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SKY & TELESCOPE

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SEPTEMBER 2023

Ramble Through September Skies

Page 58

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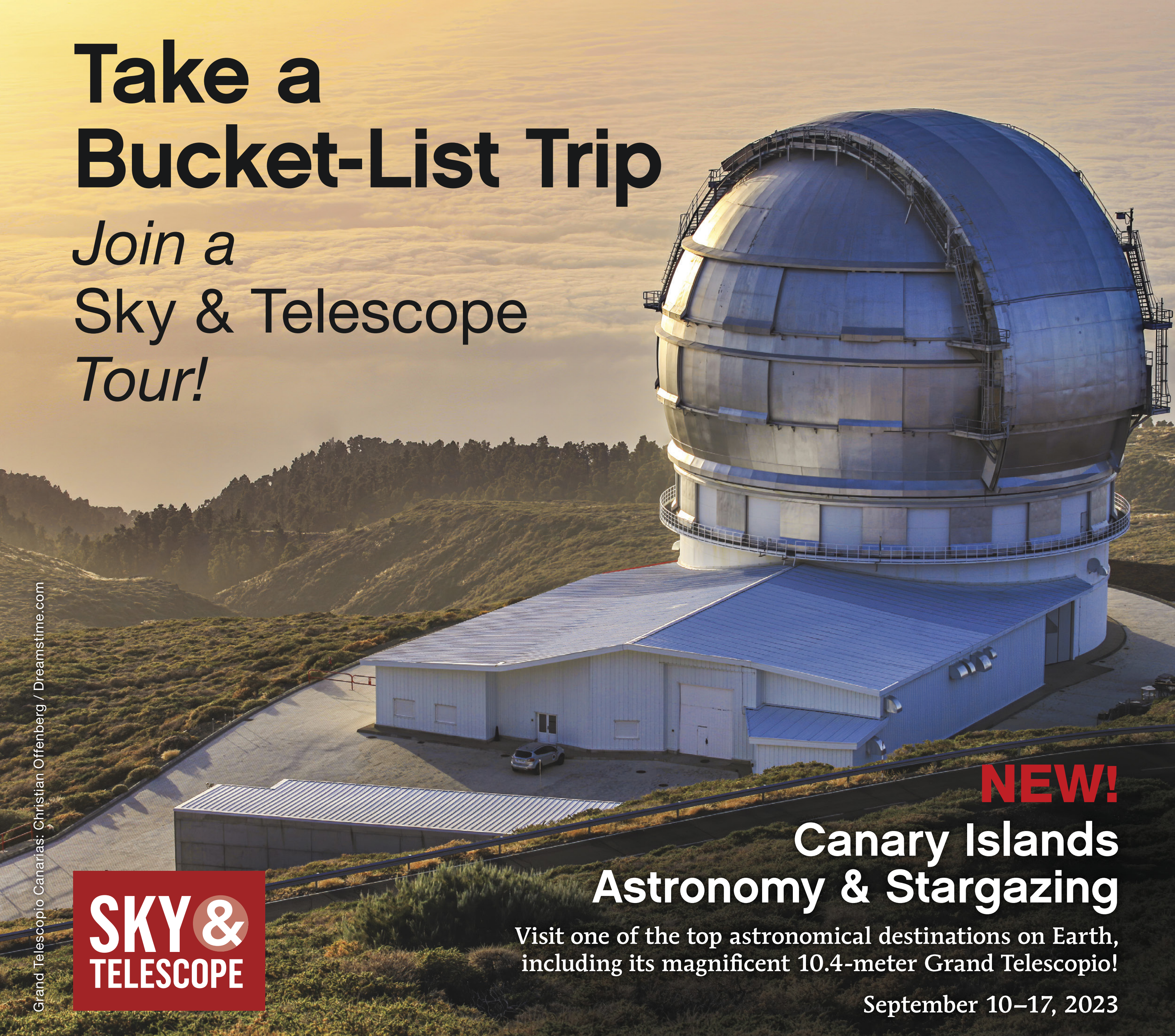
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ON THE COVER

The planetary nebula M27 shimmers in Vulpecula

PHOTO: RON BRECHER

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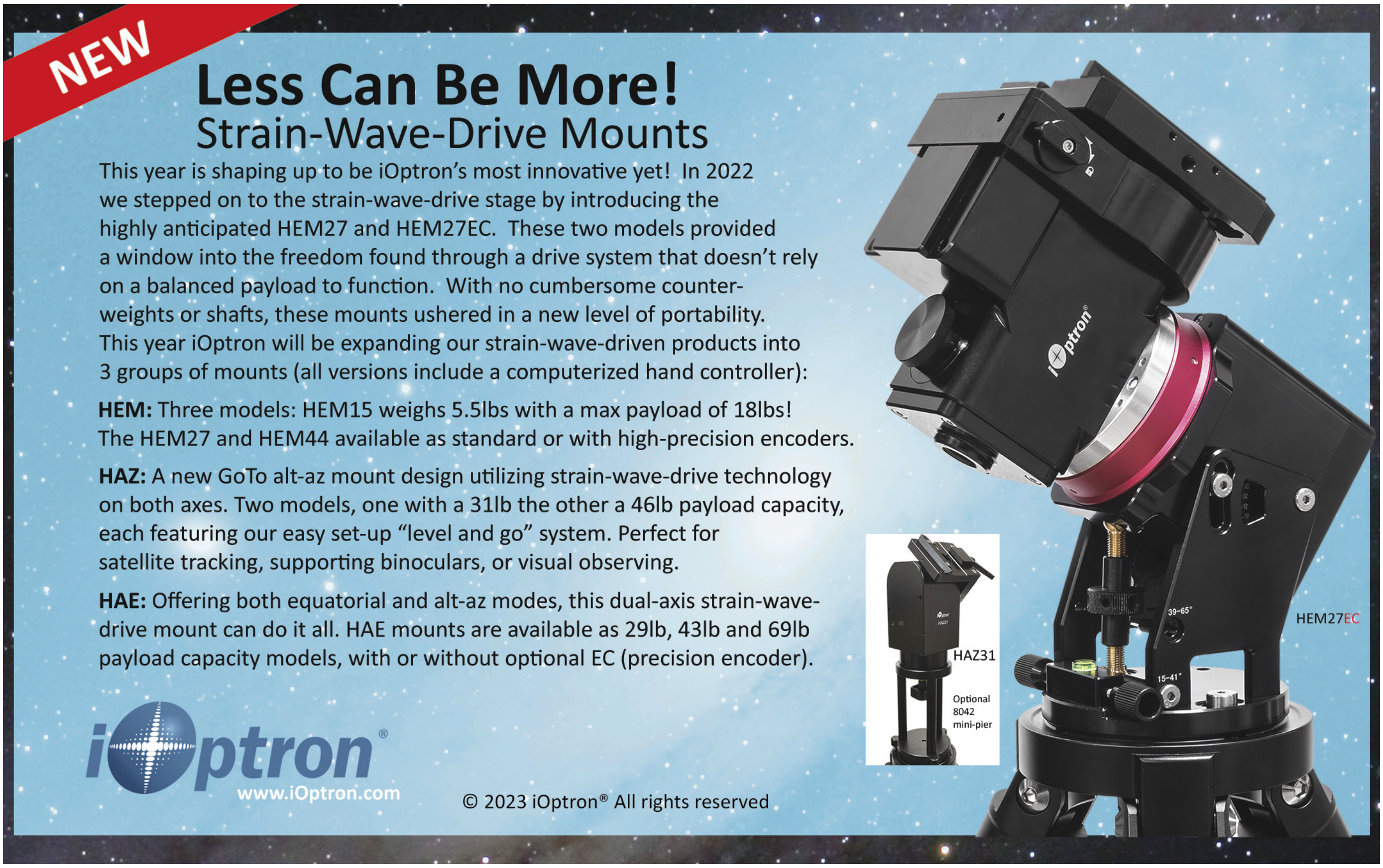
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Strain-Wave-Drive Mounts
This year is shaping up to be iOptron's most innovative yet! In 2022 we stepped on to the strain-wave-drive stage by introducing the highly anticipated HEM27 and HEM27EC. These two models provided a window into the freedom found through a drive system that doesn't rely on a balanced payload to function. With no cumbersome counter-weights or shafts, these mounts ushered in a new level of portability. This year iOptron will be expanding our strain-wave-driven products into 3 groups of mounts (all versions include a computerized hand controller):
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Sky Dye

FOR SOMEONE UNFAMILIAR with astronomy, the field might at first seem to be all about black and white. After all, the night sky is black, the stars are white — at least at a casual glance. The Milky Way, if they're fortunate enough to see it, is a pallid cloud, and the Moon appears various shades of grayish alabaster. Even when one first peers through a telescope, if not at planets, all might well look colorless.

But as our cover image shows dramatically — and as experienced amateurs know well — color is out there, if you know where to find it and how to draw it out. Throughout this (and every) issue of *S&T*, you'll find images displaying stunning hues. Using long exposures, special filters, and various processing techniques, astrophotographers have become aces at coaxing out color.

Sometimes the result is subtle, as in the tint of the blue and orange stars seen in the image of the Coathanger asterism on page 62. In other cases, images can absolutely pop with pigment, such as the one of the barred spiral galaxy M61 on page 74. Photographers can work to intensify key aspects, as Ron Brecher did in his cover shot of the Dumbbell Nebula, in which hydrogen gas glows red and oxygen blue-green.

▲ Color wheel: This JWST composite of the Cartwheel Galaxy combines near- and mid-infrared images.

NASA / ESA / CSA / STSCI / WEBB ERO PRODUCTION TEAM

Depending on what they're aiming to emphasize, photographers may end up with quite different pictures of the same object, such as those of the Andromeda Galaxy on pages 20 and 27, respectively, or of the Veil Nebula on pages 33 and 55. They may even enhance natural colors to distinguish among a complex range of tints, as in the portrait of Pluto on page 12. That one combines blue, red, and infrared images taken by the New Horizons spacecraft.

We perceive color in visible light, of course, as every schoolchild knows who's learned the ROYGBIV mnemonic for the colors of the rainbow. For astronomers, as Monica Young explains in "What Is a Spectrum?" on page 74, visible light arrives in different forms, from the continuous spectra of stars to the emission and absorption spectra of nebulae. All play up different tinctures.

But even when radiation in the non-visible parts of the electromagnetic spectrum reaches us — in the form of radio waves or ultraviolet, say — we can manipulate it such that we can "see" it. The image above from the James Webb Space Telescope, which specializes in the infrared, is a good example.

There's more to hue than beauty, too. Color itself has helped advance astronomy, as Douglas MacDougal describes in his article on page 20 about Vesto Slipher's red- and blueshift discoveries in the 1910s.

Much more could be said of color in the field we love, but suffice it to say the universe is not all black and white.

Peter

Editor in Chief

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The Essential Guide to Astronomy

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▲ Nabta Playa in Egypt is one of the oldest stone circles in the world and may have originally aligned with several bright stars. Unfortunately, tourists defaced the monoliths after the site's discovery was published in 1998.

Astronomy Around the World

Upon opening my May digital issue, I was pleased to encounter Tony Flanders' "The Past and Future of Star Names" (*S&T:* May 2023, p. 26). I found myself in familiar territory. The idea that the International Astronomical Union (IAU) is trying to standardize star names suggests that many cultures enlist a variety of designations for the same objects. After reading many different accounts of name interpretations for the same stars, I can understand the interest in this endeavor.

The Royal Astronomical Society of Canada sells a publication on indigenous culture star depictions, *Ojibwe Sky Star Map Constellation Guide* by Annette Lee and others, on its website. Its idea is to acknowledge the contribution of all cultures to the knowledge base of astronomy. I have also read *The Astronomy of the Bible* by E. Walter Maunder and *The Gospel in the Stars* by Joseph A. Seiss, just to mention some different interpretations. Eleven thousand years ago we had Göbekli Tepe in Turkey. In the 6th millennium BC, there was Nabta Playa in Egypt, and later, of course, Stonehenge in England. They were all stone-circle monuments, which may have been used as observatories.

Richard H. Allen, with his book *Star Names*, has already standardized the language issue, so I suppose codification is in order! My point is that star names, like money, have no universal value unless everybody agrees they do. This article was a rewarding read. Thanks!

Clarence Underwood
Esparto, California

▲ Göbekli Tepe in Turkey dates back to just before the domestication of plants and animals. It could be one of the world's first temples.

Missing Globular

I avidly read Scott Harrington's "Far-Out Globular Clusters" (*S&T:* June 2023, p. 20) as soon I received the June issue. I'm fond of globulars because for a quarter of a century I have spent two to four summer weeks in Linosa, Italy, a tiny island sporting very dark skies 27 nautical miles from Lampedusa in the middle of the Mediterranean Sea. Summer constellations are well placed at 36° north. Year after year, I swept almost all globulars visible in a 10-inch Dobsonian. I searched and searched for IC 1257, also encouraged by the story involving Brian Skiff I learned from Harrington's article, but in vain. Finally, I checked the Aladin Sky Atlas program (**https://is.gd/AladinAtlas**) and found nothing in that position, while the SIMBAD Astronomical Database (**https://is.gd/SimbadDatabase**) calls it a "blazar candidate." I stopped searching even when I brought my 20-inch to Linosa. What do you think? Thanks a lot, and congratulations again for your article and for your enduring efforts with your binoculars.

Lorenzo Burti
Verona, Italy

Scott Harrington replies: *I'm so glad you enjoyed it. I wonder how many Milky Way globular clusters you've seen in total. Linosa's latitude is the same as mine here, and I also mostly observe with a 10-inch telescope.*

Why you haven't been able to see IC 1257 is a bit of a puzzle to me, since I've seen it in a telescope with half the aperture of your 10-inch. It's not in a bright star field, so it takes a few minutes to find the area. But that also means that when you do find it, it's not lost in a crowded star field. I think you just have to keep trying, especially with the 20-inch. It always helps me to use a bigger telescope to look at something first before attempting it in a smaller telescope.

Finding Lunar Meteors

I was delighted to read Klaus Brasch's letter "Hunting for Lunar Meteors" (*S&T:* June 2023, p. 6) about his efforts to search for lunar meteoritic impacts. I would like to inform the readers of *S&T* that the Association of Lunar and Planetary Observers (ALPO) still has an active program headed by Brian Cudnik that's searching for lunar meteors. We welcome all interested observers to join the hunt!

Techniques have improved dramatically since Walter Haas first proposed the search effort and reported impacts are no longer rare — one is described in Volume 65, No. 3 of the *Journal of the Association of Lunar and Planetary Observers* from this summer.

Another advance comes via NASA's Lunar Reconnaissance Orbiter (LRO). The LRO has been imaging the lunar surface for over a decade, and by comparing images over time, scientists have detected more than 220 new impact craters.

Shawn Dilles
Editor of the *Journal of the ALPO*
Vienna, Virginia

Earth Cam

Seeing Earth from space is one of the great perspective-shifting marvels of our age, so I endorse Gary Deatsman's proposal in "Lunar Live Feed" (*S&T:* May 2023, p. 7) to install a high-resolution, continuous-feed video camera on the lunar surface that's permanently directed at our planet. As Deatsman suggests, the feed would capture fascinating images of Earth going through different phases and the planet's Sun-ringed fall of darkness during lunar eclipses.

Yet another new vision of our place in the cosmos. Let's do it!

Ken Kalfus
Philadelphia, Pennsylvania

Embracing the Night

Regarding Howard Banich's "Darkness Audible" (*S&T:* June 2023, p. 84), I would like to share the following quote from Sarah Williams' "The Old Astronomer" with him:

Though my soul may set in darkness, it will rise in perfect light;

I have loved the stars too truly to be fearful of the night.

Bob Anderson
Green Bank, West Virginia

I absolutely identify with Howard Banich's nighttime paranoia in "Darkness Audible" in *S&T*'s June issue. The dark skies of Nebraska, where I live, offer abundant opportunities for observation. But every time this city girl participates in a club gathering or attends the Nebraska Star Party, I imagine all sorts of creepy crawlers encroaching onto the telescope pad. Nevertheless, the drive to seek out deep-sky objects, solar system gems, and aurorae lessens my anxiety of nighttime intruders enough for me to relish the sights. Howard Banich's personal account reminded me that I'm not alone!

Sharon McLean
Omaha, Nebraska

The art department usually plays a supporting role in *Sky & Telescope*. But Leah Tiscione's evocative cartoon about fearing the dark on the last page of the June edition stole the issue. Bravo!

Alan Whitman
Okanagan Falls, Canada

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

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

1948

1973

1998

◖ September 1948

Shooting Comets "Dr. Fred L. Whipple, Harvard College Observatory, prefers to associate generically all or nearly all of the brighter visual meteors, and those bright enough to be photographed, with comets rather than with meteorites and asteroids. [He reports] that the orbits of 45 photographic meteors have been determined with considerable precision by Harvard's two-station rotating-shutter method. . . .

"He believes that bright meteors are the debris of comets rather than that they are simply small meteorites or asteroids. His preference is based upon many cases of obvious association; similarities in orbital characteristics among sporadic meteors, shower meteors, and short-period comets; the fact that meteorite falls suggest little or no shower association; and the selective elimination of small asteroidal particles as time passes."

◖ September 1973

Gamma Rays "Short, powerful bursts of gamma radiation originating outside the solar system are reported by three scientists at the Los Alamos Scientific Laboratory in New Mexico. Approximately 20 of these events have been recorded since July, 1969. . . .

"Ray Klebesadel, Ian Strong, and Roy Olson made this discovery while analyzing data from the four most recent Vela satellites, which . . . act as 'watchdogs' over the limited nuclear test-ban treaty signed in 1963. [Normally] all four of them 'see' each burst of gamma rays. As the blast, traveling at the speed of light, passes each satellite, the time is recorded to an accuracy of about 0.05 second. From the differences between the arrival times . . . it is possible to deduce the direction from which a given burst has come. In this way it has been found that the radiation does not come from the earth, moon, sun, or other planets."

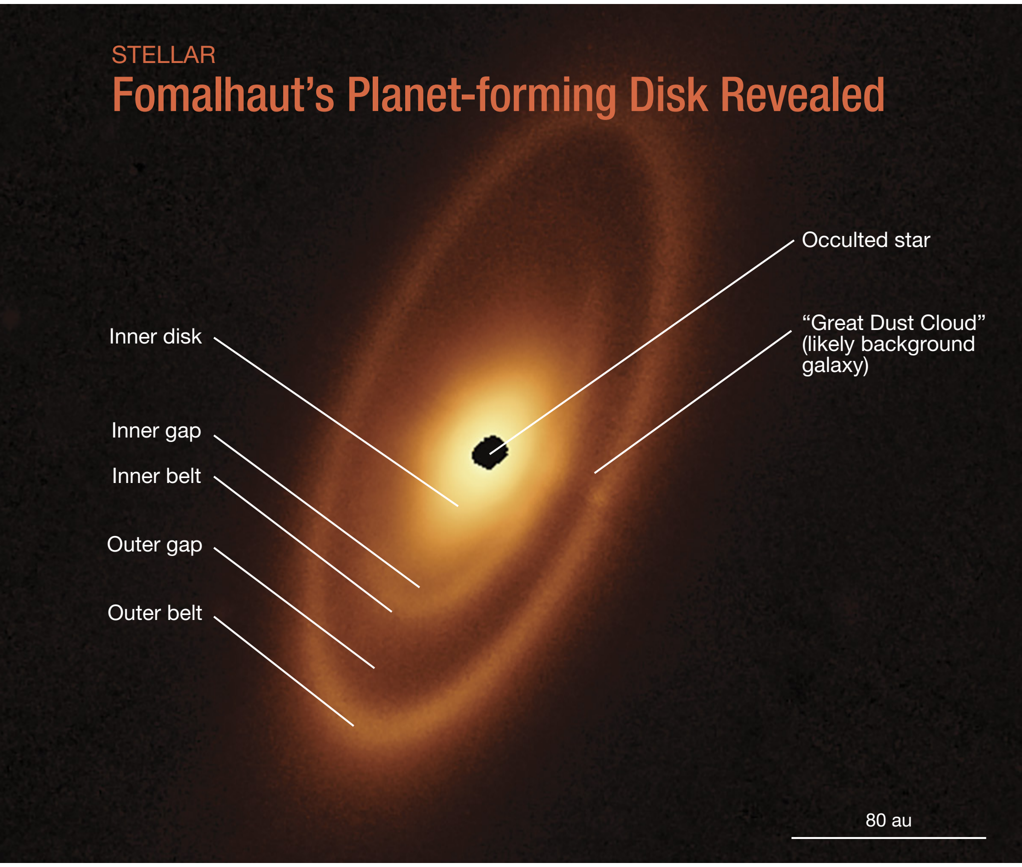
What astronomers didn't know then is that all known gamma-ray bursts have originated outside our galaxy. Sometimes they signal the collision of two neutron stars and in other cases a supernova explosion.

◖ September 1998

Gravity Boost "You might think a 10-meter telescope would be big enough for the routine task of obtaining a star's spectrum. But when that star is a 19th-magnitude mote, every photon counts. That's why Dante Minniti (Lawrence Livermore National Laboratory) and four colleagues are lucky that an otherwise unseen object happened to skirt their sightline to [a] main-sequence star in our Milky Way's bulge. [The] interloper's gravity focused the bulge star's light, nearly tripling its intensity as seen on Earth. This temporarily turned the Keck I reflector into the equivalent of a 16-meter telescope, enabling the team to measure the star's lithium content — an important chemical clue to our galaxy's history."

STELLAR

Fomalhaut's Planet-forming Disk Revealed



CONTINUING ITS RUN of groundbreaking discoveries, the James Webb Space Telescope (JWST) has snapped the clearest images yet of the dusty debris disk around Fomalhaut, a bright, young star 25 light-years away in Piscis Austrinus. The images reach a resolution and sensitivity far beyond the capability of earlier instruments.

András Gáspár (University of Arizona) and colleagues presented new details in this planet-forming disk on May 8th in *Nature Astronomy*. The team also included new Hubble Space Telescope images in their analysis.

Previously, Hubble, the Spitzer Space Telescope, and other telescopes had shown that Fomalhaut hosts a far-out ring of planet-forming debris that's akin to the Kuiper Belt in our solar system.

◀ JWST's image of the dusty disk around Fomalhaut (blocked out at center) reveals an inner disk, akin to the solar system's asteroid belt but more extended; an inner belt; and a previously imaged outer belt that's analogous to our Kuiper Belt.

NASA / ESA / CSA / A. GÁSPÁR (UNIVERSITY OF ARIZONA), PROCESSING: A. PAGAN (STSCI)

COSMOLOGY

Distorted Galaxy Hints at Nature of Dark Matter

ASTRONOMERS HAVE PROVIDED the most direct evidence yet that dark matter does not consist of ultramassive particles. The work, based on supercomputer calculations, suggests that dark matter is instead made up of *axions* — hypothetical particles so light that they travel through space more like waves.

If correct, the researchers' conclusions would not only help reveal what 85% of matter in the universe is made of; the results could also lead to new physics beyond the standard model. The study was published April 20th in *Nature Astronomy*.

Dark matter is tricky to investigate because it doesn't emit, absorb, or reflect light. So instead, a team led by graduate student Alfred Amruth (University of Hong Kong) looked for the material's influence on *gravitational lensing*. In this effect, a galaxy and its dark matter halo curve the fabric of spacetime. Light from a more distant source follows this curvature and bends around the galaxy as if it were passing through a lens.

When the foreground lens and the distant light source are closely aligned, astronomers see multiple images of the same background object. The positions and brightness of these images depend on the distribution of dark matter in the lens, providing a powerful probe of the mysterious substance.

For the past two decades, astrophysicists have struggled to reproduce these multiple images exactly, in part because they've assumed that dark matter is made of *weakly interacting massive particles* (WIMPs). If WIMPS are dark matter, then galaxies' densities should decrease smoothly as you move out from the center. Except that's not what astronomers actually infer from the lensed images.

Amruth's team turned to an alternative dark matter candidate instead: axions, ultralight particles first theorized in the 1970s. Quantum theory says that due to their small mass, axions behave more like waves than particles on large scales, interfering with each other to produce random density fluctuations. These fluctuations would make the distribution of dark matter around a galaxy bumpy. (It's worth noting that neither WIMPs nor axions have been detected directly.)

After assuming that dark matter is made of axions, Amruth and colleagues were able to recreate the observed positions and brightnesses of each image in the quadruply lensed system HS 0810+2554, in which a foreground elliptical galaxy splits the light from a background quasar into four images. "We have reached a point where the existing paradigm of dark matter needs to be reconsidered," Amruth says.

However, Edward Hardy (University of Liverpool, UK), who was not involved in the research, urges caution. "This paper is only a first step, and extensive further analysis is needed before the

Analysis of the system's brightness at different wavelengths had also suggested the presence of a dusty inner disk analogous to the main asteroid belt.

Now, the new JWST images reveal unprecedented details. In the inner system the telescope imaged the asteroid-belt analog. There's also a new belt inside the previously known one (labeled "inner belt" in the figure at left) and a new "inner gap."

"My first thought was: 'Wow!'," remarks Samantha Lawler (University of Regina, Canada), who wasn't involved in the study.

The inner dusty disk that the researchers imaged is like the asteroid belt in our own solar system in terms of the heat it emits; however, it's more extended than previously thought, from at least 10 astronomical units (a.u.) out to as far as 96 a.u. The gap and the inner belt that lie beyond this disk are both new discoveries.

Interestingly, the inner belt is misaligned with the outer, Kuiper Belt-like analog. An unseen exoplanet might have carved out the disk-belt gap, much as Jupiter's gravitational effects shape our asteroid belt. Modeling is underway to investigate the potential planet.

The JWST images also revealed a feature that the team initially termed the "Great Dust Cloud," thinking it might have been formed by a planet-scale collision. But a later look through the archives of the Atacama Large Millimeter/submillimeter Array and the Keck Observatory show emission from the same position between 6 and 18 years prior to the JWST observations. Since any part of the system would move with Fomalhaut across the sky, the archival images indicate that the source is instead in the background. Grant Kennedy (University of Warwick, UK) and colleagues posted this conclusion on the arXiv preprint server on May 17th.

Nevertheless, the JWST images have revealed a dynamic system, which will surely divulge more details in time.

■ KIT GILCHRIST

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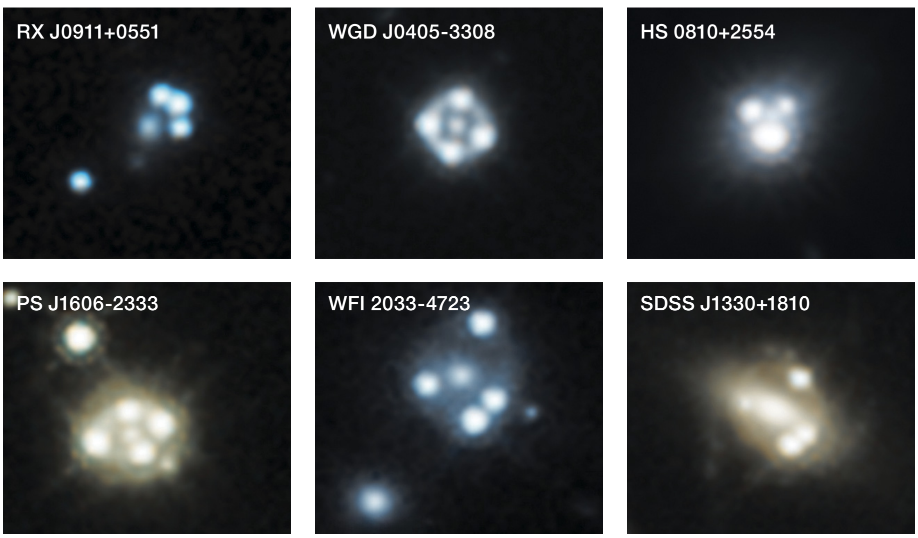
nature of dark matter is settled," he says. According to team member George Smoot (Donostia International Physics Center, Spain), the James Webb Space Telescope should discover many more gravitationally lensed systems, offering a more stringent test of the idea.

If that future work cements the study's conclusions, Hardy says it would be a spectacular discovery. "There would be major implications," he says, "not just for astrophysics but also for high-energy fundamental particle physics."

■ COLIN STUART



▲ Each of these snapshots shows multiple, distorted images of a background quasar, its light bent by a massive foreground galaxy. The system under study, HS 0810+2554, is the one at upper right with a Mickey Mouse shape.

NASA / ESA / A. NIERENBERG / T. TREU

IN BRIEF

Meteorite Crashed into New Jersey Home

When Suzy Kop stepped into her father's bedroom on May 8th, she saw a black, mango-size rock on the floor, its broken surface exposing a creamy interior. Looking around, she spotted two holes in the ceiling, and she knew something wasn't right. Some 15 minutes before Kop had arrived (around 12:30 p.m.), there was a report of a fireball in the area. As it happened, the heavy end of that falling star crashed through the roof of the home in Hopewell Township, New Jersey. The meteorite struck the floor with such force that it rebounded and punched a second hole in the ceiling before landing back on the floor. Unsure what to do, Kop called the Hopewell police for assistance. A hazmat team arrived to examine the cosmic trespasser for signs of radioactivity, though meteorites are no more radioactive than a banana. Meanwhile, the police contacted Shannon Graham (College of New Jersey); she and colleagues confirmed the rock's cosmic origin based on visual inspection, density measurements, and examination with an electron microscope. A first analysis indicates it's likely an LL-6 chondrite, a stony meteorite with low iron content.

■ BOB KING

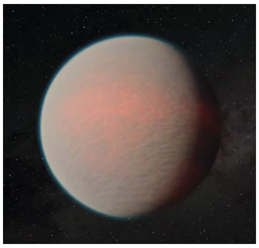
Magnets Bad for Meteorites

Amateurs often use cheap but powerful magnets to quickly identify iron-rich meteorites. But in doing so, they can erase meteorites' original magnetic fields. In the April *Journal of Geophysical Research: Planets*, Foteini Vervelidou (MIT) and colleagues show that using standard magnets on terrestrial basalt — a common analog for stony meteorites — resets the material's magnetism. "Over the last few decades, we have discovered that meteorites contain unique magnetic records that tell us how planets formed and evolved," says team member Benjamin Weiss (also at MIT). "However, even just briefly touching a fist-sized meteorite with a magnet essentially obliterates this record forever." Instead of magnets, Vervelidou and colleagues advocate using low-field *susceptibility meters*, which won't disturb the sample's original magnetism. However, these instruments are expensive, and visual inspection can also go a long way toward identifying samples.

■ DAVID DICKINSON

EXOPLANETS

Mini-Neptune Reveals (Some of) Its Secrets



◀ Artist's impression of the exoplanet GJ 1214b

ASTRONOMERS ARMED with new James Webb Space telescope (JWST) images have gotten under the high-altitude skin of the mini-Neptune dubbed GJ 1214b. The results, published May 10th in *Nature*, suggest that this planet's atmosphere is composed of some combination of water, methane, and hydrogen cyanide, all wrapped thickly in highly reflective clouds or haze.

GJ 1214b swings around its red dwarf star every 1½ days, so it's scorching-hot. But it maintains an atmosphere, and from the world's lightweight density, astronomers had suspected that water in some form would be a major constituent. But multiple attempts to take the atmosphere's spectrum as the world passed in front of its star were stymied by what appeared to be high-altitude clouds or hazes.

Now, JWST observations of the full orbit have enabled a team led by Eliza Kempton (University of Maryland, College Park) to map the temperature across the planet. The results show that this world must be almost twice as reflective as Earth is, with a Bond albedo of 0.51. (Jupiter is the closest match in the solar system.) The high reflectivity rules out previous suggestions that the enshrouding haze is made of either soot-like particles or hydrocarbon gunk known as *tholins*. Some clouds — such as potassium chloride or zinc sulfide — are reflective, but climate models suggest they wouldn't be abundant enough to explain observations.

In addition, a spectrum of the planet's nightside reveals a deep absorption feature that could be produced by some combination of water, methane, and hydrogen cyanide. The feature's depth indicates that the planet's atmosphere has many more heavy elements than the outer solar system planets do.

It's tricky to say which molecules are doing the absorbing. "All bets are on water," Kempton says, but she notes that all three molecules could be present to some degree. For now, the water-world scenario is still in the running.

■ **MONICA YOUNG**

SOLAR SYSTEM

New Moon Discoveries Put Saturn in the Lead

SATURN HAS RECLAIMED the record for most moons in the solar system with the discovery of 63 new moons. All are only a few kilometers in size and have orbits far from the planet.

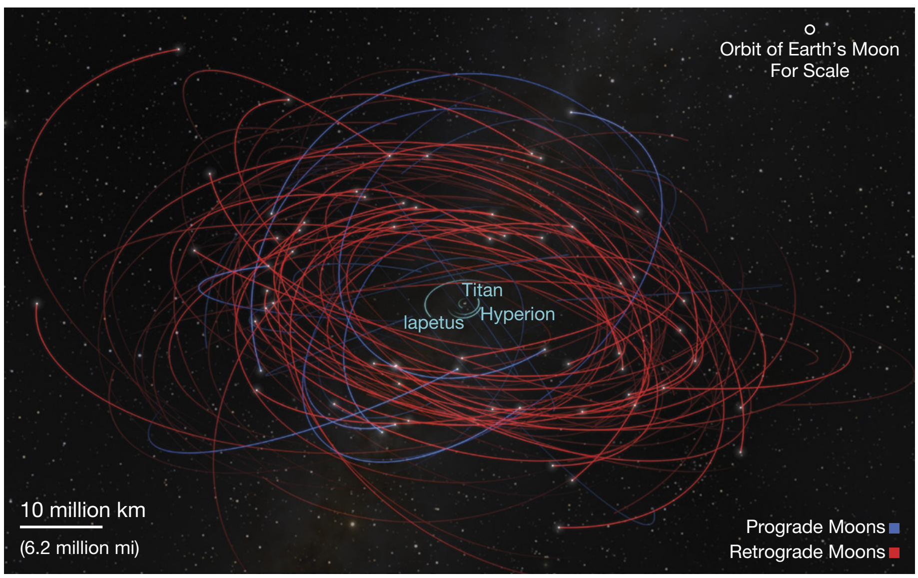
As of press time, the International Astronomical Union's Minor Planet Center (MPC) has published the moons' orbits in a series of Minor Planet Electronic Circulars issued between May 3rd and 23rd. The new discoveries bring Saturn's total moon count to 146, including 24 "regular" moons, which formed around the planet, and 122 smaller, "irregular" moons on elongated, and tilted orbits. The new reports more than double Saturn's irregular moons and put Saturn far ahead of Jupiter's 95 moons (which had put Jupiter in first place earlier this year; *S&T:* June 2023, p. 8).

The torrent of Saturnian discoveries comes from a series of observations that Edward Ashton (now at Academia Sinica Institute of Astronomy & Astrophysics, Taiwan) and colleagues made with the Canada-France-Hawaii Telescope between 2019 and 2021. In studying the size distribution of the moons orbiting Saturn, they reported many more smaller moons than larger ones, indicating a recent (100 million years ago) collision between two objects around Saturn. In order to detect the moons, the group used a shift-and-stack approach to look for objects' movement across images.

The group calculated the objects' current orbits. They then took the finds to the MPC, where astronomers ran the orbits backward to find matches among previously observed objects, improving the fitted orbit in the process.

Ashton's team estimates that Saturn has roughly 150 irregular moons at least 3 km (2 mi) across. That leaves dozens left to find in this size range, as well as hundreds of even smaller moons.

■ **JEFF HECHT**



▶ This diagram shows the present-day orbits of the 63 new moons published so far.

PLANET ILLUSTRATION: NASA / JPL-CALTECH / R. HURT (IPAC); MOON ORBIT DIAGRAM: K LY

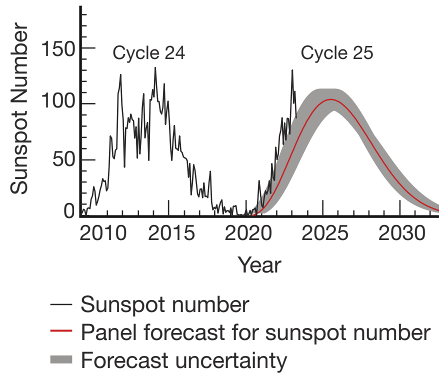
THE SUN

Solar Activity Ramps Up But Solar Cycle Still Weak

THE SUN HAS been busy lately. Activity, including sunspots and flares, began picking up steam last year before suddenly ramping up even more in early 2023. The sudden rise prompted some to wonder if the current solar cycle is becoming more active than scientists had predicted.

The Sun goes through 11-year cycles of magnetic activity during which its magnetic poles swap places. The last cycle (Cycle 24) was one of the quietest cycles on record, and the Solar Cycle Prediction Panel, an international group of experts, forecast that the current cycle (Cycle 25) would be on par with it or only slightly more active.

Lisa Upton (Southwest Research Institute), co-chair of the panel for Cycle 25, holds that the current activity still matches the panel's prediction. "It has been a decade since we've been in solar-cycle maximum," Upton says, "so people have forgotten what activity on the Sun looks like."



▲ This graph shows the monthly sunspot average compared to predicted values.

Other scientists, however, think that the panel's prediction falls short. Scott McIntosh (National Center for Atmospheric Research) and collaborators predicted in 2020 that Cycle 25 could be one of the most powerful ever recorded.

The researchers hypothesized that the solar cycle is governed by the movement of vast magnetic bands from pole to equator. When these meet at the solar equator, they cancel each other out in what the team calls a *termination event*. The timing of that event could predict the strength of the subsequent sunspot cycle, the team suggests.

However, while McIntosh's team originally predicted that the next termination event would occur in mid-2020, it didn't happen until December 2021. McIntosh and colleagues ended up issuing a more moderate prediction that still called for above-average activity.

At this point, it isn't clear who's right. The sunspot number that briefly went haywire earlier this year has since declined to a level within the panel's prediction. We will likely have to wait until the solar maximum, expected in late 2024 or early 2025, to see how this ends, Upton says: "The Sun loves to throw us for loops."

■ **JAVIER BARBUZANO**

EXOPLANETS

Star Caught Swallowing Planet

THE DINNER BELL has struck for a star in the constellation Aquila, the Eagle. Reporting in the May 4th *Nature*, Kishalay De (MIT) and a team of astronomers watched the star belch and brighten in a way that suggests it swallowed a closely orbiting planet.

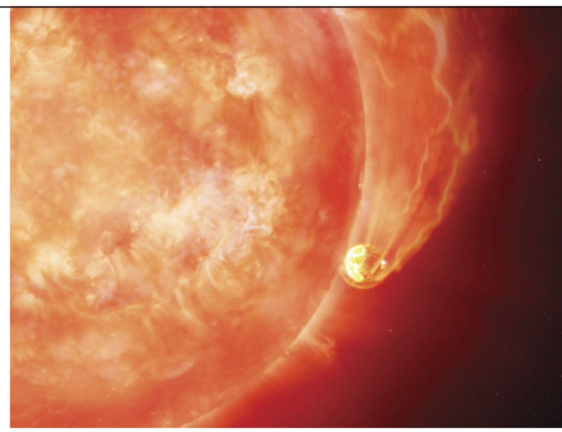
The star in question is a Sun-like star about 13,000 light-years away. Pre-outburst observations indicate it was entering its golden years, a dangerous time for the planets it hosts. As the star finishes fusing the hydrogen in its core and swells, it may engulf the closest worlds — just as the Sun will one day do to Mercury, Venus, and perhaps Earth.

De was originally searching for brilliant blasts from white dwarfs when he stumbled on a seemingly ordinary star in Zwicky Transient Facility (ZTF) data that had suddenly brightened by a factor of 100 over a couple weeks. Follow-up spectra revealed this outburst, called ZTF SLRN-2020, had released cool gas. Several months later, De and his colleagues took infrared observations that indicated a cloud of dusty gas surrounding the star.

The outburst looked surprisingly like a *red nova*, a class of stellar flare-ups thought to occur when two stars merge. But red novae are hundreds or even thousands of times brighter than this flareup, depending on the mass of the two merging objects.

The team concluded this fainter flare indicated a merger with a gas giant less than 10 times Jupiter's heft. As the planet plunged into the star, it ejected gas that glowed visibly for two weeks before cooling into a dusty, infrared-bright cloud.

"I was really struck by the timeliness and significance of this work," says Melinda Soares-Furtado (University of Wisconsin, Madison), who studies what happens when stars eat planets. "The scientific evidence hinting at a planetary engulfment event is quite compelling." Given the world's mass, it may



▲ Astronomers have observed the first compelling evidence of an aging Sun-like star engulfing an exoplanet.

have dove fairly deep, even reaching below the star's outer convective zone before disintegrating, she adds.

Astronomers have previously seen indirect signs of planet-swallowing stars, but they haven't caught a star in the act before. De's team already has JWST data in hand to explore whether they can spot the crumbs of the feast in the stellar atmosphere.

■ **CAMILLE M. CARLISLE**

CURRENT AND PREVIOUS SOLAR CYCLES GRAPH: SPACE WEATHER PREDICTION CENTER; PLANET ENTERING STAR: INTERNATIONAL GEMINI OBSERVATORY / NOIRLAB / NSF / AURA / M. GARLICK / M. ZAMANI

Long Time Coming

Planetary exploration can take up a large portion of one's life.

