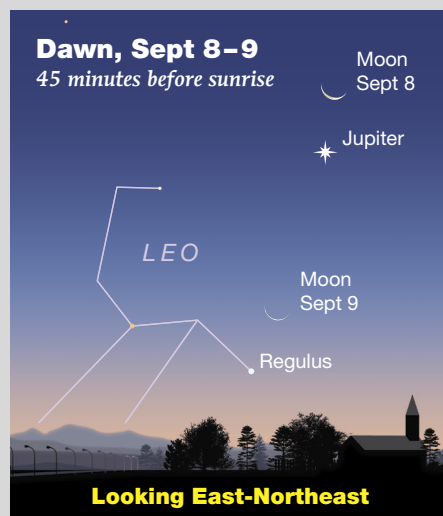
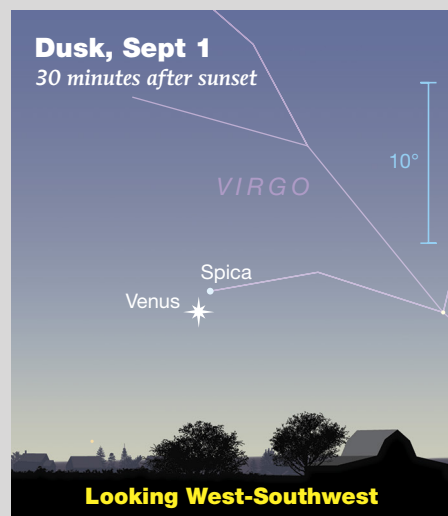
During the predawn hours, the 60%-illuminated **Moon** (just one day shy of last quarter) approaches the **Pleiades** in Taurus. Because the Moon is so bright, this event is best appreciated with binoculars. Depending on where you're located, the lunar disk will just be reaching the outer edge of the cluster as dawn brightens the sky. Indeed (as noted on page 48), a lucky few in Alaska, northwestern Canada, and eastern Russia get to see the Moon occult some of the brighter cluster stars. This is the first of two conjunctions this month featuring the Moon and the Pleiades — another takes place on the 30th. That second one, however, is less favorable for observers in the Americas.

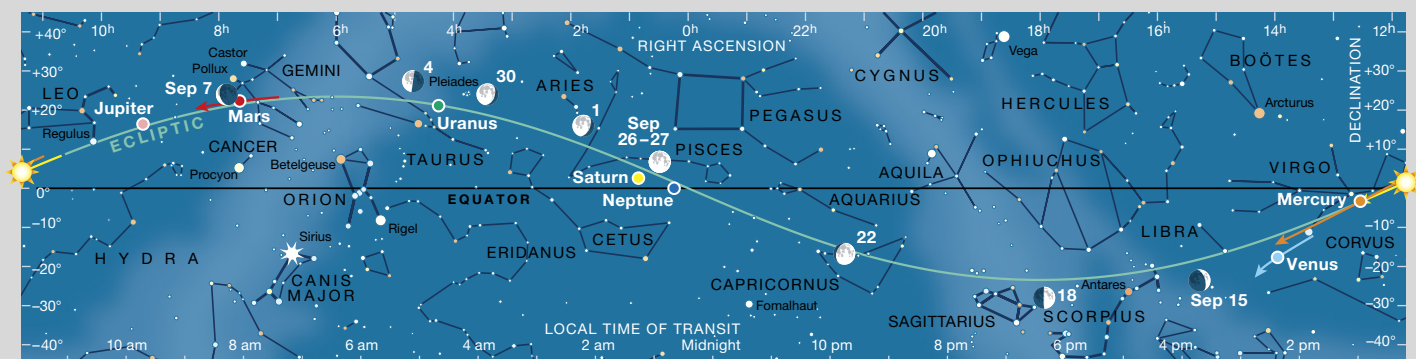
TUESDAY, SEPTEMBER 8

Early risers this morning are rewarded with the sight of an earthlit crescent **Moon** hanging roughly $3\frac{1}{2}^\circ$ above

Jupiter. Big Jove gleams mightily at magnitude -1.8 , while the lunar crescent is less than 9% illuminated. Just how close the pair get during morning twilight depends on how far west you are. On the West Coast, the gap between them closes to just 2° at the start of *civil twilight*, when the Sun is 6° or less below the horizon. The dawn duo makes for a lovely naked-eye spectacle; however, the show doesn't end when the Sun rises! As detailed on page 48, the Moon's eastward motion eventually carries it directly in front of the planet. You'll need a telescope to watch this daytime occultation visible across much of the U.S., virtually all of Canada, and most of the Caribbean, as well as Greenland and Iceland. This is the first in a series of Jupiter occultations that take place on a monthly basis until May 2027. However, today's and next month's are the only ones in the set visible from North America.

► 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 Sun and planets are positioned for mid-September; 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.

WEDNESDAY, SEPTEMBER 9

Here's another treat for those who like to get a bit of observing in before starting their work day. This morning **Mars** is less than 1° from 3.5-magnitude **Delta (δ) Geminorum**. The Red Planet is early in its current apparition and shines at a relatively feeble magnitude 1.2, a far cry from the magnitude -1.2 it will obtain at opposition next February. Even so, Mars is eight times brighter than its stellar neighbor. So why is this conjunction worth noting? Mainly because Delta (also known as Wasat) provides a handy stationary point that allows you to easily gauge the planet's eastward drift as it traverses Gemini. Note its position today

and then check again tomorrow — the configuration will be noticeably different. You'll have to wait until late February before Mars passes this close to a similarly bright star again.

SUNDAY, SEPTEMBER 13

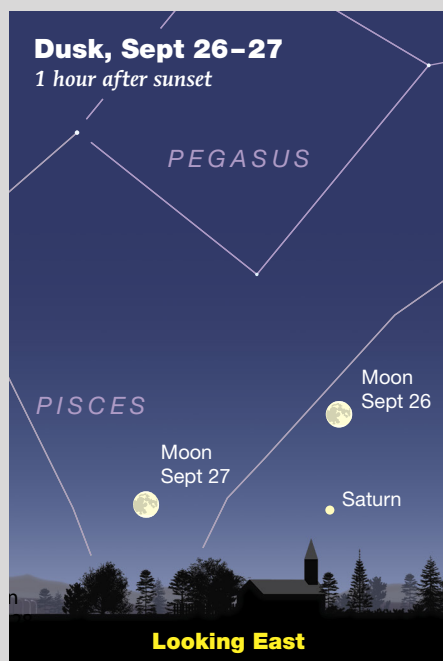
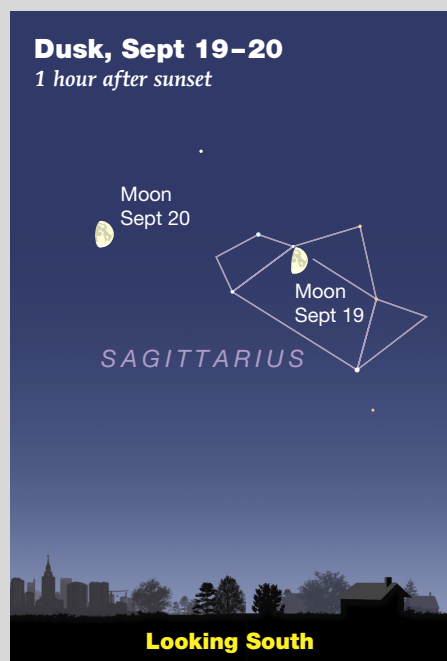
At dusk today **Venus** crosses off the last item on its to-do list for the current apparition: A conjunction with the **Moon**. Venus gleams at magnitude -4.7 about $5\frac{1}{2}^\circ$ upper left of the 9%-illuminated lunar crescent low in the west-southwest. The Moon sets just one hour after the Sun, so you'll want to start looking shortly after sunset. In fact, this evening features not one, but

two lunar conjunctions. **Spica** is parked $3\frac{1}{2}^\circ$ upper right of the earthlit crescent. Together with Venus, the trio forms a flat, $8\frac{1}{2}^\circ$ -wide, horizon-hugging triangle. Venus continues to linger at dusk as a naked-eye sight until early October when it finally succumbs to the Sun's glare. You'll have to wait until dawn in November for the next observable meeting between the Moon and Venus after the planet's conjunction with the Sun.

SATURDAY, SEPTEMBER 26

As twilight begins to fade this evening, face due east to catch sight of **Saturn** following the full **Moon** as they rise. Such a pairing can only occur when the planet in question is near opposition, as Saturn will be in just eight days, on October 4th. This makes sense when you consider that when the Moon is full, it's effectively at opposition, too — a mark it hits on a monthly basis. So, when two objects are at opposition at the same time, it's not surprising they're found in the same patch of sky, as the Moon and Saturn are tonight. As the Ringed Planet clears the horizon, it trails the Moon by roughly 6° . That gap shrinks to about $5\frac{1}{2}^\circ$ around midnight EDT. Although Saturn's brightness doesn't change much during the course of an apparition, it's at magnitude $+0.3$ tonight, which is as bright as it gets this time around.

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

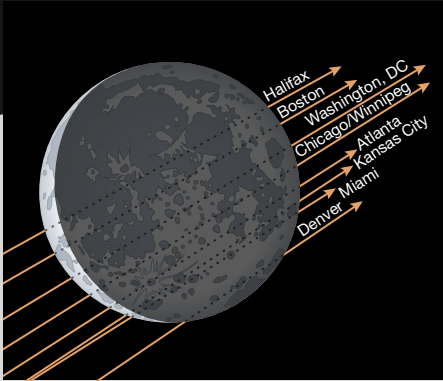


Jovian Cover-Up

September provides an opportunity to practice for an October occultation.

Okay, it's time to spill the beans. We're on the cusp of a spectacular occultation. On the morning of October 6th, the waning dawn crescent covers Jupiter and all four of its Galilean satellites. We'll have much more to say about that event in next month's issue. But September 8th offers something of a sneak preview, when the 7% waning Moon eclipses the gas giant in the daytime sky.

The occultation is visible across much of the contiguous U.S. and Alaska, except the desert Southwest and Pacific states. Jupiter disappears around 3:00 to 3:30 p.m. on the East Coast, 2 p.m. in the Midwest, and 1 p.m. in the Mountain states. Refer to the arrowed map for the occultation path for select cities. If your city isn't listed in the table below, use your favorite



▲ This diagram shows the entry and exit locations of Jupiter at the lunar limb for several U.S. cities. Times of entry and exit are listed in the adjacent table.

planetarium software to determine the times of ingress and egress. Although diluted by daylight, the pair should be readily visible in a small telescope about 30° west of the Sun at the start of the event. Try to find a shady spot that blocks the glaring Sun but still allows a view of the wispy crescent. Use binoculars to locate the **Moon**, then sweep a short distance to the left to **Jupiter**, a small, pale, gray-blue disk. Depending on atmospheric clarity you may even be able to make out some cloud bands. The Moon's bright limb will approach Jupiter. Minutes to an hour or more later, depending upon location, the planet gradually slides out from behind the dark lunar limb into a blue sky. Given Jupiter's apparent diameter of 32.1", it takes about 70 seconds for the Moon to cover the Jovian globe, and after a similar interval, to release it back into the wild.

Occultation of Jupiter on September 8, 2026

City	Disappearance (UT)	Reappearance (UT)
Halifax	18:56.2	19:51.5
Boston	18:57.3	19:55.9
Washington, DC	19:01.4	20:00.9
Chicago	18:50.7	19:51.3
Winnipeg	18:28.2	19:31.0
Atlanta	19:10.2	20:04.8
Kansas City	18:54.9	19:48.6
Miami	19:29.7	20:15.5
Denver	18:54.4	19:28.7

Zodiacal Light Zoology

ZOOS AND ZODIACAL light have at least one thing in common. They share the same ancient Greek root zōion, meaning animal or living creature. Just as a zoo houses animals, the zodiac is home to eight different beasts, along with three human figures and one inanimate object (Libra, the Scales). Together they illuminate a 16°-wide imaginary band around the sky bisected by the ecliptic — the path traveled by the Sun, Moon, and planets. The zodiac is also home to an enormous, pancake-shaped interplanetary dust cloud that stretches from the Sun out to approximately 2 astronomical units (just beyond the orbit of Mars). The cloud consists of asteroidal material and dust shed by comets.

Sunlight scattered off the scant material produces the zodiacal light, which is plainly visible to the eye: You only need a moonless sky, minimal light pollution, and an unobstructed vista to the east. Since the zodiacal light is centered on the ecliptic, it's best viewed in the Northern Hemisphere from mid-northern latitudes when it tilts steeply up from the eastern horizon before the start of dawn. September through November mornings are ideal. For the same reason, it's in good view again after dusk in the western sky from March through May.

Your best opportunity to view the zodiacal light this month is when the Moon is out of view from September 9th to the 24th. Thereafter, bright moonlight floods the morning sky, erasing the dusty phenomenon for two weeks. The next window is October 8th to 24th, followed by November 7th to 22nd.

All those potential opportunities should give you time to find a location with a dark sky to the east. I use lightpollutionmap.info as my guide.

The zodiacal light is brightest and most impressive at the edge of night,



▲ Shortly before the end of astronomical twilight on November 1, 2024, in the Oklahoma Panhandle, the zodiacal light (left) reaches from the eastern horizon all the way to the Milky Way, right of center. The triangular glow is brighter and broader near the horizon, where it's closer to the Sun, and tapers and fades along its length. Mars is visible just above center, with Jupiter at upper right.

from two hours to 90 minutes before the start of morning twilight. Once your eyes are dark-adapted, face east and look for a large, cone-shaped glow that resembles the smoky appearance of the Milky Way, but with a smoother texture. The reason an unobstructed view is important is because of its size. The dusty thumbprint is so big you need lots of dark sky to frame it. The light extends up and to the right (south) for at least 60° along the ecliptic, starting in Leo and fading out in western Gemini. There it's engulfed by the faint band of the winter Milky Way. Along its length the cone narrows from 30° to 40° wide at the base, where it's brightest, to about 5° at its barely discernible apex.

From a truly dark location the zodiacal light towers in the east majestically, making it one of the most compelling astronomical sights you'll ever witness.

Its tapered, parabolic outline recalls the head of a comet.

From the most pristine sites it's possible to see the glowing finger push past the meridian far into the western sky as the *zodiacal band* — one half of a 360° ring of dust hovering in front of the zodiac constellations across both Hemispheres.

