50 YEARS AGO:
Viking Reveals Mars
PAGE 20

TEST REPORT:
Explore Scientific's 8-inch Dob
PAGE 70

WORKBENCH:
Build a Bino-Lounger
PAGE 74

SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

JULY 2026

The Mystery of Ancient Star Polluters

Page 14

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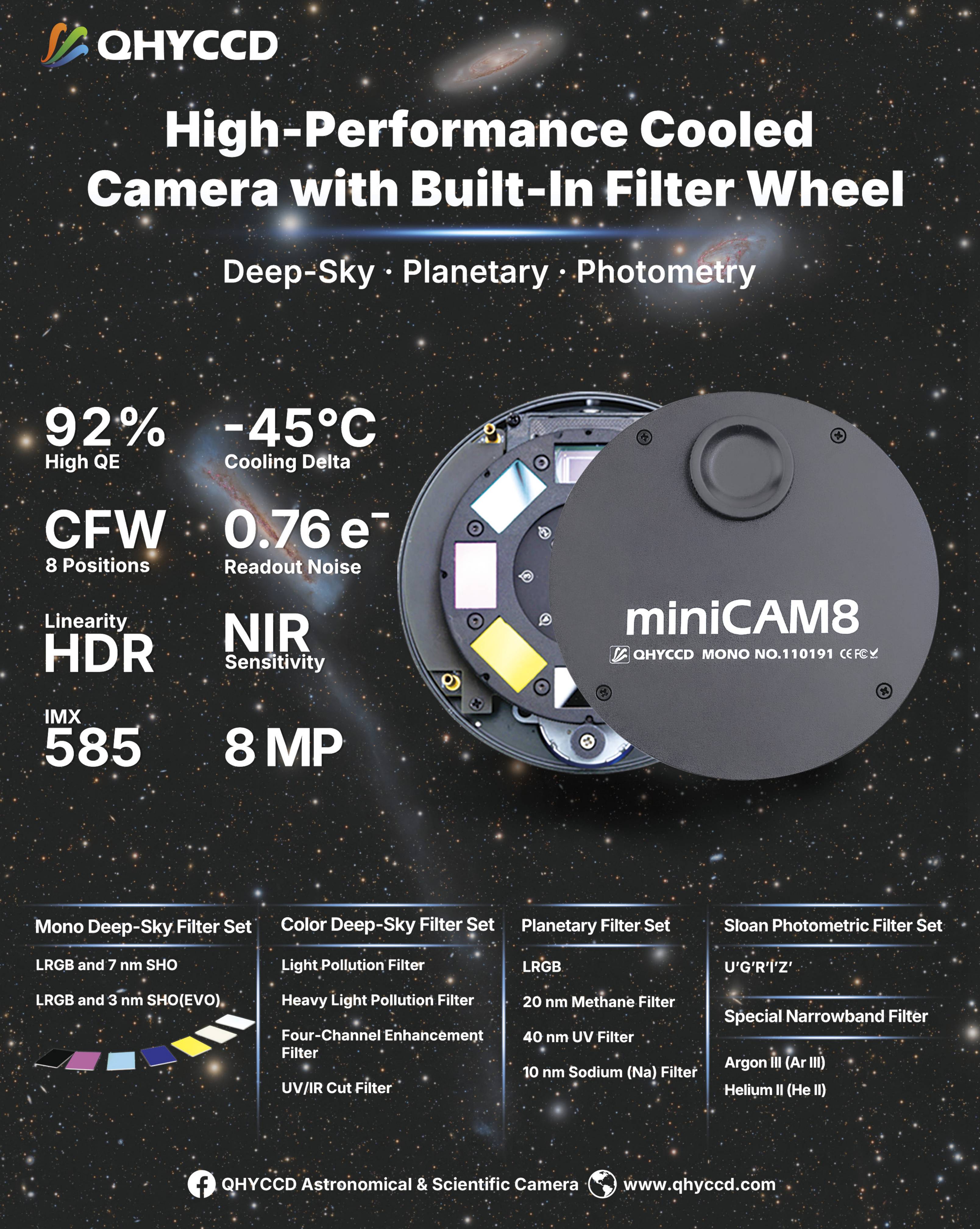
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CONTENTS

SKY&TELESCOPE
THE ESSENTIAL GUIDE TO ASTRONOMY

July 2026 VOL. 152, NO. 1

60

FEATURES

Cover Story:

14 **Ancient Star Polluters**
Strange stellar compositions are shedding light on globular clusters' early years. *By Jan Hattenbach*

20 **First Feet on Mars**
Fifty years ago, two NASA landers made history when they touched down on the Red Planet.
By Ben Evans

28 **Explore Celestial Vistas Off the Beaten Path**
Let's take a deep dive into some of summer's smaller constellations.
By Brian Ventrudo

34 **The Clover Hollow Mountain Observatory**
This residential rooftop facility puts unusual roof segments to good use.
By Paul Geithner

60 **The Big Role of Small Observatories**
How more than 300 U.S. observatories, many now forgotten, changed 1800s science.
By Trudy E. Bell

S&T TEST REPORT

70 **Explore Scientific's 8-inch Dobsonian**
By Dennis di Cicco

OBSERVING

41 **July's Sky at a Glance**
By Diana Hannikainen

42 **Lunar Almanac & Northern Hemisphere Sky Chart**

43 **Binocular Highlight**
By Mathew Wedel

44 **Southern Hemisphere Sky Chart**

45 **Stories in the Stars**
By Stephen James O'Meara

46 **Sun, Moon & Planets**
By Gary Seronik

48 **Celestial Calendar**
By Bob King

52 **Planetary Almanac**

53 **Suburban Stargazer**
By Ken Hewitt-White

56 **Pro-Am Conjunction**
By Diana Hannikainen

COLUMNS / DEPARTMENTS

4 **Spectrum**
By Diana Hannikainen

6 **From Our Readers**

7 **75, 50 & 25 Years Ago**
By Sabrina Garvin

8 **News Notes**

12 **Enchanted Skies**
By Stephen James O'Meara

58 **Book Review**
By Jaime Herndon

59 **New Product Showcase**

68 **Beautiful Universe**
By Monica Young

74 **Astronomer's Workbench**
By Jonathan Kissner

76 **Gallery**

83 **Event Calendar**

84 **Focal Point**
By Amy Steele

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ON THE COVER

The cluster Messier 15 is 33,600 light-years away in Pegasus.
PHOTO: NASA / ESA

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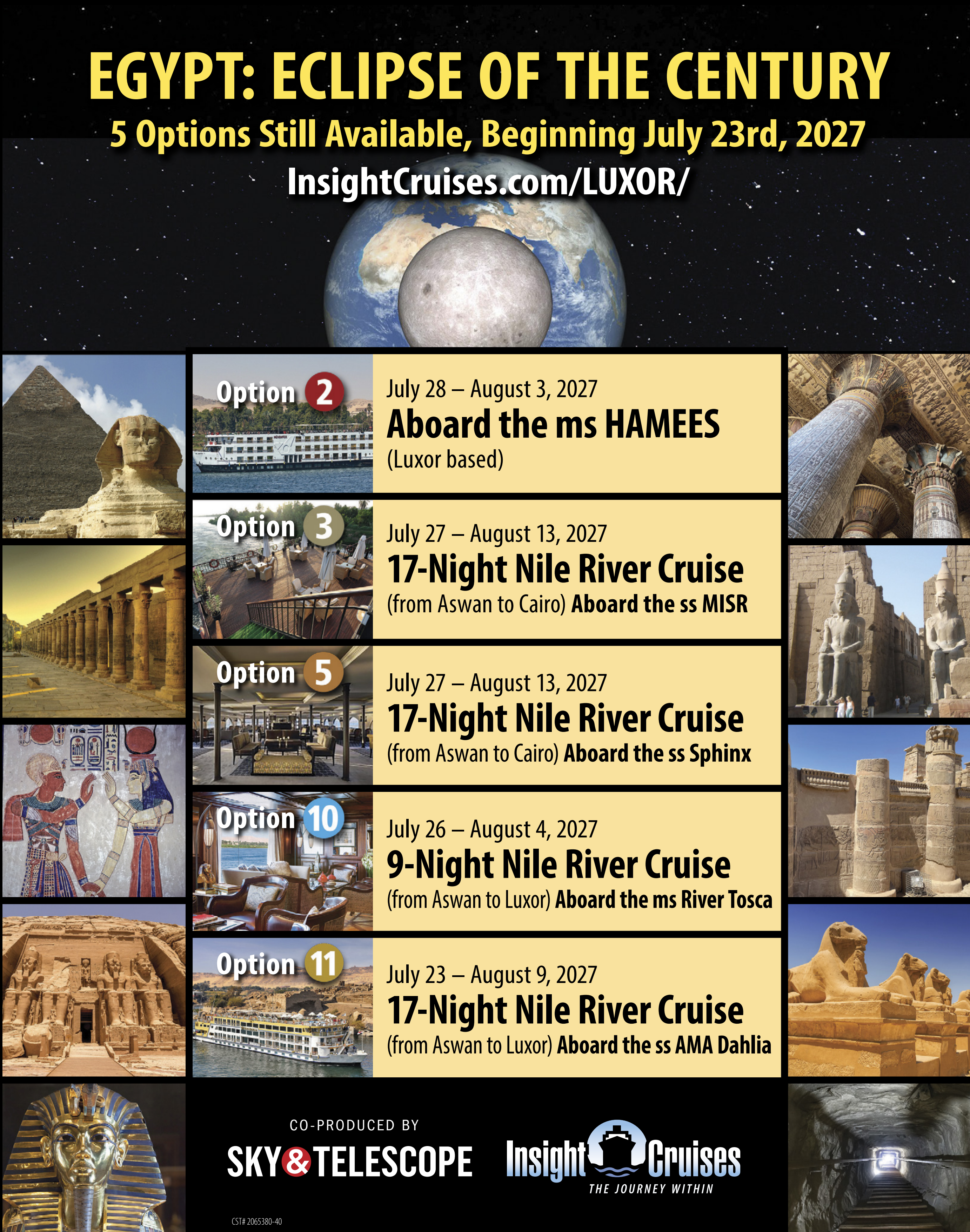
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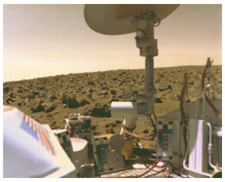
Explorations

WE HUMANS LOVE TO EXPLORE. It's almost as if it's baked into our DNA. (The paleogeneticists among you are welcome to chime in if I'm wrong.) The pioneering push starts young — just release children into nature and watch as they climb trees, follow a meandering stream, or pick rocks up to see what'll slither out from underneath.

Undoubtedly, some of our greatest exploration happens in space. We often send nifty robots as orbiters and landers to explore on our behalf. One historic example occurred 50 years ago this July, when Viking 1's lander touched down on Mars and a gobsmacked audience back on Earth witnessed the first-ever photos taken from the Red Planet's surface (page 20). The mission and its twin, Viking 2, did not achieve their goal of finding signs of life, but the two landers and orbiters transmitted more than 55,000 photos that forever changed our perception of Mars — and sparked the imaginations of untold numbers of fledgling scientists.



▲ Viking 1 landed on Mars in July 1976.

NASA / JPL

Exploration can manifest in many forms, as the various articles and columns in this issue illustrate. It can be done "from a distance," as when we turn our professional telescopes to faraway globular clusters in order to better understand their complex histories (page 14). It can involve star-hopping to celestial targets in the menagerie of July constellations (page 28). We might explore different ways in which we can incorporate a telescope into our home (page 34) or riffle through historical records to bring to life the stories of century-old observatories (page 60). Sometimes exploration can be more introspective, as when we're following detours in our life's path (page 84). Even the company behind the telescope featured in this month's test report (page 70) has "explore" in its name!

July 2026 also marks 250 years since the signing of the United States' Declaration of Independence. You will find mention of this sprinkled throughout the issue. That momentous proclamation came about due to a hardy bunch of intrepid dreamers and thinkers exploring what a better future could look like. They weren't perfect people, nor is the nation they helped create. But each generation since has carried their trailblazing spirit.

As I write this, I'm watching four souls hurtling toward the Moon aboard the Orion capsule. A few seconds before the Artemis II launch, the NASA commentator called them "four brave explorers." Hundreds of thousands gathered at the Kennedy Space Center to witness this historic moment, and legions more watched on TVs and devices around the globe. The spirit of exploration is still strong in us. Ultimately, it unites us.

Editor in Chief

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The Essential Guide to Astronomy

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P. K. Chen, Robert Gendler, Babak Tafreshi

ART, DESIGN & DIGITAL
Creative Director Terri Dubé
Technical Illustrator Beatriz Inglessis
Illustrator Leah Tiscione

ADVERTISING
Director of Strategic Partnerships Rod Nenner
ads@skyandtelescope.org

Editorial Correspondence
(including permissions, partnerships, and content licensing): *Sky & Telescope*, 1374 Massachusetts Ave., 4th Floor, Cambridge, MA 02138, USA. Phone: 617-500-6793. E-mail: editors@skyandtelescope.org. Website: skyandtelescope.org. Unsolicited proposals, manuscripts, photographs, and electronic images are welcome, but a stamped, self-addressed envelope must be provided to guarantee their return; see our guidelines for contributors at skyandtelescope.org.