EXPLORING THE SOLAR SYSTEM is a long game, with travel times measured in years. And the time from when we first propose a mission to when our spacecraft sits on the launch pad, ready to leave Earth or die trying, is often much longer still. In a way, the pace is a return to that of the age of sailing ships, when explorers left home for years at a time — though we modern planetary explorers don't physically risk our lives, just large chunks of our careers.

The Voyager program, originally called the Grand Tour and first proposed in 1969, finally launched in 1977. Between 1979 and 1989, the two Voyagers visited Jupiter, Saturn, Uranus, and Neptune, in brief flybys lasting just a few days each. In between were long years traveling the interplanetary void. The frenzied Voyager encounters every few years at NASA's Jet Propulsion Laboratory felt like family reunions, with people having visibly aged, some with newborn children in tow — and, sadly, some old friends no longer with us.

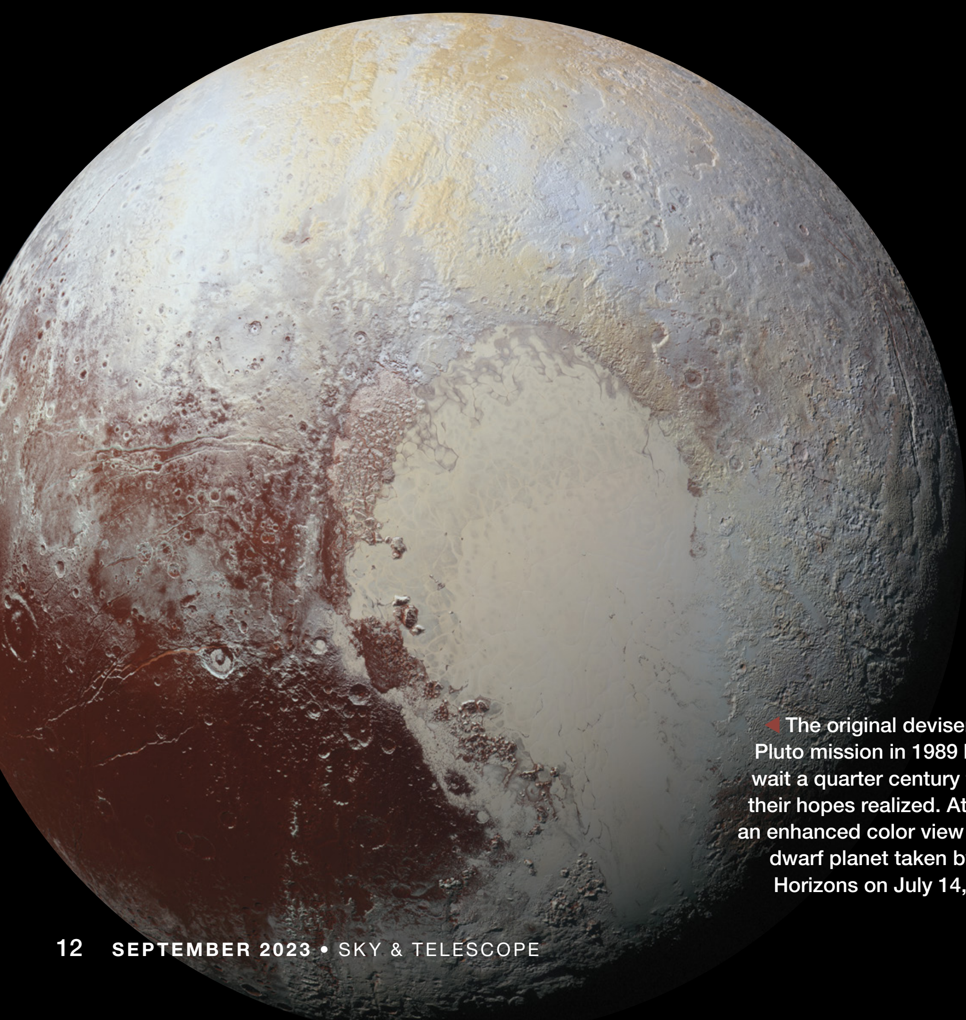
I grew up with the Voyagers, which launched the year I graduated from high school. I was fortunate to be involved as an undergraduate assistant for the Jupiter flyby in 1979, as a grad student for the Uranus pass in 1986, and working as a post-doctoral researcher when Voyager 2 had its final planetary encounter, with Neptune in 1989. That was a bittersweet moment: Twenty years after the Grand Tour was proposed, Voyager's planetary visits were over.

But that same year, a band of young explorers gathered to plan a mission to Pluto. After years of rejections and setbacks, New Horizons finally launched in 2006 and nine years later reached the dwarf planet and its system of moons (*S&T:* Nov. 2015, p. 18). Many of the scientists from the initial 1989 effort, while no longer so young, were involved in that 2015 triumph.

I was pondering these time scales recently at a meeting about the thrilling Venus missions now in the works (*S&T:* May 2022, p. 12). It was wonderful to see many students and early-career scientists excited about the decade ahead. Yet I was also suddenly acutely aware of making the transition from "mid-career scientist" to "senior scientist." The DAVINCI mission I'm involved in will, if all goes to plan, launch when I'm in my late 60s and return its data when I'm in my early 70s.

We have been trying to get these missions flown for decades. It's incredibly satisfying to now be working on a funded mission, seeing plans materialize into agents of our curiosity that will seek answers to questions we first asked when fresh out of school. Some of us joked that, after all these decades, it will be these young whippersnappers in charge when we arrive at Venus.

Sometimes my non-planetologist friends, when I tell them that what I'm working on won't bear fruit until the early 2030s, give me looks of pity. Sure, it takes patience and resilience, and there's no guarantee of success. But there's something cool about knowing that, if you stay healthy, in your later years you might make yourself useful. Overall, the feeling is one of gratitude — to be part of something big that will continue after you're gone, and, in the meantime, to be here for part of the ride on this long, slow adventure through the solar system.



The original devisers of a Pluto mission in 1989 had to wait a quarter century to see their hopes realized. At left is an enhanced color view of the dwarf planet taken by New Horizons on July 14, 2015.

NASA / JHUAPL / SWRI

DAVID GRINSPOON is author, with Alan Stern, of *Chasing New Horizons: Inside the Epic First Mission to Pluto*.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When Gregg Hallinan heard about the dramatic collapse of the giant Arecibo radio dish in Puerto Rico on December 1, 2020, he felt the pressure on his own shoulders build. With the loss of Arecibo, many radio astronomers — and in particular, pulsar scientists — would be in need of an observatory at least as sensitive as the 305-meter (1,000-foot) dish (*S&T:* Aug. 2021, p. 34). Hallinan, a radio astronomer at the California Institute of Technology, was in a unique position to provide a solution: the Deep Synoptic Array (DSA) project, a budding network of dish antennas that will be the radio equivalent of the best next-generation optical survey telescopes.

Hallinan started the DSA project back in 2013; development began snowballing in 2018. The final version, DSA-2000, will be an array of no less than 2,000 small, fully steerable radio dishes (2,048, to be precise), spread over an area 19 by 15 kilometers (12 by 9 miles) wide in a remote, 2,000-meter-altitude region in Nevada, and all linked up by optical fibers. The goal: to deliver fast and deep surveys of the radio sky, as well as detailed measurements of transient phenomena such as the still-mysterious *fast radio bursts*. Construction will start next year; "first light" with a smaller number of antennas should be achieved in 2026.

"I love Gregg's 'faster, cheaper, better' attitude," says Katie Jameson (Caltech), the lead project manager for DSA-2000, "but it's a very aggressive timeline." Everything on this project is complicated, she says, "but our small team is very good at problem solving."

A much smaller, T-shaped prototype array, with a different and slightly smaller antenna design and a maximum baseline of just 2.6 kilometers, is under construction at the Owens Valley Radio Observatory in California. Known as DSA-110, it should be completed around the time you read this article. It's already been operating with a limited number of antennas and has produced exciting results. According to co-principal investigator Vikram Ravi (also at Caltech), DSA-110 discovers one or two fast radio bursts per week, on average, and precisely pinpoints the sky positions of these millisecond-long explosions in remote galaxies. "With new facilities, it's always hard to make predictions," he says, "but we expect

CALTECH / CHUCK CARTER

DSA–2000:

DSA-2000 to discover and localize between five and 25 fast radio bursts *per day*."

It's just one of the many scientific promises of the new instrument. At a three-day science conference in Pasadena in March 2023, many dozens of astronomers discussed the huge potential of DSA-2000. "It was a fantastic success," says project scientist Fabian Walter (Max Planck Institute for Astronomy, Germany; currently on sabbatical at Caltech). "There's a very large number of different science questions that DSA-2000 is going to address, from short-lived transients to the static radio sky. With so many different communities, it will be a challenge to organize everything."

To principal investigator Hallinan, the conference was a "wonderful and very exciting" event. "Many people were quite surprised when they first learned about the true scope of the project," he says. The existing baseline design of DSA-2000 may undergo some minor tweaks following discussions among meeting participants, but according to Walter, "at least 95% of the current design is all okay."

This project is part of an emerging trend for the next decade, which is shaping up to be the decade of multi-frequency all-sky surveys. Astronomers will be keeping an eye on huge swaths of the sky at a wide variety of wavelengths in order to discover all sorts of short-lived cosmic phenomena. DSA-2000 is expected to become the major radio facility in this endeavor.

Radio Camera

Radio astronomy really took off after World War II, when astronomers first tuned in on the 21-centimeter (1,420-megahertz) radio emission of cold, neutral hydrogen gas to map the spiral arms of the Milky Way (*S&T:* Nov. 2019, p. 16). Later, it turned out that supernova remnants, active galactic nuclei, quasars, and pulsars all produce radio waves. Thanks to *synchrotron radiation* (emitted by electrons spiraling along magnetic field lines), radio astronomers are able to study cosmic magnetism. Other radio observations

▼ **DSA-2000** Artist's concept of the planned DSA-2000 array. When completed, the network will boast more than 2,000 dishes.

Mining the Radio Sky

An ambitious observatory is taking shape in the American Southwest.

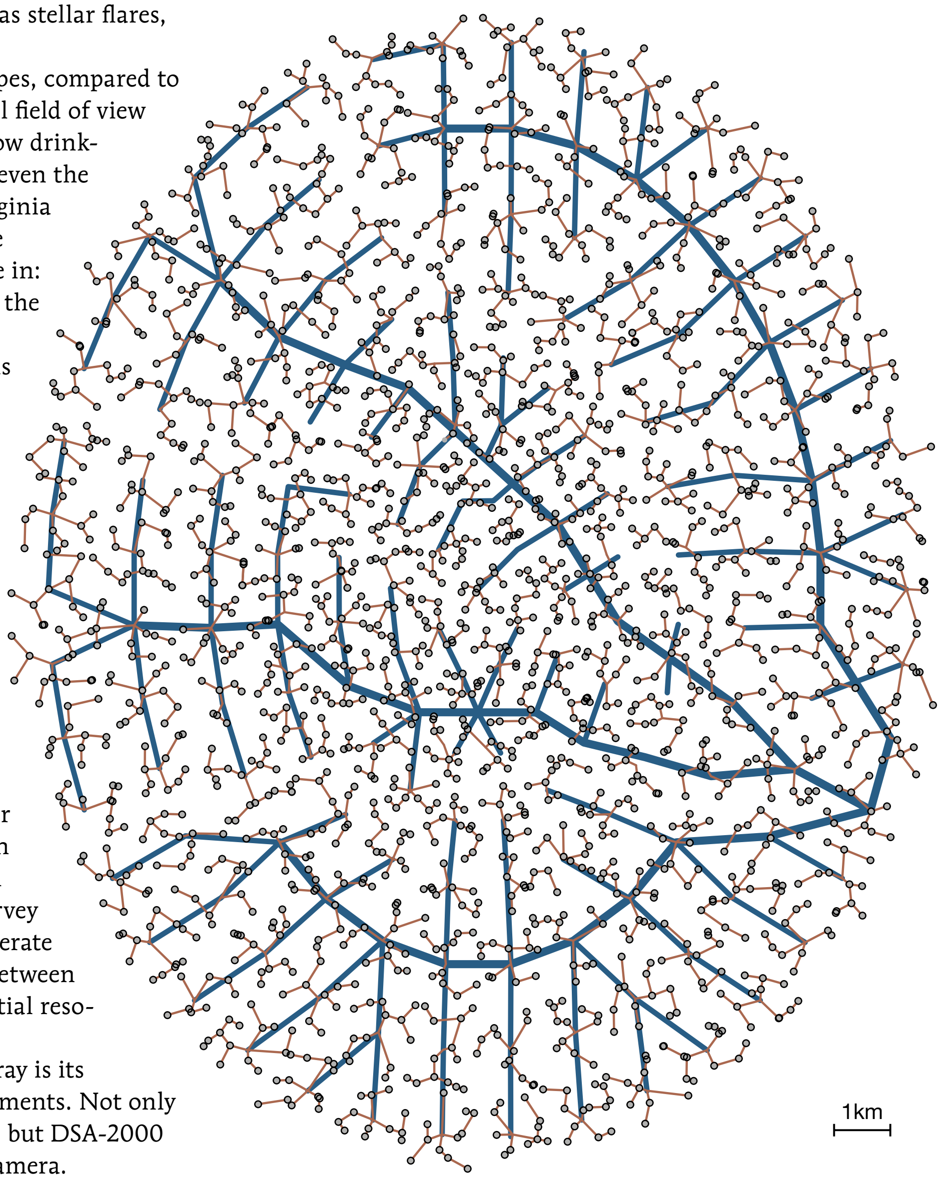
provide valuable data on one-off events such as stellar flares, gamma-ray bursts, and fast radio bursts.

The two main problems with radio telescopes, compared to optical instruments, are their extremely small field of view (as if you're watching the sky through a narrow drinking straw) and their low spatial resolution — even the 100-meter Green Bank Telescope in West Virginia can't match the human eye in terms of image sharpness. That's where interferometers come in: huge collections of multiple radio dishes, like the Karl Jansky Very Large Array in New Mexico. Combining the data from individual antennas boosts the facility's sensitivity by increasing the total collecting area of the array. It also hugely increases the spatial resolution — as if you're operating a virtual telescope as large as the array's maximum baseline.

One of the largest radio interferometers built to date (in terms of number of elements) is the MeerKAT observatory in South Africa, with 64 antennas, each 13.5 meters wide. The individual dishes of DSA-2000 will be much smaller: just 5 meters in diameter. This will provide the instrument with a large field of view of almost 11 square degrees. That's slightly larger than the field of view of the future Vera Rubin Observatory's 8.4-meter telescope, which will use the largest digital camera ever built to survey the visible sky for 10 years. DSA-2000 will operate simultaneously at thousands of frequencies between 700 and 2,000 MHz, yielding images at a spatial resolution of 3.3 arcseconds.

But the unique selling point of the new array is its unprecedented number of interferometric elements. Not only will its sensitivity be comparable to Arecibo's, but DSA-2000 will also be able to operate like a true radio camera.

As Hallinan explains, creating radio images from interferometric observations usually requires expensive infrastructure and time-consuming supercomputer calculations, as huge amounts of raw data have to be transported, stored,



▲ **THE PLAN** This map shows the DSA-2000's configuration — a vast oval spanning 19 by 15 kilometers, with each dot representing a 5-meter dish. A network of fiber-optic cables (red and blue lines) will link the telescopes together into an array.

CALTECH / DSA TEAM

Arrays of the Future

Radio astronomers are looking forward to multiple huge interferometric arrays that will be built over the next decade. One is the South African part of the Square Kilometre Array (SKA), known as SKA-Mid, which focuses on a wide frequency range between 350 megahertz and 15.4 gigahertz (*S&T:* June 2017, p. 24). (The Australian part of SKA focuses on lower frequencies and is also being built this decade.) The first phase of SKA-Mid, construction of which officially started in December 2022, will consist of the 64 existing 13.5-meter-diameter MeerKAT dishes, supplemented with 133 new 15-meter dishes. The array will have a total collecting area of 33,000 square meters (comparable to the total collecting area of DSA-2000) and a maximum baseline of 150 km.

The other future facility is the Next Generation Very Large Array (ngVLA): 244 dishes each 18 meters and finally processed to produce an image (*S&T:* Sept. 2019, p. 18). He draws a comparison to the diffraction spikes on the images of the James Webb Space Telescope. To a certain extent, this pattern, part of the *point spread function*, results from the fact that some parts of the mirror are obstructed. In the case of a radio interferometer, you could say that almost all of the array-sized virtual "mirror" is obstructed, and the only patches of usable mirror are the individual dishes. The resulting point spread function is much, much messier.

For facilities like MeerKAT and the Very Large Array, scientists must use a process known as *deconvolution* to turn raw data into useful radio images. "But with 2,000 antennas spread out over an area of 19 by 15 kilometers, we'll reach a tipping point," says Hallinan. "We get much closer to filling our full aperture. As a result, deconvolution is much simpler, and we can create images in real time, at the telescope." This novel radio-camera approach, strongly endorsed by the astronomical community's latest roadmap for research investments over the next decade, reduces the data output of the DSA-2000 array by a factor of 1,300 — from 20 exabytes to a "mere" 15 petabytes per year.

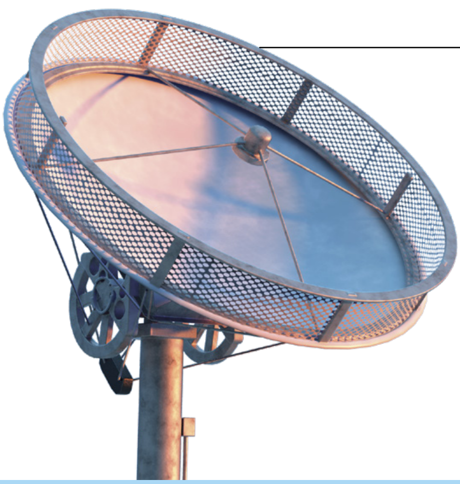
With a price tag of $144 million, DSA-2000 will be "much, much, much cheaper to build" than other future big radio interferometers, says Maura McLaughlin (West Virginia University), chair of the project's science advisory committee. (See box below.) First, with no need to transport and store huge amounts of data, the project will save about $100 million per year. Second, the receivers have been designed to work at ambient temperatures, so expensive cryogenic technology is not required. Third, the small dishes will combine off-the-shelf components with cheap, mass-produced parts.

For example, the array will use some 5,000 commercial Nvidia central processing units (CPUs). Meanwhile, the wave-guiding antenna feeds (in the prime focus of each individual dish) will include components manufactured by Fat Daddio's in Spokane, Washington — a cake-pan and bakery-tool company. "For the DSA-110 prototype, it turned out we could use one of their off-the-shelf cake pans," says Jameson. "For DSA-2000, they will produce a customized version, according to our specifications." To further reduce development costs, the dish mounts will be based on the design of the existing Allen Telescope Array in northern California. In the end, each individual dish is expected to cost no more than $25,000.

Transients Galore

DSA-2000 will revolutionize radio astronomy in many different ways. For instance, the array will be the most prolific source of precise sky positions for newly discovered fast radio bursts (FRBs). These mysterious flashes of radio waves, producing as much energy in a millisecond as the Sun does in three days, were only discovered in 2007 and are thought to be explosions at or near the surface of strongly magnetized neutron stars (*S&T:* Sept. 2022, p. 26). At the January 2023 meeting of the American Astronomical Society (AAS) in Seattle, Ravi announced the discovery of 30 bursts in 2022 with DSA-110, while this testbed array was still very much under construction. (Back in 2019, an even smaller precursor, DSA-10, discovered and pinpointed FRB 190523.) In fact, DSA-110 was purpose-built for the detection and localization of FRBs.

A detailed analysis of just one of the 30 FRBs found by DSA-110, which occurred in a relatively nearby galaxy, revealed that the halo of our Milky Way must have lost a



◀▼ **DSA-2000** Artist's concept of one of the 5-meter dishes of the DSA-2000, along with its antenna feed *(below)*, built with parts from a baking company.

CALTECH / CHUCK CARTER (2)

across and 19 smaller, 6-meter dishes, spread out over most of the United States, from Hawai'i to New Hampshire and Puerto Rico, with most of the dishes located in the American Southwest. ngVLA should reach a spatial resolution of a milliarcsecond or better, observing high radio frequencies between 1.2 and 116 gigahertz. It will thus fill the gap between existing radio observatories and the Atacama Large Millimeter/submillimeter Array in Chile, which extends to even higher frequencies (shorter wavelengths).

Both SKA-Mid and ngVLA are not optimized to carry out large surveys of the radio sky, which is the major goal of DSA-2000. In fact, says DSA-2000 project scientist Fabian Walter, "DSA-2000 will complement the other facilities and work brilliantly in concert with them. For instance, ngVLA could carry out detailed follow-up observations of new radio sources found by DSA-2000."

substantial fraction of its original *baryonic* ("normal") matter into intergalactic space, Ravi told the AAS meeting (*S&T:* Aug. 2023, p. 10). If not, the brief burst would have been smeared out more strongly over time than has been observed. This so-called *dispersion measure*, with lower frequencies arriving later than higher ones, tells you how many free electrons there are between the FRB and Earth. Even if you assume a very low contribution from the burst's host galaxy and the intergalactic medium, the observed dispersion measure for this particular burst was "incredibly low," says Ravi — much smaller than you would expect if the Milky Way's halo had as much baryonic matter as expected.

This kind of analysis is only possible if an FRB's distance is known, by measuring the redshift of the host galaxy, which, in turn, requires a precise sky position. Since DSA-2000 is expected to detect and localize at least 10,000 FRBs in its first five years of operation, including hundreds in a smaller area of sky that will be studied in much more detail, it should enable astronomers to create crude 3D maps of the tenuous intergalactic medium, explains Ravi. "It's a form of cosmic tomography, which cosmologists can use to test theories of the evolution of the cosmic web."

Another important field of research for DSA-2000 is pulsar timing — something in which Arecibo, with its great sensitivity, excelled. Pulsars are fast-spinning neutron stars that emit beams of radio waves, which briefly sweep across our vision with atomic-clock precision. However, over periods of years, the arrival times of pulses from extremely fast millisecond pulsars in various parts of the sky should be slightly affected by the very-low-frequency gravitational waves that binary supermassive black holes in distant galaxies produce. "DSA-2000 will be a real game-changer in this field," says pulsar-timing expert McLaughlin. "A quarter of the array's observing time will be devoted to pulsar timing, and up to 200 millisecond pulsars will be studied every week at better than microsecond accuracy."

▲▼ **DSA-110** DSA-2000's precursor is already up and running, with a dense, T-shaped core of antennas *(below)* and 15 more individual dishes spread out over 2.5 km *(above)*.

According to McLaughlin, hundreds of supermassive black-hole pairs — which come about from galaxy mergers — are expected to emit gravitational waves at frequencies that could be detected through pulsar timing. "At first, we will discern the so-called stochastic background," she explains. "It's like going to a crowded party: At first, you hear random noise, but later on, you start to recognize individual voices. Likewise, after two years or so, we should be able to pick out individual

CALTECH / DSA TEAM (2)

gravitational-wave sources, and even to track them down to particular galaxies." Eventually, this will tell astronomers more about the evolution and merger history of galaxies.

But DSA-2000's main job, using up 65% of the available observing time, will be to carry out repeated radio surveys of the entire visible sky, observing each 11-square-degree field for about 15 minutes before moving on to the next. Thanks to the large field of view, the array's survey speed will be about a thousand times higher than the VLA's, and some 150 times higher than MeerKAT's. And thanks to the huge sensitivity, Hallinan expects the new facility to detect at least 1 billion discrete sources, including radio galaxies and active galactic nuclei, providing astronomers with a better understanding of cosmic history.

In the local universe, 1,420-MHz observations will reveal the distribution and dynamics of neutral hydrogen gas in tens of thousands of galaxies — something that has never been possible before, according to Walter. "In the past, we could only observe one object at one frequency at a time," he says. "With DSA-2000, it's like getting everything in one shot."

Finally, DSA-2000 will be a discovery engine for many kinds of transients. By surveying the dynamic radio sky three or four times per year, it will not only find countless FRBs but also millions of other short-duration phenomena, like remote supernovae, flares from quasars, and tidal disruption events, in which stars are devoured by supermassive black holes.

Meanwhile, the array is flexible enough to quickly respond to discoveries from other facilities such as gamma-ray satellites, gravitational-wave detectors, and the upcoming Vera Rubin Observatory, searching for and studying the radio counterparts of a wide variety of astronomical transients. "Most of these haven't really been studied very well so far," says Scott Ransom (National Radio Astronomy Observatory), another member of the DSA-2000 science advisory committee. "Since we'll be imaging a big chunk of the sky at all times, we're effectively carrying out a sky survey for radio transients. This is really going to be the radio counterpart of the Rubin Observatory."

Although DSA-2000 is not yet fully funded, Hallinan and his team are confident that their ambitious plans will be realized. The National Science Foundation (NSF) has already funded the $6.3 million DSA-110 prototype array, and the DSA-2000 team will request the first tranche of construction funding from the NSF's Mid-scale Research Infrastructure program later this year. Additional support has come from Schmidt Futures, a philanthropic initiative by former Google CEO Eric Schmidt and his wife, Wendy, as well as from Caltech. "We are open to other partnerships," says Jameson.

Around the time you're reading this, the first prototype antennas of DSA-2000 should be completed. Construction of the array, possibly in Hot Creek Valley in central Nevada, is expected to commence in the summer of 2024, and the first science results could already come in by 2026 or 2027. "It's not like we need to build 2,000 antennas before pushing the start button," says Walter. "Even with 100 or 200 antennas, we can be in business already."

Hallinan, for one, can't wait. "We're building on the legacy of other radio observatories," he says, "but especially in terms of survey power, DSA-2000 will be unprecedented."

■ *S&T* Contributing Editor **GOVERT SCHILLING** travels the world in search of astronomy wonders. Next time he takes a road trip to the American Southwest, the DSA-2000 array will definitely be on his itinerary.

MILKY WAY NEIGHBOR The magnificent Andromeda Galaxy (M31) is not only a popular autumn deep-sky target for observing enthusiasts but also a historic laboratory for galactic studies. In 1912, Vesto Slipher determined the Andromeda Nebula (as it was then known) was approaching our solar system at an incredible 300 kilometers per second.

Vesto Slipher's
Fast Stars and Hotrod Galaxies

How one astronomer's historic discovery of galactic redshifts helped pave the way for modern cosmology.

One hundred years ago this autumn, Edwin Hubble spotted a Cepheid variable star in the Andromeda Galaxy (see page 26). It was a momentous discovery. First recognized by Henrietta Leavitt at Harvard College Observatory a decade earlier (*S&T:* Dec. 2021, p. 12), Cepheids were already astronomy's most valuable distance-measuring tool. Now, for the first time, Hubble had seen one in a "spiral nebula" (as galaxies were then called). The nebula's distance could at last be measured.

In the 1920s, the Rosetta Stone of astronomy was written in two languages. Its encoded secret for distances was set down in the language of Cepheid-variable light curves. However, the mystery of galactic velocities was recorded in the very different language of shifted spectral lines. By translating both languages — and thereby linking distances with velocities — a great cosmic secret would be deciphered, galaxy by galaxy.

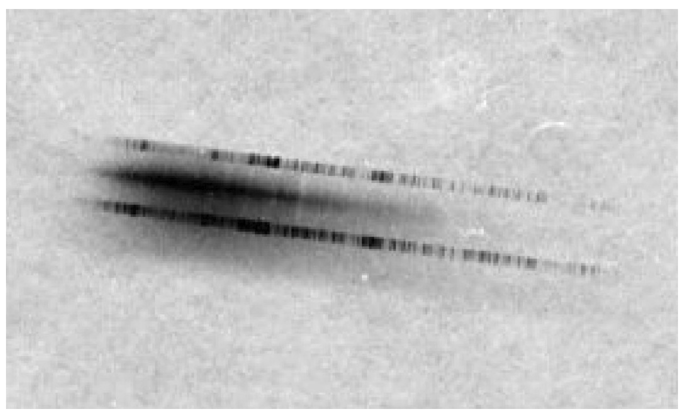
The story of how this occurred unfolded quickly over two decades and changed our entire understanding of the cosmos we inhabit. It began at Lowell Observatory in Flagstaff, Arizona, where a diligent young astronomer named Vesto M. Slipher started reading that second language, teasing velocity signals out of galactic spectra.

Measuring the Speeds of Stars

Late in the 19th century, a few enterprising scientists used the new science of spectroscopy to detect *radial motion* in stars — motion in the observer's line of sight, either toward us (velocity of approach) or away from us (velocity of recession). Determining a star's speed this way is simply another application of the familiar Doppler principle, named after Christian Doppler, professor of mathematics at the Prague Polytechnic Institute. You can hear the Doppler shift in action when a car speeds by — the sound of its engine increases in pitch until the vehicle passes by, at which time the pitch decreases. In 1842 Doppler proposed that the color of a luminous body might also appear altered depending on whether it was moving toward us or away from us. French physicist Hippolyte Fizeau in 1848 considered that the effect could be tested on spectral lines to determine velocities of astronomical objects. It was an idea worth exploring.

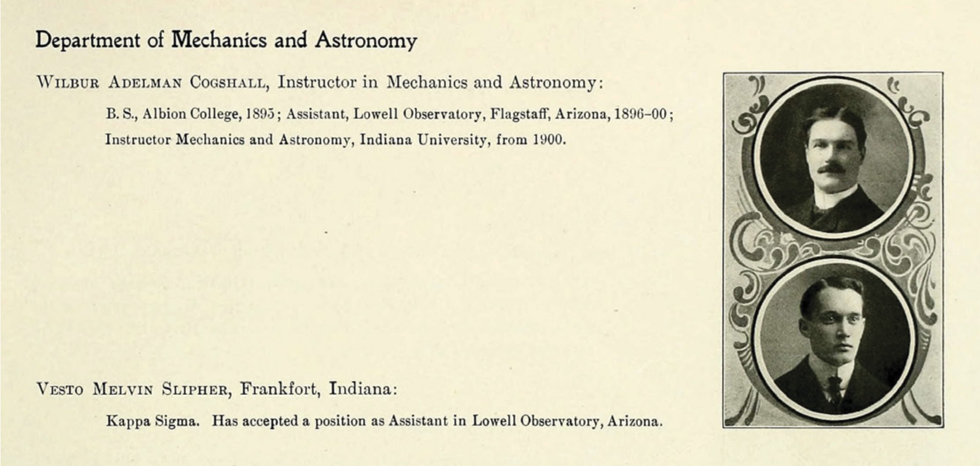
In March 1868, British amateur astronomer William Huggins tried it and detected an almost infinitesimal shift to the red in one line of Sirius's spectrum. He and others later showed that a variety of brighter stars shared surprising speeds of between 19 and 47 kilometers per second (12 and 29 miles per second). By the end of the century there was no longer any doubt about the efficacy of using the spectroscope to determine radial velocities. It was an exciting development. The spectroscope seemed like a Promethean gift, giving humankind "new and

▲ **REDSHIFT PIONEER** After college graduation, Vesto Melvin Slipher (1875–1969) was invited by Percival Lowell to join the staff of Lowell Observatory at Flagstaff, Arizona, where he remained his entire career. He soon perfected techniques in spectroscopy and made remarkable advances in galactic astronomy.



▶ **SIGNATURE OF DISTANT LIGHT** Slipher captured this spectrum of the Andromeda Galaxy (M31) on September 17, 1912. One can appreciate the challenge of discerning and measuring slight shifts in the lines in such a tiny spectral image.

ANDROMEDA GALAXY: ROBERT GENDLER, RUSSELL CROMAN / SUBARU TELESCOPE (NAOJ) / HUBBLE LEGACY ARCHIVE / NOAO MAYALL (NSF); SLIPHER PORTRAIT AND SPECTRUM OF M31: LOWELL OBSERVATORY ARCHIVES



Department of Mechanics and Astronomy

Wilbur Adelman Cogshall, Instructor in Mechanics and Astronomy:

B. S., Albion College, 1895; Assistant, Lowell Observatory, Flagstaff, Arizona, 1896–00; Instructor Mechanics and Astronomy, Indiana University, from 1900.

Vesto Melvin Slipher, Frankfort, Indiana:

Kappa Sigma. Has accepted a position as Assistant in Lowell Observatory, Arizona.

◀ **THE YOUNG V. M.** This page from the 1901 Indiana University yearbook shows a 25-year-old Vesto Slipher with the caption noting he "Has accepted a position as Assistant in Lowell Observatory, Arizona." The other portrait is of Wilbur A. Cogshall, instructor in mechanics and astronomy and himself recently an assistant at Lowell Observatory. V. M. eventually returned to his alma mater in 1909 and became Dr. Slipher. His dissertation on the "The Spectrum of Mars" was published in the *Astrophysical Journal*.

hitherto undreamed-of powers," in the words of astronomer James Edward Keeler, who himself undertook groundbreaking spectroscopic studies of the rings of Saturn.

In this heady atmosphere of discovery, a young Vesto Slipher was summoned by his father, a prosperous Indiana farmer, and told that he and his seven brothers would have a choice: They each could have 160 acres of farmland or a college education. Vesto and his younger brother Earl chose education; the others took the land. Vesto and Earl (who also went on to have a notable career in astronomy) both attended Indiana University, home of the Kirkwood Observatory.

Vesto Melvin Slipher (or V. M. as he was known) — handsome, high-collared, and serious — peers intently out of his 1901 Department of Mechanics and Astronomy yearbook page. "Has accepted a position as Assistant in Lowell Observatory, Arizona," it says. The other picture on the page is that of Wilbur A. Cogshall, instructor in mechanics and astronomy and himself recently an assistant at Lowell Observatory.

It was Cogshall who in 1901 persuaded the flamboyant Percival Lowell to invite Slipher to Lowell Observatory in Flagstaff. Lowell's priority for his new recruit was the planets — Mars famously being his particular and passionate interest. Indeed, Lowell suggested that if Slipher wanted to do other things with the observatory's equipment, it would have to be on his own time. Fortunately, there was plenty of "his own time."

The pair of astronomers made an unlikely match but a good team. The restless and impulsive Lowell had an eye for talent, and the studious, hard-working son of a farmer was the ideal assistant for getting the most out of the newly minted observatory. Slipher would later say that he had a "rather free hand" to choose his own program, "which fit happily with a spirit of exploration." The young astronomer's own ambition was the new science of spectroscopy, and he was anxious to utilize Lowell's 24-inch Alvan Clark refractor with its brand-new three-prism Brashear spectrograph to inspect everything he could find.

This was not the era of out-of-the box, ready-to-go equipment — everything was a first-time-ever adventure. It took experimentation to mount the spectrograph on the telescope, adjust it, and figure out how to use it effectively. But soon Slipher had obtained excellent spectrograms of Mars, Jupiter,

LOWELL OBSERVATORY ARCHIVES (2)

▶ **LOWELL STAFF PHOTO** This photo from 1905 shows seated at the Clark 24-inch refractor (left to right) Harry Hussey, Wrexie Leonard, Vesto M. Slipher, Percival Lowell, Carl Lampland, and John C. Duncan.

▶▶ **WHERE HISTORY HAPPENED** *Left:* The Clark 24-inch telescope is visible in its dome on Mars Hill, at Lowell Observatory in Flagstaff, Arizona. The refractor saw first light on July 23, 1896, the beginning of many decades as a workhorse of creative astronomy. Both the scope and its dome have recently been renovated to proper working order. *Right:* Photographed in 1909 by Earl C. Slipher, the big refractor is the oldest instrument on the observatory campus. The instrument was first used by Percival Lowell for his famous observations of Mars.

and Saturn, which confirmed each planet's rotation period. By 1907 he had investigated the giant outer planets in the unexplored infrared region of the spectrum, revealing spectral bands of atmospheric methane and ammonia. Discoveries continued. In 1909 he found sharp, stationary lines in the spectra of various stars nearly everywhere he looked, revealing the signature of the interstellar gas that permeated the Milky Way. In 1912 he discovered that the nebulosity surrounding the star Merope in the Pleiades cluster glowed solely by reflected starlight. It was the first solid evidence of dust in space and defined a new class of objects called *reflection nebulae*. Slipher's reputation was growing, yet an even bigger challenge lay ahead.

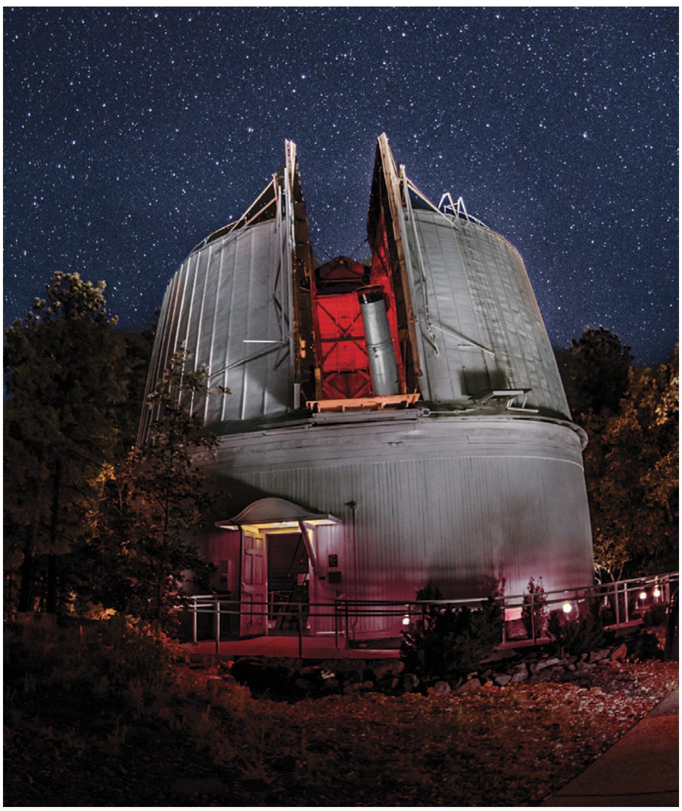
◀ **KING OF THE HILL** Percival Lowell (1855–1916) was the venerable director of Lowell Observatory who pioneered the study of Mars. Rather like a Carl Sagan of an earlier era, Lowell's astronomical curiosity and speculations about Mars had a profound effect on the public imagination. He gave Slipher a free hand to pursue his spectrographic investigations.

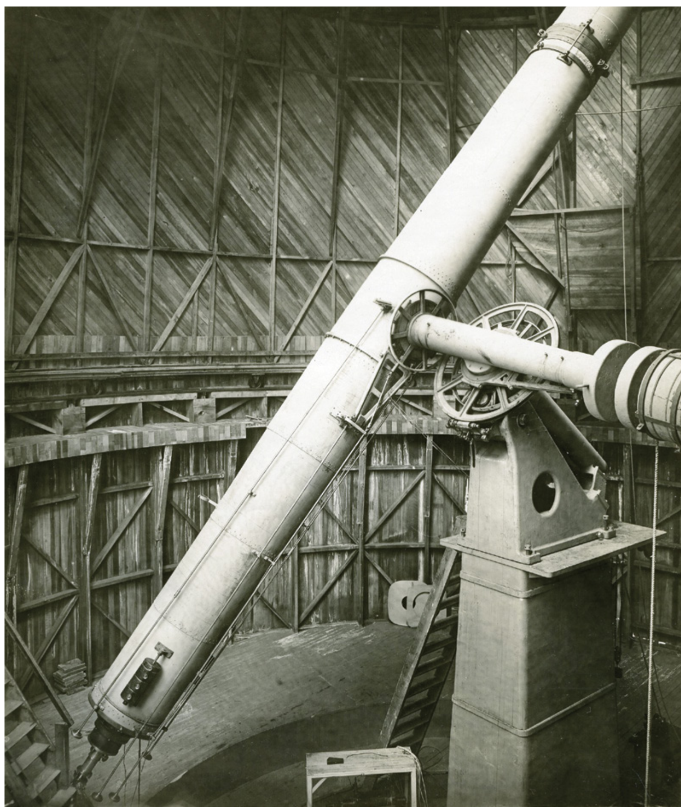
The First Galactic Spectrum

The late 19th-century discovery that stars had detectable motions led naturally to the question of whether spiral nebulae did too. No one knew whether those faint wisps of light tucked among the stars lay within the Milky Way or were instead remote, distant realms. They looked different from star clusters and the glowing patches of "gaseous nebula" lying in rich Milky Way star fields. The spiral nebulae were compact, organized, and faint.

And that was the problem. Galaxies are not sparkling points of starlight — they are dim and diffuse, making them challenging targets even for Slipher's giant spectroscope. Exposures of many hours accumulated over several nights were typically required to spread a galaxy's tiny trickle of photons into a readable, high-dispersion spectrum whose line displacements could be measured. This was true even of the brightest and biggest spiral nebula, M31 in Andromeda.

