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SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

MAY 2026

The Gateway Project

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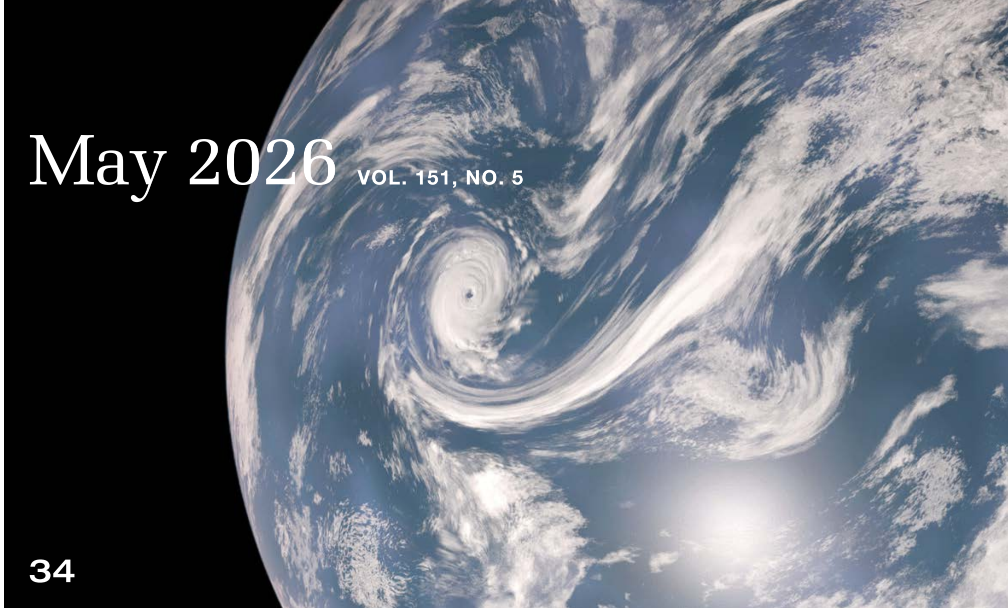
THE ESSENTIAL GUIDE TO ASTRONOMY

May 2026 VOL. 151, NO. 5



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FEATURES

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ON THE COVER

Mirror-reversed image of NGC 6188

PHOTO: JOHN KLEARMAN / JOHNKLEARMAN.COM

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Stronger Together

"IF YOU WANT to go fast, go alone. If you want to go far, go together." As one of many quotes dedicated to the spirit of collaboration, this is one of my favorites.

I'm a big believer in teamwork. Advances in professional astronomy are largely the fruit of vast networks of scientists and engineers working together, often across several continents. The Event Horizon Telescope collaboration, for example, numbered some 200 people in 20 or so countries when they worked on the groundbreaking observations that led to our first image of a black hole's silhouette (*S&T:* Sept. 2019, p. 18). The paper describing the massive multiwavelength campaign observing the first neutron-star merger in 2017, meanwhile, had almost 4,000 astronomers from more than 900 institutions. In fact, such lengthy author lists have popped up for decades in high-energy physics.

▲ Many lenses means more light-collecting power

CONDOR TEAM

But it's not only the professionals who rely on networks of colleagues to further their goals. Amateurs are doing it, too. Turn to page 20 to read about the Gateway Project, an endeavor run by members of an astronomy club based in New York City. Their vision is to provide imaging opportunities to anyone who has the interest and the passion for astrophotography but who doesn't have access to equipment or suitable sites. The project operates two telescopes, one in the Northern Hemisphere and one in the Southern, that are available for members to rent time on. But as author Rick Mavrovich notes, it's not just about the telescopes or the images. It's about the collaborative nature of the project. It's about people getting together (online) and discussing targets and pooling their time slots so as to acquire even deeper images than any single time slot could. It's about working together.

Instruments can join forces, too, to become bigger and better. Starting on page 26, Contributing Editor Govert Schilling brings us the wonderful world of compound telescopes. Instead of having a single giant lens, astronomers are fabricating instruments that bring together multiple lenses — specifically, 1,140 in the case of MOTHRA (yes, named for *that* moth, from Godzilla). Schilling regales us with tales from several compound telescopes, both already operational and in the planning stages, and shows us how all these lenses working in synch bring us exciting new results at the cutting edge of science.

To bring you, our readers, your monthly issue, we at *Sky & Telescope* work together, too. Without the collaborative spirit of our team, the job would be much harder — nay, impossible. So, here's to teamwork. Let's rejoice in doing things together that ultimately bring us deeper and farther in our quest to understand and celebrate the universe.

Editor in Chief

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▲ Astronomers combined more than 2,000 Hubble images of a patch of sky in Fornax, the Furnace, to create this Extreme Deep Field.

Deep Field Inspiration

The iconic Hubble Deep Field (*S&T:* Dec. 2025, p. 14) actually owes its name to *Sky & Telescope*. I was fascinated by astronomy in high school, and my great uncle gifted me an *S&T* subscription each year. At the time (1955), one of the regular columns in the magazine was Walter Scott Houston's Deep-Sky Wonders. Each month, Houston would suggest objects that amateurs with large telescopes might be able to observe. I was always fascinated by that column, and it was the first thing I read when I received my issue in the mail.

After I formed the team to take the HDF observations, one of the members asked me what we should call the project. I instantly answered, "Let's call it the Hubble Deep Field." The name stuck. Whenever I hear it now, I always think back on the Walter Scott Houston columns that made up my first astronomy readings. They and *S&T* deserve due recognition, and my gratitude, for fueling my early interest in astronomy!

Bob Williams
Baltimore, Maryland

Honoring Porter

After experiencing the prolific creativity of Russell Porter up close at Stellafane 1981, I enthusiastically proposed live solar displays for Science North, the new science center in northern Ontario (*S&T:* Sept. 1989, p. 258). A unique cooperation between the telescope makers of the Sudbury Astronomy Club and Science North made the idea practical.

The mounts and light paths of the main 17½-inch f/17 optics were a close parallel to those of the Jordan Marché polar telescope that Jonathan Kissner described in "A Polar Telescope in the Spirit of Porter" (*S&T:* Nov. 2025, p. 74). The main difference was that we brought the prime focus and relay light path into the Solar Observatory Theater for indoor viewing, through a slot in the overhanging theater floor. It occupied the southernmost point of the snowflake-shaped building, with the polar-aligned flat mirror just outside.

Steve Dodson
Sudbury, Canada

A Journey with the Deep Sky

I fell in love with astronomy at the age of 12 after receiving my very first issue of *S&T*. The little Deep-Sky Wonders column by Leland Copeland that accompanied the magazine's monthly sky map made me realize that it was the aesthetic side of the subject that was my passion. An article in the February 1917 issue of *Popular Astronomy* by Harvard astronomer William Pickering titled "The Sixty Finest Objects in the Sky" inspired me to survey the entire heavens for its visual showpieces and treasures. British astronomer T. W. Webb in his classic *Celestial Objects for Common Telescopes* wrote, "But it is to be hoped that some zealous lover of this great display of the glory of the Creator will carry out the author's idea, and study the whole visible heavens from what might be termed a picturesque point of view." That sealed it for me! I then told *S&T*'s famed columnist Walter Scott Houston of my plan, and he said that it was an impossible undertaking — but then characteristically told me, "Go for it anyway!" Thus began my 70-year quest that resulted, among other things, in the *S&T* series "The Finest Deep-Sky Objects." May *S&T* continue to inspire many new generations of stargazers and writers of astronomy.

James Mullaney
Lewes, Delaware

Table Mountain Memories

I enjoyed that spectacular photo of South Africa's Table Mountain in Susan Young's article "The Mountain of Stars" (*S&T:* Nov. 2025, p. 20), which chronicled the work of three historic astronomers who studied the night skies from Cape Town. I especially love the photo because it shows where I was born. Draw a line straight down from the letter "n" in the word "landform" on that page. It strikes Kloof Nek, between Table Mountain and Lions Head at the right. That is where I arrived on Planet Earth. After we moved to Lakeside, a suburb about 24 km to the south of Cape Town, I grew up assuming that the entire heavens were as spectacular as could be seen on any clear night from our backyard. Even there, Table Mountain always loomed.

Gerrit Verschuur
Fort Lauderdale, Florida

Observing 34 Tauri

It's well known that Uranus was observed several times prior to its discovery in 1781 but was always assumed to be a star. In particular, John Flamsteed observed it in 1690 and entered it into his famous star catalog under the designation 34 Tauri (*S&T:* Jan. 1978, p. 52).

Flamsteed observed Uranus on December 23, 1690, in the Gregorian calendar. (See page 85 of *The Planet*

NASA, ESA, G. ILLINGWORTH, D. MAGEE, AND P. OESCH (UC SANTA CRUZ), R. BOUWENS (LEIDEN UNIVERSITY), HUDF09 TEAM

Uranus by A. F. O'D. Alexander.) In the coming year, having completed exactly four orbits of the Sun since 1690, Uranus returns to the spot where Flamsteed saw it. So we can again observe the "star" 34 Tauri as Flamsteed did so long ago.

Planetarium software shows three dates when Uranus will occupy almost the same position it did when Flamsteed observed it: June 12 and December 19, 2026, and March 29, 2027. The June event will be difficult to observe in morning twilight, but the planet will be favorably placed for the December and March events. I encourage readers to observe this "reappearance of 34 Tauri."

Warren Morrison
Cavan, Canada

Pop-Up Moon

Over the years, you have consistently provided amateur astronomers and others with continuously fine articles about the Moon, but "Hidden in Plain Sight" by Charles A. Wood (*S&T:* Dec. 2025, p. 52) was especially enjoyable. The rilles pop up with the proper solar lighting. It was fascinating.

Carl Masthay
St. Louis, Missouri

Hunting Ancient Comets

There are 16th- and 17th-century books from Germany mentioning ancient and medieval comets that don't appear in any other known texts. No source is mentioned. But there are clues.

My conclusion is that the source for the German literature was written after the appearance of the spectacular comet in 1264 by the astrological writer and translator Stephen of Messina. Stephen of Messina had access to much earlier literature from the Near East. So the list may include useful information about comets observed more than a thousand years earlier.

It appears that the German authors came across the comet list somewhere in southern Germany. As I myself am located elsewhere, I'm looking for someone who is willing to search the archives in southern Germany, or who can at least share something useful with me. Please email me at old999new@hotmail.com.

Göran Johansson
Lund, Sweden

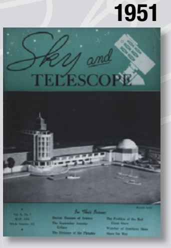
FOR THE RECORD

- The star HD 217591 on page 78 of the February issue was reemerging from behind the Moon rather than about to be covered.
- If dark energy were constant, the universe would continue to expand at an increasing rate. The "Big Rip" mentioned in "New Data Hint at Changing Dark Energy" (*S&T:* Aug. 2025, p. 8) would only occur if the density of dark energy was increasing over time.

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

75, 50 & 25 YEARS AGO by Sabrina Garvin

1951



1976

2001

May 1951

New Planetarium "In February, Bradford Washburn, director of the Boston Museum of Science, announced that the construction of the largest planetarium in New England would commence in the near future. . . .

"The planetarium will be of relatively moderate size, seating about 225 persons or more, with its interior dome 55 feet in diameter. The illusion of the sky is expected to be as good as that obtained with larger domes, and the cost of construction and operation will be considerably less. A roof deck of good size will permit observations with telescopes. Science Park, located on the Charles River dam at the eastern end of the Esplanade, has a favorably low horizon and is well protected from the bright lights of Boston."

Boston's Charles Hayden Planetarium would open its doors in October 1958.

May 1976

Aussie Eclipse "It is unusual for the same country to be crossed by the moon's umbral shadow during two consecutive total solar eclipses. On June 20, 1974, the shadow skirted Australia's southwest corner, and we now look forward to a much more favorable eclipse on Saturday, October 23, 1976.

"Weather permitting, totality will be observable from one of the most populous parts of the continent, including the metropolitan area of Melbourne, with nearly three million inhabitants. Almost all the path of totality across South Australia, Victoria, and New South Wales is accessible to observers, with a network of roads that permits selecting sites from a wide variety of terrains, including coastal plains and high mountains. Thus, thousands of amateur and professional astronomers, many of them from other countries, will station themselves within the shadow path that Saturday afternoon."

May 2001

Radioactive Stars "A team of astronomers led by Roger Cayrel (Paris Observatory, Meudon) has announced the first-ever detection of uranium in a star other than the Sun. This result has allowed Cayrel to calculate not only the age of the ancient star but a minimum age for the galaxy and universe.

"Using a sensitive new spectrograph on the 8.2-meter Kueyen unit of the European Southern Observatory's Very Large Telescope, Cayrel and his colleagues measured a trace of uranium-238 in CS 31082-001, an ancient, 12th-magnitude star in the Milky Way's halo. They then compared that to the star's thorium-232 content. Their ratio yielded an age of 12.5 ± 3 billion years.

"Unfortunately, radioactive dating of stars is fraught with potential uncertainties. Only one very weak spectral line of uranium was seen. Also, it is unclear what the initial concentrations of uranium and thorium were in the ancient star."

OBSERVATORIES

The Schmidts Fund Four New Observatories

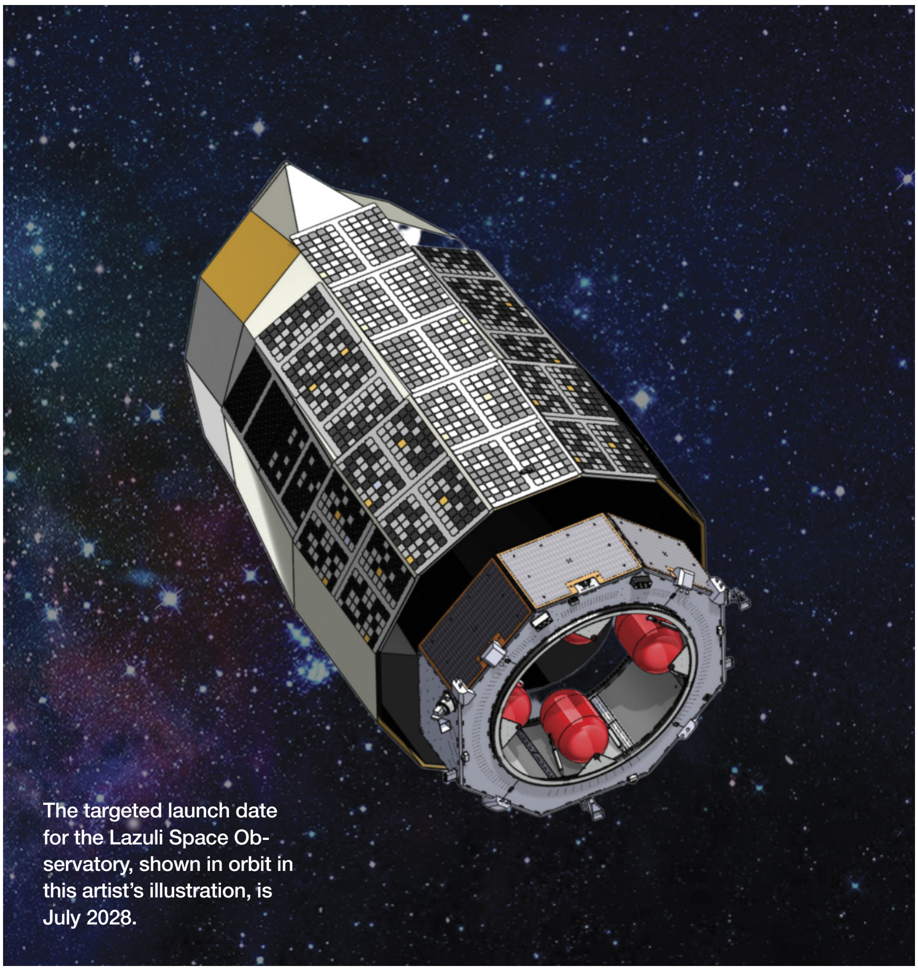
WITHIN THREE YEARS, private funding may give astronomers four new observatories — including one in space.

Schmidt Sciences, a philanthropic organization created and funded by former Google CEO Eric Schmidt and his wife, Wendy, announced the ambitious Schmidt Observatory System on January 7th at the 247th meeting of the American Astronomical Society (AAS) in Phoenix, Arizona. Schmidt Sciences expects data collection from all four observatories to begin by 2029, with all images and spectra to be made freely available to the public.

"We're going to be very fast and risk-embracing and try to do things inexpensively, and yet try to serve world-class science," says Arpita Roy, director of astrophysics and space at Schmidt Sciences. "And we will either succeed, or we will learn something."

The most ambitious of the projects is the Lazuli Space Observatory. The team aims to launch it in just two years (by 2028) to a lunar-resonant orbit, with the goal of coordinating observations with other telescopes, such as the Nancy Grace Roman Space Telescope and Vera C. Rubin Observatory. Lazuli boasts a 3-meter mirror that's even bigger than the 2.4-meter mirrors in the Hubble and Roman space telescopes, offering it more than half again the light-collecting power in the visible-to-near-infrared range.

In addition to a wide-field camera and spectrograph, Lazuli will carry a *coronagraph*, which will block out bright objects' light to enable the detection of faint nearby sources, such as exoplanets or protoplanetary disks circling their host stars.



The targeted launch date for the Lazuli Space Observatory, shown in orbit in this artist's illustration, is July 2028.

SCHMIDT SCIENCES

The observatory is designed for fast response — slewing to time-sensitive requests in at most four hours, and perhaps as fast as 90 minutes — enabling astronomers to quickly follow up on fast-changing targets.

Another ambitious project, the Deep Synoptic Array (DSA) will ultimately have 1,650 radio dishes, each one 6.15 meters across, working in tandem on the floor of a radio-quiet valley in Nevada. The array, which has been in the works for some time (*S&T:* Sept. 2023, p. 14), will for the first time make radio images on the fly, says principal investigator Gregg Hallinan (Caltech). While the view won't be as sharp as existing radio arrays, DSA will have a much faster survey speed.

"Every radio telescope ever built has detected about 10 million radio sources," Hallinan says. "We'll double that in the first 24 hours and . . . we'll detect about a billion radio sources over a five-year survey."

Not to be outdone is the Argus Array: Some 1,200 telescopes with 28-centimeter (11-inch) apertures will work together to record the sky at at visible and infrared wavelengths, probably from a site in Texas. The telescopes will be set in tilted, circular arrangements to capture 8,000 square degrees — about the same field of view as the human eye — every minute. The result: a near-continuous movie of the night sky. For more on the Argus Array, see page 26.

Accompanying Argus's visible-to-near-infrared imaging is the Large Fiber Array Spectroscopic Telescope (LFAST), which will take spectra across the same wavelength range. To do so, it will combine 76-cm telescopes in multiples of 20, set on a common frame and outfitted with two spectrographs each. LFAST will likely observe from Kitt Peak in Arizona.

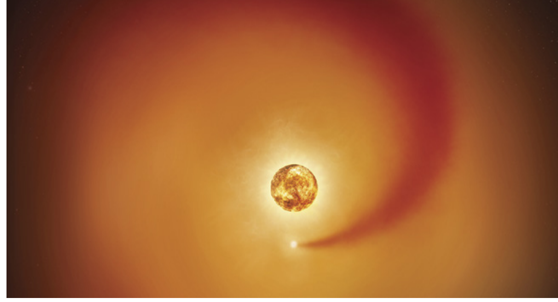
When asked how Schmidt Sciences would measure success, President Stuart Feldman joked, "Nobel Prizes per year." While the statement was in jest, it's clear — expectations are high.

■ MONICA YOUNG

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

STARS

Betelgeuse's Possible Companion Might Be Making Waves



▲ This artist's concept shows Betelgeuse orbited by a companion star trailing a dense gaseous wake.

BETELGEUSE, the bright orange star marking Orion's shoulder, might have a companion star. While astronomers haven't definitively observed this putative companion directly, they might have found what it leaves behind.

In a new study to appear in the *Astrophysical Journal*, researchers led by Andrea Dupree (Center for Astrophysics, Harvard & Smithsonian) report evidence for a dense, expanding wake in the red supergiant's extended atmosphere. The result, which Dupree announced on January 5th at the 247th AAS meeting, is consistent with the long-standing hypothesis that Betelgeuse hosts a companion.

Evidence for this companion comes from Betelgeuse's variations. The star brightens and fades following two patterns: There's a 400-day cycle, attributed to the star's own pulsations, and a cycle of 2,100 days that remains unexplained. The latter period of about six years could come from the influence of a secondary star.

If real, the companion would be modest, roughly the Sun's mass and six magnitudes dimmer than Betelgeuse. So close to the primary star, it would be embedded within Betelgeuse's atmosphere. A technique known as *speckle interferometry* previously returned a hint of the companion's presence but not a firm detection (*S&T:* Dec. 2025, p. 9).

Rather than imaging the companion directly, Dupree's team reasoned that an object orbiting deep in the atmosphere would stir the surrounding gas. To search for that signature, the team analyzed 6.5 years' worth of spectra, pairing those data with ultraviolet observations from the Hubble Space Telescope. Tracking features that strengthened, weakened, and shifted relative to the 2,100-day cycle, the researchers found patterns consistent with a moving trail of denser material.

Dupree describes these observations as "strong confirmation of the presence of a companion star."

Computational astrophysicist Jared Goldberg (Flatiron Institute) says the observations fit theoretical expectations of a companion, even if they don't constitute irrefutable proof yet.

Researchers are now looking ahead to late 2027, when the companion should re-emerge from behind Betelgeuse, offering the best opportunity yet for direct observation.

■ ANA GEORGESCU

SPACE

NASA Budget Woes Are Over — for Now

NASA'S FUNDING BILL for 2026 has resolved chaos initiated when the White House proposed a 47% cut to the agency's science divisions last year (*S&T:* Oct. 2025, p. 10). Such a plan would have axed more than 40 missions.

After months of advocacy, NASA's $24.4 billion budget represents an overall decrease in spending of only 1.7%. The bill includes specific language requiring NASA to spend no less than its allotted amounts — a measure likely designed to prevent the White House Office of Management and Budget from refusing to issue the money.

Among the projects recovered from cancellation are planned missions to Venus as well as ongoing missions to a near-Earth asteroid and the outer solar system. The Chandra X-Ray Observatory is saved, too. Congress also restored funding to NASA's collaboration with the European Space Agency for the Mars-bound Rosalind Franklin Rover and the Laser Interferometer Space Antenna gravitational-wave mission. The Nancy Grace Roman Space Telescope, set to launch as early as fall 2026, is funded at $300 million, twice the White House's request.

Under the same bill, the Laser Interferometer Gravitational-Wave Observatory, funded by the National Science Foundation, will receive $49 million, so it won't have to shutter one of its two sites — a proposal that sparked outrage in spring 2025.

However, Congress declined to fund the Mars Sample Return project, instead setting aside $110 million for "Mars Future Missions." Nevertheless, bringing home the rock samples is "still the community's top priority," says Victoria Hamilton (Southwest Research Institute). China is planning its own Mars sample return, to launch in 2028.

NASA's new administrator, Jared Isaacman, has pledged to support NASA science while pushing for stronger commercial ties. His appointment came after what was, according to a joint statement from multiple scientific advocacy groups, "a lost year for American science." But the new budget has many feeling cautiously optimistic for the first time in months.

■ HANNAH RICHTER

An artist's illustration shows NASA's DAVINCI probe — now funded through 2026 — descending through Venus's atmosphere.

BETELGEUSE: ARTWORK: NASA / ESA / ELIZABETH WHEATLEY (STSCI), SCIENCE: ANDREA DUPREE (CFA); DAVINCI: NASA / GSFC / CI LABS / MICHAEL LENTZ

STARS

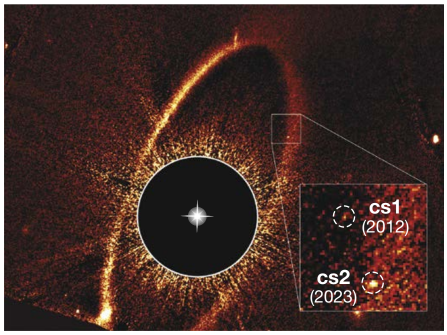
Did Asteroids Again Collide Near Fomalhaut?

OVER THE PAST TWO decades, there appear to have been not one but two collisions around the nearby, 440-million-year-young star Fomalhaut.

Images that the Hubble Space Telescope took in 2023 show a bright spot about 135 astronomical units from the star that wasn't there in earlier observations from 2014. In another image from Sept. 2024 the spot had moved, ruling out a background source.

"This is certainly the first time I've ever seen a point of light appear out of nowhere in an exoplanetary system," says Paul Kalas (University of California, Berkeley), who led the study published in the January 22nd *Science*. "We just witnessed a violent collision between two massive objects forming a huge debris cloud."

The researchers estimate that the objects that created this cloud measured less than 200 kilometers (120 miles) wide. The cloud itself will likely disperse in a few years.



▲ This composite Hubble Space Telescope image shows the debris ring around Fomalhaut. The dust clouds cs1 and cs2, as seen in 2012 and 2023, respectively, are labeled.

The team found this collision because they were looking for another dust cloud from two decades ago, which had been initially mistaken for a planet. In 2004, when Kalas and colleagues imaged Fomalhaut's infant planetary system with Hubble for the first time, they found a slightly offset belt of dust, with a sharp inner edge that suggested the presence of a shepherding planet. Those and additional observations revealed a point-like source orbiting the star within the belt, dubbed Fomalhaut b and considered an exoplanet.

But in 2013, Hubble showed Fomalhaut b had faded, expanded, and drifted slightly away from the star. And by 2014, Hubble failed to detect it at all. Rather than a planet, some astronomers suggested it was debris from a collision.

Hubble's 2023 observations show no clear evidence of Fomalhaut b, now called *circumstellar source 1* (cs1). But 1.26 arcseconds from where cs1 was found 20 years earlier, equivalent to 23.4 au away, is the new dot, cs2.

"In 2020, we showed that [cs1] is likely a result of a massive planetesimal collision in the system," comments András Gáspár (University of Arizona), who was not part of Kalas's team. "I am glad to see our earlier conclusions on Fomalhaut b validated."

Two collisions in two decades suggest Fomalhaut's protoplanetary disk might be more violent than once thought.

■ **JAN HATTENBACH**

STARS

Andromeda Arc Might Be Remnant of Dying Star

AN ARC OF GLOWING gas near the Andromeda Galaxy on the sky — named Strottner-Drechsler-Sainty Object 1 (SDSO-1) for the trio of amateur astronomers who discovered it (*S&T:* May 2023, p. 10) — might be the aftershocks of a dying Milky Way star.

The arc's glow comes from doubly ionized oxygen atoms, but it has remained unclear where those atoms are — near Andromeda or in our own Milky Way — and how they lost their electrons.

Posting to the astronomy arXiv preprint server, Patrick Ogle (Space Telescope Science Institute) and colleagues propose that the arc is a 400,000-year-old aftershock created by a *planetary nebula*, the gas layers expelled from a red giant star as its core collapsed into a white dwarf. The team has identified the white dwarf in the nearby binary system EG Andromedae as the likely culprit.

Planetary nebulae typically expand and become too faint to see after a few tens of thousands of years. But in this case, the researchers suggest, some of the dying star's debris lit up again as it rammed into interstellar gas. Ogle's team names this phenomenon a *ghost planetary nebula.*

▶ Amateurs discovered an arc of gas near the Andromeda Galaxy on the sky in 2023. Two new studies show it most likely originates in the Milky Way.

The findings are based on 525 hours' worth of imaging of SDSO-1 and its surroundings. The images reveal doubly ionized oxygen emission centered on EG Andromedae, with fainter filaments extending away from the white dwarf. The features indicate a fast-moving shock, Ogle's team argues.

Alejandro Lumbreras Calle (Aragon Center for Studies of the Physics of the Cosmos, Spain) disagrees, saying he finds the scenario "complicated to accept." In the December 2025 *Astronomy and Astrophysics*, Lumbreras Calle and colleagues find that SDSO-1 is *photoionized*, rather than shocked. SDSO-1 would be 10 times larger than any known planetary nebula. And its gas is moving too slowly and uniformly for it to be a shock front, they argue. Photons from a nearby bright source — as-yet unidentified but unrelated to EG Andromedae — might more gently strip off electrons.

Measurements of gas motion in different parts of the arc could help settle which of these scenarios, if any, is the best explanation.

■ **ARIELLE FROMMER**

Read more: skyandtelescope.org/AndArc.

CS1 AND CS2 IN FOMALHAUT SYSTEM: IMAGE: NASA / ESA / PAUL KALAS (UC BERKELEY), IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI); ANDROMEDA ARC: PATRICK OGLE ET AL. / ASTROBIN

COSMOLOGY

Starless Gas Cloud Might Be Failed Galaxy

WHILE EVERY GALAXY in the universe is anchored in an unseen halo of dark matter, there ought to be some halos in which stars never formed. Astronomers think they've found one of them.

Cloud 9 is a cold clump of hydrogen gas with no stars. "It's basically a galaxy that wasn't," says Rachael Beaton (Space Telescope Science Institute), who announced the result on January 7th at the 247th AAS meeting. The result also appears in the November 10th *Astrophysical Journal Letters*.

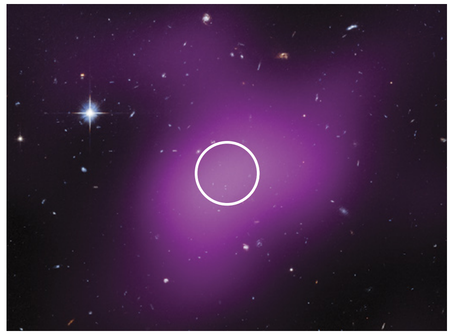
The team discovered Cloud 9 using the Chinese Five-hundred-meter Aperture Spherical Radio Telescope (FAST). Other radio observatories mapped the cloud, revealing 1 million solar masses of neutral hydrogen. But that's not enough heft to explain how the large clump stays together. The team deduced that it's probably underpinned by 5 billion solar masses of dark matter.

Intriguingly, visible-wavelength images, including from the Hubble Space Telescope, show no starlight. The team estimates there could only be, at most, 3,000 Suns' worth of stars lurking in the cloud.

The team suggests that Cloud 9 is a *reionization-limited hydrogen I cloud* (RELHIC). These isolated clumps are thought to have come together during the early cosmic epoch when the first stars began to shine.

"[The discovery] is plausible," says Matthieu Schaller (Leiden University, The Netherlands), who was not involved in the study, "if it's not a cloud in the Milky Way."

The team measured Cloud 9's distance by the speed at which it's receding in the expanding universe. It matches the recessional speed of Messier 94, which is nearby on the sky, placing the cloud at 14 million light-years away. But further observations are needed to confirm its distance and make sure it's not a much closer, ordinary gas cloud in the Milky Way.



▲ Radio emission from Cloud 9 (magenta) is superimposed on Hubble's image of the same region. Researchers searched primarily within the circle for stars belonging to Cloud 9.

■ **ARIELLE FROMMER**

COSMOLOGY

"Missing" Supernova Images Offer Measure of Universe's Expansion

DECADES FROM NOW, photons from an exploded star will arrive at Earth. Astronomers have already seen it happen: The James Webb Space Telescope captured light from a distant supernova named Ares and, according to predictions, two identical images will appear in about 60 years.

The trick is that Supernova Ares went off behind the galaxy cluster MACS J0308, whose mass splits light from background objects into multiple images. While some photons have already hit Webb's detectors, others are taking the scenic route, bending around the cluster on a decades-longer path.

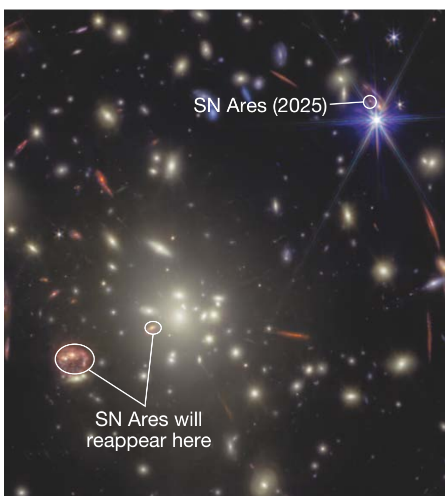
Conor Larison (Space Telescope Science Institute), who presented the results on January 7th at the 247th AAS meeting, showed several images from the Vast Exploration for Nascent, Unexplored Sources (VENUS) program. Led by Seiji Fujimoto (University of Toronto, Canada), VENUS employs the James Webb Space Telescope in imaging about 60 galaxy clusters, using them as gravitational lenses to study more distant objects.

In the case of Supernova Ares, the long lag will offer astronomers the highest-precision measurement yet of such a time delay. Studying lensed images and their time delays is one way that astronomers measure the universe's current expansion rate. Alongside other lensed supernovae, Ares could break through a current stand-off in cosmology about what that rate is (*S&T:* Mar. 2022, p. 14).

But cosmological implications from Ares are decades in the future. Fortunately, the VENUS team has found other blasts: Supernova Athena, behind the cluster MACS J0417, should have another image arriving in a year or two. The researchers have also found four other lensed supernovae whose images are all present and accounted for; more are expected as the program continues.

"Eventually, when we have enough of these [lensed supernovae], maybe around 20, we'll be able to reach a total precision that's comparable to our best current cosmological distance indicators," Larison says.

And if larger samples don't do the trick, well, we can always wait for the next images of Supernova Ares, due to arrive in 2086.



▶ The lensing effect of the MACS J0308 galaxy cluster creates multiple images of the host galaxy of Supernova Ares. The supernova will appear in about 60 years in the two images at bottom left, nearer the cluster center.

■ **MONICA YOUNG**

RADIO IMAGE OF CLOUD 9: NASA / ESA / VLA / GAGANDEEP ANAND (STSCI) / ALEJANDRO BENITEZ-LLAMBAY (UNIVERSITY OF MILANO-BICOCCA), IMAGE PROCESSING: JOSEPH DEPASQUALE (STSCI); GALAXY CLUSTER: NASA / ESA / CSA, IMAGE PROCESSING: GAVIN FARLEY

SOLAR SYSTEM

The Effect of Mars on Earth's Climate

PUNY MARS ONLY has about one-tenth of Earth's mass. Yet its gravitational tugs might pack a punch, subtly reshaping Earth's orbit to trigger large-scale shifts in our climate.

Gravitational interactions with other planets are already known to influence Earth's long-term climate via *Milankovitch cycles*. In recent years, scientists have proposed a 2.4-million-year cycle to explain several patterns, including sudden biological diversification such as the *Cambrian explosion* of marine life more than 500 million years ago.

Some pointed to Mars as a possible driver of that cycle. But Stephen Kane (University of California, Riverside) and colleagues were skeptical that Mars could exert such a strong influence on terrestrial processes. So they conducted a series of computer simulations to test these ideas, publishing results in the December *Publications of the Astronomical Society of the Pacific*.