By good fortune, two planets are embedded within the zodiacal light this month to help you find it: Jupiter in Cancer and Mars in Leo. Not only does the entity's enormity impress, its soft sheen recalls the solar system's beginnings 4.6 billion years ago. The captivating tale of "dust to us" is there for all to read as dawn breaks.

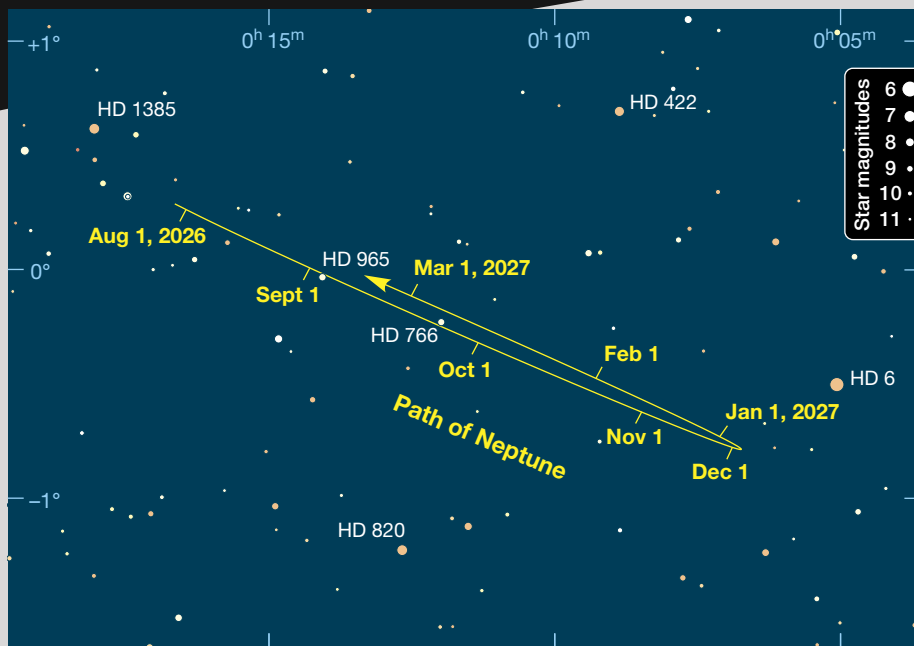
Minima of Algol

Aug.	UT	Sep.	UT
1	15:59	2	4:53
4	12:47	5	1:42
7	9:36	7	22:30
10	6:24	10	19:19
13	3:13	13	16:08
16	0:02	16	12:56
18	20:50	19	9:45
21	17:39	22	6:34
24	14:27	25	3:22
27	11:16	28	0:11
30	8:05	30	21:00

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



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



Action at Jupiter

IF YOU ARE A morning person, this is your month for Jupiter-watching. On the 1st of the month, the giant rises a bit after 4 a.m. local time on the east-northeastern horizon, ending up about 20° above the eastern horizon by sunrise. At the end of the month, it will be nearly 45° high by sunrise. The orbits of its four largest moons are angled so that they cross the planet's disk near its equator from Earth's point of view, making for ample opportunities to observe transits and shadows.

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

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

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

September 1: 6:35, 16:30; **2:** 2:26, 12:22, 22:18; **3:** 8:14, 18:09; **4:** 4:05,

Full Moon Joins Neptune at Opposition

BOTH THE MOON and Neptune reach opposition on September 26th. That night the remote blue planet cowers 6° lower right of the full Harvest Moon. Along with Saturn, located 6° lower left of the Moon, the trio forms a nifty isosceles triangle. While a pretty sight in theory, Neptune will be submerged in a flood of lunar glare, making it tricky to find. Better to track the planet down before or after the Moon arrives. Don't worry, Neptune is in no hurry. With an orbital period of 165 years, it covers a piddling 0.75° of sky this month as it moves southwest in retrograde motion in Pisces.

Neptune's movement is most apparent when it passes a star of similar brightness. This month you'll have two opportunities. On September 3rd it crawls 1° north of 8.6-magnitude HD 965. On September 23rd and 24th you'll find it 1.2° southeast of HD 766 (8.7 magnitude).

Despite an average distance from the Sun of 4.5 billion km, Neptune shines a bright magnitude 7.8 because it's about

▲ Through binoculars, Neptune appears as a star-like point of light moving westward in retrograde motion halfway between Saturn and the Circlet asterism in Pisces (see the planet chart on page 47). Use this chart to locate the planet's tiny blue disk and its brightest moon, Triton, with a telescope.

four times as big as Earth. Even a pair of 50-mm binoculars will snag it.

Through a small telescope at low magnification Neptune looks like a pale blue star. The color comes from a small percentage of methane in its atmosphere, which absorbs red light and reflects blue. Use 100× magnification or more to see the planet's 2.4" disk.

Average cloud-top temperatures at Neptune hover around -215°C (-350°F), on par with that of liquid nitrogen. Most of its mantle consists of a dense, superheated liquid made of water, ammonia, and methane surrounding a small, rocky-metallic core.

Convective currents within the heated liquid are thought to generate the planet's magnetic field. Charged particles ejected by energetic events on the Sun become trapped in Neptune's magnetic field and give rise to aurorae much like they do on Earth. Instead of oxygen and nitrogen, emissions from a charged form of hydrogen — the positive trihydrogen ion (H_3^+) — "color" the Neptunian aurorae, which radiate infrared light.

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

25: 6:32, 16:27; **26:** 2:23, 12:19, 22:14; **27:** 8:10, 18:06; **28:** 4:02, 13:58, 23:53; **29:** 9:49, 19:45; **30:** 5:41, 15:37.

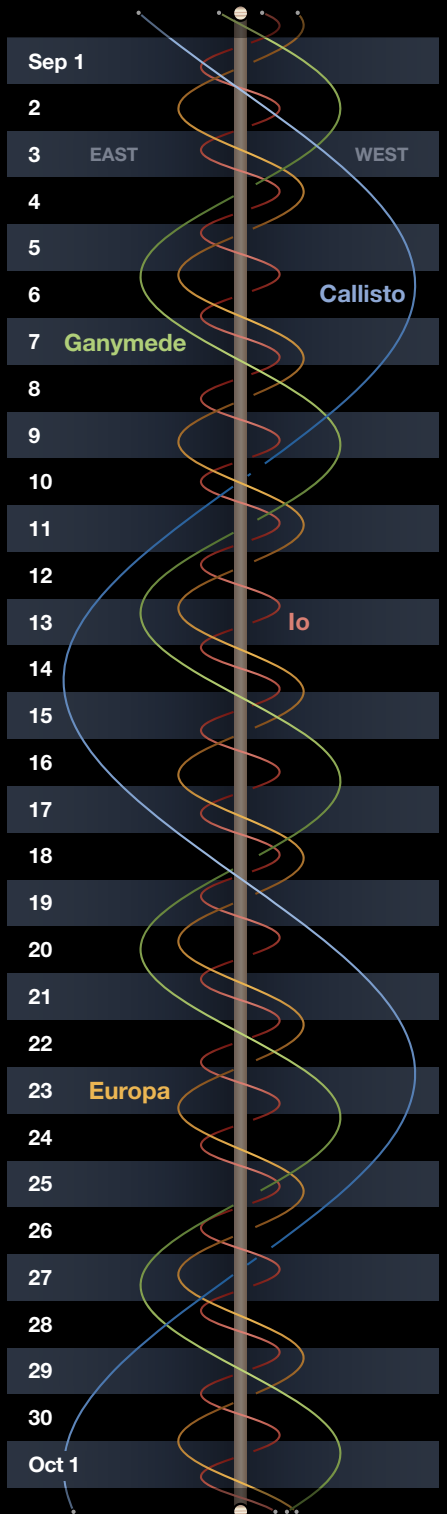
These times assume that the spot will be centered at System II longitude 91° on September 1st. If the Red Spot has moved elsewhere, it will transit 1²/₃ minutes earlier for each degree less than 91° and 1²/₃ minutes later for each degree more than 91°.

Phenomena of Jupiter's Moons, September 2026

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

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

Jupiter's Moons



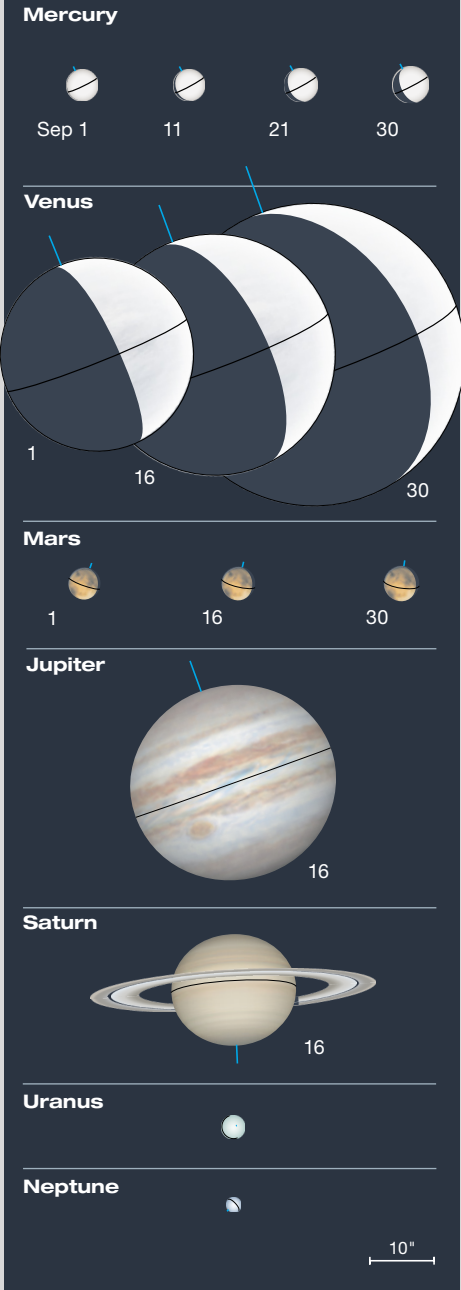
The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0^h (upper edge of band) to 24^h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites'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

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** is lost in the Sun's glare all month • **Venus** visible at dusk • **Mars** rises in the early morning and visible to dawn • **Jupiter** rises before dawn and is visible all month • **Saturn** visible all night.

September Sun & Planets

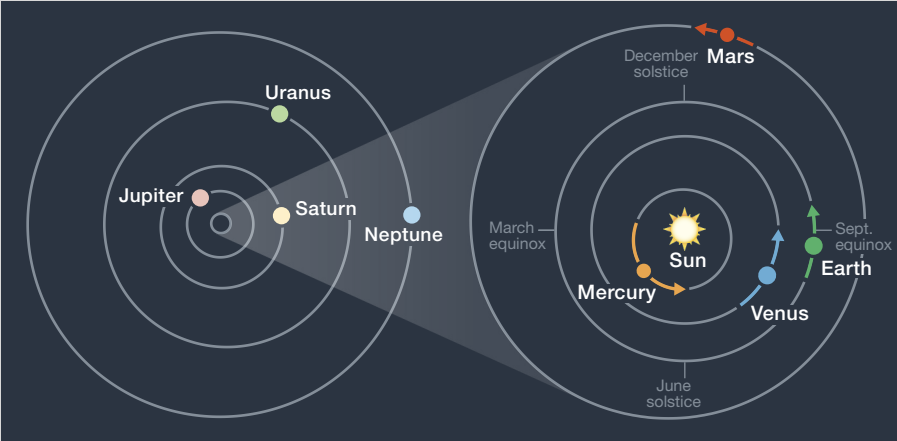
	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	10 ^h 39.5 ^m	+8° 29'	—	−26.8	31' 42"	—	1.009
	30	12 ^h 23.8 ^m	−2° 34'	—	−26.8	31' 56"	—	1.002
Mercury	1	10 ^h 57.3 ^m	+8° 23'	4° Ev	−1.5	4.9"	99%	1.377
	11	12 ^h 01.7 ^m	+0° 35'	12° Ev	−0.6	5.0"	93%	1.357
	21	12 ^h 58.6 ^m	−6° 48'	18° Ev	−0.2	5.2"	86%	1.286
	30	13 ^h 45.4 ^m	−12° 38'	23° Ev	−0.1	5.7"	78%	1.188
Venus	1	13 ^h 19.2 ^m	−12° 01'	45° Ev	−4.6	30.1"	39%	0.554
	11	13 ^h 45.0 ^m	−15° 52'	42° Ev	−4.7	34.8"	32%	0.479
	21	14 ^h 04.1 ^m	−18° 57'	38° Ev	−4.8	40.8"	24%	0.409
	30	14 ^h 12.6 ^m	−20° 44'	32° Ev	−4.7	47.2"	16%	0.353
Mars	1	6 ^h 56.8 ^m	+23° 20'	55° Mo	+1.3	5.1"	92%	1.850
	16	7 ^h 37.1 ^m	+22° 20'	60° Mo	+1.2	5.3"	91%	1.763
	30	8 ^h 12.7 ^m	+20° 58'	66° Mo	+1.1	5.6"	90%	1.672
Jupiter	1	9 ^h 03.8 ^m	+17° 19'	25° Mo	−1.8	31.8"	100%	6.196
	30	9 ^h 26.6 ^m	+15° 41'	47° Mo	−1.9	33.2"	100%	5.932
Saturn	1	0 ^h 53.1 ^m	+2° 48'	145° Mo	+0.5	19.3"	100%	8.601
	30	0 ^h 45.7 ^m	+1° 58'	174° Mo	+0.3	19.7"	100%	8.437
Uranus	16	4 ^h 13.7 ^m	+21° 02'	107° Mo	+5.7	3.7"	100%	19.118
Neptune	16	0 ^h 12.9 ^m	−0° 09'	170° Mo	+7.8	2.4"	100%	28.888

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



▲ **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 September. The outer planets don't change position enough in a month to notice at this scale.



Lyra's Shining Ring — and Beyond

A swath of sky across the southern part of the celestial Lyre makes for a rewarding star-hop.

Look high in the south at nightfall during the first half of September to find Lyra, the Lyre, adorned by zero-magnitude Vega, or Alpha (α) Lyrae. Vega is essentially the most brilliant star of mid- to late summer (Arcturus, or Alpha Boötis, is imperceptibly brighter) and adorns a petite but distinctive parallelogram of stars near the center of Lyra.