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Barry Schellenberg captured IC 1396 with 179 20-minute unguided exposures on a Paramount MX without encoders.

By far, the most outstanding feature of Series 6 German equatorial mounts is that they're Paramounts.

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[1]*Five-to-ten-minute unguided exposures are more common.*

Left to right: MYT, ME, and MX

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LEWIS WEINSTOCK

I tend to browse *S&T* issues over time and was pleased to find Howard Banich's "Dive Deep into Thor's Helmet" (*S&T:* Jan. 2026, p. 58). By chance, I had just finished processing the image of NGC 2359 at left, obtained during an imaging session near Pilot Mountain, North Carolina. Although the challenges of visual observation and deep-sky imaging are different, it was rewarding to compare Banich's drawing and keen observations with my own image. Perhaps in the future, I will be inspired to take along an eyepiece or two and experience these objects "in real time."

Lewis Weinstock
Greensboro, North Carolina

Two Peas in a Pod

I very much enjoyed Mathew Wedel's Binocular Highlight columns about Puppis on page 43 of the February and March issues. I usually observe from my home 30 miles southwest of Oklahoma City, which is somewhat light-polluted. Nonetheless, Messiers 46, 47, 48, and 93 and NGC 2539 are binocularly discernible, with M47 having some nice, bright blue stars. I have often missed the opportunity to view this area around Puppis and appreciate his calling attention to NGC 2539, with brighter Puppis 19 in front. It encouraged me to further investigate with my Dobsonian. I like to view your binocular challenges with my 7×50s and then compare them with my 12-inch f/5 Dobsonian to verify any details I noticed. Telescopes are wonderful tools, but nice binoculars are just as fun. Keep up the good work.

Ted Harp
Tuttle, Oklahoma

Matt Wedel replies: *Gary Seronik's* Binocular Highlights *book was one of my first observing guides when I started out, and I used it at the telescope just as much as with binoculars. So it means a lot to me to hear about you chasing down objects from my columns with both binoculars and a scope. As you said, both instruments are equally fun and wonderfully complementary on the observing field.*

Observing OBs

I wanted to thank Stephen James O'Meara for his "enchanting" article "The Orion OB 1a Association" (*S&T:* Mar. 2026, p. 12).

I also wanted to let him know that he is not alone in observing the OB associations. I was inspired by Joseph Caruso's "In Pursuit Of OB Associations" (*S&T:* Jan. 1986, p. 110) to visually sketch a number of the objects listed in that article. (I post all my observations at **stellar-journeys.org/OB-Tour.htm**.)

Hopefully, this article by Stephen O'Meara, along with my article in the Astronomical League's June 2025 *Reflector* magazine — "Observing OB Associations" — will encourage more amateurs to seek out these often-missed but very rewarding celestial objects.

Larry McHenry
Pittsburgh, Pennsylvania

Ursa Major Pub Crawl

"Asterism BINGO" by Robin Scagell (*S&T:* Mar. 2026, p. 6), reminded me of when I lived in San Francisco not far from an Irish bar called The Plough and the Stars. But I was too young back then to partake of its offerings. Although I now live elsewhere, to my pleasure I see that they are still shining: **theploughandstars.com**.

Rus Stolling
Fresno, California

I love your star lore, and on the Big Dipper I would like to add that the ancient Romans saw that same star pattern as seven plough oxen in the northern sky. They called it the Septentriones.

My grandfather assured me that it's still called "the Plough" in Ireland.

G. Ronald Murphy, SJ
Washington, DC

Irregular Planets

I found "The Irregulars" by Javier Barbuzano (*S&T:* Feb. 2026, p. 14) interesting, especially because the title refers to their orbits, not their size or shape.

Though the orbital mechanics are different, why was the term "irregular" not considered for what have been divisively called *dwarf planets?* Even if an object is round, if it doesn't clear its orbit, it's considered a dwarf planet, which by the International Astronomical Union's definition is not a planet. Calling such an object a planet but an irregular one seems to make much more sense.

Mike Pereira
Santa Fe, New Mexico

Where's the Fire?

I have read that temperatures in outer space can reach as low as 200°–300° Celsius below zero. But for stars to begin their life, there needs to be some form of ignition or heat generation at some point in their early stages. With that kind of cold out there, how can there be any chance of initial burning? How can they ignite at such cold temperatures?

Bill Schultz
Cincinnati, Ohio

Camille Carlisle responds: *The short answer is: gravity. Stars form when clumps of gas in cold molecular clouds collapse under their own gravity. As a clump of gas collapses, its pressure and temperature rise. The protostar grows hot enough to glow, and this light starts blowing away the cocoon of infalling gas. But the not-quite-a-full-fledged-star keeps contracting due to gravity. The squeeze raises the internal pressure and temperature higher and higher. Eventually, they get so high that hydrogen fusion ignites in the star's core. It's that hydrogen fusion that makes stars shine.*

Getting Hot in Here

I must have missed something: How does the Parker Solar Probe survive the extreme temperatures?

Steven Rudnick, PhD
Santa Fe, New Mexico

Monica Young replies: *I wrote about this exact problem in my feature on Parker Solar Probe's first results back in the November 2020 issue! The key is that Parker is experiencing radiative heat. It's the difference between putting your hand in a 350°F oven to set a tray of cookies inside versus putting your hand in boiling water.*

Of course, even the radiative environment is extreme, but Parker is made of materials that can withstand that environment.

First Law of Science Fiction

I very much enjoyed reading Ajay P. Manuel's "Star Wars: The Chandrasekhar-Eddington Clash" (*S&T:* Apr. 2026, p. 14) on Chandrasekhar's work on degenerate stars and Eddington's opposition to it. Ever since I first learned about it from Virginia L. Trimble while a student of hers at University of California, Irvine, in 1984, I have considered Eddington's opposition to be the most prominent example of Arthur C. Clarke's first law: "When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong."

Alson Wong
Rancho Cucamonga, California

Hubble's Deep Dive

What keeps me so fascinated by *S&T* is the diversity of your articles. From News Notes' late-breaking discoveries, to (my favorite) the historical articles. "Hubble's First Home Run" by N. G. Boeck (*S&T:* Dec. 2025, p. 14) was another great example of history leading us forward.

I am old enough to remember the first images from the Hubble Space Telescope. The public was amazed, to say the least. But when we saw the Hubble Deep Field images, it took that fascination to a whole new level.

I very much enjoyed reading about how the whole investigation started, the process, the people involved, and its great success.

Barbara Barnes
Junction, Texas

FOR THE RECORD

- "Cracks in Cosmology" (*S&T:* Mar. 2026, p. 34) incorrectly stated that the first atoms formed in the primordial plasma 380,000 years after the Big Bang, at a temperature of around 3000 kelvin. These numbers are true for hydrogen, but neutral helium atoms actually formed earlier and at a higher temperature.

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

75, 50 & 25 YEARS AGO by Sabrina Garvin

1951

1976

2001

◖ July 1951

Meteor Catcher "The super-Schmidt meteor camera sketched on the back cover of *Sky & Telescope* in February, 1949, has now become reality. The Perkin-Elmer Corporation has completed the first of six instruments, and it was flown to New Mexico late in May for installation at the Soledad observing station of Harvard Observatory, near Las Cruces. . . .

"Whereas cameras hitherto in use for meteor photography have been able to catch meteors only of about zero magnitude and brighter, the new instrument, with an effective focal ratio of 0.85, should reach at least 4th magnitude (visual). Thus, it should make possible photography of meteors the size of buckshot; earlier cameras could only record meteors down to the size of marbles. Even on a perfectly dark night, the limiting exposure is expected to be about six minutes. The 52-degree field covered by the camera takes in about 1/10 of the area of the visible sky, or 10,000 times the area of the moon. The rate of catching meteors is expected to be 40 times that of the meteor cameras now in use."

◖ July 1976

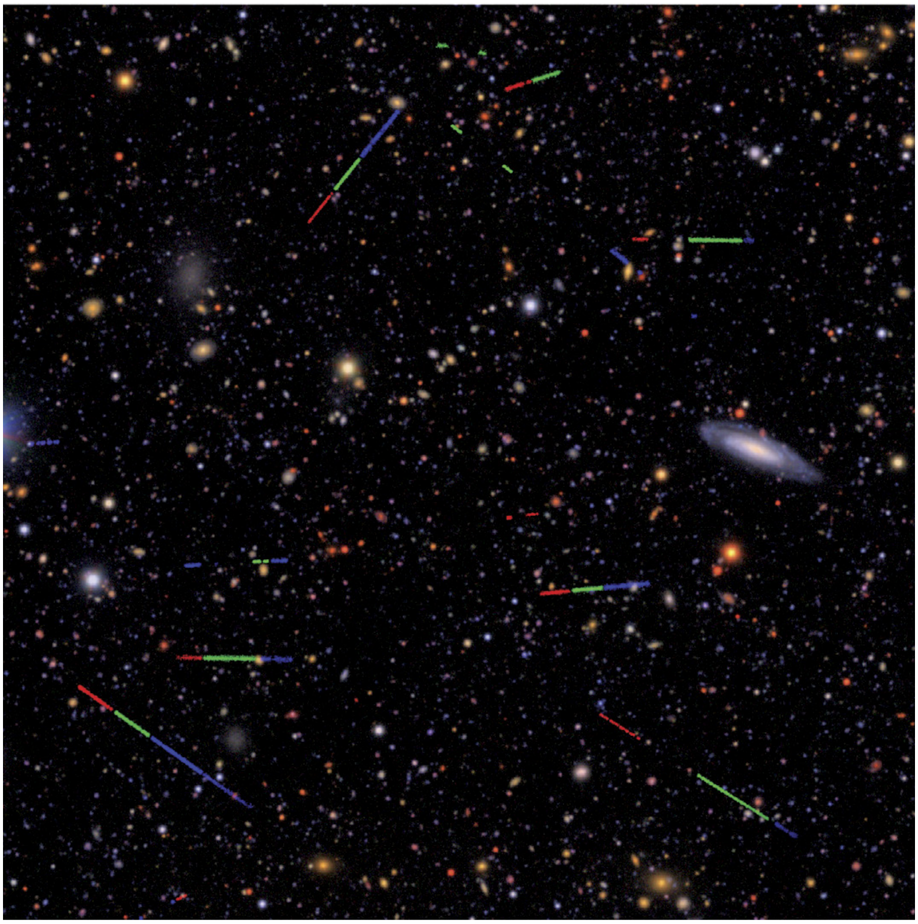
First Martian Lander "In many respects, the Viking mission to Mars represents an enormous scientific gamble. The bet has been made: two spacecraft, 15 years of planning and development, and a billion-dollar commitment to land on Mars this summer. The returns on this investment are expected soon; as this issue goes to press, the first of the twin orbiter-lander combinations is about to enter orbit around Mars in preparation for a July 4th landing.

"At the Jet Propulsion Laboratory in Pasadena, California, a team of 750 scientists, engineers, and other specialists has been entrusted with the operation and well-being of the spacecraft. They will direct the experiments that should tell us more about Mars' surface and atmosphere than we have learned in 3½ centuries of telescopic astronomy. According to Cornell astronomer Carl Sagan, 'If Viking works even moderately well, planetary astronomy will never be the same again.'"

◖ July 2001

We Smell a Rat "With respect to Bode's constellation Felis on page 118 of the April [2001] issue, on behalf of fellow felines everywhere, we'll have you know that the alleged 'cat' on that chart looks more like a common rodent to us. Witness the pathetic, spindly tail and the ratlike legs. Ugh! We'd have him for dinner."

Ken Hewitt-White sent in this letter on behalf of his cats, Comet and Scooter. After polling the furry friends of the current S&T *staff, we concur. Six out of 10 cats and two rabbits agree: That's no feline! (Unfortunately, no rats could be found for comment.)*



▲ Zooming in on the Rubin Observatory's image of the Virgo Cluster shows tiny colorful tracks made by solar system objects moving in the foreground.

SOLAR SYSTEM

Rubin Observatory Finds Fast-Spinning Asteroids

EVEN BEFORE coming fully online in June 2025, the Vera C. Rubin Observatory detected more than 1,000 new asteroids, including a couple that rotate so fast that they must have unexpected compositions holding them together.

Three of the objects are main-belt asteroids that spin around every couple of minutes. Observers have discovered a few such fast spinners before but among the near-Earth object population. Rubin's discoveries are much larger and more distant.

Dmitrii Vavilov (University of Washington) presented Rubin's asteroid discoveries on March 17th at the 57th Lunar and Planetary Science Conference in The Woodlands, Texas. While the Rubin Observatory's construction is complete, it's still undergoing a series of increasingly complicated tests of every part of its system. One such test of the Legacy Survey of Space and Time (LSST) Camera was conducted over nine nights in April and May 2025. It produced 1,185 images covering much of the Virgo Galaxy Cluster through three visible-wavelength filters. When all the images were co-added together, the resulting image revealed a depth of magnitude 26.5.

In addition to galaxies, those images contain 343,760 unique observations of objects in our own solar system, whose movements between exposures through the three filters create colorful tracks. Of 2,103 asteroids, 1,900 were previously undiscovered. Most asteroids were imaged more than 100 times, enabling astronomers to calculate their orbits and estimate their shapes based on how their brightness changed as they rotated. (An elongated body will present alternately larger and smaller faces to the viewer as it spins, dimming and brightening twice per rotation.)