Mars, as seen by Viking 1

Those results proved them wrong. While some orbital oscillations are primarily driven by Venus and Jupiter, Mars plays a critical role in others. When the team removed Mars from the simulations, two cycles — one lasting about 100,000 years and another 2.4 million years — vanished entirely. Conversely, increasing the mass of Mars strengthens these cycles.

The simulations also showed Mars's effect on Earth's *axial tilt*. Our planet's rotation axis is inclined by about 23.5° to our orbit around the Sun, but this tilt varies slightly on a 40,000-year cycle. The researchers found that a more massive Mars would lengthen these variations, stabilizing Earth's axis over longer time scales.

Mars's outsize influence on Earth stems from its location rather than its mass. The Sun's gravitational grip is weaker out at Mars, giving the planet a surprisingly large sphere of influence — one that includes Earth.

Taken together, the results suggest that Mars has played a subtle but consequential role in shaping Earth's climate, influencing long-term habitability and the evolution of life.

■ JAVIER BARBUZANO

NASA / USGS

IN BRIEF

Does Mars Have an Underground Lake?

Scientists first proposed a subglacial lake on Mars in 2018 (*S&T:* Nov. 2018, p. 8) to explain observations from the European Space Agency's Mars Express orbiter. The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) instrument detected a reflective signal below the south polar ice cap. A team, led by Roberto Orosei (now at University of Bologna, Italy), interpreted the signal as salty water in an underground lake. But new radar data from a different orbiter have reversed that interpretation. The Mars Reconnaissance Orbiter's Shallow Radar (SHARAD) sounder, which is optimized for higher-frequency near-surface imaging, saw only a faint signal from the same boundary. Gareth Morgan (Planetary Science Insitute) and colleagues describe the findings in the November 28th *Geophysical Research Letters*. The strong reflection that MARSIS observed might only be a smooth patch — such as an ancient lava flow — within irregular terrain below the ice cap. The SHARAD data, however, do not definitively disprove the subglacial lake. Orosei notes that the sounder is operating at the edge of its capability at such depths. A liquid water layer might still exist but simply be too faint for SHARAD to detect.

■ JAVIER BARBUZANO

MAVEN Lost in Space

Since December 6th, ground stations in NASA's Deep Space Network have failed to receive a signal from the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft. MAVEN was helping scientists study the interaction between the solar wind and Mars's tenuous atmosphere, addressing the mystery of how the planet lost most of its air to space. The spacecraft periodically falls out of communications range when it passes behind Mars as seen from Earth; however, this time around, it failed to reconnect when it came back in range. Preliminary analysis of signal fragments detected on December 6th suggests that the spacecraft was spinning at an unexpected rate, and its trajectory might have changed. Curiosity tried to image the spacecraft from the Martian surface on December 16th and 20th, but it was unsuccessful. Recovery efforts were hindered from December 29th through January 16th, while Mars was behind the Sun from Earth's perspective, but on January 26th, NASA announced recovery efforts had resumed.

■ DAVID DICKINSON

Three Small Astronomy Satellites Launch

On January 11th, SpaceX launched a rideshare payload that included three small astronomy-related missions. Pandora, a satellite that's part of NASA's Pioneers program, will observe 20 planet-hosting stars at visible and infrared wavelengths, measuring at least 10 transits of each world to understand their atmospheres. The Star-Planet Activity Research CubeSat (SPARCS), a NASA-funded collaboration led by Arizona State University, will monitor ultraviolet emission from 20 low-mass stars to explore the impact of stellar flares on the systems. Finally, the NASA-funded Black Hole Coded Aperture Telescope (BlackCAT), designed and built at Pennsylvania State University, will conduct a wide-field X-ray survey, capturing energies from 500 to 20,000 electron-volts. The mission's goal is to find transient events from the early universe, including gamma-ray bursts and forming black holes. All three satellites deployed successfully into Sun-synchronous low-Earth orbits and have nominal missions of one year. NASA has reported acquisition of signal from Pandora, and the SPARCS and BlackCAT teams are in the commissioning phase prior to starting data collection.

■ DAVID DICKINSON

A Baffling Lunar "Square"

Try to spot this intriguing Moon feature in the Sea of Cold.

MÄDLER'S SQUARE, an imagined lunar formation next to the 38-km-wide (24-mile-wide) crater Fontenelle on the northern edge of Mare Frigoris, has been a source of intrigue for nearly 200 years — perhaps because it's partly illusory.

In 1830, German observers Wilhelm Beer and Johann Mädler began critical observations of the Moon with a 3¾-inch Fraunhofer refractor. Four years later, the duo published *Mappa Selenographica* — the first large-scale lunar map based on precise micrometric measurements of more than 2,000 surface features. A follow-up volume, *Der Mond (The Moon)*, published in 1837, describes each measured feature. "The most remarkable formation in this area," the authors say, "is the square mountain range to the [east] of Fontenelle . . . Despite the very different heights of its sides, the analogies are so striking that it is difficult to resist the idea that this is a selenitic work of art."

In his 1977 *Guide to the Moon*, Patrick Moore takes credit for the feature's "unofficial name." However, the moniker is somewhat misleading. As Beer and Mädler explain in *Der Mond*, the effects of perspective "makes us see not a square but a rhombus. . . . If the structure were moved without changing its position relative to the cardinal points, to a location 20 degrees closer to the center of the moon, i.e., to [the crater] Helicon d in Mare Imbrium, it would appear as a perfect square when viewed from Earth."

In his 1859 *Celestial Objects for Common Telescopes*, the Reverend Thomas W. Webb saw the formation as a "nearly square enclosure foreshortened into a lozenge." But let's look at how Beer and Mädler describe each side of the Square:

Side e–d. "The highest (north-[eastern]) side of the square "is a steep slope with . . . two protruding peaks at both ends; between them is a row of small peaks, like towers on a rampart."

Side d–g. "The north[western] side has no general connection, but the position and direction of all the mountains congruate exactly with the side of a square. . . . The [western] corner is rounded and closed off by the encroaching wall of Fontenelle."

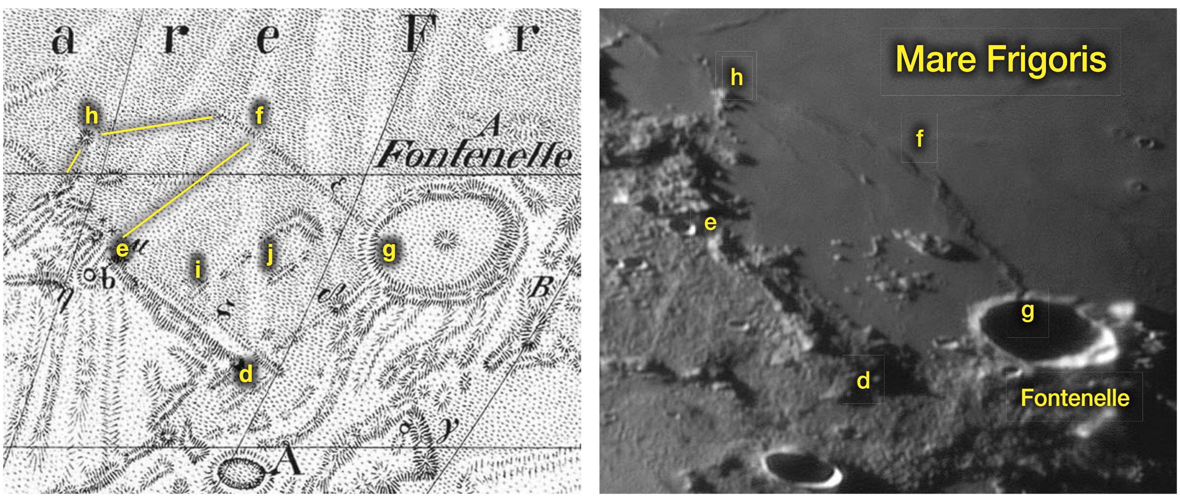
Side f–g. "The mountain range to the south runs parallel to the main rampart." This feature is a wrinkle ridge that formed when tectonic forces buckled the surface of Mare Frigoris. Beer and Mädler followed this ridge slightly beyond the Square's southeastern corner (**f**), but the ridge actually continues to the peak **h**.

Side e–f is a mystery. Of it Beer and Mädler say, "The south[east] side is not marked by a wall, but by a wide strip of light that branches off from the south corner of another strip marking the diagonal of the square."

Moore says that there's a "low ridge there, and the land to the west is slightly darker than that to the east, so that in a small telescope, such as Mädler used, the square looks complete." If so, the "wall" may be a contrast illusion. Then again, perhaps, the raised terrain that Moore indicates is so shallow that it may be sighted only during extreme lighting conditions. Indeed, Webb says, "Unfortunately, [the Square] lies in such a position that years, as Beer and Mädler observe, may pass without a good view of it." So, here lies the challenge.

By the way, within the Square, Beer and Mädler observed a "very regular cross," as well as a "row of small peaks and ramparts, the beginning of which . . . divides the square into two congruent rectangles." (In the illustration below, the cross is denoted by **i**, and the rows of peaks by **j**.) They represent the western rectangle that many observers mistake for Mädler's Square. So be aware.

■ Contributing Editor **STEPHEN JAMES O'MEARA** has been observing the Moon for nearly 50 years.



▲ **A PERPLEXING LUNAR FEATURE** *Left:* This section from Wilhelm Beer and Johann Mädler's 1834 *Mappa Selenographica* shows the "Square" marked with corners **d**, **e**, **f**, and **g**, as well as the extension to point **h**, which creates the lozenge effect, and the line connecting **e** and **f** that forms the Square's southeastern side. Features **i** and **j** are explained in the text. Compare this view of the Square with NASA's Lunar Reconnaissance Orbiter image *(right)*. South is up and east is to the left.

MOON MAP: ETH-BIBLIOTHEK ZÜRICH, RAR KS 281
MOON IMAGE: NASA / GSFC / ARIZONA STATE UNIVERSITY

Spring Outreach

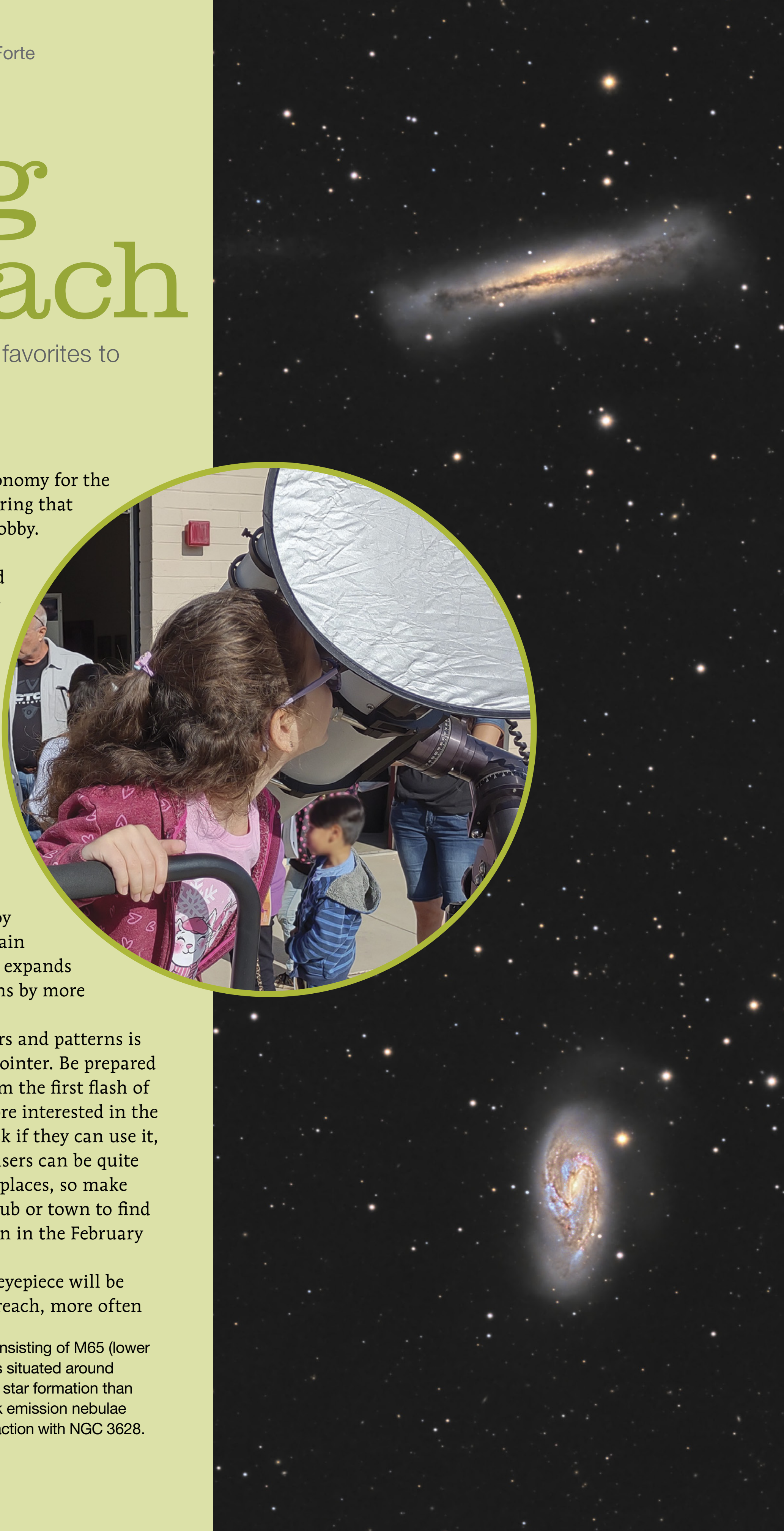
Here are some all-time deep-sky favorites to inspire people to look up.

Amateur astronomers pursue astronomy for the sheer love of the subject, and sharing that passion is a natural part of the hobby. I participated in my first organized public outreach event 30 years ago, and I still find it to be fun and rewarding. And it's important. Through outreach, we inspire new generations of scientists as well as future amateurs and dark-sky activists. It's also essential to the survival of astronomy clubs — not only does it attract new members, but those who participate in outreach programs usually stay longer with the club and are generally more active overall.

Newly minted amateurs are often reluctant to engage in outreach, perhaps feeling unprepared for the task. Yet, once they take the plunge, most really enjoy interacting with the public. They quickly gain confidence in their own knowledge, which expands exponentially as they listen to presentations by more experienced astronomers.

The most common way to point out stars and patterns is certainly with the ubiquitous green laser pointer. Be prepared for the surprise and curiosity resulting from the first flash of the laser. Young children are especially more interested in the pointer than where it's pointing. They'll ask if they can use it, and of course, you shouldn't allow that. Lasers can be quite dangerous and are not permitted in many places, so make sure to check with your local astronomy club or town to find out what rules apply locally (see the caution in the February 2023 issue, page 21).

What you choose to share through the eyepiece will be largely determined by sky conditions. Outreach, more often



▶ **LEO TRIPLET** This compact galaxy group — consisting of M65 (lower right), M66 (lower left), and NGC 3628 (top left) — is situated around 35 million light-years away. M66 shows much more star formation than M65, which appears as blue knots of stars and pink emission nebulae along its spiral arms. It's also deformed from its interaction with NGC 3628.

OUTREACH, THIS PAGE: TED FORTE; OUTREACH, FACING PAGE (2): AAS / JOSON IMAGES; LEO TRIPLET: RON BRECHER

◀▼ **SHARING THE NIGHT SKY** Public outreach events provide opportunities for astronomy club members and volunteers to show off the season's finest and most intriguing celestial sights. The goal is to encourage people to gaze skyward and perhaps inspire future astronomers.

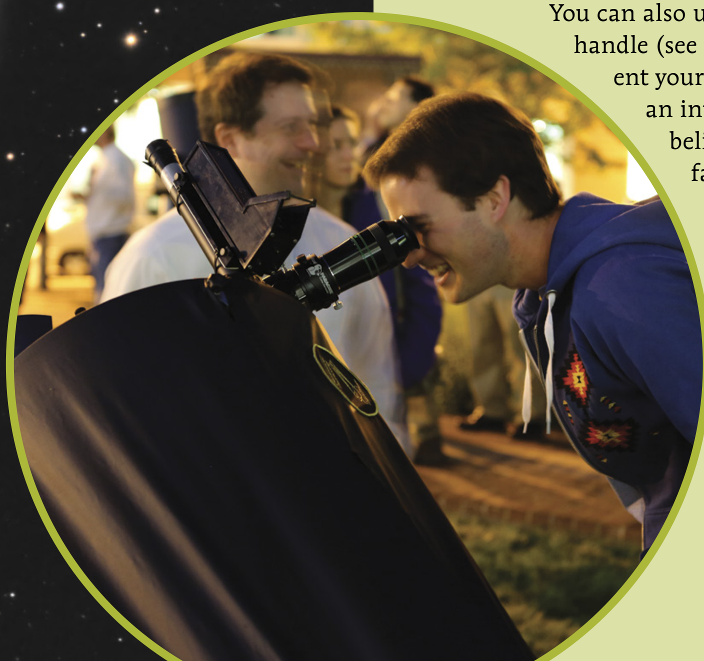
than not, is conducted in less-than-ideal urban skies. Your target selections will typically be limited to the Moon, planets, and the brightest deep-sky objects. If your telescope isn't a Go To system, you need to choose those that you can locate quickly; otherwise, your audience will soon lose interest waiting for you to find an object. I typically use a 10-inch Dobsonian without any digital pointing aids, along with a list of targets I can point to from memory.

It's helpful for any astronomer doing outreach to have a repertoire of interesting and exciting sights to share with an eager audience. Regular readers may recall that I've previously shared my favorite outreach gems for summer, autumn, and winter. What follows are what I find to be "public-tested" favorites for the spring sky.

Naked-Eye Wonders

Well placed on May evenings, the Big Dipper — part of the constellation Ursa Major, the Great Bear — is one of the best-known asterisms in the sky. I like to point it out even though most audience members are familiar with it already. After using the pointer stars to locate Polaris, you'll probably find that many people are surprised to learn that the North Star isn't as bright as they expect it to be (it's magnitude 2.0). Many are also likely to be unaware of Polaris's importance to navigation, given its near-constant position in our Northern Hemisphere sky. Explaining how one can determine geographic latitude by measuring the North Star's altitude is a great way to engage a crowd.

You can also use Mizar and Alcor in the Dipper's handle (see the star chart on page 17) to present your listeners with a fun challenge and an interesting anecdote. It's generally believed that some ancient cultures, famously the Persian and Roman armies, used the naked-eye pair as a test for sharp vision.



The constellation Leo, the Lion, stands out prominently in the spring sky. It takes only a little imagination to recognize its star pattern as a crouching lion — and it's fun to trace it out. From Leo, it's easy to point out the other zodiac constellations. About half the zodiac is always visible in the night sky. Here, of course, is an excellent chance to describe the path of the Sun and point out the ecliptic constellation of Ophiuchus, the Serpent Bearer. It'll be unfamiliar to most members of the public, and they may be astonished to learn that there's an interloping 13th constellation along the zodiac. The Sun resides within the borders of Ophiuchus from about November 30th to December 18th (see *S&T:* June 2023, p. 45).

At the Telescope

The first time a person peers into the eyepiece of a telescope can leave an impression that lasts a lifetime, so be sure to keep this in mind when selecting targets to show. My favorite spring object that's sure to please is **M104**, the Sombrero Galaxy. It's located in Virgo, the Maiden, near the border with Corvus, the Crow. My 10-inch at 120× shows this 8th-magnitude object as a thin spindle that bulges in the middle and is bisected by a dark, prominent dust lane. As with most deep-sky objects, it's more impressive in the mind's eye. I like to tell viewers to consider for a moment that the galaxy lies about 30 million light-years away, and therefore the photons they're seeing have traveled some 30 million years to reach their eyes. Those *particular* photons are theirs alone; no other human ever has, or ever will, see them again — they have, in a manner of speaking, become part of the viewer. It's a bit mind-blowing! Another concept I like to relate is that, to a human-like observer around a star in that distant galaxy with a similar telescope to the one that my guest is using, our Milky Way home galaxy might look much the same as the Sombrero looks to us.

▲ **GALACTIC DUO** Situated around 10° northwest of 1.8-magnitude Alpha (α) Ursae Majoris, M81 (bottom) and M82 are favorite targets of observers and astrophotographers alike. The two galaxies, which appear only ½° apart in the eyepiece, lie nearly 12 million light-years from Earth. M81 is notable for its large size, well-defined spiral arms, and an active nucleus that contains a supermassive black hole. M82 is known as a starburst galaxy for its prolific rate of star formation.

MAJESTIC HAT M104, the Sombrero Galaxy, is one of the most photogenic galaxies in the northern sky, with its trademark bright core encircled by a thick dust lane. The galaxy is roughly 50,000 light-years across and is located about 30 million light-years away. While you won't see this much detail in a typical amateur telescope compared to this image captured by the Hubble Space Telescope, the view will give you an idea of M104's overall shape and structure. North is up in all images.

M81 AND M82: RON BRECHER; M104: NASA / ESA / THE HUBBLE HERITAGE TEAM (STSCI / AURA);

Pierre Méchain discovered M104 just after Charles Messier's 1781 catalog was published. We know from his own notes that William Herschel had independently discovered the galaxy in 1784. Camille Flammarion added the object to Messier's list in 1921, after discovering that Messier had made handwritten notes about it in his own copy of the catalog. The nickname "Sombrero," which refers to a broad-brimmed, high-topped Mexican hat, first appeared in the June 1942 *Sky & Telescope* in an article by columnist Leland S. Copeland.

If galaxies are to be considered interesting outreach targets, pairs of galaxies are doubly so. Viewers are usually impressed by seeing two distant galaxies in the same field. While the spring sky literally teems with them, many are too faint for the typical schoolyard or parking lot. A notable exception is the remarkable pair of **M81** and **M82** in Ursa Major. At magnitudes 6.9 and 8.4, respectively, they're well within reach of an 8-inch scope. A 30-mm Plössl nicely frames the duo in my 10-inch, and at 40×, they show up well even in moderate light pollution. M81 is a grand-design spiral discovered by German astronomer Johann Elert Bode (of Bode's Law fame) in 1774 — in fact, it's sometimes referred to as Bode's Galaxy. Small telescopes will show only a large, oval patch of nebulosity with a bright core. M82, the Cigar Galaxy, is an irregular spiral seen nearly edge on. Spindle-shaped, it looks very mottled with a dark dust lane visible across its middle. M82 is considered a "starburst" galaxy due to its high rate of star formation.

Leo contains several bright galaxy groups, and one of the best is the Leo Triplet. Composed of **M65**, **M66**, and **NGC 3628**, it's a popular subject with astrophotographers and a remarkable outreach target. An eyepiece with a 50° field of view will comfortably frame the trio. Messier discovered M65 and M66 in 1780, while Herschel found NGC 3628 four years later. All three galaxies are about 35 million light-years away and are probably interacting. They are fairly similar morphologically but are angled differently to our line of sight. NGC 3628, popularly known as the Hamburger Galaxy, is one of the nicest edge-on spirals available to small scopes. This 9.5-magnitude object has a very prominent dust lane and looks slightly warped. M66, at magnitude 8.9, is the brightest of the group and has a more irregular shape than M65. Sharp-eyed observers should be able to detect hints of its spiral structure, with its southern arm particularly obvious. M65 requires large aperture (as well as high magnification) to detect any detail.

For a welcome change of pace, try the globular cluster **M3** in Canes Venatici, the Hunting Dogs (for other targets in the constellation, turn to page 53). I consider M3 the season's best example of its class. Easily located midway between Arcturus, Alpha (α) Boötis, and Cor Caroli, Alpha Canum Venaticorum, it's sure to impress viewers who have been straining to see galaxies. I like to boost the magnification as much as conditions allow to let people fully appreciate its lovely splash of stars. The globular contains tens of thousands of stars and is about 33,000 light-years away. The 6.3-magnitude cluster is well resolved even in a 6-inch telescope. Contributing Editor Stephen James O'Meara says viewing M3 is like "looking down on a snowball melting on black ice," a reference to its three-dimensional quality. Messier discovered the object in 1764, describing it as a "nebula without star" — perhaps a sad commentary on the poor optical quality of his small telescope.

Try Your Own Special Favorites

Selecting targets that really interest you can greatly enhance engagement. I've always been fascinated by planetary nebulae, and I think my appreciation for these objects filters through to an audience. Enthusiasm is infectious!

One of my favorite planetaries to share in the spring sky is **NGC 3242**, also known as the Ghost of Jupiter. This remarkable object in Hydra, the Water Snake, at magnitude 7.3 is bright and easily seen in as little as 6 inches of aperture. From

▶ **DELIGHTFUL TARGETS FOR SPRING AUDIENCES** A fun variety of celestial objects adorn the spring sky with which to regale attendees at your outreach events. You can use a green laser pointer (where permitted) to help identify stars as well as to outline the constellations and prominent asterisms.

▲ **GREAT BALL OF FIRE** Discovered by Charles Messier in 1764, M3 is one of the brightest and largest globular clusters in the sky, containing about a half million suns. It lies roughly 33,000 light-years away and measures about 180 light-years across.

▲ **A REAL CELESTIAL HOOT** M97, the Owl Nebula, is a planetary nebula whose round shape and two large, prominent dark eyes evoke the face of a staring owl. It's located about 2,000 light-years away. Planetary nebulae are actually expanding shells of luminous gas expelled by dying stars.

M3: RON BRECHER; OWL NEBULA: BERNHARD HUBL

dark sites, it looks very much like an eye; in fact, "CBS Eye" is one of its other monikers. The planetary exhibits intricate inner structure inside a blue disk (some observers see it green). Under severe light pollution, the disk appears featureless. I've seen its 13th-magnitude central star in my larger telescopes many times, but it's not usually visible in a typical outreach situation.

According to former *S&T* columnist Sue French, the first mention of the Ghost of Jupiter nickname surfaced in 1887. In *Hours with a Three-Inch Telescope*, British author and astronomer William Noble described NGC 3242 as a "pale blue disk, like a ghost of Jupiter." However, Herschel, who discovered the object in 1785, noted in a summary of his second observation in 1786 that it displayed "the light of the colour of Jupiter." Contributing Editor Steve Gottlieb suggests that this might be the original impetus for the name. According to the late noted planetary nebula observer Kent Wallace, no one seems to know who first used the CBS Eye nickname.

Another favorite springtime planetary is **M97**, the Owl Nebula, in Ursa Major. This mostly round, ghostly orb can be difficult to spot from a light-polluted schoolyard or street corner but is always worth a try. I'll often swing to it during a lull in activity to see if it'll show up well enough to share. When visible at all, this 9.8-magnitude object is perfect for demonstrating the value of patient study and averted vision. The Owl's eyes can be elusive but eventually detecting them can be a real source of accomplishment for the observer who makes the effort to see them. The best magnification to use will vary with sky conditions, but in my 10-inch, I find about 60× to be optimal.

The Owl Nebula's nickname is often attributed to William Parsons, the Third Earl of Rosse, but Gottlieb notes that Lord Rosse never used it in a publication. He explains that William Darby, author of *The Astronomical Observer: A Handbook to the Observatory and the Common Telescope*, wrote that M97 was "familiarly known in the Parsonstown Observatory as 'the owl nebula' from its resemblance to an owl." I can see the owl resemblance in photographs, but I must admit that to see its "owlness" in the eyepiece requires an active imagination.

Next to planetary nebulae, my favorite objects are bright, large edge-on galaxies. A magnificent example is **NGC 4565** in Coma Berenices, Berenice's Hair. This is another target that you might have to skip if your event's sky isn't dark enough, but at a site outside the city, it's quite extraordinary. Known as the Needle Galaxy or Berenice's Hairclip, this 9.6-magnitude object has a bright central bulge crossed by a prominent dust lane along its plane. In large scopes, it's breathtaking.

Herschel discovered NGC 4565 in 1785. I can only imagine his reaction as it filled his eyepiece — too large to fit in his field of view. He described it as, "A lucid ray with a very bright spot in the middle. . . . The nebula makes a beautiful appearance." I heartily agree.

◀ **TURQUOISE EYE** This 7th-magnitude planetary nebula in Hydra, designated NGC 3242, was probably given the nickname Ghost of Jupiter by early observers for its resemblance to the familiar planet. Modern estimates place the object's distance to be at least 1,400 light-years.

Embrace the Hype

Astronomers often dismiss the media's overblown coverage of ordinary occurrences in the sky. Blue Moons (we'll have one on May 31st), planetary lineups, and the like may seem quite common. However, anything that garners the public's attention and encourages people to gaze skyward should be celebrated as an opportunity to engage and educate.

We never know when a new comet or scientific discovery will capture the public's interest. And you can be sure that there'll always be some astronomy-themed rumor or hoax being bandied about on the web. It really doesn't matter if the interest is sparked by something actually exciting or mundane, or even made up — the increased interest is a good thing. It fosters curiosity, encourages attendance at outreach events, and fills the inbox at your astronomy club's "contact us" link. It behooves the outreach astronomer to remain plugged in to current fads, trends, and recent announcements and to be prepared to field questions about recent stories. Most importantly, we should strive to use whatever excites our audiences to make outreach thrilling, educational, and fun.

There are many facets to our hobby. Some amateurs are exclusively visual observers, many are astro-imagers, and others pursue citizen science. But no matter what your inclination is, outreach will be a rewarding addition to your astronomical pursuits. What better use can you make of your telescope, your knowledge, and your enthusiasm than to inspire others to look up? I doubt you can bestow a better gift.

Have fun!

■ Contributing Editor **TED FORTE** confesses to having convinced children that astronomers can produce bright green light from their fingertips.

FURTHER READING: The other outreach seasons in this series include winter (*S&T:* Feb. 2023, p. 18), autumn (*S&T:* Oct. 2023, p. 28), and summer (*S&T:* July 2025, p. 22).

For the discovery histories and visual observing notes on NGC and IC objects, refer to STEVE GOTTLIEB's rich and comprehensive resource, **https://is.gd/NGC_IC_Notes**.

Favorite Spring Targets

Object	Name	Type	Constellation	Mag	Size	RA	Dec.
M104	Sombrero Galaxy	Spiral	Virgo	8.0	8.6′ × 4.2′	$12^h 40.0^m$	–11° 37′
M81	Bode's Galaxy	Spiral	Ursa Major	6.9	24.9′ × 11.5′	$09^h 55.6^m$	+69° 04′
M82	Cigar Galaxy	Irregular	Ursa Major	8.4	11.2′ × 4.3′	$09^h 55.9^m$	+69° 41′
M65	—	Spiral	Leo	9.3	9.8′ × 2.9′	$11^h 18.9^m$	+13° 06′
M66	—	Spiral	Leo	8.9	9.1′ × 4.1′	$11^h 20.3^m$	+12° 59′
NGC 3628	Hamburger Galaxy	Spiral	Leo	9.5	13.1′ × 3.1′	$11^h 20.3^m$	+13° 35′
M3	—	Globular cluster	Canes Venatici	6.3	18.0′	$13^h 42.2^m$	+28° 23′
NGC 3242	Ghost of Jupiter	Planetary	Hydra	7.3	1.1′	$10^h 24.8^m$	–18° 39′
M97	Owl Nebula	Planetary	Ursa Major	9.8	2.8′	$11^h 14.2^m$	+55° 01′
NGC 4565	Needle Galaxy	Spiral	Coma Berenices	9.6	2.4′ × 0.7′	$12^h 35.6^m$	+25° 59′

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.

The Gateway Collaborative

These astrophotographers pool their resources for automated access to dark, pristine skies.

Under the dark skies near Río Hurtado in northern Chile, the faint glow of the Tarantula Nebula reaches a telescope. Its photons aren't forming an image in a lone observer's eyepiece but rather are transmitted to multiple computers thousands of kilometers away. In New York, a young designer tweaks the calibration settings on the scope in between client calls. In southern France, an artist and independent filmmaker checks that the guiding corrections are acceptable before heading to bed. And in Arizona, an entrepreneur and award-winning landscape photographer uploads a revised imaging sequence that optimizes the target's framing and exposure. The common goal of each of these disparate imagers is to capture a stunning portrait of this southern-sky marvel coordinated not from a command center but through a shared spreadsheet and a buzzing Discord server.

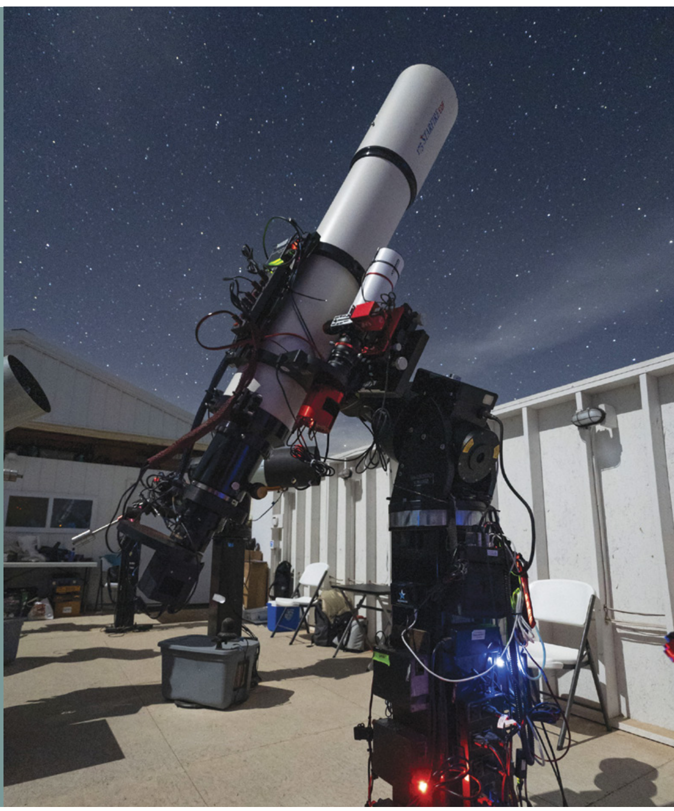
The system isn't a commercial remote-imaging platform or a top-down institutional initiative. Rather, it's a shared telescope network built by amateurs, for amateurs.

Birth of a Collective Endeavor

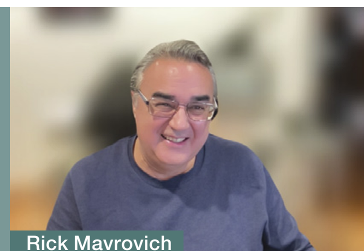
Known as The Gateway Project, the group began with a single telescope located under the dark skies of Fort Davis, Texas. Today, its scopes have access to the entire sky, with a second observatory operating in Chile's pristine southern skies. But more than its global reach, what sets Gateway apart is its philosophy: Trusted peers pooling their time, knowledge, and data in pursuit of long-term projects spanning weeks and sometimes months on end.