The heavenly Lyre sits on the western flank of the Milky Way. My unaided eyes can no longer detect the Milky Way from my suburban yard in British Columbia, yet some telescopic targets across southeastern Lyra remain alluring, thanks to their locations within rich Milky Way star fields visible in backyard scopes.

Exploring this region recently, I used two very different telescopes to obtain a broad appreciation of the objects. Join me for a quick star-hop tour.

Hop Along the Lyre

Our little Lyra tour begins at the southern end of the parallelogram, where **Gamma (γ) Lyrae** marks the southeastern corner of the figure, and **Beta (β) Lyrae**, 2° westward, anchors the southwestern corner. Gamma shines steadily at magnitude 3.3, while Beta sports a variable intensity that's easy to follow. An ultra-close eclipsing binary, Beta cycles from magnitude 3.3 down to 4.4 and back again over the course of

12.9 days. On nights when Beta reaches its peak, it rivals neighboring Gamma.

Although the famous Beta binary appears single in telescopes, my casual inspection revealed a 6.7-magnitude companion $45.6''$ to its southeast. I identified it instantly in my $4\frac{1}{4}$ -inch f/6 Newtonian reflector at $22\times$ — the lowest magnification I have in my eyepiece collection. My sighting also included 10.1- and 10.6-magnitude attendants that are $67.1''$ northwest and $85.7''$ north-northeast of Beta, respectively. Several more stars of similar brightness appeared scattered throughout the low-power field. Hey, it's almost a cluster!

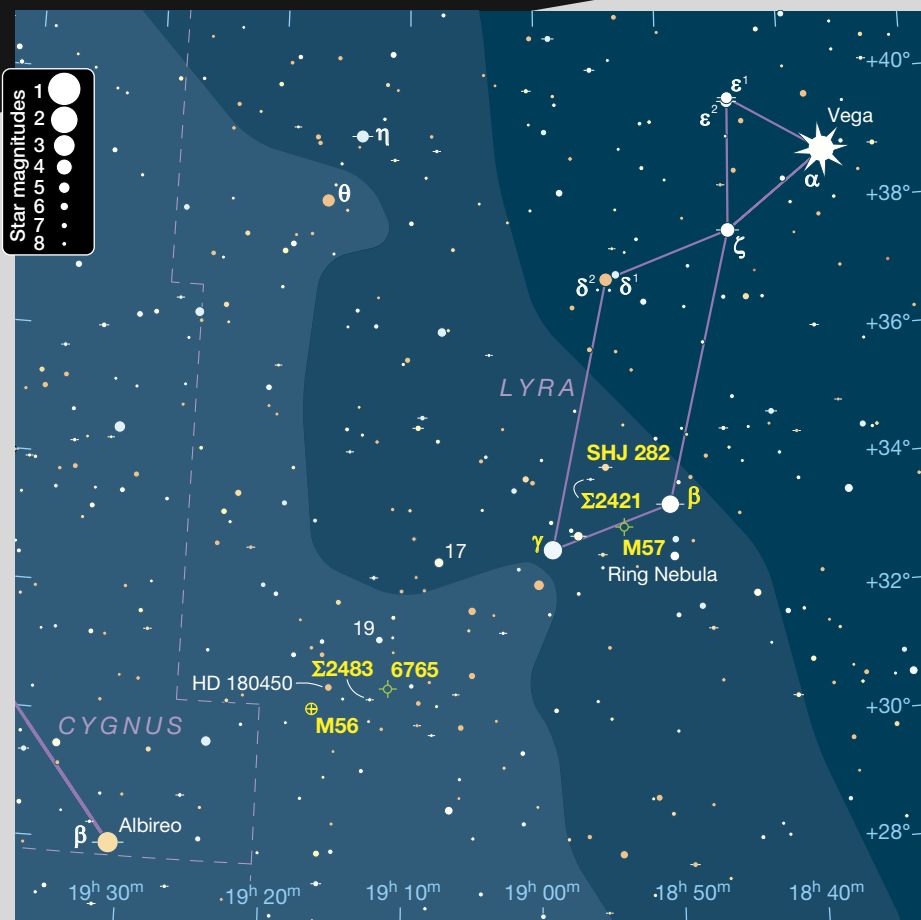
After Beta, I aimed 1.1° north-eastward where a dimmer double, designated **SHJ 282**, sported 6.1- and 7.6-magnitude elements as widely spaced as those of Beta. Only $\frac{1}{4}^\circ$ southeast of SHJ 282 is a third pairing, **S2421**, whose 8.1- and 9.3-magnitude components are separated by $24.6''$. Each of these pairs got resolved in my Newtonian reflector at $22\times$.

Lord of the Ring

The can't-miss showpiece in the Beta-Gamma zone is **M57**, the Ring Nebula. An easy catch, M57 lies approximately two-fifths of the way from Beta to

► **COSMIC DOUGHNUT** Approximately 2,600 light-years away, the planetary nebula M57, the Ring Nebula, is an expanding cloud of ionized gas ejected by a slowly dying star. This composite view was captured by combining broadband LRGB exposures with narrowband hydrogen-alpha ($H\alpha$) and doubly ionized oxygen ($O III$) images. The barred spiral galaxy at upper right is IC 1296. Whether you savor the Ring Nebula as a Cheerio, Lifesaver, Fruit Loop, or a tiny doughnut, M57 is a tasty treat for backyard telescopes. North is up in all images.





▲ **CELESTIAL LYRE** Lyra's most famous target, the tiny Ring Nebula, is conveniently located for novice deep-sky hunters in between the neighboring (and much nearer) naked-eye stars Beta (β) and Gamma (γ) Lyrae at the southern end of the well-known Lyra parallelogram. The globular cluster M56 lies 4½° southeast of Gamma Lyrae. A few faint double stars along this corridor of sky make the star-hop interesting.

Gamma Lyrae. I could see both bright stars plus the two aforementioned faint doubles and M57 all together in my wide-field eyepiece at 22×.

M57 is a superb planetary nebula. Even so, I must admit that when viewed in a small telescope at low magnification, the Ring was underwhelming. A slightly elongated object measuring 86" by 63", M57 comes in at magnitude 8.8. Using the 4¼-inch at 22×, my averted vision registered M57 as a minuscule, ghostly disk. If I stared directly at the wee wonder, it disappeared. Thankfully, the Ring perks up with increasing magnification. At 54×, the disk exhibited a teeny central hole; 72× produced M57's iconic doughnut shape. The misty doughnut held up at 108×, even in my soupy, gray sky.

My 7.1-inch f/15 Maksutov-Cassegrain telescope delivered a more impres-

sive doughnut. The Mak-Cass is simply a bigger, more powerful light bucket than the 4¼-inch. The ocular yielding 22× on the Newtonian generated 90× on the Mak-Cass. Working at 90×, my 7.1-inch showed M57 as an oval annulus whose sides were brighter than the ends. The central hole appeared dusky, not black. At 300×, the Ring appeared more noticeably elliptical, but very pale. Cupping my hands around the eyepiece to block out stray light, I discovered that the attenuated ends simply blended into the background sky. The monster magnification had created a "broken ring" — two opposing crescents of nebulosity not quite joined at the ends.

The broken ring can be repaired. Threading a light-pollution filter onto an eyepiece improved the contrast between the nebula and background

sky. An ultrahigh-contrast (UHC) narrowband filter is better, and so is a doubly ionized oxygen (O III) filter. Viewing at 300× with the aid of either filter reconnected the ends of M57. That said, M57 is a delicate piece of astral jewelry.

No Minor Messier

Lyra is home to one other entry in Charles Messier's famous catalog: the globular cluster **M56**. Although not a top-tier specimen, M56 pulls its weight — at 7.1' in diameter, M56 is much larger than the Ring, and at magnitude 8.3, it's almost half a magnitude brighter. The cluster isn't located near any prominent stars, but getting to it is easy.

M56 resides in an attractive Milky Way field roughly halfway between Gamma Lyrae and Beta Cygni (Albireo). Those stars are separated by more than 8°; trying to aim a scope at the correct spot between them is usually an exercise in frustration. Instead, I centered Gamma Lyrae in my 8×50 finderscope and approached M56 via four successively shorter star-hops. I began with a 1¾° jump from Gamma to 5.2-magnitude 17 Lyrae, then a 1.5° hop to 5.9-magnitude 19 Lyrae, followed by a 1° hop to orangey, 5.9-magnitude HD 180450. A final ½° nudge southeastward landed my scope on the cluster. M56 was too faint for the finderscopes, so I adjusted carefully by looking through the main scopes at low magnification.

M56 is no ball of fire. The brightest cluster members are around 13th magnitude, and they aren't densely packed. In terms of concentration, where 1 is the most compact and 12 the least, M56 is a fairly loose, class 10 globular. Yet my 4¼-inch detected it pretty easily. The Newtonian at 27× barely yielded a tiny fuzzball; however, 72× revealed a diffuse, round glow that was gently brighter toward the middle. At 108×, the glow became subtly textured, provided the telescope was sharply focused. A 10.2-magnitude star immediately west of the cluster was helpful for refocusing.

Scrutinizing M56 with my 7.1-inch

scope was a satisfying exercise. Trained on the globular at 90x, the long-focus Mak-Cass showed a grainy mass, plus a peripheral scattering of some extremely marginal pinpoints. At 113x, I could tease out a few feeble dots of light from the “grain.” When seeing conditions were near-perfect, 300x picked up several more flickering pinpricks. Definitely a cluster, not a smudge!

Comfort and Joy

Magnification is a double-edged sword. Each increase in power makes our two Messier objects larger but dimmer. The image becomes harder to focus, and it shakes whenever the instrument is touched. Appreciating the finer aspects of any faint fuzzy requires a comfortable observing position, a dark-adapted eye, and lots of patience. I sit on a repurposed bar stool with a soft cushion and a pneumatic lever for adjusting height. Huddled over the eyepiece, I wait patiently for a moment or two of steady air. Catching the best possible view is always a joyful moment.

After M56, I enjoyed stepping over to **Σ2483**, a delightfully compact binary slightly less than 1° west-northwest of the cluster. The 8.0- and 9.1-magnitude components of Σ2483, just 10.0” apart, resolved beautifully in my 4¼-inch at about 50x. A 9.7-magnitude tertiary star lies 71.2” southwest of the tightly bound duo. I wouldn’t bother chasing down such an obscure binary, but given its proximity to M56, my attitude was: Go for it!

Before closing off, I’d like to mention an object close to Σ2483, though not likely detectable in backyard telescopes. My celestial no-see-um is the planetary nebula **NGC 6765**. Measuring only 40” in diameter, NGC 6765 glows at magnitude 12.9. I’ve observed this dim devil from a rural site but never from the city. NGC 6765 hides a mere 20’ northwest of Σ2483. If your sky is better than mine, give it a try.

■ Contributing Editor **KEN HEWITT-WHITE** loves to explore Lyra, named after an ancient kind of harp. The harp is also his favorite musical instrument.

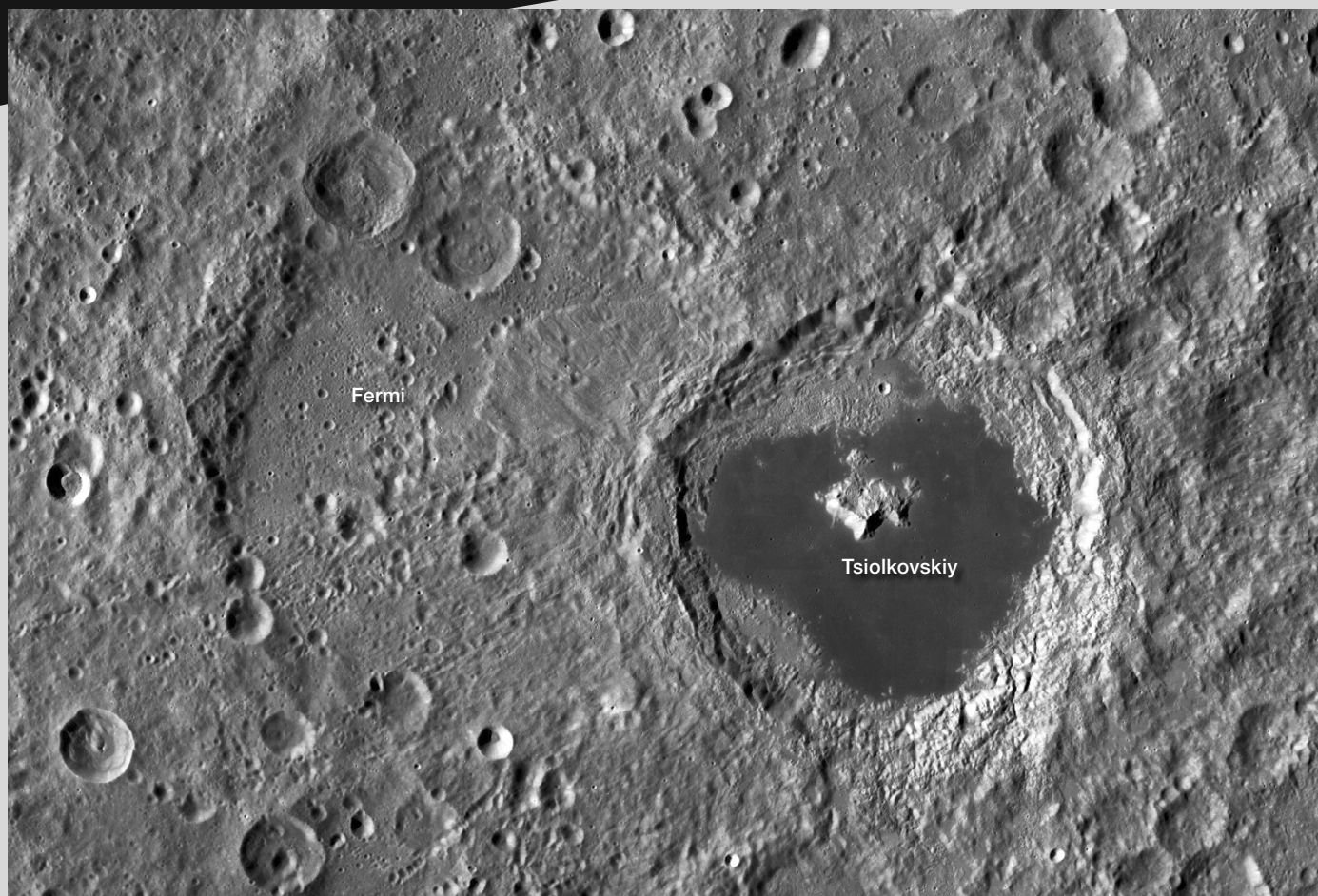


▲ **SECOND-PLACE FINISHER** Some 33,000 light-years from Earth, 8.3-magnitude M56 is a remote hive of old suns adrift in the vast halo of globular clusters surrounding the Milky Way. M56 certainly isn’t a highly regarded globular, but it’s well worth observing in backyard telescopes. In truth, M56 is a bigger and brighter deep-sky object than M57. Note the 10.2-magnitude blue-white star to the right (west) of the cluster. It’s handy for refocusing your telescope, if necessary, as you study M56 at different magnifications.