Of the 76 objects that have reliable rotation periods, a surprising number (16) are *superfast* rotators, with rotation periods under 2.2 hours, and three (2025 MN_{45}, 2025 MK_{41}, 2025 MJ_{71}) are *ultrafast*, spinning around in less than 5 minutes. The standout is 2025 MN_{45}, which at nearly 1 kilometer (0.6 mile) long and with a period less than 2 minutes, is "definitely the fastest one of its size," Vavilov says.

If an asteroid is a loosely collected rubble pile, like near-Earth asteroids Bennu, Ryugu, and Dimorphos-Didymos, then its shape represents a balance between gravity and centrifugal acceleration. Rocky rubble-piles larger than 150 meters across can't spin any faster than once every 2.2 hours — otherwise, loose bits of asteroid will drift right off the surface. Faster-spinning objects must be made of denser material, or perhaps they have more internal cohesion than a rubble pile does.

Both 2025 MN_{45} and 2025 MK_{41} are large enough that even sticky clay wouldn't hold them together against their fast spins. The former is rotating at a rate close to the strength limit for solid, unfractured rock.

"Probably it's one big piece of a solid rock or even metal," Vavilov concluded at the conference. "They're not supposed to rotate that fast, but yet they do."

One ultrafast spinner in a large survey could result from some unusual composition or history, but for three of 76 to be ultrafast rotators, "it seems like this has to be common," remarks asteroid expert Bill Bottke (Southwest Research Institute).

As astronomers seek to explain how the solar system makes so many large, cohesive objects and spins them so fast, Rubin will produce the data they need — including colors, which provide clues to objects' compositions.

■ EMILY LAKDAWALLA

STARS

Super-Bright Supernovae Are Birth Cries of Magnetars

IT'S DIFFICULT to understand what can produce 10 or even 100 times the energy of a typical supernova (known as a *superluminous supernova*).

Astronomers largely agree that *magnetars* are behind such brilliant blasts. These neutron stars boast powerful magnetic fields that, along with their fast spin, could power the initial outpouring of energy. But magnetars by themselves don't explain the "bumpy" fade that follows, in which the supernova rebrightens for brief periods only to dim again.

Joseph Farah (Las Cumbres Observatory) led a team that monitored one such supernova, SN 2024afav. They watched the fading supernova for the better part of a year using the Las Cumbres Observatory's Global Supernova Project, a network of telescopes that work together to observe supernovae around the clock. The Fred Lawrence Whipple Observatory in Arizona also contributed data.

New observations came in roughly every 12 hours over 200 days, capturing detailed views of at least four diminishing bumps in the event's light curve. For each bump, the supernova brightened a bit before continuing to fade, like a tennis ball bouncing to a stop.

The team realized that the diminishing bumps could correspond to a known phenomenon: *Lense-Thirring precession* in which an object with an intense gravitational field drags spacetime around with it as it spins.

That effect wouldn't be noticeable if the magnetar were on its own. But some of the material that attempted to escape in the supernova is falling back onto the newborn magnetar. The drag created by the magnetar's 4.2-millisecond rotation causes that gaseous disk to precess in a way that exactly explains the bumps in the light curve of SN 2024afav.

▲ Artist's concept of a magnetar surrounded by a gaseous disk with Lense-Thirring precession.

While the scenario is convincing in this case, it's unclear whether it explains other examples. "At present, no single model can account for all bumpy superluminous supernovae," argues Zi-Gao Dai (University of Science and Technology of China), who has studied other such blasts.

The Vera C. Rubin Observatory should provide the supernovae needed to test various scenarios: It's expected to discover thousands of superluminous supernovae over the next decade.

■ **MONICA YOUNG**

SOLAR SYSTEM

Lunar Impact Ruled Out for 2024 YR_4

THE MOON IS SAFE from asteroid 2024 YR_4 after all. While previous best estimates of the asteroid's trajectory showed a 4.3% chance of Moon impact in 2032 (*S&T:* June 2026, p. 56), that possibility has now been ruled out.

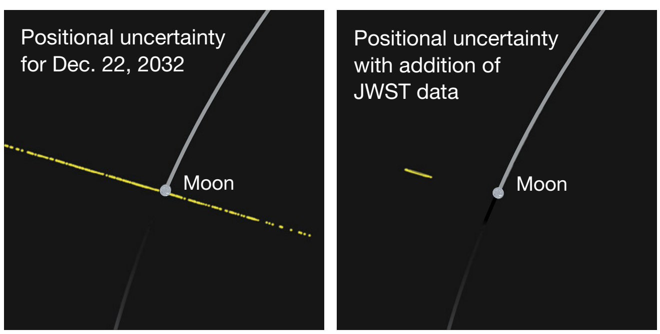
Two independent methods, one using new images from the James Webb Space Telescope and one using archival images to track the object's path back to 2016, both arrived at similar estimates of where the object will be during its closest approach on December 22, 2032 — near, but not *at*, the lunar surface.

The JWST exposures were taken in February, when the asteroid was moving past a number of stars previously observed by the European Space Agency's Gaia satellite. Those stars served as positional references that helped narrow the uncertainty in the asteroid's trajectory by about twelvefold at the time of its 2032 approach. The team, led by Andrew Rivkin (Johns Hopkins University Applied Physics Laboratory), reported in the March *Research Notes of the AAS* that the rock would miss the Moon by about 23,000 km (14,000 miles). Based on the same data, NASA issued an official estimate of 21,200 km, which is consistent with the published result.

Meanwhile, amateur astronomers Sam Deen and Derek Lam found seven potential pre-discovery archival images, posted on the astronomy arXiv preprint server on February 28th: four images from the Intermediate Palomar Transient Factory in California, two from the Subaru Telescope in Hawai'i, and one from the Cerro Tololo Inter-American Observatory in Chile. All were taken during the asteroid's close approach in 2016. Refining the trajectory, Deen and Lam showed YR_4 would miss the Moon by about 22,000 km — in agreement with the JWST data.

"I think the future of planetary defense depends on all sorts of people using all sorts of techniques," Rivkin notes. "Having interested and motivated amateur astronomers looking at the archives is an important piece, and having these very, very capable big space telescopes demonstrating that they can make these hard observations is another piece."

■ **DAVID L. CHANDLER**



▶ The addition of Webb data reduced uncertainty in the position of asteroid 2024 YR_4 on Dec. 22, 2032. (Possible positions marked yellow.)

MAGNETAR WITH WARPED DISK: JOSEPH FARAH AND CURTIS MCCULLY; ASTEROID TRAJECTORY: NASA / JPL CENTER FOR NEAR-EARTH OBJECT STUDIES

THE SUN

The Solar Cycle's Imprint on the Sun's Interior

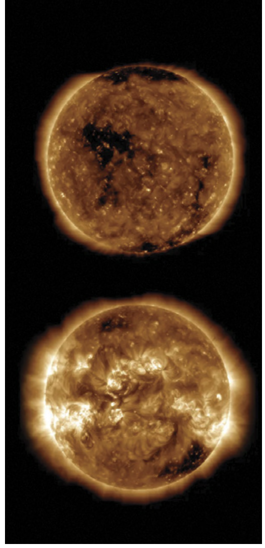
SOLAR ACTIVITY RISES and falls in a pattern that peaks roughly every 11 years, driven by flips in the Sun's magnetic field. To explore the quietest periods of this cycle, a team led by Sarbani Basu (Yale University) turned to *helioseismology*. Just as seismologists use earthquakes' vibrations to analyze our planet's interior, helioseismologists can use pressure waves (aka sound waves) to paint a picture of the solar interior.

Different types of sound waves travel to different depths inside the Sun. By measuring tiny shifts in their frequencies — changes of just a few parts in 1 million — astronomers can reconstruct variations in temperature, density, and pressure beneath the solar surface.

Working with data from the six telescopes of the global Birmingham Solar-Oscillations Network (BISON), Basu's team studied helioseismic data across four successive solar minima, the quietest phases of the solar cycle. The team published results in the March *Monthly Notices of the Royal Astronomical Society*.

"Revealing how the Sun behaves beneath its surface during these quiet periods is significant, because this behavior has a strong bearing on how the activity levels build up in the cycles that follow," Basu says.

Basu's team looked for a distinctive "glitch" in the sound waves, created when helium loses an electron. This ionized helium changes the compressibility of plasma in the outermost 10% of the Sun. By tracking this signal, the astronomers discovered that the minimum preceding Solar Cycle 24, which



◀ The Sun in ultraviolet, as seen by the Solar Dynamics Observatory, during solar minimum *(top)* and maximum *(bottom)*.

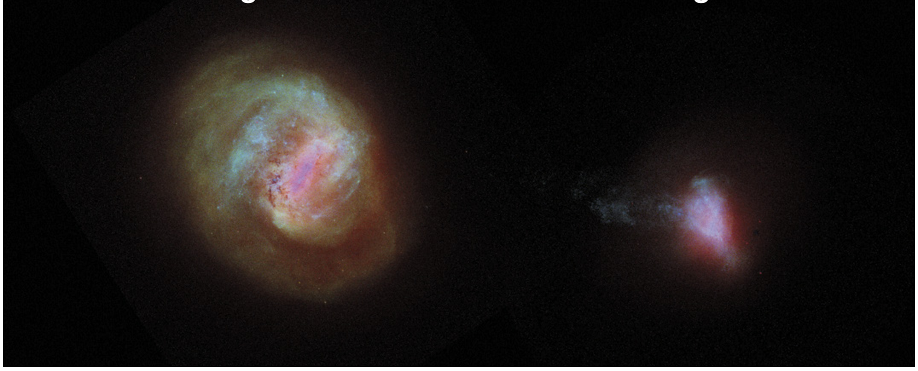
occurred in late 2008, showed a stronger helium glitch than the other three minima. That minimum was also one of the quietest and longest on record (*S&T:* Nov. 2013, p. 10), and the stronger helium signal indicates that subtle structural changes were occurring below the visible solar surface. The unusually weak magnetic activity during this time could have increased gas pressure and temperature in the outer layers of the Sun. The higher temperatures result in a stronger helium glitch, even though the amount of helium isn't changing.

The deep minimum thus left a clear fingerprint in the Sun's interior.

■ **COLIN STUART**

GALAXIES

The Small Magellanic Cloud Is Transforming



◀ This image shows the density of stars in the Large and Small Magellanic Clouds (left and right, respectively). Red, green, and blue indicate the stars' ages, from older to younger.

THE SMALL MAGELLANIC CLOUD (SMC), a dwarf galaxy near the Milky Way, has transformed after a collision with its nearest neighbor, the Large Magellanic Cloud (LMC), some 100 million years ago. In the March 20th *Astrophysical Journal*, Himansh Rathore (University of Arizona) and colleagues detail the collision's reverberations across the smaller galaxy.

The study resolves a long-standing discrepancy that has puzzled astronomers: The SMC's gas appears to rotate, with one side moving toward us and the other away. Yet the stars don't show the same signal. This disagreement should not be possible, since the stars were born from the gas.

But the team's computer simulations tell a different story. The researchers found that, as the two galaxies passed through each other, the LMC's gravity began shredding the SMC's gas. As viewed from Earth, one part of the stretched-out gas would move away from us while another part comes toward us. The result is a signature that appears like rotation but isn't. The collision wouldn't have the same effect on the SMC's stars, which would instead scatter randomly.

While the gas motions were the smoking gun, other clues also pointed to a collision. For one, the stars have a different center of mass than the gas. That's because the LMC's gas exerted intense pressure on the SMC's gas as the two galaxies streamed through each other. This effect, called *ram pressure*, works only on gas, effectively pushing it away from the stars.

Team members have made the case for a past collision before. "What was missing," says team member Gurtina Besla (University of Arizona), who advises Rathore, "was the theoretical framework to actually understand how that could possibly happen." Now, the team has shown exactly how a collision reproduces the observations.

■ **ARIELLE FROMMER**

Read more: skyandtelescope.org/SMC

SATELLITES

SpaceX Aims to Launch 1 Million AI Data Centers

SPACEX HAS ASKED the Federal Communications Commission (FCC) for permission to launch up to 1 million new satellites to act as AI data centers. That's 100 times more satellites than in the company's Starlink network.

"In the long term, space-based AI is obviously the only way to scale," wrote SpaceX CEO Elon Musk in a statement.

But that conclusion isn't obvious to other experts, including Jonathan McDowell, an astronomer and space-sustainability expert who recently retired from Harvard & Smithsonian's Center for Astrophysics.

"The industrial scale of this is staggering," he says, adding that it may be a publicity stunt. "I don't think it's going to happen in the next few years." SpaceX did not respond to *S&T*'s requests for comment.

If the plan were to go through, data centers would be launched to Sun-synchronous orbits as well as orbits inclined at 30°. The satellites' altitudes would be between 500 and 2,000 km (300 and 1,200 mi). Between the large radiators needed for cooling as well as solar panels for power, the satellites would likely be "ginormous," McDowell says, probably 100 meters (330 feet) from tip to tip.

From those orbits and with those sizes, the satellites "would be visible all night long over much of Earth over much of the year," according to John Barentine (Dark Sky Consulting). "It is so potentially transformational to the night sky that I think it would really endanger the hobby [of stargazing]." Increased visual and radio interference would further challenge ground-based astronomy — the company has even asked the FCC for an exemption to use some protected radio bands.