Several years ago John Kasianowicz, a research scientist and an experienced amateur astronomer, had set up a scope for remote imaging. The system consists of an Astro-Physics 175-mm f/8 StarFire EDF refractor and an FLI MicroLine ML16200 CCD camera mounted on a 10 Micron GM3000 German equatorial mount and located at the Dark Sky Observatory telescope-hosting facility (**darkskyobservatory.com**) in Fort Davis. But he later found that he didn't have time to fully utilize the system. Rather than taking it offline, John saw the scope as an opportunity. He approached Stan Honda

GATEWAY NORTH: STAN HONDA; ONLINE MEETING: RICK MAVROVICH

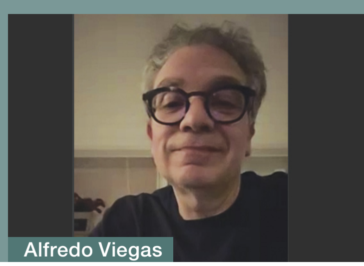



Stan Honda


Rick Mavrovich


John Klearman


David Gluchowski


Alfredo Viegas


Preston Stahly

and Alfredo Viegas of the Amateur Astronomers Association (**aaa.org**), my club based in New York City, and suggested a novel arrangement: For the cost of renting the pier in the remote facility, the club could use the telescope, sharing access to a high-quality imaging platform without the cost of ownership. Club members were ecstatic about the opportunity to image, and several immediately contributed to the expense.

For about a year, the Fort Davis scope (dubbed the Gateway Project) became the hub of AAA club activity. As word spread, Antoine Ribaut — an astronomer and international artist splitting his time between France and New Mexico — heard about the project. He operates a remote observatory in Río Hurtado, Chile, with an Astro-Physics 130-mm f/6.3 StarFire GTX and QHY600M CMOS camera on a 10 Micron GM2000 mount. Recognizing the opportunity to expand access, Ribaut partnered with the club to extend the Gateway concept to the Southern Hemisphere, opening new skies to participants.

And with that, the project evolved into an all-sky endeavor — a model for shared, collaborative astronomy that others could follow.

Democratizing Deep-Sky Access

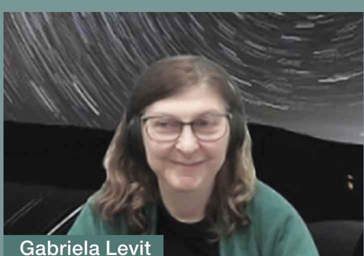
What sets the Gateway Project apart isn't the gear or locations — it's the way access is structured to empower serious amateurs, foster deep collaboration, and make professional-grade imaging radically more accessible.

Each of the two scopes supports up to 12 operators; some sign up for a slot on just one telescope, others on both. Participation is treated as a donation to AAA. Currently, the club is asking $500 for access to one scope for a year, or $850 for both. In return, each operator gets two scheduled imaging sessions per month, which each operator scripts and manages remotely using *N.I.N.A.*, (which stands for Nighttime Imaging "N" Astronomy; *S&T:* Sept. 2023, p. 28) and other shared planning tools.

But the real strength of Gateway is in its collaborative operating structure. Participants often organize around selected targets, pooling their time and slots to gather deep, multi-night datasets that would be difficult or cost-prohibitive to capture alone. Some may image a single object over the course of several months; others divide their time across multiple objects. The ethos is simple: More signal equals less noise, which produces great data that's then processed into eye-popping results. The spectacular images capture people's attention, which in turn directs them to the project.

In the early days of Gateway, communication was a challenge. One night in particular, I unknowingly shot two full sessions using the wrong binning values. My exposures, taken under excellent conditions with perfect tracking, couldn't be stacked with the rest of the team's data. It felt like a loss, but we made the files available in our data library in case one day someone might find a use for them.

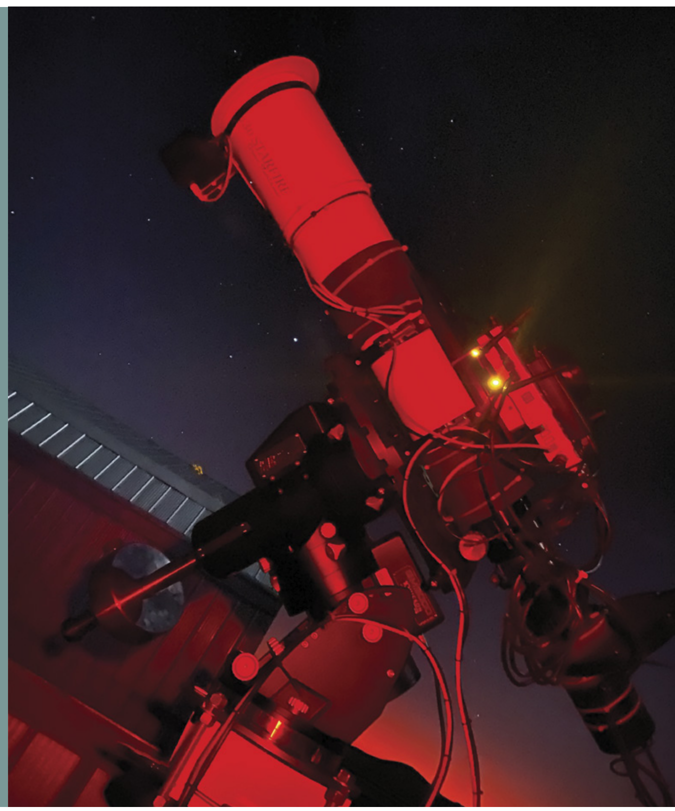
That's how the process went at first. Individual members programmed their exposures in different ways. File names



◀ **SHARED ACCESS** *Far left:* The Gateway North telescope resides under Bortle 2 skies at Dark Sky Observatory in Fort Davis, Texas. The system consists of an Astro-Physics 175-mm StarFire refractor paired with an FLI MicroLine ML16200 CCD camera with a full array of color and narrowband filters. Additionally, an Astro-Tech AT60 ED scope rides piggyback with its ZWO ASI2600MC Pro camera for wide-field imaging. Users enter their targets using *N.I.N.A.* planning software.

◀ **MAKING PLANS** Members of the Gateway Project meet every other month to discuss the operations of the scopes so as to continually improve efficiencies. The author is second from the left in the upper row.

▼ **SOUTHERN GATEWAY** An Astro-Physics 130-mm Gran Turismo refractor with a QHY600M CMOS camera allows members to image objects remotely from the Southern Hemisphere.



GATEWAY SOUTH: ANTOINE RIBAUT

were inconsistent and often confusing. The whole project felt less like a professional observatory and more like a sixth-grade band learning to stay in rhythm. But every misstep was a valuable lesson — from these mistakes, operating templates emerged and standards solidified. Slowly, the dissonant noise coalesced into harmonious music.

For AAA members stuck under urban skies, Gateway offers something even more powerful: remote access to Bortle 1 and 2 skies in some of the darkest locations on Earth.

The Power of Many

Much of the Gateway Project's success comes down to one factor that's hard to quantify, and that's trust. Its nature represents a new kind of amateur astronomy taking hold in the last few years. Not just cooperative, but collaborative in the truest sense.

Imaging targets are discussed and refined in team meetings on the Discord instant-messaging platform (**discord.com**), often weeks in advance. Members coordinate to avoid redundancy, optimize operations during clear-sky windows, and distribute the work efficiently. Operators exchange *N.I.N.A.* scripts, compare sequencing setups, and occasionally jump in live to troubleshoot a peer's session.

In post-processing, members share stacking techniques and color-balancing workflows, often as annotated walkthrough tutorials or real-time presentations. In many cases, several participants jointly process a dataset, either in stages or side-by-side, treating the final image as a true creative collaboration.

This stands in contrast to the traditional image of amateur astronomy as a solitary pursuit. Gateway offers a hybrid model: individual autonomy within a collaborative framework. You can work solo or tap into a global network of shared expertise. The result isn't just better images. It's a learning loop: newcomers grow faster, veterans refine their techniques, and the collective output improves with every cycle.

Members tend to gravitate toward their personal strengths in the project. "I enjoy the process of collecting data, experiencing the wonder of seeing images download in real time," says Gateway participant and AAA member John Klearman. "Our collaboration allows me to focus on the creative aspect of astrophotography. It lets me spend more time nudging an image into the realm of art, and that's my true passion."

The project helps bring newcomers to astrophotography quickly up to speed. I personally began imaging two years ago with a ZWO SeeStar S50 smartscope (see the review in the March 2024 issue, page 66). I was completely new to the hobby, with no background in deep-sky image processing. Just a few months later, I was offered an operator slot on Gateway North (the 175-mm telescope). Within a year, I was contributing to collaborative projects and serving on the Gateway committee that meets informally every two months to review what worked and what could be improved going forward.

While I still consider myself a complete amateur, I'm now producing images I'm genuinely proud of. I never would've improved so quickly without the accelerated learning that came from working alongside more experienced astro-imagers

SINUOUS SHOCKWAVES This deep shot of the Vela Supernova Remnant processed by John Williams represents 137 hours of exposure through LRGB, hydrogen-alpha, and oxygen III filters.

JOHN WILLIAMS

like John Klearman, David Gluchowski, Alfredo Viegas, and others. Their insights, feedback, and camaraderie have made the Gateway Project feel more like a real community than simply a couple of remote telescopes. As David puts it: "Collaborative projects have really accelerated my improvement as a photographer. Working with others has encouraged me to experiment with new ideas and make tweaks to existing methods. Above all else, it's a joy to communicate and share the passion with others."

Imaging Projects and Results

The project has so far produced an impressive array of deep-sky results, including the Eastern Veil Nebula (NGC 6992), the Tarantula Nebula (NGC 2070), and the Dumbbell Nebula (M27). These aren't quick, one-night captures; rather, they're built from multiple-night integrations and often enhanced by shared post-processing insights from team members.

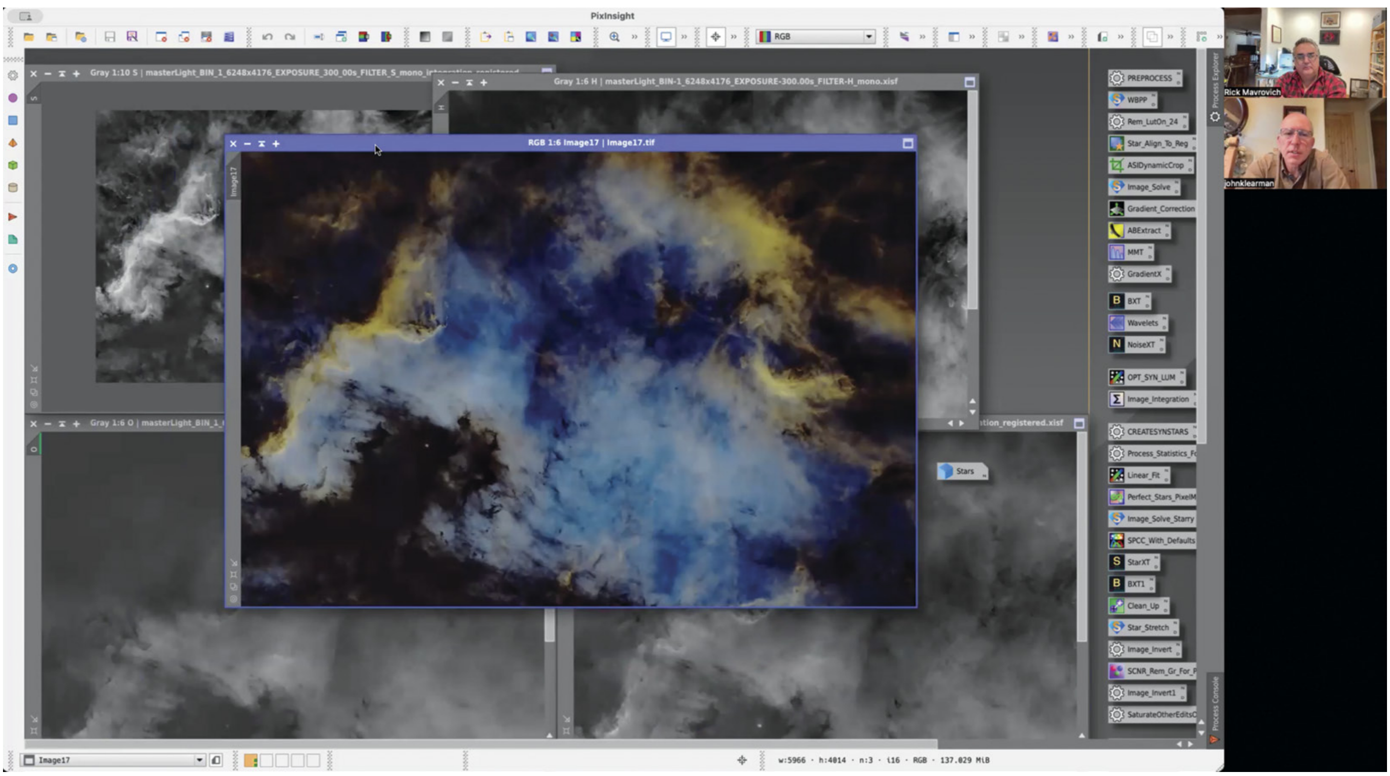
Some images are individual achievements, while others are the product of collaborative acquisition, with several operators contributing their allotted time to the same project. A notable example is the Dumbbell Nebula, captured by one operator using Gateway North. The project combined both narrowband and color exposures over multiple nights, resulting in a deep, high-resolution portrait of this famous planetary nebula.

Gateway South (the 130-mm scope) opens up a different part of the sky that never clears the horizon for most participants. Targets like the Running Chicken Nebula (NGC 6188),

▲ **REACHING OUT** Due to a trick of perspective, the cometary globule CG 4 in Puppis (center) appears to grasp toward the spiral galaxy PGC 21338 (left). Gateway team members Andrew Warner and David Gluchowski pooled their time on Gateway South to capture the pair. In addition, both artists contributed to the processing of the final result.

47 Tucanae, and the Eta Carinae Nebula (NGC 3372) are all within reach from our scope residing in the Chilean Andes near the Vera C. Rubin Observatory (*S&T:* Dec. 2025, p. 28).

But it's not just the images, it's the process. Contributors coordinate imaging sequences, refine stacking workflows, and swap processing techniques or share feedback on each other's work. In some cases, two or more imagers will co-create a final image, collaborating on both the data collection and the entire post-processing pipeline, blending their technical skills and artistic visions in real time.



▲ **IN THE WORKS** The author receives advice from team member John Klearman on a Discord server. Here, they discuss processing a narrowband image of the North America Nebula (NGC 7000) using *PixInsight*.

NEBULA REACHING FOR GALAXY: ANDREW WARNER & DAVID GLUCHOWSKI; PROCESSING MEETING: RICK MAVROVICH

UNIQUE INTERPRETATIONS These three versions on this and the facing page of NGC 6188 in Ara used the same data set, but each was processed by individual members. *Above:* Andrew Warner used all 84 hours of color and narrowband data to produce this enhanced composite version, while John Williams's version *(facing page, left)* used a more customized palette. John Klearman chose to approach the data with a more traditional Hubble palette *(facing page, right),* with the added twist of flipping the image to appear mirror-reversed.

ANDREW WARNER

LEFT: JOHN WILLIAMS; RIGHT: JOHN KLEARMAN

When an operator finishes a project, they retain a two-week period of exclusive access to the data. After that, the data enter the Gateway archive and become available to other operators and a tier of data subscribers — amateurs who support the project with a modest fee in exchange for access to its growing library of datasets that are available for learning, practice, and publication.

Gateway participants are encouraged to share their processed results publicly. The only requirement is to credit the AAA for the data, following the guidelines posted in our official gallery at **https://is.gd/gatewaygal**.

What's Next?

What began with a single telescope and a handshake has blossomed into full access to the entire sky, and it's still evolving. The next steps include streamlining the membership structure to make it easier for new participants to use the equipment, either as operators, data subscribers, or collaborators. As the project grows, so does the need for better coordination, documentation, and onboarding resources. More importantly, the team is looking ahead to education and outreach. In addition to welcoming college-level astronomy students as interns to help manage operations and data workflows, Gateway has also opened an operator slot to high school students, many of whom have never experienced a truly dark sky.

One particularly memorable example was helping to train a young intern, Salvador Nissenblatt Peña from Pomona College. Over several days via Zoom, we walked through the telescope controls, how to interpret the data, and how to engage with the Discord planning threads. When I told her she was now fully onboard and ready to run things on her own, her face lit up with a mix of excitement and panic. I gave her my number, reassured her she wasn't alone, and then added, "You're now holding the astronomical equivalent of a Ferrari. Have fun racing through the skies." Her expression then shifted to sheer joy, and watching that was one of the most rewarding experiences I've had since joining the project.

Looking ahead, Gateway contributors are exploring ways to leverage this unique global network for scientific discovery. Some project ideas include coordinated supernova searches and others like it that demand sustained access to dark skies and long integration times. With instruments in both hemispheres and a growing talent pool of operators, Gateway is well-positioned to contribute meaningfully to the broader astronomical community.

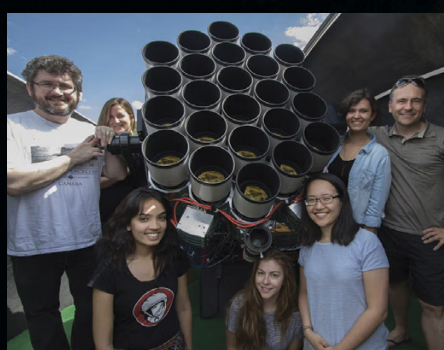
There's even discussion underway about adding a third donated telescope in another time zone to expand the project's observing windows and global coverage. As a 501(c)(3) nonprofit, tax-exempt organization, we're extremely grateful to those who have made their equipment available, and we're open to new members and future partnerships that align with the project's collaborative spirit.

This quiet astrophotography collaboration between a few peers has evolved into something far more noteworthy: An incubator for talent and a reminder that passion, paired with access, can open the universe.

■ **RICK MAVROVICH** is a board member of the Amateur Astronomers Association in New York City and founding operator of the Gateway Project. By day, he runs a banking advisory firm. To learn more or inquire about getting involved, visit our club website at **aaa.org/gateway**.

 by Govert Schilling

COMPOUND EYES



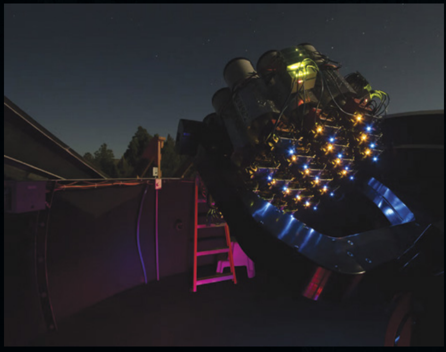
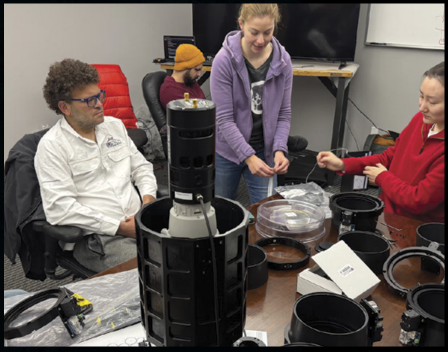
TEAM DRAGONFLY AND TEAM MOTHRA (5); IMAGES OF MOTHRA IN CHILE: IMAD PASHA / TEAM MOTHRA (2)

Why build a giant telescope when you don't have to?

A revolutionary telescope is taking shape in northern Chile. At El Sauce, a peak some 25 kilometers (16 miles) south of the new Vera C. Rubin Observatory, engineers are constructing a 4.8-meter (16-foot) refractor with a huge field of view. The new project doesn't sport one giant lens, though. Instead, its aperture will be divided across 1,140 individual telephoto lenses, all working together like the compound eye of a giant insect. "We're adding about 20 lenses each week," says Pieter van Dokkum (Yale University). "By the end of 2026, the array will be complete."

The Modular Optical Telephoto Hyperspectral Robotic Array (MOTHRA) is the brainchild of van Dokkum and his collaborator Roberto Abraham (University of Toronto), who also worked together on the much smaller Dragonfly Telephoto Array in New Mexico (*S&T:* May 2019, p. 64). Dragonfly combines 48 high-end Canon telephoto lenses on two separate mounts into a single instrument to look at extremely diffuse objects such as dwarf galaxies. MOTHRA is Dragonfly on steroids, with almost 24 times more light-collecting power, tunable hydrogen-alpha (Hα) filters to detect cold hydrogen gas, and improved detector technology. "It's the most powerful wide-field narrowband imager ever," says Abraham.

◀▼ **EVOLVING IDEA** The Dragonfly project morphed from an initial setup with three lenses to a 48-lens array. Subsequent prototypes have now led to the MOTHRA array (main image and below, far right), which will have more than 1,000 lenses spread across 30 mounts. Second photo from left shows Abraham (left) and van Dokkum (right) with the first Dragonfly PhD students. Other photos show additional project members and iterations.


MOTHRA is a prime example of a *distributed-aperture telescope*. The idea is straightforward: Combine a large number of relatively cheap, off-the-shelf optical elements to achieve results similar to (or even better than) a single, large telescope would give you. More than 50 years ago, when electronic detectors began to replace photographic film, British astrophysicist Michael Disney already realized the potential of optical arrays. “The array . . . should yield much more good astronomy for a given initial cost,” he concluded in a 1972 paper in *Monthly Notices of the Royal Astronomical Society*.

Today’s largest telescope optics also consist of multiple elements. The mirror of Europe’s 39.2-meter Extremely Large Telescope, under construction in Chile, is made up of 798 hexagonal segments. The proposed international Giant Magellan Telescope will use seven 8.4-meter mirrors to collect as much starlight as a single 25.4-meter instrument. But such behemoths operate as one big instrument, bringing all the collected starlight together in one single focus.

Instead, the elements of a distributed-aperture instrument — which can be small telephoto lenses or larger telescopes — each have their own focus and electronic detector. Dedicated computer software can combine the individual observations into one final image. The result is the telescopic equivalent of a hive mind.

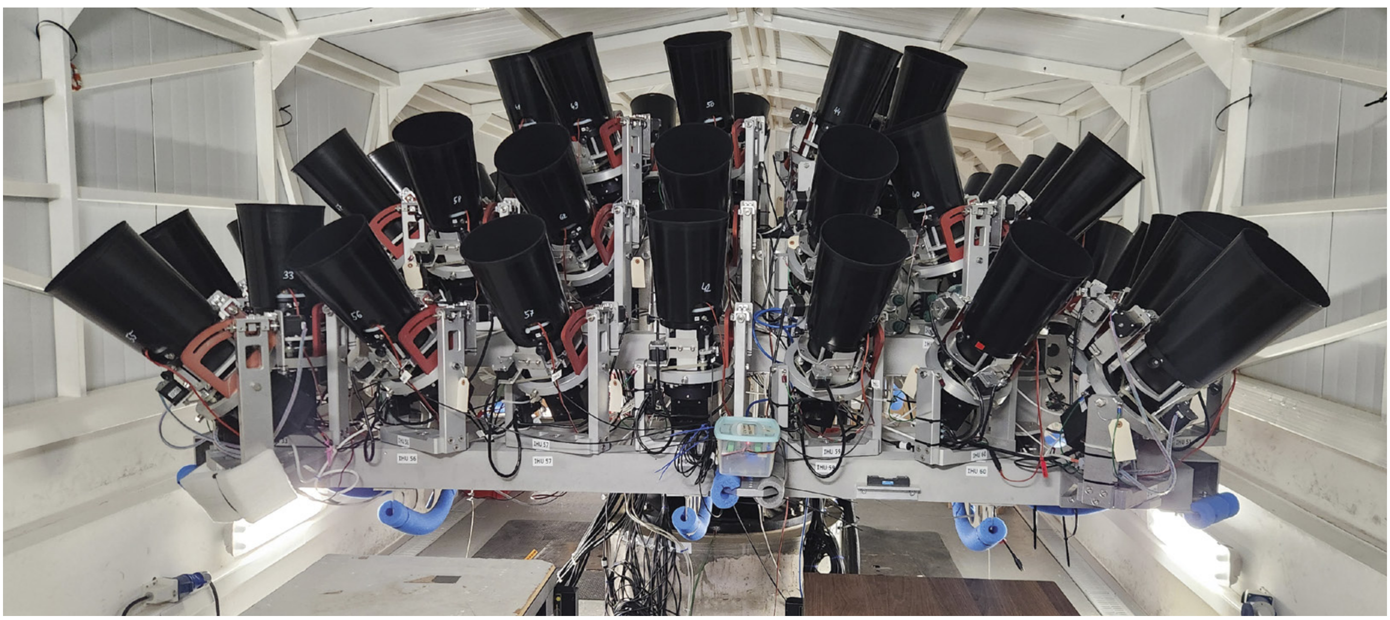
Eyes on the Sky

There are basically two ways for an array telescope to improve on the capabilities of a single instrument. First, you can train each and every element of the array on the same area of sky. By stacking the individual images, you greatly increase sensitivity, in particular for structures with low *surface brightness*, like extremely tenuous wisps of intergalactic matter. Both Dragonfly and MOTHRA use that approach.

But you can also point your individual telescopes in different directions, linking together what they see to achieve a huge combined field of view. With this arrangement, you’re more likely to detect rare transient objects and phenomena, such as supernova explosions, Earth-approaching asteroids, and exoplanets crossing the faces of their host stars.

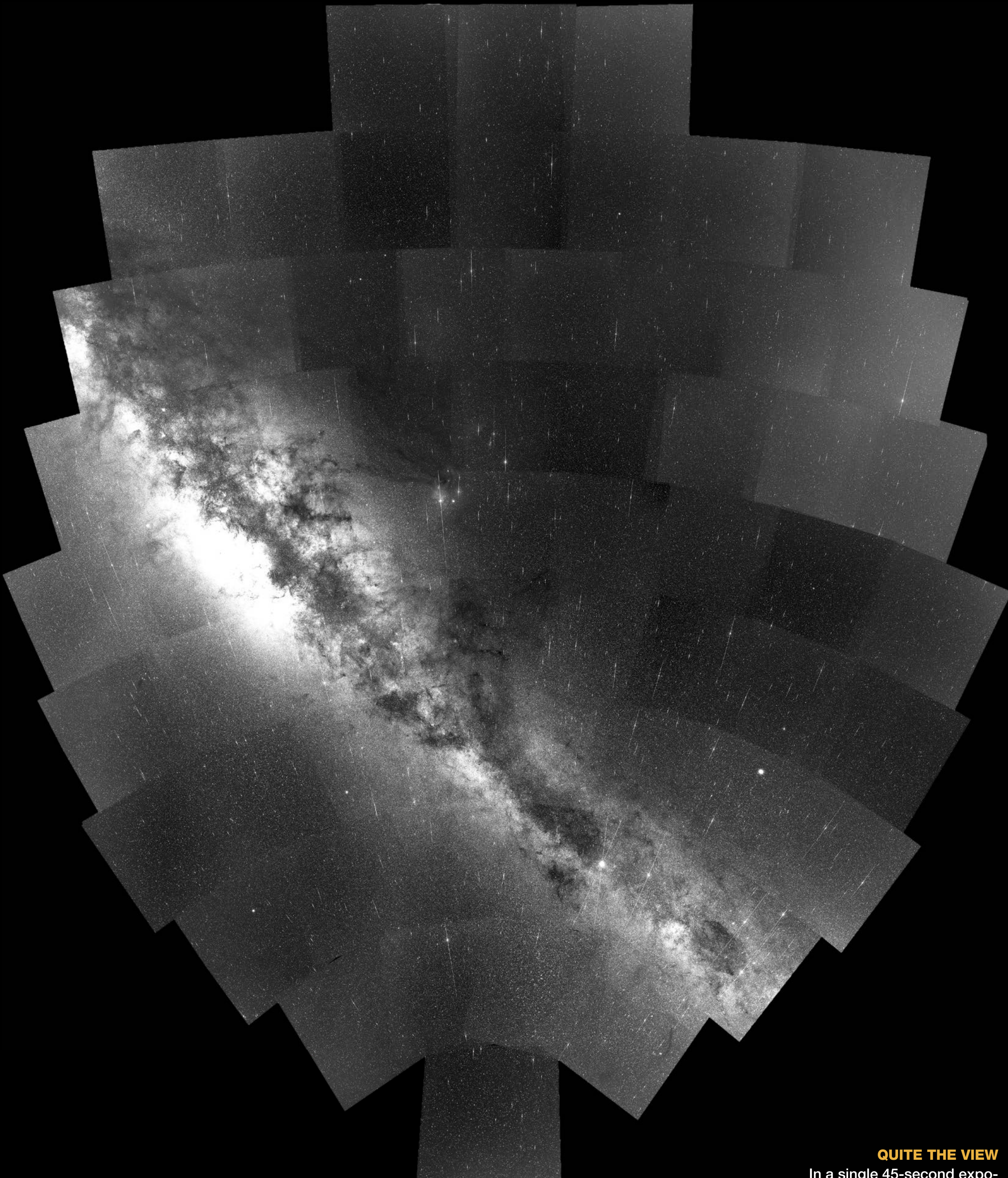
Two well-known facilities of the second kind are the All-Sky Automated Survey for Supernovae (ASAS-SN) and the Asteroid Terrestrial-impact Last Alert System (ATLAS). Both distribute their individual elements geographically. Using a total of 20 Nikon 400-millimeter (16-inch) lenses at five different sites, ASAS-SN — a project headed by Ohio State University astronomers — records the entire sky every night, down to 18th magnitude. Among the thousands of distant supernovae it has detected is SN 2015L, one of the most luminous stellar explosions ever observed, which was as bright as 570 billion Suns. The ATLAS survey of the University of Hawaiʻi, meanwhile, uses four 50-centimeter (20-inch) telescopes in different locations around the globe. Apart from supernovae, it has discovered numerous asteroids and comets, including the interstellar object 3I/ATLAS. A fifth station with sixteen 28-cm telescopes has recently been completed at Teide Observatory in the Canary Islands.

Similar collections of telephoto lenses or small telescopes are scanning the skies for extrasolar planets that temporarily block a tiny fraction of their parent star’s light during periodic transits. Among the most successful exoplanet-hunting arrays (as you can tell from the many exoplanets that bear their names) are the Wide Angle Search for Planets (WASP, led by Don Pollacco of the University of Warwick, UK) and the Hungarian-made Automated Telescope Network (HAT, or HATNET). Other exoplanet search programs, like the European Next-Generation Transit Survey (NGTS) and the



▲ **HATPI ARRAY** HATPI uses 64 Mitakon 154-mm cameras, each with focal ratio f/1.6 and a field of view of about 11°, to create the array’s combined field of view of more than 9,100 square degrees.

GÁSPÁR BAKOS / PRINCETON UNIVERSITY / HATPI PROJECT



GÁSPÁR BAKOS / PRINCETON UNIVERSITY / HATPI PROJECT

QUITE THE VIEW
In a single 45-second exposure, the HATPI instrument observes one quarter of the sky at a spatial resolution of 20 arcseconds per pixel.

American MEarth project (pronounced "mirth"), use multiple commercial 20- or 40-cm telescopes to look for transits across specific types of stars.

The nice thing about an array telescope is that you can easily expand it, greatly increasing the system's efficiency without the need for new R&D investments. As Kenneth Lanzetta (Stony Brook University) notes, "once you know how to build one element, you know how to build 100 elements."

Thus, the team behind HATNET (led by Gáspár Bakos of Princeton University) is now also operating a new facility called HATPI, at the Las Campanas Observatory in Chile. The suffix PI (π) refers to the facility's huge instantaneous field of view, approximately equal to π steradians (about 10,000 square degrees). Its 64 Mitakon 154-millimeter lenses capture the sky from the zenith down to 35° altitude — about one-quarter of the sky — in a single 45-second exposure. By securing hundreds of such exposures per night, HATPI is set to reveal numerous stellar explosions, planetary transits, near-Earth asteroids, and more. According to team member Geert Jan Talens (University of Oxford), commissioning observations took place from late 2022, with official operations starting January 1, 2025.

Monster Vision

MOTHRA is totally different. All of its 1,140 *optical tube assemblies* — high-end, specially coated 400-mm Canon telephoto lenses — will observe the same part of the sky, with a field of view of 9 square degrees. This approach combines an impressive total aperture (akin to a 4.8-meter telescope) with the relatively short focal length of the individual components, yielding the equivalent of a focal ratio of f/0.08 — something that would be outright impossible with a single lens. By digitally stacking the separate images, extremely faint nebulosity stands out, especially when exposure times of many hours are spent on one particular field.

▲ **CONDOR** The 10-element version of the Condor Array Telescope, part of the evolution to a larger setup in both New Mexico and Chile. Condor studies both low-surface-brightness targets and transient events.

CONDOR TEAM

MOTHRA's predecessor, Dragonfly, successfully demonstrated this novel "compound eye" approach. It started operations in 2013 with just three Canon lenses, equipped with SBIG CCD cameras. Before long, the remotely controlled array, located at New Mexico Skies Observatory, comprised 48 lenses on two different equatorial mounts, each in its own Astro Haven clamshell dome. Dragonfly excels in studying the low-surface-brightness sky. Among its results are the discovery of dark matter–dominated *ultra-diffuse galaxies* (UDGs) and faint dwarf galaxies that appear to lack dark matter altogether (*S&T:* July 2018, p. 8). The array also imaged extremely diffuse loops and shells of gas around more normal galaxies.

During the pandemic, the team built four additional mounts, each carrying 30 lenses outfitted with ultra-narrowband filters, to study the incredibly dilute gas around and between galaxies that forms the connective tissue of the so-called *cosmic web*. Because the Hα emission from neutral hydrogen arrives at a specific wavelength that shifts with the source's motion and its cosmological distance (the latter as a result of the expansion of the universe), the filters were designed to be tunable. This tunability enables the precise observation of the hydrogen spectral line all the way out to the Virgo Cluster of galaxies, at a distance of some 65 million light-years.

"But then we were approached by a private donor who was interested in seeing our Dragonfly Spectral Line Mapper expanded to a much larger facility," says van Dokkum. "Thus, the four New Mexico mounts became the nucleus of MOTHRA," an acronym that echoes the name of the giant moth from the Monsterverse best known for the prehistoric reptile Godzilla. MOTHRA will eventually consist of 30 mounts, each carrying 38 telephoto lenses, and will be divided across two huge roll-off roof enclosures atop El Sauce's 1,525-meter peak.

According to Abraham, the Canon factory in Japan had to train a whole new assembly line for the expensive lenses (some $12,000 apiece) to meet MOTHRA's demand. The 1,140 Atik cameras will use rapid-readout and low-noise CMOS detectors instead of more traditional CCDs, yielding 64 gigabytes of raw data for every exposure — 10 times as much as one Vera Rubin Observatory image.

The main science goal is imaging the local cosmic web. Observations of distant quasars and fast radio bursts have already indicated that most of the "normal" matter in the universe must be located around and between galaxies instead of inside them, but, says Abraham, "we will take actual images of this stuff."

Eye of the Condor

Dragonfly has inspired other projects, like Macquarie University's Huntsman Telescope at Siding Spring Observatory in Australia. Named after an eight-eyed spider species, this 10-element array telescope, sporting the same Canon lenses used by Dragonfly, officially opened in 2022 and is now upgraded to also track satellites during the daytime, says

▲ **BLACKGEM** The three 65-cm telescopes of the BlackGEM array peek out of their elevated domes at La Silla Observatory in Chile.

principal investigator Lee Spitler.