The task was daunting, but Slipher was ready for it. He had replaced the Brashear spectrograph's original f/14.2 lens with a much faster f/2.5 optic, and after experimenting with chemical dyes and plate baths was able to enhance the sensitivity of his photographic plates. With these improvements in hand, in the autumn of 1912 Slipher trained the 24-inch Lowell refractor toward Andromeda to capture the spectrum of M31. Remarkably, Slipher's first exposure of almost seven hours on September 17th showed that "the nebular lines were perceptibly displaced" toward the blue end of the spectrum. Cautiously repeating his work, Slipher produced three more plates by the end of the year. After measuring the line shift in each of the four plates with a spectrocomparator and taking their mean,





OBSERVATORY EXTERIOR: KEN SANGER / LOWELL OBSERVATORY; CLARK REFRACTOR AND LOWELL PORTRAIT: LOWELL OBSERVATORY ARCHIVES (2)

Slipher concluded that the Andromeda nebula was speeding toward our solar system at the remarkable speed of 300 km/s.

This result was sensational. This was the highest velocity ever measured — 15 times greater than the average velocity of any star (about 20 km/s). "It looks as if you have made a great discovery," Lowell wrote. He encouraged Slipher to press on: "Try some other spiral nebula for confirmation." Slipher's report in the 1913 *Lowell Observatory Bulletin* (Vol. 2, No. 58), concluded modestly that "it might not be fruitless to observe some of the more promising spirals for proper motion."

A Historic Discovery

Buoyed by his success, Slipher expanded his program at Lowell. In April 1913 he turned his instrument toward the Sombrero Galaxy (M104, NGC 4594), an edge-on spiral just west of Spica. The resulting spectrogram showed a host of fine vertical lines — this time shifted toward the red. The message was clear: The galaxy was receding from our solar system at the astonishing velocity of about 1,100 km/s — faster than anything yet seen.

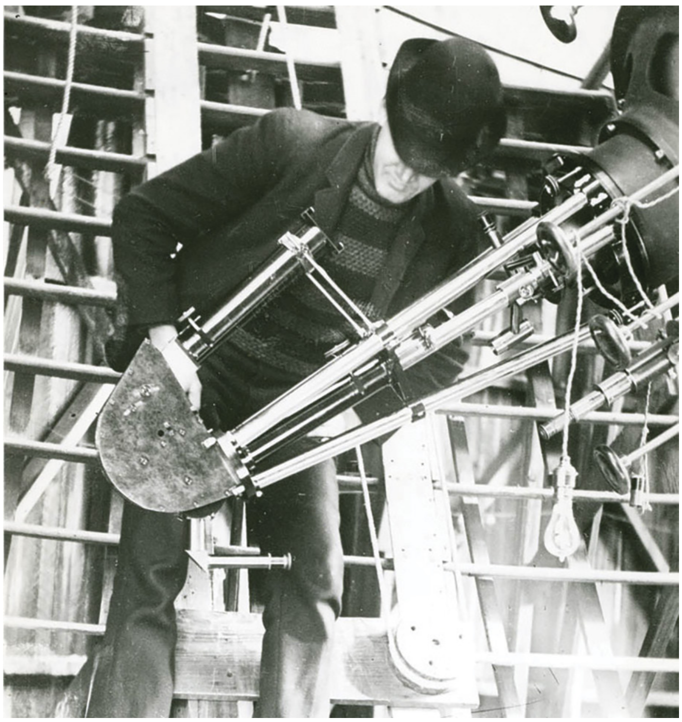
Soon he obtained even more surprising results. At the 1914 meeting of the American Astronomical Society, Slipher showed that out of 15 galaxies he observed, the spectra of 11 were significantly shifted toward the red, indicating recessions at extraordinary speeds. It was a remarkable finding, rich with implications, though the causes were then unknown. His redshift results, according to historian of science Robert W. Smith, "were widely regarded as a tour de force." His findings gave the first indication of a systemic, galactic redshift in our universe, one of the most fundamental discoveries in the history of science. This was the year before Einstein published his general theory of relativity, which conceived of gravity as curvature of a four-dimensional continuum of space and time (*S&T:* Dec. 2015, p. 18).

By 1917 Slipher had measured and re-measured the spectra of 25 galaxies, which were reported in his 1917 paper "Nebulae," published in the *Proceedings of the American Philosophical Society* (Vol. 56, No. 5). Of the 25 galaxies surveyed, four were approaching (blueshifted) and 21 were receding (redshifted). The evidence was piling up that galactic recession was a very real phenomenon. In that year, he calculated that NGC 584 in Cetus was receding from us at about 1,800 km/s, the fastest-moving object yet discovered.

Slipher's remarkable findings, along with his discovery of galactic rotations (indicated by inclined spectral lines), helped put to rest the argument that spiral nebulae lay within the Milky Way. "This is the so-called 'island universe' theory, which regards our stellar system and the Milky Way as a great spiral nebula which we see from within," he said. "This theory, it seems to me, gains favor in the present observations."

Slipher and Hubble

With all the evidence Slipher had assembled, why didn't he put the pieces together to theorize that the universe is expanding? Without knowing the distances to his spirals, this



▲ **CROWN JEWEL** V. M. Slipher working with the new Brashear scope mounted on the 24-inch Clark telescope. With it Slipher could measure the spectral line shifts of galaxies — studies that laid the foundation for the discovery of the expanding universe.

▲ **COSMOLOGICAL GIANT** Edwin Hubble (1889–1953) used Slipher's galactic velocity data, combined with the distance data offered by Hubble's discovery of galactic Cepheid variable stars, to create his all-important, straight-line, "velocity-distance relation" diagram.

SLIPHER AND SPECTROSCOPE: LOWELL OBSERVATORY ARCHIVES; HUBBLE PORTRAIT: JOHAN HAGEMEYER / WIKIMEDIA COMMONS / PUBLIC DOMAIN leap in reasoning was simply too great to make. Distance was the other language of the cosmic Rosetta stone — one that Hubble would soon learn to read fluently.

The parallax method was already being used to discover how distant nearby stars were, but the spirals showed no parallax whatever. With Leavitt's discovery at Harvard of the correlation between period and luminosity in the brilliant Cepheid variable stars, the door to measuring galactic distances was now open. All that remained was to find a Cepheid in a spiral nebula. With the construction of the new 100-inch Hooker reflecting telescope on Mount Wilson in California, and the sharp eyes of Edwin Hubble and Milton Humason, that possibility was now ripe for investigation.

Hubble outlined his ambitious "general nebular program" for Mount Wilson Observatory in a February 23, 1922, letter to Slipher, who chaired the Nebular Section of the International Astronomical Union (IAU). It was a sweeping vision encompassing every corner of galactic astronomy. Within the letter's five typed pages, however, there isn't a single reference to determining galactic distances. In deference to Slipher's work on radial velocities, Hubble added in his own hand, "I avoid the subject of radial velocities of nebula, leaving the consideration [of] that entirely to you." That was about to change.

In the autumn of 1923, during a survey of novae in M31, Hubble discovered two novae and a puzzling, 18th-magnitude object he presumed to be another nova. Comparison with earlier Mount Wilson images confirmed the faint blip was instead, as Hubble put it, "the first extragalactic Cepheid," with a period of about a month. According to Hubble's 1936 account in *The Realm of the Nebulae*, the exciting discovery triggered an intensive, all-out search to find more. The harvest bore abundant fruit.

On July 14, 1924, Hubble told Slipher that he "may be interested to hear that variable stars are now being found in the outer region of Messier 31." With the huge eye of the Hooker reflector, Hubble had seen winking Cepheids lurking among the galaxy's tenuous star clouds. This was crucial because wherever Cepheids are seen, distances can be calculated and distance-velocity relations derived. Hubble stated he was "bashful" to report anything prematurely, but the fire was lit. On December 20, 1924, Hubble informed Slipher that he'd found 14 Cepheids in M31, 27 in M33, and had also detected variables in M81, M101, and NGC 2403.

Slipher's recession measurements combined with this new data made the next six years a watershed of discovery for Hubble and astronomy. Hubble's first straight-line, distance-velocity relation appeared in his classic 1929 paper "A Relation Between Distance and Radial Velocity Among Extra-Galactic Nebulae," published in the *Proceedings of the National Academy of Sciences* (Vol. 15, No. 3). The diagram presented a clear marker of an expanding universe. And the work continued. On April 11, 1930, Hubble reported to Slipher, "We now have between 25 and 30 velocities in addition to your great list. Ours are mostly for very faint nebulae. The maximum velocity shift is +11,500 km., and the distance-velocity relation is pretty well established." He added: "Your observatory is receiving so much well deserved recognition these days that my own congratulations will be lost in the crowd." He concluded with a handwritten note, "More power to you all. It's what we have learned to expect from Flagstaff."

▲ **THE BROTHERS SLIPHER** This portrait from around 1930 shows Vesto (left) and his younger brother Earl at Lowell Observatory. Earl joined the Lowell staff as an astronomer in 1908 and became a pioneering expert on planetary photography.

LOWELL OBSERVATORY ARCHIVES

Dawn of a New Universe

As is often the case in scientific breakthroughs, the giants on whose shoulders the discoverer stands are often less well remembered. But there's never been any doubt about the importance of Slipher's pioneering work. In presenting the Royal Astronomical Society's Gold Medal to Slipher in 1933, its president F. J. M. Stratton declared that Slipher "laid the foundations of the great structure of the expanding universe." As Hubble told Slipher, "The first steps in a new field are the most difficult and the most significant," adding, "Once the barrier is forced, further development is relatively simple."

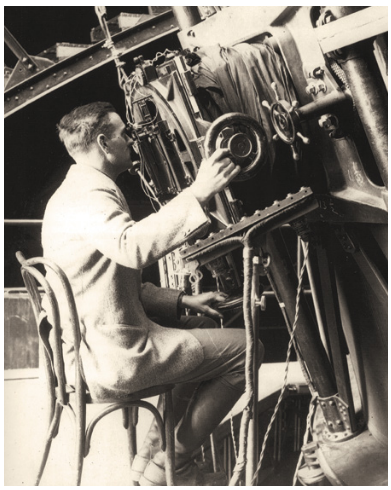
In later years, Slipher pushed his spectroscopic equipment in new directions, observing the night sky, auroral displays, and the zodiacal light. After Lowell's death, Slipher supervised the work of the observatory, including the successful search for the mysterious Planet X (Pluto). In accepting the Henry Draper Medal in 1933 from the National Academy of Sciences, Slipher, with customary modesty, said that "some one else might have accomplished much more, but surely no one could find more pleasure in doing it than I."

■ **DOUGLAS MACDOUGAL** is the author of *Newton's Gravity: An Introductory Guide to the Mechanics of the Universe* (Springer, 2012). You can read his blog at **douglasmacdougal.com**. He wishes to thank Kevin Schindler and Lauren Amundson at Lowell Observatory for their generous assistance.

Hubble's Eureka Moment

Edwin Hubble's historic 1923 insight upended our understanding of the universe at the time.

In October 1923, Edwin Hubble photographed a star in the Andromeda Galaxy. This seminal observation would eventually prove not only that *spiral nebulae* truly lay outside the Milky Way, but it also opened the door for Hubble to discover and research numerous galaxies. And thus he demonstrated that the universe was not static as had been thought for millennia, but instead it was expanding. David Soderblom of the Space Telescope Science Institute once called this Cepheid variable "the most important star in the history of cosmology." Hubble's eponymous telescope imaged the star in 2010–2011 with the input of American Association of Variable Star Observers (AAVSO) members. When I first heard of this work, I asked myself, "Can this star be seen *visually* in an amateur instrument?"



▲ **HUBBLE WITH THE 100-INCH HOOKER** In the 1920s professional astronomy was still a very hands-on experience. Here Edwin Hubble is seated at the focus of the 100-inch Hooker telescope. He'd go on to make many significant discoveries with this instrument.

PICTORIAL PRESS LTD / ALAMY STOCK PHOTO

Inconstant Stars

Documentation of variable stars (those that exhibit changes in brightness) exists in ancient Chinese and Korean texts, while German pastor David Fabricius reported the first European discovery, which was of Omicron Ceti, or Mira, in 1596. English observer John Goodricke studied variable stars in the 1780s with his neighbor Edward Pigott, who had a well-equipped observatory. The Royal Society awarded Goodricke its highest honor, the Copley Medal, for his interpretation of Algol's variability. He was also credited with the discovery of Delta Cephei, now considered the prototypical Cepheid variable. These are massive, very bright stars that vary in a specific manner on time scales of days or weeks — and the longer the star's pulsation period, the greater its luminosity.

Henrietta Swan Leavitt, working at the Harvard College Observatory, published the period-luminosity relation based on her studies of nearly 1,800 Cepheid variables in the Small Magellanic Cloud in 1908. (See *S&T:* Dec. 2021, p. 12 for an in-depth story on Leavitt's life and work.) The linear relationship between the log of Cepheids' periods and their luminosities is now called the Leavitt Law in her honor, and it's a fundamental cornerstone of modern cosmology.

In 1906, George Ellery Hale initiated plans for work to begin on the glass and building to house a 100-inch reflector on Mount Wilson. On the morning of November 2, 1917, a small group gathered to see first light for the world's largest telescope. Among the invitees was the English poet Alfred Noyes, who later wrote in his poem entitled "Watchers of the Sky" that the telescope would ". . . attack / That darkness . . . and win new worlds." After several attempts, the astronomers eventually aimed their instrument at a star, which they saw as a finely focused pinpoint, justifying the collaborators' toil and trouble.

Hubble, who had accepted Hale's offer to join the staff at Mount Wilson in 1919, knew of the Cepheid period-luminosity relation and initiated a search for these variables in the Andromeda Galaxy (M31) with the Hooker 100-inch telescope. The nature of spiral nebulae was at the center of astronomical debate at the time, with many believing the Milky Way to be the whole of what existed. On the night of October 5–6, 1923, Hubble noted that a star southwest of M31's core that he had marked with an "N" for nova was, in fact, dimming and rebrightening, which defied the known behavior of novae. Hubble crossed out the "N" and instead marked "VAR!" in bright red. This was the first of several dozen Cepheids he would find in this galaxy, after which he identified many more in M33 and other galaxies.

His distance calculations quickly led him to surmise that all these "nebulae" were extragalactic, that is, outside the bounds of the Milky Way. Hubble's results were first reported to the public about a year after the find in the *New York Times* on November 23, 1924, and then presented at the January 1, 1925, meeting of the American Astronomical Society. It wasn't until more than four years later that Hubble published his

GLORIOUS ANDROMEDA M31, more familiarly known as the Andromeda Galaxy, is a naked-eye object under dark skies and an easy target even in small instruments. But you'll need a really big telescope, such as the author's 32-inch, to identify Hubble's variable star.

◀ **TINY VARIABLE** M31-V1's coordinates are RA $00^h\ 41^m\ 27.3^s$, Dec. +41° 10′ 10.4″. If you center the small arrow-shape asterism in your field of view (12′ × 12′ at left), you should be able to spot Hubble's variable star (arrowed).

WIDE VIEW OF M31: MASIL IMAGING TEAM; ZOOM: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

observations in the *Astrophysical Journal*. That same year, 1929, Hubble recognized the relationship between galaxies' distances and their speeds of recession — the farther a galaxy lies from us, the faster it's receding. The universe was expanding! These two revelations must have offered the young astronomer a profound sense of discovery and accomplishment.

Homing in on M31-V1

In a tribute to the legendary man and his observations of this star, in late 2010 NASA planned to point the Hubble Space Telescope (HST) at M31's famous Cepheid, M31-V1 (officially cataloged as M31 V0619). AAVSO members observed the star for about six months beforehand in order to generate multiple light curves over the star's period of 31.4 days. This was so Hubble scientists would know when to aim the telescope at the star — they wanted to catch it at or near maximum and minimum brightness, and detailed studies of the star's phase didn't exist (even if basic parameters were known). HST observed the target four times between December 2010 and January 2011. M31-V1's light curve displayed the typical profile of a Cepheid: a relatively slow decline in brightness for most of the cycle (25 days for M31-V1), followed by a more rapid recovery in six to seven days.

I was curious about M31-V1, and in my correspondence with Matthew Templeton, then science director at the AAVSO, I learned that all observations thus far had been imaging. So I decided to observe it visually. The star's magnitude range — 18.5 to 19.8 — is accessible in my 32-inch reflector from my home in Minnesota. But the autumn weather was poor for several years. Then, the late evening of September 23, 2019, was magnificent. There was no dew or wind, and I had until just past midnight before a waning crescent Moon would enter the sky. I rapidly found the field using Megastar charts and a red plate from the *National Geographic Society — Palomar Observatory Sky Survey*.

The Cepheid sits within an arrowhead-shape asterism of seven stars 1.5′ across, with the tip pointing west. The three westernmost stars of that group form an equilateral triangle 20″ on a side, with M31-V1 its southeastern member. The arrow's tip star to the Cepheid's west-northwest is magnitude 18.0, just a bit brighter than our target star's brightest magnitude. I hadn't calculated where in its cycle the star would be that night, so I didn't know what its magnitude should be, but I could tell right away that it was quite a bit fainter than the tip star. As chance had it, the Cepheid was on day 23 of its 31.4-day cycle, just before the minimum magnitude of 19.8. I observed the area for about 75 minutes, employing a number of eyepieces that gave magnifications from 363× to 650×, in seeing that was 7/10 and transparency 7–8/10. Finally, with a 6-mm Zeiss Abbe Ortho at 521×, I confirmed M31-V1 just before midnight. Being sure to see it several times, I rejoiced in a journey retracing the history — and appreciating the importance — of this singular star.

■ **DAVE TOSTESON** enjoys when history and cosmology combine with atmospheric clarity to recreate "Eureka!" moments of observation.

Automation with

This powerful software controls your imaging equipment while you enjoy the night sky.

Getting ready for a night of deep-sky astrophotography in the digital age can be a complex process. Gone are the days when all you needed were film, a camera, and the patience to manually guide exposures. They've long been replaced by digital cameras, filter wheels, electric focusers, and many other electronically controlled parts. With this complexity, you need all your hardware and software up and running in the proper sequence for them to do the right things at the right times. Often this means several different programs that each control part of your entire setup. I think of it like an orchestra, with individual devices as instruments played by various musicians — the software and drivers. But an orchestra needs a conductor to ensure that everyone plays their part in perfect harmony. In other words, we need software to automate our imaging "performance."

Several companies offer software to automate your deep-sky imaging tasks. There's *ACP Expert* (**acpx.dc3.com**), *Sequence Generator Pro* (**sequencegeneratorpro.com**), *TheSkyX* Imaging edition (**bisque.com**), *Voyager* (**software.starkeeper.it**), and *N.I.N.A.* (**nighttime-imaging.eu**). While each program is very capable, I settled on *N.I.N.A.* (which stands for Nighttime Imaging 'N' Astronomy) to control my equipment. It's a free, open-source program that continues to improve through user suggestions and contributions. Here are the important steps I use with the program to ensure a productive session from twilight through sunrise each clear night.

Getting Started with Automation

While you're getting acquainted with *N.I.N.A.*, I suggest you continue using your current methods until you're comfortable with its use. You can do much of the initial setup and familiarization with *N.I.N.A.* during the day or on moonlit nights when you might otherwise not be imaging.

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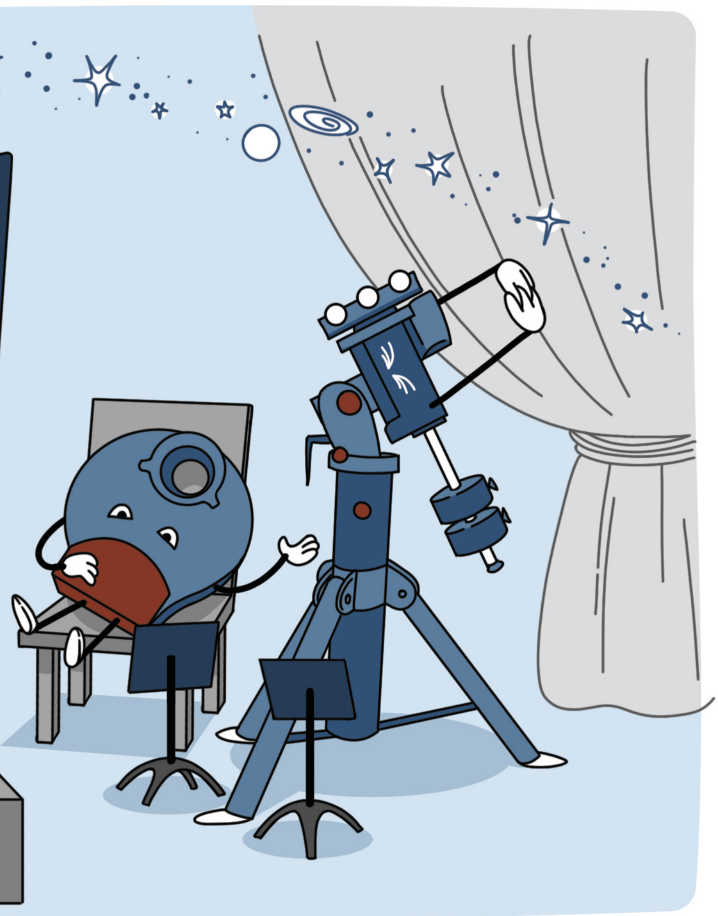


N.I.N.A.

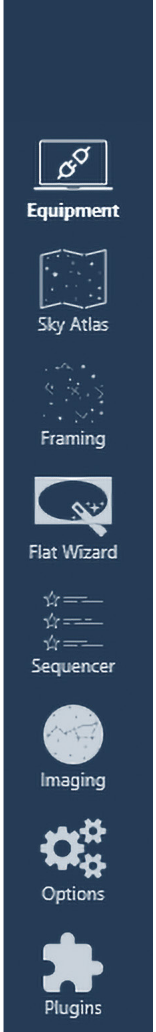
Before installing the program, it's important to update all your various equipment-control programs and device drivers — much of what *N.I.N.A.* does is manage your device-specific software. For example, I use *TheSkyX Imaging* to control my mount and *PHD2* to autoguide (**openphdguiding.org**). Each program must be working correctly on its own before it can interface properly with *N.I.N.A.* Make sure that you can manually execute any command you plan to have *N.I.N.A.* automate.

After installation, launch the program and start exploring to get familiar with its interface. The main menu is the vertical strip of icons (oddly called tabs in the program documentation) located along the left side of the screen.

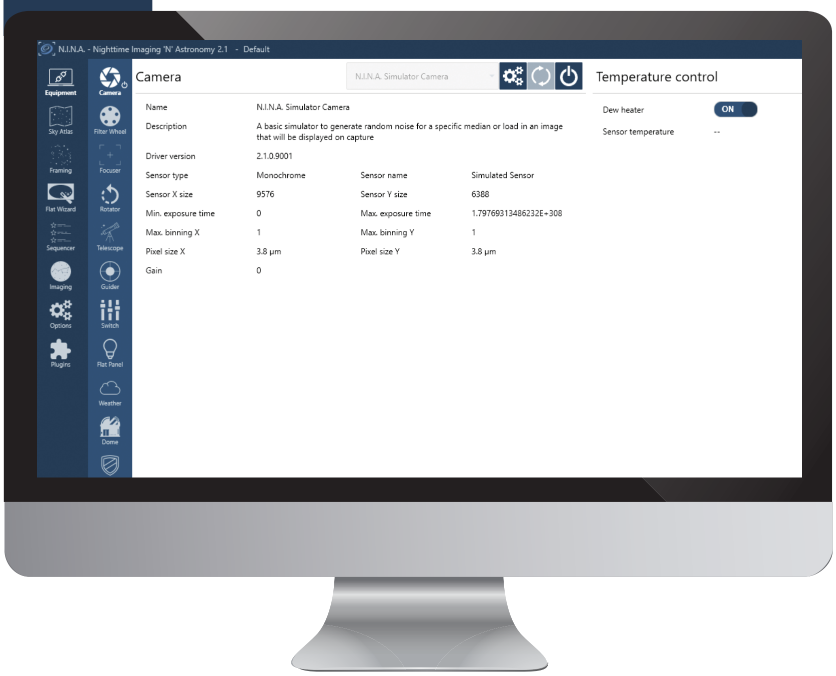
Let's start by selecting the ***Equipment*** tab at the top left of the main menu. When you select this tab, various components such as your camera and filter wheel appear in a second vertical strip on the left. Select and test your connection for each type of device, one by one. You'll only need to go through the procedure once for each component, though you may need to change some parameters if you swap out your imaging telescope, guidescope, or off-axis guider. After everything is configured, you can click the power button icon at the bottom of the menu to connect or disconnect all equipment and launch any other necessary software automatically.

After ensuring that each device communicates with *N.I.N.A.*, clicking the ***Options*** tab in the main menu reveals a new submenu for specifying options for a range of equipment and tasks. Select ***General*** to create your general profile. If you perform astrometry, you should enter your specific location details here. The Equipment tab is where you'll input your camera and telescope's particular characteristics and specify the other programs you want *N.I.N.A.* to utilize. For example, select a planetarium program from the pulldown menu.

Some programs require that you grant permission before *N.I.N.A.* can access it. One particularly important group of settings determines the file format and naming structure used when your images are saved. You'll find this in the upper left of the screen when you click the ***Imaging*** tab. Here, you can specify



▼ **CONTROL TO THE LEFT** *N.I.N.A.*'s main menu is a vertical strip of icons (called tabs) found along the left side of the application's main window. Clicking on the ***Equipment*** button opens a sub-menu that allows you to connect and configure your imaging equipment.



COMPUTER: IEPS / SHUTTERSTOCK.COM

whether files should be saved as TIFF, FIT, or *PixInsight*'s lossless-compression XISF format. The last tab in this submenu is ***Plate Solving***, where you'll select your preferred program to precisely point and frame your targets.

Creating a Sequence

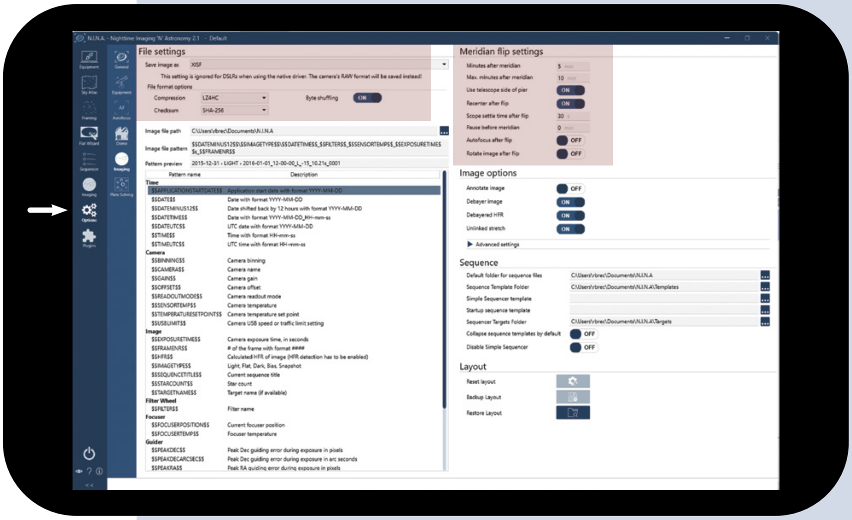
Once all your support programs are working and you have ensured that *N.I.N.A.* can communicate with your accessories, you can begin to build an imaging sequence — your orchestral score.

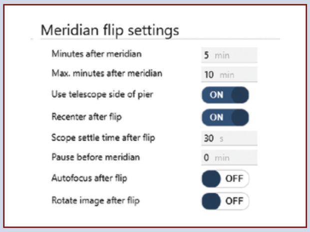
You most likely already have an established imaging routine, so this is where you'll transcribe that into instructions that *N.I.N.A.* will execute. Since your sequences won't change much from session to session, it's a good idea to make a template that you can easily modify to use with different targets. A basic sequence might contain these instructions:

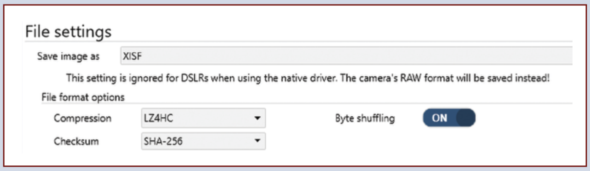
- At startup, cool the camera to -25°C slowly over a 30-minute period.
- Wait until nautical dusk, then unpark the mount.
- Slew to a star and focus.
- Slew to the imaging target and plate-solve to match the predetermined framing.
- Start autoguiding.
- Capture 300-second exposures through each filter. Loop until nautical dawn; autofocus periodically. Perform a meridian flip if needed.
- At dawn, stop autoguiding.
- Park the scope and warm camera (disable cooling).

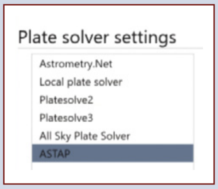
Most of these steps will be executed sequentially, while others are performed periodically, or conditionally. For example, the "Capture 300-second exposures" step is conditional (set to loop until dawn) and also includes additional instructions, called *triggers,* that perform periodic functions like refocusing every hour or executing a meridian flip if neccessary.

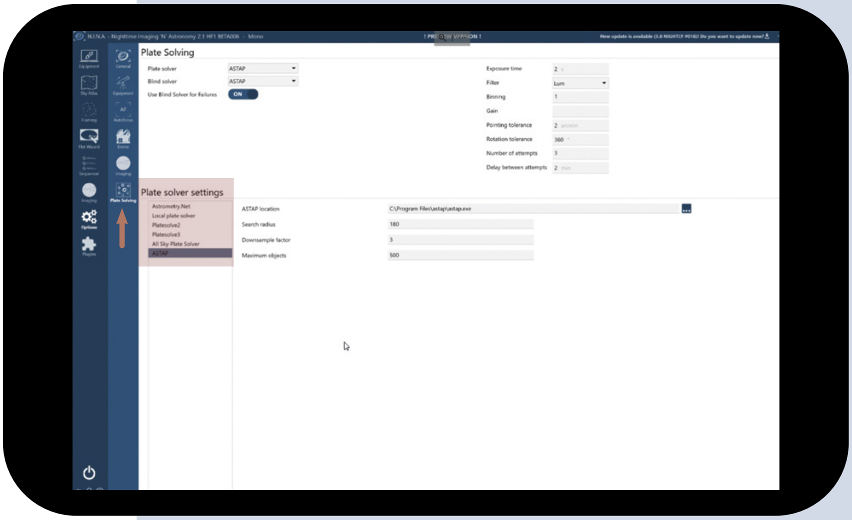
Translating your routine into a *N.I.N.A.* sequence is easy. Clicking on the ***Sequencer*** tab presents five options: Add new target, Load





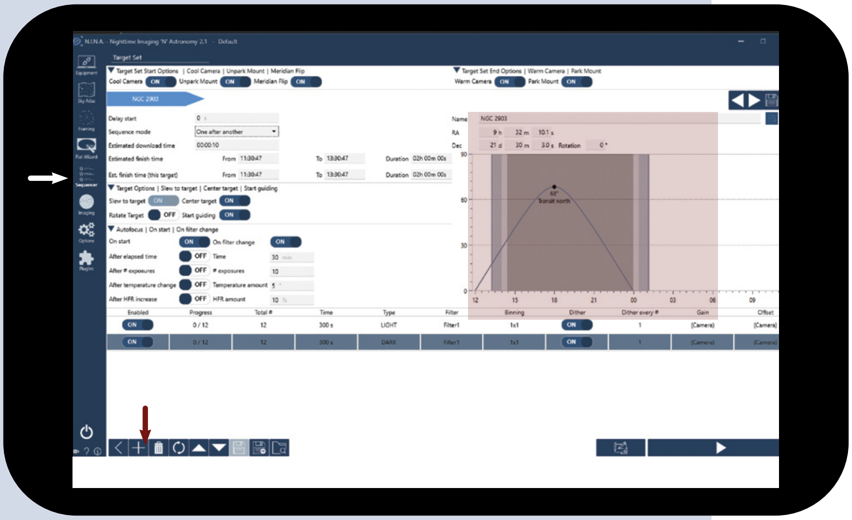


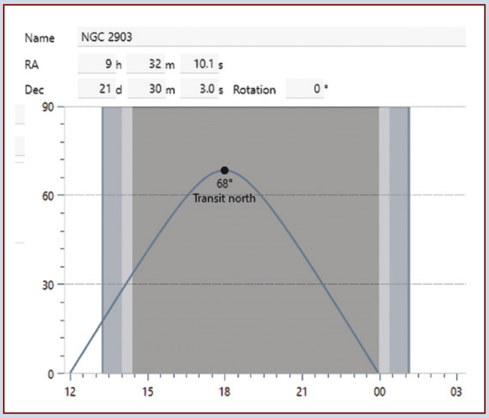


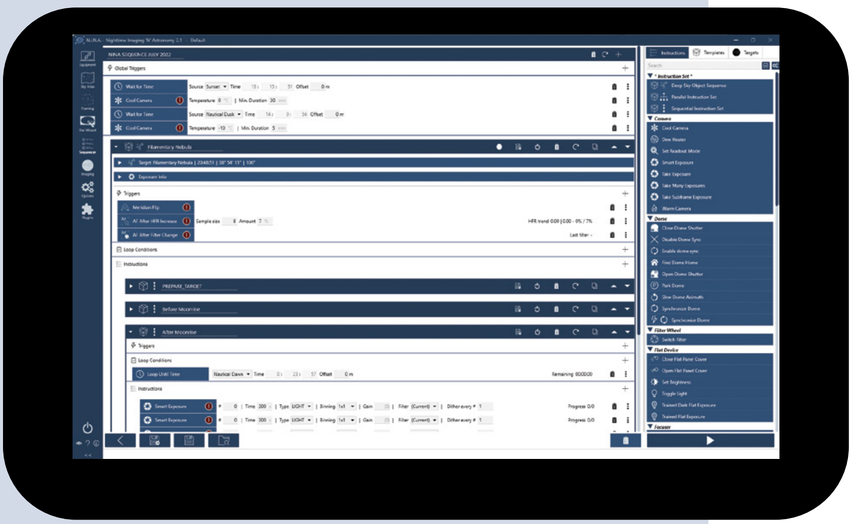


▶ **SET AND FORGET** *Top:* The *Options* tab is where you'll set the file format that your images will be saved in (TIF, FIT, or XISF) as well as some of the general actions required for photographing throughout the night, such as a meridian flip. You'll rarely have to revisit these settings unless you change major components of your equipment.

▶ **PRECISION POINTING AID** *Bottom:* Including a plate-solve action in your imaging run ensures that your target is right where you want it in the field of view and allows you to point at the same spot night after night. Set up this action by selecting one of the options at bottom left. If necessary, you can adjust the settings at upper right of the window.







target, Open target set, Import target, and Advanced Sequencer. Since this is your first use, click on ***Add new target*** to begin.

I like to think of sequences as like a sandwich. The groups of startup and shutdown steps are the bread, which will be the same on most nights, and imaging instructions is the meat, which will change the most.

Next, examine each setting in the Target Set Start Options section along the top of the window and adjust as needed. Now click the Save icon (the floppy disk at top right). You've just saved a template, which you can open and modify later by clicking ***Sequencer > Load Target***.

Continuing with this sequence, enter the name of your target in the appropriate line, then click the pushpin icon to the far right of the line to retrieve its coordinates from your planetarium program. Alternatively, you can use the ***Sky Atlas*** and ***Framing*** assistant tools in the main menu to help with this task. Click the Sky Atlas tab and enter the target's catalog number or common name, then click ***Search***. Each returned result is then listed along with information about how the object will move across the sky during your imaging session. If you decide to evaluate this target further, click the ***Set for framing assistant*** button.

For the Framing assistant to work, you'll first need to select an image source from the pulldown menu at top left in order to display an annotated picture of the object and its surroundings. Next, click ***Load Image*** and in a few moments the image will appear. Assuming you've input your camera information correctly, your target will appear in the middle of the image with your camera's field of view (FOV) overlaid. You can then click and drag the FOV outline with your mouse to better frame the object and rotate the FOV (provided you have a camera rotator connected or plan to manually rotate the camera to match the displayed framing).

Once you have your image composed to your liking, click on the downward arrow on the right side of the ***Add target to sequence*** button and select ***Legacy Sequencer***. Now click the ***Sequencer*** tab in the main menu to confirm that your chosen target is in the sequence. This is a great time to save the sequence with a new name.

◀ **KEEPING IT SIMPLE** *Top:* The ***Sequencer*** tab is where you set up the automation for most routine imaging sessions. A helpful graph shows the elevation of your chosen target throughout the night at top right. Each command required (for example, changing filters, or setting the number of exposures) is added by clicking the + button at bottom left. *Bottom:* The ***Advanced Sequencer*** provides additional flexibility and access to optional plugins.

Expand the ***Target Options*** and ***Autofocus*** areas of the sequence by clicking on the arrows on the left side of the window and adjust the settings. Next, input the imaging details — the exposure length, filter selection, and so on — adding as many rows of instructions as you need using the + button at the bottom left. These actions will be executed sequentially unless the Sequence mode is changed from "One after another" to "Loop." In that case, you'll need to specify how many times the sequence should repeat in the Total # line.

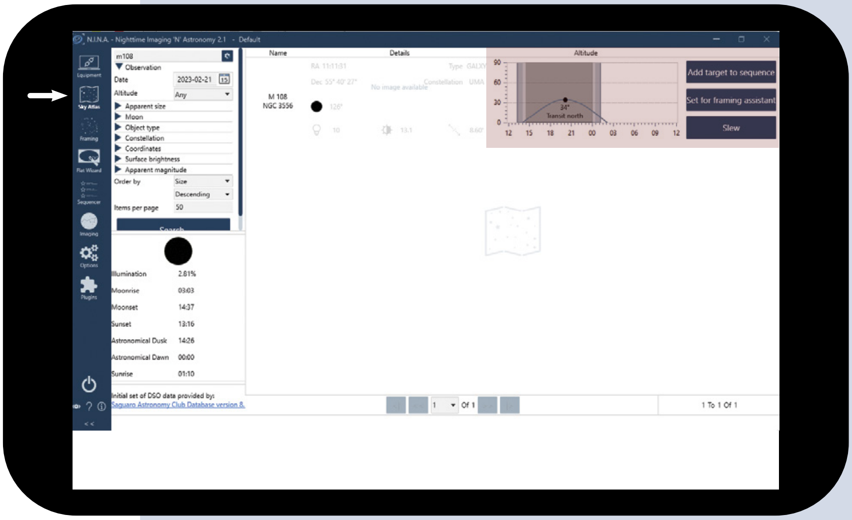
Now your first sequence is ready to run. Hit the ***Start Sequences*** button at the bottom right of the window, and your automated imaging session will begin. Don't get discouraged if it takes some time to get everything working reliably; mediocre nights are great for dialing everything in. You'll likely need to tweak some settings, particularly under the main menu's ***Options*** tab.

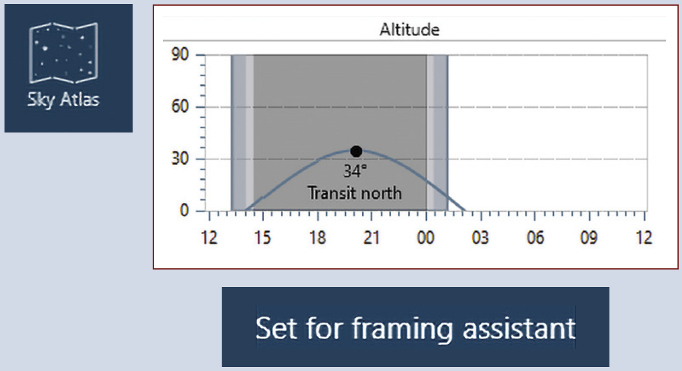
While your sequence is running, check out the ***Imaging*** section in the main menu. This section is fully customizable, though the default presentation is very well organized. It provides a snapshot of the entire night's sequence and lets you monitor everything from focus adjustments to guiding performance. It also inspects each frame and reports the size and number of stars detected. When you're ready to pack up for the night, press the square ***Stop sequences*** button in either of the Imaging or Sequencer sections.

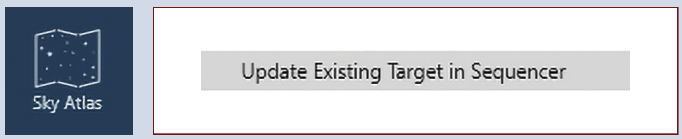
It's easy to write sequences that also record your flat-field-, dark-, and bias-calibration frames. If you're feeling a little more adventurous, try the ***Flat Wizard*** on the main menu. It enables you to generate flat-field images and their matching dark-calibration frames for one or more filters using a variety of methods, depending on your illumination source. You'll find the interface intuitive once you're familiar with the various features described above. You can also find extensive documentation for most of the Flat Wizard's settings as well as for all the software's other features at **https://is.gd/NINAdocs**.