The satellites raise other concerns, from the emissions that the projected hourly launches of SpaceX's Starship rocket would release into Earth's atmosphere, to the challenges of space-junk

SPACEX

▲ An artist's concept shows SpaceX's Starship rocket deploying satellites to low-Earth orbit. What those satellites would actually look like isn't known yet.

avoidance when in orbit, to the damage to Earth's upper atmosphere (including the ozone layer) created by the satellites' reentries.

Other countries have their own plans for orbital data centers, so even if SpaceX never actually reaches its million-satellite goal, some orbital data centers are likely to become a reality. But at least in the U.S., the FCC must first grant permission following extensive review. As of press time, the commission has not yet reached a decision.

■ KATHRYN HULICK

IN BRIEF

Rubin Begins Alerts

In a single night of observations on February 24th, the Vera C. Rubin Observatory produced 800,000 alerts of ephemeral events, including new asteroids and supernovae. Rubin is scouring the entire night sky every few nights to create an ultra-wide, ultra-high-definition, time-lapse record of the heavens. When something appears different from last time Rubin looked, a system sends an automated alert to astronomers. That system includes a series of intelligent software platforms known as *brokers*. These brokers use machine-learning algorithms to filter, sort, classify, and cross-reference the alerts before distributing them to scientific teams and observatories. Anyone, including the public, can access the seven official brokers, which specialize in different aspects of the data. Once the observatory's Legacy Survey of Space and Time is fully operational, the number of nightly alerts is expected to jump up to 7 million, and the odds of discovery are high.

■ COLIN STUART

Read more and find links to the brokers at **skyandtelescope.org/Rubinalerts**.

A Molten, Sulfurous World

Just 35 light-years away, a puffy planet known as L98-59d has revealed a unique composition. The world is at least 50% larger than Earth but at most twice as massive, with an average density estimated between 2.2 and 3.45 grams per cubic centimeter. (Earth, for reference, is about 5.5 g/cm^3.) Follow-up observations, including from the James Webb Space Telescope, hint at a sulfur-rich atmosphere. The world currently orbits its star at 0.05 astronomical unit, and a thick atmosphere normally wouldn't survive such radiation. To explain the observations, Harrison Nicholls (University of Oxford, UK) and colleagues developed detailed simulations of the planet's evolution over billions of years, with results published March 16th in *Nature Astronomy*. They conclude that L98-59d originated much farther out than its current orbit, where it incorporated large amounts of sulfur compounds. Now, its current close-in orbit sustains a very deep ocean of hot, sulfurous magma, from which sulfur-rich molecules evaporate to maintain a thick atmosphere. The world may be slowly changing, the team suggests, transitioning from a farther-out "sub-Neptune" to a closer-in "super-Earth."

■ GOVERT SCHILLING

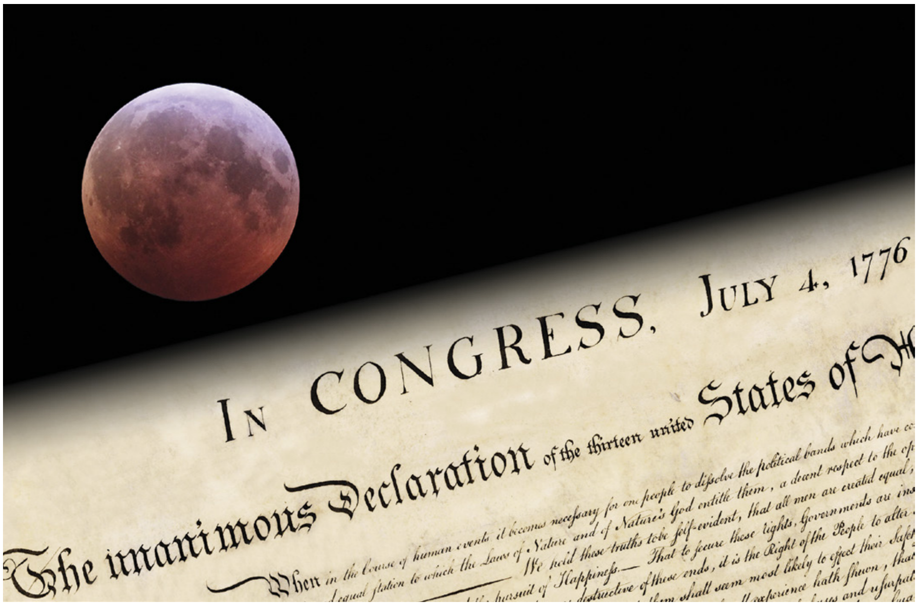
Ryugu Has All the Nucleobases, Too

A new analysis published March 16th in *Nature Astronomy* shows that material retrieved from the asteroid 162173 Ryugu by the Japanese Hayabusa 2 mission contains many complex organic molecules — including all five nucleobases, which form the basis for the genetic material of all life on Earth. These compounds were previously found in samples returned from 101955 Bennu as well as some meteorites. The finds suggest that life's building blocks are ubiquitous in the solar system. Nucleobases come in two classes: *purines* and *pyrimidines*. "One of the most surprising findings was that the relative abundances of purine and pyrimidine bases vary among extraterrestrial samples," says team lead Toshiki Koga (Japan Agency for Marine-Earth Science and Technology). Purines dominate in the Murchison meteorite, for example, while pyrimidines rule in the Bennu sample and in the Orgueil meteorite. The Ryugu sample contains roughly equal amounts of both. Differing proportions presumably arose due to different chemical and environments and evolutionary histories, the researchers conclude.

■ DAVID L. CHANDLER

The Heavens in 1776

Celestial fireworks marked America's birthday.



▲ **TOTALITY OF 1776** A total eclipse of the Moon graced the skies a few weeks after the 13 American colonies declared their independence from the British Crown on July 4th.

EDWIN L. AGUIRRE / S&T

ON JUNE 7, 1776, Richard Henry Lee, a delegate from Virginia, read a resolution before the Second Continental Congress "that these United Colonies are, and of right ought to be, free and independent States, . . . absolved from all allegiance to the British Crown." Over the next three weeks, while Congress considered the resolution, Thomas Jefferson began drafting the Declaration of Independence. Congress reconvened on July 1st, and the next day it adopted Lee's resolution. They then reviewed and edited the declaration. After additional tweaks were made to it on July 4th, Congress approved the final draft and ordered it printed.

In her diary (written later in life), Quaker historian Deborah Norris Logan, who was 14 in the summer of 1776, recalls that on July 4th she was standing in her yard around noon when she heard the first public reading of the document from the steps of the Pennsylvania State House, where the declaration was adopted. The Sun would have been some 70° above the southern horizon, accompanied by four of the five known planets (which, naturally, wouldn't have been visible). The Sun and three of those planets — Jupiter, Venus, and Mercury — were gathered in Gemini, with Mars a bit farther west in Taurus. (Uranus, also present, wouldn't be discovered until nearly five years later.) All looked down upon the scene like celestial witnesses.

Later that month, on the evening of July 31, 1776 — only two days before John Hancock became the first delegate to sign a parchment copy of the declaration — a total lunar eclipse occurred over the colonies. The full Moon was near perigee, and those under clear skies would have seen a fully eclipsed Moon rise in Capricornus — and remain ominously red for nearly 50 minutes.

One can only imagine how the sight of this blood-red Moon climbing above the horizon might have affected some people's psyches, especially since, as Logan recalls in her diary, the adoption of the declaration was a "time of fearful doubt and great anxiety with the people, many of whom were appalled at the boldness of the measure." Furthermore, though many colonial ministers' thoughts trended toward the scientific point of view, astronomical phenomena were still being interpreted by some preachers through the lens of biblical prophecy.

To the superstitious, the lunar eclipse of July 31st may have proved to be a bad omen. During the Battle of Long Island, the first major conflict after the primary signing of the declaration, the Continental Army suffered a major loss — with 300 dead, up to 800 wounded, and 1,100 militants captured.

Two major astronomical events occurred around the time of the American Revolution: the 1769 transit of Venus and the annular solar eclipse on January 9, 1777. These were followed by the great 1833 Leonid meteor storm, which produced about 50,000 to 150,000 meteors per hour, and the long-anticipated 1835 return of Halley's Comet. While these events inspired public interest in astronomy, some saw the meteor storm in a biblical context. In 1845, Mormon prophet Joseph Smith wrote that it seemed "as though all the artillery and fire-works of eternity were set in motion to enchant and entertain the Saints, and terrify and awe the sinners of the earth."

If you're in a celebratory mood this July, go out with your telescope and try to visualize your own celestial pyrotechnics by looking at two deep-sky objects: NGC 6939 in Cepheus and NGC 6946 in Cygnus. These objects lie only 40′ apart and can be seen in the same low-power field. NGC 6946 is the star-spangled-banner of starburst galaxies. Known as the Fireworks Galaxy, its rate of supernovae —10 since 1917 — is explosive. NGC 6939, on the other hand, is an 8th-magnitude open star cluster, whose pale and stringy appearance, especially through small telescopes at low power, can, with imagination, be viewed as a smoke trail lingering in the air after a pyrotechnic display. Happy Fourth!

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

 by Jan Hattenbach

Ancient Star Polluters

CHANDELIER CLUSTER
This globular, also known as NGC 6723, is about 28,000 light-years away in Sagittarius. It was imaged as part of a Hubble legacy survey.

Strange stellar compositions are shedding light on globular clusters' early years.

Globular clusters make for great views in any telescope. These balls of hundreds of thousands of densely packed stars are the oldest, most massive star clusters in the Milky Way. Scientifically, they've aided us in understanding the phases of stellar evolution and even helped us identify where the galactic center lies.

Now, there is mounting evidence that they carry hints of unprecedented stellar extremes, pointing to unique conditions in the early universe when they formed.

The evidence comes from globulars' stars, which aren't as uniform as they should be. When a stellar cluster forms, its members should be born around the same time and with the same chemical makeup, because they're coalescing from a single, giant cloud of gas. Carbon, nitrogen, aluminum, iron — every element heavier than hydrogen should be sprinkled in the gas (and, therefore, in the stars) in a certain proportion, like the ingredients in a baking recipe.

Yet astronomers don't see this expected uniformity in globulars. Instead, some of their stars appear to have been "polluted," their complement of elements changed from the standard recipe. "These stars are often the majority of the stars in the clusters," says Antonino Milone (University of Padova, Italy).

This so-called *multiple populations problem* is changing how astronomers think about globulars as a whole. Nate Bastian (then at Liverpool John Moores University, UK) and Carmela Lardo (then at EPFL Laboratory of Astrophysics, Switzerland) concluded in a 2018 review article, "The traditional concept of globular clusters as simple stellar populations, where all stars share the same age and abundances . . . is now a view of the past." But finding the source of the pollution has proven to be immensely difficult.

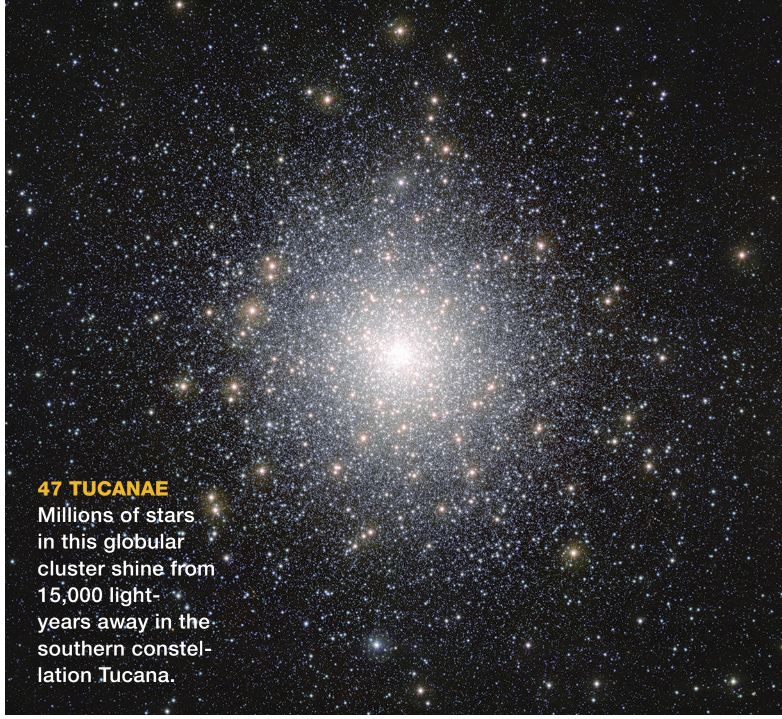
Strange Chemistry

Hints of odd abundances in globular cluster stars date back to the 1950s, but it was the Hubble Space Telescope that made the problem fully apparent.

In 2015, as part of Hubble's Legacy Survey of Galactic Globular Clusters, Giampaolo Piotto (also Padova) and his team implemented a novel approach: The researchers studied the stars' brightness in specific ultraviolet filters to determine their compositions. Since elements and molecules in a star's outer layers absorb light at specific wavelengths, the star will appear brighter or fainter in certain filters depending on which substances are present.

Using this method, Piotto's team analyzed a greater number of stars than could have been done with spectroscopy, cataloging 57 galactic globular clusters in all. The team identified stellar populations in unprecedented detail.