Meanwhile, a team led by Lanzetta received National Science Foundation (NSF) funding to explore a slightly different approach, using sizable refracting telescopes instead of telephoto lenses. The Condor Array Telescope, operational since 2020 at the Dark Sky New Mexico Observatory, sports six 18-cm TEC refractors on a single mount, equipped with large-format ZWO CMOS cameras. A similar setup, funded through the American Museum of Natural History and Stony Brook University, has just been completed on the 5,640-meter-high Cerro Chajnantor mountaintop in Chile's Atacama desert, increasing the total number of Condor telescopes to 12. With new NSF money, both sites will soon host two additional scopes. There are plans to "significantly expand" the array, according to Lanzetta.

"I was motivated by Dragonfly," he says, "but I asked myself: What would I do differently? I realized that if you're staring at a single patch of sky for dozens of hours on end, you might as well want to study point sources."

That requires much sharper images than Dragonfly produces, hence the choice for a relatively small number of elements with longer focal lengths, providing better resolution.

"By adding up many short exposures, we eventually obtain a deep image," says Lanzetta, "but by analyzing the images one by one, we also track rapid time variability of all point sources in the field." So although Condor's prime science driver is still the low-surface-brightness sky (using filters to study the cosmic web at higher redshifts than Dragonfly does), the array can also detect things like short-duration transits of Earth-like planets orbiting in the habitable zones of white dwarf stars.

In addition, with six telescopes working in tandem, it's possible to fully characterize the six modes of polarization of the observed source, by using six different filters. A source's light can be polarized, with light waves oscillating in a preferred direction, by intervening magnetic fields. Condor could measure the polarization of optical counterparts of *gamma-ray bursts* (brief, extremely luminous explosions in remote galaxies) less than 20 seconds after their discovery, providing valuable information on the role of magnetic fields during the very first stages of the event.

Other groups also use robotic arrays of medium-size telescopes to discover and study explosive transients. The BlackGEM array at the European La Silla Observatory in Chile consists of three wide-field 65-centimeter telescopes that scan the skies for faint optical counterparts of gravitational-wave events — so-called *kilonovae* that result from the catastrophic collision of neutron stars (*S&T:* Feb. 2018, p. 32). So far, the team hasn't found a kilonova, says principal investigator Paul Groot (Radboud University, The Netherlands). That doesn't render the array useless, though: When there are no alerts from gravitational-wave observatories, BlackGEM surveys the night sky, looking for (among other things) compact white-dwarf binaries. Such binaries, with orbital periods of just a few minutes, are expected to produce a faint background "hum" of gravitational waves, which astronomers need to characterize because it might disturb the sensitive measurements of the future space-borne gravitational-wave detector LISA.

ESO

The Gravitational-Wave Optical Transient Observer (GOTO) has similar goals. Located both on La Palma in the Canary Islands and at Siding Spring Observatory in Australia, GOTO operates a total of thirty-two 40-cm telescopes, in groups of eight. Each group has a combined field of view of 44 square degrees.

"BlackGEM is more sensitive," admits principal investigator Danny Steeghs (University of Warwick), "but it has a smaller field of view — their plan to expand the array to 15 telescopes has not panned out. Another advantage is that we are located at different geographical latitudes and longitudes. If all array telescopes were in Chile, I'd be worried to miss out on some short-lived events."

All-Sky Eye

Of course, if you don't want to miss anything that flashes or crackles in the heavens, you have to continuously keep an eye on the whole sky, similar to what HATPI does. However, although telephoto lenses like HATPI's may have wide fields of view, they collect much less light than telescopes, so there's a tradeoff between sensitivity and sky coverage.

That is, unless you have money to spend, like Nicholas Law (University of North Carolina, Chapel Hill). Supported primarily by the private philanthropic initiative Schmidt Sciences, Law and his colleagues are building the Argus Array — a massive collection of no fewer than 1,200 telescopes, each 28 cm in diameter. With a total light-collecting area equivalent to an 8-meter-diameter telescope, Argus will provide an almost all-sky view down to 20th magnitude at 1-arcsecond resolution, with exposure times of just 1 minute.

Argus builds on the experience of Evryscope, an earlier project led by Law, which has stations in Chile and California. Each station sports about two dozen 6-cm telescopes. In 2016, Evryscope South detected the first bright superflare from our nearest stellar neighbor, Proxima Centauri.

With its unprecedented scale and unconventional design, Argus would be one of the most complex astronomical instruments ever built. A small prototype with just 38 telescopes, called the Argus Pathfinder, operated at the Pisgah Astronomical Research Institute in North Carolina between late 2022 and 2024. According to Law, the commissioning of the full array might start as early as 2027.

"Argus is a good project, but keeping the whole thing running will be a big challenge," comments Pollacco, who isn't on the team. That's because the 1,200 telescopes have to track the sidereal motion of the sky during exposures. In contrast, Pollacco's own future project, called the Digital Telescope, contains no moving parts. The idea is to have at least 800 commercial 20-cm Celestron telescopes, each looking at a different part of the sky. Since the telescopes will have stationary mounts, the stars will move across the array's field of view. But by continuously reading out the CMOS detectors and taking this motion into account, computer algorithms can synthesize deep images of the night sky without star trails. "It's quite straightforward," says Pollacco.

A European Research Council grant has now funded the construction of a prototype with 52 telescopes on La Palma. "I've got the money in my bank account," quips Pollacco. "We expect the first data by the end of 2026." The full array would cost some 25 million euros ($29 million) and could be built in four years' time, maybe on Chile's Cerro Paranal, which is home to the European Very Large Telescope. "One advantage is that we don't need a big enclosure. Our stationary telescopes can be close together, under a simple roll-off roof."

An Eye on the Future

If astronomers were to build several big Argus- or Digital Telescope–like arrays, in both hemispheres and distributed in longitude, then the dream of continuously monitoring the whole universe at high sensitivity and resolution would come an important step closer. "There's still a lot to learn, especially on short time scales," says Steeghs, "and the technology is available in principle, although the huge data rates remain a bottleneck." To give an idea: The Argus Array will produce 244 gigabytes of data *per second* — way too much to store. Part of the data analysis will have to occur in real time.

Another future development would be to add spectroscopic capabilities. Optical fibers could transmit the light from

▲ **GOTO** Poised to follow up on gravitational-wave events, the GOTO project splits its 32 telescopes between four mounts and two sites, one in the Canary Islands *(left)* and the other in Australia, giving the project access to both the Northern and Southern Hemisphere skies.

MARTIN DYER / GOTO COLLABORATION (2)

▲▶ **ARGUS** These artistic renderings show the planned Argus Array, which will combine 1,200 scopes, each 28 cm in aperture, into eight arrays of 150 scopes to record a near-continuous movie of the visible and near-infrared sky. Each circular array will track the sky for 15 minutes, then reset. The location isn't finalized but will likely be somewhere in Texas. First light might come as soon as 2027.

ARGUS SETUP: NICHOLAS LAW / ARGUS ARRAY PROJECT; BUILDING RENDERING: M3 ENGINEERING & TECHNOLOGY CORP. / ARGUS ARRAY PROJECT

hundreds of individual telescopes to a single large spectrometer, to study the chemical composition, motion, or redshift of astronomical objects, including transients. A number of smaller prototypes of such spectroscopic array telescopes are already in operation or under construction. One of them is the European Multi-Array of Combined Telescopes (E-MARCOT) Pathfinder at Calar Alto Observatory in Spain, which has seven 40-cm telescopes on one single mount.

And then there's the Large Fiber Array Spectroscopic Telescope (LFAST), a project conceived by Roger Angel (University of Arizona) and also funded by Schmidt Sciences. When completed, LFAST would consist of many dozens of telescope mounts, each carrying twenty 76-cm telescopes, for a total of hundreds or even a few thousand individual elements. Fiber optics would enable extremely sensitive, high-resolution spectroscopy, for instance to study the composition of exoplanet atmospheres. A prototype with just 20 scopes is being built at Kitt Peak National Observatory in Arizona.

Meanwhile, Chinese astronomers, in cooperation with other countries including South Africa and Brazil, are working towards the Global Open Transient Telescope Array (GOTTA) — an AI-powered collection of 125 wide-angle 1-meter telescopes distributed across the globe. They could carry out individual observations and quick surveys of huge swaths of sky, or many of them could point to one particular object at the same time, their images combined to reach much higher sensitivity — in essence combining the two types of array telescopes at will.

A similar concept, but with the added bonus of spectroscopy, is being developed by Paul Groot. His Time Domain Telescope (TDT) could possibly consist of four hundred 1.3-meter telescopes in different locations, all fiber-connected to a small number of spectrometers. Again, the telescopes would work in tandem for the very faintest sources, or individually on brighter objects. "Our slogan is: Spectra when you need them, anywhere, anytime," Groot says. He plans to submit the TDT proposal to the European Southern Observatory as a candidate for their next flagship project after the Extremely Large Telescope (ELT), which will achieve first light in 2029.

For centuries, the history of ground-based optical astronomy has been dominated by the desire to build ever-larger single telescopes. However, that race has apparently come to an end. Although there will always be a need for huge facilities like the ELT, especially in the field of high-resolution, diffraction-limited imaging, recent developments in detector technology and computer power have opened up whole new avenues for studying the universe in exquisite detail.

"Things evolve really fast," says MOTHRA's Abraham. "Who knows where we are 10 years from now?" To him, that's another big advantage of distributed-aperture telescopes: They are extremely flexible. The individual elements of an array telescope are relatively small and easy to develop (or even available off-the-shelf), whereas the design and construction of a huge instrument can take decades.

From El Sauce, where MOTHRA is taking shape, you can see the building of the Vera C. Rubin Observatory in the distance, as impressive as a dinosaur. Says Abraham's colleague Pieter van Dokkum: "With Rubin's budget of $700 million, we could buy twelve thousand 35-centimeter telescopes and link them up to achieve the light-gathering power of a 38-meter mirror."

■ Ever since he was a young boy, Contributing Editor **GOVERT SCHILLING** has enjoyed looking at the night sky with his organic distributed-aperture device, consisting of two 10-millimeter lenses some 6 centimeters apart.

OCEAN

TYPE: ZUBAIR YOUNUS / SHUTTERSTOCK.COM; WATER WORLD: WALTER MYERS / SCIENCE PHOTO LIBRARY

DIVE IN This artist's concept depicts a terrestrial exoplanet with a global surface ocean and Earth-like atmosphere.

WORLDS

Might planets replete with liquid water bedew the galaxy?

In 2017, astronomers discovered what they thought was a supersize rocky exoplanet. The world, LHS 1140b, appeared to be a planet around seven times heavier than our own, orbiting a cool red star about 40 light-years from Earth.

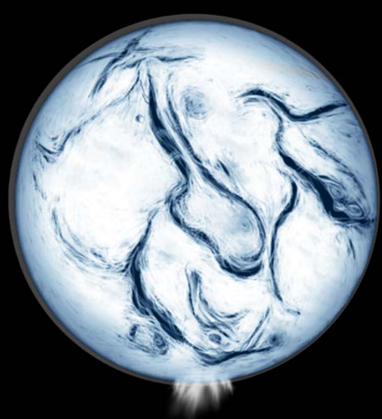
The observers found the planet in a survey of red dwarfs while looking for worlds in the *habitable zone*, the region around a star where temperatures are moderate enough for liquid surface water to exist on an Earth-like planet. Based on estimates of its density, LHS 1140b seemed to be a super-Earth, a scaled-up version of Earth with an even denser, terrestrial composition.

When Charles Cadieux, then a graduate student at the University of Montreal, developed new tools to accurately determine a planet's mass, he tested the method on LHS 1140b. However, deriving a more accurate mass for the world yielded an exciting surprise: The exoplanet was actually lighter than previously thought, meaning that it could not be entirely made of iron and rock. Instead, a large portion (something like 10% to 20%) of the planet might be composed of water — a bona fide blue marble.

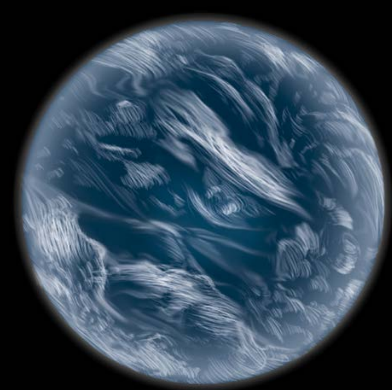
Water is an essential part of life on Earth, and it covers 71% of our planet's surface (*S&T*: Mar. 2023, p. 34). Yet it makes up only a fraction of a percent of Earth's mass. Elsewhere in the galaxy, so-called *water worlds* could contain anywhere from 1% to 50% water by mass, depending on which expert you ask.

Water worlds could exist in a range of conditions, from frozen ice planets to balls of hot steam. With the right temperature and atmospheric conditions, some could sustain vast amounts of liquid water, making them *ocean worlds* far wetter and wilder than our instinctive picture of a watery planet.

Kinds of Ocean Worlds

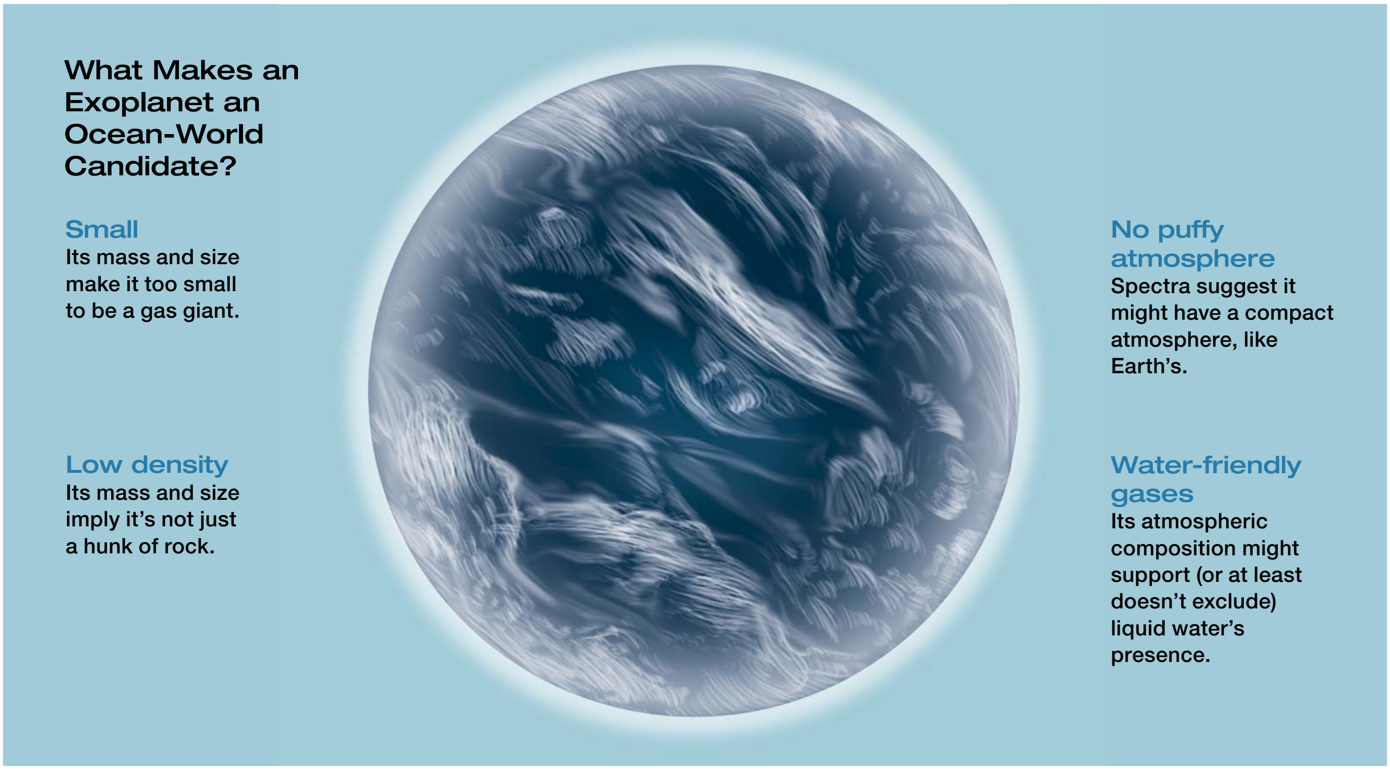


Some ocean worlds could have thick ice shells on the surface and a liquid sea below, as on Saturn's moon Enceladus.



Other ocean worlds might have an atmosphere that creates the right temperature and pressure to sustain surface oceans.

BEATRIZ INGLESSIS / *S&T* (2)



BEATRIZ INGLESSIS / *S&T*

Some of these ocean worlds could have a terrestrial atmosphere similar to Earth's. Others might have a hydrogen atmosphere. And another flavor of ocean world might be like those that lurk among the largest moons in the outer solar system, with subsurface seas sloshing beneath icy shells.

Beyond the solar system, there are around 10 water-world candidates discovered to date, all orbiting red dwarfs. Theoretical studies have suggested that at least 10% to 20% of exoplanets with sizes between one and four times that of Earth could be water-rich.

But astronomers don't know yet whether these exoplanets are what they appear to be. "There is no convincing evidence of a single water world outside the solar system," says David Charbonneau (Harvard University), who was part of the team that originally discovered LHS 1140b. For most exoplanets, researchers must deduce possible compositions based on the world's size and mass, and the data can't pinpoint the true composition with certainty.

That's not to say they don't exist, says Charbonneau — their formation is perfectly possible. The possibility suggests that, in order to find seas around other stars, we might need to look at worlds far more alien than our own.

Detecting New Worlds

To determine an exoplanet's bulk composition, astronomers start with its average density, calculated using the planet's observed mass and radius. Scientists measure the mass and radius using specific methods.

The most common way astronomers find planets is by searching for *transits*, or the periodic dips in a star's brightness when the planet passes in front of its star. Given the star's size (estimated from its brightness and temperature; hotter, more luminous stars are generally bigger) and the fraction of starlight hidden during the transit, scientists can deduce the planet's width.

To estimate the planet's mass, astronomers rely on the *radial-velocity technique*, recording the small wobbles in a star's position as the planet gravitationally tugs on it.

Combining these measurements of a planet's size and mass, astronomers can estimate the world's overall density. From there, they can make educated guesses about its internal structure and composition. For example, a planet with a density similar to Earth's is likely rocky, while a less-dense planet is probably made of lighter substances such as gases or ices.

Cadieux's work on LHS 1140b started as a project to refine these standard techniques, which led him and his colleagues to discover that the planet's mass, and therefore its density, was lower than previously thought. The team then used the new density measurement to recalculate the planet's internal structure. They found two possibilities: LHS 1140b could either be made up of just a rocky core and a hydrogen-rich atmosphere (a *mini-Neptune*), or it might contain a rocky core, a deep water ocean, and a nitrogen-rich atmosphere similar to Earth's — the overall density is around the same in both scenarios.

This situation is what astronomers call having *degenerate solutions*: Different models produce the same result and are virtually indistinguishable without more information.

Fortunately, the two scenarios make distinct predictions about LHS 1140b's atmosphere. And astronomers have a way to deduce what the world's atmosphere might contain.

As the planet transits, light from its host star passes through the planet's upper atmosphere. Various molecules absorb the light, each at different wavelengths. This process leaves unique chemical fingerprints, creating a *transmission spectrum* that encodes the atmosphere's composition in the starlight (*S&T:* Dec. 2024, p. 34).

Cadieux's unexpected results led to a project to observe the planet's transmission spectrum with the James Webb Space Telescope (JWST). If the planet were a mini-Neptune, then its atmosphere would be primarily composed of hydrogen and helium, which would create a puffed-up envelope extending around 700 kilometers (430 miles) that the researchers would see easily during the transit. Conversely, if it were a water world, then the atmosphere should be much more compact, made of heavier stuff that keeps it hugging the surface like on Earth and makes it harder to spot.

The spectrum that the team observed was largely devoid of features, meaning it couldn't possibly be a mini-Neptune planet. Beyond that, though, they couldn't determine whether a compact atmosphere or no atmosphere at all would better explain the spectrum they saw. Without an atmosphere, the planet's water would either boil off into space or freeze solid.

How To Build an Ocean Planet

Forming a water-rich world is a natural possibility in planetary systems, given that water is one of the most common compounds in the cosmos. Depending on where a planet forms in the swirling disk of material around its star, it can end up containing a significant portion of water.

Terrestrial planets are made primarily of what astronomers call *refractory materials*, such as iron and silicates. These can withstand a fair amount of heat and so remain in solid form closer to the star. On the other hand, so-called *volatile* compounds — like carbon dioxide or water — vaporize more easily, so they are only abundant farther out, where they're stable as ice.

Different models produce the same result and are virtually indistinguishable without more information.

Planets that form beyond water's *snow line*, or the place where water is cold enough to condense into ice in the planet-forming disk, will naturally accumulate higher amounts of water. In our own solar system's outer reaches, water makes up around 50% of the icy moons by mass. So water worlds, if they exist, would most likely have to form in the far regions of their planetary systems, too. Some might then migrate inward to their star's habitable zone and thaw.

Once the planet heats up, its ability to sustain a water ocean on its surface is contingent on factors such as having the right atmosphere to regulate the temperature and pressure that enable liquid water to exist. Greenhouse gases like carbon dioxide can keep a planet warm, while clouds and hazes can reflect starlight, cooling the planet down.

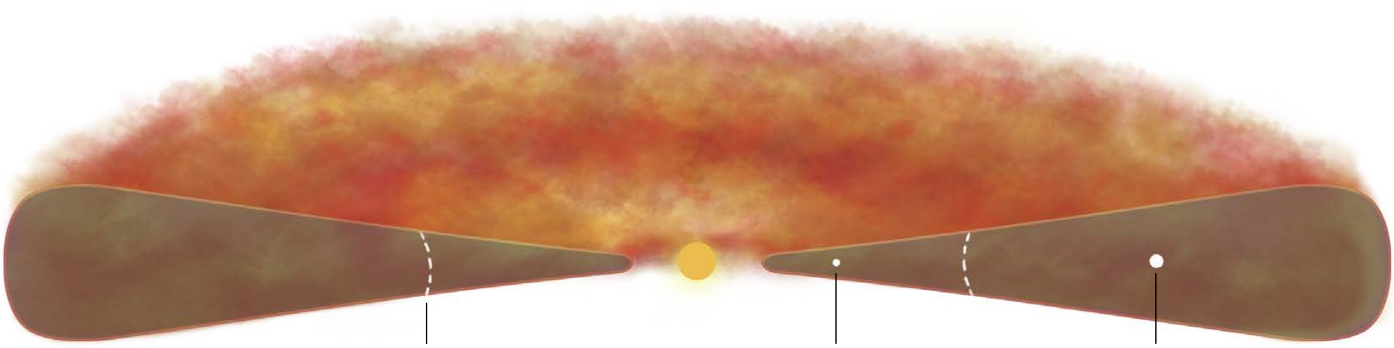
However, ocean worlds may not need to exist in the traditional habitable zone to maintain liquid water. Jupiter's moons Europa, Callisto, and Ganymede, Saturn's Enceladus, and Neptune's Triton all lie too far from the Sun to have liquid on their surfaces, yet internal heating appears to keep subsurface oceans inside them melted.

"They're so much farther out in the solar system, they're very cold on the surface," says Robin Wordsworth (Harvard), whose research encompasses exoplanet and planetary science. "So they're snowballs, essentially, but with liquid water only in their deep interiors."

This kind of "snowball" ocean world could also exist elsewhere. Tidal heating — created by the tug of mutual gravity with another body — or heat released from the decay of elements, called *radiogenic heating*, could both maintain subsurface oceans on such a body.

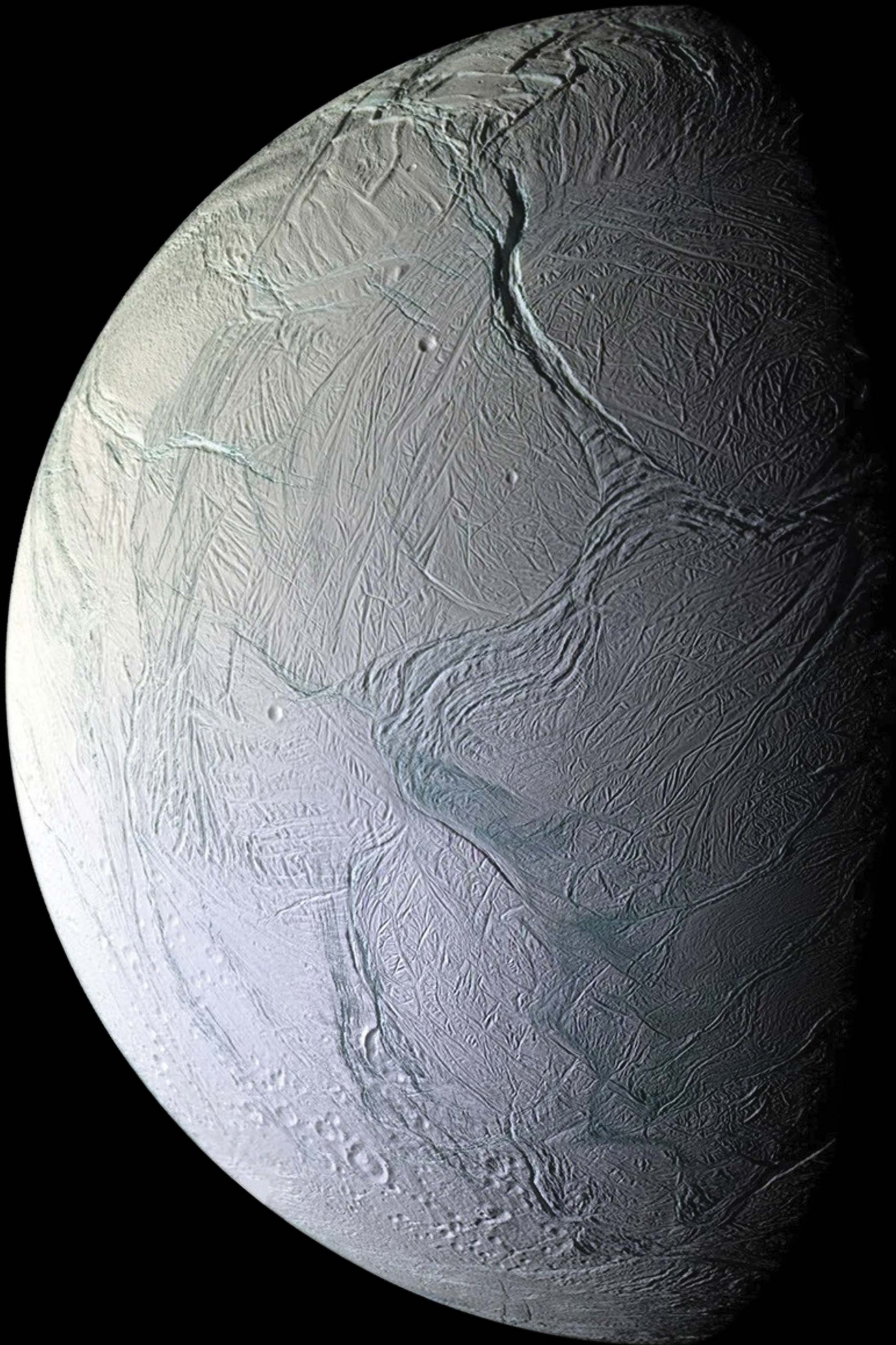
Lynnae Quick (now at Johns Hopkins Applied Physics Laboratory) led a study that considered whether different

Where Worlds Collect Their Water



Not to scale

BEATRIZ INGLESSIS / S&T



NASA / JPL / SPACE SCIENCE INSTITUTE

heating sources could create subsurface oceans on exoplanets. She and her colleagues looked at 53 terrestrial-size exoplanets and calculated their internal heating rates, based on the amount of radiogenic and tidal heating they estimated the planets could experience. They found that 14 planets (around one-quarter) could support liquid water, that nine could sustain subsurface oceans beneath icy shells, and that all 53 would also have volcanic activity thanks to tidal heating.

"Volcanism is one of these means by which a planet just spews its innards out in order to get heat out," Quick says. Volcanoes also release important molecules like water vapor and carbon dioxide that can transform the atmosphere and surface. But too much volcanism can lead to a scorched surface far too hot for water to exist in liquid form.

Hycean Worlds

Another scientist has proposed a more radical idea for a different kind of water world, one that could also orbit beyond the traditional habitable zone: a planet with a hydrogen-rich envelope like a gas giant, but with a liquid ocean underneath.

These *hycean worlds* — a portmanteau of hydrogen and ocean — were conceptualized by Nikku Madhusudhan (University of Cambridge, UK) following potential detections of water vapor on the planet K2-18b. Observations of the exoplanet had indicated an atmosphere rich in hydrogen and helium, with a hint of what might've been water or methane.

In 2020, Madhusudhan and his team aimed to determine what the planet's internal structure could be, based on its transmission spectrum. Like LHS 1140b, there were degenerate scenarios — for example, K2-18b might be a *gas dwarf*, a rocky world with a hefty hydrogen envelope, or a Neptune-like world with a rocky interior, an icy mantle, and a thick, hydrogen-rich atmosphere.

The third scenario, the hycean world, "was the novelty," Madhusudhan says. If the atmosphere contains just a thin layer of hydrogen, then the planet could sustain liquid water beneath it. "I had not expected that at all, by any stretch of imagination," he says.

In 2021, Madhusudhan and his colleagues formalized the concept of hycean worlds, determining the properties that would allow these worlds to maintain deep liquid oceans, anywhere from tens to hundreds of kilometers deep.

JWST observations taken in 2023 indicated the potential hint of water vapor in K2-18b's spectrum was due to methane instead. But the data did not rule out the possibility that water might be part of the planet's makeup as well — the telescope may simply not probe the atmosphere deep enough to detect it. Recent results collected by Madhusudhan and his colleagues have pointed to the planet being water-rich after all, making it a promising ocean-world candidate.

However, maintaining a hycean environment requires very specific conditions. Hydrogen is a powerful greenhouse gas, trapping heat by absorbing the planet's outgoing radiation. Add too much hydrogen, and the planet's surface becomes so hot that water vapor and liquid water become indistinguishable, mixing with the hydrogen envelope to form a blend of liquid and gas.

A hycean world would thus rely on a delicate balance. "It can work, but you should think of it as like throwing a dart at a dartboard from a very big distance and trying to get a bullseye," Wordsworth says. "You have to get exactly the right amount of hydrogen for it to be a hycean world."

A recent study has cast doubt on the ability of these worlds to retain their water, though. Aaron Werlen (then at ETH Zurich, Switzerland) and others suggested that mini-Neptunes could have long-lasting magma oceans that preclude a watery environment: Although these planets could accumulate a lot of water when they first form, interactions between their molten interiors and primordial atmospheres would destroy most of the water, preventing the planet from becoming hycean.

Ultimately, while different models might explain water worlds or disprove them, robust observations are what will demonstrate the presence of water — or the lack thereof.

◀ **OCEAN WORLD** Saturn's moon Enceladus, shown here in an enhanced-color mosaic of images captured by NASA's Cassini spacecraft, hides a sea beneath its icy shell. The water leaks out as geysers from the tiger stripes near the south pole (teal streaks in bottom half of image).

Ice Giants, Not Water Worlds

Astronomers typically call Uranus and Neptune *ice giants*, because they formed far out where volatiles like water, methane, and ammonia condense into ices. They probably have high water content in their interiors. But we don't know their exact compositions or if they even have distinct layers inside. Their thick envelopes of hydrogen and helium could create intensely high pressures in their interiors that form blended, exotic phases of water. In this case, there would be no clear interface between atmospheric gas and liquid water, the way we would envision on a water world.

The Future of Ocean Worlds

JWST is the first telescope with the tools to effectively probe the atmospheres of water-rich candidates and distinguish between degenerate scenarios. Searching for ocean worlds is more complicated than simply detecting water, however: Mini-Neptunes that have the same densities as water worlds will also have trace amounts of water.

"That measurement is a little subtle, because there's going to be water signatures in either case, but that's kind of the next frontier," Charbonneau says. "So there's a bunch of current projects with the James Webb Space Telescope to try to go in and pursue that idea."

The Habitable Worlds Observatory (HWO), a proposed

NASA flagship mission slated to launch in the late 2030s or thereafter, would shed even more light on these watery worlds. The telescope was ranked a top priority in the astronomical community's last decadal survey. Previous surveys have led to JWST, Hubble, and other major observatories.

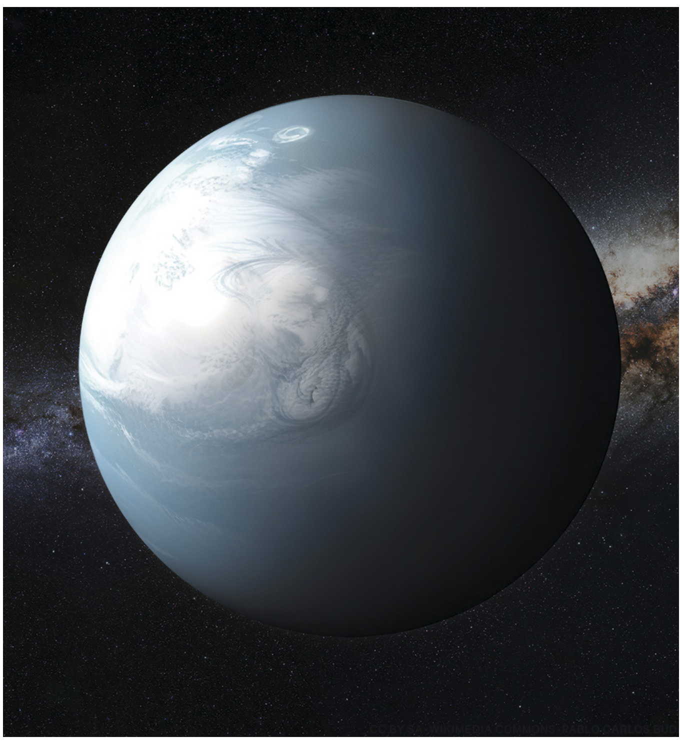
HWO aims to search for habitable worlds and even signs of alien life — not through transits and transmission spectroscopy, but by blocking the star's light so that astronomers can see photons from the planet itself.

"You're going to be able to get information coming from deeper in the planet," Wordsworth says. With transmission spectroscopy, astronomers only see the very edge of the atmosphere (the portion that the star's light passes through), and it's challenging to piece together the surface conditions based on a very small bit of the upper atmosphere.

"It still won't be trivial to go after liquid water, but there's a bunch of clever ideas out there for how you can do it," Wordsworth says.

One idea is searching for the glint of sunlight reflecting off a liquid surface ocean. Another is searching for water indirectly by assessing the chemicals in the planet's atmosphere. For example, seeing sulfur compounds would indicate that there probably isn't an ocean present, because these would readily dissolve in liquid water.