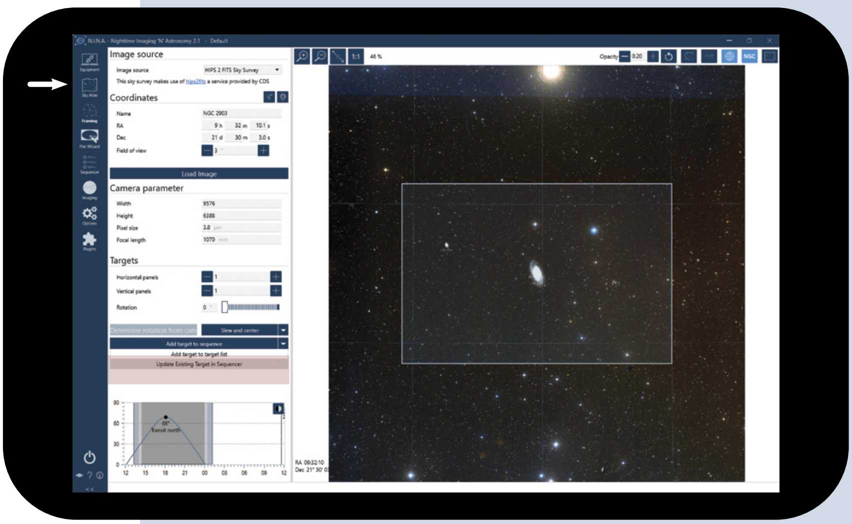
Room for Expansion

The puzzle-piece ***Plugins*** tab on the bottom of the main menu takes you to a menu where you can add modules to increase the software's capabilities. They are easy to install (click Install and restart the program), and each plugin's page describes its use. Plugins open up some interesting and useful options, and there are a few that I recommend for most users. Hocus Focus is an alternative to *N.I.N.A.*'s native focus routine that seems to





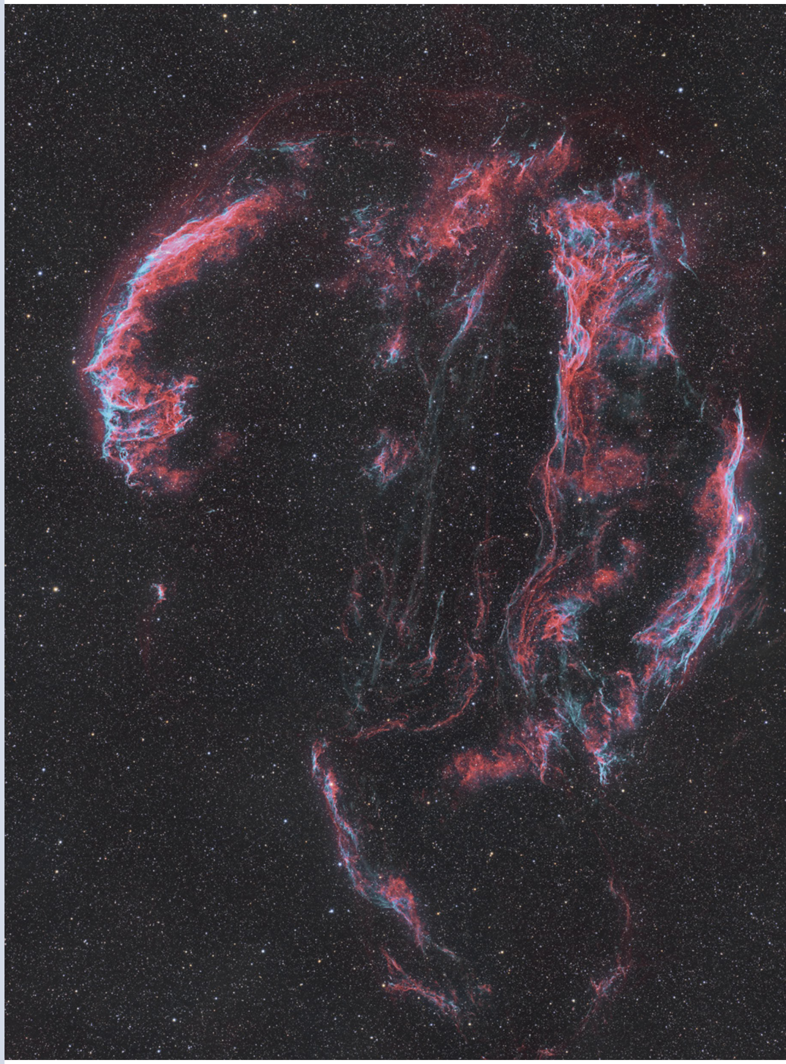




◀ **CHOOSING TARGETS** *Facing page, top:* Searching for an object by its official designation or common name in the ***Sky Atlas*** tab will show you whether it's currently well placed for imaging. When you're satisfied that your target is accessible, click ***Set for framing assistant*** to bring up a preview of the object.

◀ **COMPOSITIONAL CONSIDERATIONS** *Facing page, bottom:* The ***Framing assistant*** shows your camera's field of view plotted on an image of the sky centered on the object selected from the Sky Atlas. Use your mouse to move the frame until you're pleased with the composition. You can also rotate the frame to match the orientation of your camera. When you're ready, transfer your settings into the sequence using the ***Update Existing Target in Sequencer*** button.

▲ **CALIBRATION ASSIST** The *Flat Wizard* makes short work of acquiring flat-field-calibration frames (and their matching darks), whether you need flats for one filter or a series for each of your filters.



▲ **FINAL TWEAKS** *N.I.N.A.* orchestrated all the equipment used to record this colorful image of the Cygnus Loop over several nights while the author enjoyed visual observing.

VEIL NEBULA: RON BRECHER

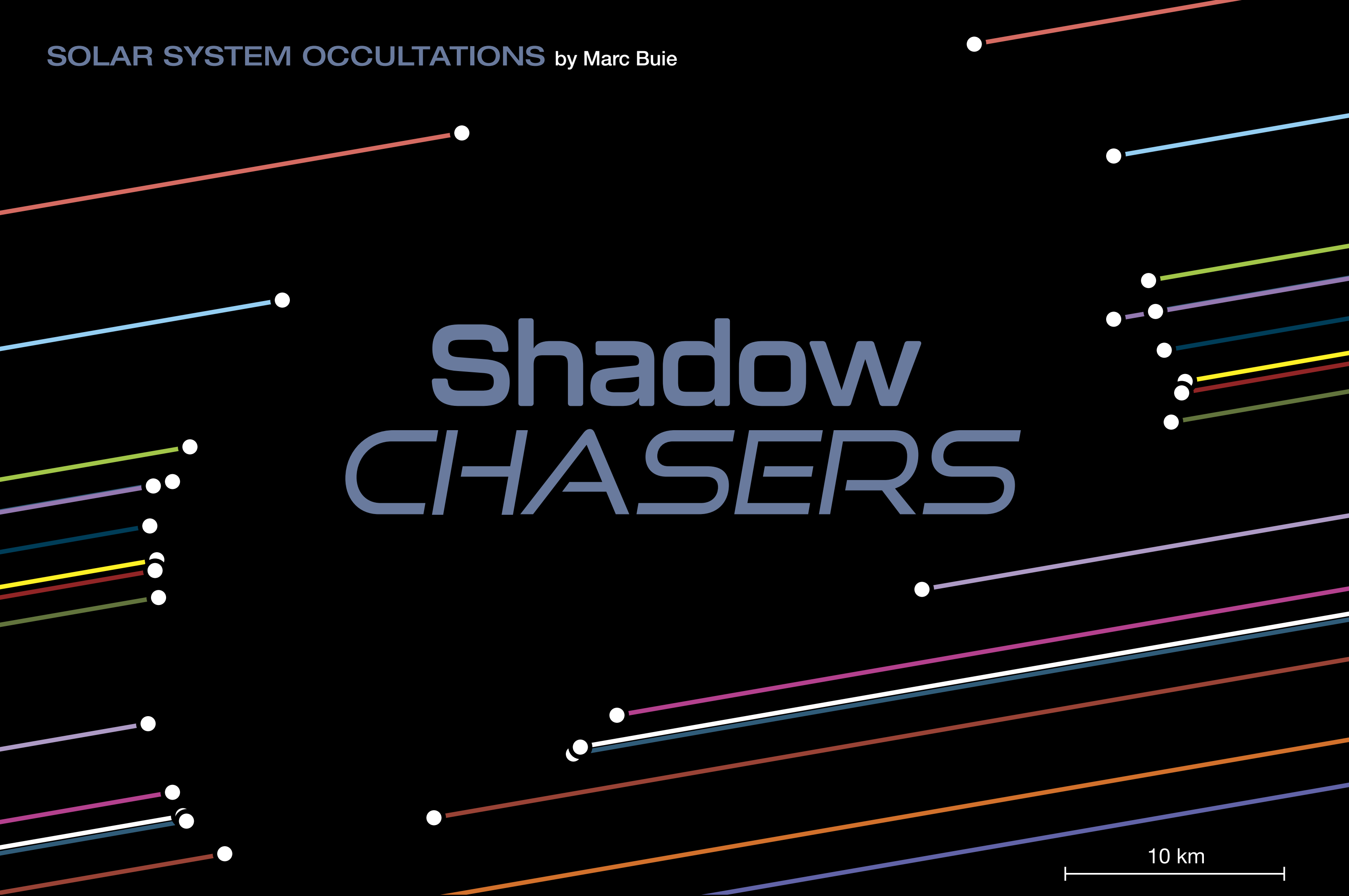
operate more quickly and can also help diagnose sensor tilt and other equipment problems. The Scope Control plugin displays your telescope's pointing position on the Imaging tab and moves the scope with a virtual control pad (which is helpful when adjusting the framing of a target).

After carefully evaluating several alternatives, I chose *N.I.N.A.* to automate my deep-sky imaging and have been very satisfied with its performance. Once you have the software in synch with your equipment, you'll find it easier to shoot the night sky than ever before, and you may even accumulate more data than you did when you had to personally monitor the gear. Best of all, you can then use your new free time for other pursuits like visual observing, socializing, or even catching up on sleep.

■ Contributing Editor **RON BRECHER** hosts *PixInsight* image-processing workshops at **mastersofpixinsight.com**, often while *N.I.N.A.* runs his observatory.

 by Marc Buie

Shadow CHASERS



Using backyard telescopes and teamwork, observers can discover details about small objects across the solar system.

Are you looking for something fun and useful to do with your telescope? Perhaps you should give occultations a try. Occultations are when one astronomical body passes in front of another, blocking the farther one from view. It's the same concept as a solar eclipse: Swap our Sun for a distant star and our Moon for an asteroid or other solar system body, and if you are at the right place at the right time, you will see the star briefly disappear from view. Watching a star blink out for a short time can be just as addicting as witnessing totality.

However, observing an occultation requires more effort. You almost always need binoculars or a small telescope, for example. And if you want to raise it from a fun activity to a scientific endeavor, you may need to join forces with others.

Decades ago, the number of successful occultation observations was no more than a handful per year. But the release of the amazing star catalog from the European Gaia mission has changed that (*S&T:* Feb. 2023, p. 34). Personally, I view the Gaia project as one of the most important space-based telescopes ever. Gaia has given us ultra-precise positions for all the stars that we'd ever use for occultations. We can now use its catalog to accurately predict when a tiny near-Earth asteroid or a far-out Kuiper Belt object — or anything in between — is going to pass in front of a star, and where on Earth we need to be in order to see it. Today, there's more than one successful observation per night, mostly by members of the International Occultation Timing Association (IOTA). The number that could be observed is far higher, though, if only more people were motivated and equipped to make these observations.

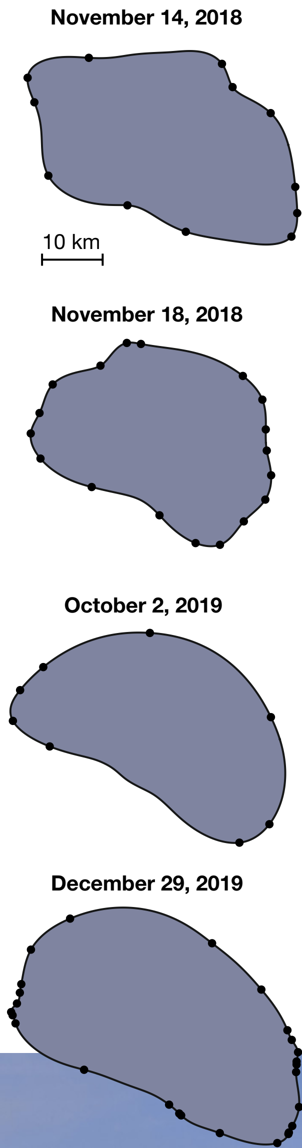
▲ **SILHOUETTE** Based on more than a dozen teams' observations (chords), this plot is a projection of the shadow the Trojan asteroid Leucus cast on Earth as it briefly blocked an 11th-magnitude star from view. Dots mark when each site saw the star disappear and reappear.

There's good reason to be motivated. The scientific opportunities occultations present are tremendous. With nothing more than a handful of wink-outs, carefully timed and combined, we can estimate the size and shape of small objects across the solar system, even out to 100 a.u. — three times farther than Neptune. These results not only support planetary exploration missions, they also give us access to far more bodies than we'll ever be able to visit with spacecraft.

Occultations 101

When you observe an occultation event, one of two things happens: Either you see the star blink out, or you don't. Both results are scientifically important. One tells you where the object is and something about its size, and the other tells you nothing is there — which may also tell you something about its size. The measurement you make is the time when the star disappears and the time when it reappears. Such a positive observation is referred to as a *chord*. Combine this information with the observing location and how quickly the object's shadow moved across your location, and you can place two points on the edge of the occulting body's outline.

A single chord can be useful, especially for an object's first recorded occultation, and you can observe it by yourself. Bagging a one-chord occultation observation has also become relatively easy. Indeed, such single-chord results dominate the record of detections in the past year.

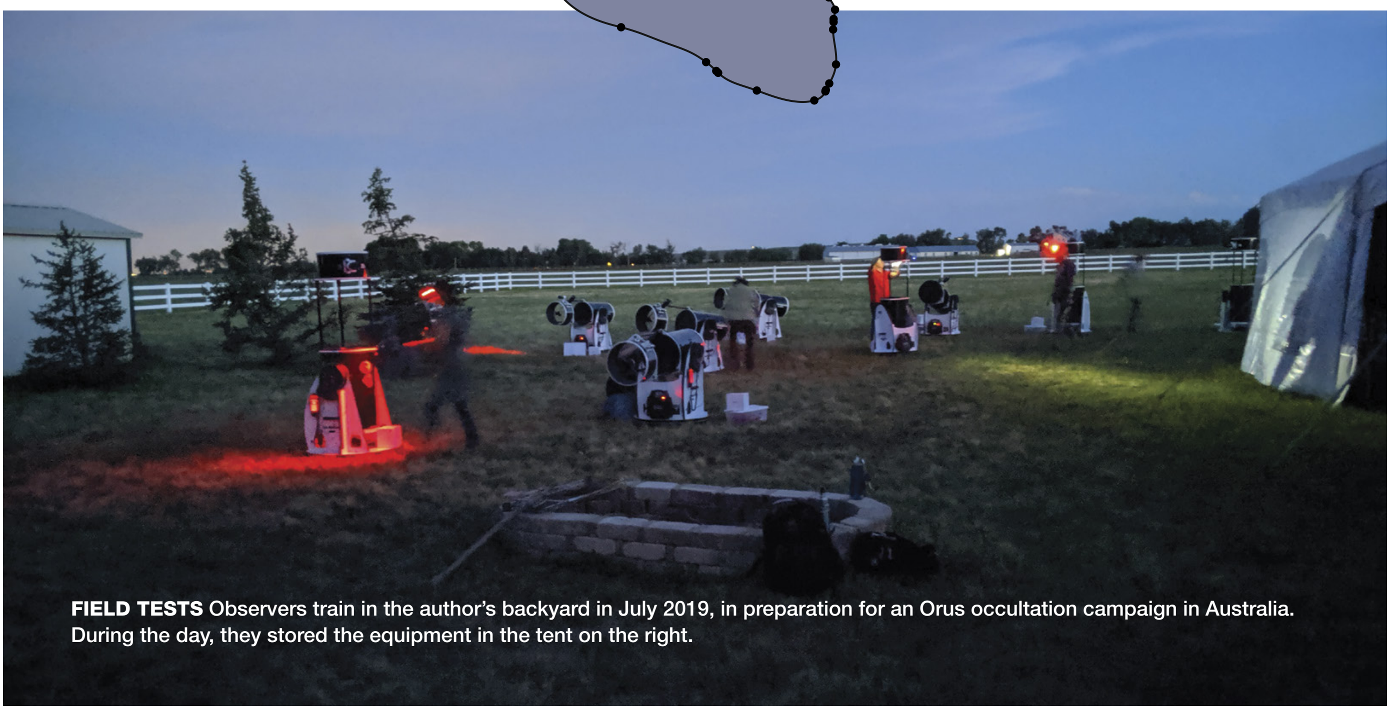


◀ **LEUCUS** A series of four occultation events caught the asteroid Leucus at different angles, giving us a sense of its 3D geometry. Dots mark where observers saw the background star blink out and in again.

However, if you want to know more about an object, you need multiple chords. Adding more observing stations in different locations along and across the occultation path increases the number of chords. By improving the spatial resolution, these stations can build up a detailed silhouette of the body and reveal its shape and nature.

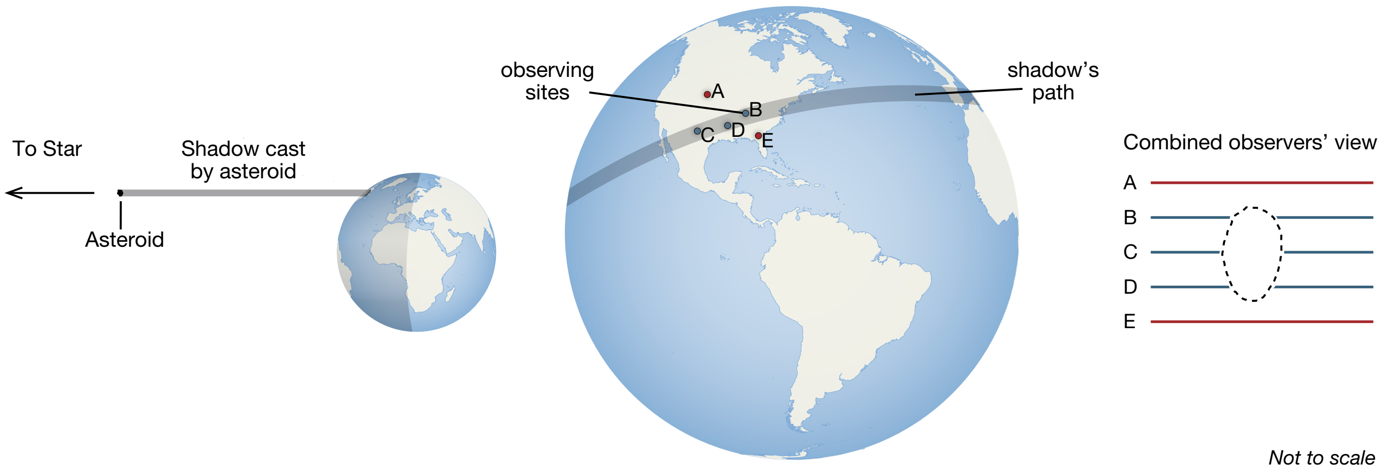
One of the earliest success stories supported by Gaia data was the 486958 Arrokoth occultation, seen in southern Argentina in 2017. Star positions from Gaia, combined with Hubble observations of Arrokoth, made it possible for us to obtain a multi-chord observation of this distant Kuiper Belt object prior to New Horizons' exciting flyby in 2019. The occultation clearly showed two circular objects stuck together — a flattened snowman shape confirmed by New Horizons when it zoomed past.

Another outcome of observing a multi-chord occultation is that you can measure the exact position of the asteroid on the sky by noting how close the center of the asteroid passes to the known position of the star. (You



FIELD TESTS Observers train in the author's backyard in July 2019, in preparation for an Orus occultation campaign in Australia. During the day, they stored the equipment in the tent on the right.

LEUCUS PROFILE: LEAH TISCIONE / S&T, SOURCE: THE AUTHOR; SERIES OF LEUCUS PROFILES AND OBSERVERS IN THE FIELD: THE AUTHOR (2)



▲ **HOW OCCULTATIONS WORK** When an asteroid passes in front of a distant star, it casts a shadow on Earth (*left*). This shadow moves across Earth's surface in a narrow path over time (*center*). Observers outside the path won't see anything (sites A and E), but those inside the path will see the star disappear and then reappear (sites B, C, D). Combining the observations, astronomers can determine the asteroid's outline (*right*).

BEATRIZ INGLESSIS / *S&T*, SOURCE: IOTA

can even do this using a single-chord observation, albeit with less precision.) I refer to this measurement as *occultation astrometry*, and it can reach a precision roughly 100 times better than the best ground-based telescopes and even 10 times better than the Hubble Space Telescope.

Better positions result in a more accurate orbit, improving future occultation predictions. Scientists can also use such improvements to help navigate a spacecraft to its target, as we did for the New Horizons flyby of Arrokoth. Occultation work directly enabled the highest-resolution picture of Arrokoth.

Team Effort

The most efficient way to obtain detailed shapes with occultations is to coordinate with other observers, and this is what I have been doing for the past five years. I pick a target for scientific exploration, define the goals of the experiment, pull together the equipment and observers, and lead a coordinated campaign. These large campaigns have mostly been supported from spacecraft mission budgets, first with New Horizons and now with the Lucy mission to Jupiter's Trojan asteroids (*S&T:* Feb. 2022, p. 12). Compared to the cost of a mission, occultations are an incredible bargain, but they still aren't cheap. The resources in time, money, and personnel required for a single campaign are twice as big as what a typical three-year research grant covers. Nevertheless, the results are worth it.

Every occultation campaign has its own unique personality, but there are some universal characteristics. It all starts with selecting an object and predicting which stars it will pass in front of. From this selection, we determine basic aspects of a campaign. The rough size of the object, combined with the uncertainty in the prediction of where its shadow will fall, dictates the spread over which we must deploy observers.

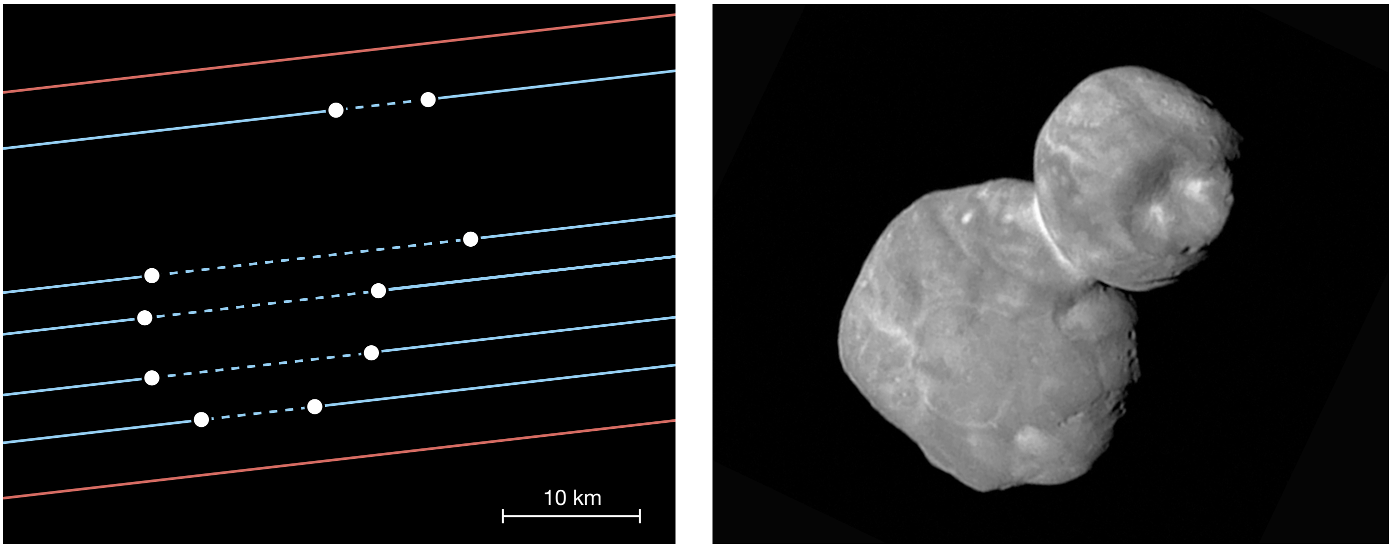
For instance, consider a 100-km object with an uncertainty of 200 km in the location of its shadow. To have a 99.7% chance of success — in astronomical parlance, *three sigma*, where sigma is a measurement of how close the observed value is to the predicted one — the team will need to spread out over 1,300 km. This wide swath covers not just the shadow's size but also three times the error range, both above and below the predicted centerline (in other words, 100 + 3×200×2 = 1,300).

The next factor is to decide the data resolution we want. If our goal is two chords, then the spacing between teams should be about 50 km. Putting these constraints together means we'd need 27 observing stations. Such a campaign would expect only two out of 27 stations to see the event.

While this result would be useful, it wouldn't really tell us much about the detailed shape of the object. After this initial success, however, the uncertainty in the location of the object's shadow drops by roughly a factor of 10. The spread of the stations for the second effort would thus drop to 220 km. The same team of 27 could then be spaced out by 8.5 km and expect 11 teams to see the occultation and retrieve a very nice shape for the object.

Once we know the guiding parameters for a campaign, we put out a call for observers. We reach out to past observers, but I also encourage new participants as well. My goal is to have about 20% of the teams be people that have never done this before. I provide all of the equipment needed for the observations; all that is needed from an observer is interest and the time commitment for the campaign itself.

My usual campaign pattern is a four-day event. The first day is when everyone meets the rest of the team, including their observing partners. Also included in the first day is basic training on setting up the telescopes and how to run the camera. The first night is a general observing session, with



▲ **ARROKOTH** Occultation data from a campaign on July 17, 2017 *(left)*, indicated Arrokoth has a bilobate shape — a result confirmed by this image *(right)* from the New Horizons spacecraft.

a goal of finding the target star sometime during the night. This first effort is done with everyone working in the same location so that my support team can circulate among the observers to provide help and additional training as needed. Each afternoon, we conduct additional briefings and resolve lingering problems.

The second night is a little harder. The team breaks up into smaller groups that work separately, requiring a bit more independence than the first night. The goal of this night is to take a short test data set on the target star, preferably at the same time of night as the actual event.

The third night is the dress rehearsal. Every team is now on its own, and the observers go to the site that they'll use on event night. They aim to take data in exactly the same manner as needed during the event.

By the fourth night, everyone is ready.

This four-night pattern has been extremely successful and quite resilient to observers' level of experience. Another consequence of the experience is the community we build together: Everyone finds satisfaction in the shared group experience and the overall outcome, not just in their own individual experiences. I feel very strongly that the team experience brings a deeper connection to all involved while at the same time maximizing the scientific value of the effort.

▲ **OBSERVER'S PARADISE** A look inside the equipment tent (seen on page 35) reveals the author's 23 largest telescopes ready to go.

OCCULTATION PROFILE: ADAPTED FROM M. W. BUIE ET AL. / *ASTRONOMICAL JOURNAL* 2020; ARROKOTH IMAGE: NASA / JHU APL / SWRI; EQUIPMENT TENT: THE AUTHOR

▲ **THE TEAM** The author's team in Oviedo, Spain, for a 2021 Polymele occultation.

Recent Results

NASA's Lucy mission to the Jovian system is a voyage meant to unlock the secrets of Jupiter's Trojan asteroids. To improve Lucy's observations, we're using occultations to conduct an initial reconnaissance of the mission targets. The five primary targets, Polymele, Leucus, Orus, Eurybates, and Patroclus, ranging from 20 to 120 km (12 to 75 miles) in diameter, represent a diverse sample for study. The sizes, shapes, and astrometry we collect will assist in the planning of the spacecraft flyby.

The most exciting results have come from Polymele, the smallest of the five. Due to its smaller size and fainter brightness, it is also the least observed of the targets. Photometry of Polymele shows a very slight variation in brightness as it rotates, which many assumed meant that the asteroid is nearly spherical. Our two first occultation results in 2021 and 2022, combined with a spherical assumption, disagreed with each other about the inferred size. For them to agree, the light curve would have to have a much larger amplitude.

The resolution to Polymele's contested size and shape came from our successful campaign in March 2022. For this campaign, I deployed 21 stations spaced 1.8 km apart along with 14 additional stations sprinkled in among the teams, all scattered along the shadow path from Kansas to North Carolina. Of these stations, 28 collected useful data. The resulting 12 chords revealed an elongated object twice as long as it is high. Guided by these new data, we now see that Polymele has a shape more like a flat disk, similar in size and aspect ratio to the larger lobe of Arrokoth.

Along with solving the mystery of Polymele's shape, we also snagged a big surprise. Two observers noticed a brief occultation in their data that couldn't have been Polymele. We quickly realized that we had seen an object in orbit around the asteroid: a Trojan moon. This event was definitely a lucky occurrence, and it makes Polymele the third of Lucy's targets to have a companion — Eurybates has a small moon, and Patroclus is a binary.

We have given the moon the informal name of Shaun (an homage to a sheep in the *Wallace and Gromit* universe). Based on the discovery observations, Shaun is about 5 to 6 km across compared to the dimension of 13 by 26 km for Polymele, and it orbits about 200 km away.

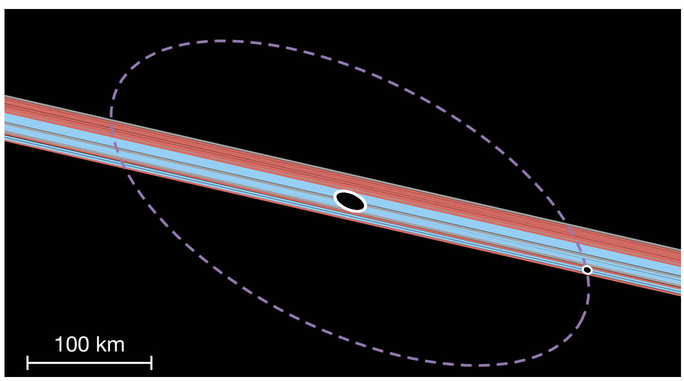
Since this discovery, we've focused our efforts on trying to find the moon again. To see Shaun, the observing stations must be spaced closer than the moon's size, otherwise it could slip between observers. For our February 2023 campaign, I chose to target a spacing of 2 km to give us a chance to obtain multiple chords, but more importantly to make sure that there was redundancy in the observations in order to minimize the chance of completely missing Shaun due to equipment failures. The spacing constraint required 100 stations to cover the 200 km zone of interest. I don't think there's ever been a case of a coordinated deployment of telescopes on a single object with this many stations.

We began preparations in the middle of November 2022, at a time when we were still busy coordinating campaigns in France involving Eurybates and Orus. The first step was to buy 29 new telescopes and all the accessories. That brought the total number of telescopes I could deploy up to 90. Half of these are 11-inch Celestron CPC 1100 Schmidt-Cassegrain telescopes, and the rest are Sky-Watcher's 8-inch 200P Dobsonians or 16-inch Flextube 400P Dobs. By adding additional IOTA observers, we reached a final tally of 95 telescopes in the U.S., while additional observers in Spain and Portugal added extra coverage on Polymele.

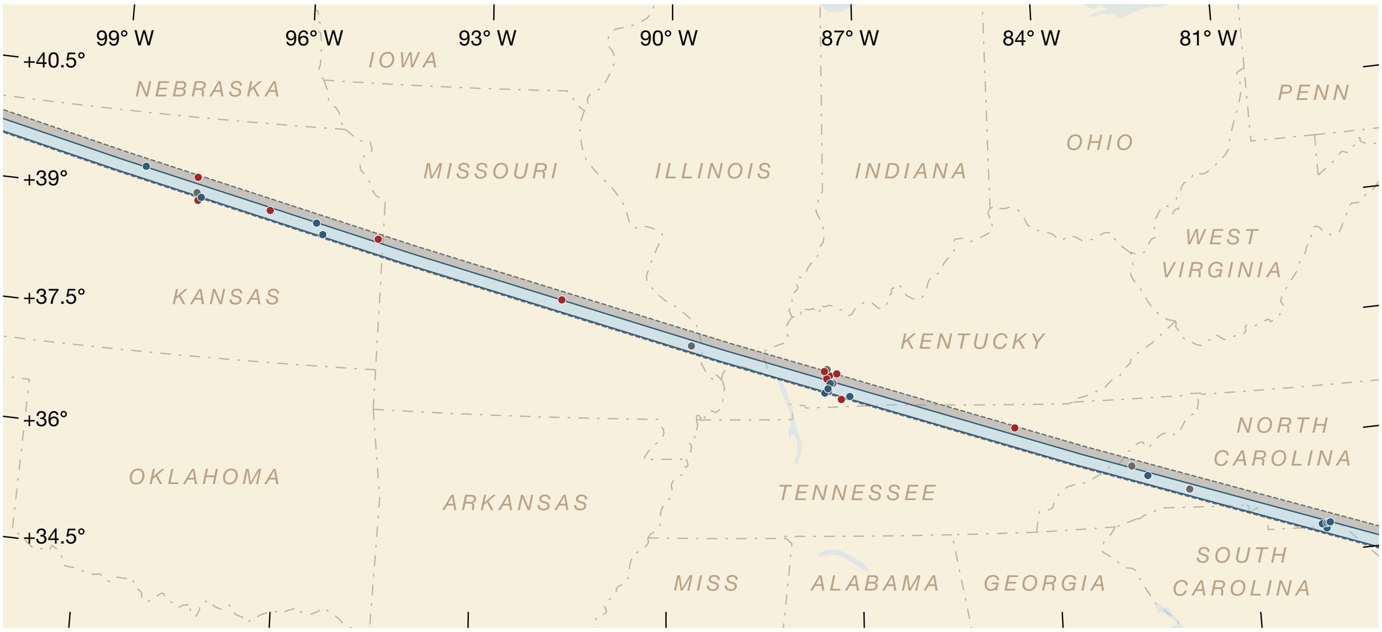
Nothing went smoothly. Supply-chain issues made it hard to obtain the equipment we needed in time. Also, in mid-January we only had about half of the observers we needed. We reached out again to universities where we had already been recruiting: University of Michigan; Northern Arizona University; University of Colorado, Boulder; University of Central Florida; and University of Virginia. One week before

▼▶ **SHAUN THE MOON** Observers tracking Polymele not only caught the asteroid itself but also a small moon, orbiting about 200 km from Polymele. The center and right panels show the asteroid and moon profiles in more detail, with possible outlines fit to the data. Blue chords are observers who detected an occultation, red are observers who didn't, and gray are unsuccessful attempts to collect data.

Polymele system



TEAM PHOTO: THE AUTHOR; POLYMELE PROFILE SERIES AND MAP: LEAH TISCIONE / S&T, SOURCE: THE AUTHOR



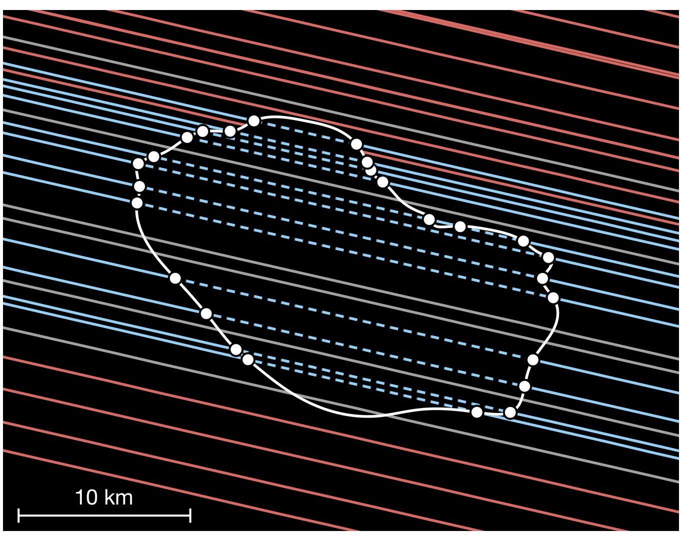
▲ **FINDING POLYMELE'S MOON** In March 2022, observers spread out along Polymele's predicted occultation path (gray) to try to catch the asteroid's shadow. Several observers were successful (blue dots). The actual path (blue) was slightly different than the predicted one.

the event, we had 200 observers signed up, but in that final week before the campaign about 50 dropped out, bringing us back down to dangerously low levels with no time left for additional recruiting.

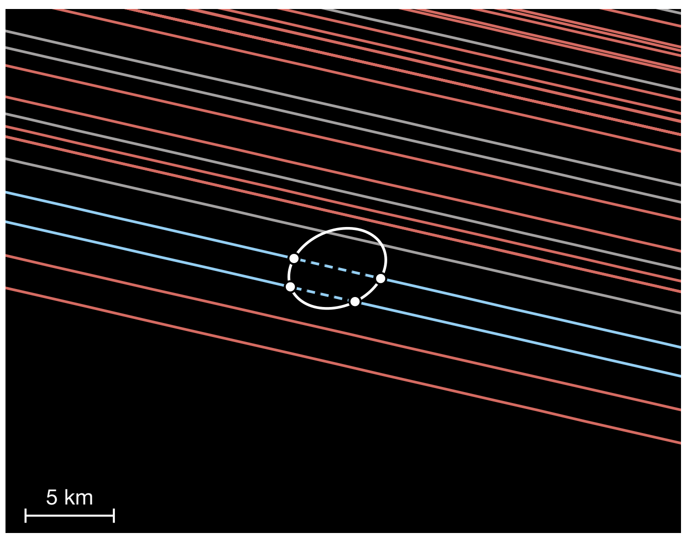
Deciding on an observing location was a big challenge. The occultation could be seen along a narrow band running from southwestern Kansas to just north of Detroit. Each section of the path had its own benefits, but the strategy had to be based on weather, not ease of deployment. In early February, anything can happen in this part of the country. Climate and recent weather statistics suggested we could expect worse weather the further east we went. On the other hand, the weather on any given night could wipe out any or even all of the relevant regions. Deciding too soon would risk everything. Weather forecasting these days is pretty good 48 to 72 hours ahead of time, and this set the decision timetable.

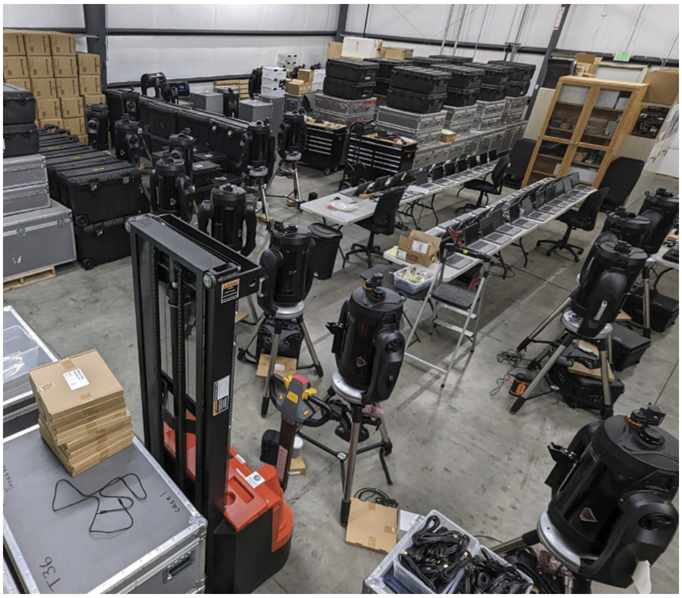
We spent our first two nights in Colorado. The first practice night was held in bitter cold on an icy parking lot with 90 telescopes. The night was a controlled sort of chaos, and everyone worked hard learning about their gear and then loading everything into their vehicles. The second night wasn't as cold but was still a significant challenge as everyone continued their learning and practice. By then, the weather forecasts were starting to become reliable and indicated the

Asteroid

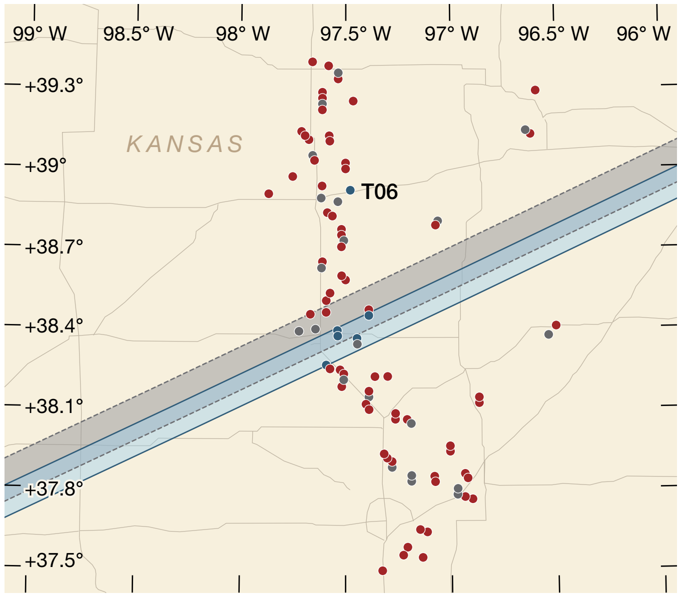


Shaun the Moon





▲ **UPGRADE** The author now has a warehouse for storing and prepping the nearly 100 telescopes deployed in campaigns. Much of the gear is boxed up in crates in this photo, but new stuff that's being set up and tested is unpacked.