Almost all clusters, it turns out, host two distinct families of stars. The first, *Population 1* (P1), is what we might call



47 TUCANAE Millions of stars in this globular cluster shine from 15,000 light-years away in the southern constellation Tucana.

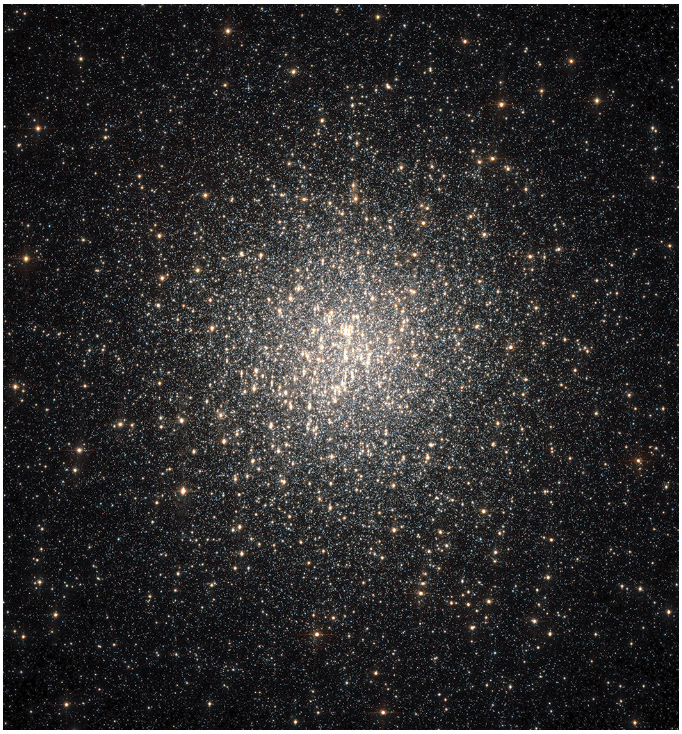
"normal" stars: They have the same chemical composition as other ancient stars in our galaxy. The second, P2, look much like the first but with subtle distinctions: "These stars have the same abundance of heavy elements as normal stars, but with significant differences in light elements," explains Milone, who was a member of Piotto's team. (Here, "light elements" refers to those only slightly heavier than hydrogen.) "In some, we found more helium and nitrogen, but less oxygen or carbon," he adds. "The stars also feature variations in sodium, aluminum, or magnesium."

The pattern of these light elements' abundances suggests they were created in extremely hot hydrogen-fusion reactions. The Sun, being a rather low-mass star, burns the hydrogen fuel in its core at a moderate 15 million kelvin. More massive stars, however, sustain much higher core temperatures at which the elements carbon, nitrogen, and oxygen become involved as catalysts in hydrogen fusion, in a series of reactions called the *hot CNO cycle*. These reactions create telltale chemical fingerprints — fingerprints that astronomers find only in the spectra of P2 stars. For example, whenever a P2 star has a lot of sodium, it has less oxygen; when it has a lot of aluminum, it tends to have less magnesium. "That's exactly what one expects from nuclear hydrogen burning at high temperatures," says Mark Gieles (University of Barcelona, Spain).

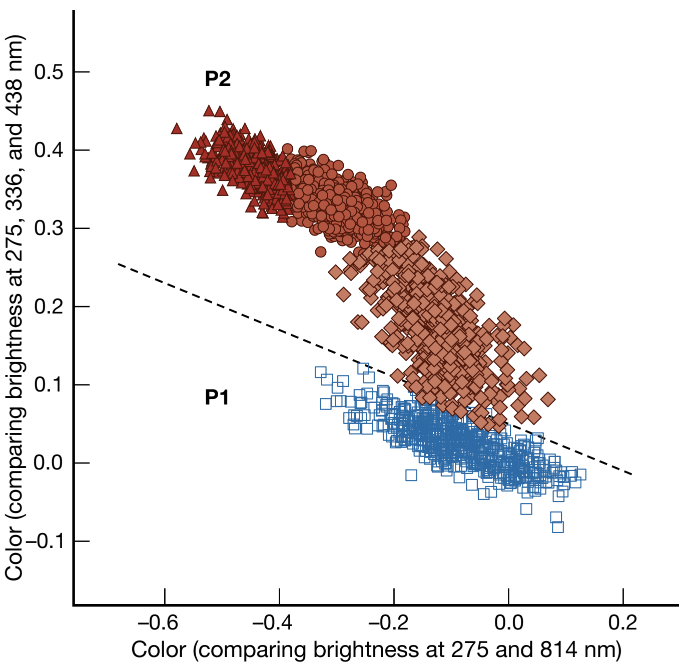
Population I and II vs. Population 1 and 2

Don't confuse globulars' two stellar populations with the galaxy's Population I and II stars. In the Milky Way, metal-poor Population II stars enrich subsequent Population I stars via supernova explosions. Iron abundances are thus higher in Pop I stars. Across globulars' Population 1 and 2 stars, on the other hand, only light-element abundances change, while iron abundances remain the same.

NGC 6723: NASA / ESA; 47 TUC: ESO / M.-R. CIONI / VISTA MAGELLANIC CLOUD SURVEY, ACKNOWLEDGMENT: CAMBRIDGE ASTRONOMICAL SURVEY UNIT



▲ **ANCIENT STAR CITY** Hubble also imaged the massive, 12.5-billion-year-old globular cluster NGC 2808, about 30,000 light-years away in Carina, as part of the same legacy survey as NGC 6723.



▲ **MULTIPLE POPULATIONS** The colors of red giant stars in NGC 2808 are plotted in this graph, revealing multiple populations. A star's brightness when viewed in one filter relative to another tracks absorption by certain elements. The diagonal dashed line separates P1 stars from "polluted" P2 stars, which in this case can be further divided into three subpopulations. The P2 stars contain progressively more helium and nitrogen, moving from bottom right to top left of the plot.

There's just one problem: Most P2 stars are too small to drive these reactions.

Globular clusters are old, and so are their stars. The most massive stars are long gone. Of the stars remaining, many P2 members are low-mass *main-sequence stars*. These stars are actively fusing hydrogen into helium, but they cannot achieve the core temperatures required for the CNO cycle's reactions to run rampant.

Even if they could, there's no route to transport such elements upward. The boiling motions of convection can mix things up, but like the Sun, P2 stars have thick radiative zones that separate their cores from the convective outer layers. Those radiative zones block core material from reaching the stars' visible surfaces.

For these reasons, experts agree that the various light elements had to be made in hot hydrogen reactions that occurred *outside* the P2 stars in which we see them today. But where did the material come from? How did it get out of the polluters — which apparently were able to sustain hot hydrogen fusion — and into these other stars?

"At every conference I went to, there was a session about this," Gieles recalls. But none of the ideas proposed over the years really worked.

Connecting the Dots

Many researchers have collected details on the two populations over the years. Put those details together, and you start painting an intriguing picture: The polluting stars must have been massive, but they also must have released the polluting debris before they died in supernova explosions — while the P2 stars were still forming.

The most massive P1 stars would have evolved quickly and gone supernova. Shortly before exploding, their cores would have fused the heaviest element they could make: iron. In our galaxy and beyond, supernovae recycle that iron into the interstellar medium. Subsequent stellar generations coalesce from this enriched gas, so generally speaking, the more iron a star contains, the later it formed.

But spectra show that the amount of iron is the same in the P1 and P2 stars of any given cluster. Studies of other age markers agree that both populations formed at approximately the same time. P1 and P2 members thus seem to belong to a single generation of star formation, not two.

Observations provide another fact: The more massive a cluster is, the higher the number of enriched stars it contains. This rules out any polluter from outside the cluster, as these sources' effect would not be tied to the cluster's mass.

Most experts therefore agree that it was stars inside the globular clusters themselves that sustained the hot hydrogen burning and somehow polluted the Population 2 objects. The polluting stars must have had the ability to fuse hydrogen at up to 60 million kelvin and to churn out their core material onto other stars.

And finding the polluters isn't easy, because those massive stars are now long gone.

NGC 2808: ESA / NASA / G. PIOTTO (UNIV. OF PADUA, ITALY) & A. SARAJEDINI (UNIV. OF FLORIDA), ACKNOWLEDGEMENT: DAVIDE DE MARTIN (ESA / HUBBLE); GRAPH: BEATRIZ INGLESSIS / *S&T*, SOURCE: N. BASTIAN & C. LARDO / *ANNUAL REVIEW OF ASTRONOMY & ASTROPHYSICS* 2018

Normal Stars or Exotic Behemoths

For many years, intermediate-mass *asymptotic giant branch* (AGB) stars — those with between roughly four and eight solar masses — have been prime suspects. AGB stars have evolved beyond the main sequence; their cores are mostly carbon and oxygen ash, surrounded by nested shells that fuse helium into carbon and (above that) hydrogen into helium.

Models show that in AGB stars with enough mass, not only do the hydrogen shells reach the required temperatures for hot hydrogen burning, but the stars themselves dredge up inner material. While such stars aren't big enough to go supernova, their strong stellar winds blow their enriched outer layers away.

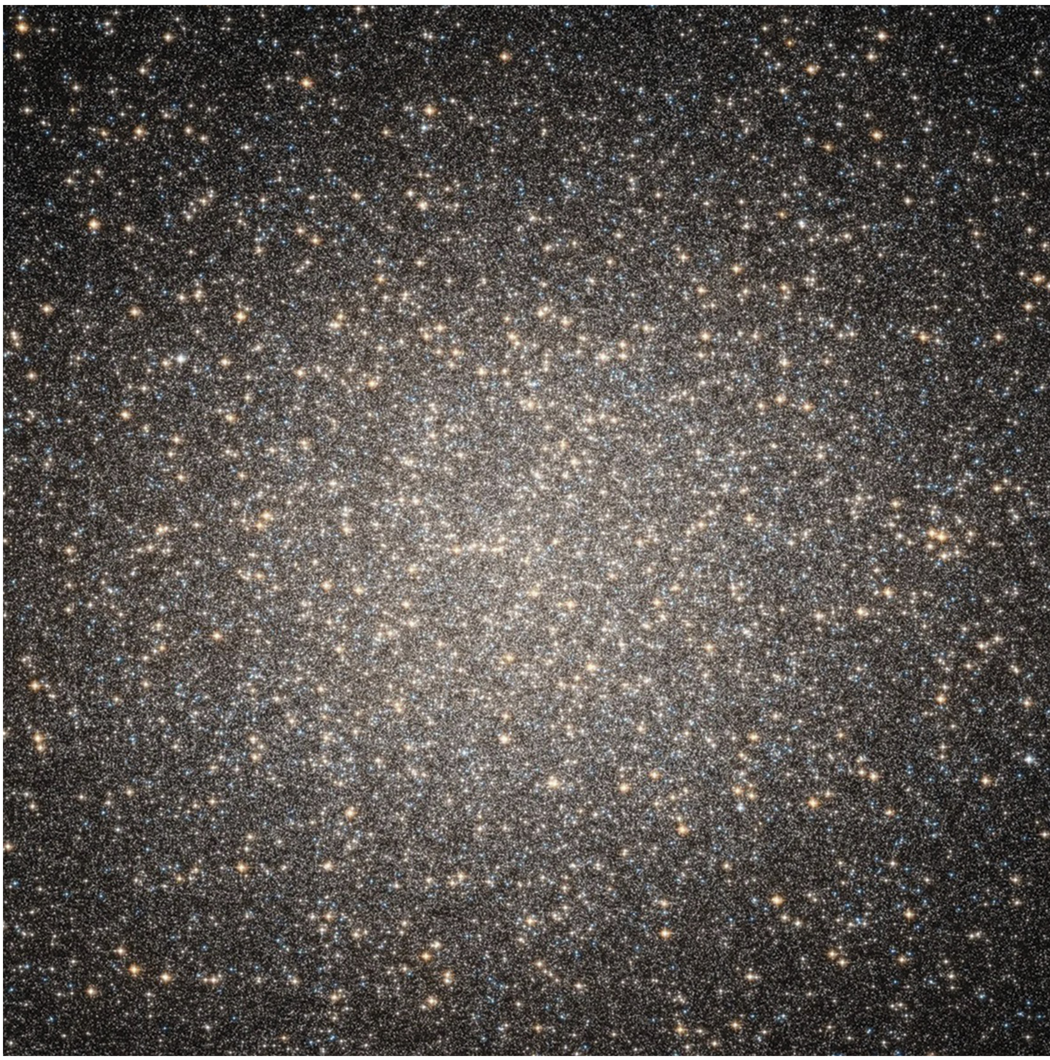
In this scenario, the cluster first forms a generation of "normal" stars — the ones we call P1. When some of these stars reach their AGB phase, they shed vast amounts of enriched material. This material then mixes with the pristine gas in the still-forming cluster, and a second generation of stars, those we call P2, forms.

The AGB scenario has been quite popular, because it relies on fairly ordinary stars and known processes. However, the timeline is too slow. It takes about 30 million years for a star of roughly five solar masses to reach its AGB stage. By this time, any gas left from the first burst of star formation should have dispersed, blown out of the cluster by the most massive stars' winds. To build another generation of stars, that gas would have to reverse its outward motion, returning despite the remaining stars' winds.

"So you'd need the original gas of the cluster to somehow stick around for about 30 million years, mix with the AGB winds, and then fall back into the cluster," Gieles says. "That seems very contrived!"