While HWO's main goal will be to search for signs of life on Earth-like planets, it will also search for other kinds of worlds that could host habitable environments. These could include ocean planets.



▲ **HYCEAN WORLD** This artist's concept shows a hypothetical type of water world, where a global ocean exists beneath a relatively thin hydrogen atmosphere.

Mini-Neptunes that have the same densities as water worlds will also have trace amounts of water.

But a lot of caution is necessary before declaring these worlds fit for life: Liquid water isn't the only thing life needs in order to exist. Another requirement is the right chemical ingredients. Madhusudhan argues that hycean worlds (if they're out there) could sustain the ingredients for life as we know it, the CHNOPS elements — carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.

For some worlds, however, the hycean environment could be only a temporary state between stages. If they orbit too close to their host stars, puffy mini-Neptunes likely lose their atmospheres and shrink to become rocky super-Earths. During this transition, the planet might become hycean before its water evaporates.

"That's really interesting, because you probably would have prebiotic chemistry happening at the same time, and you might have conditions for life to form there, but it's transient," Wordsworth says.

"We don't really have any clue how life formed on Earth," Charbonneau says. "How life that's different from life on Earth formed — that's even harder to imagine."

One popular theory is that terrestrial life originated in shallow pools, with access to light and crucial nutrients. For life to form on a world with a deep ocean, a different mechanism would need to provide the necessary energy — perhaps something like the deep-sea hydrothermal vents we see on Earth. Scientists suspect such vents might lie beneath the icy shell of Saturn's moon Enceladus.

Subsurface ocean worlds face additional struggles. "The smaller the body, the less the internal heat, the fewer external heat sources that come in through things like tidal interactions, [and] the quicker you'll freeze your body solid," says Alexander Hayes (Cornell University), a planetary scientist who studies the ocean worlds of the solar system. "And so the question isn't 'How common are ocean worlds?' To me, it's 'What's the longevity of ocean worlds?'"

"The water worlds are an excellent example of how our intuition wasn't all correct when we started discovering exoplanets in large numbers, because there's no direct analog of these kinds of worlds in the solar system," Wordsworth says.

If they do exist, then these worlds could expand our idea of an ocean planet beyond Earth's blue seas, revealing how worlds beyond the solar system might form and evolve to create watery environments stranger than science fiction.

■ **ARIELLE FROMMER** recently obtained her bachelor's degree in astrophysics and physics from Harvard. She is currently a guest researcher at Leiden Observatory in the Netherlands, where she is studying exoplanet atmospheres and improving her bike-riding skills.

SKY AT A GLANCE
May 2026

3 EVENING: Face southeast to see the waning gibbous Moon trailing Antares by about 1½° as they rise above the horizon. Turn to page 46 for more on this and other events listed here.

6 MORNING: The Eta Aquariid meteor shower is expected to peak. Although this display favors viewers in the Southern Hemisphere, those in the Northern Hemisphere can expect to catch a few meteors. This year, however, moonlight will severely hamper the experience (see page 49).

14 DAWN: Turn to the east-northeast to see Mars trailing the waning crescent Moon by a bit less than 7° as they climb above the horizon before sunrise.

18 DUSK: The two-day-old Moon hangs in the west-northwest, with Venus blazing a bit more than 2° lower left. The scene becomes more dramatic as twilight deepens and the pair sinks toward the horizon.

20 DUSK: After sunset, face west to see the delightful lineup of the Moon and the two brightest planets across Gemini. Jupiter is some 7° lower right of the waxing crescent, with Pollux right of the pair forming a triangle. Venus completes the tableau farther to the lower right.

22 DUSK: High in the west-southwest, the first-quarter Moon is about 3° lower right of Regulus, Leo's brightest light. Follow the duo as it sets in the west.

26 DUSK: Look south to see the waxing gibbous Moon gleaming around 5¼° right of Spica, Virgo's lucida.

30 DUSK: The nearly full Moon rises in the southeast some 2½° ahead of Antares, the smoldering heart of the celestial Scorpion. Large swaths of Oceania and southern South America will see the Moon eclipse the star.
—DIANA HANNIKAINEN

▲ NGC 4565, also known as the Needle Galaxy, is an edge-on spiral galaxy in the constellation Coma Berenices, or Berenice's Hair. Turn to page 14 to read more on this and other springtime targets for an inspiring outreach session. MASIL IMAGING TEAM

MAY 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
31						

FULL MOON
May 1
17:23 UT

LAST QUARTER
May 9
21:10 UT

NEW MOON
May 16
20:01 UT

FIRST QUARTER
May 23
11:11 UT

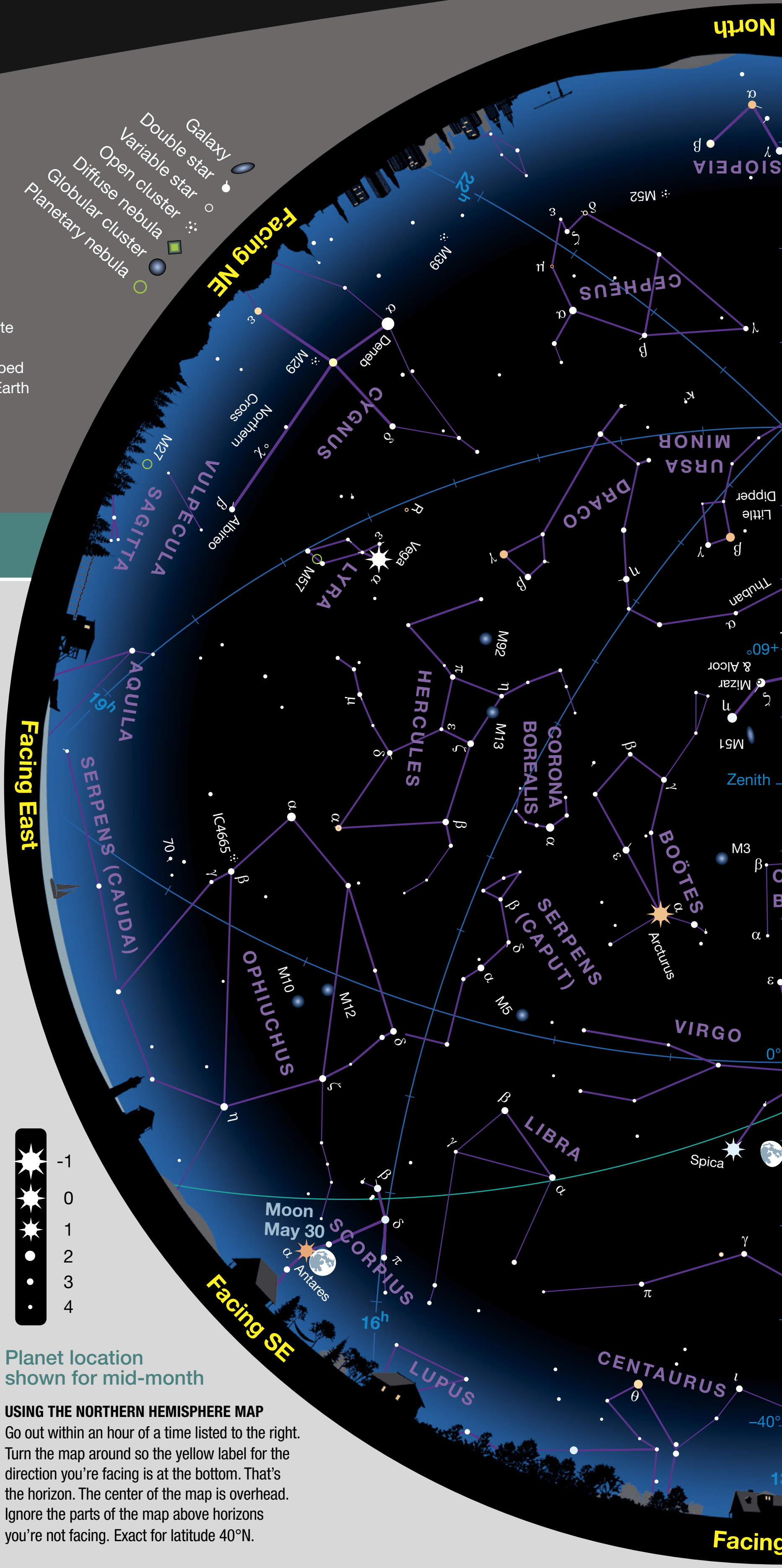
FULL MOON
May 31
08:45 UT

DISTANCES

Apogee 405,839 km	May 4, 23^{h} UT Diameter 29′ 26″
Perigee 358,076 km	May 17, 14^{h} UT Diameter 33′ 22″

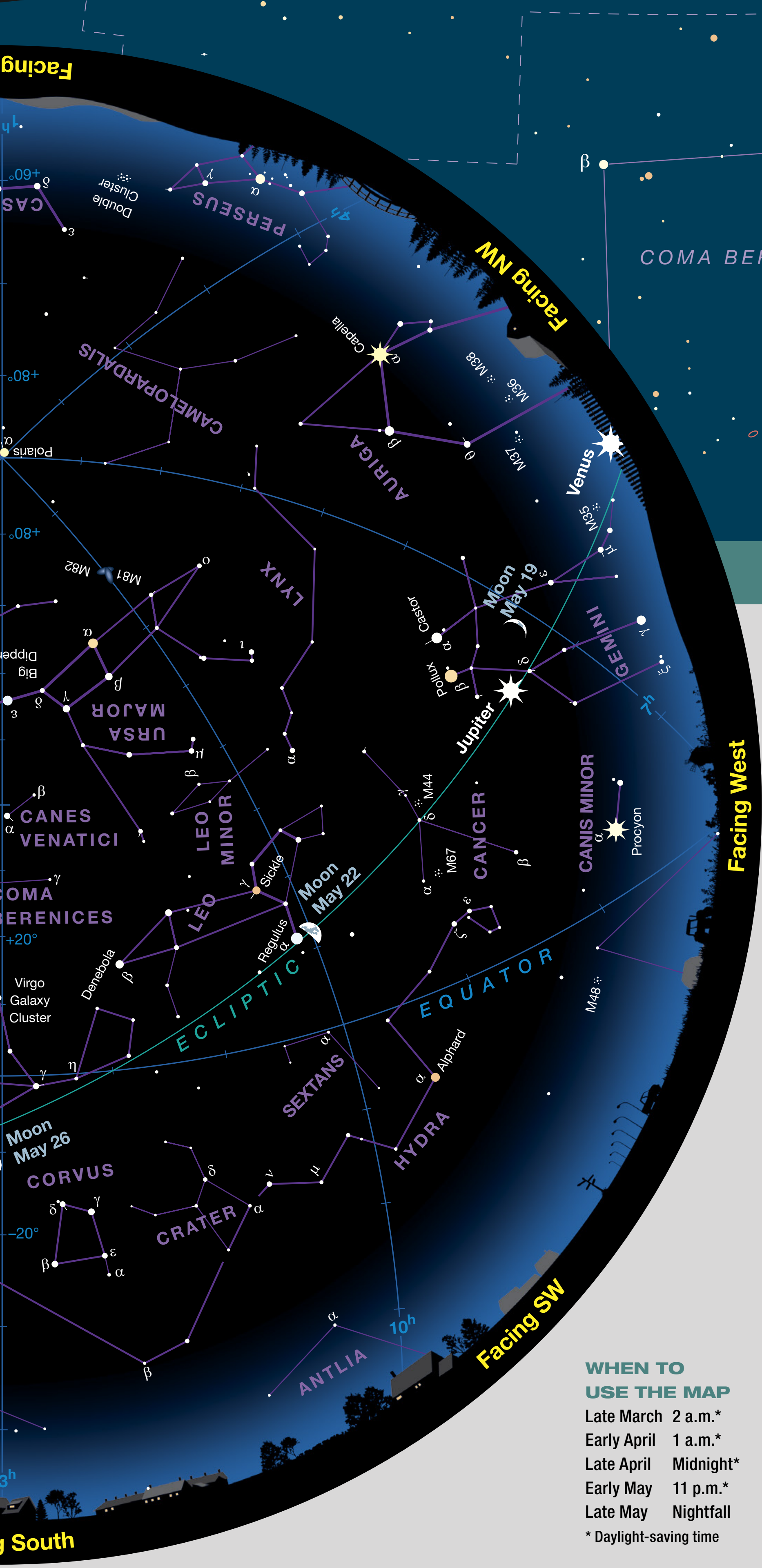
FAVORABLE LIBRATIONS

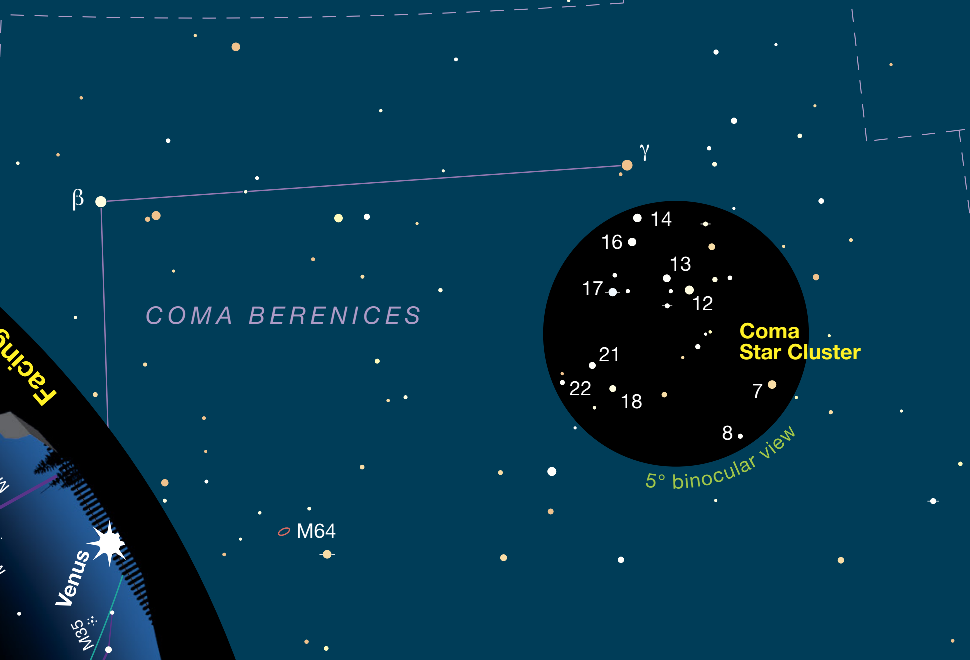
- Compton Crater — May 1
- Gioja Crater — May 4
- Mare Orientale — May 13
- Harlan Crater — May 21



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

Stars in My Eyes

In December 2015, I got an email with a wild and humbling question: Would I be interested in taking over the Binocular Highlight column for Gary Seronik? I said yes, a little nervously; Gary was and is one of my favorite astronomy writers, and I was just getting started. My first column came out in the June 2016 issue, so this one in May 2026 completes my 10th year on the job.

Choosing favorite deep-sky objects is like choosing desserts — I'll try them all, thank you very much. And I often revisit favorites, to savor them some more. One such object is the **Coma Star Cluster** in Coma Berenices, or Berenice's Hair (also Collinder 256 and Melotte 111). The constellation takes its name from the cluster, supposedly the lustrous locks of the 3rd-century BC Egyptian queen, placed in the night sky for all to admire. The Coma Star Cluster is a true open cluster, and a close one, only about 280 light-years away. At magnitude 1.8, the cluster is an easy catch without optical aid under reasonably dark skies — scan for it some 2° south of 4.3-magnitude Gamma (γ) Comae Berenices. In binoculars it blossoms as an archipelago of 5th- to 7th-magnitude stars, with reefs and shoals of dimmer suns filling out the scene. My 10×50 binoculars will fit the whole cluster, but I prefer the wider framing in my 7×50s. And don't miss the ragged spill of 5th- and 6th-magnitude stars that trails off to the south-southwest. It's the kind of view I can get lost in, and often have.

It's a privilege to have this venue to write about my favorite things. I always want to use it to pay forward the advice my editors have given me: Go explore the night sky and make it your own.

■ **MATT WEDEL** is increasingly entertained by his job description: Take the endless night sky and decant it into monthly servings.

WHEN TO USE THE MAP

Late March	2 a.m.*
Early April	1 a.m.*
Late April	Midnight*
Early May	11 p.m.*
Late May	Nightfall

* Daylight-saving time

MAY 2026 OBSERVING

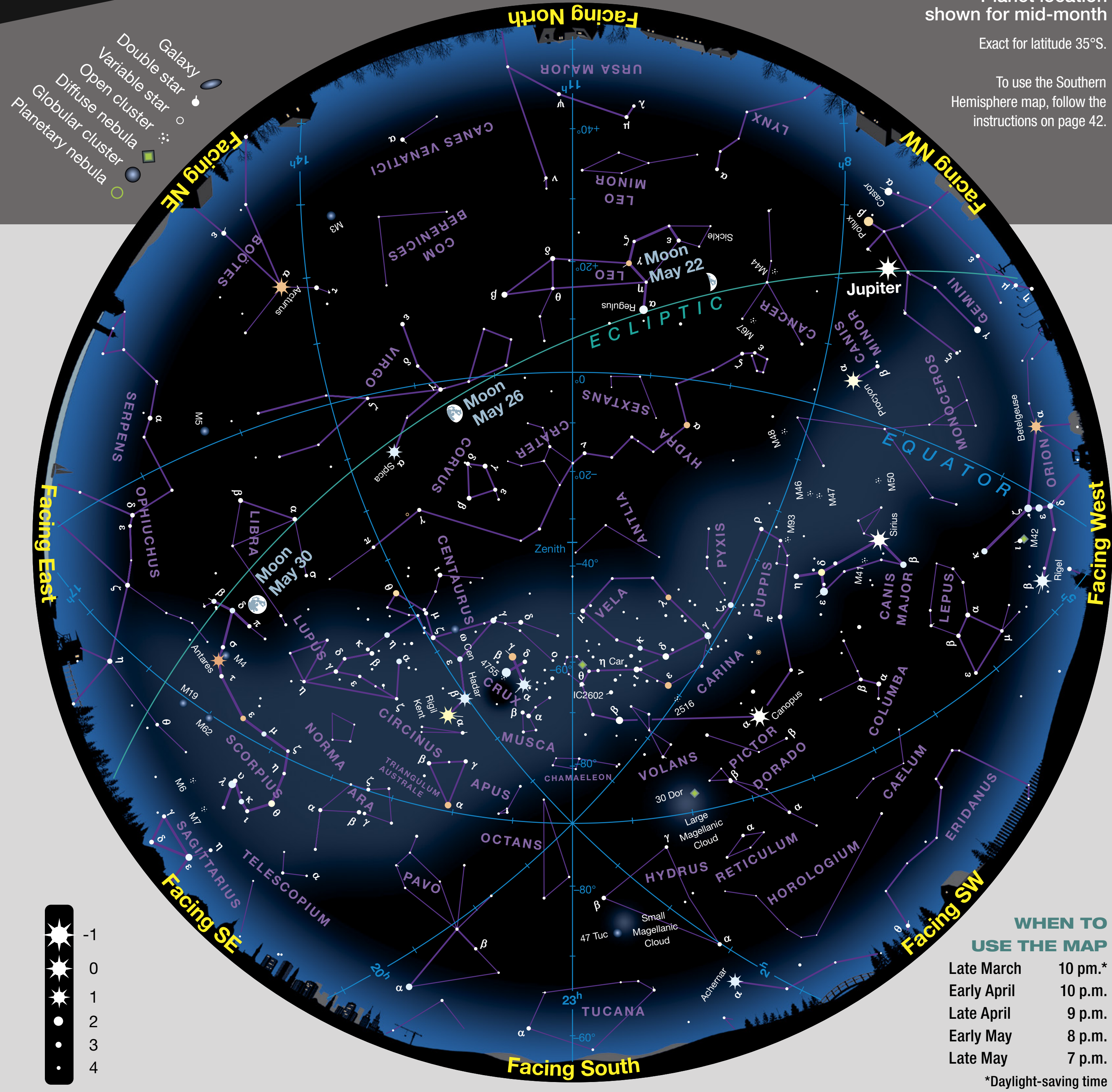
Southern Hemisphere Sky Chart

by Jonathan Nally

Planet location shown for mid-month

Exact for latitude 35°S.

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



WHEN TO USE THE MAP

Late March	10 pm.*
Early April	10 p.m.
Late April	9 p.m.
Early May	8 p.m.
Late May	7 p.m.

*Daylight-saving time

I ALWAYS FEEL a bit sorry for Beta (β) Centauri, as it often tends to be overlooked in favor of its sibling, Alpha (α) Centauri. Both are triple-star systems in **Centaurus**, with Alpha's smallest member, Proxima (too faint to be seen) being the closest star to our solar system at a distance of 4.24 light-years. Alpha's two brightest stars (4.34 light-years from us) produce the single −0.3-magnitude star we see with the unaided eye.

I think Beta Centauri is fascinating. Comprising two hot, blue stars and a dim dwarf companion, its combined brightness of magnitude +0.6 makes it the 11th-brightest star system (Alpha is third brightest). But it's also about 390 light-years away, so imagine how bright it would be if it were as close as Alpha Centauri — it would be far brighter than Sirius and would outshine Venus. ■

Virgin Goddesses and a Queen

Find out what Athena and Queen Elizabeth I have in common with Virgo.

Virgo, the Virgin, may be the most misunderstood constellation — in the sense that the figure's identity as a virgin is a confused concept. *Virgo* is Latin for *virgin*, yes. But today's definition strays from the classical meaning — namely an unwed maiden. Virgo is also related to "virago," which means a "woman of extraordinary stature, strength, and courage." In other words, an autonomous, unmarried woman.

Of the many classical deities associated with the constellation, two stand out in my mind in relation to this older definition: 1) Astraea, virgin goddess of Justice, who lived longest among the mortals during the Golden Age, only to withdraw to the heavens when lawlessness and injustice increased during the Bronze Age; and 2) inviolate and vigorous Artemis, virgin goddess of the hunt, who not only protected unmarried women and nature, but granted strength and health to others.

It won't take a leap of the imagination now to look upon Virgo as another legendary virgin: Athena, Greek goddess of wisdom, strategic war, and the crafts — though she was also associated with fertility, agriculture, and justice. While Athena is not directly linked to any constellation, she embodies all the classical concepts of Virgo. Let's explore.

The Greek word for virgin is *parthenos*. And "Parthenon" is the name of the marble temple on the Acropolis in Athens, which was dedicated to the goddess Athena. Its centerpiece was the statue of Athena Parthenos, whose worship arguably surpassed that of all the other Greek deities in Athens. This colossal statue stood 40 feet tall, and symbolized — beyond wisdom, strategy, and protection — the power of femininity in a labyrinthian world dominated by male deities.

▲ *Left:* Dutch Golden Age painter Rembrandt created this image of the virgin goddess Athena in oils circa 1655. Note Athena's helmet (ornamented with an owl) and spear, which symbolize wisdom and strategy in war, and her shield, which represents the power to protect. *Right:* A portrait in oils of Queen Elizabeth I, the powerful and wise Queen of England. It was likely painted from life by an unidentified artist around 1575.

Many traditions agree that Athena sprung into life fully grown from the head of Zeus, the king of the Olympians. She also emerged armed from head to toe, with helmet, shield, and spear. According to Hesiod's *Theogony* (circa 700 BC), Athena's mother was Metis, goddess of wisdom and Zeus's first wife. When it was foretold that she would bear a child greater than Zeus in wisdom and strength, he swallowed Metis, only to give birth to Athena through his head.

Formidable in strength and mighty in mind, Athena rejected all romantic advances, as she considered such pursuits a distraction. Instead, she dedicated herself to wisdom and the strategies of war. As a goddess of battle, Athena stood by Greece in their war against Troy. But in times of peace, Athena used her wisdom to help humanity prosper. As a protector of agriculture, she assisted people by inventing the plow and rake. She taught mortals how to yoke oxen to plow their fields.

In other words, Athena epitomizes every aspect of what most mythographers align with Virgo, including embodying a woman's independence and strong will. So, see if you can imagine Virgo as Athena. You'll find the constellation midway up from the southern horizon on the Northern Hemisphere Star Chart on pages 42–43. Its brightest star, 1st-magnitude Spica, represents a sheaf of wheat held by the goddess.

By the way, you might also wish to imagine Virgo as Elizabeth I, the Virgin Queen (1533–1603) — the only English queen never to have married. Like the goddess Athena, Elizabeth I was a powerful woman, strong of character and mind. Claiming to rule by divine right, she proved that a woman was perfectly capable of ruling a nation.

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

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

Return of the Red Planet

Mars glows feebly at dawn while the Moon meets Antares . . . twice!

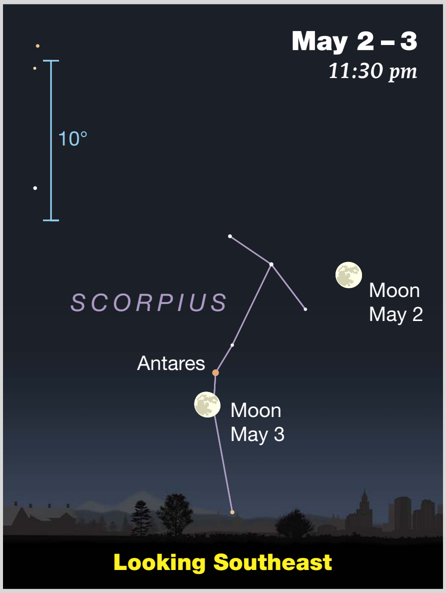
SUNDAY, MAY 3

Late this evening, cast your gaze toward the southeast to catch sight of the 94%-illuminated waning gibbous **Moon** rising just 1° below **Antares**, the leading light in Scorpius, the celestial Scorpion. It's always an arresting sight when the cold, gray Moon sits near the flickering flame of this ruddy 1st-magnitude star. Binoculars make the relative hues of both objects more obvious — and when a bright star is near the horizon, Earthly atmospheric effects make the flickering effect especially intense.

Keep watching the duo after the lunar disk clears the horizon; roughly 5 minutes later you'll see 2.8-magnitude **Tau (τ) Scorpii** rise a bit more than ½° below the Moon. As midnight (Eastern Daylight Time) approaches and the night of May 3rd becomes the morning of the 4th, the Moon lies directly between Antares and Tau Scorpii. Eventually the Moon's diagonal path brings it closer and closer to Tau until the space between them narrows to just 10′ at 1:30 a.m. EDT. Because the Moon is just 2½ days past full, you'll likely need binoculars to draw the star out from the lunar glare.

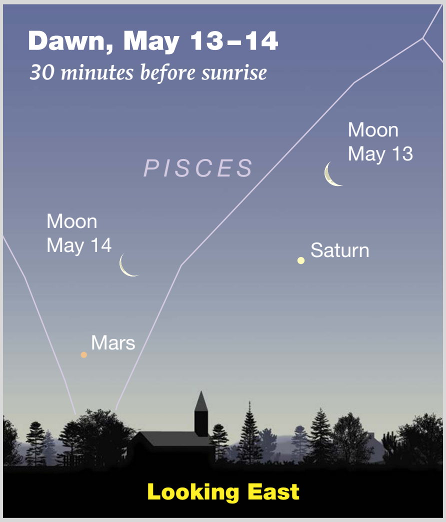
Even after this event concludes, the Moon isn't done with Antares — they have a second rendezvous this month on the 30th. On that occasion, they're about 1° apart when morning twilight lightens the sky on the 31st.

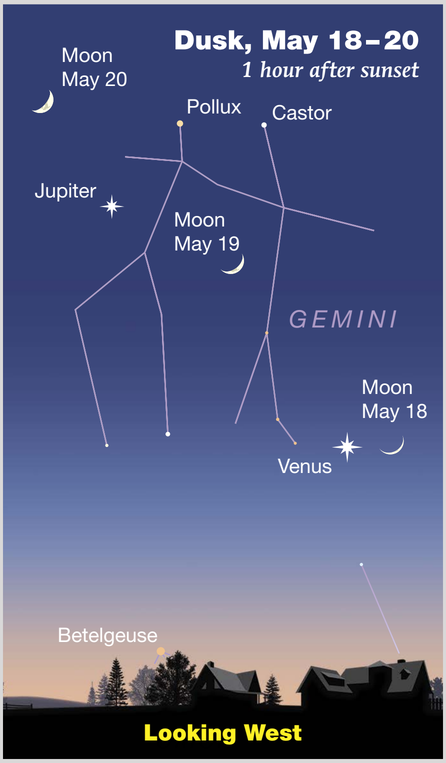
▼▶ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west). European observers should move each Moon symbol a quarter of the way toward the one for the previous date; in the Far East, move the Moon halfway. The blue 10° scale bar is about the width of your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

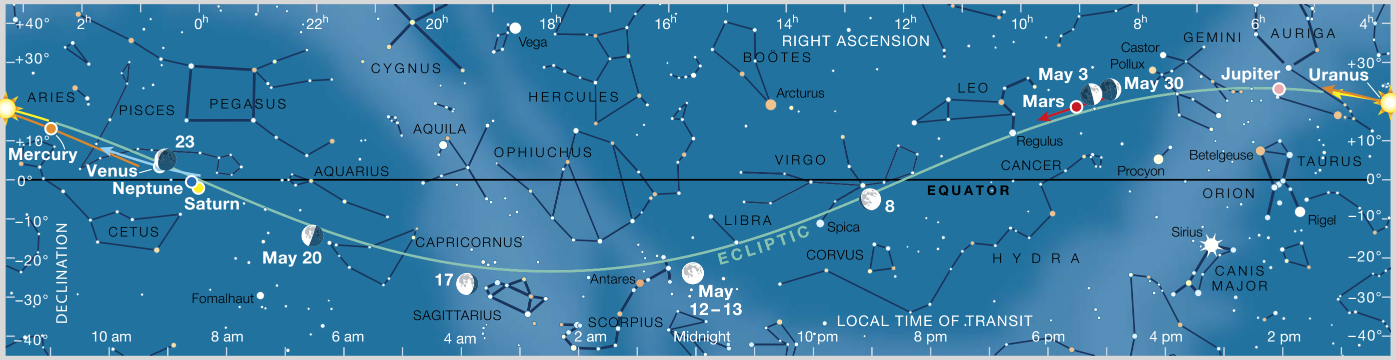


THURSDAY, MAY 14

As the sky begins to brighten at dawn today you should get your first naked-eye glimpse of **Mars** since it slipped out of view at dusk back in September. A couple of things make this morning particularly favorable. First, the gap between the Red Planet and the Sun is finally great enough for a little breathing room. Mars clears the east-northeastern horizon just after 4:30 a.m. local daylight time — roughly 70 minutes ahead of the Sun. Second, a pretty, 8%-illuminated waning crescent **Moon** hovers 7° upper right of Mars. Find the Moon, and you should be able to find Mars. This morning marks the beginning of a new Martian apparition that will see the planet slowly brighten from +1.2 magnitude to a maximum of –1.2 magnitude in February 2027 — a nearly tenfold brightness increase! In that same span of time Mars's peach-







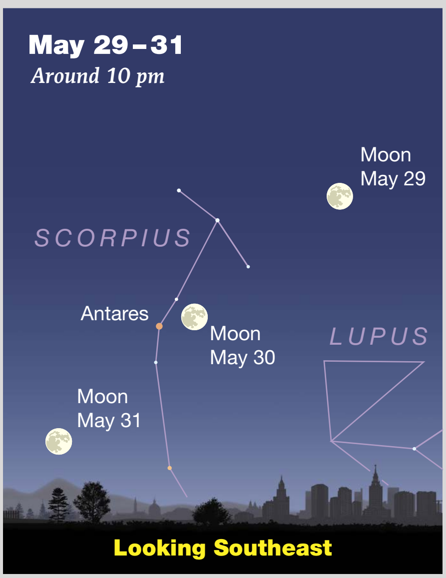
▲ The Sun and planets are positioned for mid-May; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit"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

hued disk will grow from a tiny 4.0″ to a more telescope-friendly 13.8″. And it all starts now.

Completing the dawn tableau is +0.9-magnitude **Saturn**, glowing conspicuously some 10½° right of the lunar crescent. Like Mars, the Ringed Planet is at the start of a new apparition — one that climaxes when it reaches opposition in October this year.

MONDAY, MAY 18

The finest conjunction of the month occurs when the **Moon** meets **Venus** at dusk today. Of course, any time these celestial luminaries get together in twilight or at night, it's bound to be the best pairing of the month. However, with one notable exception next month, this is the closest the two get at dusk for the rest of 2026. (That "notable exception" is next month's daylight occultation of Venus by the Moon; more about that in our June issue.) As twilight gets underway today, the two objects are well above the west-northwestern horizon with just a bit more than 2° separating them. You should have no trouble seeing *earthshine* illuminating the "unlit" portion of the lunar disk. This ghostly effect is the result of sunlight reflecting off the Earth and landing on the Moon's nightside. The lunar crescent itself is, of course, basking in daylight arriving directly from the Sun.



This evening's conjunction is enhanced by several additional lights. Upper right of the Moon-Venus duo is the fourth-brightest star visible from mid-northern latitudes, **Capella**, in Auriga. Even more conspicuous is **Jupiter**, glowing upper left of the pair at a similar distance as Capella. Look again on the following evening (the 19th), and you'll see the Moon positioned between Venus and Jupiter, though noticeably closer to the latter than the former.

FRIDAY, MAY 22

If you like planets, May is definitely your month. As already noted, Mars and Saturn grace the dawn sky, while Jupiter and Venus rule at dusk. This evening you can add one more planet to your tally: **Mercury**. Tonight, you have the chance to catch the innermost planet as it hovers just above the west-northwestern horizon. However, there are two caveats to note. First, Mercury's altitude is only 3° half an hour after sundown. That's not very high — you'll need a completely unobstructed horizon for sure. Second, even if you have such an ideal location, binoculars will be a big help. It's only because the little planet shines so brightly (–1.4 magnitude) that it's possible to catch it at all when it's this low. However, if Mercury eludes you this evening, don't despair. It's just beginning its dusk apparition and continues to climb higher each night until June 10th, after which it begins to sink sunward once again.