▲ **TRACKING SHAUN** A campaign in February 2023 deployed dozens of observers to Kansas in an attempt to catch Polymele's moon again. (Each dot is an observing station.) A few observers saw Polymele (blue dots along path), and one lucky observer (call sign T06) caught Shaun.

western regions of interest (which were closest to us) would be seeing increasing clouds on event night. The closest area on the map that seemed to be safe at event time was near Salina, Kansas.

Thursday, February 2nd, was a travel day, with everyone making their way to Salina in time for the dress rehearsal. Equipment difficulties plagued us throughout the effort. Friday, February 3rd, was a scramble to solve these problems and decide where teams needed to go for their observations that night. Finally, night arrived, and the campaign was in the hands of the observers.

The weather held, and the deployment plan worked out perfectly. The prediction for where Polymele's shadow would fall was largely accurate, and observers in the U.S. and Europe succeeded in measuring another superb profile of the asteroid. Those in the shadow's path easily saw the occultation as it happened.

Back at the hotel afterward, we had a data-processing party for the observers. The question everyone was asking was, *Had we seen Shaun?* At the time everyone left for home, we still didn't know. Two days later, an observer reported seeing something interesting in their data. It was then a quick and easy task to confirm that we had indeed succeeded in detecting Shaun again.

There is still much work to do to complete the analysis and know what it tells us about Polymele and Shaun. Based on the deployment's design, there should have been three positive detections of Shaun. Unfortunately, the stations immediately to the north and south of the detection were unable to collect useful data. In this case, though, one was enough, especially when combined with other negative observations.

Getting Involved

This work is not without its challenges. On the organizing side, the cost of supporting such tightly coordinated efforts is high, putting this work mostly out of the reach of traditional research funding and forcing me to explore new ideas to break the current funding paradigm. For volunteers, learning how to use the equipment to find nondescript stars in the sky also takes effort and practice.

Nevertheless, I find people have overwhelming enthusiasm for this type of astronomical observation, and I work to provide these opportunities wherever and whenever I can. To date, we have directly involved more than 750 different people in the Lucy campaigns. This is truly one the best examples of citizen science I've seen. The task requires effort and commitment that is within reach of just about anyone, and at the end of the campaign, everyone shares in the joint success and the community built among participants. People go away hungry for more.

For the motivated, I recommend first learning how to observe occultations on your own by working with IOTA: **occultations.org**. This is a great way to gain experience prior to when these big campaigns come around, and observers around the world can participate. Those interested in joining future campaigns can also read more at **lucy.swri.edu/occultations.html**.

Maybe someday, I'll see you in the field.

■ Planetary scientist **MARC BUIE** (Lucy science team) has had a lifelong fascination with telescopes. His dedication to occultation research has lasted since first hearing about it in 1977. He leads the Lucy occultation-campaign program.

WAREHOUSE: THE AUTHOR; MAP: LEAH TISCIONE / *S&T*, SOURCE: THE AUTHOR

OBSERVING
September 2023

4 **EVENING:** The waning gibbous Moon rises in the east-northeast with Jupiter about 6° to its right. Turn to page 46 for more on this and other events listed here.

5 **EVENING:** The Moon, one day before last quarter, trails the Pleiades by less than 5° as they climb above the east-northeastern horizon.

10 **DAWN:** High in the east the waning crescent Moon hangs some 4° below Pollux. Castor completes the line of three lights.

11 **DAWN:** Face east to see the thin lunar crescent in Cancer around 3½° left of the Beehive Cluster (M44).

12 **DAWN:** The soft glow of the zodiacal light should be visible beginning some two hours before morning twilight at northern latitudes. Find a dark location with a view toward the east, and look for a faint, hazy pyramid of light tilted toward the right, stretching up through Cancer and Gemini into Taurus. You should be able to enjoy this sight for the next two weeks or so.

13 **DAWN:** The almost-new Moon and Leo's brightest star, Regulus, clear the eastern horizon in tandem with about 4½° separating them.

16 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:12 p.m. PDT (see page 50 for a table of Algol minima).

19 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:01 p.m. EDT.

20 **DUSK:** Look toward the southwest after sunset to see the waxing crescent Moon a bit more than 4° lower right of Antares as the pair sink toward the horizon.

23 **AUTUMN BEGINS** in the Northern Hemisphere at the equinox, 2:50 a.m. EDT.

26 **EVENING:** The waxing gibbous Moon gleams some 3° below Saturn. Face south-southeast to catch this sight.

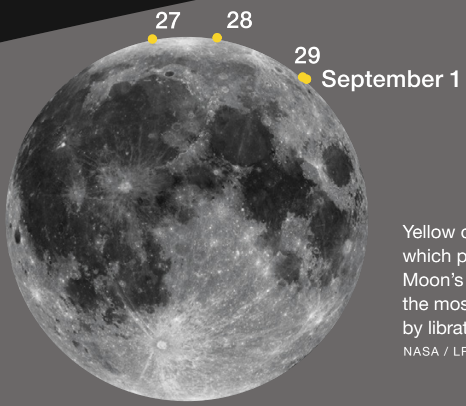
— DIANA HANNIKAINEN

◀ The Milky Way soars high in Hawaiian skies, showcasing the characteristic dark clouds and lanes that snake through multitudes of suns. The four stars that make up Herman's Cross shine between the palm fronds — see the Binocular Highlight column on page 43 for more on this asterism. JOHN JOHNSTON

SEPTEMBER 2023 OBSERVING

Lunar Almanac

Northern Hemisphere Sky Chart



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

MOON PHASES

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

LAST QUARTER
September 6
22:21 UT

NEW MOON
September 15
01:40 UT

FIRST QUARTER
September 22
19:32 UT

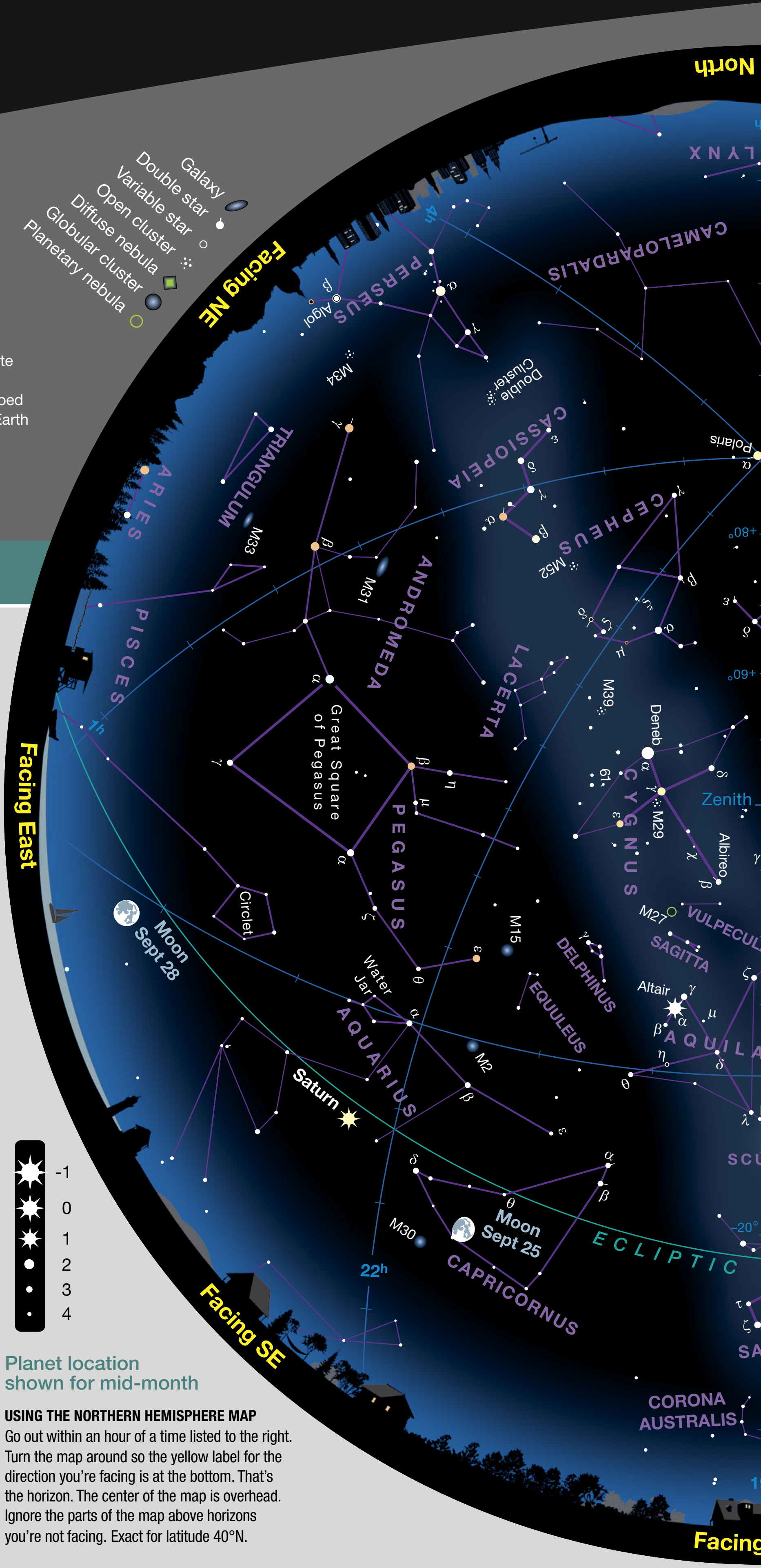
FULL MOON
September 29
09:58 UT

DISTANCES

Apogee	September 12, 16^h UT
406,290 km	Diameter 29′ 25″
Perigee	September 28, 01^h UT
359,913 km	Diameter 33′ 12″

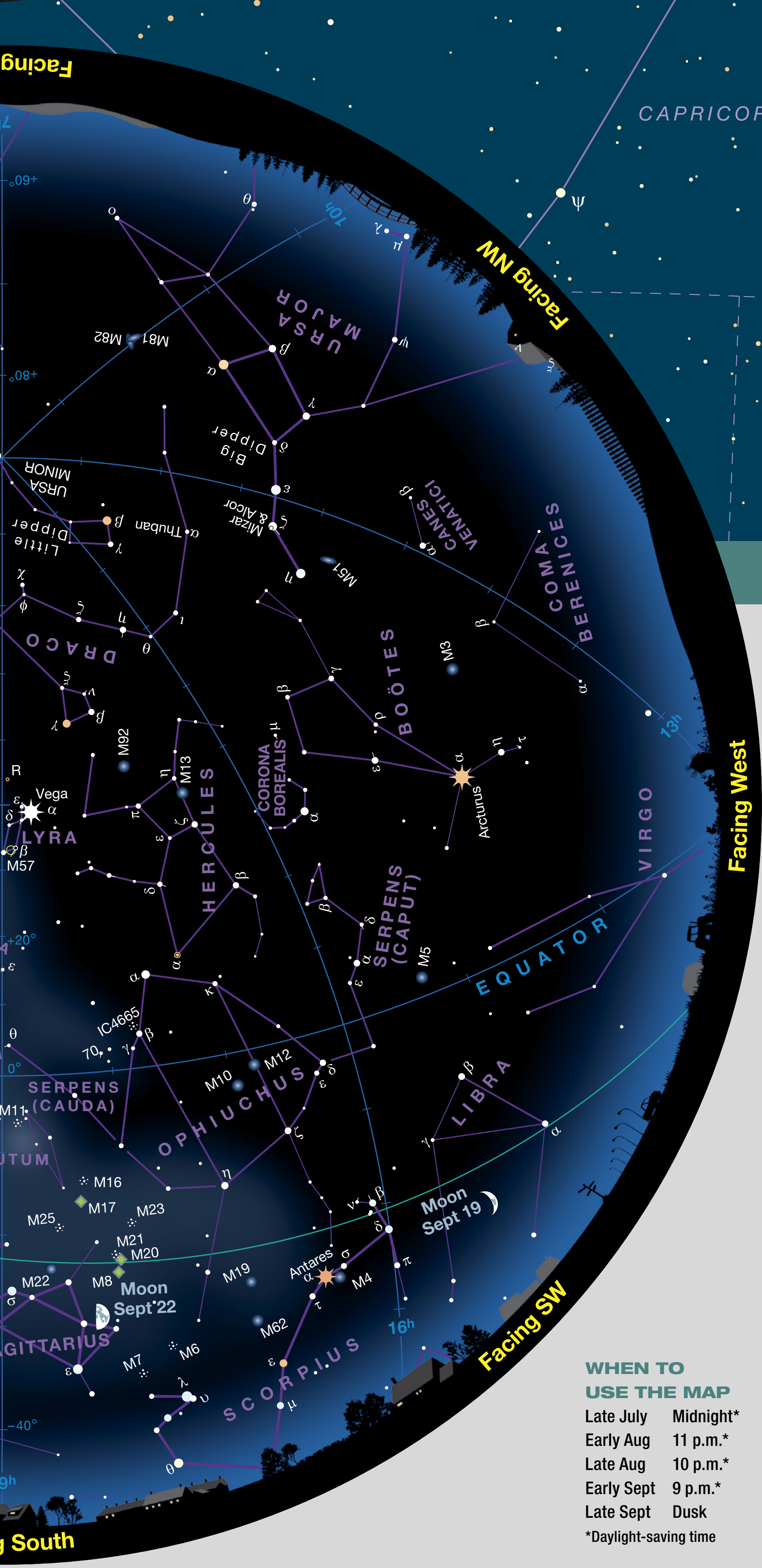
FAVORABLE LIBRATIONS

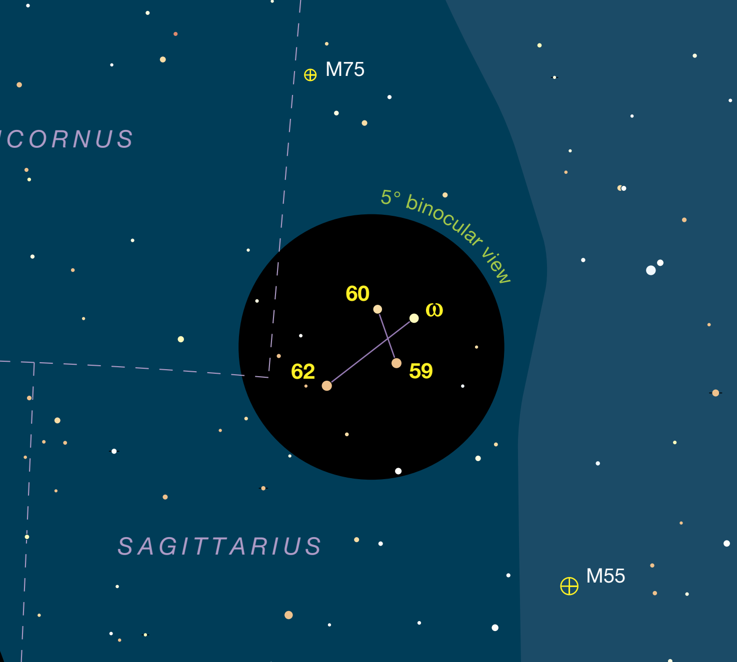
- Mercurius M Crater — September 1
- Poncelet Crater — September 27
- De Sitter Crater — September 28
- Mare Humboldtianum — September 29



Planet location shown for mid-month

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





WHEN TO USE THE MAP

Late July	Midnight*
Early Aug	11 p.m.*
Late Aug	10 p.m.*
Early Sept	9 p.m.*
Late Sept	Dusk

*Daylight-saving time

Binocular Highlight by Mathew Wedel

Hooray for Herman's Cross

Near the eastern border of Sagittarius, the Archer, you'll find a neat little cross asterism formed by four 5th-magnitude stars: **59**, **60**, **62**, and **Omega (ω) Sagittarii**. At 2° tall and 1° wide, the asterism is big enough to be spotted with the naked eye, and it makes a fun binocular target. Look for it about halfway between the 4th-magnitude star Psi (ψ) Capricorni and the Teapot of Sagittarius.

Ready for a quick trip down memory lane? In the Chinese constellations, this group of four stars is known as Gŏu Guó, or Dog Territory. The Alexandrian astronomer Ptolemy recorded it as the "Tetrapleuron," which means quadrilateral. In his 1603 *Uranometria*, Johann Bayer Latinized the Greek "Tetrapleuron" to "Terebellum," and in 1801 Johann Bode included the Terebellum in his *Uranographia* atlas. Sometime thereafter astronomers stopped labeling it, at least in European and American star atlases.

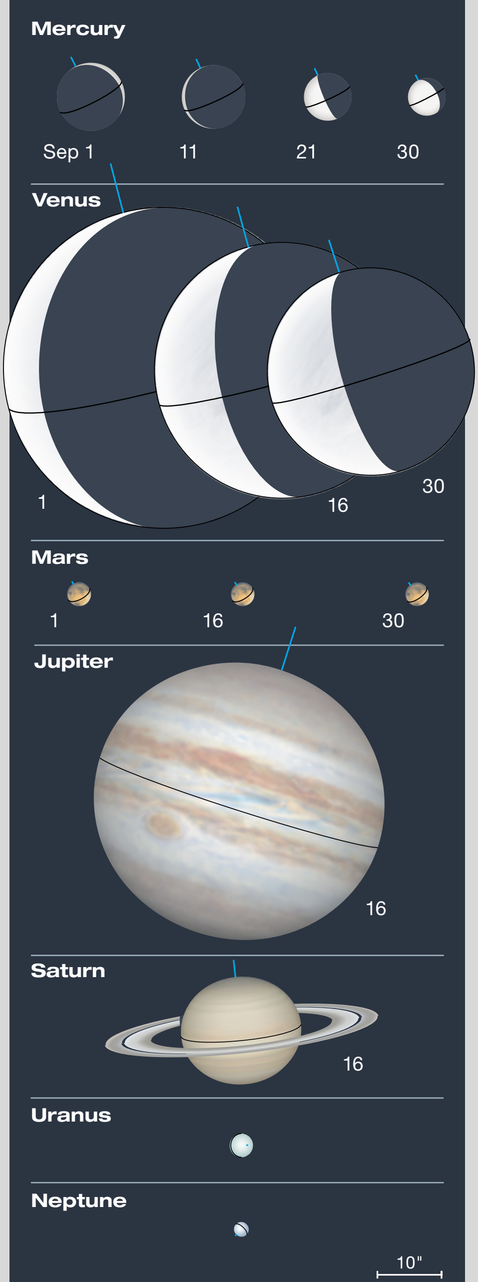
American amateur astronomer Herman Heyn stumbled across the quartet in 1986. He couldn't find it plotted in any modern atlases, so in 2006 he christened it "Herman's Cross." We can't go back to calling it the Terebellum, because in 2017 the International Astronomical Union formalized the name Terebellum for Omega Sagittarii alone. So, Herman's Cross it is.

I love this story. It exemplifies what astronomy has always been: a very human enterprise, in which we discover things in the sky and share them. Some things get discovered repeatedly, and that's okay; the thread is unbroken because new generations keep adding to it. Herman Heyn passed away in 2021 after a long life of sharing the stars. Let's go observe this little set of stars his honor.

■ **MATT WEDEL** just loves it that people can be brought together by things as distant as the stars.

SEPTEMBER 2023 OBSERVING

Planetary Almanac



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

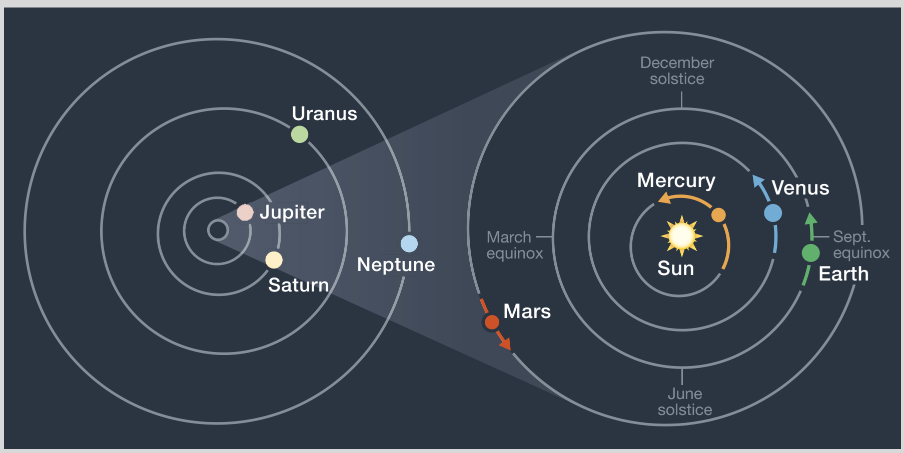
▶ **ORBITS OF THE PLANETS** The curved arrows show each planet's movement during September. The outer planets don't change position enough in a month to notice at this scale.

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dawn starting on the 15th • **Venus** visible at dawn all month • **Mars** is lost in the Sun's glare this month • **Jupiter** rises in the evening and is visible until sunrise • **Saturn** transits in late evening and sets at dawn.

September Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	10^h 38.6^m	+8° 34′	—	–26.8	31′ 41″	—	1.009
	30	12^h 23.0^m	–2° 29′	—	–26.8	31′ 56″	—	1.002
Mercury	1	11^h 09.9^m	+0° 30′	11° Ev	+3.3	10.6″	6%	0.633
	11	10^h 40.1^m	+5° 42′	9° Mo	+3.4	9.9″	5%	0.679
	21	10^h 45.9^m	+8° 22′	18° Mo	–0.3	7.4″	42%	0.904
	30	11^h 30.4^m	+5° 09′	15° Mo	–1.0	5.8″	79%	1.149
Venus	1	8^h 49.8^m	+10° 04′	27° Mo	–4.6	49.9″	11%	0.334
	11	8^h 54.1^m	+11° 11′	35° Mo	–4.7	43.0″	20%	0.388
	21	9^h 11.6^m	+11° 31′	41° Mo	–4.8	36.9″	29%	0.452
	30	9^h 35.4^m	+11° 03′	44° Mo	–4.7	32.3″	36%	0.516
Mars	1	12^h 10.3^m	–0° 25′	25° Ev	+1.8	3.8″	98%	2.487
	16	12^h 45.9^m	–4° 23′	20° Ev	+1.7	3.7″	99%	2.521
	30	13^h 20.1^m	–8° 03′	15° Ev	+1.7	3.7″	99%	2.541
Jupiter	1	2^h 52.7^m	+15° 08′	113° Mo	–2.6	43.9″	99%	4.487
	30	2^h 48.6^m	+14° 46′	142° Mo	–2.8	47.6″	100%	4.141
Saturn	1	22^h 23.0^m	–12° 01′	175° Ev	+0.4	19.0″	100%	8.766
	30	22^h 15.5^m	–12° 43′	145° Ev	+0.6	18.6″	100%	8.927
Uranus	16	3^h 21.2^m	+18° 07′	120° Mo	+5.7	3.7″	100%	19.109
Neptune	16	23^h 47.5^m	–2° 45′	176° Mo	+7.8	2.4″	100%	28.903

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**.



Little Gem Delphinus

The starry Dolphin frolics in the shallows of the Summer Milky Way.

▲ **LEAPING DOLPHIN** The little constellation of Delphinus lies just east of the bright swath of Milky Way running through Aquila, north into Cygnus. During September, the entire region is well placed for early-evening viewing. (North is to the upper-left in this photo.)

ALAN DYER

The famous Summer Triangle formed by Vega, Altair, and Deneb is at its early-evening highest as summer ends. Impressive as that big, bright asterism is, I often find myself drawn to a pair of small constellations that accompany the Triangle across the sky: Delphinus, the Dolphin, and Sagitta, the Arrow. This time out, let's give the Dolphin its due.

Although Delphinus can be difficult to see in light-polluted conditions, this little gem of a constellation really stands out in a clear, dark country sky. And "gem" is an especially good descriptor for Delphinus — its four main stars are arranged in an elongated diamond shape. The quartet of Alpha (α), Beta (β), Gamma (γ), and Delta (δ) serves as the Dolphin's body, while an extension formed by Epsilon (ε) provides the tail. These five stars shine at magnitudes 3.8, 3.6, 4.4, 4.4, and 4.0, respectively. You'll note that less than a full magnitude separates the brightest from the faintest — something that, in my view, adds to the constellation's charm.

Delphinus includes five additional stars bearing Greek letters, but they don't attract much attention because they're relatively faint and aren't part of the main Dolphin pattern. The quintet of "bonus" stars are, Zeta (ζ), Eta (η), Theta (θ), Iota (ι), and Kappa (κ). Brightest of the bunch is 4.6-magnitude Zeta, and 5.7-magnitude Theta is faintest.

But which of Delphinus's stars stands out as the most interesting? My pick is Gamma Delphini, the Dolphin's northeast-pointing nose. However, you need a telescope to see why: Gamma is a beautiful double whose components at magnitudes 4.4 and 5.0 are 8.9″ apart.

In addition to "gem," the other adjective I used for Delphinus was "small." Of the 88 officially recognized constellations, Delphinus ranks 69th in terms of area. But even that placement slightly flatters our aquatic friend — from nose to tail it spans less than 6°. Thankfully, the Dolphin is bracketed by the even smaller figure of Sagitta and the tiny (ranking #87!) and indistinct constellation of Equuleus, the Little Horse.

Under good sky conditions, Delphinus appears to be leaping out of the dark waters east of the bright summer Milky Way. The image of a frolicking dolphin calls to mind the Greek myth most commonly connected with Delphinus. In this ancient story, the great poet and musician Arion was returning on a ship from a musical competition with a small fortune in winnings, which the crew plotted to get their greedy hands on. As the sailors approached him menacingly, Arion pleaded to play one last song. While his music enchanted nearby dolphins, it didn't move the evil hearts of the crew, and Arion threw himself into the sea to escape their murderous clutches. The thieves sailed onward to Arion's home city, where they claimed the musician had fallen overboard and drowned in a tragic accident. What they didn't realize was that one of the dolphins listening to Arion's music had rescued him and delivered him home ahead of the thieves. It's fun to imagine the looks of shock on their faces when they saw Arion alive and well just before they were carried off to face their just punishment.

Only Alpha and Beta Delphini have proper names. However — as moving as the story of Arion and the dolphin is — their names didn't originate in myth or legend. Sualocin (Alpha) and Rotanev (Beta) first started appearing in 19th-century star atlases, but scholars initially couldn't figure out their meaning or derivation. It turns out that the astronomer Giuseppe Piazzi had mischievously created them by reversing the letters of his assistant's first and last name: Niccolò Cacciatore. In English this translates to Nicholas Hunter, which in Latin is Nicolaus Venator — hence Sualocin and Rotanev.

■ **FRED SCHAAF**'s favorite view of Delphinus came in 1976 when Comet West visited the constellation.

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

A Busy Month for the Moon

A quartet of planets adorns the sky from dusk to dawn.

MONDAY, SEPTEMBER 4

This evening before bed, step outside and look toward the east-northeast to see **Jupiter** and the waning gibbous **Moon** rising together, separated by less than 7°. They aren't especially close, but anytime these two get together, it's sure to be eye-catching. And Jupiter is bright. Only Venus outclasses the gas giant, which shines at magnitude –2.6. For the first time this apparition, Jupiter crosses the *meridian* (the imaginary line that connects due north to due south and passes directly overhead) before the start of morning twilight. For many, that milestone signifies the start of the prime Jupiter-observing season.

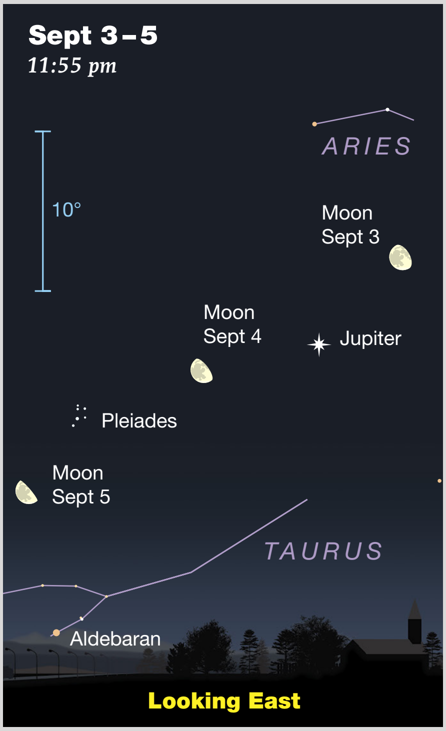
As the pair climb higher and the evening of the 4th transitions into the morning of the 5th, the Moon drifts farther away from the planet. However, look roughly 7° to the left of the Moon for the **Pleiades**, in Taurus. The cluster, the Moon, and Jupiter form a tidy, equally spaced three-in-a-row configuration. The sight isn't quite as arresting as it sounds, however, because the stars of the Pleiades struggle to be seen next to the bright Moon.

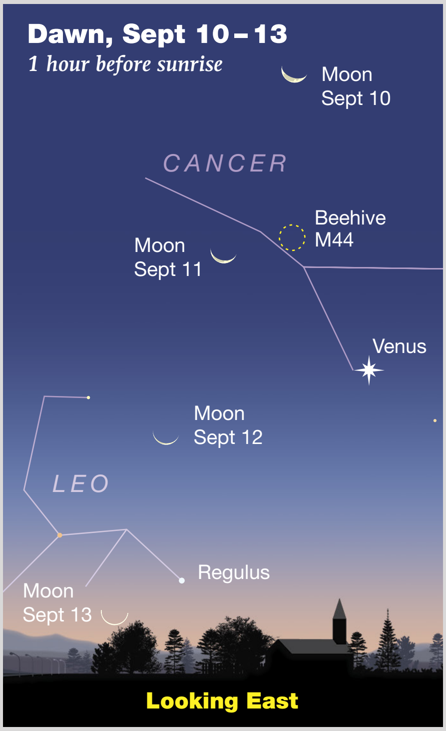
MONDAY, SEPTEMBER 11

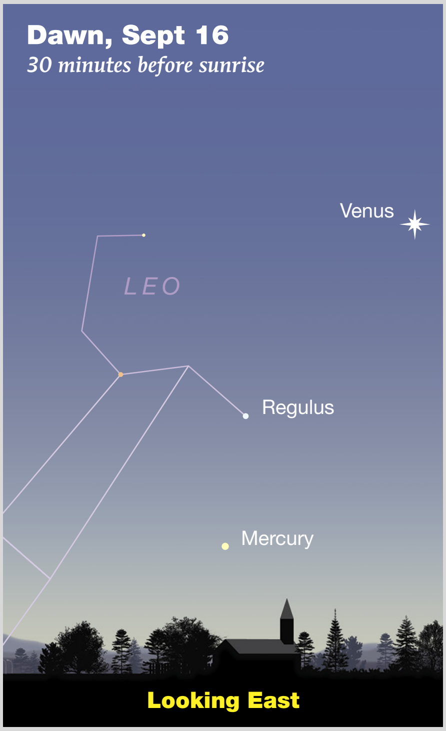
Early risers get a good show at dawn today when a thin crescent **Moon** pairs up with the **Beehive Cluster** (M44) in Cancer. The Beehive is a fine binocular object, but as a naked-eye sight it's a poor second to the Pleiades. That's why the best Beehive-Moon pairings occur when the Moon is a slender crescent, and its light doesn't completely overwhelm the bees in the hive.

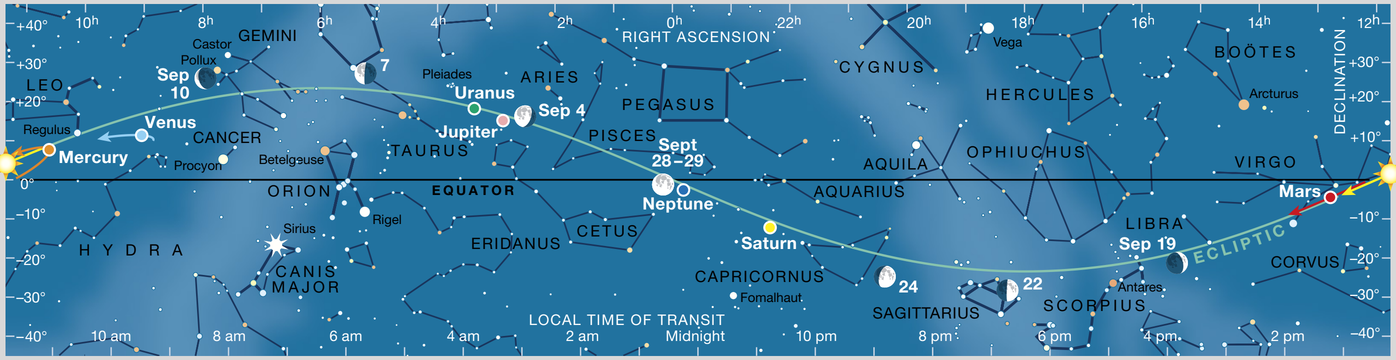
On this particular morning, it's 12% illuminated as it rises about 3½° left of M44. However, you'll likely find your attention diverted by the presence of brilliant **Venus**, some 11° below right of the Moon. The Morning Star gleams at magnitude –4.7 and pops up above

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









▲ The Sun and planets are positioned for mid-September; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit" tells when (in Local Mean Time) objects cross the meridian — that is, when they appear due south and at their highest — at mid-month. Transits occur an hour later on the 1st and an hour earlier at month's end.

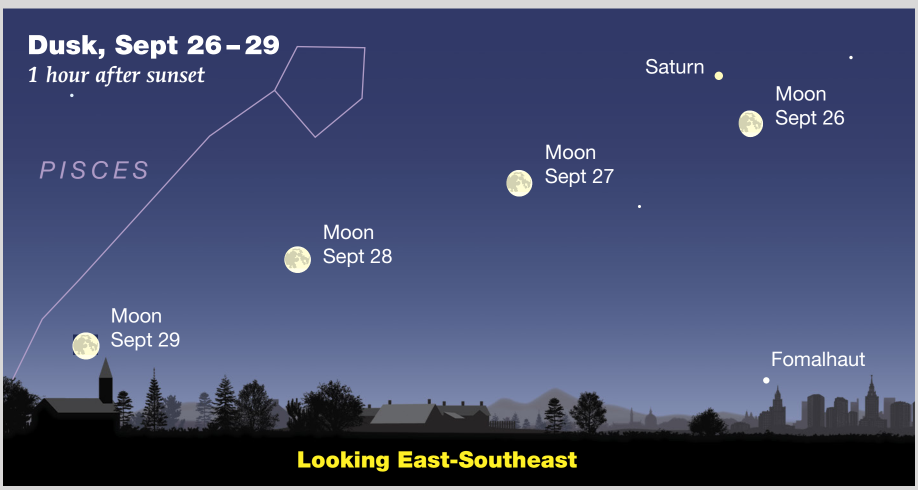
the east-northeastern horizon around 4 a.m. local daylight time — less than an hour after the Moon. In addition to the lunar crescent and Venus, the morning sky from the eastern horizon to the zenith is peppered with a multitude of bright winter stars and **Jupiter**. It's quite a scene and one well worth getting up for even without the Beehive-Moon pairing.

WEDNESDAY, SEPTEMBER 20

The best stellar encounter for the **Moon** this month occurs this evening when it sits a little less than 4½° right of **Antares**, in Scorpius. The two have been meeting regularly since January, sometimes getting closer than at other times. Indeed, in August the Moon occulted the star as seen from much of the U.S., Canada, and northern Mexico. The 2023 series of encounters concludes next month, but that event occurs nearer to the horizon and in twilight — so don't miss out on tonight's conjunction since the next good one will be at dawn in January (but that will be a *very* good one). If you miss tonight's meet-up, you have another (less impressive) shot tomorrow night as the waxing crescent will be positioned 8½° to the star's left.

WEDNESDAY, SEPTEMBER 22

Mercury-watchers will want to set an early alarm this morning to catch the fast-moving little planet's best dawn appearance of the year. This particular date marks Mercury's greatest elongation from the Sun, which suggests that this is the best time to view the planet during its current apparition. And it is. Half an hour before sunrise, the –0.5-magnitude speck is 10.5° above the east-southeastern horizon. But it's not always the case that the timing lines up quite so neatly. As it happens, at the equinox (which occurs on the 23rd), the angle the ecliptic makes to the horizon at dawn is very steep as seen from mid-northern latitudes. At other times of the year, however, the angle is much shallower, resulting in a difference of several days between the date of greatest elongation and when Mercury actually appears highest.



TUESDAY, SEPTEMBER 26

The final planet to receive a visit from the **Moon** this month is **Saturn**, now one month past opposition and hovering above the southeastern horizon as darkness falls. The Ringed Planet's lunar companion hangs just 3½° below right during the early evening, and the gap between them closes to a bit less than 3° later on. Although the Moon is a 92%-illuminated waxing gibbous, Saturn is bright enough (magnitude +0.5) to hold its own. Indeed, the nearest, similarly bright point of light is the 1.2-magnitude star **Fomalhaut**, lying nearly 20° south of the planet in the faint constellation Piscis Austrinus. Saturn itself dominates the big-but-dim zodiacal figure of Aquarius — something it will continue to do (with or without the Moon's help) until the second half of April 2025.

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

Hyperactive Comet Hartley

An icy visitor pays a return visit this month to delight telescope users.

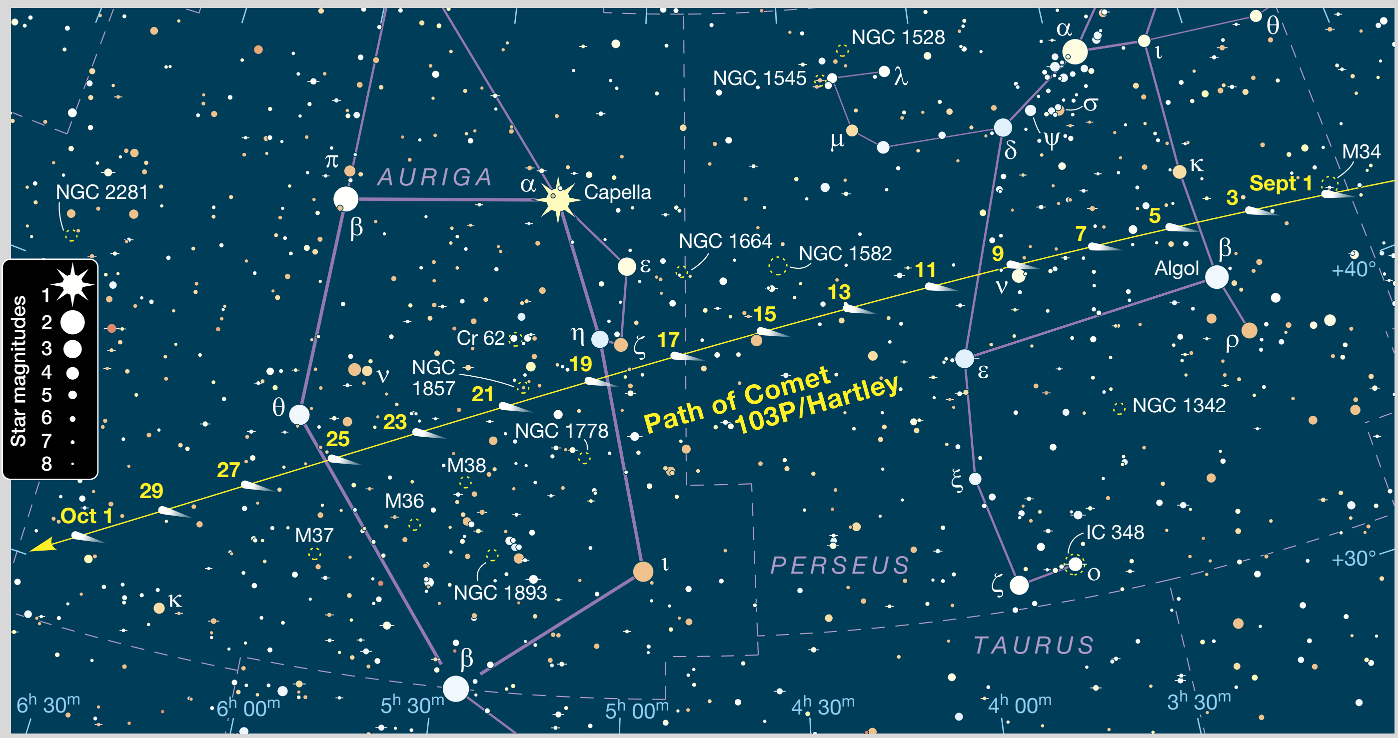
Periodic comets are a joy. We get to tag along and watch them grow from fuzzy midges to tailed wonders and back again as they make their way sunward and then return to the deeps. Whenever a favorite fuzzball recedes from the Sun and fades from view, I find it hard to say goodbye. That's why I look forward to the return of Comet 103P/Hartley. This periodic comet last reached perihelion in 2017, when it was poorly placed and faint. The most recent favorable apparition occurred more than a decade ago, in the fall-winter of 2010-11, when it reached 5th magnitude. Clearly, we're overdue.

Hartley arrives at perihelion on October 12th, making September ideal for watching it brighten from around 9th to 8th magnitude. From a dark sky, a 6-inch telescope should easily show Hartley's fuzzy coma, bright false nucleus, and perhaps hints of a westward-pointing tail.