In and Around Southern Lyra

Object	Type	Mag	Size/Sep	RA	Dec.
γ Lyrae	Star	3.3	—	18 ^h 58.9 ^m	+32° 41′
β Lyrae	Double star	3.3, 6.7	45.6″	18 ^h 50.0 ^m	+33° 22′
SHJ 282	Double star	6.1, 7.6	45″	18 ^h 54.9 ^m	+33° 58′
Σ2421	Double star	8.1, 9.3	24.6″	18 ^h 56.0 ^m	+33° 47′
M57	Planetary nebula	8.8	86″ × 63″	18 ^h 53.6 ^m	+33° 02′
M56	Globular cluster	8.3	7.1′	19 ^h 16.6 ^m	+30° 11′
Σ2483	Double star	8.0, 9.1	10.0″	19 ^h 12.4 ^m	+30° 21′
NGC 6765	Planetary nebula	12.9	40″	19 ^h 11.1 ^m	+30° 33′

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



Lunar Lobes

Look for these distinct features found in certain overlapping craters.

Large cosmic projectiles impacting the Moon have drastically transformed its surface. The most visible result is that a crater is excavated, throwing debris hundreds of kilometers distant, with some even escaping the Moon. The target area is obliterated in the process and the adjacent terrain is fractured and blanketed by excavated materials. Bright rays made up of secondary craters extend up to a thousand kilometers or more. The thickest ejecta are deposited at the crater rim, which thin out into a continuous layer and feather out about one crater radius

away. The interior walls of large craters are broken up by concentric faults that collapse inward to form terraces. But this isn't always the case.

A. J. Blance of the United Kingdom's Open University, working with European colleagues, has recently identified *lobate topography* as an additional type of deformation created during crater formation. The ejecta features they describe have distinct, rounded ends and don't thin out as continuous ejecta do. The team has identified 92 lobed craters on the Moon as well as others on Mercury, Mars, and Ceres, indicating that the processes creating them are fairly common. Nearly 98% of these occur where a crater forms on or across the rim of a preexisting crater. Highly cratered terrain, such as the lunar highlands, contains more lobe examples than the mare regions, where large craters rarely overlap.

Three origin scenarios are proposed for the lobes. They could be part of

▲ Farside crater Fermi (left) contains the largest lobe found on the Moon.

the ballistically emplaced continuous ejecta thrown out during the excavation stage of crater formation. But their thickness and steep margins suggest that most lobes are completely different from normal ejecta. The second theory posits that collapsed rim rocks are made fluid by crustal water (on Mars) or even atmospheric gases (on Earth) and thus have significant thickness and coherence. However, only a few lunar lobes exhibit evidence of flow. The third proposal is that the lobes could be giant landslides where parts of the rim of a newly formed crater collapses into the deep floors of overlapped preexisting craters. The tops of the source lobes are often marked by scarps showing where the rim collapsed.

Although fluidization may have helped the flow of some collapsed

lobes, scarps at the top of most of these lobes were caused by the rocks' mechanical failure and the collapse of the new crater's rims across floors of older craters. The existence of impact melt on the surfaces of some lobes confirms that the landslides occurred during crater formation and not at some later time.

The best known and most dramatic lunar lobe is found in **Tsiolkovskiy**, a 184-km-wide (114-mile-wide) crater on the lunar farside. Tsiolkovskiy's giant deposit extends from the western rim of the crater to halfway across the floor of the adjacent older, 241-km-wide **Fermi** crater. The deposit is as much as 500 meters (1,640 feet) thick near the rim of Tsiolkovskiy and thins out to 100 m along its steep-sided margins. The lobe is widely interpreted as a landslide containing material that collapsed from Tsiolkovskiy's rim, which is 500 m lower where it faces Fermi than along other sections. The lobe's surface is crossed by striations radiating from the rim, showing that the collapsed material also flowed, not just tumbled across Fermi's floor. Similar large lobes seen in some craters on Mars are assumed to exist because the planet's crust commonly contains water, which could have made

the collapsed rim materials more fluid. Some large terrestrial landslides flowed smoothly due to saturation, but others were not wet — proving that volatiles aren't required. Although some lunar lavas include a small amount of water, there's no evidence that Tsiolkovskiy's non-volcanic rim rocks did.

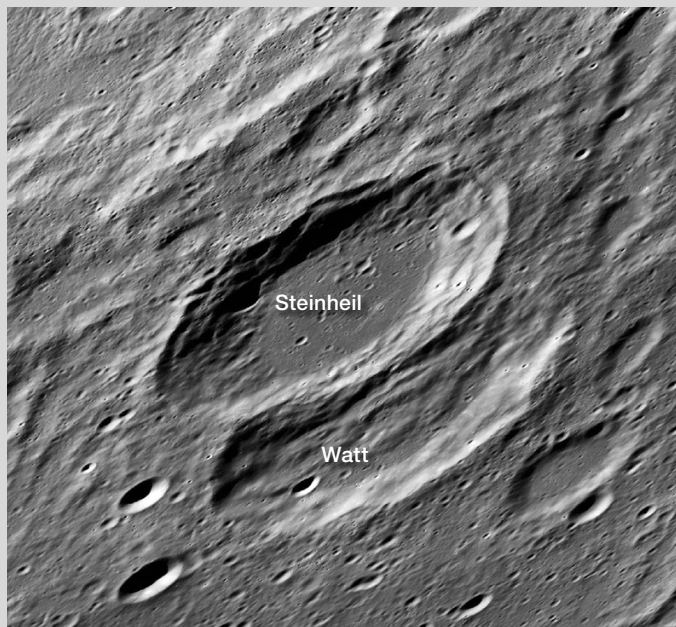
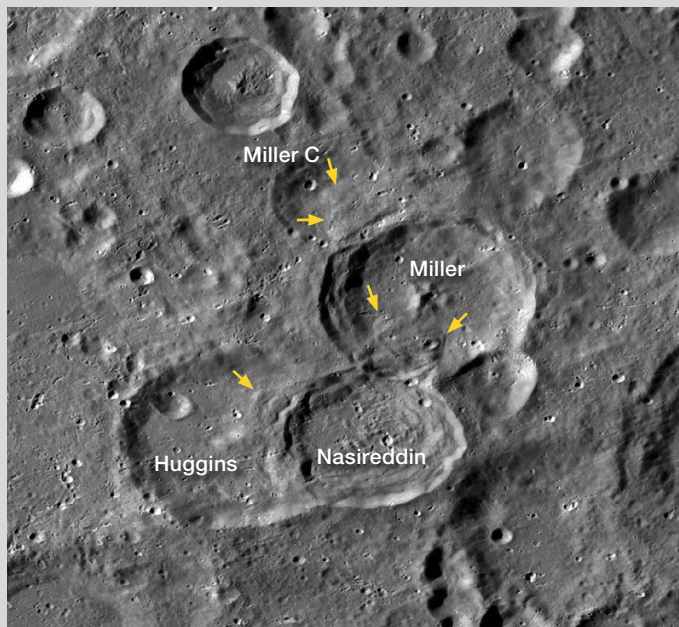
Of the nearly 100 lunar craters that Blance's group identified as having associated lobes, only two are easily viewable telescopically. The first is **Nasireddin**, at the center of a trio of craters about 260 km east-northeast of Tycho. Nasireddin is a 52-km-wide complex crater that cuts across the rim of the older, 66-km-wide **Huggins** to the west and had a less-certain interaction with 62-km-diameter **Miller** to the north. In some places the rim of Miller seems fresher than Nasireddin's, but the large mass of material stretching 23 km from Nasireddin's rim nearly to Miller's central peak is a prominent lobe, suggesting that Miller is the older of the two craters. A curved scarp that's part of Miller's rim shows that that crater's rim rocks comprise much of the lobe. Miller itself is the source of a thick, rectangular lobe that extends from the crater's northwestern rim and nearly fills the floor of the overlapped

35-km-wide degraded crater **Miller C**. Nasireddin is also the source crater for a smaller lobe that extends 12 km onto the floor of **Huggins**.

The second-best visible example of a lobate crater is **Steinheil**, a 65-km-wide crater adjacent to Janssen, south of Mare Nectaris. Steinheil is a smooth-floored, older crater that overlaps about a third of the even older, 68-km-diameter **Watt** crater, causing large, jumbled ridges of wall material to spread across most of Watt's floor. This lobe is quite different than most others, appearing like an expansive arc of Steinheil's rim that collapsed into the older Watt.

Tralles and **Aristoteles** are two other telescopically observable, possible lobed craters with debris on the floors of adjacent craters. Tralles cuts the rim of **Cleomedes**, north of Mare Crisium, and Aristoteles does the same for **Mitchell** at the eastern end of Mare Frigoris. When observing them, look for evidence to determine if they are lobes or simply parts of normal walls of younger craters.

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



▲ **Left:** Nasireddin crater overlaps Huggins and possibly Miller craters. The arrows show the extent of lobate topography within the group. **Right:** Lobe outflow covering most of the floor of Watt crater is evidence that Steinheil formed at a later period than Watt.



▲ ELECTRONIC EYEPIECE

Pegasus Astro now offers the world's first smart eyepiece for telescopes. The SmartEye (\$1,998) is a camera with a $3,008 \times 3,008$ -pixel array Sony IMX533 color CMOS sensor paired with a powerful internal computer and rear-mounted $2,560 \times 2,560$ OLED display. The device functions as both a camera and an electronically assisted astronomy device when coupled to your telescope. The SmartEye records and stacks short exposures that are viewed directly in the OLED display on the back of the unit with a 90° apparent field viewer. In addition, SmartEye includes built-in, dual-band Wi-Fi that connects to mobile devices running the *SkySafari Pro* app that then lets your scope perform as a plate-solving Go To system. The device also functions as a deep-sky camera that includes dual-stage thermoelectric cooling down to -30°C and controlled with your favorite astronomical imaging software. The SmartEye comes with a 2-inch nosepiece, a USB-C power cable, and a hard case. Requires 12V, 2-amp power supply (not included).

Pegasus Astro

Kolokotroni 10, 19001, Keratea, Greece
pegasusastro.com



▲ MULTIPURPOSE SOLAR SCOPE

Lunt Solar Systems announces a new addition to its flagship line of solar telescopes. The LS130MT Universal Solar & Astronomical Telescope (starting at \$7,495) is a 130-mm (5.1-inch) f/7 ED triplet apochromatic refractor that's equipped for both solar observation as well as viewing the night sky. The standard kit includes a removable internal pressure-tuned hydrogen-alpha etalon with 0.45-angstrom bandpass that produces high-contrast views of the chromosphere. The scope comes with an 18-mm, 2-inch format diagonal blocking filter and a 2-inch, dual-speed Feather Touch focuser. Upgrades are available, including larger blocking filters, an internal double-stack filter, a white-light solar wedge, and a calcium module at additional cost. Included with purchase are 8-, 12-, 16-, 19-, and 27-mm eyepieces, a 7.2-to-21.5-mm zoom eyepiece, a pair of hinged tube rings, a solar finder, a Vixen-style dovetail mounting plate, and an aluminum storage case with custom-fitted foam.

Lunt Solar Systems

2520 N. Coyote Drive, Suite 111, Tucson, AZ 85745
520-344-7348; luntsolarsystems.com



◀ GO TO MOUNT

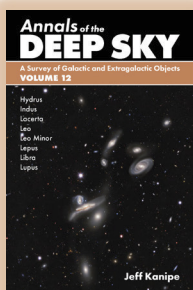
Sky-Watcher recently announced a new computer-driven mount for small telescopes. The HEQ5-R Pro (\$1,695) is a German equatorial Go To mount featuring dual belt drives combined with stepper motors capable of slew speeds up to 800x. The mount head weighs 11.8 kilograms (26 pounds) and can bear an instrument load of 15 kg, excluding counterweights. Its dual-format saddle accepts both Losmandy-D and Vixen-style dovetail mounting bars. And like most recent Sky-Watcher mounts, the HEQ5-R Pro incorporates a cable-management system with several passthrough ports, including one USB-A port, a pair of 2.1-mm power ports, and an ST-4 compatible autoguider port on its saddle plate, to prevent cable snags during operation. The mount also has built-in Wi-Fi and is controlled either with the included SynScan hand paddle or *SynScan Pro* app for iOS and Android devices. Each purchase comes with an adjustable rolled-steel tripod weighing 6 kg, two 5-kg counterweights, and a DC power cable.

Sky-Watcher USA

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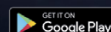
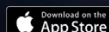
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BARNARD AT THE 36-INCH This colorized “selfie” was taken shortly after Barnard’s September 9, 1892, discovery of the fifth satellite of Jupiter, Amalthea, bringing to a successful conclusion the search for planetary satellites that had begun earlier that summer with Venus.

SPCOLLECTION / ALAMY

Connoisseurs of astronomical literature have long appreciated the aperitifs and desserts of half-forgotten mysteries. Often set aside in lieu of the “main course” of scientific discovery, these enigmas haunt astronomy’s fringes and linger in the memory. Their solution invites the interest of amateur sleuths, and sometimes — in the hands of former *Sky & Telescope* editor Joseph Ashbrook, for instance — they may even serve up an answer.