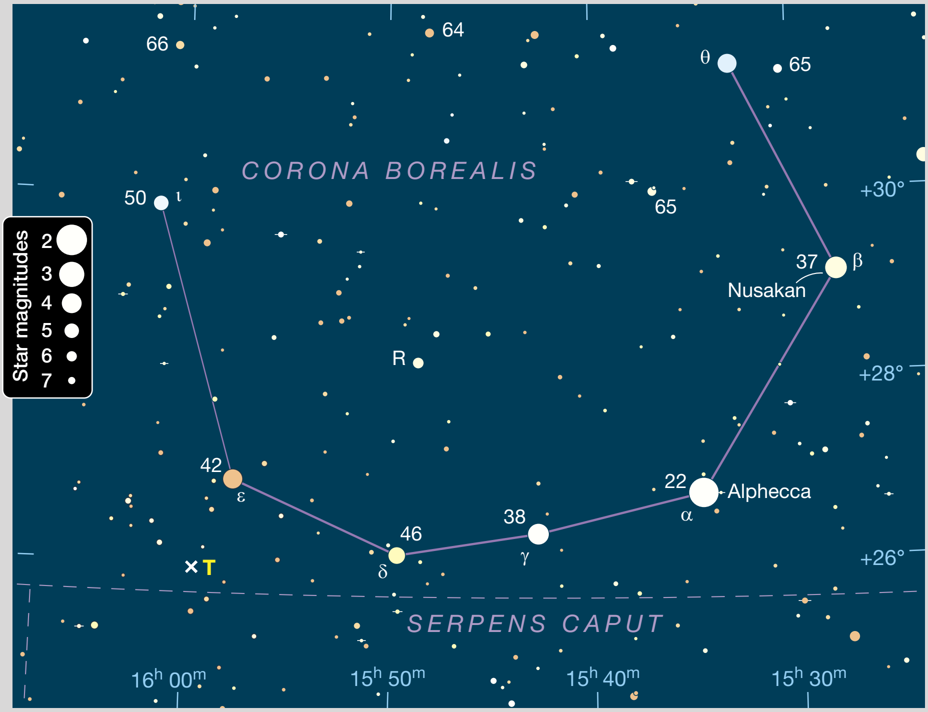
SUNDAY, MAY 31

As the month concludes, **Venus** reaches its greatest altitude as the reigning Evening Star. The distinction is largely academic, however, since the planet remains at essentially the same height for several weeks. That said, the date is notable because it marks the beginning of the end for this apparition, which got underway at the start of February. However, unlike Mercury whose comings and goings seem to happen at lightning speed, Venus's departure will take months to unfold. The brilliant planet will retain its Evening Star title until October, when it transitions into a morning object at the end of the month.

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

Still Waiting for T Cor Bor's Big Boom

The star system is "filling the tank" in preparation for its long-anticipated outburst.



◀ It's easy to navigate to T Coronae Borealis. Start at Alphecca and star-hop partway around the crown to 4th-magnitude Eta (η) Coronae Borealis. From here, use the detailed chart to pinpoint the recurrent nova. During quiescence the star hovers around 10th magnitude with slight variations in its light. When the nova eruption finally occurs, we'll see a fast rise to around 2nd magnitude — similar to Alphecca — followed by a relatively quick decline to around 6th magnitude within the first week, and then a gradual, slow fade back to minimum.

Whenever the constellation Corona Borealis is visible, I reflexively look just below the crown shape, hoping to catch the next outburst of T Coronae Borealis (T CrB). You too? Many of us have vigilantly watched this spot since 2024, when a dip in its 2023 brightness heralded a potential outburst sometime between spring and fall of 2024. Because the star had behaved similarly just prior to its last eruption on February 9, 1946, astronomers were confident that fireworks were just around the corner (*S&T:* Mar. 2024, p. 34).

T CrB is a tightly orbiting stellar pair composed of a massive white dwarf and a solar-mass red giant 3,000 light-years from us. The giant is overflowing its *Roche lobe*, losing mass to the white dwarf. The dwarf's immense gravity pulls the material, mostly hydrogen gas, into a swirling accretion disk around itself. Friction within the disk causes the gas to spiral inward until it impacts the star's surface. Over time, hydrogen accumulates on the dense dwarf's surface until the build-up of heat and pressure triggers runaway nuclear fusion, resulting in a massive explosion.

A typical blast is about 200,000 times brighter than the Sun. T CrB, which normally flutters around magnitude 10 and requires a 3-inch telescope to see, soared to magnitude 3.0 in 1946 and to about 2.0 during the previous outburst in May 1866. Its rise to peak brilliance takes a matter of hours and lasts only a day or two, so when the next explosion occurs, stay mobile so you can dodge the clouds.

Thousands to tens of thousands of years typically separate outbursts in classical novae, but T CrB is one of 10 known *recurrent novae.* These stars' accreted material ignites at intervals of 100 or fewer years; T CrB's outbursts occur at approximately 80-year intervals. The one prior to 1946 was observed on May 12, 1866. Brad Schaefer (Louisiana State University) discovered two additional historical eruptions in 1787 and 1217.

In a September 2025 paper in *Astronomy & Astrophysics*, Italian astronomer Ulisse Munari (University of Padua) and collaborators examined and compared T CrB's behavior from 1936 to 1945 (eight years prior to its 1946 outburst) with that from 2015 to 2023 (eight years before its expected eruption in late 2024). Both periods saw an uptick in the rate of mass transfer from the accretion disk onto the star's surface, a sign that the dwarf was accumulating enough mass to tip the scales and "go nova."

Six months after the end of the 1946 transfer, T CrB blew its top. Astronomers anticipated a similar event in 2024, but it's been more than two years and still no dice — unless it happens in the gap between this writing and publication. Differences between the two lead-ups might explain the delay. Prior to the 1946 eruption, the overall amount of light radiated by the accretion disk was considerably greater compared to the current cycle. The authors suggest this may mean that not enough material has been transferred yet from the disk to spark a thermonuclear runaway. But there's a bit of good news: Over the past year or more, the inflow rate of gas through the disk has increased above the norm, strongly hinting at an imminent outburst.

Others have tried their hands at sussing out the star's next move. Jean Schneider's (Paris Observatory) 2024 paper "When Will the Next T CrB Eruption Occur?" outlines a method based on previous eruption dates and the binary star's orbital period. He points out that the separation in dates between successive previous outbursts is an integer multiple of the system's 227.6-day orbital period, and he tentatively anticipates "with a precision of a week or two" when T CrB will pull the pin. Using his formula, its next eruption could happen around June 25, 2026.

In Schaefer's extensive work on the star, he forecast the potential 2024 outburst based on close similarities between T CrB's behavior prior to the 1946 eruption, both the star's high state (when it greedily siphons gas) and the pre-eruption dip months before detonation. But after missing its deadline in 2024, T CrB surprised observers in 2025 when it brightened again, switching from its normal low state (low-rate accretion) to high.

"No one has any inkling why," says Schaefer. "So, the 2026 eruption schedule is not following the 1946 eruption schedule. T CrB will do what it knows best . . . for reasons that no one knows."

That's why observers should remain vigilant. This month the variable beckons from high up in the eastern sky as soon as it gets dark. It's located 5½° east of 2nd-magnitude Alphecca, the crown's brightest gem — for now. When T CrB goes boom, it may give Alphecca a run for the money.

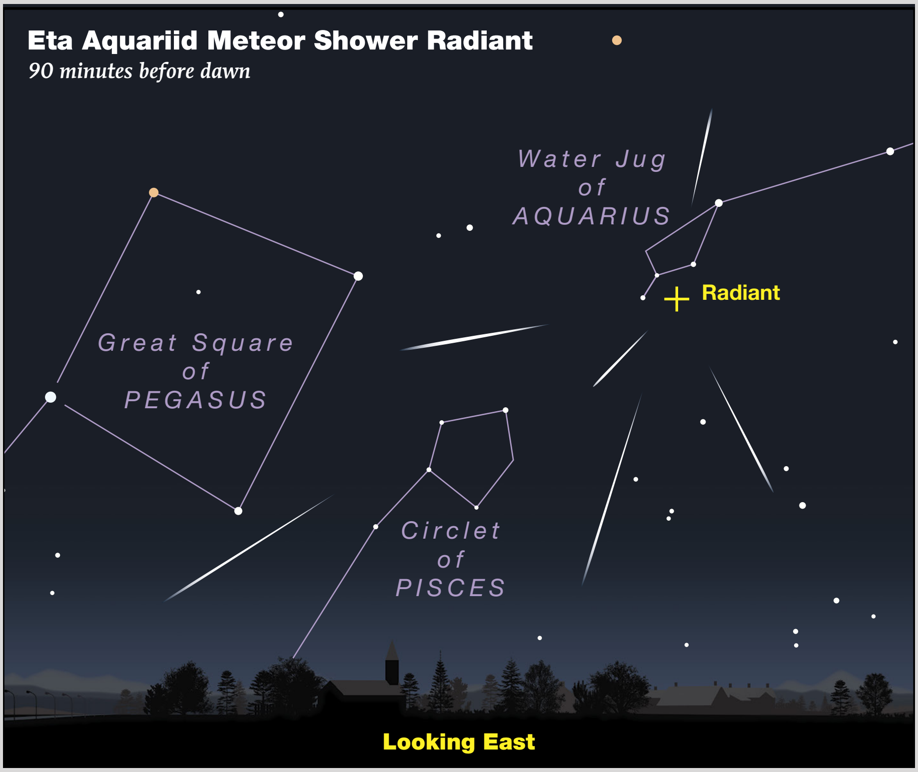
"Sooner or later, we'll see the hellfire of the H-bomb of T CrB," Schaefer notes.

You can monitor any brightening trend by routinely photographing the constellation with a smartphone. From my house, a handheld 10-second exposure with my iPhone easily shows stars to magnitude 6.5. To be alerted to the coming eruption, subscribe free to The Astronomer's Telegram at **astronomerstelegram.org**. The American Association of Variable Star Observers will also alert members immediately of the eruption. No need to join; you can start a free website account by following the links at **aavso.org/faq**.

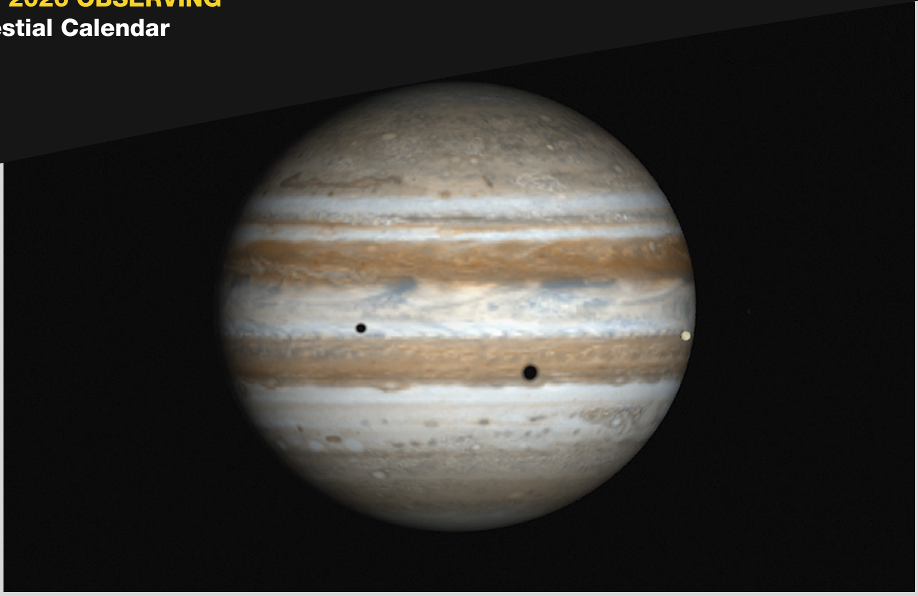
Eta Aquariids Battle Moonlight

IF YOU LIKE SQUEEZING the juice out of life, I've got a meteor shower for you. The annual Eta Aquariid shower will generate some 50 fast-moving meteors per hour at its peak for tropical latitude observers one or two hours before dawn on the morning of May 6th. Due to the low altitude of the radiant, observers at mid-northern latitudes might ordinarily see 10 to 30 meteors per hour under moonless, rural skies. Unfortunately, this year the 81% waning gibbous Moon in Sagittarius will reduce that to fewer than 10. On the positive side, shower members often leave bright and persistent ionization trails called *trains*.

These particles stream from a radiant in northern Aquarius near the star Eta (η) Aquarii, which reaches 15° to 20° altitude at the start of morning twilight. Why not observe what you can of the shower, then catch Saturn in the southeastern sky in mid-twilight and finish the morning with a refreshing sunrise? Make a night of it, and you'll be less likely to be disappointed if the shower bombs.



▲ The Eta Aquariids peak in moonlight on the morning of May 6th, but they'll be active for about a week around that date. The swift flashes originate from dust shed by Halley's Comet. Observers have an hour or two of good viewing before the start of dawn twilight.



STELLARIUM

Jupiter Has More Under Its Belts

▲ This simulation shows the dual shadows of Europa (left) and Ganymede (right) around midnight Eastern Time on the night of May 15–16. Europa appears just inside Jupiter's western limb. North is up.

WITH JUPITER LONG past opposition and flirting with dusk, you may have moved on to other targets. Before you do, let me entice you to linger a little longer with the gas giant. Three double-shadow transits of Ganymede and Europa are on tap May 8th, 15th, and 22nd before the mighty planet succumbs to solar glare.

The May 15th double transit begins at 11:20 p.m. EDT, when Europa's shadow appears, and ends at 1:26 a.m. EDT, when Ganymede's shadow disappears. Although the start will be visible from the Eastern Time Zone, Jupiter will be very low in the northwestern sky. Circumstances are much better across the rest of the U.S., where observers will have at least an hour to spend watching cat chase mouse.

This month marks the start of the Galilean moons' mutual-occultation season. This much-anticipated observing opportunity occurs about every six years, when Earth crosses their orbital plane. Now through May 2027, the four satellites will repeatedly occult and cast shadows on each other. Most of May's events are minor or poorly timed for the Americas. But on the evening of May 24th, a remarkable sequence of events involving Io and Europa will unfold about one Jupiter-diameter east of the planet, with both moons hidden in its shadow.

At 10:48 p.m. EDT, Io emerges from Jupiter's shadow. Europa, which lies immediately east of Io, will be in the shadow at this time and hidden from view. Next, Io occults Europa (still fully eclipsed) starting at 10:58 p.m. Although Europa will be little more than a dim, 19th-magnitude speck, might the right combination of camera and exposure be able to capture it?

At about 11:27 p.m., Europa begins to emerge from eclipse while still partially occulted by Io. Several minutes later it's fully in sunlight but still somewhat hidden behind Io. At high magnification in good seeing, the "touching" moons may resemble an imperfectly resolved double star. The two finally detach at around 11:38 p.m. and slowly glide apart. Some or all of the sequence will be visible throughout much of the Americas. The Midwest and western states will have the best views.

For a list of mutual events, check out the French Institute of Celestial Mechanics, Celestial Dynamics and Ephemeris (IMCCE) Satellites Phenomena page at **https://is.gd/Jupsat_events**. You'll find additional information at the *Documentation* link.

Action at Jupiter

THE CURRENT JUPITER apparition is rapidly winding down, and this month presents your last opportunity to see the giant planet at its telescopic best before its conjunction with the Sun on July 29th. As May begins, Jupiter is already well past the meridian by sunset and has an altitude of 30° or greater only until around 10 p.m. local daylight time. By the end of the month, it's lower than that shortly after sunset. During May the Jovian disk shrinks from 35.6″ down to 33.2″ — significantly smaller than its opposition peak of 46.6″.

Any telescope reveals the four big Galilean moons; binoculars usually show at least two or three. As seen from Earth, the moons change positions along an almost straight line. Use the diagram on the facing page to identify them by their relative positions on any given date and time. Interactions between Jupiter and its satellites and their shadows are tabulated on the facing page.

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

April 1: 4:17, 14:13; **2**: 0:09, 10:04, 20:00; **3**: 5:56, 15:52; **4**: 1:48, 11:43, 21:39; **5**: 7:35, 17:31; **6**: 3:26, 13:22, 23:18; **7**: 9:14, 19:10; **8**: 5:05, 15:01; **9**: 0:57, 10:53, 20:49; **10**: 6:44, 16:40; **11**: 2:36, 12:32, 22:28; **12**: 8:23, 18:19; **13**: 4:15, 14:11; **14**: 0:07, 10:02, 19:58; **15**: 5:54, 15:50; **16**: 1:46, 11:41, 21:37; **17**: 7:33, 17:29; **18**: 3:25, 13:20, 23:16; **19**: 9:12, 19:08; **20**: 5:04, 14:59; **21**: 0:55, 10:51, 20:47; **22**: 6:43, 16:39; **23**: 2:34, 12:30, 22:26; **24**: 8:22, 18:18; **25**: 4:13, 14:09; **26**: 0:05, 10:01, 19:57; **27**: 5:52, 15:48; **28**: 1:44, 11:40, 21:36; **29**: 7:32, 17:27; **30**: 3:23, 13:19, 23:15

May 1: 9:09, 19:05; **2**: 5:01, 14:56; **3**: 0:52, 10:48, 20:44; **4**: 6:40, 16:36; **5**: 2:31, 12:27, 22:23; **6**: 8:19, 18:15; **7**: 4:11, 14:06; **8**: 0:02, 9:58, 19:54; **9**: 5:50, 15:46; **10**: 1:41, 11:37, 21:33; **11**: 7:29, 17:25; **12**: 3:21, 13:16, 23:12;

13: 9:08, 19:04; **14**: 5:00, 14:56; **15**: 0:51, 10:47, 20:43; **16**: 6:39, 16:35; **17**: 2:31, 12:26, 22:22; **18**: 8:18, 18:14; **19**: 4:10, 14:06; **20**: 0:01, 9:57, 19:53; **21**: 5:49, 15:45; **22**: 1:41, 11:36, 21:32; **23**: 7:28, 17:24; **24**: 3:20, 13:16, 23:12; **25**: 9:07, 19:03; **26**: 4:59, 14:55; **27**: 0:51, 10:47, 20:42; **28**: 6:38, 16:34; **29**: 2:30, 12:26, 22:22; **30**: 8:17, 18:13; **31**: 4:09, 14:05

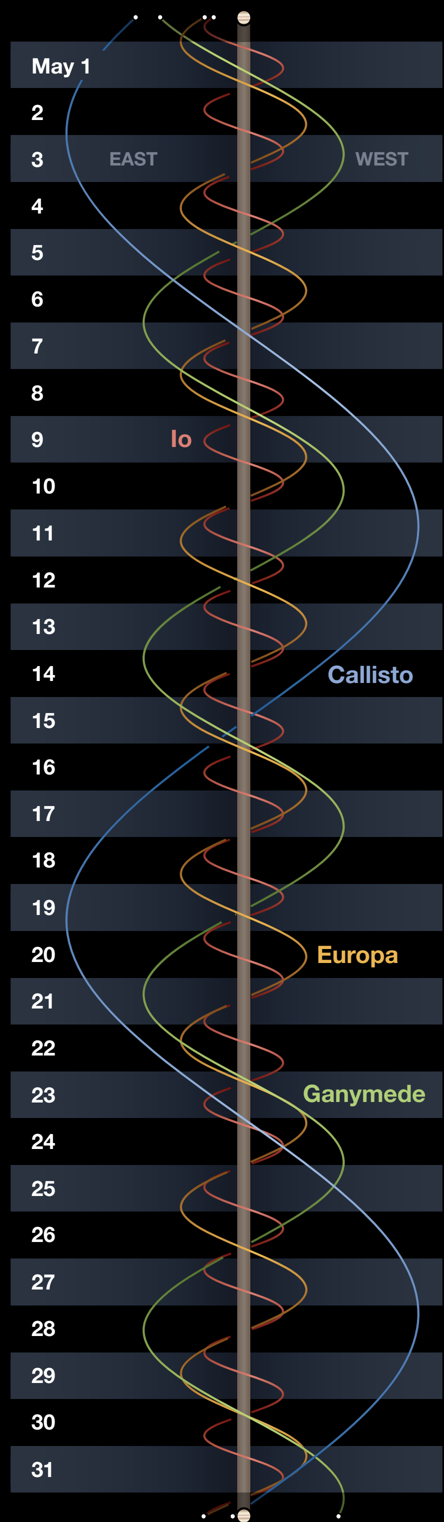
These times assume that the spot will be centered at System II longitude 89° on May 1st. If the Red Spot has moved elsewhere, it will transit 1²/₃ minutes earlier for each degree less than 89° and 1²/₃ minutes later for each degree more.

Phenomena of Jupiter's Moons, May 2026

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

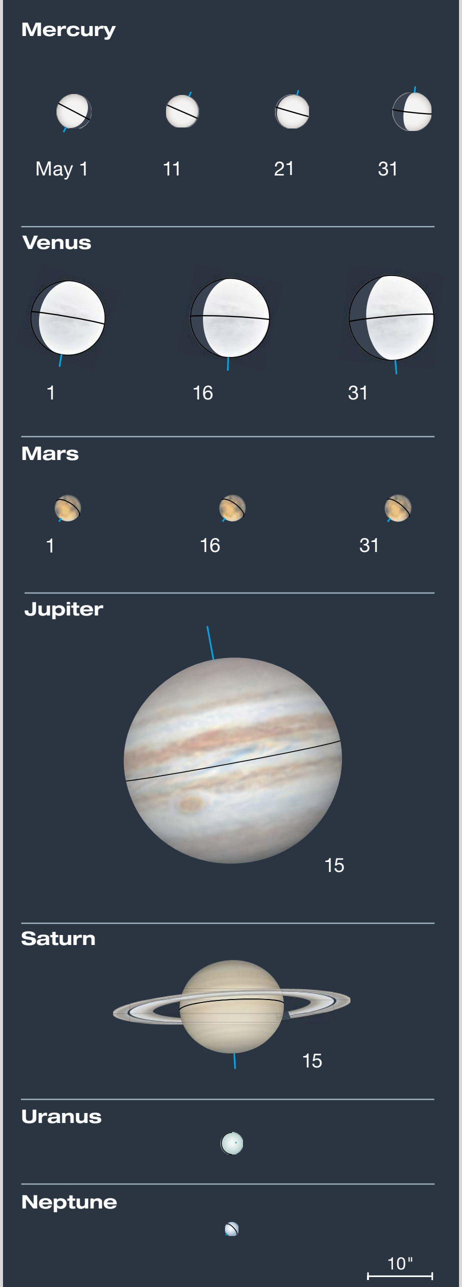
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, 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** visible at dusk starting on the 22nd • **Venus** visible at dusk • **Mars** reappears at dawn on the 14th • **Jupiter** visible at dusk and sets around midnight • **Saturn** visible low in the east-southeast at dawn.



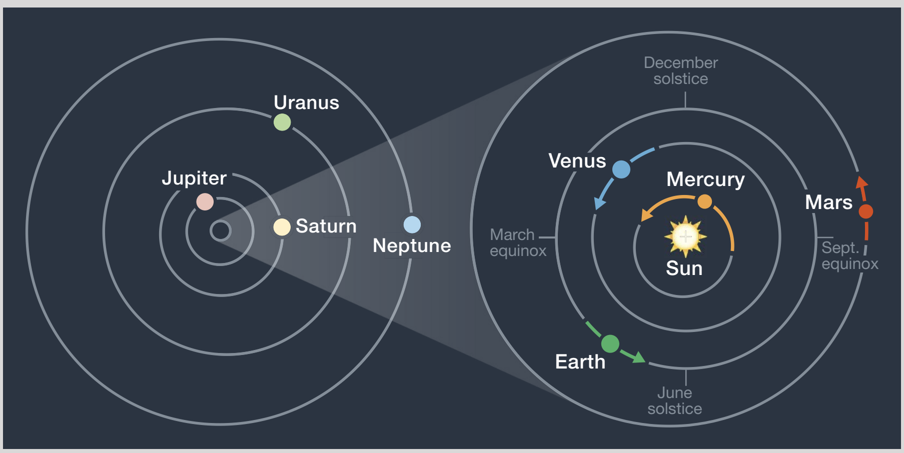
▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

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

May Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	2^h 31.5^m	+14° 54′	—	–26.8	31′ 45″	—	1.007
	31	4^h 30.1^m	+21° 50′	—	–26.8	31′ 33″	—	1.014
Mercury	1	1^h 37.8^m	+8° 06′	15° Mo	–0.8	5.4″	87%	1.250
	11	2^h 53.4^m	+16° 04′	4° Mo	–1.8	5.1″	99%	1.322
	21	4^h 21.3^m	+22° 43′	8° Ev	–1.6	5.3″	95%	1.280
	31	5^h 46.9^m	+25° 32′	18° Ev	–0.7	6.0″	72%	1.121
Venus	1	4^h 24.0^m	+22° 31′	28° Ev	–3.9	11.6″	88%	1.438
	11	5^h 16.0^m	+24° 22′	30° Ev	–3.9	12.0″	86%	1.384
	21	6^h 08.7^m	+25° 05′	32° Ev	–3.9	12.6″	83%	1.326
	31	7^h 01.0^m	+24° 37′	35° Ev	–3.9	13.2″	80%	1.263
Mars	1	1^h 00.4^m	+5° 29′	24° Mo	+1.2	4.2″	98%	2.245
	16	1^h 42.9^m	+9° 50′	27° Mo	+1.2	4.2″	97%	2.218
	31	2^h 25.9^m	+13° 47′	31° Mo	+1.3	4.3″	97%	2.186
Jupiter	1	7^h 20.6^m	+22° 32′	68° Ev	–2.0	35.6″	99%	5.544
	31	7^h 41.8^m	+21° 48′	44° Ev	–1.9	33.2″	100%	5.943
Saturn	1	0^h 35.7^m	+1° 29′	32° Mo	+0.9	16.1″	100%	10.325
	31	0^h 46.9^m	+2° 35′	57° Mo	+0.9	16.7″	100%	9.979
Uranus	16	3^h 54.6^m	+20° 09′	6° Ev	+5.8	3.4″	100%	20.471
Neptune	16	0^h 14.3^m	+0° 06′	51° Mo	+7.9	2.2″	100%	30.501

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



THE BEAR CHASERS This illustration from Alexander Jamieson's 1822 *Celestial Atlas*, depicts Boötes, the Herdsman, holding the leashes of Canes Venatici, the Hunting Dogs, as they chase after Ursa Major, the Great Bear, shown partially at upper right. The star Cor Caroli, Alpha (α) Canum Venaticorum, is adorned with a crown and a heart since it honors an English monarch.

ALEXANDER JAMIESON / CELESTIAL ATLAS (1822) / UNITED STATES NAVAL OBSERVATORY LIBRARY / PUBLIC DOMAIN

Night of the Bloodhounds

Try this short hop from a bright double star to a distant galaxy.

Mid-May 2025, nightfall: I was setting up a couple of telescopes in my backyard near downtown Chilliwack, a small city 100 km (60 miles) east of Vancouver, British Columbia. My badly light-polluted suburban sky seemed useable high in the south. Good! I wanted to explore the den of Canes Venatici, the Hunting Dogs.

Taking a moment to gaze up at the Big Dipper, I noticed that the 2nd-magnitude star Alkaid at the end of the Dipper's handle (see the chart on page 17) was approaching the zenith. Alkaid, also designated Eta (η) Ursae Majoris, as a zenith marker is a perk of my observing location just north of latitude 49°. From Alkaid, I shifted my gaze downward to Canes Venatici. For American observers roughly 10° south of me, it's this constellation (rather than the Dipper) that drifts across the zenith each spring.

Canes Venatici's zenithal passage is hardly dramatic, yet the 19th-century Scottish poet Thomas Carlyle saw it as a vibrant dash of the dogs: "What thinks Boötes of them as he leads his Hunting Dogs over the Zenith in their leash of sidereal fire?" Wow!

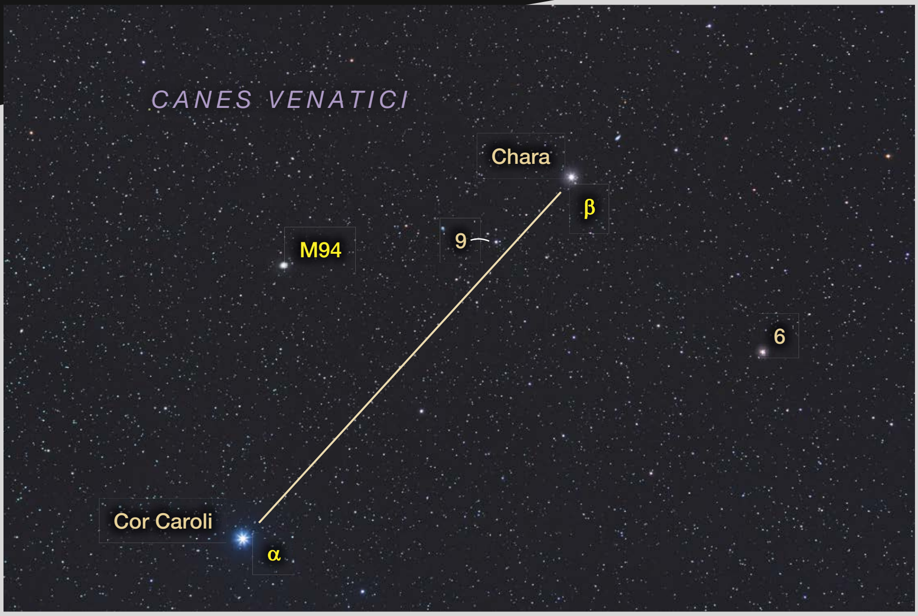
Seeing Double

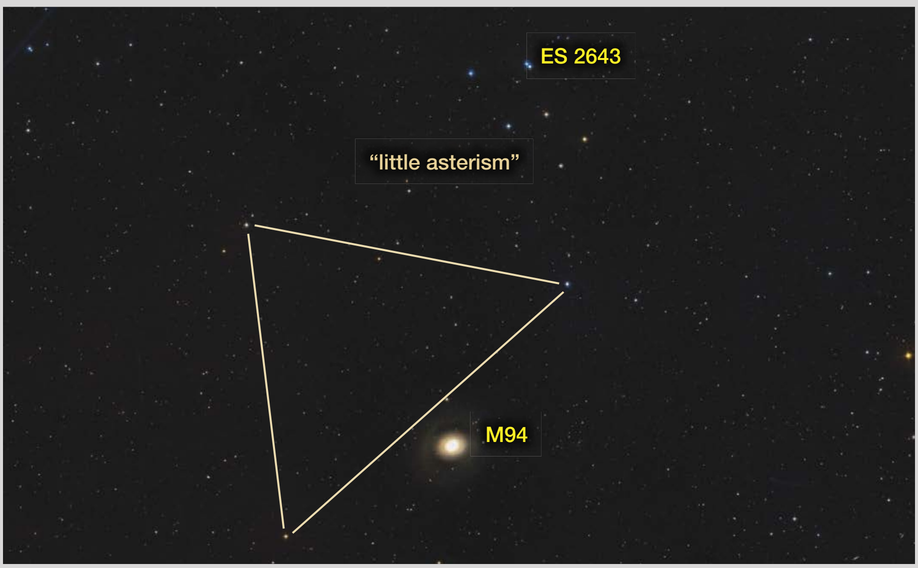
We should take Carlyle's poetic flourish with a grain of salt — there isn't much "sidereal fire" in Canes Venatici. The inconspicuous constellation below the Big Dipper possesses only two stars brighter than magnitude 4.5. Fortunately, 2.9-magnitude **Alpha (α) Canum Venaticorum** has a secure place in celestial lore because of its evocative name, Cor Caroli. The alliterative moniker translates as "Charles's Heart," possibly in honor of King Charles I of England who was executed in 1649, or perhaps his son, Charles II, who restored the English monarchy in 1660 — but not Charles III, the current king!

Cor Caroli is also attractive in a telescope. Listed in double-star catalogs as Struve 1692 (Σ1692), blue-white Cor Caroli features a creamy-white, 5.5-magnitude companion 19.2″ to the southwest. The unequal tandem is alluring in any scope working at low to medium magnification. Despite its obvious beauty, though, Σ1692 may not be a true binary. According to the Hipparcos-2 Catalogue, Cor Caroli itself is 115 light-years away, but the distance to its "companion" is less certain. The duo could be a line-of-sight *optical double*. Either way, Σ1692 is a rewarding telescopic study.

When I aimed my 4¼-inch Newtonian reflector at Cor Caroli, the steep angle of the telescope tube was literally a pain in the neck due to the instrument's original straight-through 6×30 finderscope. I didn't get Cor Caroli perfectly centered on the finder's crosshairs, so it appeared near the western edge of the low-power field of the main scope. That slight inaccuracy led to a minor discovery: an inconspicuous set of pinpoints ½° east of Cor Caroli. I determined this neighbor to be **Σ1702**, a wide double exhibiting 8.7- and 9.4-magnitude stars a breezy 35.9″ apart. My small scope resolved both Struves in one 27× field of view.

Chart 53 of *Uranometria 2000.0 Deep Sky Atlas* (I still use my 25-year-old copy) plots two tiny dots 19′ apart, 35′ southwest of Cor Caroli. The westernmost dot is marked as a double star. A bit of research revealed it to be a tough binary named **Σ1688**. I nudged Cor Caroli to the northeastern edge of the telescope's 27× field of view and, as expected, the dim star appeared near the southwestern edge. Σ1688 boasts a





◀ ZENITHAL HUNTING GROUND This month's tour area lies about 15° south of the handle of the Big Dipper. A line drawn from 2.9-magnitude Alpha (α) Canum Venaticorum to 4.2-magnitude Beta (β) Canum Venaticorum creates the simple outline of this constellation. The other stars of Canes Venatici aren't visible to suburban stargazers without optical aid. However, several pretty double stars and one gorgeous galaxy (M94) are featured here for backyard telescopes. North is up in all images.

WIDE-FIELD CONSTELLATION: ALAN DYER
CLOSE-UP VIEWS: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY (2)

separation of 14.4″, but it challenged me that night because I was trying to pick up its components of magnitudes 9.2 and (gulp) 11.1 under bright, suburban skies. I needed 93× magnification to split the very faint, uneven pair.

My 10-inch Newtonian (fortunately equipped with a right-angle finderscope) resolved Σ1688 at 64×, though not easily. Higher power improved the resolution; however, it was obvious I'd reached a visual threshold. When I observe at home, stars of 11th magnitude are about as faint as I can go.

Going Deeper

The second-brightest member of Canes is **Beta (β) Canum Venaticorum**, also known as Chara ("joy" in Greek). The 4.2-magnitude star was barely visible to my unaided eyes 5¼° northwest of Cor Caroli. I strained again to employ the straight-through finder on my smaller Newtonian to place Chara in the low-magnification field of view.

From Chara, I hopped 1° southeastward to 6.4-magnitude 9 Canum Venaticorum and carefully centered it in the low-power field. My right eye glued to the eyepiece, I shifted the reflector a tad more than 2¼° directly eastward — an easy move since the scope is on an equatorial mount — to the 8.2-magnitude galaxy **M94**. I spotted M94's pale glow next to a northwest-leaning triangle about 1° in length and formed by two 8.7-magnitude stars and one 8.5-magnitude star.

The M in M94 is for Charles Messier, but it just as easily could honor Pierre Méchain, Messier's French colleague, who discovered the object on March 22, 1781. After receiving notification from Méchain, Messier observed the "nebula without star" and made it the

▶ **ELEGANT LITTLE SPIRAL** M94 lies approximately 15.3 million light-years away. This face-on starburst galaxy exhibits a nested, ringlike set of spiral arms. Its bright active core is surrounded by a dominant inner ring, about 7,000 light-years in diameter and dotted with pink emission nebulae and massive, young blue stars. Around it is a less impressive outer ring of older suns spanning some 45,000 light-years across, as well as a faint "halo" of ill-defined spiral structure.