Massive stars, which evolve faster than AGB stars, could speed things up. A star of 20 to 50 solar masses, for example, produces sodium and aluminum in its core as well as lighter elements in surrounding shells. However, it would have to spin fast to mix heavier elements into its outer envelope, before slinging them out into the cluster. But if two massive stars were in a close binary system, they could mutually extract enriched gas from each other.

In 2013, Bastian, Gieles, and others proposed a scenario in which material from binary donors mixes with the gas fall-



NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA), ACKNOWLEDGMENT: A. COOL (SAN FRANCISCO STATE UNIVERSITY) / J. ANDERSON (STSCI)

Globulars of a Different Stripe

Not all globular clusters have the same origin. In most, iron abundances are relatively similar between stars, which means supernovae didn't play a significant role in their evolution. The vast majority (85%) of globular clusters in the Milky Way (and the type with multiple populations that are described here) fall in this category.

But rarely, globular cluster stars have a spread of different iron abundances. Astronomers think these clusters might once have been the cores of dwarf galaxies, cannibalized by the Milky Way. Famous clusters such as Messier 54 and Omega Centauri (at left) fall in this category.

ing onto still-forming, lower-mass stars, creating the second population 5 to 10 million years after the first one. That's more than 10 times faster than in the AGB scenario.

However, this scenario struggles to explain why P2 stars are more numerous that P1 stars in most clusters. If enrichment requires a complicated process like binary interactions, then the expectation is that the cluster should end up with fewer P2 members compared to P1.

The easy way to solve this problem is to assume that the cluster was more massive at birth and later lost many of its P1 stars. Simulations show that galactic tides and other forces strip globular clusters of stars, throwing them into the Milky Way's halo. A cluster's P1 stars may be more vulnerable to tidal stripping than P2 for a couple reasons: First, P1 stars don't bunch up in the cluster's center the way P2 stars do — there are plenty of them in the outskirts. P1 stars also move more slowly within the cluster. (Both characteristics probably arise because P2 stars formed close to the polluter stars: Those long-gone, higher-mass stars would have tended to fall into the center of the cluster, where they'd also move faster.)

If globulars were bigger in their early years — and for some clusters that's 13 billion years ago, very early indeed — then they could have had a significant effect on their galaxies and the universe at large.

The oldest globulars formed during the *epoch of reionization*. This major transformation in the universe started about 150 million years after the Big Bang, when the first stars formed. Ultraviolet light tore the electrons off the hydrogen gas filling the cosmos, creating ionized bubbles. By the time reionization ended, a little less than 13 billion years ago, most of the universe had become ionized. Massive early globulars might have contributed some of this early light.

But how massive the clusters were is still up in the air, depending on how the P2 stars came to be. As Bastian and Lardo concluded when they reviewed the subject in 2018, neither AGB stars nor binary interactions nor massive early clusters (nor other explanations not covered here) convincingly explain all of the observational details.

Extremely Massive Stars

That's why, in 2025, Gieles and his Barcelona colleague Paolo Padoan presented their own model to explain multiple populations: They propose the phenomenon is a natural outcome of star formation. But the suggestion comes at a price: It requires truly gigantic stars no one has yet seen.

Gieles thinks stars with 1,000 or so solar masses may be a simpler solution than the many others proposed. Unlike merely massive stars, "such gigantic stars would be highly convective, making it more likely that material that is being made inside reaches the surface," he explains. The enriched material would escape as strong winds, eliminating the need for complicated mechanisms like binary interactions.

Gieles admits he's entering a gray zone here: We know of very few stars that exceed 100 solar masses (the most massive one, R136a1 in the Large Magellanic Cloud, is just shy of 300 solar masses; *S&T:* Aug. 2024, p. 34). Luckily, when he began exploring the idea, his office neighbor Padoan had just worked with a couple of colleagues to develop a theory that allows stars to grow to the required sizes.

Stars form when clouds of gas collapse under their own gravity. That gas is usually very turbulent, forming long, thin filaments rather than a smooth cloud. "It's this supersonic turbulence that generates dense cores of a broad range of masses, and some of them collapse into stars," Padoan explains. "So in this sense, it's the turbulent flow that sets the mass of a star, not gravity itself."

In this context, stars will keep growing as long as they're fed via filaments — which means as long as there's matter available. The mass of the heaviest stars in a given cluster is therefore set by the total amount of gas available in the cluster. Typical globulars contain up to a few million solar masses, and Padoan's calculations show that the gas supply necessary to build such a cluster could enable stars of 1,000 solar masses or more to form, even when accounting for losses to stellar winds.

With such massive stars around, the P2 compositions can be explained naturally. Globular cluster formation starts

BEATRIZ INGLESSIS / *S&T*, SOURCE: M. GIELES ET AL. / *MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY* 2025

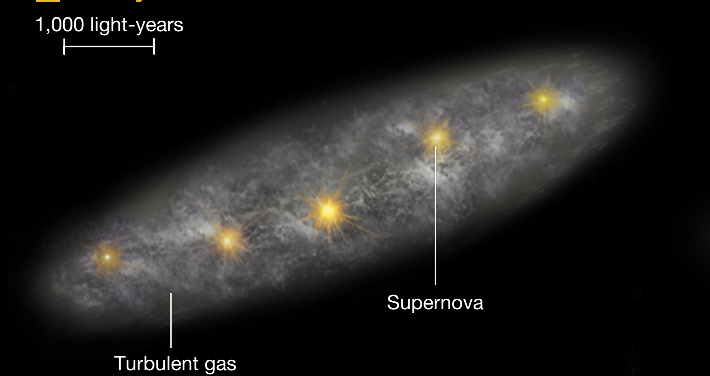
Ancient Polluters: Massive Stars

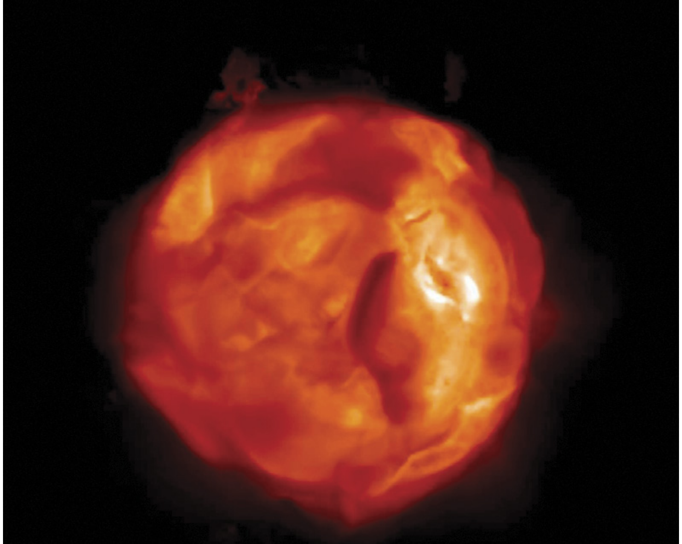
1 Supernovae mix up gas in the galaxy, driving large-scale turbulent motions.

2 The momentum of the turbulent gas then converges into flows that feed star-forming clouds.

3 The heftiest stars, with up to 1,000 times the Sun's mass, tend to come together quickly and close to a cluster's center. They blow out stellar winds carrying byproducts of their own hot hydrogen fusion. Those winds then mix with the inflowing gas, creating a mix of enriched material from which Population 2 stars form soon thereafter.

1 Galaxy





BOIL TO THE SURFACE A simulation of an AGB star shows the giant convection cells that dredge up heavier elements from the interior. The same phenomenon occurs in extremely massive stars, too. Stellar winds then blow away the enriched material.

A. CHIAVASSA, B. FREYTAG & M. SCHULTHEIS

with P1 stars, some of which grow to extremely high masses and begin burning hydrogen at high temperatures. Internal convection brings this enriched gas to the surface, and from there winds cast it out, polluting low-mass stars in the still-forming cluster. Crucially, the massive stars' winds are not powerful enough to reverse the inflow of cold gas that's still streaming in from outside. Instead, the winds mix with that pristine gas, and out come P2 stars. Multiple populations thus form in a continuous burst that lasts up to 2 million years; P2 stars appear near the end of that period.

This idea also helps astronomers understand why there are so many P2 stars in globular clusters. The extremely massive P1 stars — which have long since exploded and disappeared — would have polluted many still-forming P2 stars. Meanwhile, the remaining, lower-mass P1 stars would already have formed, and their stellar winds would prevent the inflow of polluted gas.

"Some people will say, 'We don't see stars with 1,000 solar masses,'" Gieles says. "But we also don't see these abundance anomalies in young clusters. Clearly the early universe was different. Maybe it's not too weird to think that the more extreme environment of the early universe led to more massive stars."

This gargantuan-star scenario is still "under construction" and may not be the last word, Padoan says. "We are still working on it; it remains a difficult problem."

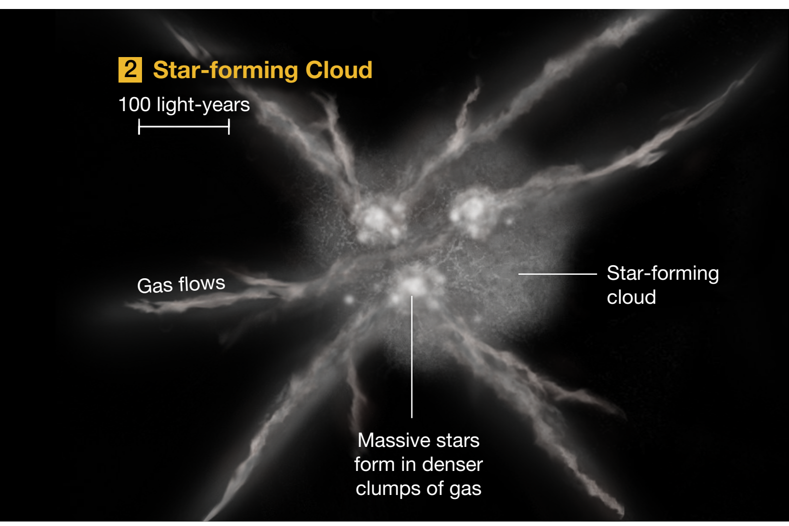
Curiously, the James Webb Space Telescope has recently discovered suspiciously strong nitrogen signals in a high-redshift galaxy, a signal that Gieles says hints at extremely massive stars. (Nitrogen is created in low-mass stars, too, but is difficult to extract.) "We also see young clusters in nearby galaxies with 'blobs' whose luminosities are indicative of about 1 million solar masses," Gieles adds. "Some of them are very nitrogen-enhanced, too. That could be because there are stars of 1,000 solar masses present, but we can't be sure since we cannot yet resolve these stars. The blobs may also contain dozens of 100-solar-mass stars instead."

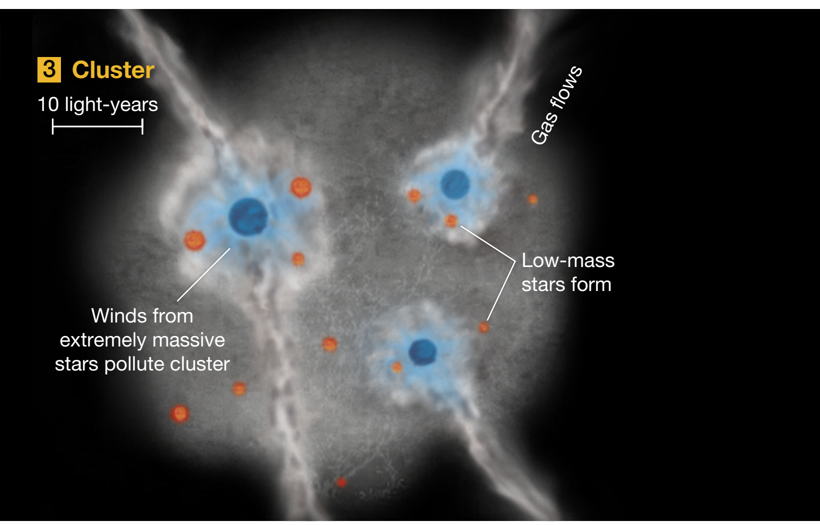
The coming generation of 30-meter telescopes, such as the Extremely Large Telescope that's currently under construction in Chile, might see these stars. The best place to look for them would be dwarf galaxies that started forming stars late, because these galaxies would retain fairly pristine gas that better resembles the material found in the early universe. Another way to prove their existence would be to search local globulars for black holes of a few 100 solar masses — potential leftovers from their proposed predecessors.

Solving the multiple-populations mystery might teach us not just how stars and clusters work, but about galaxy formation as a whole. The first, lowest-metallicity stars in the universe probably formed in globular clusters, Gieles points out. "When the JWST looks at objects at high redshift, it's really looking at globular cluster formation, which is the first step of galaxy formation."

"To understand galaxies," he adds, "we must understand globular clusters."

■ **JAN HATTENBACH** is a science writer based in Spain. He enjoys observing globular clusters in his telescope.