Sliding eastward across central Perseus in early September, 103/P puts on a good appearance in the northeastern sky starting at around 10:30 p.m. local daylight time. It fights the waning gibbous Moon during the first week of September but will be in a dark sky afterwards, until the Moon returns around September 27th. As Hartley creeps eastward into Auriga, its evening altitude declines. That's when your best views will come after midnight or just before dawn, when the comet culminates nearly overhead for skywatchers at mid-northern latitudes.

Hartley's circuit takes it through a rich region of the northern Milky Way and includes several must-see, deep-sky flybys:

- within ½° of the bright open cluster M34 in Perseus on the night of August 31–September 1
- 6′ north of the 11.4-magnitude galaxy NGC 1186 (also in Perseus) on September 3rd at around 2:30 UT (10:30 p.m. EDT)
- 30′ southwest of the 7th-magnitude open cluster NGC 1857 (Auriga), on the morning of September 20th
- 2.1° north of the open cluster M38 (Auriga) on September 21–22
- 3° north of the open cluster M37 (Auriga) on September 25–26.



▲ Comet 103P/Hartley as imaged on November 1, 2010, during its most recent favorable apparition. This time, the comet passes nearest to Earth on September 26th at a distance of 56.9 million kilometers (35.4 million miles), the last time this century it will come this close.

ROLANDO LIGUSTRI

Comet 103P/Hartley is a Jupiter-family body — a group of short-period comets with orbital periods of less than 20 years whose orbits have been modified by the planet's gravitational influence. In Hartley's case, it circles the Sun every 6.5 years. Curiously, it rotates on two axes — spinning on its short axis every 18.3 hours while also rotating along its long axis.

Data gathered by the Deep Impact (EPOXI) spacecraft flyby in November 2010 reveal that Hartley's 2.3-kilometer-long (1.4 miles), peanut-shape nucleus ejects "hyperactive" amounts of water compared to other comets of similar size. A team of astronomers led by Michał Drahus also observed that the comet's rotation rate was rapidly slowing due to mass loss from its highly active nucleus. In a 2011 article in *Astrophysical Journal Letters*, they noted, "At the present rate, the nucleus will stop rotating during the fourth or fifth return from now (perihelion in 2036 or 2043)." After that, it will start to speed up again, but in the opposite direction. Eventually 103/P will spin fast enough to potentially break apart around the year 2200.

In other words, catch Comet Hartley while you can!

A Double Dose of Psi

LUNAR OCCULTATIONS are exciting to watch and timing them can potentially provide scientifically valuable information. On the night of September 27–28, the dark limb of the almost full (97%-illuminated) Moon will cover 4.2-magnitude Psi^1 (ψ^1) Aquarii and 4.4-magnitude Psi^2 (ψ^2) Aquarii, one after the other. Observers across the contiguous U.S., Canada, Mexico, and Central America will see the first disappearance, while the second occultation will be visible from the western two-thirds of the U.S., most of Canada, and parts of Mexico.

The brilliant Moon will make this a telescope-only event. In Kansas City, Missouri, the Moon's dark, southwestern limb occults Psi^1 at 9:11 p.m. CDT followed by Psi^2 at 10:09 p.m. Just 6 minutes later at 10:15 p.m., Psi^1 reappears along the bright northeastern limb and Psi^2 later, at 10:45 p.m.

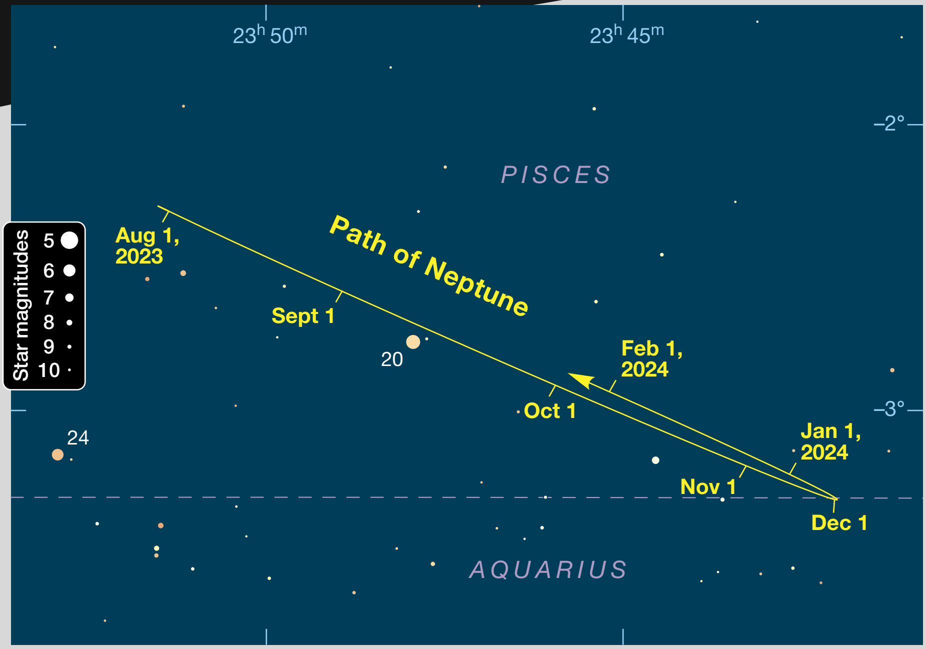
You can simulate the occultations for your specific location with planetarium software such as *Stellarium*.

Neptune at Opposition

THE BRIGHTEST PLANETS naturally get a lot of telescopic attention because most of them appear large enough to display interesting surface or atmospheric features. Neptune, on the other hand, is our solar system's most distant major planet and presents the tiniest disk, despite being four times larger than Earth. When it reaches opposition on September 19th, it will be 4.3 billion kilometers away and shine at magnitude 7.8. The ice giant looks like a field star at low magnification — albeit a blue-colored one — due to the methane in its atmosphere, which absorbs red light. But a 6-inch telescope and a magnification of around 150×, combined with good seeing, will turn this faint "star" into a 2.4″-wide dot. Beyond that little else is visible, though experienced imagers occasionally tease out bright bands and cloud formations. The fun of tracking down Neptune is seeing a world so very far away and imagining what it might be like to be there.

A few facts give us a clue. Consider its winds. Tearing around the planet at 2,000 kilometers per hour, they're nearly five times faster than Earth's most powerful gusts and earn Neptune the distinction as the windiest place in the solar system. Because Neptune isn't a solid, rocky body, its atmosphere experiences differential rotation like that on Jupiter and Saturn, but to a far greater extreme. Neptune's equatorial region spins once every 18 hours compared to 12 hours at the poles. The planet also radiates 2.6 times more energy than it receives from the Sun, likely fueling its ferocious winds and occasional colossal storms.

Unlike many of the solar system's biggest moons, Neptune's largest, Triton, circles the planet at a steep angle (157°) and orbits backward. Planetary astronomers suspect Triton was once a Kuiper Belt asteroid that Neptune captured. When Triton is at its greatest north or south elongation, which



occurs approximately every three days, it's positioned about 16″ northeast or southwest of the planet. At magnitude 13.4, Triton is relatively easy to spot in a 10-inch telescope with a magnification of 200× or greater.

This apparition, Neptune plods through southwestern Pisces, about 5° south of the constellation's dim but distinctive Circlet asterism. To find the planet, first locate 5.5-magnitude 20 Piscium. Neptune stays within ½° of the star all month. Center 20 Piscium in the field of view of a low-magnification eyepiece, and you can be sure Neptune will be nearby. On the morning of September 11th, the planet passes just 3.5′ north of the star.

Use the map above to pinpoint Neptune and consult the Triton Tracker app on the Tools page at **skyandtelescope.org** to keep tabs on the big moon.

Minima of Algol

Aug.	UT	Sept.	UT
2	8:14	2	21:09
5	5:03	5	17:58
8	1:51	8	14:46
10	22:40	11	11:35
13	19:29	14	8:23
16	16:17	17	5:12
19	13:06	20	2:01
22	9:54	22	22:49
25	6:43	25	19:38
28	3:32	28	16:27
31	0:20		

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

▲ Perseus reaches the zenith during pre-dawn hours in September. Every 2.87 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Use this chart to estimate its brightness in respect to comparison stars of magnitude 2.1 (Gamma Andromedae) and 3.4 (Alpha Trianguli).

Action at Jupiter

AS NOTED on page 46, for the first time during this apparition Jupiter crosses the meridian before the start of morning astronomical twilight. The exact date that occurs depends on your latitude, but for observers at 45° north it's September 8th. For those farther south, it occurs earlier and for those farther north, it's later. Of course, Jupiter can be productively observed long before it reaches the meridian and can be viewed well after morning twilight begins. During September, the planet's disk grows from 43.9″ to 47.6″ while it brightens slightly, from magnitude –2.6 to –2.8.

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

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

August 1: 6:50, 16:45; **2**: 2:41, 12:37, 22:32; **3**: 8:28, 18:24; **4**: 4:20, 14:15; **5**: 0:11, 10:07, 20:02; **6**: 5:58, 15:54; **7**: 1:49, 11:45, 21:41; **8**: 7:36, 17:32; **9**: 3:28, 13:23, 23:19; **10**: 9:15, 19:11; **11**: 5:06, 15:02; **12**: 0:58, 10:53, 20:49; **13**: 6:45, 16:40; **14**: 2:36, 12:32, 22:27; **15**: 8:23, 18:19; **16**: 4:14, 14:10; **17**: 0:06, 10:01, 19:57; **18**: 5:53, 15:48; **19**: 1:44, 11:40, 21:35; **20**: 7:31, 17:27; **21**: 3:22, 13:18, 23:14; **22**: 9:09, 19:05; **23**: 5:01, 14:56; **24**: 0:52, 10:47, 20:43; **25**: 6:39, 16:34; **26**: 2:30, 12:26, 22:21; **27**: 8:17, 18:13; **28**: 4:08, 14:04; **29**: 0:00, 9:55, 19:51; **30**: 5:47, 15:42; **31:** 1:38, 11:33, 21:29

September 1: 7:28, 17:24; **2:** 3:19, 13:15, 23:11; **3:** 9:06, 19:02; **4:** 4:58, 14:53; **5:** 0:49, 10:44, 20:40; **6:** 6:36, 16:31; **7:** 2:27, 12:23, 22:18; **8:** 8:14, 18:09; **9:** 4:05, 14:01, 23:56; **10:** 9:52, 19:48; **11:** 5:43, 15:39; **12:** 1:34, 11:30, 21:26; **13:** 7:21, 17:17; **14:** 3:13, 13:08, 23:04; **15:** 8:59, 18:55; **16:** 4:51, 14:46; **17:** 0:42, 10:37, 20:33; **18:** 6:29, 16:24; **19:** 2:20, 12:15, 22:11; **20:** 8:07, 18:02; **21:** 3:58, 13:53, 23:49; **22:** 9:45, 19:40; **23:** 5:36, 15:31; **24:** 1:27, 11:23, 21:18; **25:** 7:14, 17:09; **26:** 3:05, 13:01, 22:56; **27:** 8:52, 18:47; **28:** 4:43, 14:39; **29:** 0:34, 10:30, 20:25; **30:** 6:21, 16:17

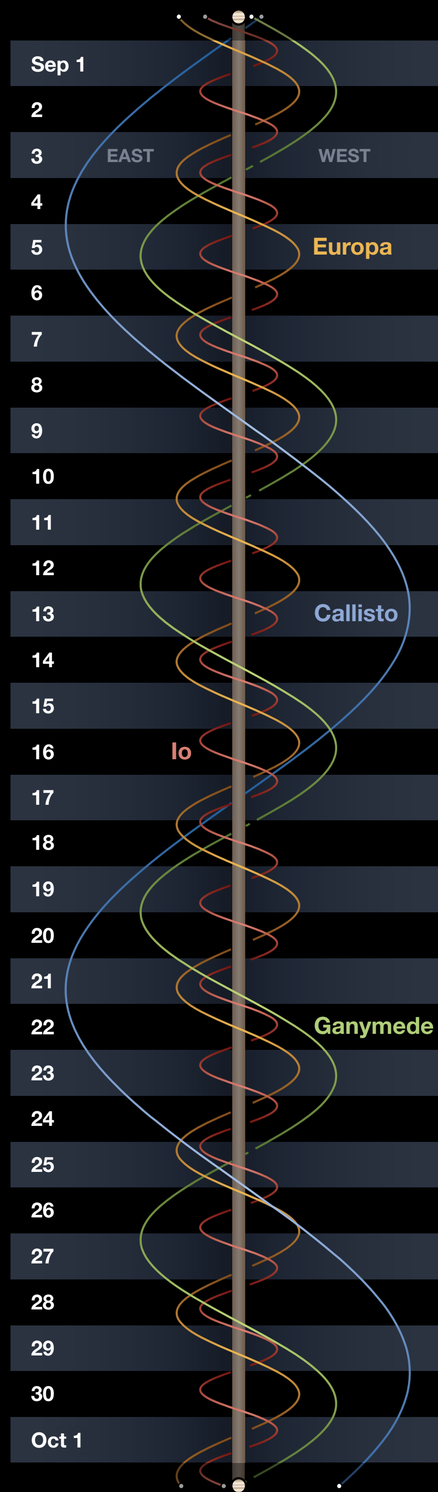
These times assume that the spot will be centered at System II longitude 44° on September 1st. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 44° and 1⅔ minutes later for each degree more than 44°.

Phenomena of Jupiter's Moons, September 2023

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

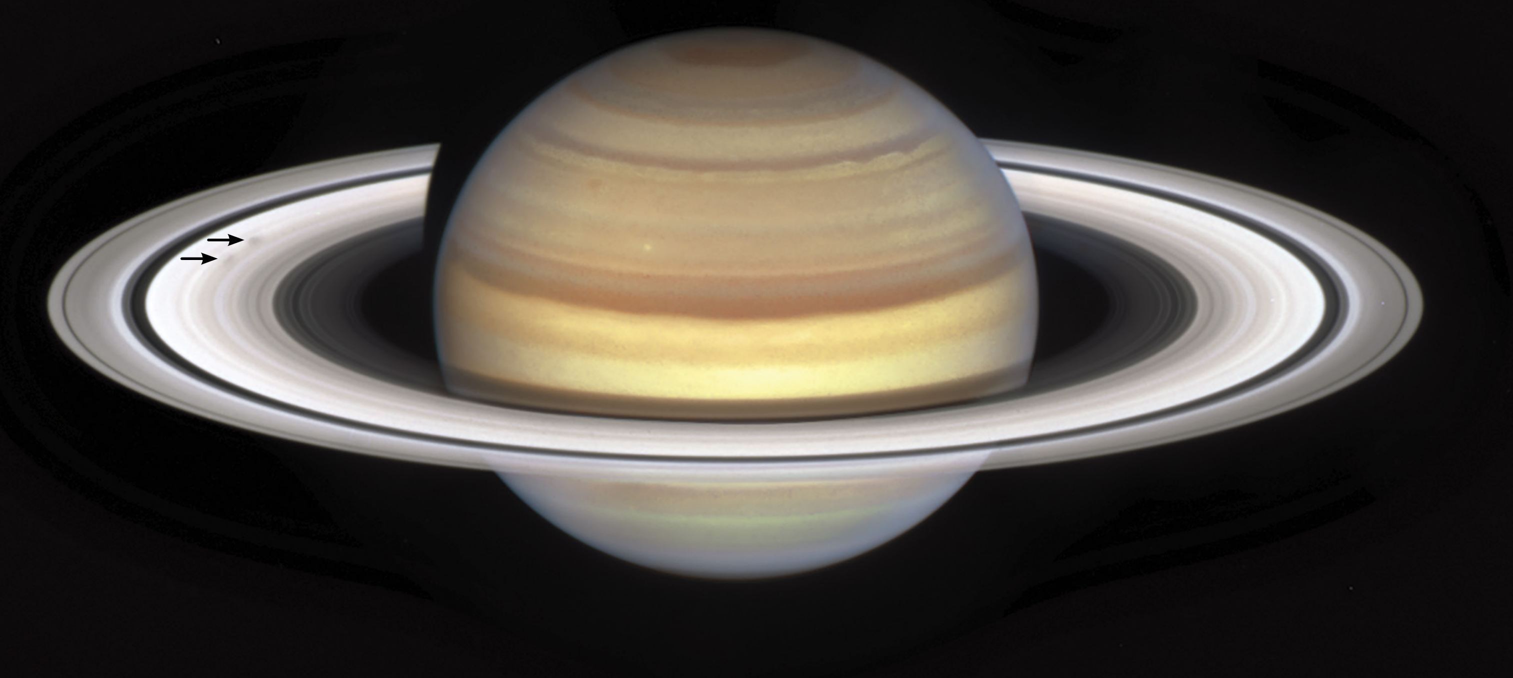
Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 5 hours ahead of Eastern Standard Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede,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

Jupiter's Moons



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

Exploring the Solar System by Thomas A. Dobbins and William Sheehan



Suspense at Saturn II

Do recent observations herald the return of ring spokes?

▲ On September 22, 2022, the Hubble Space Telescope recorded a pair of dusky smudges in ring B resembling the "baby spokes" imaged by the Cassini spacecraft in 2005.

NASA / ESA / AMY SIMON (NASA / GSFC), IMAGE PROCESSING: ALYSSA PAGAN (STSCI)

During the late 1970s the eagle-eyed observer Stephen James O'Meara repeatedly glimpsed dusky, ephemeral streaks crossing Saturn's B ring through the 9-inch Clark refractor at Harvard College Observatory in Cambridge, Massachusetts. Although it would prove to be one of the last great planetary discoveries made by a visual observer, O'Meara's description of ghostly linear features rotating like rigid bodies was initially greeted with skepticism (*S&T:* Aug. 2022, p. 28).

Kepler's third law of planetary motion dictates that objects in the inner regions of the ring should have shorter orbital periods than those in its outer regions. Particles at the inner edge of ring B revolve around Saturn every 7.9 hours, while those at its outer edge circle the planet every 11.4 hours. Radial features that mimic a rotating lighthouse beacon or the spokes of a bicycle wheel just didn't seem possible, so O'Meara's reports were written off as optical illusions.

When NASA's twin Voyager spacecraft flew past Saturn in 1980 and 1981, they captured hundreds of images of faint, shadowy fingers radiating across ring B. In movies assembled from these images, "spokes" 6,000 kilometers (3,730 miles) long are seen to form in as little as 5 minutes. Once these structures coalesce, they initially orbit Saturn at the same rate as the axial rotation of the planet's magnetic field, indicating that they are electrically charged. They persist for several hours before gradually shearing out, with their broad ends facing Saturn, as their constituent particles gradually begin to move in trajectories controlled by gravitational rather than electromagnetic forces. Confined primarily to the central regions of ring B at distances of 43,000 to 57,000 km above Saturn's cloudtops, spokes are absent in the A and C rings.

The fact that coherent, linear structures thousands of kilometers long could revolve around Saturn without being torn apart by differential rotation initially baffled the Voyager project scientists. When the spacecraft's cameras recorded images of the rings backlit by the Sun, the dark spokes seen during approach suddenly appeared bright. This optical behavior, known as *forward scattering*, is exhibited by minute particles that are approximately equal in diameter to the wavelength of the light that illuminates them, like motes of cigarette smoke in a sunbeam. The spokes are composed of exceedingly fine grains of icy dust measuring only a few millionths of an inch across levitating above the ring plane due to electrostatic repulsion.

During the 1990s, the Hubble Space Telescope and several ground-based telescopes routinely imaged spokes. The spokes abruptly and mysteriously vanished in 1998 and were still absent when the Cassini spacecraft swung into orbit around Saturn in July 2004. In September 2005, the spacecraft's cameras recorded the sudden appearance of "baby spokes" in the form of small, diffuse patches in ring B. Full-fledged linear spokes like those the Voyager spacecraft imaged developed during 2007, persisting until 2013.

The mechanism responsible for generating spokes is still not well understood. But the most popular model holds that random collisions between meteoroids and ring particles generate transient clouds of dense plasma that impart an electrical charge to the resulting debris. According to University of Colorado physicist Mihály Horányi and Carolyn Porco, leader of the Imaging Team for the Cassini-Huygens mission, the background plasma environment surrounding the rings plays a vital role in determining whether impact ejecta stay aloft long enough for spokes to form.

When the background plasma density is high, electrical charges on particles lofted above the plane of the rings rapidly dissipate, causing the particles to quickly fall back into the rings. Charges are more persistent when plasma density is low, so the levitated grains continue to be repelled and follow trajectories aligned with Saturn's magnetic field until their charges are slowly depleted.

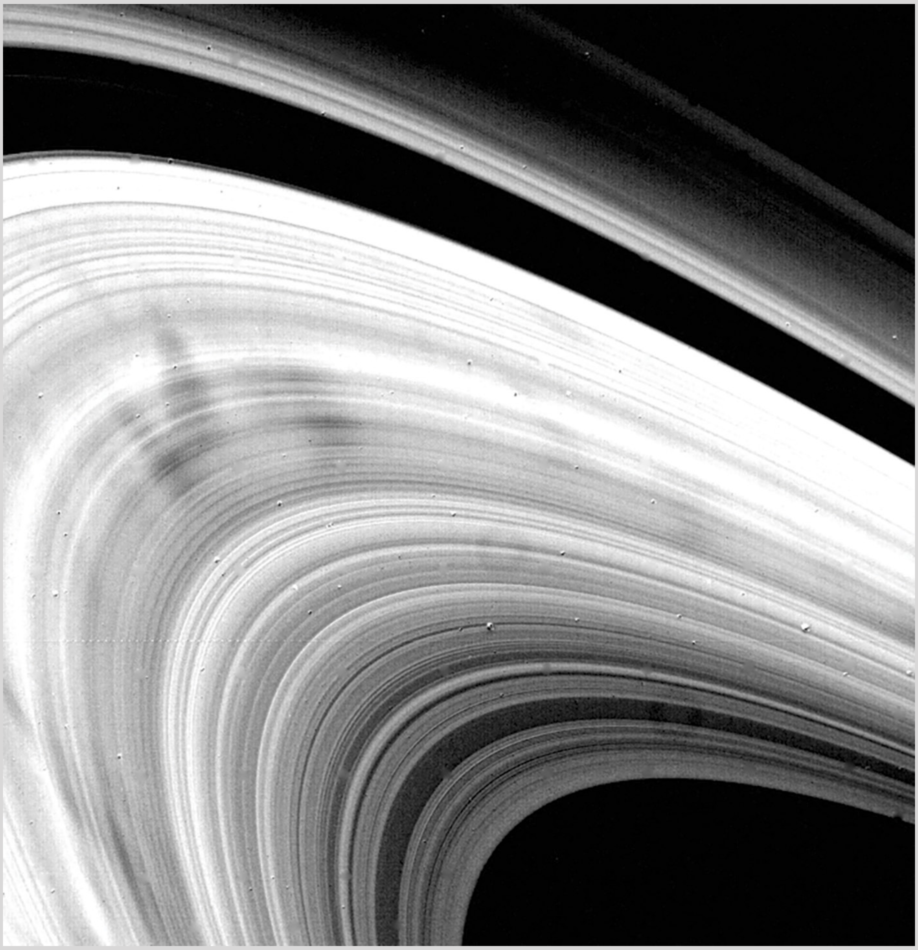
The density of the plasma surrounding the rings depends largely on the angle between the Sun and the rings. Photoelectrons generated by the interaction of incident solar radiation and ring particles seem to turn off spoke formation when the angle between the Sun and the rings exceeds 17°. Spokes appear to be a seasonal phenomenon, disappearing near Saturn's summer and winter solstices and gradually reappearing as the planet approaches its equinox, when the angle between the Sun and the ring plane is relatively low and fewer photons strike ring particles.

Saturn ponderously circles the Sun once every 29.4 years, so each season lasts more than seven Earth years. Summer solstice in Saturn's northern hemisphere occurred in May 2017, and the autumnal equinox is coming up in May 2025. According to NASA planetary scientist Amy Simon, "the precise beginning and duration of the spoke season is still unpredictable, rather like predicting the first storm during hurricane season."

Last September, renowned British planetary imager Damian Peach, veteran Austrian observer Martin Stangl, and the Hubble Space Telescope independently recorded small, dusky smudges in ring B resembling the "baby spokes" that Cassini imaged in 2005. In February of this year, NASA issued a press release announcing that the appearance of these features heralded the advent of "spoke season."

The "baby spokes" are at the very limit of visibility in large backyard telescopes, but in coming months we can expect much larger linear spokes to develop. These low-contrast, faint fingers will still be among the most challenging targets for visual observers and imagers alike. Careful monitoring of ring B on nights of very steady seeing may reward you with glimpses of these fleeting trophies.

■ Contributing Editors **TOM DOBBINS** and **BILL SHEEHAN** will both be watching Saturn this year with great anticipation.



▲ The Voyager 2 spacecraft captured this high-resolution image of spokes on August 22, 1981, from a distance of 4 million kilometers. The contrast of these ghostly features was greatly exaggerated to make them more visible — they are only about 10% darker than their surroundings.

Winging it with Cygnus

The eastern wing of the Swan is feathered with deep-sky delights.

Welcome to Cygnus . . . again! I explored the wide western wing of the mythic bird a year ago (Sept. 2022, p. 54), and now I'm inviting you to join me for a return trip, this time along the celestial Swan's sprawling eastern wing.

But I have a problem.

I'm observing from the north side of a small city loaded with lights. The brilliantly illuminated car and RV dealerships scattered all over town are photon factories, and our recently installed LED streetlights give the night sky a sickly grayish pallor. Now a neighbor two doors south of me has put up an unshielded porch light that shines with supernova intensity. What's a determined stargazer to do?

Answer: Grumble quietly, talk to the neighbor, and keep observing.

Thankfully, in September Cygnus soars high overhead at nightfall, where the local light dome is least bothersome. Let's get out there.

Getting Going

My chosen staging point is 2.2-magnitude Sadr, or Gamma (γ) Cygni. Use the chart on page 56 to find your way as we embark from this stellar signpost.

Embedded in the Cygnus Milky Way, Gamma is surrounded by ragged patches of faint nebulosity and an especially rich starfield. Inside a 2° circle of sky centered on Gamma, my city-based telescopes pick up hundreds of stars, bright and dim.

For tonight's exploration, I'm setting up a 4.7-inch (120-mm) f/7.5 apochromatic refractor on an equatorial mount, and a 10-inch f/6 Newtonian reflector on a Dobsonian mount. These instruments are of contrasting aperture, yes, but both permit me to make some very satisfying observations of the glittering Gamma region — and more.

If I want to start off with a panoramic view, I need a low-power, wide-angle eyepiece. My favorite is a 30-mm model with a 70° apparent field of view. In the refractor it generates 30× and a true field (TFOV) 2.3° in diameter. The same eyepiece on the reflector delivers 50× and a TFOV of almost 1.5°. On either scope, the 30 mm pulls in a lot of starlight around Gamma Cygni.

Amid all the glitter is a petite open cluster lying a scant ½° north-northeast

◀ **GAMMA GLITTER** The area immediately surrounding Gamma Cygni (Sadir) is rich with faint (but very photogenic) nebulosity, stars, and tiny open clusters. Although visually underwhelming, these clusters harbor closely spaced binary stars that resolve in small backyard telescopes. The whole region is stunning when viewed with a low-power, wide-angle eyepiece, though only the brightest patches of nebulosity are visible, and only if observed under suitable sky conditions with a filter.

MDW SKY SURVEY

of Gamma. **NGC 6910**, just 10′ in diameter, is anchored by a wide double star dubbed **GRF 15**. The 7.2- and 7.5-magnitude jewels, a generous 199.3″ (3.2′) apart on a northwest-southeast slant, are bridged by a wavy arc of 10th-magnitude stars. Two more glints jutting westward make the cluster resemble a squashed letter Y. My refractor working at 30× barely detects the wobbly Y, but 100× nails it. The reflector picks up several additional stars around the main formation. Nice!

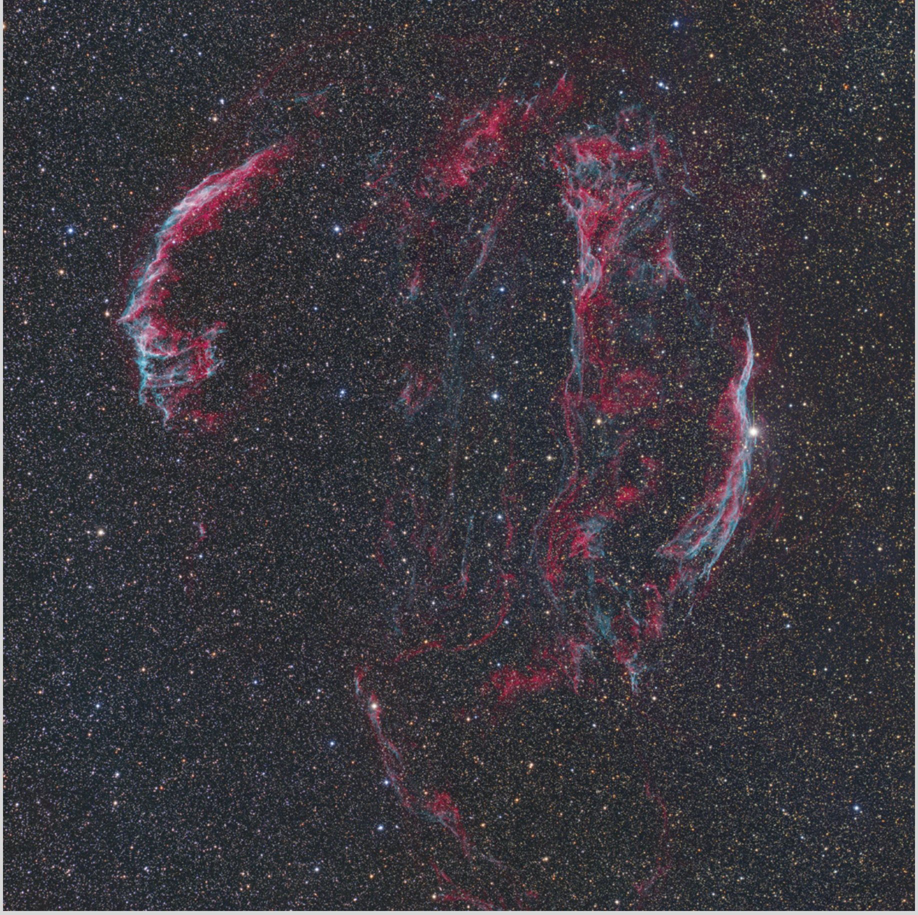
Duds and Doubles

Three other clusters scattered across the upscale Gamma neighborhood are disappointingly dull. But each of these obscure targets contains what I call a buried binary — a seemingly single cluster member that splits into two at medium to high power. The buried binaries are easy to identify once you've nailed their host clusters.

Exhibit A is hiding in plain sight. The harboring cluster is **Collinder 419**, located one degree west-northwest of Gamma. A circular assemblage only 5′ in diameter, Cr 419 is effectively obliterated by its 6.0-magnitude lucida, an incredibly hot, massive star of spectral class O. This blinding cluster-buster is the primary component of **Struve (Σ) 2666**. My scopes tease out its 8.2-magnitude secondary sun as a mere speck 2.8″ east of the primary.

Shifting a bit more than ½° east-southeast of Gamma scoops up a lackluster cluster with an exotic name: **Dolidze 10**, or Do 10 for short. The Dolidze dud is essentially a 6′-wide quadrilateral of four 8th- and 9th-magnitude stars. It's saved from being the worst cluster in the known universe by Exhibit B, a double named **Dembowski 22** (D 22), which adorns the quad's northern corner. The double comprises 8.2- and 9.5-magnitude stars 2.9″ apart — a delicate duo indeed.

Nearly 1° south-southwest of Gamma is another Dolidze cluster, **Do 5**. A puny puddle of pinpoints 10′ across, Do 5 yields — wait for it — five or six dim dots scattered around a 2.5′-wide triangle of 9th-magnitude stars. A



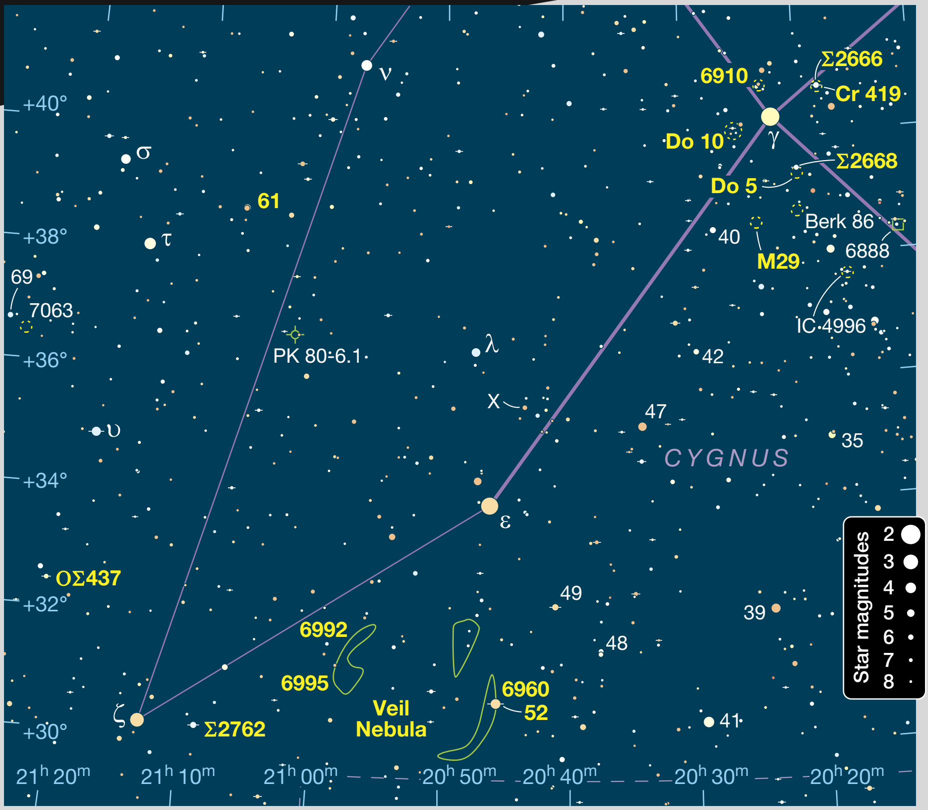
▲ **DELICATE VEIL** A vast, wispy supernova remnant, the Veil Nebula is best observed from a dark country site. And yet this filamentary wonder is faintly visible from suburban locations when the telescope is equipped with a nebula-enhancing UHC or O-III filter. The bright star near the right edge of the field is 4.2-magnitude 52 Cygni, which signposts the Veil's western arc, NGC 6960.

MDW SKY SURVEY

East Wing Goodies

Object	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 6910	Open cluster	7.4	10′	20^h 23.2^m	+40° 47′
GRF 15	Double star	7.2, 7.5	199.3″	20^h 23.1^m	+40° 48′
Cr 419	Open cluster	7.6	5′	20^h 18.1^m	+40° 43′
Σ2666	Double star	6.0, 8.2	2.8″	20^h 18.1^m	+40° 44′
Do 10	Open cluster	—	6′	20^h 26.3^m	+40° 07′
D 22	Double star	8.2, 9.5	2.9″	20^h 25.5^m	+40° 06′
Do 5	Open cluster	—	2.5′	20^h 20.5^m	+39° 23′
Σ2668	Double star	6.3, 8.5	3.5″	20^h 20.3^m	+39° 24′
M29	Open cluster	6.6	10′	20^h 24.1^m	+38° 30′
52 Cyg	Double star	4.3, 9.5	5.9″	20^h 45.6^m	+30° 43′
NGC 6960	SNR	~6.0	70′	20^h 45.7^m	+30° 43′
NGC 6992/95	SNR	~8.0	60′	20^h 56.3^m	+31° 45′
Σ2762	Double star	5.7, 8.1	3.3″	21^h 08.6^m	+30° 12′
OΣ437	Double star	7.2, 7.4	2.5″	20^h 23.2^m	+40° 47′
61 Cyg	Double star	5.2, 6.1	31.9″	21^h 06.9^m	+38° 45′

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.



◀ **WINGING IT** In mid-September, the 2.2-magnitude star Gamma (γ) Cygni, also known as Sadr, crosses the zenith soon after nightfall for observers at latitude 40° north. The author's tour runs from Gamma southeastward past 2.5-magnitude Epsilon (ε) Cygni, or Gienah, to 3.2-magnitude Zeta (ζ) Cygni.

truly stupendous sight. (Just kidding.) But hang on. A few arcminutes north of the triangle is Exhibit C, an uneven binary listed as **Σ2668**. Its 6.3- and 8.5-magnitude components are a whopping 3.5″ apart — easy-peasy.

These tandems, a stone's throw from Gamma Cygni, resolve in both my scopes — refractor and reflector — at around 100×. Give 'em a try.

On the Wing

An almost 2° push south-southeastward from Gamma sweeps up **M29**. Spanning 10′, the open cluster contains few members, none of them bright. Viewed in my refractor at 30×, M29 is a hazy knot of starlight in the Milky Way. A modest increase to 38× presents the bare bones of this skeletal grouping — two semi-parallel arcs of 9th- and 10th-magnitude stars, eight in all. At 100×, another seven or eight background members help bind the rows together. The reflector working at 127× reveals 15 faint stars, for a grand total of 23. Wowzers! (Kidding again.)

Next, we head southeastward to 2.5-magnitude Epsilon (ε) Cygni, then veer a few degrees southward to 4.2-magnitude **52 Cygni**, a strongly unequal double. The 4.3- and 9.5-magnitude stars, 5.9″ apart, resolve at medium to high magnification. And for the eagle-eyed, there's more here. 52 Cygni overlays **NGC 6960**, one of the two main segments of the celebrated Veil Nebula. Using the 10-inch reflector, can I separate the wispy supernova remnant from a gray city sky? I should at least try because, well, one never knows what one might see.

And I see nothing. Nada. Zilch.

That is, until I insert the Amazing Magic Thing (AMT). Ta-da! The ghostly Veil materializes with the aid of an ultra-high contrast (UHC) narrowband filter. Even better is the doubly ionized oxygen (O-III) filter. Applying either AMT, I can glimpse the slightly wavy jet-contrail form of NGC 6960, and also the crescent-shaped **NGC 6992/95**, 2° to the east-northeast. Both sections show at 50×, though I prefer the view at 64×. To my further surprise, the Veil also comes to life in the little refractor. In that scope, the low-power UHC view is best. Wowzers — and this time I mean it!

The Swan's eastern wingtip is established by 3.2-magnitude Zeta (ζ) Cygni. One degree west of Zeta is **Σ2762**, a binary system displaying 5.7- and 8.1-magnitude elements 3.3″ apart. My refractor handles Σ2762 at 129×. In the 10-inch, the primary glows warmly yellow. Less than 3° northeast of Zeta is a pair of 6th-magnitude stars, separated by nearly 12′, on a northeast-southwest slant. The southwestern one is a binary called **OΣ437**. It offers 7.2- and 7.4-magnitude stars 2.5″ apart. The closely spaced yellow-orange suns are a satisfying catch in both scopes at 150×.

Our final target **61 Cygni**, is famous, but tricky to find. It marks one corner of a two-degree-wide triangle whose other vertices are held by 4th-magnitude Tau (τ) and Sigma (σ) Cygni. The triangle lies halfway between Zeta Cygni and 1st-magnitude Deneb. Only 11.4 light-years from Earth, 61 Cygni was the first star to have its parallax measured. However, 61 Cygni is a double celestial act. Its 5.2- and 6.1-magnitude components, 31.9″ apart, exude a deep-orange hue. The alluring 61 set looks great at low magnification in any telescope.

Long-focal-length instruments are adept at slaying double stars. My 7.1-inch f/15 Maksutov-Cassegrain effortlessly resolves every Cygnus double described here. Moreover, it delivers pristine views of the clusters NGC 6910 and M29. My one disappointment with the Mak is that it can hardly register the Veil Nebula. The scope has some worthy attributes, but low magnifications and wide-angle fields of view aren't part of the package.