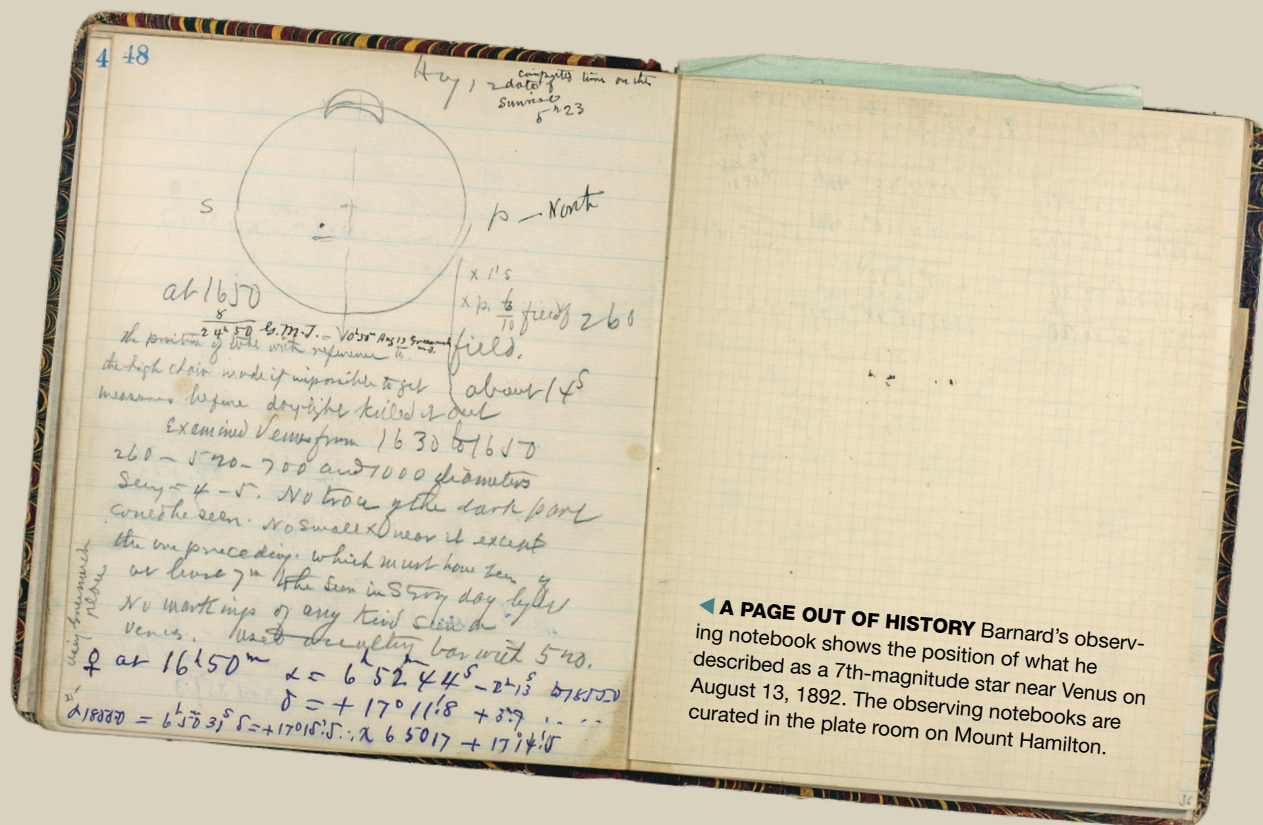
Among the most tantalizing of these cases has been an unexplained observation of a star near Venus — seen once, and never again — by Edward Emerson Barnard in August 1892. His singularly acute eyesight, meticulous methods, and numerous discoveries have made him a legend among observers and given particular credibility to the case.

Rising from abject poverty, Barnard was apprenticed from an early age to a photography studio in Nashville, Tennessee, after the Civil War. He acquired a small telescope that he used to discover several comets and, as a result, was named a junior member of the original staff at Lick Observatory.

From its opening in 1888 on Mount Hamilton near San Jose, California, the observatory boasted what was at the time the world’s largest refractor, a 36-inch built by Alvan Clark & Sons. There, Barnard added more comet discoveries (he would be credited with at least 16 total); made many important observations of planets, double stars, and nebulae, mostly with the observatory’s 12-inch refractor; and used an old portrait lens to pioneer wide-angle photography of comets and the Milky Way.

A Mystery Solved?

More than a century’s worth of sleuthing has come up with a deceptively simple solution to E. E. Barnard’s 1892 “unexplained observation.”



◀ **A PAGE OUT OF HISTORY** Barnard’s observing notebook shows the position of what he described as a 7th-magnitude star near Venus on August 13, 1892. The observing notebooks are curated in the plate room on Mount Hamilton.

However, because of his junior status, Barnard was not granted regular use of the 36-inch, a situation which made him desperately unhappy. Only in July 1892, after a long and bitter battle with the observatory's autocratic, West Point-trained director, Edward Singleton Holden, did he finally receive his own regularly scheduled night — Friday — on the great telescope.

Wanting to show that the opportunity had not been wasted on him, Barnard immediately set out to search for unknown satellites orbiting the planets. If successful, his efforts would join his name to those of Galileo Galilei, Christiaan Huygens, and others — including Asaph Hall, who only five years earlier had discovered the two satellites of Mars at the U.S. Naval Observatory in Washington, DC.

A Star Near Venus

What is not generally known is that this quest included Venus, whose history of deceiving observers into thinking it possessed a satellite is depressingly long. At one point, even Gian Domenico Cassini, discoverer of four of Saturn's moons, had fallen prey to deception.

Doubtless well aware of the difficulties but also of the unprecedented potential of Lick's giant glass combined with his own scrupulous methods and keen eye, Barnard set out with cautious hope. From his observing books, we can infer that he made his first search for Venusian satellites on the morning of August 13, 1892.

As the sky began to brighten toward dawn, Barnard put the planet, then at an elongation of 38.5° from the Sun and

nearly at its greatest brightness, in the field of the great refractor. It was low in the sky and hard to reach with the telescope; he had to set the observatory's elevator floor to its maximum height, stand at the topmost rung of the observing ladder, and hang precariously onto the telescope with both hands. After a preliminary scan for markings and the elusive *ashen light* (a faint glow on Venus's night side, which as far as I know he never could see), he began his search for satellites. In his observing log he recorded, "No small x [star] near it [Venus] except the one preceding which must have been of at least 7m [magnitude] to be seen in strong daylight." Since any satellite as bright as 7th magnitude would have been discovered long before, Barnard dismissed it at once from contention.

Barnard, as usual, worked alone. Given the awkward position of Venus, it was not possible to use the telescope's setting circles to determine a position for the star. He did, however, work out its coordinates relative to Venus's position as given in the *American Ephemeris and Nautical Almanac*. He turned to the *Bonner Durchmusterung*, the great 19th-century star catalog compiled by Friedrich Wilhelm Argelander, to search for the star's identity. Argelander's catalog includes stars down to about 9th magnitude, so it should have been easy to discover the identity of a 7th-magnitude star. Barnard found none.

For unknown reasons, but most likely due to the pressure of other work, Barnard abandoned the star near Venus, seemingly forever. Not for 14 years — by which time he had long since left Lick for Yerkes Observatory in southern Wisconsin — did he return to it again.

In 1906, he published a short notice in the German journal *Astronomische Nachrichten*, in which he wrote, "Perhaps it may not be too late, after fourteen years, to call attention to an observation . . . but I think now that it is best to put it on record." Without explaining the long delay, he described the circumstances of the observation and noted that there was no "considerable star" in this position. In addition, he ruled out a few other possibilities. It was not one of the brighter asteroids, since they were all accounted for and far from Venus at the time. It could not be an intra-Mercurial planet, as it was outside Mercury's orbit. A planet interior to Venus was, in his words, "not probable" (most likely due to its brightness). And an optical reflection ("ghost") from the image of Venus was "out of the question," implying that he had moved the telescope, and — unlike a ghost — the star had remained in its position relative to the planet.

What Could It Have Been?

Though Barnard himself ruled out what the star could not have been, others, in due course, speculated as to what it might be. The most obvious suggestion at the time, mooted by Frederick John Marrian Stratton of the Solar Physics Observatory at Cambridge and English amateur Charles Lewis Brook, was a nova seen just this once before fading from view. The same idea occurred to the German astronomer Max Wolf, who for years had been photographing the Milky Way and discovering scads of asteroids with a 16-inch astrograph at



▲ **MYSTERIOUS PLANET** Barnard's best-ever sketch of Venus was made at the 12-inch refractor at Lick Observatory on May 29, 1889. Despite his keen eyesight and use of large instruments, Barnard failed to see many of the details on the planets reported by observers using smaller instruments. Some of the latter, such as the spoke system reported by Percival Lowell and his colleagues at Flagstaff, were clearly illusory.

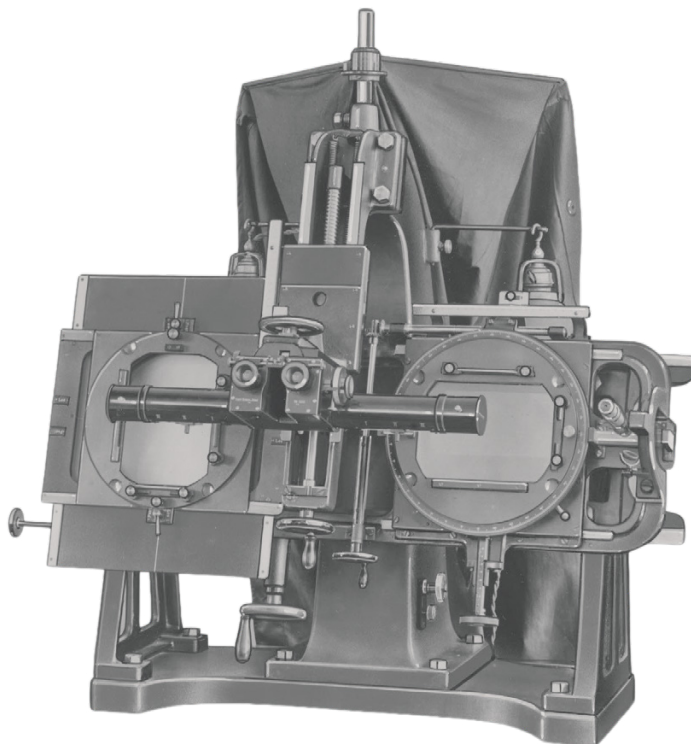
the Heidelberg Observatory. Searching through his archives, Wolf found a few relevant plates and used a *stereocomparator* (a forerunner of the blink comparator) to examine the faintest stars on two images for possible variations in brightness. One plate had been taken on December 22, 1891, the other on December 26, 1892. Wolf concluded:

I can assert that at the indicated position and in its vicinity the plates are completely identical up to the stars of 14th magnitude. Thus, if the bright object seen by Barnard on 1892 August 12 [13] had been a nova it would have to have descended below 14th magnitude, which is not very likely, by Dec. 26 of that year.

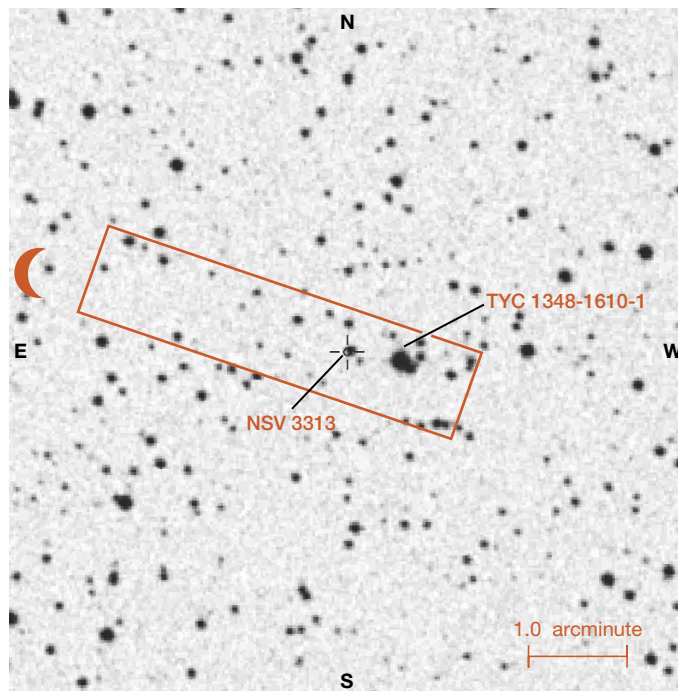
In fact, there are a few novae known to fade by this amount in even shorter periods of time. The recurrent nova T Coronae Borealis, for instance, takes about 60 days to fade seven or eight magnitudes after maximum brightness, while Nova Cygni 1975 faded eight magnitudes in 100 days. So the nova theory lingered.

In 1956, *Sky & Telescope* editor Joseph Ashbrook devoted one of his classic “Astronomical Scrapbook” articles to Barnard’s observation (*S&T*: June 1956, p. 356). In it, he recounted the case of d’Agelet’s star. While cataloging stars on the nights of July 26th, 27th, and 29th in 1783, the French astronomer Joseph Lepaute d’Agelet determined, with a mural quadrant, the precise position of a 6th-magnitude star in Sagittarius. It was subsequently found to have gone missing. (D’Agelet himself would later disappear as a member of the ill-fated scientific circumnavigation of Earth by Jean François de Galaup, comte de Lapérouse.) However, between 1942 and 1950, Harold Weaver, working with the 60-inch reflector at Mount Wilson Observatory, photographed the region in red and blue light and found a 19th-magnitude star in the right position. It was uncommonly blue in color and of variable brightness, characteristics typical of a nova in its late post-maximum phase, and proved to be a cataclysmic variable, now dubbed WY Sagittae (Nova 1783). Ashbrook thought that Barnard’s mysterious star might be a similar case, and suggested that “were a search with a large telescope to show a very blue variable star of about 18th to 20th magnitude in the location given by Barnard, astronomers would be able to add a Nova Geminorum 1892 to their list of reasonably assured new stars.” Indeed, though unconfirmed, Barnard’s observation was included under the designation NSV 3313 in the *New Catalogue of Suspected Variable Stars*, published in 1982, and listed as a cataclysmic variable in 1997, though its status was later downgraded to “very uncertain.”

Another sleuth of astronomical mysteries, Richard Baum, agreed as to the likelihood of this explanation, but he also wondered about the possibility that Barnard had seen a sun-grazing comet. Whatever it was, Baum suggested, “All we can conclude is that Barnard was not deceived. He was too careful an observer. He reported honestly what he saw, and all we can do is speculate on what he may have seen while acknowledging that what he saw was unexpected and unknown.”



▲ **DOUBLE VISION** German astronomer Max Wolf used this large-format stereocomparator, nicknamed the “astronomical model,” to help rule out the nova hypothesis. The Carl Zeiss company loaned this instrument to Wolf.