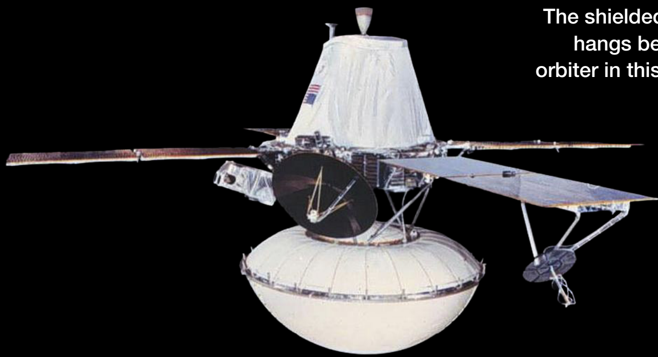




VIKING'S 50TH ANNIVERSARY by Ben Evans

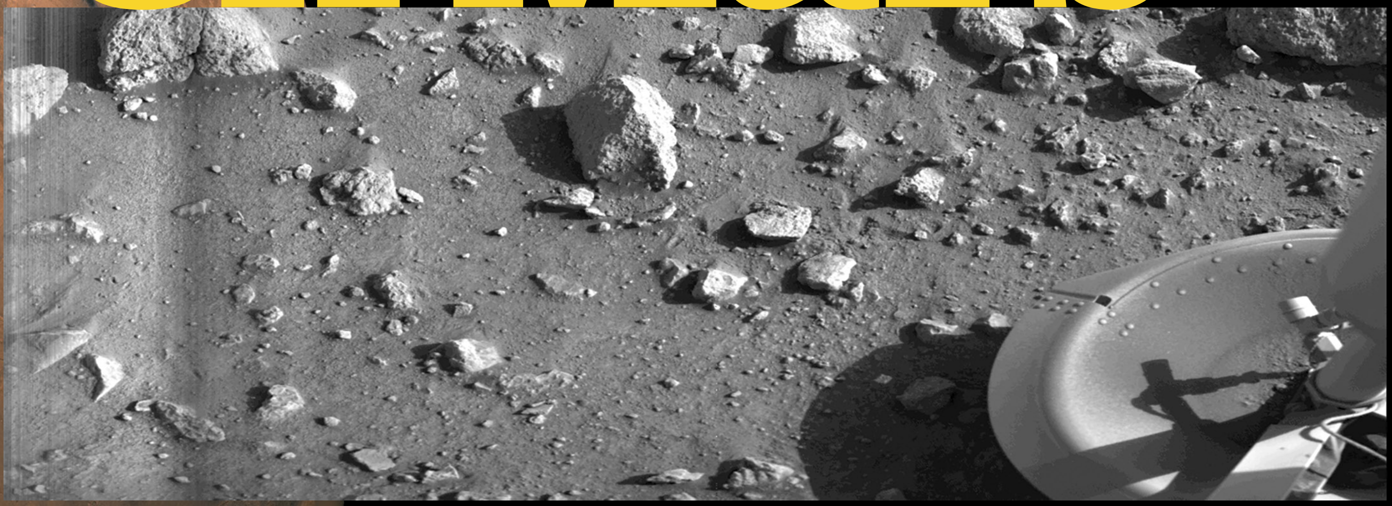
First Fee

FIRST LOOK At right is the first photograph ever taken from Mars's surface. Viking Lander 1 snapped the shot minutes after landing in Chryse Planitia (marked on globe). The central large rock is about 10 cm (4 inches) wide. The dark vertical band at left might be due to clouds or airborne dust temporarily blocking sunlight.



SPACE STORK The shielded lander hangs below the orbiter in this image.

t on Mars



Fifty years ago, two NASA landers made history when they touched down on the Red Planet.

FIRST IMAGE: NASA / JPL; GLOBE: NASA / JPL / USGS; VIKING ORBITER: NASA

On July 20, 1976, Viking Lander 1 alighted on a planet that long ago may have resembled early Earth. Shielded from temperatures of 1,500°C (2,700°F) by a protective aeroshell, the craft streaked through Mars's wafer-thin atmosphere at a blistering 4.6 km/s (10,000 mph).

A sturdy supersonic parachute arrested its descent. Retrorockets then guided it to the western slopes of Chryse Planitia, the "Plain of Gold" north of Mars's equator. About 3.4 billion years ago, Chryse may have held a large body of water.

Viking 1 landed on an undulating plain, littered with porous, angular boulders interspersed with wind-built sand drifts, all drearily backlit by a creamy, butterscotch sky. But this desolate place whispered of a watery past — and if there was water, then life might once have stirred here as well.

Launched in the summer of 1975, the twin Viking orbiters and their landers reached Mars at a time when public fervor and scientific consensus about life on the Red Planet were in highly polarized flux. Our first robotic forays to Mars had brought mixed results: a jumbled, confusing picture of a world that seemed utterly inhospitable to life yet bore unmistakable signs of past habitability. Mission planners hoped the Vikings would clarify things.

The Viking spacecraft wouldn't find definitive signs of life, however. In accomplishing the first fully successful landings on Mars half a century ago, the paired missions gave us detailed measurements of the planet's atmosphere and soil chemistry and paved the way for the next generation of robotic explorers.

But thanks in part to the crafts' failure to find life, that future exploration was a long time in coming.

Funding Woes

Blood-red Mars has bewitched us for centuries. Early ideas of Martian life oscillated between utopias peopled by enlightened beings to dystopias like that of the tripod-stalking beasts imagined in H. G. Wells's *The War of the Worlds*. Odd linear surface markings ignited early speculation that Mars had "canals," fashioned by intelligent Martians in a last-gasp bid to irrigate their desiccated, dying world.

But the canals proved to be optical illusions. Mars's romantic allure faded, and Martians morphed instead into motifs for humanity's deep-seated fears, depicted as bellicose monsters or victims of ruined civilizations.

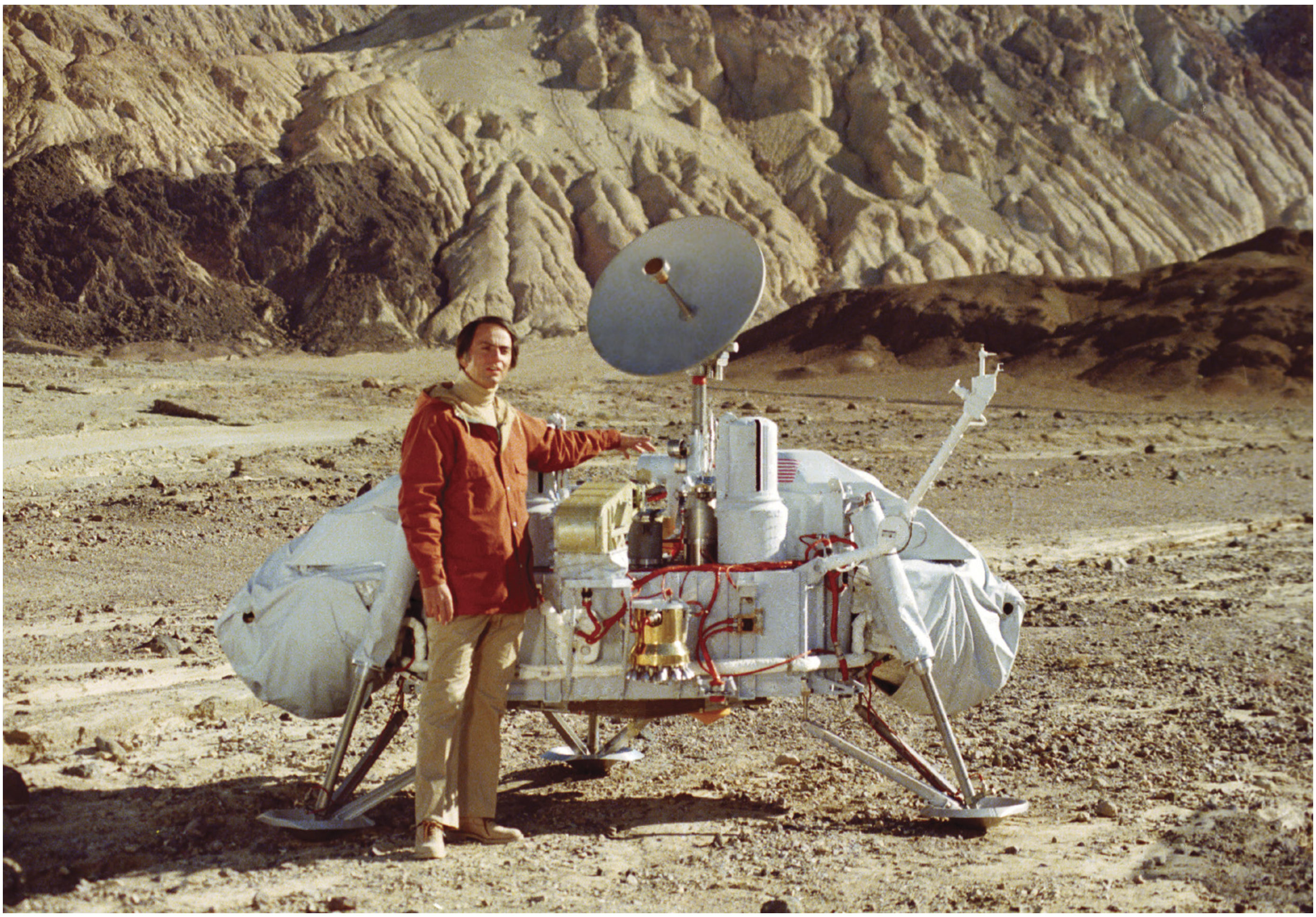
In 1965, Mariner 4 quenched any last hopes of canals or advanced alien societies. When it flew past Mars, it revealed a thin carbon dioxide atmosphere and a surface pressure roughly 1% that of Earth's own — insufficient for liquid water to exist or rain to fall. The thin air, and the solar ultraviolet radiation it failed to block, rendered the planet's dry, cratered surface unfit for life.

It spelled bad news for Project Voyager. Not to be confused with the spacecraft duo of the same name that would later explore the outer solar system, this Project Voyager comprised two pairs of robotic orbiters and landers that NASA planned to launch in 1971 for the Red Planet. Although the landers would descend to Mars under parachutes, the thin atmosphere and low pressure also required the addition of retrorockets to land safely — which imparted extra cost and weight penalties. Hopes to launch the Voyagers on a pair of Saturn IB rockets were snarled by Congressional budget cuts.

Consideration was next given to lifting both Voyagers atop a giant Saturn V, a rocket 6.6 times too powerful for the job, which hiked costs from \$1.25 billion to \$2.4 billion and postponed launch to 1973. But Voyager's woes ran deeper than

Martian Memorials

The Viking landers still sit on Mars, but under different names. In 1981, NASA christened Lander 1 the Thomas Mutch Memorial Station, in honor of the mission's imaging team leader. Lander 2 was renamed the Gerald Soffen Memorial Station in 2001, after Viking's project scientist. And in 1984, NASA transferred ownership of Lander 1 to the Smithsonian — the first time in history that a museum took possession of an artificial object on another planet.



▼ **DREAMING OF MARS** Astronomer and science communicator Carl Sagan stands with a Viking lander model in Death Valley, California.

NASA / JPL

runaway budgets. By the end of 1967, the Vietnam War would claim more than 20,000 U.S. lives, and Great Society programs to tackle poverty and racial injustice at home gnawed at federal finances. Congress cut Voyager's funding in August 1967, citing "stringent fiscal circumstances."

In its place, NASA proposed two flybys that would release simple probes to make "hard" landings on Mars. These would launch on Titan IIIE/Centaur rockets, slightly smaller than the Saturn IB. In November 1968, the mission was named Viking, after the medieval Scandinavian adventurers who colonized northern Europe and established toeholds in Greenland and North America. It reflected the Vikings' spirit of discovery and yearning for exploration.

Even the Viking project found itself pared to the bone as budgets continued to tighten. But after Russia's Venera 4 made the first measurements from Venus's atmosphere in 1967, Thomas Paine — who led NASA from October 1968 through September 1970 — agitated for Viking to possess broader capabilities and a wider scientific remit.