■ Contributing Editor **KEN HEWITT-WHITE** is president and treasurer of the Dud Clusters Society, an unofficial organization of uncertain registry and declining membership.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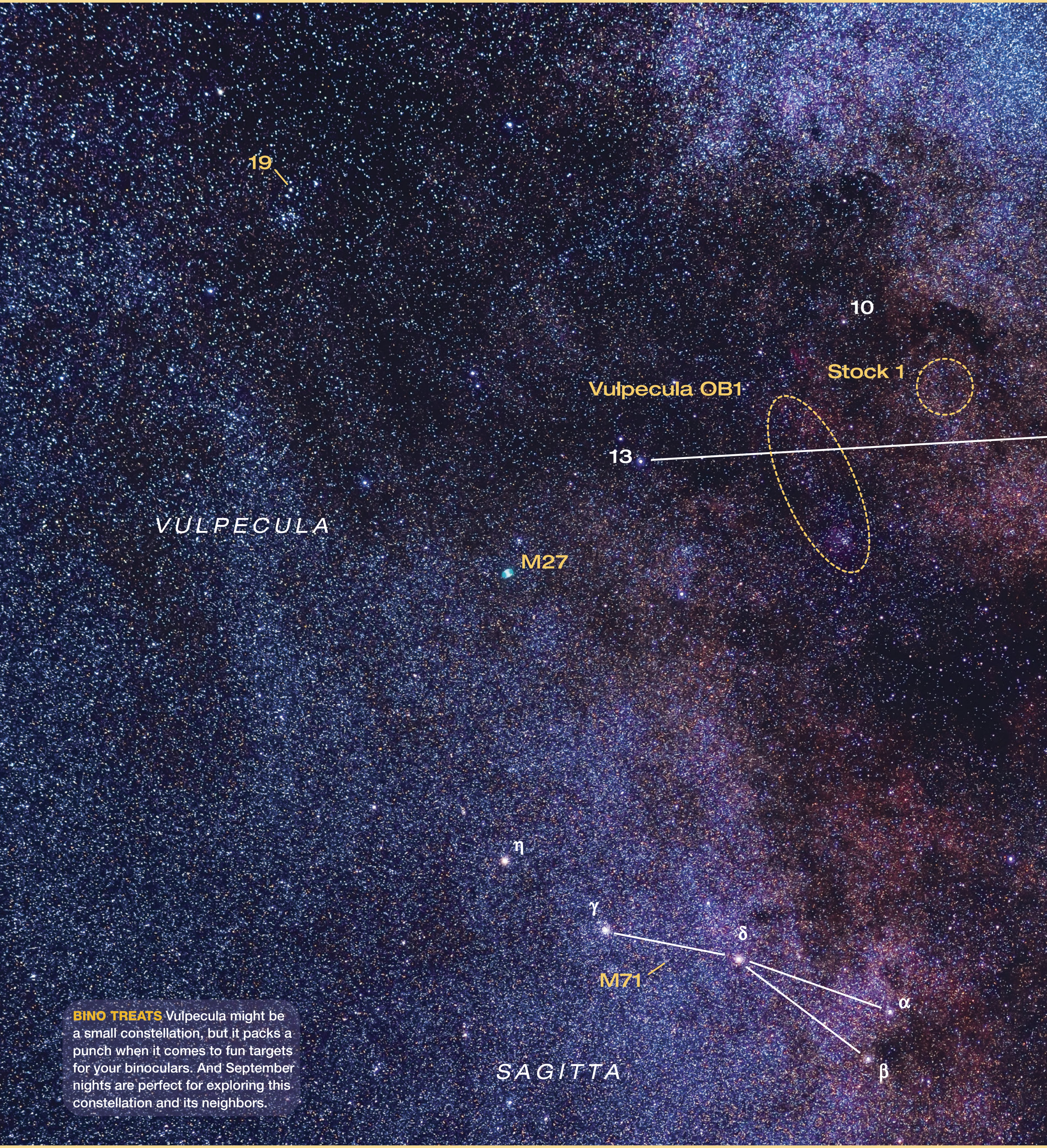
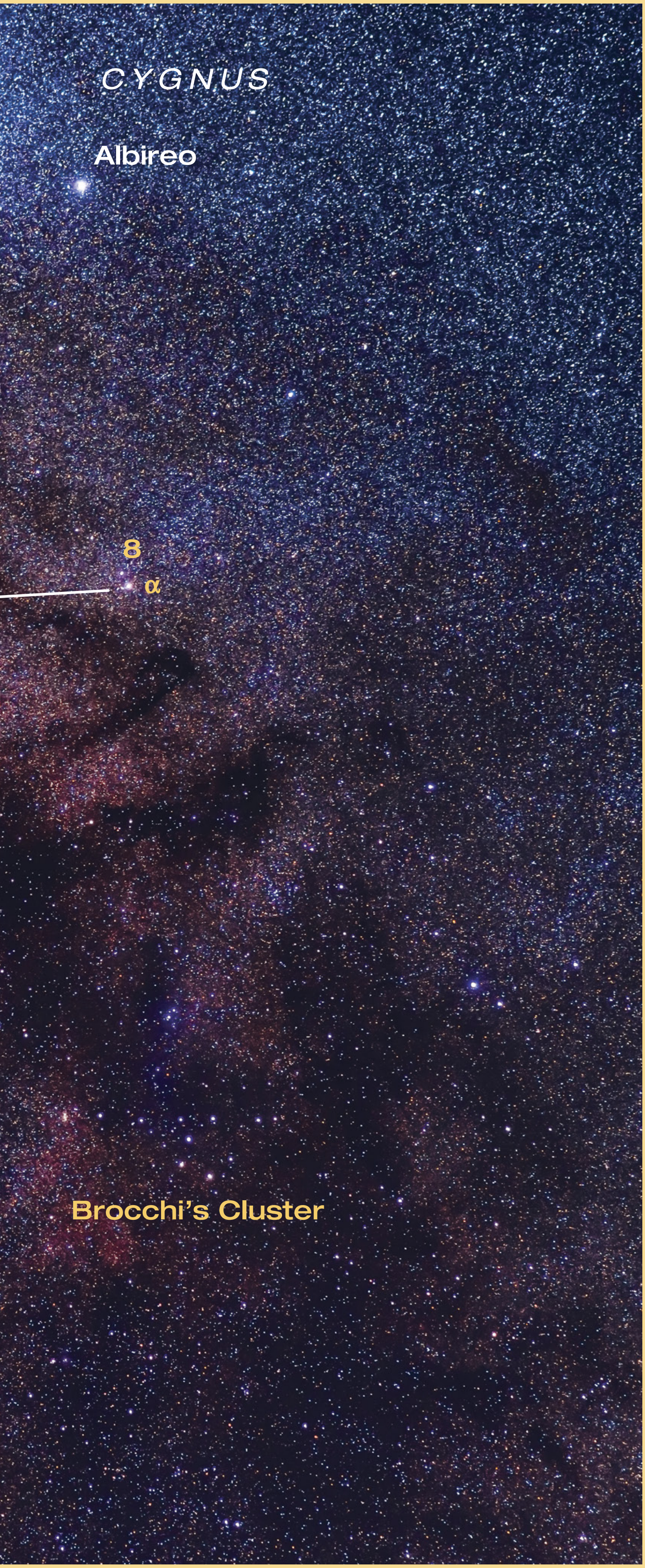


BINO TREATS Vulpecula might be a small constellation, but it packs a punch when it comes to fun targets for your binoculars. And September nights are perfect for exploring this constellation and its neighbors.



ALAN DYER

September Ramble Through the Milky Way

Grab your favorite binoculars and get up close with late-summer targets.

On warm summer evenings I like to lie back in a lounge chair and study the Milky Way. Our home galaxy arcs high above the horizon, and it's easy to understand why some cultures refer to it as "the backbone of night." Just as our backbones form the core framework of our bodies, so too does the galactic band reveal something of the anatomy of the cosmos, with star clusters and nebulae as signposts along the way. The only dissecting tools we need are clear skies, optics, and a guide. So, grab your binoculars, and let's get started.

This is the sixth installment in our binocular tour of the Milky Way. In previous articles we voyaged from Canis Major to Hydra (*S&T:* Dec. 2015, p. 32); Monoceros to Gemini (*S&T:* Mar. 2017, p. 30); Perseus to Auriga (*S&T:* Jan. 2018, p. 60); Cepheus to Cassiopeia (*S&T:* Oct. 2019, p. 28); and through Cygnus (*S&T:* Sept. 2021, p. 34). This time we'll roam across the summer Milky Way from Lyra and Vulpecula to Aquila and Ophiuchus.

As in previous tours, I made my observations using 15×70 binoculars with a 4° field of view, but almost every object on our trip will be visible in 10× or even 7× binoculars. Instead of deliberating over gear, get your favorite instrument and find the darkest skies you can — as we roam along the spine of the galaxy, the view will be both informative and rewarding.

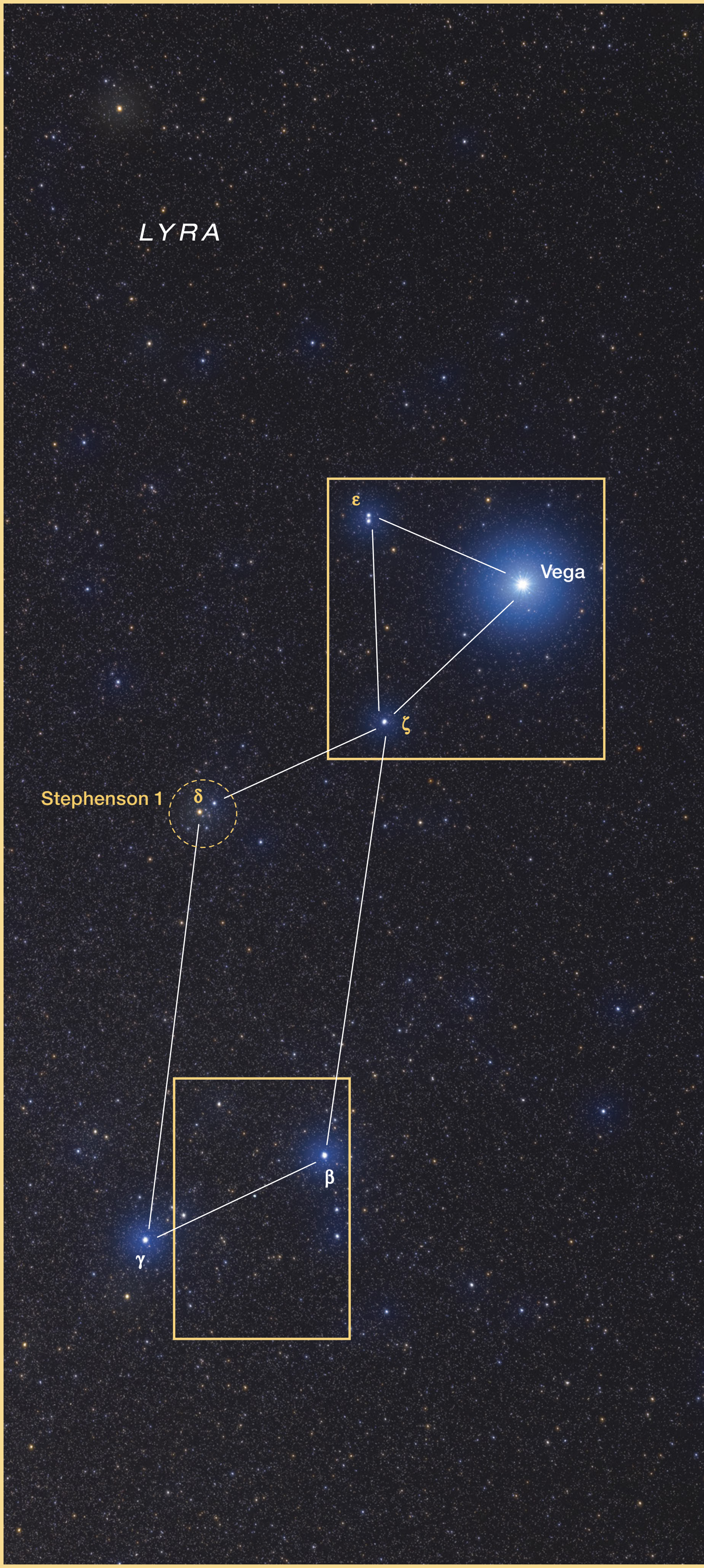
Lounging in Lyra

We'll start our road trip with a visit to Lyra, the Lyre. This tiny constellation packs a variety of delights for the eye and the mind. Let's begin with the bright triangle formed by Vega, or Alpha (α) Lyrae, **Epsilon (ε) Lyrae**, and **Zeta (ζ) Lyrae**. At magnitude 0.0, Vega is one of the brightest stars in the night sky, and at 25 light-years from us it makes a handy measuring stick for thinking about cosmic distances.

Epsilon Lyrae is the alluring "Double Double" star. With a separation of 209″, 5th-magnitude Epsilon^1 Lyrae and Epsilon^2 Lyrae are wide enough to be split with the naked eye under good conditions, and any binoculars will tease them apart easily. However, you'll need a telescope magnifying more than 100× and

▲ **LINGER IN LYRA** The Lyre is brimming with enticing double stars for your binoculars, such as Epsilon Lyrae at upper left and Zeta Lyrae at lower left in the image above, which roughly corresponds to the upper box in the widefield image at right.

▲ **SHIMMERING RING** M57, also known as the Ring Nebula, hangs delicately almost exactly halfway between Beta and Gamma Lyrae. This image (which roughly corresponds to the lower box at right) was acquired with a 4.2-inch telescope, but you should enjoy the view in binos, too.



reasonably good seeing to resolve each of those binary stars into their separate components. Zeta Lyrae, the third point of the triangle, is a more challenging binocular double. At 44″, I find this 4th- and 6th-magnitude pair a straightforward split at 10× but a real challenge at any lower magnification.

At the northeastern corner of the Lyra parallelogram you'll find **Delta (δ) Lyrae**, an optical double of physically unrelated stars. Separated by 619″, 6th-magnitude Delta^1 Lyrae and 4th-magnitude Delta^2 Lyrae are an easy naked-eye split but see if you can detect a color difference. Delta^1 Lyrae is a blue-white main-sequence star, whereas Delta^2 is an orange-red giant that appears yellow in binoculars. Also take in the field around the pair — a swarm of 8th- and 9th-magnitude stars spanning about ⅓° comprise the open cluster **Stephenson 1**.

At the southern end of the Lyra parallelogram, look just over a third of the way from Sheliak, or Beta (β) Lyrae, to Sulafat, or Gamma (γ) Lyrae, to spot **M57**, the renowned Ring Nebula. Although the Ring is detectable in 7×50 binos, this 9th-magnitude planetary nebula just starts to appear as more than a fuzzy star in 15×70s, and it isn't clearly a ring without resorting to binoculars with greater magnification. The estimated distance to M57 is 2,500 light-years, or 100 times that of Vega — hang onto that number, as it will come in handy in a moment.

A little more than halfway between Sulafat and Albireo, or Beta Cygni, you'll find the 8th-magnitude globular cluster **M56** (which is outside the left-hand side of the image on page 60). Like almost all globs, it's not particularly impressive in binoculars. Rather, the interest lies in taking in the combined light of around 100,000 suns across a distance of nearly 33,000 light-years, about 13 times farther than M57. M56 and M57 are separated by a bit more than 5½°, and I've never been able to spot them in the same field — my 15×70s don't go wide enough, and my widefield, low-power binos don't magnify enough for me to confirm them both as nonstellar. Still, this is one of my favorite cosmic odd couples, where two deep-sky objects look similar in binoculars, despite their wildly different natures and distances.

The Fox and the Arrow

Southeast of M56 there's Albireo, possibly the most famous double star in northern skies. I covered that lovely pair with the rest of Cygnus in 2021, so let's explore Vulpecula, the Fox. From Albireo sweep a bit more than 3° south-southwest to find a nice, wide optical double star formed by 4.4-magnitude **Alpha Vulpeculae** and 5.8-magnitude **8 Vulpeculae**. I can't observe this field without a rueful shake of the head. When I was first learning the sky, I lost count of the number of times that I went looking for Albireo and found this Vulpecula pair instead. Together they're only a little less bright than their more famous neighbor, and with an apparent separation of 424″ they're more than 10 times farther apart. There shouldn't be much of a color contrast, however, since both stars are orange giants. Nevertheless, I've always seen 8 Vulpeculae as faintly blue. The perception of color in double stars is notoriously variable among observers — what do you see?

About 3½° east-northeast of Alpha Vulpeculae is 10 Vulpeculae. About halfway between the two stars you should see the 5.2-magnitude open cluster **Stock 1**, a sparse collection of suns that sprawls across a whole degree of sky. The cluster is more concentrated at its southern side and continues to the north as three chains of stars, like a sheaf of grain. In the other direction, look for a pretty tumble of glints starting at 10 Vulpeculae and running about 5° to the southwest, parallel to the spine of Cygnus. This is just the

▲ **DELECTABLE DUMBBELL** M27, a pretty planetary nebula in Vulpecula, the Fox, is a must-see on this binocular tour of late-summer targets. But note that you won't view it through your binos the way it looks in this image acquired with a 10-inch f/3.6 scope. That should not detract from the pleasure of laying your own eyes on this remarkable object.

▲ **GRACEFUL GLOBULAR** The globular cluster M56 in Lyra comprises some 100,000 stars and lies some 33,000 light-years away. Look for it less than ½° southeast of the 6th-magnitude star HD 180450, which shines at upper right in this image taken with a 24-inch f/3 telescope.

LYRA: GIUSEPPE DONATIELLO; M57: RAINER SPARENBERG / STEFAN BINNEWIES / JOSEF PÖPSEL / CAPELLA OBSERVATORY; FULL LYRA: ALAN DYER; M27: RON BRECHER; M56: STEFAN BINNEWIES / JOSEF PÖPSEL central portion of the **Vulpecula OB1** association, a grouping of bright young suns birthed only recently — within the last few million years! — from the vast clouds of gas and dust in the Orion spiral arm of the Milky Way.

That chain of stars leads to a point about 4½° due south of Alpha Vulpeculae, where you'll find one of the best asterisms in the sky: **Brocchi's Cluster**, also known as the Coathanger. Many asterisms require at least a little mental effort to see as their namesakes, but the Coathanger is unmistakable (albeit upside down in binoculars), with six stars in a nearly straight line forming the bar and four more making up the hook. The Coathanger is cataloged as the open cluster Collinder 399, but recent studies using satellite data suggest it's just a chance grouping after all. Still, it's fun to look at, and it always gets a few cries of delight when I point it out at summer star parties.

While we're at this end of Vulpecula, let's slide east into the tiny constellation Sagitta. *S&T* Consulting Editor Gary Seronik has described Sagitta as a "binocular constellation," and indeed the whole arrow asterism spans less than 5°, so it will fit into the field of most 7× and 10× binoculars. The constellation's only deep-sky object of note for binocular observers is the globular cluster **M71**. At 8th magnitude, M71 should

▲ **CELESTIAL COATHANGER** Brocchi's Cluster provides a delightful eyepiece view in no matter what optics. Of course, in north-up orientation it doesn't look like a coathanger, so we've turned the image upside down for your full enjoyment. The image above was taken with a 4.2-inch f/5 telescope.

INSIDE THE VULPECULA OB1 ASSOCIATION The open cluster NGC 6823 glimmers in front of the emission nebula NGC 6820 as seen in this image acquired with a 10-inch f/6.8 telescope. Both cluster and nebula contribute to an enormous loose grouping of young stars.

RON BRECHER (2)

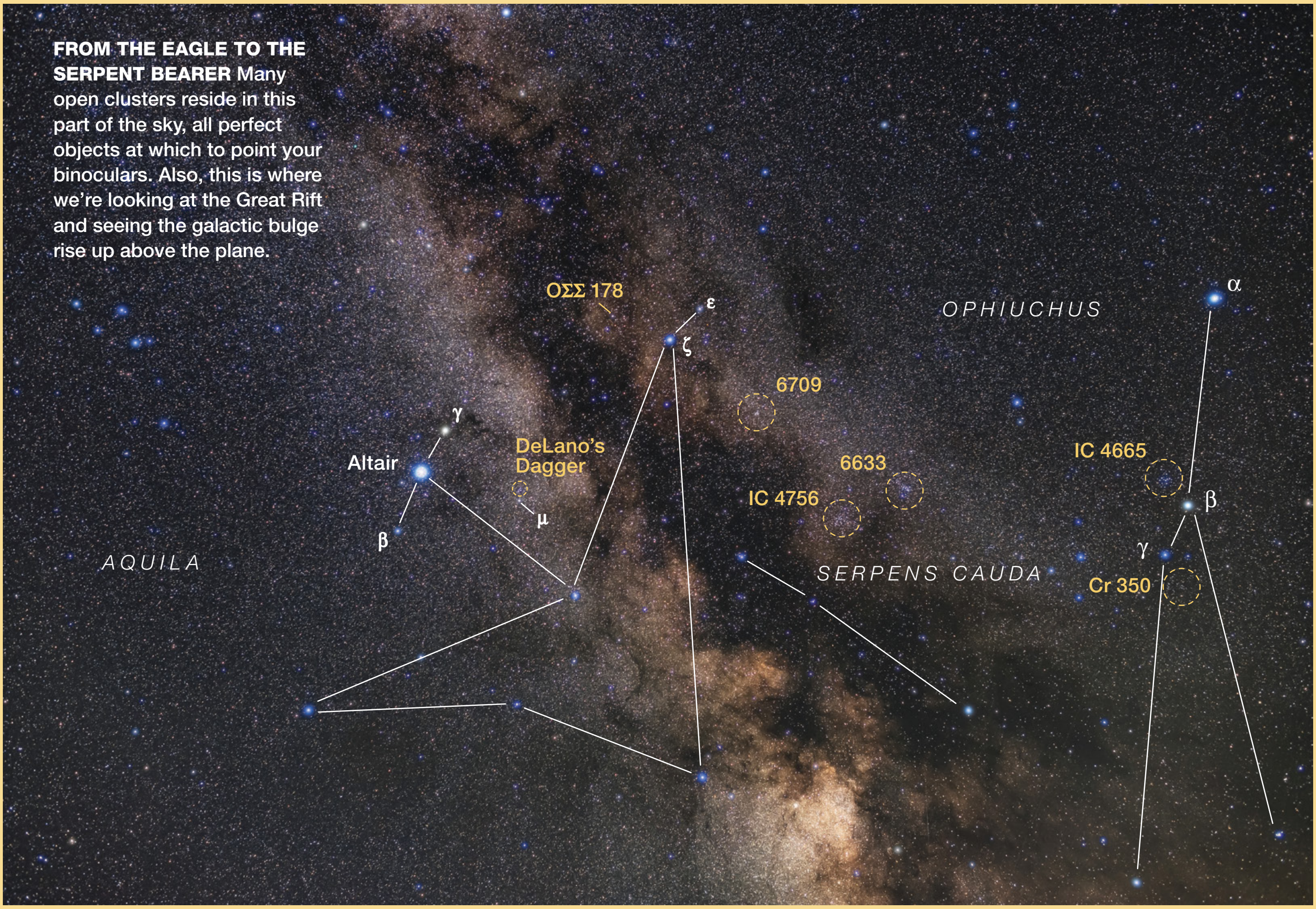
be a straightforward catch in binos about halfway between Gamma and Delta Sagittae, but its surface brightness is low, and it doesn't take much in the way of haze or light pollution to push this true faint fuzzy below the threshold of visibility.

Heading back into Vulpecula, we come to **M27**, the famous Dumbbell Nebula. Here's how I prefer to get there: Follow the cosmic arrow about 1.5° past Gamma Sagittae to Eta (η) Sagittae, and then look for a ragged chain of 6th- to 8th-magnitude stars running back to the north-northwest, at a right angle to the line between Gamma and Eta Sagittae. Follow that string of stars for 3° to find the 7.1-magnitude nebula. Don't expect the Dumbbell to reveal its famous shape unless you are working with big, mounted binoculars, but it should be visible as a distinctly fuzzy patch even at 10×. M27 lies about 1,400 light-years away, about 1,000 light-years closer to us than M57. I find it moving that across such a vast gulf we can watch the dissolution of these dying suns into planetary nebulae.

Slewing about 5° northeast of M27 you'll find the star **19 Vulpeculae**. This 5th-magnitude orange-red giant is flanked on either side by a 7th- and an 8th-magnitude blue-white stars. The companions are not physically related to 19 Vulpeculae, but they make a nice binocular triple all the same. Scan a little more than 5° east-northeast of 19 Vulpeculae to pick up the open cluster **NGC 6940** (just outside the field of view of the image on page 58). Even in the rich star fields of the galactic band, you'll have no trouble spotting this 6th-magnitude marvel, which packs dozens of stars into an area 25′ in diameter. Virtually all the true cluster members are 11th magnitude and dimmer, but you may be able to resolve a few brighter foreground stars. Also see if you can detect a northeast-southwest elongation of the cluster.

Angling Around the Eagle

Now we're going to reverse course and fly south to link up with Aquila, the celestial Eagle. The most eye-catching spectacle here is the three-star chain formed by Altair, or Alpha Aquilae, and its attendants Alshain and Tarazed — Beta and Gamma Aquilae, respectively. About 4½° southwest of Tarazed, look for 4.4-magnitude Mu (μ) Aquilae. Just north of the star you'll spot a neat little dagger of 7th- to 8th-magnitude suns spanning roughly 1°. My friend David DeLano pointed out this grouping to me years ago on an observing run at the Salton Sea in southern California. Although this asterism could be mistaken for an open cluster, I've never found a named object plotted here on star atlases, so for convenience I refer to it as **DeLano's Dagger**.



FROM THE EAGLE TO THE SERPENT BEARER Many open clusters reside in this part of the sky, all perfect objects at which to point your binoculars. Also, this is where we're looking at the Great Rift and seeing the galactic bulge rise up above the plane.

ALAN DYER

▲ **STELLAR CONGLOMERATIONS** Open clusters are great targets for binoculars, and many are on offer on this tour. You'll find NGC 6633 (at top right in the image above) in Ophiuchus and IC 4756 (bottom left) in Serpens Cauda, or the Serpent's Tail.

ALSON WONG

Let's turn to the northwestern corner of Aquila, where Zeta Aquilae and Epsilon Aquilae form the western wing of the Eagle. Scan a bit more than 2.5° northeast of Zeta Aquilae to spot **ΟΣΣ 178**, a wide, uneven double star. With a separation of 90″, this 5.7-magnitude yellow giant and its 7.6-magnitude white companion were an easy split in my 15×70s even at low magnifications.

Pause here and take in the naked-eye view. Under clear, dark skies you'll see that the bright star fields of the galactic arms are riddled with dark nebulae, quite apart from the Great Rift that slashes from northeast to southwest. I'm not much of a dark nebula observer — I can hum the tune, so to speak, without knowing the words — but I appreciate the beauty and complexity that these vast dust clouds lend to the field.

In particular, look for a broad band of light forming a shallow arc stretching more than 20° from Zeta Aquilae to Beta Ophiuchi and the eastern shoulder of the celestial Serpent Bearer. Here we start to see the central bulge of the Milky Way rearing above the plane of the galaxy. The galaxy's Great Rift broadens out at this point as well, into a wide delta of darkness that Russian-American astronomer Sergei Gaposchkin called "the Sweep." As viewed from Earth, that dark dust is superimposed on the more distant galactic bulge, defining the southeastern border of the stellar superhighway that curves between Aquila and Ophiuchus. We'll follow that road in the home stretch of this tour.

Start 5° southwest of Zeta Aquilae with **NGC 6709**. This 6.7-magnitude open cluster is composed mostly of faint stars; for a challenge, scan the eastern half for a close pair of 9th-magnitude red giants. But wait — there's more! Put the cluster on the eastern side of your field of view to find a narrow wedge, densely packed with stars, that fans about 3° west-northwest from NGC 6709. This wedge looks a bit like the tail of a comet streaming away from the cluster, and it's bookended at its corners by two nice optical doubles (all 7th magnitude): HD 172827 and HD 172744 to the northeast and HD 171975 and HD 172010 to the southwest.

Of Snakes and Handlers

Another 6° sweep to the south-southwest will bring you to a rich field with two bright open clusters, **IC 4756** and **NGC 6633** (both magnitude 4.6). IC 4756 is in the northernmost reaches of Serpens Cauda, the tail of the celestial Serpent, and NGC 6633 takes us across the border into Ophiuchus. IC 4756 is more distant, at roughly 1,600 light-years compared to 1,200 light-years for NGC 6633, so its larger apparent size is genuine. I see twisting star chains winding out from the center of IC 4756 like the arms of a starfish. As for NGC 6633, amateur astronomers Michele Bortolotti and Guido Rocca of Verona, Italy, pointed out the resemblance of the cluster to their home country's famous boot shape. To me the correspondence is striking — there's even a stellar Sicily anchored on the 6th-magnitude foreground star HD 170200.

Two more lovely open clusters await us in the eastern shoulder of Ophiuchus. Start at Gamma Ophiuchi and look 1.5° due south for the open cluster **Collinder 350**. The light of this 6.1-magnitude cluster is spread across an area larger than the full Moon, so it's easy to overlook. My 15×70s reveal a sprawling swarm of 9th- and 10th-magnitude stars that barely congeals out of the rich background glow of the Milky Way.

The last stop on our tour is another open cluster, but it's no elusive faint fuzzy. A little more than 1° northeast of Beta Ophiuchi you'll see **IC 4665** — and you *will* see it. With a magnitude of 4.2, a diameter of roughly 1°, and a face spangled with 6th- and 7th-magnitude suns, this wonder is a true binocular showpiece. Despite the visual fireworks, somehow IC 4665 evaded cataloging for a long, long time. Although it was independently discovered many times — by Philippe Loys de Cheseaux in 1745, Johann Elert Bode in 1782, and Caroline Herschel in 1783 — the cluster wasn't added to the *Index Catalogue* until 1908, when Solon Bailey of Harvard College Observatory spotted it on a photographic plate. Imagine: After more than 160 years of telescopic observation, a naked-eye cluster in the Milky Way was finally cataloged from a photograph!

We pause here at the margin of the galactic center, where dense congregations of star clusters and nebulae beckon us through Scutum and Sagittarius, the Shield and the Archer, toward the glittering heart of the Milky Way. For me, that will require another article (or several), but you can continue your exploration of our galactic home on the next clear night.

Bon voyage, traveler!

■ Contributing Editor **MATT WEDEL** loves few things more than bushwhacking through the hinterlands of the Milky Way with binoculars. He's probably out doing that right now.

FINDER CHART: Go to **https://is.gd/Bino_Ramble_finder_chart** for a widefield finder chart of the targets featured in this article.

Treats for Binoculars

Object	Type	Constellation	Mag(v)	Size/Sep	RA	Dec.
Epsilon Lyrae	Multiple star	Lyra	4.7, 4.6	209″	$18^h\ 44.3^m$	+39° 40′
Zeta Lyrae	Multiple star	Lyra	4.3, 5.6	44″	$18^h\ 44.8^m$	+37° 36′
Delta Lyrae	Multiple star	Lyra	5.6, 4.3	10′	$18^h\ 54.0^m$	+36° 56′
Stephenson 1	Open cluster	Lyra	3.8	40′	$18^h\ 54.5^m$	+36° 54′
M57	Planetary nebula	Lyra	8.8	86″ × 63″	$18^h\ 53.6^m$	+33° 02′
M56	Globular cluster	Lyra	8.3	7.1′	$19^h\ 16.6^m$	+30° 11′
Alpha Vulpeculae	Star	Vulpecula	4.4	—	$19^h\ 28.7^m$	+24° 40′
8 Vulpeculae	Star	Vulpecula	5.8	—	$19^h\ 29.0^m$	+24° 46′
Stock 1	Open cluster	Vulpecula	5.2	52′	$19^h\ 35.8^m$	+25° 10′
Vulpecula OB1	OB association	Vulpecula	—	—	$19^h\ 44.0^m$	+24° 13′
Brocchi's Cluster	Asterism	Vulpecula	3.6	90′	$19^h\ 26.2^m$	+20° 06′
M71	Globular cluster	Sagitta	8.1	7.2′	$19^h\ 53.8^m$	+18° 47′
M27	Planetary nebula	Vulpecula	7.1	480″ × 340″	$19^h\ 59.6^m$	+22° 43′
19 Vulpeculae	Star	Vulpecula	5.5	—	$20^h\ 11.8^m$	+26° 49′
NGC 6940	Open cluster	Vulpecula	6.3	31′	$20^h\ 34.4^m$	+28° 17′
DeLano's Dagger	Asterism	Aquila	—	1°	$19^h\ 35.0^m$	+07° 53′
ΟΣΣ 178	Double star	Aquila	5.7, 7.6	89.6″	$19^h\ 15.3^m$	+15° 05′
NGC 6709	Open cluster	Aquila	6.7	13′	$18^h\ 51.3^m$	+10° 19′
IC 4756	Open cluster	Serpens Cauda	4.6	40′	$18^h\ 38.9^m$	+05° 26′
NGC 6633	Open cluster	Ophiuchus	4.6	27′	$18^h\ 27.2^m$	+06° 30′
Collinder 350	Open cluster	Ophiuchus	6.1	40′	$17^h\ 48.2^m$	+01° 18′
IC 4665	Open cluster	Ophiuchus	4.2	41′	$17^h\ 46.3^m$	+05° 43′

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.

Testing Askar's Versatile V Scope

This modular telescope offers the choice of two apertures and six focal lengths for a versatile astrophotography package.

◀▲ Askar's new V refractor is a versatile telescope (perhaps that's what the "V" stands for) that comes with 60-mm and 80-mm objective lenses and three field flatteners for imaging. The background photo was made with the 60-mm and reducer lens.

ALL IMAGES COURTESY OF THE AUTHOR

Askar V

U.S. Price: $1,695
sharpstar-optics.com

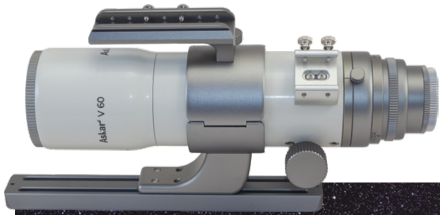
What We Like
Sharp optics
Excellent fit and finish
Versatile choice of focal lengths

What We Don't Like
Minor off-axis aberrations
Adapter threads can bind
Pungent foam in case

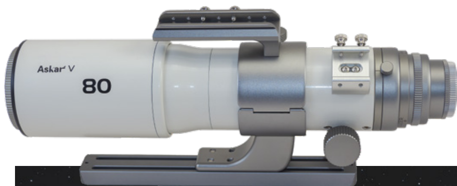
JIANXING SHARPSTAR OPTICAL INSTRUMENTS has certainly taken the astrophoto world by storm in recent years. The company has introduced many lines of telescopes, both refractors and reflectors, under the Sharpstar brand and also under their subsidiary Askar brand.

I previously reviewed several Sharpstar models, most recently the Askar FMA230 and Askar FRA500 astrographic refractors (*S&T:* July 2022, p. 64). With so many telescopes in the Sharpstar/Askar catalog, deciding which is the best for your particular needs can be confusing. Here's one solution: a modular telescope that's really six telescopes in one, dubbed the Askar V.

I tested an early unit on loan from Sharpstar. I was told the final shipping production scopes differ from the sample I tested only in having shorter threads for attaching accessories and a minor cosmetic change to the focuser.



The 7.5° by 5° field of the Askar V's 60-mm lens combined with the reducer is ideal for framing wide star fields in the Milky Way, such as the one shown here in Gemini. This is a stack of 3-minute exposures at f/4.5 with a filter-modified, full-frame Canon R camera.



The Askar V with the 80-mm lens and extender provides a 3.4° by 2.3° field and 600 mm of focal length — enough reach for framing galaxy groups such as the Leo Trio. This image is a stack of 3-minute exposures at f/7.5 with a Canon R.

The V Scope Concept

The idea of a modular telescope isn't new. For many years, Japanese manufacturer Borg has offered instruments with swappable front objectives and a choice of focusers.

Sharpstar takes the concept a step further by offering a single package that includes three field-flattener lenses, which each work with the included 60-mm and 80-mm objective lenses, at an attractive price.

The Askar V comes in a carrying case that houses the assembled scope with its 80-mm f/6.25 objective, with room for the 60-mm f/6 objective and the three accessory lenses: a 0.75× reducer corrector, a 1× flattener, and a 1.2× extender corrector. You even get a blower brush for cleaning the optics — very nice!

In all, when first opening the case, the array of gear is an impressive sight, making for a satisfying unboxing experience. Not so impressive is the smell! I've never had to criticize the smell of a telescope case before, but the foam padding emits quite a pungent chemical odor, though it does dissipate after a few weeks.

Each flattener accessory has two barrel positions: Retracted for use with the 80-mm lens, and extended when paired with the 60-mm. You change the settings by turning the black barrel until it comes loose, then pushing it in or pulling it out until a second set of threads engages to lock the lens in the new position.

Each flattener has metal front and rear screw-on caps that are the same for all three units, so there's no fussing with getting the correct caps back on each. The rear of the unused objective lens also has a screw-on metal cap to protect the optics when not on the telescope. Though the two front lens caps are identical and can be interchanged, they are labeled "60" and "80".

With the 80-mm objective and heaviest flattener lens, the Askar V weighs 3.6 kilograms (7.9 pounds) and is 44.5 centimeters (17.5 inches) long with the dew shield retracted. With the 60-mm lens, the V weighs 3 kg and is 35.3 cm long. The entire package with both lenses and the three flatteners in the case weighs 7.9 kg, within airline baggage carry-on limits, though at 23 inches long the case might exceed the length allowed.

Mechanical Quality

The Askar V tube is painted with a textured cream enamel, with all the fittings finished in a matte silver. The overall appearance is one of quality and

▲ The Vixen-style dovetail bar's long slots facilitate balancing the telescope when used with heavy cameras and accessories. Buying another dovetail bar, which is often required with small telescopes, shouldn't be necessary.

▲ The three included flatteners can each be configured to operate with either the 60-mm or 80-mm objectives by sliding their internal barrels between two locking positions. All are shown in their extended 60-mm settings.

▲ The V comes in a carrying case with labeled receptacles for the 60-mm objective and three flattener lenses. Removing a foam cutout makes room for an optional user-supplied electronic focuser.

luxury. The focuser is a 2-inch-format, dual-speed rack-and-pinion model with 90 mm of travel. That's more than enough to accommodate the various focus positions required by the three flatteners, as well as for visual use with a user-supplied 2-inch star diagonal. Despite the V's modularity, the focuser isn't removable.

There's a graduated scale on the focuser barrel for ease of resetting focus when you swap lenses and flatteners. A welcome feature is the lockable camera rotator with a degree scale. Its motion was smooth and didn't shift focus when turned, nor did it introduce any tilt of the camera that I could detect.

However, I found the single index mark could end up out of sight under the barrel, making the scale less useful in practice.

The focuser proved to be smooth and precise. With a heavy load of a two-inch star diagonal and big Tele Vue 42-mm Panoptic eyepiece, it racked in and out with no slippage of either the coarse- or fine-speed motions, even when the scope was aimed straight up. I never had an issue when focusing my Canon cameras, either.

Each flattener includes an M54-to-M48 adapter ring, for attaching camera T-rings or adapter tubes. The ring accommodates 2-inch filters and has threads that are readily accessible and not deeply recessed as in some of Sharpstar's other telescopes.

The tube is held securely in a single clam-shell cradle, equipped with a handle machined with a Synta-standard dovetail channel for accepting guidescopes or other ride-along accessories, such as a minicomputer. Another Synta dovetail bracket on the tube provides a second attachment point, and there are holes on the focuser for bolting on a third shoe if needed.

The tube comes with a generous 29-cm-long Vixen-style dovetail bar, which has dual slots along its full length. As with most anodized dovetail bars, I found this one's lovely finish was easily scratched.

Screwing the objectives off and on the tube took little effort as the threads have a slight film of lubricant to make the motion smooth, without binding or chatter. I had no issues with collimation shifts after swapping one lens for the other.

As with the Askar scopes I previously tested, I found the rear adapters could bind, making them tough to remove at times, particularly after being inadvertently tightened when installing a camera. If this were my scope, I would apply a little lubricant here.

The 60-mm objective comes with an integrated 70-mm-deep dew shield that cannot be removed or retracted. The 80-mm lens has a sliding dew shield that extends out 65 mm. While its motion is smooth and secure, there's also a lock screw to hold it in place.

In all, the impression of the V is of a solidly made telescope with top-class fittings and no plastic parts. Even the slip-on cover for the fine focus knob is machined metal. The telescope was a nightly pleasure to use.

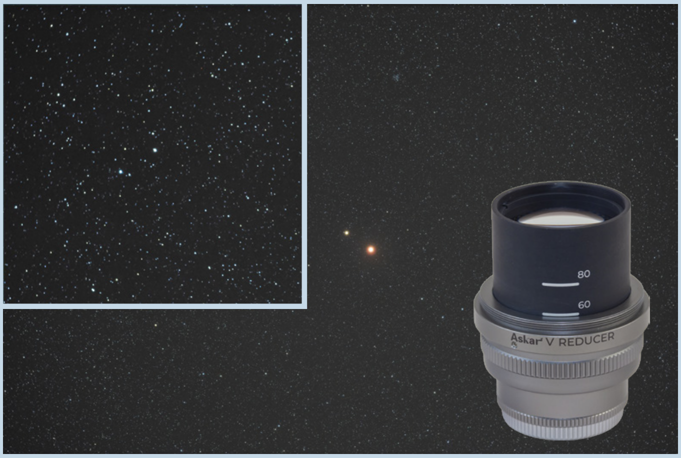
Visual Performance

While photography is clearly the main purpose of the V ensemble, both 60-mm and 80-mm objectives can be used visually with the included 2-inch visual back. In a high-power star test, I saw no sign of astigmatism from malformed or pinched optics and, once cooled down, only the barest trace of spherical aberration, true of most refractors I've tested. In focus, stars looked textbook-perfect, with cleanly defined central Airy disks surrounded by crisp first diffraction rings and suppressed outer rings.