▲ **MYSTERY STAR FIELD** This image shows the field near Venus (small red crescent to the left) with a box indicating possible positions and their uncertainties calculated from data given in Barnard’s observing book. The box includes the 11.4-magnitude star TYC 1348-1610-1, an ordinary B9 main-sequence star, and NSV 3313. The image is the American Association of Variable Star Observers finder chart for NSV 3313.



▲ **COMET HOLMES** Barnard imaged this tailless comet sailing past the Andromeda Galaxy with the 6-inch Willard lens on November 10, 1892. Comet 17P/Holmes is a member of Jupiter's family of comets, with a period of 6.9 years.

Other Possibilities

The mystery, in other words, endured. At last, in late 2024 and early 2025, a group of colleagues and I grew tired of reading that and decided to try to put the matter to rest one way or the other.

We began with Barnard's original observing books in order to confirm the basic data. We determined the position at which he recorded the 7th-magnitude star, with error bars for the various versions of his calculations. Closest to the position indicated by Barnard was an 11th-magnitude star, TYC 1348-1610-1. It is a very ordinary, blue main-sequence star with a B9 spectral type and no variability. At its present magnitude it could not explain Barnard's observation, nor could it possibly have flared up by four magnitudes at any time.

We also ruled out a 15th-magnitude star close to this position, the one designated NSV 3313. The All-Sky Automated Survey for Supernovae (ASAS-SN), which scans the sky nightly, shows it to vary by 0.26 magnitude, with a period of about 0.48 day.

To investigate the nova hypothesis, team members Tim B. Hunter and James McGaha carried out deep imaging of the area on

the night of December 29, 2024, at the Grasslands Observatory near Tucson, with the Observatory's PlaneWave CDK24 24-inch f/6.5 reflector. They centered on the star TYC 1348-1610-1, imaging an 8.6'-wide field in the Cousins-Johnson V, B, and R bands with a limiting magnitude around 20, as Ashbrook had suggested. They examined images and found no planetary nebula, supernova remnant, nova shell, or gas cloud. Nor did any stars in the area have a blue excess (as for a nova) or an unusually red color (as for a flare star).

Another member of our team, Brad Schaefer (Louisiana State University), searched the vast Harvard College Observatory collection, which consists of half a million digitized photographic plates taken from 1888 to 1989. Schaefer closely examined some two dozen plates of the relevant area dating from 1891 to 1894 and compared them to a later deep plate (taken on December 22, 1894). He also found nothing suspicious. Every visible star was of nearly the same brightness on the deeper plate as on the others, as well as matching data from the first- and second-epoch Palomar Digital Sky Survey.

We also searched the database of the European Space Agency's Gaia mission, but again the results were negative. There were no variable stars for NSV 3313; novae were also ruled out. So we had proved that Barnard's mystery star could not be another d'Agelet's Star.

What then? As Barnard himself had found, none of the brighter asteroids had been in the area at the time. But was it possible that Barnard had seen a comet's central condensation, while most of the coma and tail lay hidden in twilight, and not realized what he was looking at? This seemed unlikely. Barnard was one of the most prolific discoverers and observers of comets of all time. If it had been a comet, he should, with his vast experience, have found it obvious that the object was not starlike but diffuse or extended. Furthermore, no known comet could be traced back in time to correspond with Barnard's observation. Team member David Levy is the only person alive today whose reputation and experience as a visual observer and discoverer of comets rivals Barnard's own. He was sure that Barnard would have seen and recognized any coma, even under less-than-optimal observing conditions. So a comet was out.

An optical ghost of some kind still seemed a remote possibility, even though Barnard had specifically addressed and rejected it. Optician Roger Ceragioli (University of Arizona) looked thoroughly into the possibility, including double-bounce reflections from the lens elements of the great refractor that might conceivably have produced Barnard's impression

◀ **BARNARD'S EYEPIECE** In a reenactment of Barnard's observation of stars in bright twilight, Roger Ceragioli used this 14-mm Steinheil eyepiece, provided by John W. Briggs. The ocular is the only known survivor from a set of 11 ranging from 5 to 88 millimeters that were imported from Germany in 1897 to be among the first available for use with the Yerkes refractor, where Barnard concluded his career after working at Lick with the 36-inch.



of a 7th-magnitude star. While theoretically possible, it did not seem very likely. For one thing, the Clarks, the opticians who had fashioned the Lick lens, were very well aware of the ghost problem. They took pains with their lenses to avoid combinations of curves that would yield a focused ghost image. Furthermore, there was no history of complaints against the 36-inch on such grounds.

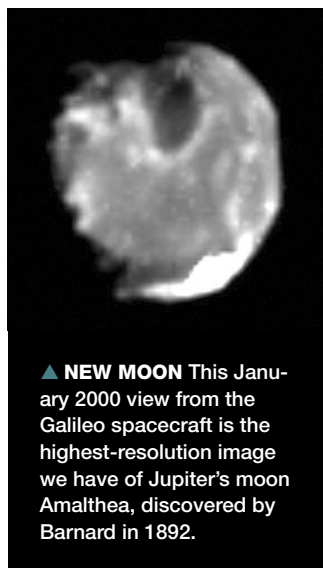
Eyepiece ghosts were another possibility, as they were hard to suppress in the 19th century. However, simply by moving the telescope to see whether the ghost followed Venus or not, Barnard would have proved that he was not seeing a mere reflection of Venus in the eyepiece. He certainly would have done this test. A ghost, too, seemed a hopeless dead end.

A Serendipitous Observation

At this point, we were ready to accept defeat. However, with compulsive thoroughness, and wanting to wipe from the books every last vestige of doubt about the ghost theory, Ceragioli decided to test his 12.25-inch f/15 folded achromatic refractor with a variety of eyepieces, including an old Steinheil such as Barnard might have used. (The Steinheil had recently been rescued by yet another colleague, John W. Briggs.) On April 24, 2025, Venus was holding forth brilliantly in the morning sky, and Ceragioli caught it as the stars faded and only the Summer Triangle remained visible to the naked eye. With an eyepiece magnifying 150 $\times$, he was dumbfounded to see a bright star above Venus in the eyepiece. It was no ghost; on moving the telescope, he found that it moved with Venus. He then consulted his planetarium program: Venus was indeed passing a star, HD 222860, and it remained visible half an hour before sunrise. Though he had guessed that the star was perhaps 4th or 5th magnitude, to his considerable surprise he found the magnitude listed as only 8.0.

According to the often-quoted maxim of Sherlock Holmes, “When you have eliminated the impossible, whatever remains, however improbable, must be the truth.” Logicians refer to this as the Holmesian fallacy, since in practice it is impossible to eliminate all possibilities. We had been on the verge of succumbing to the fallacy when a solution finally dawned on us.

Inspired by Ceragioli’s observation, we wondered whether Barnard, too, could have overestimated the brightness of the star he saw by several magnitudes. Initially, this seemed highly unlikely, given Barnard’s meticulous methods and observational skill. But in August 1892, he had only just begun to use the 36-inch on a regular basis. Most of his experience up to that point had been with Lick’s 12-inch refractor. He was 34 years old and at his prime as an observer, with exceptionally keen eyesight. On the other hand, the human



▲ **NEW MOON** This January 2000 view from the Galileo spacecraft is the highest-resolution image we have of Jupiter’s moon Amalthea, discovered by Barnard in 1892.

eye is notoriously bad as an absolute photometer, especially in unfamiliar circumstances. Not having any comparison stars in the field of view on the morning of August 13th, he would have presumably had to rely on his memory of what a 7th-magnitude star looked like based on his extensive experience with the 12-inch. What, we asked, was the possibility that he had simply overestimated the brightness of the 11th-magnitude star TYC 1348-1601-1?

The matter could be put to the test. In 1989, Schaefer had written computer programs to model the detectability of light sources seen through a telescope against a uniform background over a wide range of brightnesses, sizes, and shapes (for example, *S&T*: Nov. 1989, p. 522). He calculated the limiting magnitude for the 36-inch refrac-

tor in twilight conditions to be 14.3 at the start of Barnard’s observation. This is Pluto-range brightness! When he stopped observing because of the advancing dawn, the limiting magnitude was still 13.8.

We surmised that Barnard probably relied on his memory of limiting magnitudes with the 12-inch (11.9 by Schaefer’s calculations), and guessed that the TYC star was 7th magnitude, rather than 11th as is actually the case. In other words, Barnard had made a simple mistake. The mysterious star proved to be the ordinary, stable B9 main-sequence star TYC 1348-1610-1, which must have been shining steadily at 11th magnitude in exactly the position Barnard had found it, all along. He had overestimated the magnitude because of the dawn sky’s brightness, lack of comparison stars, and his initial unfamiliarity with the 36-inch Lick refractor.

Our sleuthing proved (were any further proof needed) how extraordinarily careful and judicious Barnard was as an observer. Yet even he was capable of making a very human error. The mystery of the mystery star was solved.

Not quite a month after his observation, Barnard’s search for unknown planetary satellites — unproductive in the case of Venus — was rewarded with the discovery that made him internationally famous. This, also made with the 36-inch refractor, was the fifth satellite of Jupiter, Amalthea. It was the first Jovian moon discovered since Galileo and Simon Marius discovered the first four in 1610 (*S&T*: Aug. 2025, p. 20). It remains the last satellite of the solar system to be found using the old visual methods.

■ Contributing Editor **WILLIAM SHEEHAN** has long admired Edward Emerson Barnard’s skill, dedication, and accomplishments, and has written numerous articles on Barnard as well as the biography *The Immortal Fire Within: The Life and Work of Edward Emerson Barnard* (1995), and the double biography, *Parallel Lives of Astronomers: Percival Lowell and Edward Emerson Barnard* (2024).

Under the Hood

When I first began as a science journalist, I thought of the images that accompany stories as eye candy. A picture might be worth a thousand words, but the real story was the text — the artwork was filler we added to make the page more inviting.

But working with S&T's art department taught me to think differently. Illustrations help to tell the tale in a way that words don't. They make the abstract concrete and the complex intuitive. They present information in novel ways, ways that might help a reader who would otherwise feel lost. Our creative director and illustrators aren't mere beautifiers; they're visual storytellers.

This symbiosis shines most in our magazine's detailed illustrations, diagrams, and infographics.

These visuals don't begin with a prefab template. Sometimes they start with reference diagrams the editor pulls together from elsewhere, with guidance on which parts to imitate or ignore. Other times they begin as a sketch, occasionally by the author but more often by the editor. When sketching, I might pull on existing graphics for inspiration, or I might devise the thing from scratch.

Still other times, the illustration begins with words and numbers. Infographics may start as spreadsheets. For big conceptual illustrations, I write a detailed description of the science the art should convey. I might even include suggestions for color, texture, and drawing style, if those matter for accuracy and clarity. (If they don't, then I try to stay out of the artists' way and trust to their genius.)

I then discuss everything with the art team — what we're trying to communicate, what the underlying physical processes are, etc. They read through the materials and pepper me with questions.

Then our artistic masterminds get to work. When creating, they think about things like the "information hierarchy" — the top-level idea and the details undergirding it. Visually communicating this hierarchy helps guide readers through the science's logic smoothly. They also consider not just the individual graphic's content, style, and size, but how it works with everything else in the article. We iterate drafts until we're all satisfied.

The result is often magnificent. A few paragraphs become a mesmerizing vista of black holes growing in the primordial plasma (S&T: Apr. 2025, p. 34). Doodles become engaging cartoons explaining the giant planets' oddball moons (S&T: Feb 2026, p. 14).

And a tongue-in-cheek drawing on a piece of scrap paper becomes the delightful caricature on this page.

—CAMILLE M. CARLISLE

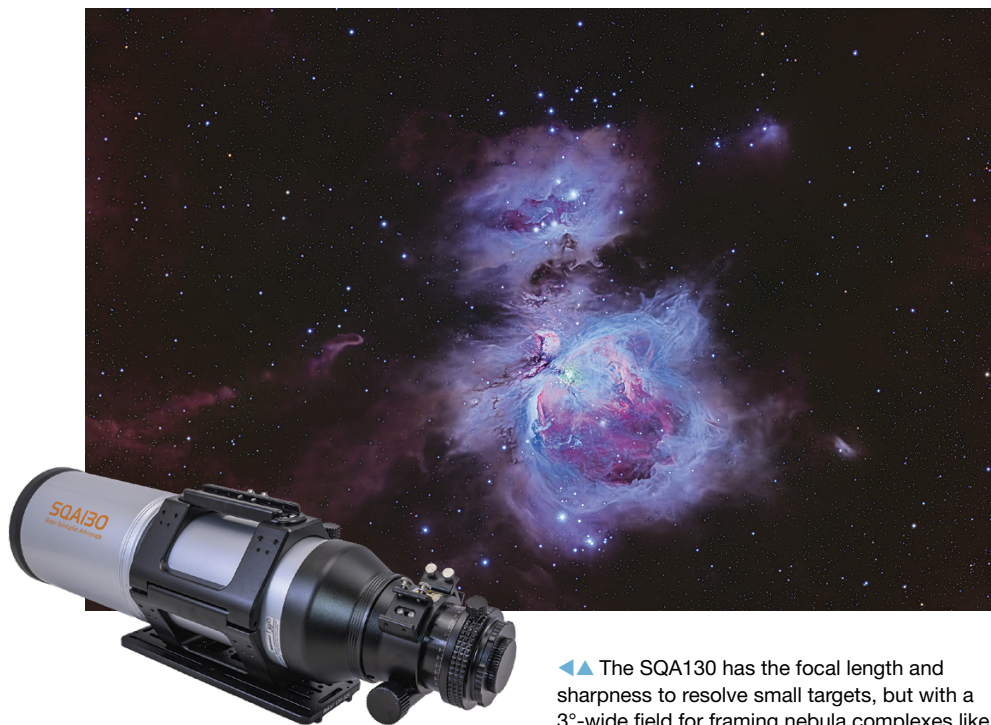


Illustration by
Leah Tiscione / S&T



The Askar SQA130 Astrograph

This instrument promises image quality a cut above lesser telescopes.



WHEN I REVIEWED the smallest member of Sharpstar/Askar's Super Quintuplet Astrograph (SQA) series last year (S&T: Sept. 2025, p. 68), I was impressed with its performance. The little SQA55 proved to be a tack-sharp, wide-field astrograph. It was the first in an expanding line of "super astrographs," instruments that offer sharper stars across a wider field than we had seen in most previous refractors.