R. JAY GABANY

94th entry in his now-famous catalog. "Its center is brilliant, the nebulosity slightly diffuse," wrote Messier. "It resembles the nebula which is below the Hare, No. 79: but this one is finer and more brilliant." The latter part of his description is telling, because M79 is a moderately concentrated globular cluster while M94 is a face-on spiral galaxy — a physical difference that was well beyond Messier's ability to determine.

Statistics can be misleading. M94 is listed in modern observing catalogs as 14.4′ × 12.1′ in extent; however, only the galaxy's inner region is perceptible in backyard telescopes. Indeed, my suburban impression was similar to Messier's description 245 years ago. At low power, the galaxy was merely a cotton ball of light. Bumping up to 72×, I perceived a compact fuzzball maybe 2′ across. A 9.6-magnitude star stood guard 8′ north of the fuzzball, and another one of magnitude 11.1 glimmered 5′ west of it. At 97×, the diffuse object was marginally larger and sharply brighter toward the middle. Like many galaxies I've observed in my blanched sky, M94 resembled a ho-hum, tailless comet — or, yes, an unresolved globular cluster.

Finding M94 in my 10-inch reflector was tricky, as it was on a Dobsonian mount. A target near the zenith is no friend of these mounts. The otherwise agile Dob balked at the azimuth push-pull needed to acquire M94 and keep it centered in the eyepiece field. I persevered, of course. At 90×, the "comet imposter" was definitely more prominent. At 169×, its misty edge blended into a tenuous outer halo that increased the diameter to 3′ or 4′. At 227×, the halo was obvious and the central region gleamed. In moments of steady seeing, I could detect a minuscule nucleus.

A Lucky Find

The final stop in my brief Canes Venatici venture was, like Σ1702 next to Cor Caroli, another satisfying example of a "serendipitous sighting." The lucky view occurred after I had observed M94 in my smaller scope at low magnification. I simply wondered if there was anything of interest nearby. As I swept systematically around the area, a little elongated asterism caught my eye about 1° north-northwest of M94.

Almost 24′ long and 12′ wide, the geometric pattern displayed a half dozen stars ranging in magnitude from 8.5 to 8.8. One of them formed a 45.1″-wide double I later identified as **Espin 2643** (ES 2643). The 8.8-magnitude northeastern component of ES 2643 shone blue-white, while the 8.6-magnitude southwestern spark was yellowish white. Nice!

This May around mid-month, there'll be no evening moonlight to spoil your appreciation of the Hunting Dogs leaping high up on "their leash of sidereal fire." I hope you'll hop over to the bloodhounds to get a decent view of M94 and the other targets.

Good luck!

■ Contributing Editor **KEN HEWITT-WHITE** has been observing deep-sky objects for 60 years.

Canes Showpieces

Object	Type	Mag	Size/Sep	RA	Dec.
α Canum Venaticorum	Double star	2.9, 5.5	19.2″	$12^h\,56.0^m$	+38° 19′
Σ1702	Double star	8.7, 9.4	35.9″	$12^h\,58.5^m$	+38° 17′
Σ1688	Double star	9.2, 11.1	14.1″	$12^h\,53.6^m$	+37° 58′
β Canum Venaticorum	Star	4.2	—	$12^h\,33.7^m$	+41° 21′
M94	Galaxy	8.2	14.4′ × 12.1′	$12^h\,50.9^m$	+41° 07′
ES 2643	Double star	8.6, 8.8	45.1″	$12^h\,49.1^m$	+42° 13′

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.

Seeing Double

Try to resolve these close galaxy pairs.

On May 29, 1821, John Herschel conducted a trial sweep for nebulae using a replica of his father's famed 20-foot reflector. His father, William, who was then 82 years old, guided the session while his aunt Caroline assisted by taking notes. Starting at the 5.7-magnitude star 108 Virginis, two galaxies — **NGC 5846** and NGC 5850 — drifted into view after 20 minutes. William had discovered the pair decades earlier, but on this night John noticed that NGC 5846 "appears to have two nuclei."

NGC 5846 is a 10.0-magnitude, giant elliptical in Virgo about 90 million light-years away. Herschel's second nucleus, designated **NGC 5846A**, is a rare compact elliptical at the southern edge of NGC 5846's halo. Its outer stellar layers have been tidally stripped as it plunges through the halo of its massive neighbor, while ram pressure has expelled a trailing tail of hot, X-ray-emitting gas.

Even seasoned observers have struggled with NGC 5846A's appearance. In 1877, John Louis Emil Dreyer, using Lord Rosse's 72-inch Leviathan, described it as nebulous, but a year later dismissed it as a mere star. Former *Sky & Telescope* Contributing Editor Sue French spotted NGC 5846A in a 10-inch reflector at 231× and noted a "starlike spot with a tiny aureole of haze around it."

Tidal Plumes and Tails

Herschel's ambiguous companion sets the theme of our tour: close pairs and mergers where galaxies or galactic nuclei may masquerade as stars. A great example is **HCG 79**, commonly known as Seyfert's Sextet, whose five physical members (the sixth lies in the background) could fit within the confines of the Milky Way. Studies of the group's star-formation history reveal an early episode of intense activity, when the galaxies first crossed paths and exhausted much of their gas. As a result, a recent second pass has been mainly a "dry" interaction, without triggering new bursts of star formation despite the member's close separation.

French astronomer Édouard Stephan discovered this group in June 1876 using

▲ **CLOSE COMPANIONS** NGC 4410A and NGC 4410B are the close duo at upper center, alongside their companions, NGC 4410C and NGC 4410D, stringing along to the upper left. The glorious face-on spirals NGC 4411A and NGC 4411B hang just below the quartet. North is up in this image and the sketches.

JIM THOMMES

the 31-inch silvered-glass reflector at the Marseille Observatory in southern France. He only cataloged a single "nebula" (later listed as NGC 6027) but also mentioned a "very faint star involved, two very faint stars near." I bet at least one of these faint stars is a minuscule galaxy.

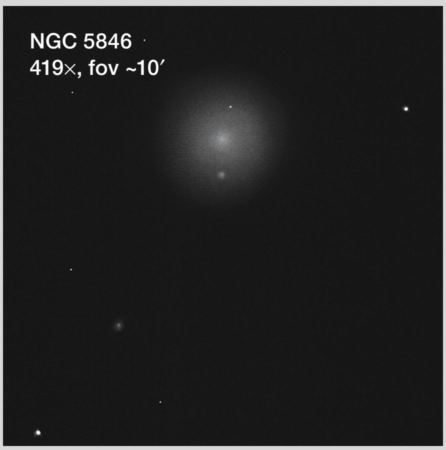
HCG 79 lies in northeastern Serpens Caput, 1.9° east-southeast of 4.8-magnitude Rho (ρ) Serpentis. Viewed through my 14.5-inch reflector at 158×, it appears as a lumpy 14th-magnitude glow that easily fits in a 1′ diameter circle. At 226×, the glow resolves into three teensy knots — HCG 79a, HCG 79b, and HCG 79c — along with the two faint, nearby stars. So, I can easily relate to Stephan's confusion! You'll need at least an 18-inch scope to glimpse any of the remaining members.

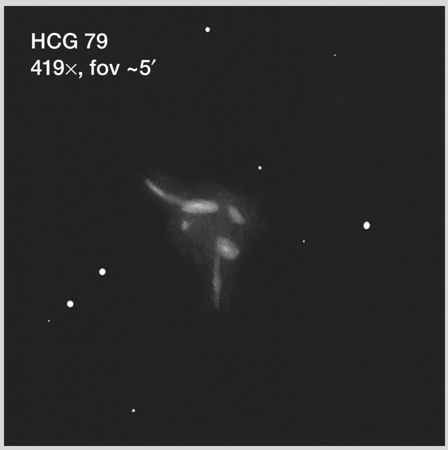
Our next targets, **NGC 4782** and **NGC 4783**, are an overlapping pair of elliptical galaxies in Corvus with a dumbbell-shaped halo. Optical and X-ray studies reveal dramatic tidal distortions, including a bridge of hot gas stretching between them, and long tidal plumes streaming outward. Simulations suggest NGC 4783 recently made a high-speed flyby of its larger neighbor, offsetting both nuclei in opposite directions. That near miss — probably 15 to 25 million years ago — leaves the pair in a loosely bound orbit that may end in a merger roughly 800 million years from now.

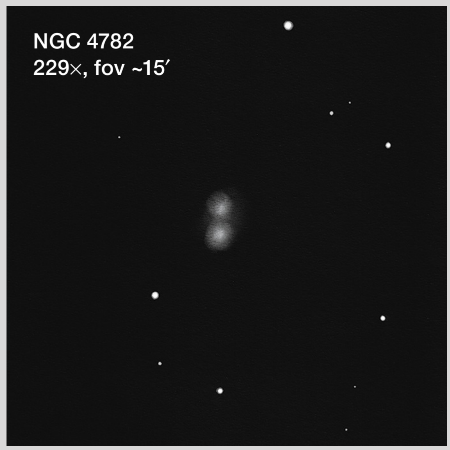
To locate 11.7-magnitude NGC 4782 and its companion, NGC 4783, navigate 3.7° east-southeast of 8th-magnitude M104, the Sombrero Galaxy. I first tracked these objects down in 1981 with an 8-inch Schmidt-Cassegrain and found the two halos barely touching at 100×. Through my 18-inch scope at 285×, each galaxy sports a bright, compact nucleus, and the pair is wrapped up in a common halo.

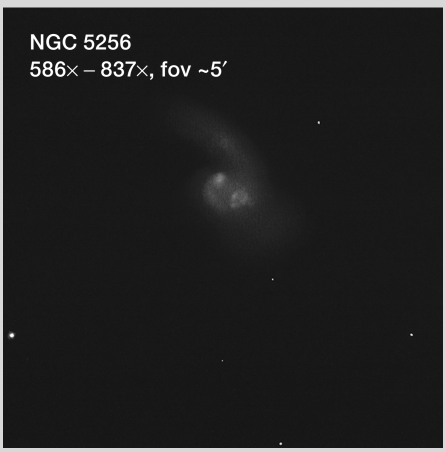
Moving to the north, **NGC 4410A** and **NGC 4410B** are a merging duo, only 19″ apart, with multiple tidal tails and plumes. Radio and optical studies reveal that NGC 4410A is encircled by a ring of star-forming H II regions, likely sparked by a head-on collision with NGC 4410B. The pair has ensnared two neighbors to the east in a stunning four-galaxy chain. A broad tidal bridge links to NGC 4410C, and yet another bridge ties NGC 4410C to NGC 4410D.

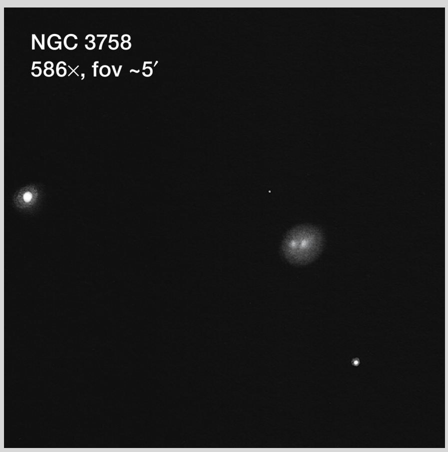
Situated about 350 million light-years away, this foursome belongs to a larger group of about a dozen galaxies behind the Virgo Cluster. From 8.9-magnitude M86, you'll need to steer 3.9° due south, or from 8.4-magnitude M49, head 1.3° northwest. My 24-inch scope at 375× resolves the NGC 4410 pair, although their halos overlap.

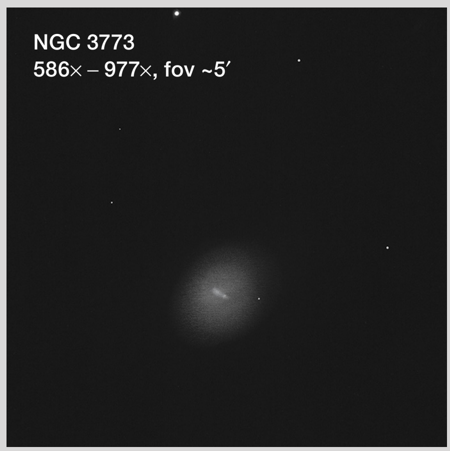












ALL SKETCHES: UWE GLAHN

▲ **SKETCHING AT THE EYEPIECE** German astronomer Uwe Glahn captured these close pairs using his 27-inch f/4.2 Dobsonian for all targets except NGC 4782 and NGC 4783 for which he was at the eyepiece of his 8-inch f/4 Newtonian.

Close Pairs

Objects	Constellation	Mag	Sep	RA	Dec.
NGC 5846, NGC 5846A	Virgo	10.0	44″	15^h 06.5^m	+01° 36′
HCG 79	Serpens Caput	13.9	23″	15^h 59.2^m	+20° 46′
NGC 4782, NGC 4783	Corvus	11.7	39″	12^h 54.6^m	–12° 34′
NGC 4410A, NGC 4410B	Virgo	12.8	19″	12^h 26.5^m	+09° 01′
NGC 5256	Ursa Major	13.2	10″	13^h 38.3^m	+48° 17′
NGC 3758	Leo	14.2	6″	11^h 36.5^m	+21° 36′
NGC 3773	Leo	12.0	3″	11^h 38.2^m	+12° 07′

Angular 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 and listed for the main galaxy.

NGC 4410B spans 20″ to 25″ across and features a conspicuous nucleus, while 12.8-magnitude NGC 4410A glows more diffusely. NGC 4110C and NGC 4110D appear as oval smudges to the northeast. The tidal bridges require your imagination, but in my mind's eye the connections are easy to trace.

Closing the Gap

NGC 5256 (also designated Mrk 266) is a spectacular merger some 400 million light-years away in eastern Ursa Major. It contains two active galactic nuclei (AGN) separated by a mere 10″ — less than 20,000 light-years in projection. The southwestern nucleus hosts a heavily shrouded AGN, driven by a supermassive black hole weighing at least 70 million Suns. Based on merger simulations, these dual black holes should coalesce in 50 to 300 million years. Inflowing molecular gas from the merger is fueling both AGNs, while also igniting a starburst that has boosted the system's infrared luminosity to roughly 340 billion times that of the Sun. A galactic-wide superwind from this frenzy of activity has blown huge loops of ionized gas and dust into intergalactic space.

To find 13.2-magnitude NGC 5256, slide 1.8° southwest of 2nd-magnitude Alkaid or Eta (η) Ursae Majoris, the end star in the Big Dipper's handle. In my 24-inch at 375×, its appearance only hints at the ongoing violence. NGC 5256 is an irregular 40″ × 30″ patch with a brighter northeastern knot (nucleus) that occasionally pops into view, while its southwestern partner is marked by a faint, ill-defined spot. But knowing that each nucleus harbors a supermassive black hole on a collision course makes the view exciting.

NGC 3758 (Mrk 739) in Leo also hosts a dual AGN — the eastern nucleus, Mrk 739E, has long been recognized as an active black hole, but the western nucleus, Mrk 739W, proved elusive to categorize. Optical, radio, and ultraviolet studies showed no AGN signature until a 2011 investigation with the Swift and Chandra space telescopes revealed a variable, hard X-ray source — evidence that an AGN is hidden behind dust and gas.

Spectroscopic studies suggest that NGC 3758 is still in the early stages of interaction after a first encounter. Mrk 739W is a young, star-forming spiral seen in the foreground, while Mrk 739E houses a black hole weighing between 16 and 17 million solar masses.

Fourteenth-magnitude NGC 3758 is conveniently placed 1° west-northwest of 5.3-magnitude 92 Leonis and only 0.5° southwest of Copeland's Septet (HCG 57). From 420 million light-years away, its two nuclei are separated by just 6″, which corresponds to 12,000 light-years — about 45% of the distance between the Sun and the Milky Way's center, a tight challenge requiring steady skies and high power. *Sky & Telescope* Contributing Editor Scott Harrington managed to occasionally split the pair using his 16-inch reflector at 440×, transforming an apparent bar-like center into two tiny knots during moments of superb seeing. I had little difficulty resolving them through Jimi Lowrey's supersize 48-inch Dob using 697×, noting Mrk 739E as slightly brighter.

While NGC 3758 demonstrates a pair in the midst of a first encounter, **NGC 3773** brings us to the late stages of coalescence. Hidden within this 12th-magnitude galaxy is one of the tightest known double nuclei, separated by a measly 3.2″. At a distance of some 60 million light-years, this translates to less than 1,000 light-years apart — on the verge of a final merger. Rather than hosting a twin AGN, one of the nuclei contains a young population of massive Wolf-Rayet stars — their short lifespan is a clear sign of a very recent starburst.

NGC 3773 lies just below the tail of Leo, 3.6° southwest of 2.1-magnitude Denebola, Beta (β) Leonis. I had a chance to view this galaxy at high power through Lowrey's 48-inch during last year's Texas Star Party. Using 610×, the bright central glow appeared elongated toward a faint 16.6-magnitude star hugging the galaxy's western flank. In moments of excellent seeing at 813× and 1,038×, the galaxy revealed its secret: The central bar resolved into two quasi-stellar points, with the larger eastern nucleus shining slightly brighter.

These close interactions and mergers have reshaped the galaxies and fueled both black holes and starbursts. For amateurs with larger telescopes, they offer an observational challenge and a chance to glimpse the chaos of galactic evolution.

■ Contributing Editor **STEVE GOTTLIEB** enjoys viewing all manner of deep-sky objects from northern California. For more of his favorite observing projects, see **adventuresindeepspace.com**.

FINDER CHARTS: To help you navigate to these targets, you can download finders at **skyandtelescope.org/GDMay2026**.

▲ CAMERA TRACKER

iOptron unveils the HST MiniTracker ($549), an ultra-portable drive for wide-field astrophotography with DSLR or mirrorless cameras. The MiniTracker weighs just 0.8 kg (1.8 lbs) yet can bear up to a 4-kg load without counterweight. The unit is driven with a single strain-wave gear and features four drive rates: sidereal, solar, lunar, and 0.5× (half sidereal) for nightscape photography. The HST MiniTracker includes a Vixen-style dovetail rail to attach to its optional Adjustable AZ/EQ Base ($79) or it can be mounted directly to a standard photo tripod. You can power the unit three ways: by an internal, rechargable battery, three AAA batteries, or an external 5-volt power bank (not included).

iOptron
1 Merrill St., Woburn, MA 01801
781-569-0200; ioptron.com

▲ SCOPE COVER

Celestron introduces a solution for long-term outdoor protection. The Weatherproof Telescope Cover ($59.95) is made of aluminum-laminated fabric designed to shield your rig from the elements when leaving it set up outside for months on end. The interior is lined with 210D polyester that resists snags and tears while pulling it over your instrument. The cover also blocks solar radiation to reduce heat buildup in direct sunlight. It's designed to fit all Celestron telescopes up to an 11-inch Schmidt-Cassegrain on an equatorial mount and measures 147 cm × 180 cm (58 × 71 inches). It includes a black shock-cord drawstring with ball-style lock to secure it to your scope.

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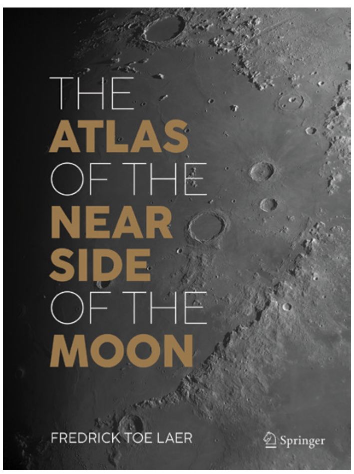

◀ NEARSIDE LUNAR ATLAS

German amateur astronomer Fredrick Toe Laer has published *The Atlas of the Near Side of the Moon* (hardcover for $44.99 or eBook PDF for $34.99). This 2025 publication is based on the Lunar Reconnaissance Orbiter Wide-Angle Camera mosaics, providing a photographic atlas that plots every official IAU-named feature as well as many unofficial ones. The book is divided into five chapters and is organized similarly to the popular *Atlas of the Moon* by Antonín Rükl. It depicts the lunar surface visible from Earth on 76 primary maps and 18 charts of the libration zones and polar regions. Each map is paired with a list of all the named features and points of special interest on the facing page. Several detail maps include the six Apollo lunar landing sites and several particularly interesting crater chains and other unusual areas. The book closes with an 83-page index of all listed features. 305 pages, ISBN 978-3-031-99277-3 (hardcover), ISBN 978-3-031-99278-0 (eBook).

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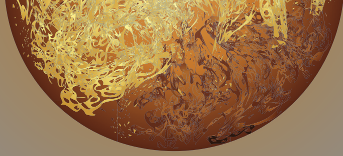


“Stop Trying to Sh

What is that strange light in the daytime sky?

Skywatchers recognize Venus as the brilliant planet that can appear both as an “evening star” following sunset and as a “morning star” before sunrise. But Venus can make an appearance as a bright dot in the daytime sky, too.

Several factors combine to reveal our neighboring planet during daylight hours. First is its apparent distance from the Sun in the sky. The term *elongation* refers to the angle between Venus and the Sun, as seen from Earth. Daytime sightings become most likely during a few weeks before or after greatest elongations, when Venus appears farthest from the Sun in the sky and is not hidden in its glare. Such day-time sightings require ideal weather and dark blue skies.

Successful observations also become more likely at times when Venus is near the meridian in the southern sky. This position puts the planet near its highest altitude, with the least atmospheric obscuration.

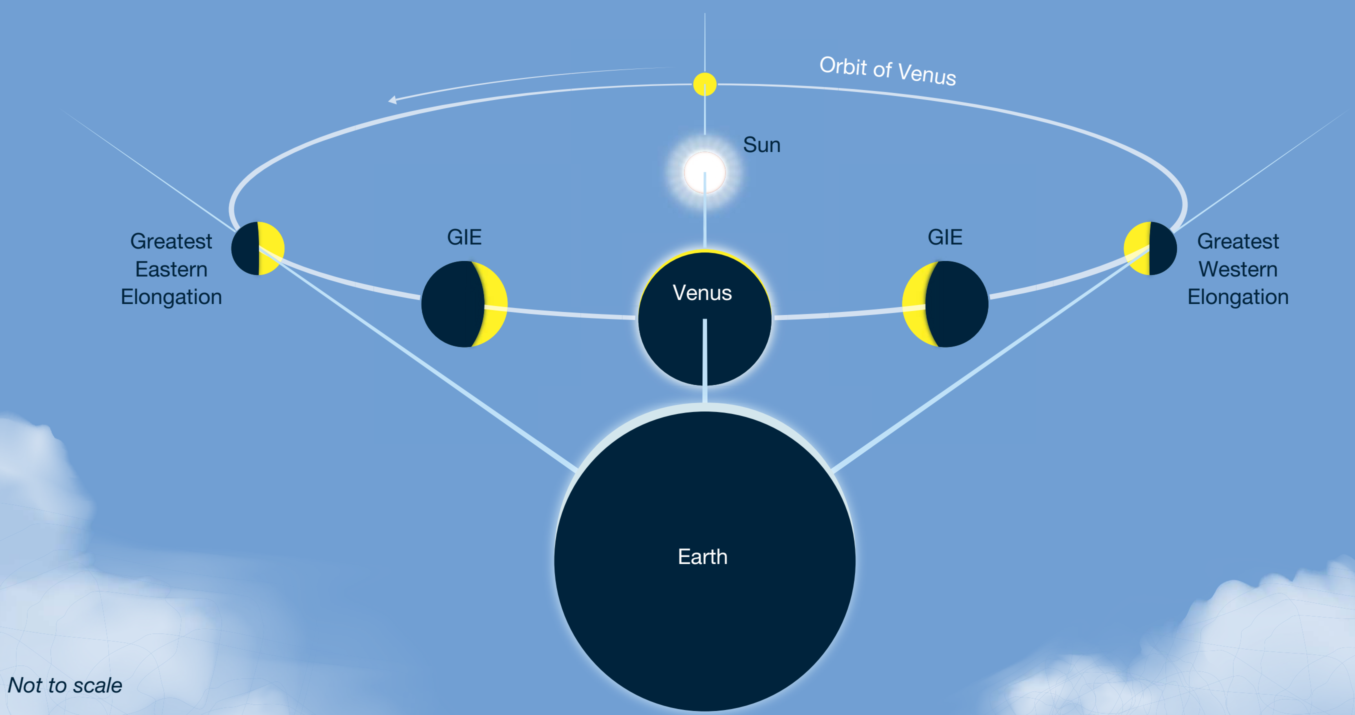
Also essential is that observers must focus their eyes at infinity. That’s easier when Venus happens to be near distant objects such as the corners of buildings, chimneys, treetops, and even clouds or the Moon (*S&T:* August 1954, p. 353).

But this is not a story about how you can spot Venus for yourself. This is a story of what sometimes happens when Venus catches people unawares.

Daytime sightings of Venus have occurred throughout history. A few examples involve Napoleon Bonaparte in 1797, Henry David Thoreau in 1854, Abraham Lincoln in 1865, and, most dramatically, the U.S. military in 1945. These events have caused amazement and, in some cases, antagonism.

The 18th and 19th Centuries

Notable sightings before the 20th century fall on the amazement end of the spectrum of reactions.



▲ **THE ORBIT OF VENUS** As seen from Earth, Venus can be up to 47° from the Sun at *greatest elongation*. East of the Sun, it appears in the evening sky; west of the Sun, in the morning sky. Venus will look brightest at the point marked *greatest illuminated extent* (GIE).

oot Down Venus”

▶ NOT FAST ENOUGH The fast interceptors at New Mexico’s Kirtland Field, the closest U.S. Army Air Forces base to the site of the Manhattan Project, were unable to fly high enough to shoot down Venus.

On December 10, 1797, a crowd lined the streets of Paris as Napoleon Bonaparte made his way to the Luxembourg Palace for a celebration of victories in his Italian campaign. French astronomer François Arago (1786–1853) preserved an account of an unusual celestial sighting on that day in his work *Astronomie Populaire*.

> *General Bonaparte, proceeding to the Luxembourg, where the Directory was to give a celebration for him, was very surprised in seeing the crowd assembled in the Rue de Tournon paying more attention to the part of the sky placed above the palace, than to his person and the splendid staff who accompanied him. Upon questioning he learned that the curious were viewing with astonishment, although it was broad daylight, a star which they took for that of the conqueror of Italy, an allusion to which the illustrious general seemed not indifferent when he himself with his own keen-sighted eyes observed the bright heavenly body.*

Arago himself recognized that “the star in question was none other than Venus.” Venus was about 46° from the Sun on that date and reached greatest elongation on January 3, 1798. Note that some modern authors and websites mistakenly place this event in the *country* of Luxembourg rather than at the correct site on the Rue de Tournon just north of the Luxembourg *palace* in Paris.

The journal kept by the naturalist Henry David Thoreau (1817–1862) records another sighting. Thoreau took a walk with his friend William Tappan near Walden Pond on the afternoon of January 9, 1854. The pair were watching the sky for meteorological phenomena when they noticed a bright dot in the heavens:

How Bright?

Predicting the brightness of Venus is difficult, as it depends on a combination of Venus’s phase (what fraction of the disk is illuminated) and distance from Earth (how large the disk appears in our sky). Both *S&T* and the *Astronomical Almanac* have replaced the traditional term *greatest brilliancy* with *greatest illuminated extent* (GIE), described by California amateur Mark Gingrich (*S&T:* May 2001, p. 62). Venus is at or near its brightest predicted magnitude for a few days before and after GIE.

We were looking for rainbow-tinted clouds, small whiffs of vapor which form and disperse, this clear, cold afternoon, when we saw to our surprise a star, about half past three or earlier, a mere round white dot. . . . This was about an hour and a half before sunset.

Computer planetarium programs set for this location, date, and time show that the object was Venus. The planet had reached greatest elongation on December 18, 1853.

About a decade later, and only a few weeks before the end of Abraham Lincoln's life, spectators in Washington, DC, also made a daylight sighting of Venus. Sergeant Smith Stimmel (1842–1935), one of Lincoln's bodyguards, described the scene immediately after the famed orator delivered his memorable Second Inaugural Address on March 4, 1865. The presidential party left the Capitol and proceeded along Pennsylvania Avenue. Stimmel recalled:

I noticed the crowd along the street looking intently, and some were pointing to something in the heavens toward the south. I glanced up in that direction, and there in plain view, shining out in all her starlike beauty, was the planet Venus. It was a little after midday at the time I saw it, possibly near one o'clock; the sun seemed to be a little west of the meridian, the star a little east.

A rainstorm that morning had washed pollution from the skies. Stimmel correctly noted that this remarkable daylight sighting was possible "owing to the peculiarly clear condition of the atmosphere and the favorable position of the planet at that time." Stimmel went on to say that Lincoln and his entourage saw Venus as well. Venus had reached greatest elongation on February 25, 1865.

The U.S. Military in 1945

But the daystar's appearance has sometimes had a more serious effect. Incidents from 1945, the last year of World War II, provide two examples of occurrences when the U.S. Navy and the U.S. Army Air Forces planned attacks upon and even tried to shoot down this mysterious object in the heavens. To their surprise, the extraterrestrial body in question was beyond the range of Earth weapons.

February 1945: Battleship USS *New York*

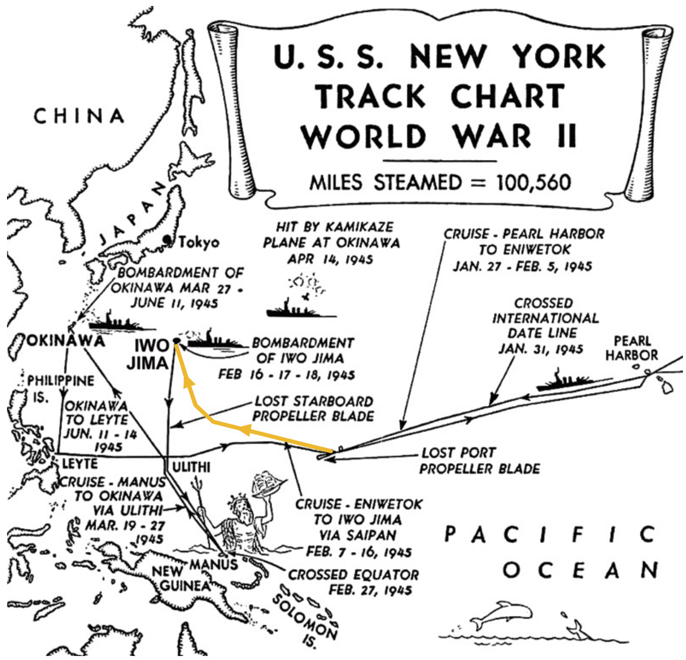
The ship's extensive service in the Atlantic during the early years of World War II included participation in the Operation Torch invasion of North Africa and duty as an escort for convoys. By the end of 1944, USS *New York* moved to the Pacific Theater. In the three days of bombardment that preceded the invasion of Iwo Jima on February 19, 1945, the battleship played a major role by firing at the volcanic island an estimated 612,000 kg (1.35 million pounds) of ordnance, including more than a thousand 14-inch shells.

After the war's end, the *New Yorker* magazine printed an article about the exploits of the battleship named after the state of New York. As part of the essay, the authors described an event that took place during its trip from Pearl Harbor to Iwo Jima. The *New York* had lost a propeller blade 1,600 km (1,000 miles) into its journey and was ordered to Eniwetok Atoll for repairs. From there, it proceeded to Saipan, and on to its final destination.

A young yeoman has told of an occurrence on this momentous trip of the New York*. . . . Everything was placid . . . when a strange object was seen following the vessel. It looked like a luminous metallic balloon and was immediately and unanimously judged to be a Japanese secret weapon of some sort.*

▼ **USS NEW YORK IN ACTION** USS *New York* firing her 14-inch guns during the bombardment of Iwo Jima on February 16, 1945.

▶ **PACIFIC TOUR** This chart shows the path of USS *New York* during the last year of World War II. In February 1945, somewhere between Eniwetok and Iwo Jima (marked in yellow), the battleship employed its 20-mm, 40-mm, and 3-inch guns in an unsuccessful attempt to shoot down a mysterious object — the planet Venus.



USS *NEW YORK* FIRING: NATIONAL ARCHIVES; MAP OF USS *NEW YORK* IN PACIFIC: UNITED STATES NAVY, REMIXED BY DON OLSON

"You should have seen our captain," the yeoman said. "He came back to the fantail and looked through his special binoculars. 'I see it,' he said quietly. He was a great man in a crisis.

"Marines were assigned to the twenty-millimeter guns, and they gathered in a little group on the starboard side of the bridge. The privates began opening ready boxes, and the gunnery sergeant, very professional, put on his flash gear and rubbed pink cream on his face. The captain yelled, calmly, of course, to the gunnery officer up in the sky control, 'Guns, give me a range on that object!' The gunnery officer replied, 'Approximately, sir, eight thousand eight hundred yards.' The captain said, 'Good. I thought it was about that. Let 'em have it.'

"The twenty-millimeters sounded like popguns, and the tracers faded into the sky, very short. The gunnery officer switched to the forty-millimeters, and they were short, too. The Marine sergeant shouted, 'Bring them more to the left!' The captain yelled, 'Goddam it, guns, you're short! Open it up, open it up!' The gunnery officer switched to the three-inch dual-purposes and opened the range to fifteen thousand yards. Still too short. We signaled to the destroyer alongside and it tried its five-inch guns. Still no dice. . . .

"Finally, the navigator, who'd been asleep, came topside, rubbing his eyes. He put his hands down, looked around, and said, 'What the hell you shooting at? That's Venus, a damn planet.' That's what Venus looked like out there," the yeoman concluded, "a Japanese secret weapon. The gunnery officer said he guessed he was pretty short on that range."

Greatest elongation of Venus occurred on February 3rd that year, placing the planet beyond the Sun's glare. Venus also reached maximum brightness, in the configuration known as *greatest illuminated extent* (GIE; see tipbox on page 63), on March 10, 1945. These dates bracket the time period when USS *New York* was sailing from Eniwetok to Iwo Jima and identify this trip as an especially favorable time for a daylight sighting of Venus.

The astronomer Clarence H. Cleminshaw (1902–1985), acting director of Griffith Observatory in Los Angeles during the war, wrote a bimonthly column on sky phenomena for the *Publications of the Astronomical Society of the Pacific (PASP)*. His essays for the first two issues of 1945 support the navigator's identification of the bright object as Venus and specifically note that during this period "Venus . . . can be seen in full daylight without a telescope."

July 1945: The Manhattan Project

We know about this next incident because of an episode of a television series hosted by Eleanor Roosevelt on NBC in 1950.

The "flying saucer" craze began in 1947 with a sighting by private pilot Kenneth Arnold. He described a puzzling encounter that happened in the skies above Washington state. Arnold reported a group of craft that had unusual shapes and were apparently capable of speeds greater than any Earth airplane. Newspapers sensationalized the event by printing headlines such as "Supersonic Flying Saucers Sighted by Idaho Pilot, Speed Estimated at 1,200 Miles an Hour" in the *Chicago Sun* on June 26, 1947.

Scenes of the U.S. military doing battle with aliens who came in flying saucers to our planet became a staple of science-fiction movies in the 1950s. Earth weapons invariably proved useless against the invaders until some plot twist near the end of the film enabled our forces to prevail.