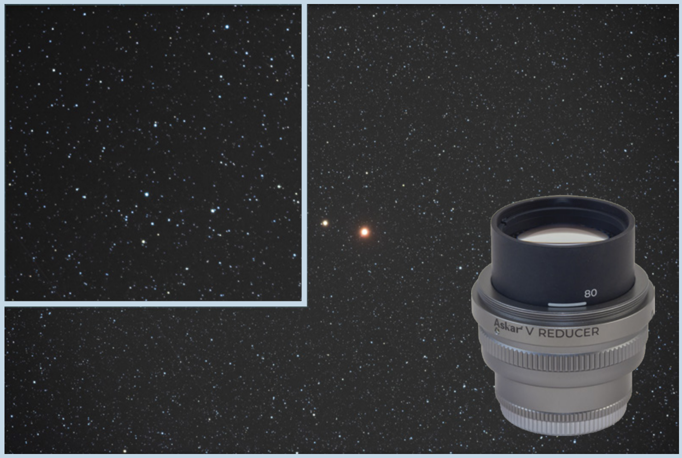
The main lenses are each triplets incorporating two ED elements of anonymous glass type. In focus, there was no sign of chromatic aberration even on Venus or on bright stars. Inside focus I detected only a trace of a magenta rim and a faint cyan rim outside focus when examining bright stars. This was color correction as good as I have seen in all but the very finest apochromatic refractors. This level of performance means either combination can serve as an excellent visual telescope even for high-magnification view-

▼ This array of pictures compares each of the Askar V's six photo combinations. The full image illustrates the level of vignetting, while an enlargement of the upper left corners displays edge aberrations. All are single images taken the same night, April 13, 2023, when Mars (on the right) was close to the star Epsilon Geminorum.

60-mm with Reducer



80-mm with Reducer



60-mm with Flattener

80-mm with Flattener

60-mm with Extender

80-mm with Extender

▲ The trio of images in this column shows the 60-mm objective with the 0.75× reducer, 1× flattener, and 1.2× extender, yielding focal lengths of 270 mm, 360 mm, and 446 mm, and f-ratios of f/4.5, f/6, and f/7.4, respectively. The reducer and extender each produce astigmatic stars at the corners, but the flattener is nearly perfect. A similar level of vignetting appears in each.

▲ This column's trio of images shows the 80-mm objective with the same reducer, flattener, and extender but now yielding focal lengths of 384 mm, 495 mm, and 600 mm, and f-ratios of f/4.8, f/6.2, and f/7.5, respectively. The reducer and flattener show very slight star elongation, but now the extender is nearly perfect. The 80-mm paired with the reducer produced the most vignetting of the six combinations.

▲ The focuser includes a handy degree scale on the camera rotator. The flatteners each present a camera-side M54 male thread, into which screws an adapter ring that presents an M54 female thread. A step-down adapter screws into that, with camera-side male M48 threads, and that can accept a 2-inch filter, as shown.

ing, with the little 60-mm particularly attractive as an airline-portable scope.

Photographic Performance

Each flattener requires the standard back focus of 55 mm to the camera sensor. I tested all six combinations with my full-frame Canon R, fitted with a Canon RF-to-48-mm T-ring.

The 60-mm objective and reducer combination produced the worst off-axis performance, with stars beginning to elongate beyond a 30-mm image circle. The 60-mm plus flattener combination yielded nearly perfect stars to the corners of a full-frame detector.

The same objective mated with the extender showed some elongation at the frame corners.

The 80-mm and reducer pairing had only minor star bloating at the extreme corners but did show the most darkening of the corners from vignetting. The 80-mm and flattener combination exhibited only minor aberrations at the corners, while the 80-mm and extender lens pairing produced nearly perfect stars corner to corner. Test images recorded only a trace of chromatic aberration, which added slight blue halos to stars in most of the combinations.

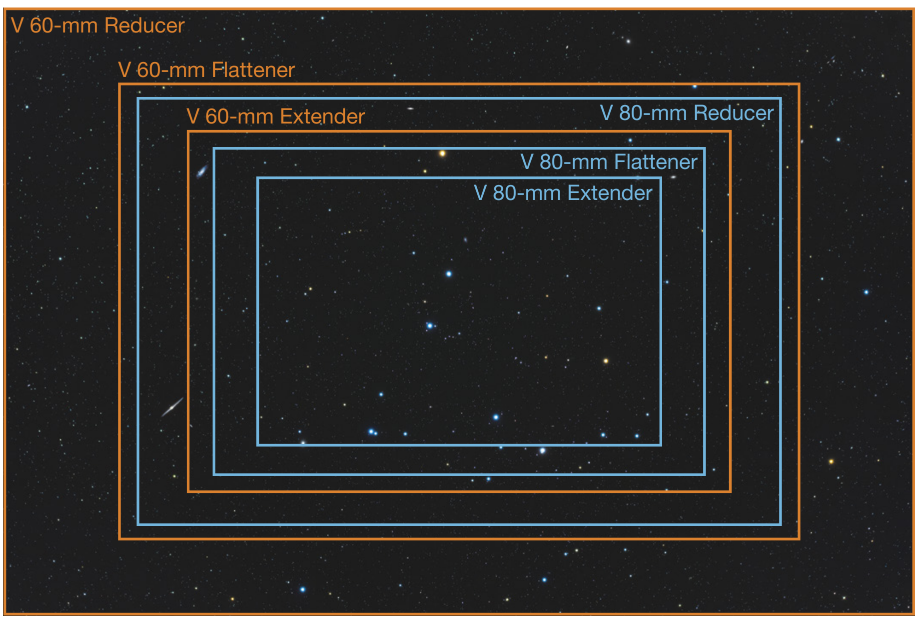
Mix and Match

One important consideration is the field size each combination offers. The 60-mm with the field flattener provides a nearly identical field (5.6° by 3.8° with a full-frame sensor) as the 80-mm with the focal reducer (5.5° by 3.7°). Likewise, the 60-mm and extender (4.7° by 3.1°) is similar to the 80-mm with the flattener (4.1° by 2.7°). However, in both cases using the 80-mm lens provides about a one-stop faster photographic speed.

The little 60-mm objective is most useful when combined with the reducer for a generous 7.5° by 5° field and 270-mm focal length at f/4.5, great for large nebulae and star fields. The 80-mm with the extender provides the other extreme choice: 600 mm of focal length at f/7.5 for a 3.4° by 2.3° field of view. That's tight enough to be useful for bright galaxies and groups of galaxies.

The 80-mm with the reducer (at f/4.8) or flattener (at f/6.2) will be the prime combinations for most other targets. However, the 60-mm will have the advantage of providing similar fields in a smaller package, useful for travel to remote dark-sky sites or to eclipses.

So, while the Askar V ostensibly allows users to choose between six focal lengths, in practice only four are likely to be employed, with the 60-mm lens reserved for targets that need its wide field with the reducer, or when portability is paramount.



▲ The above picture illustrates the fields of view that each V combination delivers, on a background image of Melotte 111 taken with the 60-mm lens and reducer for the widest field. Two pairs of combinations produce similar fields of view.

Recommendations

The Askar V is such a good deal that I have to wonder if Sharpstar Optical isn't undermining sales of its other telescopes by introducing it. The cost of buying three or four separate telescopes and their optional reducers makes the V an extremely attractive package.

It's not quite a jack of all trades, but for a portable apo astrograph it comes close, without the downfall of being a master of none. While individual telescopes optimized for each focal length might provide slightly better performance on- and off-axis, I saw no aberrations with the Askar V, either visually or photographically, that would make me not recommend it. And its mechanics had no compromises to speak of.

For someone willing to spend a little more than for one apo refractor (for example, the Sharpstar 61 EDPH III with reducer is $750), you get a very versatile package, good for both Milky Way star fields and bright autumn galaxies. If the V stands for "versatile," the model is well-named.

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

▲ SMART GUIDER

Celestron unveils its latest innovation in the form of a guiding system for its telescopes that does much more than guide your photos. The StarSense Autoguider ($799.95) is a computerized camera and optic that automatically aligns your Celestron telescope system in three minutes with no user input. The unit consists of a CMOS camera with an integrated micro-computer and lens that examines a star field and identifies star patterns to quickly establish exactly where the telescope is pointing. It uses a Sony IMX290LLR monochrome detector paired with a dual-core processor to boost the pointing accuracy of your Celestron telescope system. The device includes an easy polar-alignment routine and will also track celestial objects with sub-arcsecond accuracy. Its 4-element, 28-mm optics provide sharp stars across the detector, ensuring adequate guide stars are found with virtually every pointing. The StarSense Autoguider works with recent NexStar+ hand controllers and its *CPWI* telescope control software.

Celestron
2835 Columbia St., Torrance, CA 90503
310-328-9560; celestron.com

▲ PLANETARY IMAGER

Camera manufacturer QHYCCD announces a new camera for planetary imaging and autoguiding. The QHY5III715C ($199) is a high-speed video camera designed around a Sony IMX715 color CMOS detector, which has a 3,840 × 2,192 array of 1.45-micron-square pixels. The small pixels in this 8.4-megapixel camera achieve a spatial resolution of less than 1 arcsecond per pixel when paired with optics having a focal length of just 300 millimeters (12 inches). The camera can record up to 42 frames per second in 8-bit mode, or 23 fps in 16-bit format, and an internal, 512-megabyte DDR3 image buffer ensures no frames are dropped during downloads. Its body is designed to fit directly in any 1¼-inch focuser and requires just 8 mm of back focus. The QHY5III715C also functions as an autoguider and connects to your telescope mount via an ST-4-compatible guide port. Each purchase includes a 1.5-meter USB 3.2 Type-C cable, a 2-meter guiding cable, replaceable adapters for C-mount and 1.25-inch filters, and a focus locking ring.

QHYCCD
503, Block A, Singularity Center, Shahe Town, Changping District, Beijing, China 102206
+86(10)-80709022-602; qhyccd.com

◀ TINY GO TO

Mount manufacturer iOptron rolls out another model in its popular line of strain-wave mounts. The HEM15 Hybrid SWG Mount w/ iPolar ($1,498) uses a high-torque, strain-wave drive in its right ascension axis and a belt-driven declination motor to achieve precision slewing and tracking throughout the sky. The mount head weighs just 2.5 kg (5.5 lb) yet boasts a load capacity of 8.2 kg without the need of cumbersome counterweights and shafts. The HEM15 also includes a built-in iPolar electronic alignment aid. The mount is controlled with the *iOptron Commander Lite* app (available for Apple and Android devices) or other compatible third-party software and apps connected via its internal Wi-Fi. Users attach their optics with Vixen-style dovetail mounting plates. Each purchase includes a soft carry case and a limited two-year warranty.

iOptron
6F Gill St., Woburn, MA 01801
781-569-0200; ioptron.com

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

The Right (Angle) Polar Scope

Gain years more enjoyment from your equatorial mount.

◀ The right-angle adapter simply pushes onto the eyepiece of the polar-alignment scope.

REGULAR READERS of this column will know that I'm not especially fond of German equatorial mounts. My reason is mostly due to the contortions a person must go through to observe with one, but it's also due to one particular contortion during setup that gets harder and harder as I age: hunkering down to sight through the polar-alignment scope.

New York amateur Tom Deever had the same problem, but unlike me, he figured out a fix that let him continue to enjoy his mount. Tom reasoned that right-angle finderscopes eliminate the bending over to look through a straight-through finder, so why couldn't a person make a right-angle polar scope?

Tom started with a simple mirror, hoping that would let him peer through the polar scope from above, but that proved unsuccessful due to the much farther distance between his eye and the finder's eye lens. There simply wasn't enough eye relief for the mirror. Tom says, "After that failure, I realized what I needed was a very simple, inexpensive optical relay system."

A relay lens takes the focused image coming out of a telescope and sends it onward to a second focal point or to another relay lens. With the right combination of lenses, you can extend the focal point outward as far as you like. You'll find relay lenses in periscopes, endoscopes, and even the Orion Linear Binoviewer that I wrote about in the March issue.

Tom had a 7× loupe handy, and he noticed that the lens housing would fit nicely into the smaller side of a right-angle telescope diagonal that he also had on hand. A 7× loupe has a focal length of approximately 1.5 inches (3.8 centimeters), which was just about perfect. Tom says, "I have just enough optical design knowledge to be dangerous, and I realized that if I had another 1.5-inch focal length lens I could construct a relay optical system within the diagonal." He wanted the input lens to be as large as possible, so he looked for a second 1.5-inch-focal-length eye loupe lens that had a diameter around 1 inch. Finding such a lens on Amazon was surprisingly easy.

Then it was just a matter of arranging the lenses to provide a focused image on the exit side of the diagonal. You can calculate the lenses' placement, or you can simply experiment until you get an acceptable image. Tom found the location to be very forgiving, and he soon located the sweet spot for both lenses, with the diagonal used backwards compared to its normal placement in a focuser. He secured one lens in place with O-rings and the other with expansion rings.

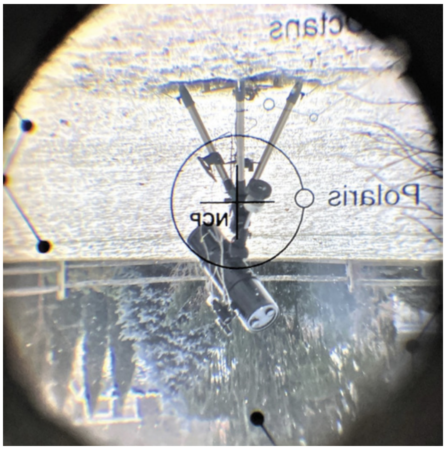
To connect the diagonal to the polar scope, Tom built a wooden framework that screws to the diagonal housing and slips over the polar scope's eyepiece. Strips of Velcro loops provide padding, leaving the setup just snug enough to stay put but providing enough adjustability to find the best final field of view.

The relay lenses add some vignetting. The original polar scope has a field of view of 8°, and Tom estimates the FOV of his right-angle system to be about 5°, so there's some loss. But since you only need to see one star (at least in the Northern Hemisphere) that needs to be about half a degree off center, there's still plenty of field for acquiring and aligning Polaris.

Even better: In experimenting with this setup on my own workbench, I found that I can push the eye relief

▲ *Left:* The adapter is simple to make and very forgiving in placement. *Right:* The first of the two relay lenses fits down inside the diagonal. That allows the eye lens to stand out a ways for more comfortable viewing.

ALL IMAGES COURTESY OF TOM DEEVER



▲ With the relay diagonal in place, the view is inverted left-right and the field is upside-down, plus there's enough chromatic aberration to name a crayon after, but that doesn't really matter when polar aligning.

well out from the diagonal, giving me that "hovering in space" look that I love so much about those wonderful RKE eyepieces that used to come with Edmund Astroscans. The image completely fills the eye lens even with my eye an inch away, providing a very pleasing view. Bear in mind that single-element lenses introduce aberrations that would be unwelcome if a person were to use this simple setup for observing, but for a polar scope they work fine.

Of course, the extra lenses and the mirror flip the images in all sorts of directions. The view winds up with the reticle inverted left-right and the sky upside down. Not a problem with a polar-alignment scope, because the reticle has an obvious placement circle for Polaris, and that doesn't change unless you alter the aim of the polar scope. All you're doing with the right-angle adapter is changing the angle at which you're looking at it.

All in all, this is a wonderfully simple modification that greatly improves the usability of an equatorial mount. My hat's off to Tom Deever.

For more information, contact Tom at **tdeever@hotmail.com**.

■ Contributing Editor **JERRY OLTION** has dug his equatorial mount out of the closet and is using it again — without back pain!

What Is a Spectrum?

▲ **NEWBORN STARS** The bright reddish glow in this image of galaxy M61 (NGC 4303) comes from ionized hydrogen (specifically, the hydrogen-alpha emission line at 656.28 nm), which marks the presence of newborn stars.

ESO / PHANGS

HOW HOT IS THAT STAR? Could we breathe the air on that exoplanet? Just how much mass is in that supermassive black hole? The universe actually provides answers to questions like these — but it's written in code that we must first decipher. And that code is embedded in the *spectrum* of light.

Most light consists of photons of many different wavelengths mixed together. We don't ordinarily see those wavelengths individually, though, unless something like a prism or even a raindrop spreads them out. Glass and water alike bend blue light more than red and can thus unfurl sunlight into all the colors of the rainbow. Astronomers may use a *diffraction grating* or a grating prism (*grism*) instead, but the function is the same.

The Code of the Continuum

We see rainbows in a whole new light when we plot their spectrum on a graph, putting wavelength on the *x*-axis and brightness on the *y*-axis. These plots reveal the shape of the continuous spectrum, or *continuum*, by showing the source's brightness at each wavelength. The continuum's shape in turn encodes information about the object that's emitting the light (such as the Sun).

Take stars. Their spectrum is characteristic of an idealized concept that physicists call a *blackbody*. Blackbodies absorb all the energy they receive, reflecting nothing, and they distribute this energy evenly within themselves. It turns out that the hot, dense gas of stars comes close to this simple ideal. But (and you might already be thinking this) the term itself is a bit of a misnomer: Since such objects can and do radiate, they are anything but black.

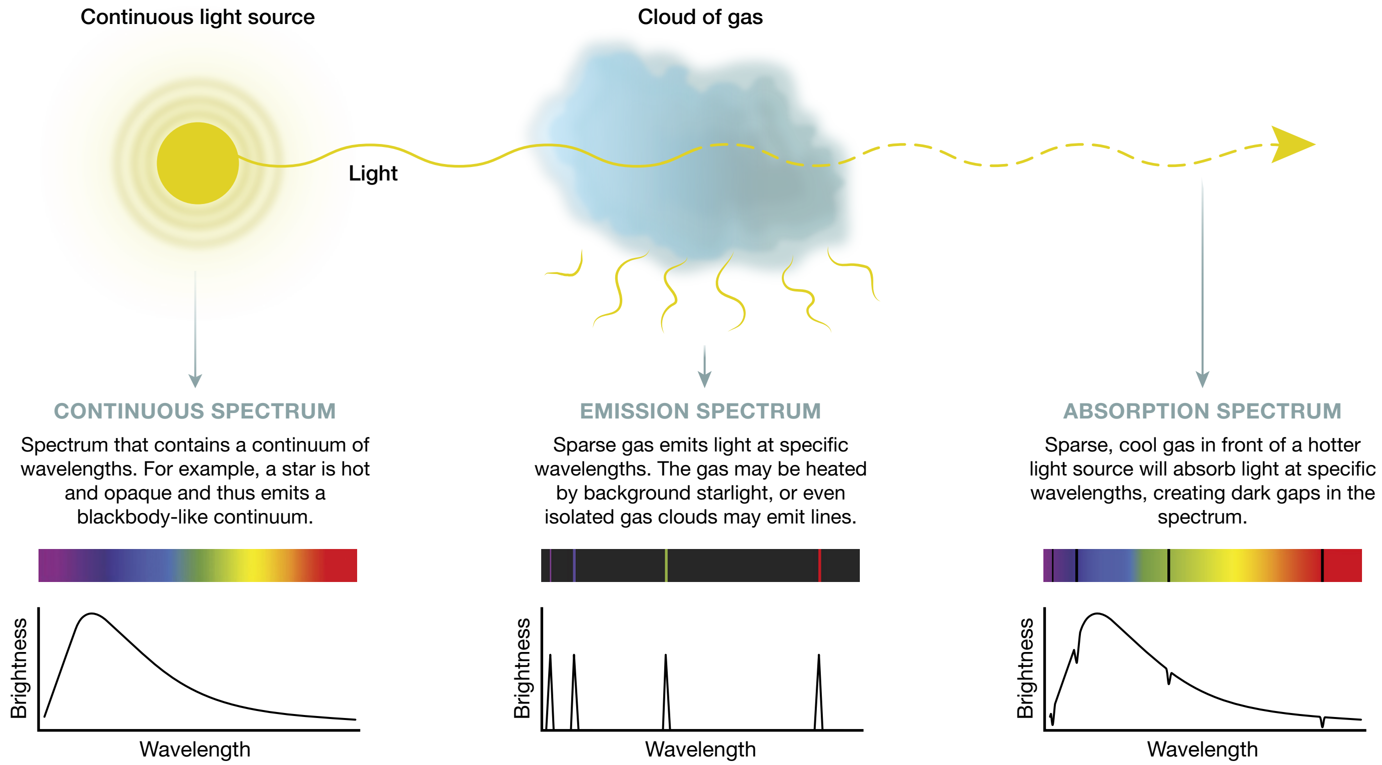
A star's spectrum brightens quickly over shorter wavelengths before fading more slowly over longer wavelengths. The wavelength at which we see the most light — the peak of the spectrum — depends on how hot the star is. You can see an example firsthand in a candle flame. The tip of the flame, where the flame is cooler, is orange in color; the hotter base, on the other hand, burns blue.

If an object is really hot — to be extreme, take a newborn white dwarf at 100,000K (180,000°F) — the continuum won't peak at visible wavelengths but rather in the more energetic ultraviolet. Likewise, the blackbody spectrum of cooler objects will peak at longer, less energetic wavelengths. The temperature of the universe itself, whose radiation we call the *cosmic microwave background*, is 2.7K and peaks at, you guessed it, microwave wavelengths.

Not all continua originate directly from heat. Light may also come from *nonthermal* sources. For example, electrons spiraling around the magnetic fields that thread a supernova remnant emit a continuum of electromagnetic waves known as *synchrotron radiation*. Depending on the energies of the electrons doing the radiating and the strength of the magnetic fields they whirl around, that continuum may come out anywhere from radio wavelengths all the way up to X-ray energies. Wherever it falls, the continuum takes on a fundamentally different shape from a blackbody, shedding light on the nature of the emitter.

Deciphering Spectral Lines

Sometimes light isn't a continuum at all. Sparse, hot gas emits light at specific wavelengths known as *emission lines*, producing not a rainbow but a series of lines arranged in rainbow order. Every



▲ **THE CIPHER** Every spectrum contains a code, usually a mixture of a continuous spectrum (or continuum) from the emitter itself as well as emission and absorption lines from intervening gas. Lab experiments and theoretical calculations help astronomers crack this code.

element or molecule emits lines in a unique series of wavelengths, a fingerprint that betrays its identity.

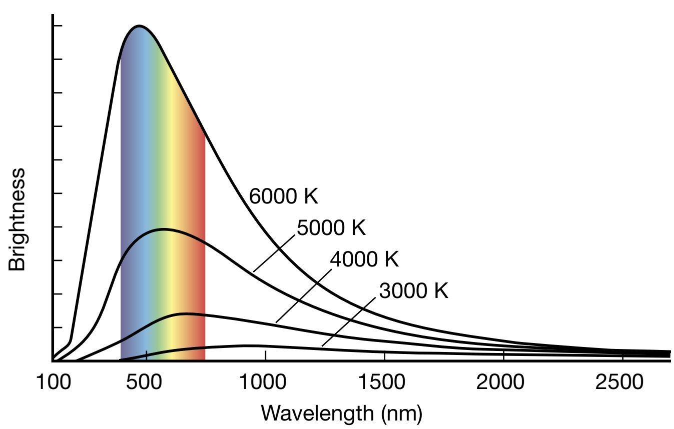
On the other hand, if the continuum of starlight passes through cooler, diffuse gas, then those specific wavelengths are absorbed instead. *Absorption lines* are how we can understand the atmospheres of distant planets: As the planet crosses the face of its star, starlight shines through the thin sliver of atmosphere visible from Earth. Gas in the exoplanet's atmosphere absorbs some of the starlight. Those absorption lines in the star's spectrum tell us what kind of air, if any, the exoplanet has. Things like the spectral line's thickness and brightness (or depth, in absorption) encode the temperature, density, and motions of the gas.

In fact, a line's mere presence can alert astronomers to unusual circumstances: Certain lines — called *forbidden lines*, but really they're only highly improbable — originate in gas more rarefied than any we can make on Earth. Astronomers use other lines to gauge certain types of activity. For example, the harsh ultraviolet radiation from newborn stars strips electrons from (or *ionizes*) surrounding hydrogen atoms, so the brightness of ionized hydrogen's emission lines can indicate how many stars are forming there.

The light emitted from objects moving away from us shifts to longer wavelengths, and vice versa, so a spectrum can also reveal otherwise-invisible motion. For example, if a star's spectral lines shift rhythmically toward the red end of the spectrum, then back toward the blue end, the star is likely orbiting an unseen companion. Similarly, a spectrum of the gas orbiting a black hole reveals motions that in turn lead to the behemoth's mass.

A spectrum, it turns out, is much more than light spread out into its component colors. It's one of the languages by which we can understand the universe around us. ■

▶ **BLACKBODIES** Stars emit continua that are close to what a blackbody would produce, so that the peak of the spectrum depends solely on the star's temperature. Most stars emit the most light within the visible range. (Note the heat and light we see come from a star's visible surface; stars' interiors are much hotter than that.)



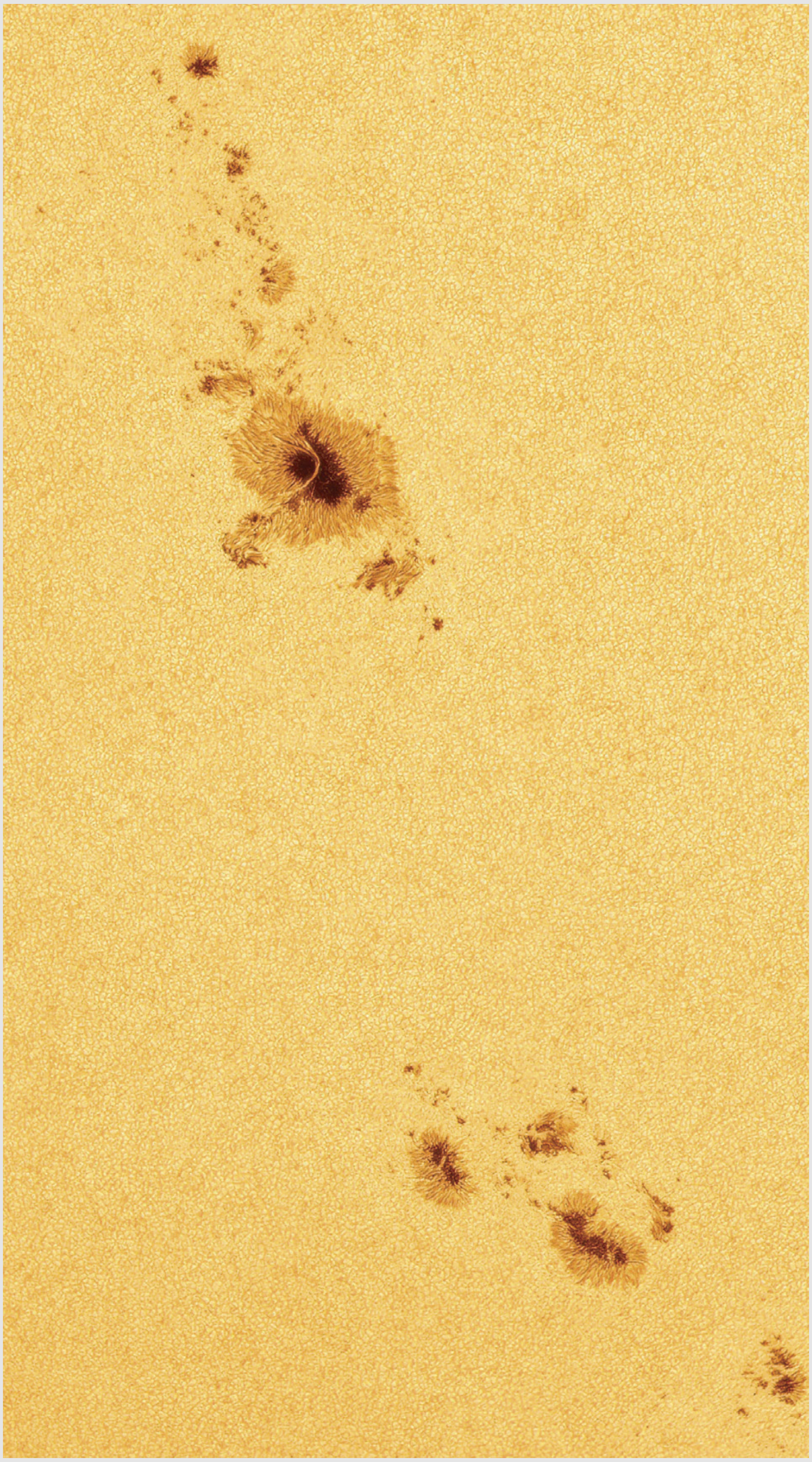
BEATRIZ INGLESSIS / S&T (2)

ELEPHANTS UNDER THE STARS

Philippe Mollet

The heart of the Miky Way from Scutum to Centaurus shines down on three elephants enjoying a watering hole in Nata, Botswana. Antares stands out above the Milky Way with Scorpius's hook hanging to its right.

DETAILS: *Canon 6D camera with 15-mm lens. Total exposure: 10 seconds at f/2.5, ISO 4000.*



△ BRIDGING THE GAP

Mark Johnston

Among the stunning light-and-dark solar granules, this high-resolution image captures two sets of sunspots decorating the photosphere in active regions 3297 and 3296. A brilliant light bridge of hot solar gas leaps over the largest sunspot at upper center.

DETAILS: *TEC APO140FL refractor and QHY5III200M camera. Stack of 120 frames through a Baader Solar Continuum filter.*

ROSY CLOUDS

Mark Johnston

Faint, pinkish clouds of emission nebulosity bridge the gap between the Trifid Nebula, M20 (top), and the Lagoon Nebula, M8 (bottom). North is to the upper right.

DETAILS: *Celestron EdgeHD 9.25-inch Schmidt-Cassegrain and ZWO ASI2600MC Pro camera. Total exposure: 2.7 hours through dual-bandpass filter.*

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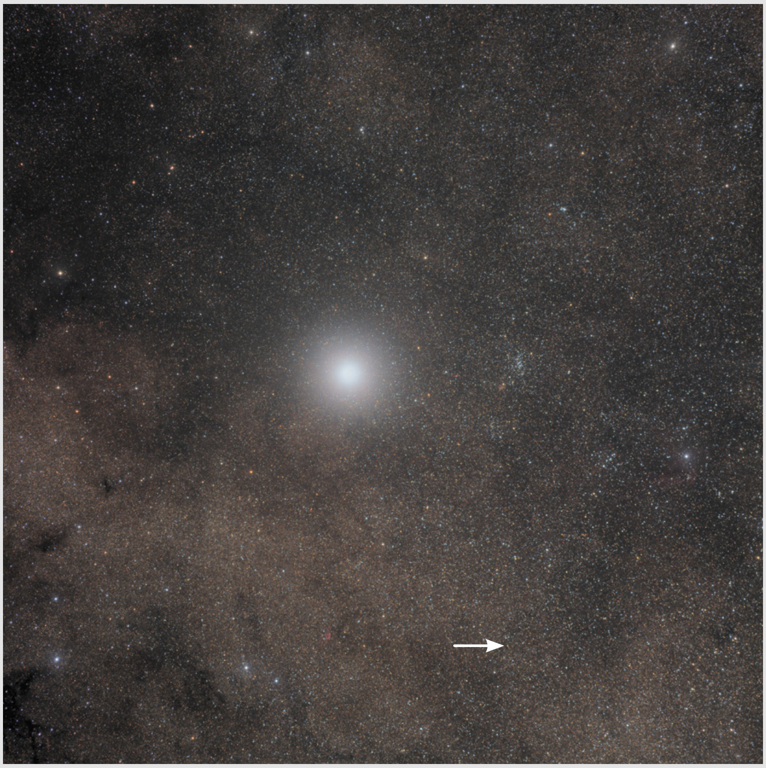


◁ HOWDY, NEIGHBOR

Dan Crowson

Rigil Kentaurus, or Alpha Centauri (center), the third brightest star in the sky, is actually a system of three stars a little more than 4 light-years away in Centaurus. The dimmest member of this system, Proxima Centauri (arrowed), is also the closest star to the Sun.

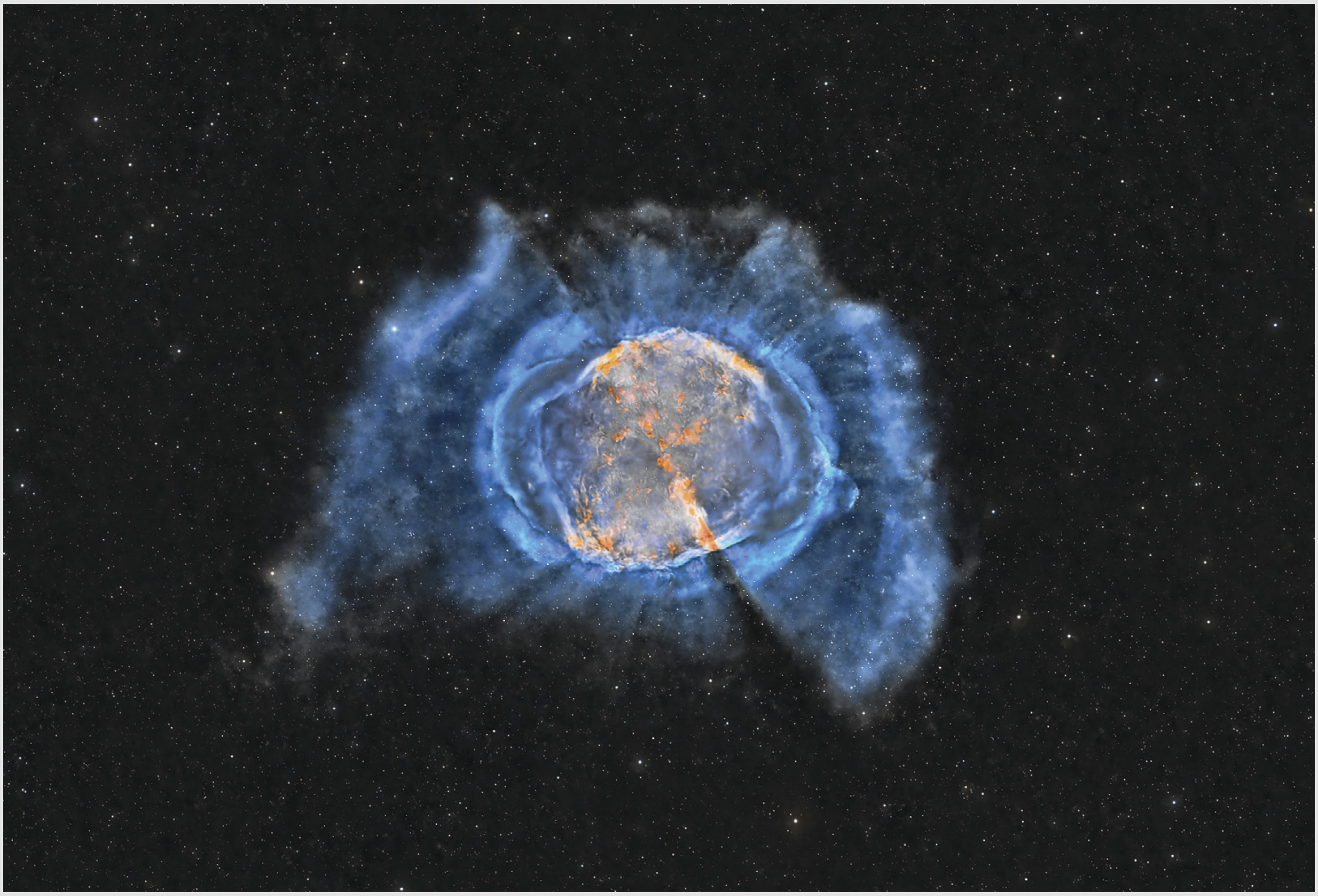
DETAILS: *Takahashi FSQ-106ED astrograph and FLI PL16083 camera. Total exposure: 56 minutes through LRGB filters.*

▽ NEBULOUS MARIPOSA

Patrick Cosgrove

Bluish shells of ionized hydrogen and oxygen expand outward from the central core of M27 in Vulpecula. In this deep narrowband image, the bipolar planetary nebula resembles a butterfly more than it does its common name, the Dumbbell.

DETAILS: *Astro-Physics 130-mm StarFire refractor and ZWO ASI2600MM Pro camera. Total exposure: 10.25 hours in narrowband filters.*



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Event Calendar

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

July 26–29
ALCON 2023
Baton Rouge, LA
alcon2023.org

August 8–12
TABLE MOUNTAIN STAR PARTY
Oroville, WA
tmspa.com

August 12–20
MOUNT KOBAU STAR PARTY
Osoyoos, BC
mksp.ca

August 14–20
MAINE ASTRONOMY RETREAT
Washington, ME
astronomyretreat.com

August 16–20
NORTHERN NIGHTS STAR FEST
Palisade, MN
https://is.gd/NorthernNights

August 16–20
SASKATCHEWAN SUMMER STAR PARTY
Maple Creek, SK
sssp.saskatoon.rasc.ca

August 17–20
IOWA STAR PARTY
Coon Rapids, IA
iowastarparty.com

August 17–20
STARFEST
Ayton, ON
nyaa.ca/starfest.html

August 17–20
STELLAFANE CONVENTION
Springfield, VT
stellafane.org/convention

August 17–20
THEBACHA & WOOD BUFFALO DARK SKY FESTIVAL
Fort Smith, NWT
tawbas.ca/dsf-info.html

August 18–20
NORTHWOODS STARFEST
Fall Creek, WI
cvastro.org/northwoods-starfest

August 18–20
NOVA EAST STAR PARTY
Smileys Provincial Park, NS
novaeast.rasc.ca

August 18–22
ALMOST HEAVEN STAR PARTY
Spruce Knob, WV
ahsp.org

September 8–16
OKIE-TEX STAR PARTY
Kenton, OK
okie-tex.com

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

Almost Forgotten

A little-known past member enriches the history of Madison's local astronomy club.

MY ASTRONOMY CLUB, the Madison Astronomical Society, got its start in the 1930s. As with most such clubs in those days, it was a man's world. But as I researched its beginnings, one woman stood out in the crowd of men.

Paula Birner, an elementary-school teacher, was new to Madison in the fall of 1934. A year before the club's birth, she had appeared on local radio stations doing a program called "Watchers of the Sky." Birner went on to be a key member as our club organized the following year, and she was omnipresent in it for the next 14 years. In an age when a woman's role in clubs like ours was largely that of spouse to her husband — the member — Birner gave talks and, later in the 1930s, authored a series of columns for the *Wisconsin State Journal* on astronomy and practical observing.

Birner married in the mid-1940s but was soon widowed. She left Madison and continued her teaching career in Racine, Wisconsin, now under her married name, Paula Birner Carey. Her life was busy: Carey was active in the teacher's union and the parent-teacher association, and she anchored various writing workshops and classes.

But her love of astronomy beckoned. In the fall of 1956, she wrote a letter to the editor of the *Racine Journal Times* appealing to others who shared her passion for astronomy. "Somewhere in Racine, or thereabouts, there must be kindred souls," she wrote. "Wish they would communicate with me. We could form a club and have some fun!"

Carey's letter worked. Within months a Racine astronomy club was formed, and she would later serve on its board. In 1963, the club built a formidable observatory — the Modine-Benstead Observatory — and in May 1964 *Sky & Telescope* published an article highlighting the achievement. Its author, of course, was Paula Birner Carey.

Her technical know-how shines through in the article. "As a Newtonian of short focal length (80 inches)," she wrote about the observatory's convertible 16-inch reflector, "it is suitable for deep-sky viewing and photography; as a Cassegrain (320 inches), it can be used for lunar and planetary studies."

I never got to meet her — she died in 1993 — but I relate to her attachment to the hobby. I imagine her playing up astronomy with her students but longing for a group of adults to share her interest in the stars. She wanted to recapture the community she'd found in Madison around observing the heavens, and she succeeded brilliantly, helping to establish not just one but two vibrant astronomy clubs in Wisconsin.

◀ **STELLAR ACHIEVER** Paula Birner Carey was a founding member of two Wisconsin astronomy clubs — one in Madison, the other in Racine. She appears here in the mid-1940s.

FAMILY OF PAULA BIRNER CAREY

Carey never remarried after her husband died in 1948, and she had no children. Details of her life and love of the hobby are hard to come by. Sometime after her retirement from teaching in Racine in the late '60s or early '70s, she returned to Madison. She must have lived out her retirement in the city where she first helped organize an astronomy club four decades before. She rejoined our Madison club and attended meetings, and she continued to serve on the board of the Astronomical League. By then she would have been in her 70s.

I questioned older members of our club, trying to find anyone who recognized the name or had even met Carey. Only one or two could bring her to mind. They remembered her attending meetings — the nice gray-haired woman sitting in the back. One of them recalls her speaking of the Racine club. But I bet nobody at the time suspected that this kind older lady sitting among them was a founder of their club.

I bet nobody at the time suspected that this kind older lady sitting among them was a founder of their club.

Carey's last recorded activity in our club was a donation she made in her mid-80s to our new observatory. To the end, she thought of the club — her first club — and wanted to see it grow.

■ **JOHN RUMMEL** is a Madison, Wisconsin-based amateur astronomer, retired school psychologist, and current historian for the Madison Astronomical Society. Reach him at **darksky2500@gmail.com**.


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