Since the SQA55's introduction, the series quickly grew to include 70-mm, 85-mm, and 106-mm models. I've used the mid-sized SQA85 and can attest to its high quality. The latest and largest member of the series, introduced earlier this year, is the SQA130. When Sharpstar Optics, which now sells most of its refractors under the Askar brand, offered to send an early production unit for testing I was certainly interested. Would the big 130 perform as well as its smaller siblings in the series?

◀▶ The SQA130 has the focal length and sharpness to resolve small targets, but with a 3°-wide field for framing nebula complexes like M42 and its companions. The image above is a blend of long and short exposures to retain the bright core details. The author used a stock, full-frame Canon EOS R5 mirrorless camera for all the test images.

Design Specifications

Like the other four members of the SQA series, the SQA130 is an f/4.8 Petzval design with five lens elements — two of which are made of low-dispersion SD glass. The 130-mm objective is a triplet, augmented by a single full-aperture focal reducer lens mounted mid-tube, and a final sub-diameter flattener lens at the rear in the focuser. The effective focal length is 624 mm, producing a 3.3° by 2.2° field on a full-frame (24-mm by 36-mm) camera sensor.

Stars are promised to be pinpoint across a 55-mm-wide image circle, with disks no more than 4.4 microns across at the corners of a full-frame sensor, and 4.8 microns at the edges of a medium-format (33-mm by 44-mm)

Askar SQA130

U.S. Price: \$4,799
sharpstar-optics.com

What We Like

Tiny stars to the corners of full-frame sensors

Superb focuser and camera rotator

Very easy to set up and use

What We Don't Like

Slight vignetting

Heavy for its size

Adapters do not accept filters

**Prices subject to change*

sensor. By comparison, spot sizes at the frame edges of many refractors are typically 10 to 30 microns, enlarged and distorted by optical aberrations, often into winged shapes.

The published Modulation Transfer Function chart (a measure of optical performance across the frame) is a nearly perfect straight line, almost unheard of in the world of camera lenses. Field illumination is promised to drop off by only 5% at 22 mm from the center of the field.

These are premium specs that come at a premium price. At \$4,799 the SQA130 is more costly than similar aperture telescopes in the Askar line, such as its 130PHQ (\$3,499) and the larger APO140 (\$2,499). However, the SQA130 is still less expensive than some of the premium telescopes on the market.

SQA130 is also hefty, weighing in at 11.7 kg (25.8 lbs) with its mounting plates and tube rings. I did all my testing with it on my Astro-Physics Mach1 mount, a traditional German equatorial. Most mid-sized, strain-wave mounts



◀ *Far left:* The mounting plate is a 300-mm Losmandy D plate slotted for shifting its position to balance the telescope. The focuser is tapped to accept brackets for third-party focus motors. *Left:* All lenses are multi-coated, and the tube interior is blackened and rifled. But the full-aperture lens at mid-tube rules out concentric baffles down the length of the tube.

can handle the SQA130 (I tried it on a ZWO AM5). But I'd definitely recommend adding counterweights to prevent the rig from toppling over when the tube is on the eastern or western sides and far off balance.

I'd also suggest purchasing the \$65 SQA Handle Bar as an essential accessory. It attaches securely to the top mounting plate and makes it easier (though still not easy!) to heft the scope around, with less chance of it slipping out of your grasp.

Mechanical Quality

As with all the Askar telescopes I've tested, the focuser on the SQA130 is superb. It's a 3.2-inch-format, rack-and-pinion model with a 10:1 dual-speed motion. The focus travel is just 30 mm, but it was sufficient for my gear, admittedly just a simple mirrorless camera

body. Using an adapter that provided the standard 55 mm of backspace to the sensor, the focuser reached infinity when racked out to 17 mm, leaving plenty of room on either side for the back focus requirements of filter wheels, filter drawers, and off-axis guiders.

The focuser was silky smooth, solid, and precise, with no perceptible backlash or image shift. The entire focuser doesn't rotate but includes a removable camera rotator. This rotator is graduated in 1° increments, which I found handy for framing a field exactly as I wanted and repeating the framing over multiple nights. The rotator also proved easy to turn even at subfreezing temperatures, with no image shift. It has a large lock knob and a wide-ribbed surface that makes it easy to adjust with gloves on, a feature I was thankful for during my winter test nights.

The telescope comes with adapter rings for M48-, M54-, and M68-threaded accessories, but none of the adapters accept filters, a shortcoming with most of the SQA astrographs with the sole exception of the SQA55. To shoot through filters, I purchased the Askar M54 Filter Drawer (\$164).

The only baffles or field stops possible in the tube are located near the focuser. However, I saw no evidence of lens flares from bright objects just outside the field. The dew cap also has a large, glove-friendly lock; if left unlocked, with the scope aimed straight up the dew cap will slide down the tube.

The Optics

The quality of the SQA's mechanics and fittings are what discerning imagers have come to expect with most new telescopes made for serious astrophotography today.



Blowups of a single processed frame of the open clusters M46 and M47 in Puppis reveal the SQA130's fine star points and lack of optical aberrations, right down to the very corners of the full-frame Canon R5 sensor with its 4.4-micron photosites.

What the SQA series uniquely promises to deliver are super-sharp stars. Keep in mind this is an *astrograph* — a photographic instrument only. The back focus is too short to accommodate an eyepiece to look through this scope (or any of the other SQAs), so all my testing had to be through imaging.

As promised, stars proved pinpoint across the entire full-frame sensor of my 45-megapixel Canon EOS R5 with

its 4.4-micron photosites. Even at pixel-peeping levels, there was no visible coma, astigmatism, or lateral chromatic aberrations distorting stars at the corners. The image analysis tools in the program *Siril* (siril.org) showed very little tilt in my test images. So, while the focuser lacks any tilt adjustments, I didn't need them.

Star sizes measured as small as 1.5 to 3 pixels, equal to roughly 2" to 4" across

at the plate scale of 1.45" per pixel when paired with the Canon R5. This is down at the level where seeing conditions will blur images. The sky, not the telescope, was the main factor limiting resolution.

I shot both with the camera sensor at the standard 55 mm of back space and with a filter drawer and T-ring combination that was about 7 mm shorter. Stars looked equally good across the frame in either case, demonstrating the Petzval design's tolerance for spacing between sensor and optics. There's no need to fuss over counting every millimeter of component thickness. On the other hand, with all SQAs their f/4.8 focus is the only choice; there's no optional reducer to provide an even faster focal ratio.

In testing the degree of light falloff across the frame, I did find a small but noticeable darkening just at the extreme corners (22 mm from the center), measuring about one-quarter of an f-stop, or 25%. This is more than the promised 5% drop-off in illumination and might be imparted by the 48-mm Canon T-adaptor I was using. I measured the illuminated circle, and it matched the advertised 55 mm, so the SQA130 will fill a medium-format sensor. How well wasn't something I could test.

A bright star placed at any of the extreme corners showed pairs of subtle dark streaks emanating from the stellar disk. I couldn't see any evidence of clips at the periphery of the lens cells intruding into the light path that might be causing diffraction effects, and this doesn't quite look like normal aperture vignetting.

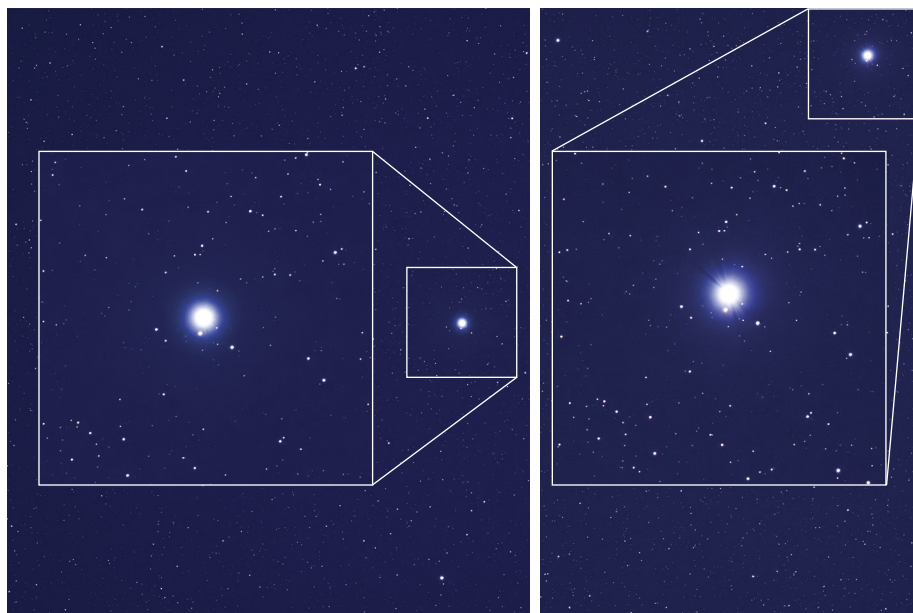
The effect was noticeable only in shots taken specifically to look for odd corner flaws. It was much less prominent than what I see in some refractors, where severe aperture vignetting adds dark, bipolar shadows to stars at the edges. And in all the astrophotos I took, star shapes and sizes were exceptional across the frame.

Comparing Askars

While the SQA130 astrograph does indeed produce exceptionally sharp stars, I wondered if I could see the



▲ A single exposure of Castor, Alpha (α) Geminorum, in twilight and with the contrast boosted shows a fairly uniform field illumination, except for a slight darkening at the extreme corners.



▲ Single exposures of bright, 1.6-magnitude Castor show a perfect star shape at the center, but a slight, bipolar shadow effect with the star at the corners. Each corner showed the same effect.



▲ These single frames — shot on consecutive nights at the same times and with the same camera — attempt to show the difference in star sharpness between the Askar SQA130 and the Askar APO120 with its 0.8× reducer. It takes pixel-peeping to see a difference, mostly in the corners.

difference in real-world examples between the premium SQA130 and a “lesser” telescope of similar aperture and focal length. The closest competitor I had on hand was the Askar APO120 (\$1,699) I tested two years ago (*S&T*: Aug. 2024, p. 70). When coupled with its 0.8× Reducer/Flattener (\$220), the APO120 provides a focal length of 672 mm at f/5.6, so it’s longer and photographically slower than the SQA130. Over two nights I shot the same field, the Orion Nebula, at the same altitude with the same camera, the R5.

At the pixel-peeping level, I could see the SQA130’s stars were indeed a little smaller and sharper. But the difference wasn’t obvious and may not show on the printed page. However, as I noted earlier, at these focal lengths and at the altitude of Orion from my home in Canada, the seeing conditions, if not wind and guiding errors, are likely to prevent realizing the sharpness a super astrograph like the SQA can provide.

While the field was more uniformly illuminated in the SQA than in the

APO120, the difference was again not marked. Of course, the SQA130 is about half an f/stop (50%) faster than the APO120, which can be helpful in some imaging situations.

While this was just one test on one object, I think it demonstrates how we’ve reached the point of diminishing returns — where further small, though measurable, improvements in image quality demand a sizeable premium in price and, in the case of the SQA130, weighing almost double that of the APO120, with its lightweight design. And, as noted above, the SQA scopes can be used only for imaging; the APO series works well as both visual and photo telescopes, but with strict back spacing required.

Recommendations

The SQA130 is a serious commitment in cost and mounting requirements for a strictly photographic instrument. You’ll reap the full benefits of its superb optics only if you use a full-frame, if not medium-format, camera and one with

photosites 4 microns or smaller — and only if your site often experiences good seeing conditions.

And do consider its weight. The SQA130 is about as big and heavy a telescope as I care to lift on and off a mount in a portable setup. Those with younger and stronger backs will be more tolerant of the scope’s heft. But once I got my rig set up, I was able to use the SQA130 to get the best captures of popular winter sky targets I’ve ever taken.

We’re fortunate indeed to now have such a wide choice of high-quality telescopes of all sizes and types for our enjoyment of the night sky. If you’re serious about having the very best in an imaging scope and are willing to pay the price, the SQA130, or one of its smaller companions in the SQA series, will serve you well.

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

Focusers and 3D Printing

These devices are a case study in “maker” culture and the KISS design principle.

IF THERE'S A TELESCOPE that works well without a focuser, I haven't seen it. I consider the focuser's importance second only to the optics. But good focusers are usually expensive, and making one yourself often means machining metal. This is a problem for the “from-scratch” corner of DIY telescopes — for optics, you can point a beginner toward John Dobson's videos; for focusers, no such luck.

The first barrier is how fine an adjustment a focuser really needs. According to Albert Highe's telescope-making books, at $f/4$ the focuser needs to hit roughly

a 0.025-mm (0.001-inch) sweet spot. The first telescopes I made, however, were $f/8$. The relationship between focus tolerance and focal ratio is square: twice the focal ratio buys me four times the tolerance. Although there are plenty of clever focuser plans online, most need extensive shopping lists of screws, bearings, and such. And I found that a crude, 3D-printed helical screw design with a big wheel handle is able to hit these softer focus-tolerance numbers just fine — the wheel offers enough granularity (one pinky-width turn is less than that tiny

focus sweet spot), and wrapping some plumber's tape on the threads makes the action smooth and slop-free. The whole thing is just two sets of prints plus some nuts and thumbscrews.

Jerry Oltion wrote about the telescope that this focuser went into: my 3D-printed Hadley reflector with a 114-mm ($4\frac{1}{2}$ -inch) $f/8$ spherical mirror (*S&T*: Jan. 2023, p. 70). I estimate that thousands of these scopes were made since then, and I chalk this up squarely to the “keep it simple, smarty-pants” (KISS) design philosophy, which focuses on off-the-shelf hardware as well as publishing my source files freely online.

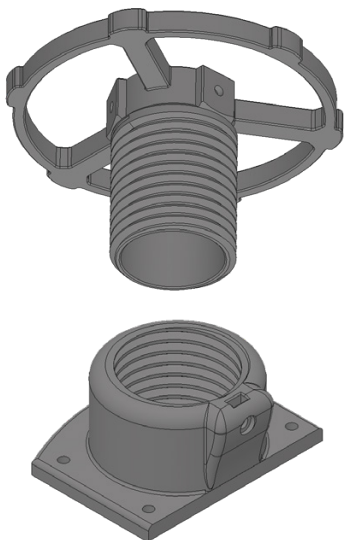
The choice to make the design open source was easy — printing itself is only accessible after decades of open-source projects. With the computer-aided design (CAD) files, makers can tweak, test, and publish any improvements or changes. And boy, do they!