On March 26, 1950, Roosevelt brought on as guests Captain Jack Adams and First Officer George W. Anderson of Chicago and Southern Air Lines. Newspaper stories had quoted the pilots' accounts of seeing, from the cockpit of their DC-3 airliner, a 30-meter (100-foot) disk moving at incredible speed in the skies above Arkansas. They described the craft as giving off a strange purple light from glowing windows in a circular pattern that ringed the underside. They brought to the New York television studio a sketch of the flying saucer to display on air. The show's transcript includes the following exchange.

Mrs. Roosevelt: Last Tuesday when I took up my paper, I saw that we had again sighted in the air strange objects flying very fast. . . .

Anderson: Neither Jack nor I have ever seen anything that approached this. I mean it's nothing like a jet or anything like that we've ever heard or seen other than the flying saucer itself. . . .

Shane and Galaxy Clustering

After the war's end, Donald Shane returned to California and assumed the position of director at Lick Observatory. One monumental research project, carried out with Carl Alvar Wirtanen, involved counting galaxies on 1,246 glass plates taken with a 20-inch astrograph. Each plate depicted a 6° × 6° area, and the astronomers recorded the galaxy counts for each 10′ × 10′ square in a grid that covered the plate. Each plate contained 1,296 squares, for a total number of more than one-and-a-half million such squares. The result was the pioneering Shane-Wirtanen catalog that revealed galaxy clustering.

▶ **ID BADGE** Every participant in the Manhattan Project wore an ID badge with a photograph and an identifying letter and number. Shown here is the badge of Donald Shane, the Berkeley astronomer and assistant director of scientific personnel at Los Alamos, and most likely the astronomer who asked Manhattan Project personnel to "Stop trying to shoot down Venus!".

U.S. ARMY

Mrs. Roosevelt: I will say I've been a little skeptical before. I thought people were seeing things. . . . That was certainly very interesting, and I thank you for coming here today.

Roosevelt may not have been convinced, but she was sufficiently interested to write a letter to former Los Alamos Laboratory director Robert Oppenheimer, who had overseen the development of the atomic bomb. She included some of the newspaper clippings and asked for the opinion of the distinguished scientist.

Oppenheimer was highly skeptical of the flying-saucer reports. To show that even trained scientists were not immune to "errors of suggestion and hysteria," his May 1950 letter replying to Roosevelt related the story of a morning at Los Alamos during the war, when scientists left their laboratories to gaze at a bright object in the sky.

Manhattan Project served as the code name for the massive undertaking to create atomic bombs during World War II. The scientific work took place at a secret location (Los Alamos) on a remote plateau in New Mexico. The first half of July 1945 was an especially tense time for the scientists and engineers as they prepared for the Trinity Test, when they would learn whether their plutonium device would work as designed.

Oppenheimer told Roosevelt:

During the war, very shortly before the test of the first atomic bomb, people at Los Alamos were naturally in a state of some tension. I remember one morning when almost the whole project was out of doors staring at a bright object in the sky, through glasses, binoculars and whatever else they could find.

Project officials called on the nearby Kirtland Field base of the U.S. Army Air Forces to send fast interceptors to investigate. But the base reported back that "they had no interceptors which had enabled them to come within range of the object." The letter continues:

Our director of personnel was an astronomer and a man of some human wisdom; and he finally came to my office and asked whether we would stop trying to shoot down Venus. I tell this story only to indicate that even a group of scientists is not proof against the errors of suggestion and hysteria.

▶**UFO MANIA** The flying saucer craze began in 1947 and continued throughout the 1950s, as evidenced by this movie poster from 1956.

COLUMBIA PICTURES

Oppenheimer did not name the astronomer who acted as the voice of reason. However, the abundant documentation of the Manhattan Project allows us to determine that this must have been Donald Shane (1895–1983), who served as professor and chairman of the astronomy department at University of California, Berkeley, before the war and as assistant director of scientific personnel at Los Alamos. Just as the navigator of USS *New York* had done, Shane quickly recognized the planetary identity of the mysterious bright light in the New Mexico sky.

Shane was correct: Venus had reached greatest elongation on June 24, 1945. Cleminshaw's contemporary column on sky phenomena for the July/August 1945 *PASP* issue pointed out that "Venus is conspicuous in the morning sky."

Before the advent of smartphones, some experts estimate that about half of all UFO sightings can be attributed to Venus. The examples from World War II prove that the U.S. military has contemplated attacks upon and even fired on an extraterrestrial object. However, this body posed no threat to Earth. As Shane so eloquently stated: "Stop trying to shoot down Venus!"

Venus in 2026

As this issue of *S&T* appears, readers will be able to observe brilliant Venus in the evening sky, where the planet will remain as a prominent object for the rest of the spring and summer. But later this year, Venus will also provide a chance to catch it in daytime — it will reach greatest elongation on August 15th and will be at or near peak brightness from September 14th through 26th. Greatest illuminated extent occurs on September 18th.

During the last weeks of summer 2026, challenge yourself to make your own daytime sightings of Venus. A 15%-lit waxing crescent Moon will be about 5° east of Venus (to the left) for North American observers on the afternoon of September 14th and could serve as a guide to the planet's position. Observers in Europe and Africa will see the Moon occult Venus on that date.

If you do see it, please don't try to shoot it down.

■ Contributing Editor **DON OLSON** is professor emeritus of physics at Texas State University. He is the author of four books in his Celestial Sleuth series, including the most recent volume, *Celestial Sleuthing: More Mysteries in Art, History, and Literature* (2026).

Planetary Peekaboo

Of the many sights you can see through a telescope, few are as beautiful as witnessing the Moon pass in front of a major planet. The geometry involved is humbling when you consider that your eyeball and our satellite have to line up exactly with another celestial body millions of kilometers away.

I've been fortunate to see several lunar occultations of all the naked-eye planets, and each has its own charm. These events offer some of the best opportunities to witness celestial mechanics at work in real time.

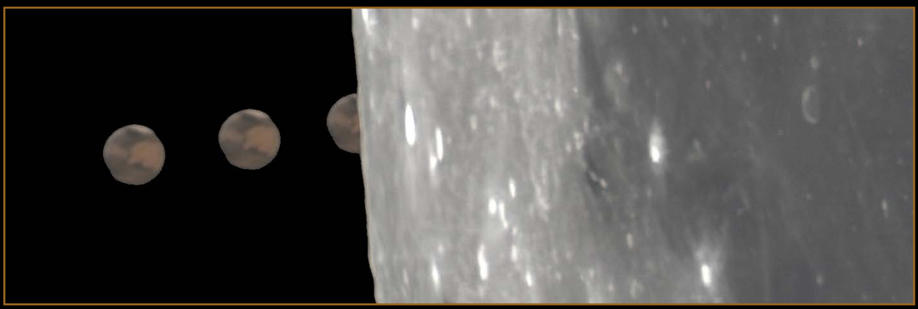
On the evening of January 13, 2025, I had an excellent view of the full Moon passing in front of Mars with the constellation Gemini as backdrop from my backyard observatory in Litchfield, New Hampshire. The planet had just reached its closest point to Earth and would achieve opposition a few days later, so it was big, bright, and easy to see very close to the dazzling Moon. My anticipation grew as I watched Mars while the lunar limb entered the eyepiece field from the west.

The hemisphere of the Red Planet visible at the time was riddled with large albedo markings, including Mare Acidalium at upper left, Margaritifer Sinus and Mare Erythraeum at lower left, and Sinus Meridiani at right. Although the North Polar Hood was dissipating, it still hid the planet's icy polar cap from view.

As the planet slipped behind the lunar disk, each of these features quickly disappeared behind Hedin Crater's rim. The Red Planet's color seemed particularly vivid that night, likely due to the opposition effect. The virtually colorless Moon made for a striking contrast to Mars's tannish ochre and bluish gray markings — until the planet's disk vanished, in less than a minute.

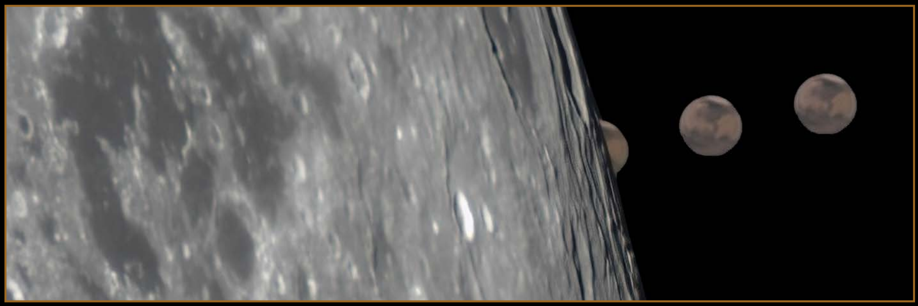
But that was only half the show — from my location in southern New Hampshire, the Moon was almost perfectly aligned with Mars, so the planet passed behind the lunar disk almost dead center. It would be another 75 minutes before the Red Planet peeked out again on the opposite limb.

I waited with bated breath as the moment approached, glancing



between the eyepiece on my Astro-Physics Stowaway refractor and watching the monitor showing the view through my Celestron C14. Finally, Mars began to emerge from behind the Moon, though it didn't appear on the sunlit limb. Full phase occurred many hours prior, so the Moon's eastern limb was slightly shadowed. Mars appeared a few arcseconds above the sunset limb beyond Jansky H crater, offering a much more dramatic display than its ingress. I watched for a full minute through the eyepiece while blindly clicking the record button on my planetary camera attached to the larger scope. Within a minute, the planet had completely emerged. I marveled at the view a few minutes longer, noting how the planet had rotated a bit since its disappearance. Sinus Meridiani was now nearing the planet's western limb while Aurorae Sinus was visible rising on its east. And with that, the show was over.

Lunar occultations are a treat to witness, and fortunately, they happen fairly frequently. You can experience the next one when Venus is the target on June 17th this year; another occurs in the morning hours on October 6th when the Moon hides Jupiter. Mark your calendars!
—SEAN WALKER



Photographs by Sean Walker

The MirroSky SPi53 Smart Telescope

We test Spectrum Optics' new modular smartscope.

▲ The MirroSky SPi53 smartscope seen in its basic operating configuration, ready for an evening of imaging.

MirroSky SPi53

U.S. Price: $649.99*
spectrumoi.com

What We Like

Modular design allows for hardware upgrades

Reliable Go To and tracking

What We Don't Like

Tiny tripod

No internal battery

**Prices subject to change*

ASTROPHOTOGRAPHY HAS NEVER been more accessible. Today's smartscopes automate much of the setup that once kept many potential astro-imagers on the sidelines. These devices streamline alignment, tracking, and image capture into a process managed entirely from a smartphone or tablet.

Spectrum Optics, a relative newcomer to the astro-gear industry, introduced its MirroSky SPi53 smartscope early last year, though it takes a distinctly different approach than most. Rather than a closed system, it's designed as a modular platform, one that can evolve as your interests grow or technology improves. The SPi53 keeps the camera, motorized mount, and optical tube assembly (OTA) as separate components. This permits users to swap in their own small existing telescope, or mount their own scope and the 53-mm as a Go To finder for visual and photographic use. Spectrum calls this versatile modular approach the *MirroSky Intelligent Astrosystem*.

What's in the Box

The SPi53 comes in a black-and-silver metal carrying case with lockable latches and two keys. The case measures 36.3 × 31.75 × 16.5 centimeters (14.3 × 12.5 × 6.5 inches) and weighs less than 5.7 kg (12.5 lbs) fully packed for easy transport. Inside, components sit securely in dense foam cutouts.

The MirroSky Intelligent Camera houses a small computer and the system's imaging sensor, a color Sony IMX662 CMOS detector with 2.9-micron-square pixels in a 1,920 × 1,080 array. The camera also includes a threaded 1¼-inch nosepiece to fit in the 53-mm aperture f/4.2 ED refractor's helical focuser.

The scope rides on a compact alt-azimuth mount. This dual-axis, stepper-motor platform uses metal worm gears with 130 teeth on each axis capable of bearing payloads of up to 3 kg (6.8 lbs). The mount includes a Vixen-style dovetail saddle to connect the optical tube, as well as altitude and azimuth locks for manual pointing and an M12-threaded port that accepts an optional counterweight shaft (not included). The tabletop tripod is attached via a ⅜-inch tripod socket on the drive base. Spectrum Optics offers an optional EQ wedge for equatorial operation, sold separately.

▶ The SPi53 comes in a metal carrying case with custom foam cutouts for the tabletop tripod, camera, mount, tube assembly, and cables. Also included is a finderscope extension post to mount the tube on the side of a user-supplied telescope.

For power and connectivity, the system includes two USB-C cables (one primary, one spare), a 12-volt AC power adapter, and a USB-C to 5.5-mm center-positive barrel adapter for use with an external 12-volt battery. The system requires 12 volts DC at 1.2 amps.

A printed quick-start guide includes a QR code that links to the full online manual, which covers setup instructions for the device's three operating configurations. The package also includes a viewfinder-style dovetail rail, two M5 screws, and a hex wrench.

Basic Setup

Right out of the box, assembly took less than five minutes for the default configuration of the scope, camera, and mount working as a basic smartscope. This is the easiest of the three modular

ALL PHOTOS ARE COURTESY OF THE AUTHOR.

options and the setup I used for the majority of my testing.

The included tabletop tripod was adequate for getting started with the system, though I found its low profile to be challenging for some situations. If you have a standard photo tripod with a ⅜-inch mounting screw, that will work, just be mindful of its center of gravity. The mount has a built-in bubble level on the top to aid with alignment.

The refractor is mounted within adjustable tube rings, similar to a 50-mm finderscope, that are connected to a small Vixen-style dovetail bar that slides easily into the mount's dovetail plate. This saddle is marked with an arrow pointing in the direction of the telescope's objective lens.

Once its dust caps are removed, slide the camera into the focuser with the "TOP" label facing upward, then secure it with thumbscrews. The camera connects to the mount via a USB-C cable. I found I could rotate the camera to adjust the framing of targets — a welcome flexibility that other smartscopes with permanently installed cameras lack.

Something you won't find with the SPi53 is autofocus — its non-rotating helical focuser is manually operated. Before powering on, I set it to its marked infinity position, which proved sufficient for initial plate-solving, though I fine-tuned focus on the actual targets later.

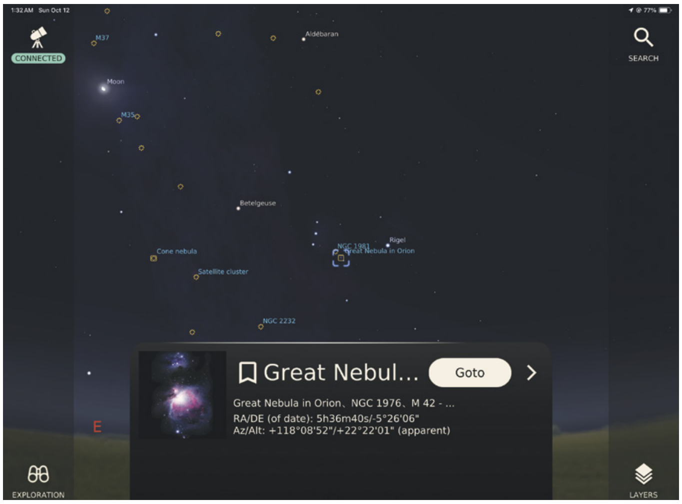
For better or for worse, the SPi53 lacks both an internal battery and a power button. Simply plugging in the included AC adapter turns the system on. A small red indicator illuminates, and within seconds, the mount begins its homing sequence, an automated altitude sweep that finishes with the scope parked horizontally.

As the mount completed its initialization, I launched the *MirroSky* app on my tablet (a free download through the Apple App Store and Google Play Store) and connected to the SPi53's Wi-Fi network. The system supports both 2.4 GHz and 5 GHz bands. I used 2.4 GHz for its better range, and it maintained a stable connection from some 30 feet indoors. A green indicator appears in the app's upper corner once connected.

▲▶ *Top:* The 53-mm refractor is secured to the mount with a short Vixen-style saddle and dovetail bar. Its tube rings are similar to some 50-mm finder brackets and include two thumbscrews and a spring-loaded post that permits independent adjustments when using the scope as a guidescope in dual-scope mode (configuration 3). *Right:* The saddle plate is marked pointing in the direction that the OTA should be installed. Note the clutch knob on the bottom of the saddle that permits free movement of the axis.

▲▶ *Above:* The camera includes both an M42 or T-thread interface and a 1¼-inch nosepiece to connect it to most focusers. *Right:* The rear of the camera is marked to show proper orientation when installed. It connects to the mount with a USB-C cable that plugs into the port marked POWER. The ST4 autoguiding port on its upper right allows the camera to operate as an autoguider.

▲▶ *Above:* The telescope's helical focuser is marked with an infinity position, which is used for the initial setup to be close to focus. Two knurled thumbscrews allow rotating the camera. *Right:* Two larger thumbscrews secure the camera and prevent it from wiggling in the focuser.



▲ The MirroSky app includes a planetarium-style sky map accessed with the ***EXPLORATION*** icon on the lower-left of the screen. Here you can select targets simply by clicking on them and then hitting the ***Goto*** button.

▲ As exposures complete, they are sent to the *MirroSky* app where they are evaluated and stacked. The app handily displays how many exposures were combined and how many were rejected.

Upon first launch, the app asks for your location and photo library permissions. I granted both, understanding that location data provide accurate coordinates and time, which are essential for pointing. (You can manually update location within the app if necessary.) Photo library access is also required since the SPi53 sends most astro-images directly to your device for stacking and display.

Imaging and Observing

For terrestrial viewing or casual sky scanning, the ***EXPLORATION*** screen located at the bottom left in the *MirroSky* app provides a live camera feed without needing to perform a Go To alignment. In this mode, you can manually control the mount's axes, adjust the slewing speed, and fine-tune camera settings such as exposure and resolution. The app doesn't appear to offer a means of recording images or video in this mode, suggesting it's designed primarily for real-time viewing only.

For night-sky use, the app offers several ways to locate celestial objects. Most intuitive is the planetarium view called ***SKYMAP STG***, where you pan, zoom, and select targets directly. Alternatively, the ***SEARCH*** function at top right lets you find objects by popular name, catalog numbers, or celestial coordinates. The app also organizes targets by several categories, including Planets, NGC, Messiers, IC, and Stars. When opened, each list is organized by when the objects are visible based on their altitude at the time. While you can shoot video and crop the field of view to zoom in on a planet, the scope's small aperture and short focal length isn't suitable for planetary ventures.

When a target is selected, the app prompts confirmation and the SPi53 begins its automated plate-solving sequence. The telescope slews toward the object while taking short exposures to verify its position. The software analyzes each image in real time, comparing star patterns to its internal database. This continues until the selected object is centered in the field of view. (For me, this took an average of about three minutes.) If a target is below the horizon, the app alerts you beforehand and asks you to pick a different one. Once alignment is complete, the live feed updates with the object centered and ready to be imaged.

The SPi53 excelled at locating deep-sky targets and star fields, but, like many other smartscopes, it struggles with the Moon. The issue is that the Moon's dazzling brightness washes out nearby stars, preventing the system from using plate-solving to confirm its position. In several tests, the scope failed to center the lunar disk or missed it completely. The app does attempt to work around this by first slewing to a bright nearby star it calls a "calibration star," then suggests using the manual controls to locate and center the Moon. I found this method effective, though time-consuming.

Before starting a sequence, I reviewed the camera's exposure settings. The app automatically loads default values based on the selected object type. For bright targets like the Moon, the system defaults to millisecond exposures with low gain settings. For faint deep-sky objects, exposures lengthen to several seconds with moderate gain (around 34), settings I found worked well across a variety of targets and sky conditions.

You can also override these default settings by clicking the ***PRO*** icon. Here you can change the gain, exposure length, and total number of exposures to record. In alt-azimuth mode, I kept individual exposures at less than 30 seconds to minimize *field rotation,* where stars at the frame edges begin to elongate or trail around the frame's center. In addition, the edges of the field become noisy where the stacked frames don't overlap. This becomes exacerbated with longer imaging sessions overall, though it can be overcome by imaging in equatorial mode and using longer exposures.

The sensor itself is fairly sensitive, though shows thermal noise in the form of hot pixels. I found it essential to record and apply dark calibration frames to get the best quality results. Without these dark frames, images are riddled with red, green, and blue pixels that get worse the more images are stacked. Enabling the ***Darks*** feature prompts the system to take calibration frames matching your current gain and exposure settings as well as ambient temperature. These are then automatically applied during stacking to reduce fixed-pattern noise and those colorful hot pixels. The workflow is easy — just enable the feature and confirm the imaging sequence, then the app tells you to place the dust cap on the scope. Once confirmed, it records the darks then applies them throughout the evening or until you power down the system. Dark frames aren't retained after shutdown in the app. Note that if you change gain or exposure length during the night, you'll need to capture a new set of darks before continuing shooting light frames.

Once the darks are complete, the app asks you to remove the dust cap. After confirmation, the SPi53 begins capturing exposures of the intended target. The system analyzes each sub-exposure as it comes in, calibrating, aligning, and stacking it with previous frames to increase the image's signal-to-noise ratio. Details gradually emerge on the screen of your smart device in real time. I was pleasantly surprised to see M42, the Orion Nebula, taking shape after just a few short exposures from my Bortle 6 skies at home. And M31, the Andromeda Galaxy, revealed its spiral structure similarly quickly. The *MirroSky* app displays useful details like the total exposures, frames captured, frames stacked, and frames rejected. I was impressed with how well the little device tracked. When it needed to reject an exposure, the algorithm did a fine job identifying the frame and tossing it out.

When an imaging sequence finishes, the app gives you the option to save the final stacked image to your device's photo library. I found it important to save the image sooner rather than later because if the app sits idle for too long after a session completes, the final image is cleared and is lost forever. Users can access the raw, unprocessed images and calibration files using the *MirroSky Desktop Client* program for Windows, though you'll need to connect via its Wi-Fi. The saved final images sent to my tablet include metadata such as target name or total integration time.

While the app's stacking pipeline is streamlined and effective overall, it isn't intended for post-processing. Adjustments such as additional stretching, color balance, or cropping need to be done in a third-party image editor, if desired.

Beyond the Basics

The SPi53's modular design distinguishes it from most smartscopes available today, which arrive as fully integrated, non-upgradable units. The SPi53 system supports two additional operating configurations and an equatorial mode that expands its capabilities (a feature more and more smartscopes are able to do these days). All advanced configurations and EQ mode require a more robust tripod than the tabletop version provided.

The second operating configuration allows you to replace the included 53-mm scope with a different optical tube assembly that you might already own, provided it uses a Vixen-style dovetail and doesn't exceed the mount's 3-kg payload capacity. Compatible telescopes can be up to about 70-mm aperture at f/6 or faster, opening the door to larger apertures, different focal lengths, and higher-quality optics.

▶ The SPi53 can also be paired with a short OTA of your own, with your scope used for observing or astrophotography while the 53-mm refractor functions as a digital finder for Go To pointing or autoguiding long exposures.

Heavier imaging trains require careful balancing to prevent tipping and straining the mount. Sliding the telescope forward and backward in its dovetail saddle until the system remained level was straightforward before retightening the OTA locking knob. Although a port is included that accepts an additional counterweight shaft, there wasn't any available on the company's website at the time of this review.

The third configuration accommodates two telescopes for a visual smartscope experience. You can use your own scope for observing while the 53-mm OTA is used for pointing. Alternatively, the 53-mm scope and intelligent camera can function as a guidescope and autoguider while your scope is used as an astrograph, though this requires operating in equatorial mode. This needs an equatorial wedge (sold separately) to tilt the mount's azimuth axis toward the celestial pole. Whichever flavor you choose, careful attention to weight distribution and optical alignment between the two tubes is essential. The tube rings of the 53-mm OTA include alignment screws that allow you to point the OTA at the same field as your imaging scope.

Final Considerations

The SPi53 bridges the gap between turnkey smartscopes and traditional dedicated imaging rigs, offering automation without locking in hardware or limiting users to astro-imaging alone. Its modular design addresses real concerns about technology obsolescence, and the hardware foundation proved reliable throughout testing. The ability to add your own scope to the system for both visual and more advanced imaging makes it a particularly versatile platform. It'll be interesting to see how this product evolves.

■ **SARAH MATHEWS** shares her passion for astronomy on her YouTube channel at **youtube.com/@SarahMathsAstro**.

A Giant 3D-Printed Purple Spyglass

Here's a collapsing telescope that truly travels well.

WHILE I PITCH some of my projects as "travel scopes," I admittedly don't travel much farther than my car with any of them. Amateur telescope builder Jasonn Pellegrini has handily outdone me here, with his 6-inch f/9 refractor that fits in a backpack. Inspired by spyglasses from the age of sailing, he made a nesting-doll-like telescope he enjoys using for wide-field observing and public outreach.

Pellegrini, a self-described refractor guy, had long wanted a six-incher as his main stargazing rig. But he found the "yard cannon" form of such large instruments unappealing. One day, while observing the Sun with this project's predecessor, a home-built 100-mm f/9 refractor, he had a lightbulb moment — he could solve the bulky size of the optical tube assembly (OTA) by making the tube itself collapsible.

He then designed the refractor using the web-based computer-aided design software *Onshape* (**onshape.com**), with Russian nesting dolls in mind. Rather than friction fit or telescoping action, the tube sections are threaded and they're nested together when the tube is disassembled. For the objective lens, he used a 150-mm doublet achromat that he purchased on AliExpress (**aliexpress.com**), a site whose optics I've also had good luck with.

Not surprisingly, Pellegrini's unique scope is 3D-printed. Before we dig in further, many readers have written in with questions on 3D printing: how to get started and which printers I would recommend.

Pellegrini used a Bambu P1S for his project. Bambu Lab (**bambulab.com**) printers are some of the best bang-for-the-buck machines on the market. They ship as turnkey systems and usually need very little maintenance. They're also fast and reliable, though some users have reservations about their cloud-based platforms and services, closed-software ecosystems, and customer support. I have a large Bambu X1C in my classroom and am consistently impressed with its speed and repeatability.

On the other end of the spectrum is Prusa Research (**prusa3d.com**). This Czech company has built its reputation on consistency and outstanding customer service. It has nurtured a deeply mature ecosystem of open-source hardware and software, and you can trace a line from this company back to its grassroots origins in hobbyist 3D printing. I still use my first printers, a pair of Prusa Mk3s+ (now superseded by

◀ The 3D-printed, 6-inch f/9 purple spyglass is shown assembled in its observing configuration. Note the salvaged MoonLite focuser, 3D-printed tube rings, and matching knobs.

▶ The scope's 3D-printed screw-on lens cap (*top*) features debossed lettering and grippy edge cutouts. Its removable center section reveals a built-in Bahtinov mask (*right*) for quickly focusing the telescope.

TELESCOPE PHOTOS: JASONN PELLEGRINI (4)

its later models), and they've been truly trusty. Prusa printers tend to be pricier, but one of its newer versions comes with best-in-class tech support, European charm, a snazzy orange-on-black color scheme, and a pack of gummy bears.

Pellegrini chose whatever cheapest printer filament he could find in his favorite color for his projects: "I grew tired of black-and-white telescopes and never saw a purple one before." One important point about filaments: Each thermoplastic material behaves differently. Pellegrini did his prototyping on the refractor tube using PLA (polylactic acid), a popular workhorse filament. It's stiff, easy to use, and prints to a nice finish, but it has a low *glass transition temperature* (the point where the polymer turns from glassy to rubbery state). While they won't melt in the Sun, PLA prints left baking in summer heat or inside a hot car can quickly deform. And sure enough, Pellegrini found his prototype scope eventually flattened inside a hot tent, a victim of its sauna-like conditions. This also happened with my very first Hadley telescope (*S&T:* Jan. 2023, p. 70).

Other filaments offer better heat resistance or extra properties but may be more challenging to print. ASA (acrylonitrile styrene acrylate), a relative of the familiar ABS (acrylonitrile butadiene styrene) seen in Lego bricks, offers superior heat and ultraviolet resistance and durability. But both ABS and ASA are prone to warping and release styrene fumes during printing, so proper enclosure and ventilation are recommended.

Prints can be surprisingly sturdy. Pellegrini chose ASA filament to print his tube rings, noting that he also trusts this material with his much-heavier Takahashi 130 OTA. The printed tubes of his purple refractor can handily hold an old, hefty MoonLite focuser he salvaged as well as a large diagonal and wide-field eyepiece. Pellegrini remarks that he doesn't feel any sagging or slop in the OTA — "the tube sections are double-walled, with grid-like infill, so they're quite strong but light," he notes.

▲ After disassembling the tube sections, the refractor fits neatly in a backpack or duffel bag.

Freedom of design also can't be understated. His giant spyglass is completed with a dust cap that he debossed its name into and also contains a built-in Bahtinov focusing mask. In addition, the lens cell allows for full collimation. And he's far from finished tinkering, having already prototyped a printable telescope mount that I hope to see soon. Stay tuned.

Overall, Pellegrini is quite pleased with his purple spyglass. "It really helps reinforce the idea that astronomy doesn't have to be expensive," he remarks. "Most people can't believe I printed the scope; it shows that you can build your own equipment, whether it's using 3D printing, woodworking, or metalworking."

■ Contributing Editor **JONATHAN KISSNER** is already shopping for bolder filament colors.

▶ Jasonn Pellegrini enjoys using both his purple scope and red 100-mm f/9 refractor for outreach. The latter provides excellent planetary views while the larger instrument gives nice wide-field views of deep-sky objects.

JASONN PELLEGRINI PHOTO: DIANA HANNIKAINEN / *S&T*

△ BUSY SOL

Patricio Calderari

The solar disk appears riddled with granulation and large sunspots on August 31, 2025. Several spots, including AR 4197, which is rightmost of the group of sunspots at bottom center, unleashed M-class solar flares.

DETAILS: *Pentax 75 SDUF refractor with Nikon D850 DSLR camera. Total exposure: 1⁄1,600 second at ISO 400 through a white-light solar filter.*

△ NEAR AND FAR

Francis Bozon and Cecil Navick

Cometary Globule 4 in Puppis is a dense cloud of dust and gas containing many newborn and embryonic stars. Through a trick of perspective, the nebula appears to be reaching towards the edge-on spiral galaxy PGC 21338 at upper left.

DETAILS: *PlaneWave CDK14 corrected Dall-Kirkham astrograph with ZWO ASI6200MM CMOS camera. Total exposure: 52 hours through color and narrowband filters.*

▷ THE SPANISH DANCER

Kfir Simon

NGC 1566 in Dorado is an intermediate spiral galaxy with two prominent arms tightly wound around its active core. The star to the right is 8th-magnitude HD 27713.

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

▽ DIMMED MOON

Shyam Krishnan

The eclipsed Moon rises left of the center of the Milky Way as seen above Wadi Rum in Jordan on the evening of September 7, 2025.

DETAILS: *Astro-modified Nikon Z7II mirrorless camera with 14-to-24-mm zoom lens at 14-mm, f/2.8. Total exposure: 15 seconds at ISO 3200.*

△ GLITTERING JEWELS

Massimo Di Fusco

Messier 18 may be a relatively sparse open cluster located in Sagittarius, but this colorful image makes its 8th- and 9th-magnitude stars stand out against this busy region of the sky.

DETAILS: *Astrosysteme Austria ASA 500N Newtonian astrograph with FLI ProLine PL16803 CCD camera. Total exposure: 30 minutes through red, green, and blue filters.*

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ACCESSORIES

JEWELRY

Ad Index

Event Calendar

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

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

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

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

April 15–18
MIDSOUTH STARGAZE
French Camp, MS
rainwaterobservatory.org/events

April 25
ASTRONOMY DAY
Everywhere!
astronomyday.astroleague.org

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

May 14–17
BOOTLEG SPRING STAR PARTY
Harmon, IL
bootlegastronomers.com

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

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

June 11–14
CHERRY SPRINGS STAR PARTY
Coudersport, PA
cherrysprings.org

July 11–15
GOLDEN STATE STAR PARTY
Adin, CA
goldenstatestarparty.org

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

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

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

August 8–16
MOUNT KOBAU STAR PARTY
Osoyoos, BC
mksp.ca

August 10–16
ALMOST HEAVEN STAR PARTY
Spruce Knob, WV
ahsp.org

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

Bringing Stars to People

If we want to better engage in science with everyone, we should meet them where they're at.

I NEVER CONSIDERED that the home I grew up in shaped how I thought about science. Neither of my parents finished high school, but they imbued us with curiosity. We watched *Tomorrow's World*, Attenborough documentaries, and the odd episode of *Star Trek*. Questions were always welcome.

It wasn't until I left my academic science career to study theater that I realized how unusual that was. In rehearsal rooms, I met people who had never grown up with conversations on how the world worked. For them, scientific curiosity had been quietly filed under "Not For Me."

That stayed with me as my career shifted into science communication. Speaking on the grand stages was terrific, but looking out at those audiences, I often thought, "These people will be fine. They already love science." So, I asked myself, who *isn't* in this room?

Science museums and other astronomy-related venues probably face similar questions. Who's walking through your door? Are visitors already connected to STEM — and know what that acronym means (science, technology, engineering, and mathematics) — or are you reaching families with no prior link to science at all?

Sociologists call this *science capital*, the experiences that make science feel familiar. By the age of 10, most children have already decided whether science is "their thing." Their parents and guardians' comfort level with science plays an important role. And if we rely on the old "deficit model," assuming that simply explaining science to kids is enough to bridge the gap, we'll just keep reaching the same audiences.

That's why I founded Town Scientist, a community-based engagement project in Ireland. The idea is simple: Build trust first.

Instead of presenting science as something "out there," done by "other people," we did science with our neighbors. We met families where they were: I worked with my local library and other groups to connect with parents in my community. We used WhatsApp instead of mailing lists and covered transport, so no one was excluded.

Over nine months in 2025, we delivered more than 100 community-led science activities. We ran an online rocket-building series for families with my husband, Dave — who happens to be a former NASA engineer — followed by an in-person launch day. We brought families to local science venues, many for the first time, and during Space Week (held in October), Armagh Observatory and Planetarium in Northern Ireland shipped its portable dome 50 kilometers (30 miles) south to us in Dundalk, Republic of Ireland. All free of charge.

Participants' confidence in discussing science rose from 38% to 85% after the program. One parent told us, "I thought science was for clever people, not me. Now I talk about it with my kids." Another said, "Having someone from here made all the difference."

Everyone shares the same night sky, yet the stars can feel distant if people don't see a place for themselves in that story. When a parent looks through a telescope with their child, though, something shifts. Science becomes theirs.

During Science Week, that shift became real. I brought European Space Agency astronaut Rosemary Coogan to my hometown to speak and meet families. For the first time, an astronaut walked the same streets I did as a child. I can't help but think what that moment might mean for the families I work with. To see an astronaut up close. To imagine themselves in that world.

Once trust is built and wonder is invited in, anything can happen.

■ **NIAMH SHAW** is an academic-turned-science communicator based in Dundalk, Ireland.

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