Now there are many other focusers in the mix — notably, a nonrotating focuser. This clever design uses a clamping ring and rails printed into the threaded drawtube. A captive wheel then turns this drawtube without rotating the eyepiece or camera. One person mixed the original Hadley's iconic handwheel into this; another one added a small locking ring; someone else secured the collet so that it doesn't pop out, and so on. Printing and assembling these new focusers was surreal. None of my original work is left in the files, yet they show the same idea and design language. And they snapped right into the same focuser shoe with the same #10 mounting screws.

Soon, people far more talented than a weekend engineer like me got

◀ This close-up view of the author's 3D-printed helical focuser for his 114-mm ($4\frac{1}{2}$ -inch) Hadley telescope shows the large handwheel for fine focusing.





▲ The author's handwheel and focuser base diagrams illustrate the Hadley focuser's simple design and assembly. Not shown are the thumb-screws for locking the eyepiece and focuser.

their hands on the design. One tinkerer remade it from scratch, true to all dimensions but fully parameterized. This means a telescope maker in Europe can type in measurements for metric screws, and whoosh! One loading screen later, the telescope is now compatible with international hardware. Another might want a larger secondary or scale the design to fit a handmade 6-inch mirror. What was once a framework for the garden variety 4½-inch f/8 is now adaptable to any aperture between about 4 and 10 inches, using any rod diameter for trusses, and any screw — all with the simplicity of the original design.

This system was a boon to me especially — then a graduate student and instructor, I had precious little time for CAD. So, I gambled on some eBay optics my ATM circles were deeply curious about: a 4½-inch f/3.9 and a 6-inch f/3. Their Ronchigrams (a simple method to assess mirror quality) were great, and sure enough, the document spat out perfect files for these scaled versions. In mere hours of design time I had two new telescopes, ready to print. They each assembled neatly in a single evening.

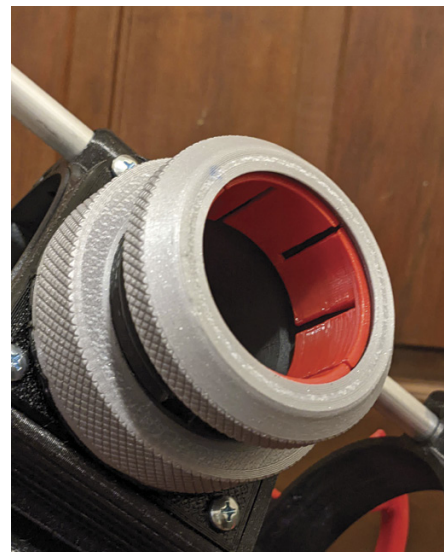
► The author with his 3D-printed Hadley telescope, named after British astronomer John Hadley, who created the first truly useful reflecting telescope.



▲ Telescope maker Sasha Demenko 3D-printed and assembled this Crayford-style focuser, which required some bushings, bearings, and a polycarbonate tube.

If the ads here are to be believed, fancier scopes beget fancier eyepieces. For the larger, faster optics we needed a real focuser. On the parametric version, one designer came up with 45° thread teeth, which allowed for a much tighter focus tolerance. And with a little wax, the focuser was slop-free, even on those large, heavy “hand grenade” eyepieces.

By now, I had my feet back under me and was able to get back to tinkering. I added my own flavor to the focuser, in



▲ The author's focuser for his 114-mm f/3.9 rich-field reflector. He added diamond knurling to someone else's CAD files to demonstrate how to perform fine printing. Note the red clamping collet, which was printed using a more flexible filament. A chamfered edge mated with the top screw ring causes the collar to pinch inward, centering and securing the eyepiece in the focuser.

the form of diamond knurling; I then worked with others to devise a clamp that seated a coma corrector lens permanently between the focuser and the secondary mirror. And this setup doesn't even need to go on a Hadley-style telescope. Now, equipped with a \$100 GSO-brand coma corrector, a novice can enjoy tack-sharp, wide-field views in a Newtonian the size of a loaf of bread. (Twist-top correctors, with adjustable spacing to compensate for various eyepiece designs, otherwise start at around \$300.)

In closing, I'd like to impart one advice: If you make something to be 3D printed, please share the CAD files as well. The community took my focuser and Hadley telescope project a hundred times further than I ever could've on my own, and their new “things” have been just as useful to me. What was one instrument is now a whole ecosystem, ready to house any mirror.

■ Contributing Editor JONATHAN KISSNER is always on the lookout for innovative ATM projects. Enthusied tinkerers can send him their DIY ideas at workbench.kissner@gmail.com.





IONIZATION FRONT

Devon Lucan

NGC 1499, the California Nebula, is a bright emission nebula in Perseus. Named for its similarity to the U.S. state, it bears little resemblance in deep exposures through emission-line filters.

DETAILS: *Sky-Watcher Esprit 100mm ED refractor with ZWO ASI6200MM Pro camera. Total exposure: 98 hours through Chroma narrowband filters.*

▷ STELLAR TWILIGHT

Andrei Pleskatsevich

Messier 57 (the Ring Nebula) is a bright planetary nebula residing in the constellation Lyra. This image reveals its bluish central star as well as bluish bands of thicker nebulosity in its otherwise dark central region.

DETAILS: Celestron 9.25-inch Schmidt-Cassegrain telescope with ToupTek ATR2600C camera. Total exposure: 25 minutes through a Radian Triad narrowband filter.



▽ ODD STARS

Kfir Simon

Although similar to planetary nebulae, WR 31a (left) and AG Carinae (right) are produced by extremely energetic stars shedding material into space. WR 31a is a Wolf-Rayet star, while AG Carinae is a luminous blue variable.

DETAILS: ASA600 24-inch Ritchey-Chrétien telescope with Moravian G3 61000 Pro camera. Total exposure: 4 hours through RGB and hydrogen-alpha filters.

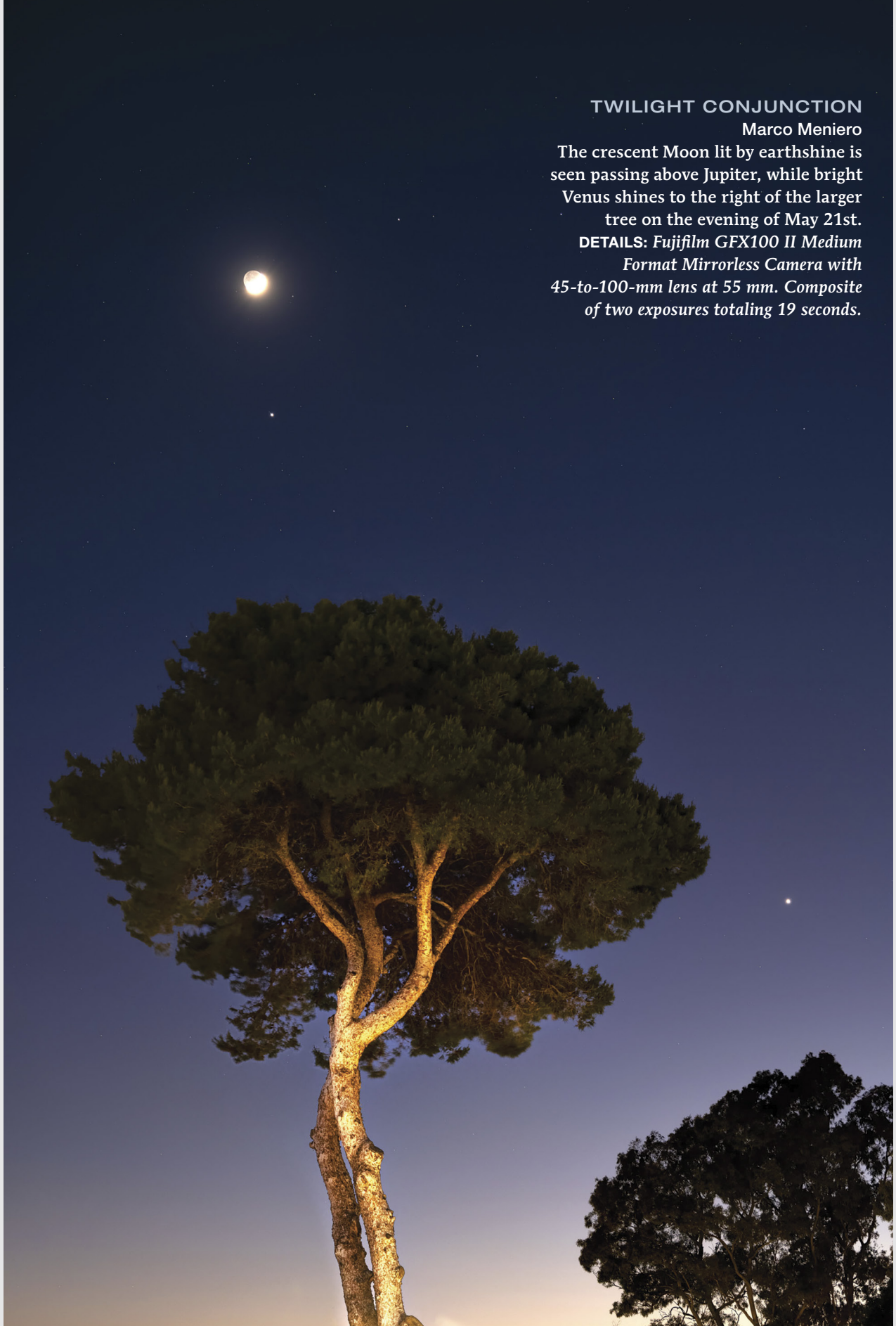


TWILIGHT CONJUNCTION

Marco Meniero

The crescent Moon lit by earthshine is seen passing above Jupiter, while bright Venus shines to the right of the larger tree on the evening of May 21st.

DETAILS: *Fujifilm GFX100 II Medium Format Mirrorless Camera with 45-to-100-mm lens at 55 mm. Composite of two exposures totaling 19 seconds.*



POCKET MILKY WAY**Steve Leonard**

This picture of the central bulge of the Milky Way seen above French River, Ontario, was recorded by simply propping a smartphone against a rock.

Several bright nebulae are visible, including M8 just right of center.

DETAILS: *Pixel 8 smartphone in astrophotography mode. Total exposure: four minutes.*



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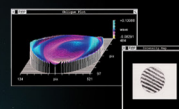


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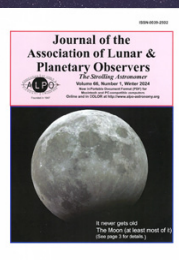
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Event Calendar

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

August 8-16

MOUNT KOBAY STAR PARTY

Osoyoos, BC
mksp.ca

August 10-17

ALMOST HEAVEN STAR PARTY

Spruce Knob, WV
ahsp.org

August 11-16

SASKATCHEWAN SUMMER STAR PARTY

Maple Creek, SK
sssp.saskatoon.rasc.ca

August 12-15

ALCON

Covington, KY
alcon2026.org

August 12-16

NOVA EAST

Smileys Provincial Park, NS
novaeast.rasc.ca

August 13-16

STARFEST

Ayton, ON
nyaa.ca/starfest.html

August 13-16

STELLAFANE CONVENTION

Springfield, VT
stellafane.org/convention

September 3-6

THEBACHA & WOOD BUFFALO DARK SKY FESTIVAL

Fort Smith, NT
tawbas.ca/dark-sky-festival.html

September 7-13

MAINE ASTRONOMY RETREAT

Washington, ME
astronomyretreat.com

September 9-14

NORTHERN NIGHTS STAR FEST

Palisade, MN
mnastro.org/northern-nights

September 10-13

BOOTLEG FALL STAR PARTY

Harmon, IL
bootlegastronomers.com

September 10-13

GREAT LAKES STAR GAZE

Millersburg, MI
greatlakesstargaze.com

September 11-13

CONNECTICUT STAR PARTY

Goshen, CT
asnh.org

September 11-13

IDAHO STAR PARTY

Bruneau Dunes State Park, ID
tinyurl.com/IDStarParty

September 11-13

NORTHWOODS STARFEST

Fall Creek, WI
cvastro.org/northwoods-starfest

September 19

ASTRONOMY DAY

Everywhere!
astronomyday.astroleague.org

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

Astro 101 Bloopers Reel

What the author hopes his students take away from an observatory visit and what they actually do can be two quite different things.

I ASK STUDENTS in my introductory astronomy classes to visit our campus observatory and write a report about the experience. Some reports are first-rate. Others take a more humorous note, whether intentional or not, as seen in the following snippets drawn from a selection of reports (lightly edited for flow, while leaving all typos as is):

"Lastly, I found how to test to make certain that your scope isn't pointed at the Sun: Put your hand in front of the lens and see if it burns. We gazed at other things, but I can't remember what they were called."

"It was sunny tonight. When it was first mentioned that the room wasn't heated, I thought that this just meant that the heat wasn't turned on yet. Brrr. I kept imagining that someone was going to accidentally shut the door to the roof, and we'd all be trapped up there for the night. It seems hard to believe that somebody could invent something like this."

"As I left, I happened to glance up in the sky and saw the North Star, and I remembered the story of the Three Wisemen who followed that star to Jesus. It's too bad that I can't just follow a star and find my way through downtown Minneapolis."

"We observed Arksaurus. It amazes me that we can see a star that is 25 times larger than the Sun. It's really hard to imagine, but I'm sure that they (its discoverers) wouldn't lie to us."

"I saw the planet Jupiter very good. It looked like a snowball in the sky. I thought that the image would be larger than it was, but I guess Jupiter is quite a way from the Earth."

"I can't come up with the exact date I attended the Observatory event. A Dave Matthews cover band was playing on campus."

"Inside the Excusatory is a telescope with a sider scope. It seemed like everything was in its certain place or position for some particular purpose."

"The guy in charge was named Brain. He was pretty friendly. So said my girlfriend."

"We checked out M31. Seeing it through the microscope reviled that it was a dusty poof. These views confirmed that all the photos I've seen are right."

"I ate plenty of carrots for the previous several days, hoping to either see in the dark or turn orange. I took my finance with me, because it was a 'cheap date.'"

■ **THOMAS HOCKEY** is a professor of astronomy at the University of Northern Iowa. He tries to convey to his students the importance of writing well, but he's not always successful. Hockey is the 2026 recipient of the American Astronomical Society's 2026 LeRoy E. Doggett Prize.

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People (actual people) you may know and more than likely, respect, are saying the Helix has more increased (cleaner) views of the Sun they've ever seen. You should check that out.

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