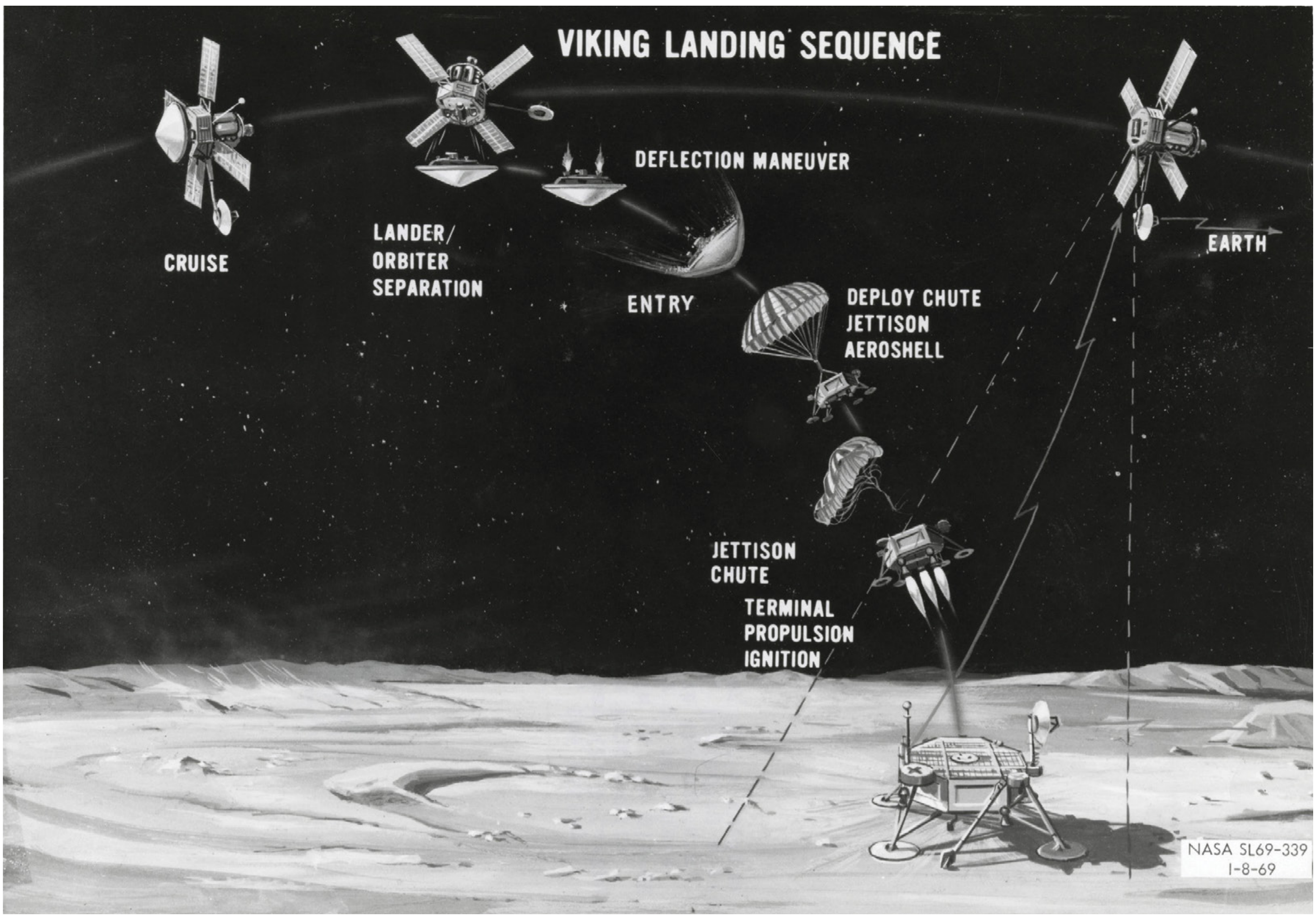
"It is a little hard to recapture the mood of the times," said senior NASA leader and former NASA Chief Scientist John Naugle in a later interview. "We were in competition with the Russians. They had a good strong program of landers. . . . We had to establish a good solid scientific mission."

Paine replaced the flyby modules with instrument-laden orbiters and substituted the impact probes with "soft" landers. "You don't do these things very often," he reportedly said, "and when you do them, you should really do them right."

The orbiters were tasked with ferrying the landers to Mars, then scouting and certifying suitable landing sites. Roughly the size of a small car, each orbiter carried four solar arrays that together generated 620 watts of power, sufficient to run a small coffee machine. Alongside the high-resolution cameras that would map the planet's surface, other instruments would profile atmospheric and surface temperatures, gauge water-vapor concentrations, and determine chemical compositions, pressures, and gravity fields.

The grand-piano-size landers were designed for 90-day surface lives. Their plutonium powerplants were deemed a necessary substitute for solar panels on Mars's surface, where even at noon sunlight is barely half as strong as it is on Earth. The landers carried a variety of instruments, includ-

▼ **LANDFALL** Landing on Mars is a multi-step process. The planet's atmosphere is thick enough that spacecraft need heat shields to survive entry, but not thick enough to make parachutes sufficient to slow descent for a soft landing. The Viking landers thus used a combination of heat shields, parachutes, and retrorockets. Subsequent Mars missions have followed adapted versions of this complex sequence.



NASA

ing a seismometer, a sampling arm to dig for soil specimens, and meteorological sensors to enable the first Mars weather reports. Two cameras facilitated monochrome, infrared, stereoscopic, and — for the first time on a robotic mission — color photography.

But the experiments that piqued public interest were those that looked for life. These instruments sought evidence of metabolism, growth, and photosynthesis — all hallmarks of terrestrial biology.

Meanwhile, costs continued to escalate in lockstep with the mission's growing complexity, almost tripling to more than $1 billion by the eve of launch. Experiments ran over-budget, the landers' footpads needed to be resized to ensure firmer grounding on rugged alien terrain, and solar arrays and fuel tanks aboard the orbiters were enlarged as Viking's complexity and power needs mushroomed. Congressional budget cuts forced launch to slide again to 1975.

"Viking was . . . the most expensive planetary mission ever," recalled former NASA Mars Program Director Scott Hubbard, "about $7 billion in today's dollars, which dwarfs anything but the James Webb Space Telescope." No single failure aboard either lander could stop more than one experiment — a tough ask for a machine with 61,000 parts.

Death-Defying Landing

Meanwhile, humanity's corpus of Mars knowledge steadily increased. In 1971, Mariner 9 revealed that ancient Mars was probably more clement than it is now, with valleys and braided channels uncannily resembling dried-up riverbeds. How long those more temperate conditions lasted, and what enabled them, remains an active area of research today (*S&T:* Oct. 2025, p. 14).

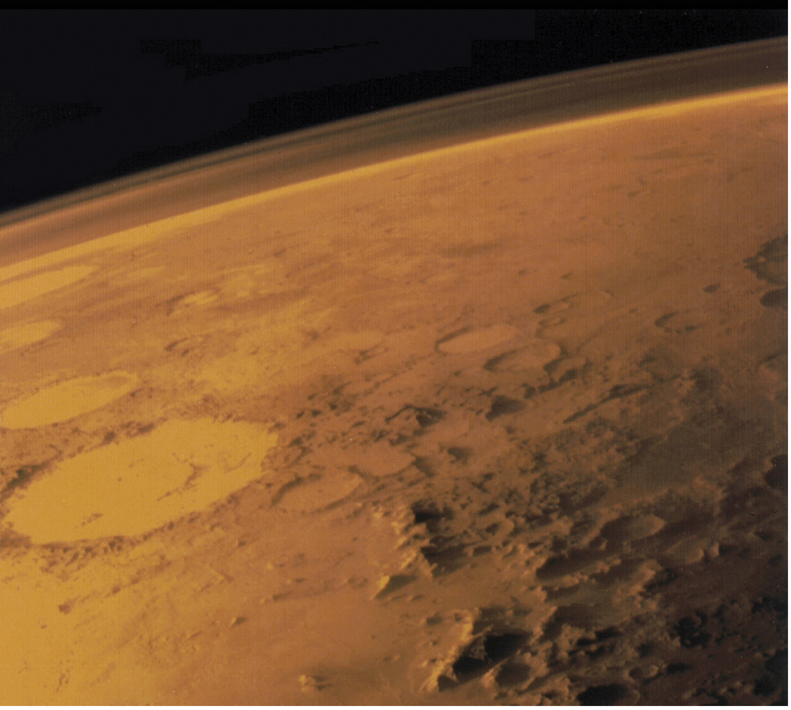
Martian life — if it ever existed — may have reached only microbial, not multicellular, levels. Even the remotest chance of finding life demanded that Viking be comprehensively sterilized before launch, to negate any risk of terrestrial bacteria reaching Mars.

Heat provided a predictable, reliable agent to sterilize every Viking component — from seals to solders, gaskets to wires. But sterilization also risked damaging delicate sensors or embrittling spacecraft parts. Titanium helped alleviate thermal expansion effects. Builders used inorganic construction materials whenever possible. Magnetic tapes, bearings, and gears utilized heat-resistant dry lubricants.

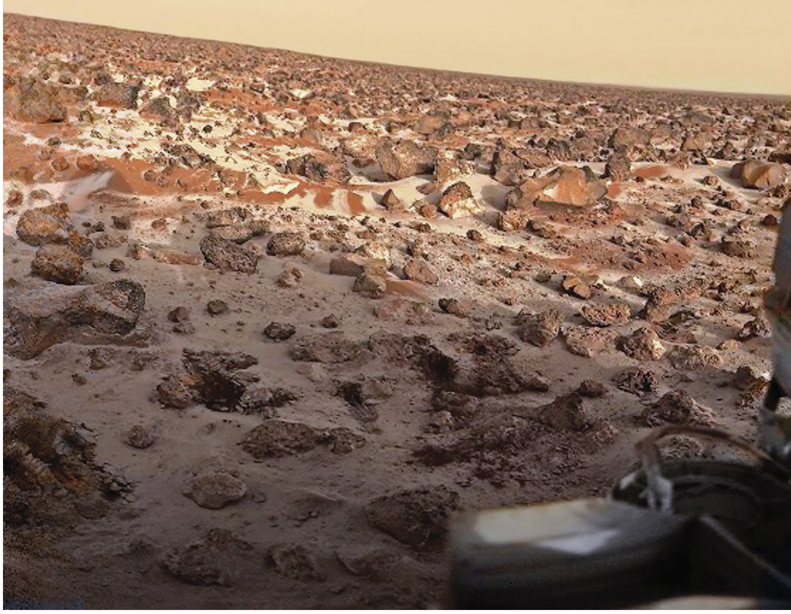
Before launch, each lander was baked for 47 hours of "terminal sterilization," including 30 hours heated to 112°C. They were then each encased in a two-piece, egg-shaped *bioshield*. Fabricated from coated, woven fiberglass 0.13 mm (0.005 in) thick, the bioshields kept the landers hermetically sealed and free from terrestrial microbes.

NASA planned to launch one craft on August 11, 1975, followed by the other on the 21st, both from Cape Canaveral's Launch Complex 41. But the first launch was delayed by a faulty valve and an accidental drainage of the spacecraft's batteries. Finally, at 5:22 p.m. EDT on August 20th, the rocket roared off the pad. The Titan's two stages propelled Viking 1 smoothly into Earth orbit, then the Centaur upper stage fired twice to send the spacecraft on a 10-month

THIN SHROUD Mars's atmosphere is visible along the planet's limb in this Orbiter 2 image.



CHILLY A thin layer of frost covers the ground around Lander 2. Image processor Ted Stryk used a "super-resolution" technique to process this image, but it's still small because the lander used its low-resolution mode to take it.



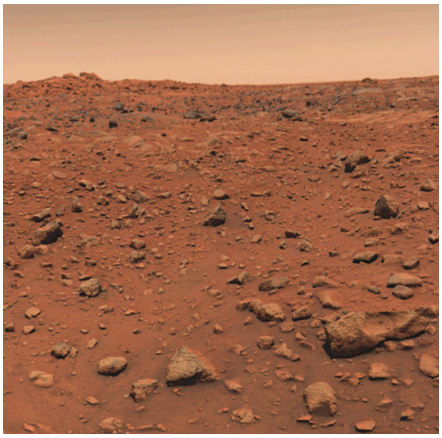
trek halfway around the Sun to Mars. Viking 2 followed on September 9th, its own launch having been delayed by a radio antenna malfunction.

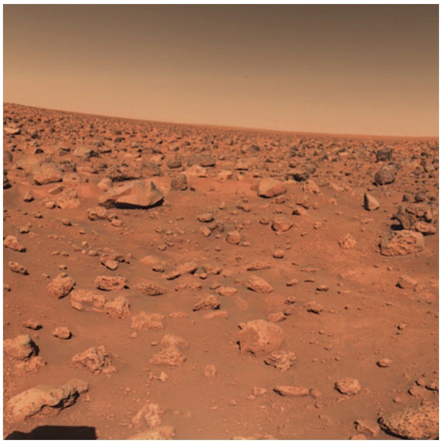
But the gremlins were not yet done. During their respective cruises to Mars, both craft had trouble: Viking 2's batteries proved sluggish, one of three soil-sampling ovens on both landers failed, and Viking 1 endured a persistent leaky fuel valve.

After traveling 700 million km, Viking 1 entered Mars orbit on June 19, 1976 — so precisely that one admiring engineer likened it to shooting a basketball from Los Angeles through a hoop in New York's Madison Square Garden.

NASA had already selected a group of low-elevation landing zones that they thought were promising places to look for evidence of life. Landing sites needed to have gentle slopes, few large boulders, and soils that were neither too soft nor too rocky for the landers.

Lander 1 was meant to set down on July 4, 1976, the bicentennial of the U.S. Declaration of Independence. "What a splash," joked Viking engineer Ernie Reyes. "Bugs Bunny would like that!"





◀ **AND NOW IN COLOR** The first color pictures of Mars's surface, taken by Lander 1 *(top)* and its twin *(bottom)*. The tilted horizon in Lander 2's image is due to the craft's own tilted stance.

Sadly, an Independence Day landing was not to be. The primary landing site's terrain was significantly rougher than the Martian average. "The smallest thing we had seen on Mars," said mission director Thomas Young, "was about the size of the Rose Bowl." Areas that looked safe in grainy Mariner photographs were actually scarred by deep gullies, scattered craters, and rocky outcrops — hardly ideal for a lander with just 22 cm (8 in) of ground clearance.

Mission planners instead selected a new site to the west, on Chryse Planitia's western flank: a region formed billions of years ago, perhaps by floodwaters rushing from equatorial canyons. On July 20th, orbiter and lander parted company.

Encased in its protective aeroshell, Lander 1 entered Mars's atmosphere at an altitude of 240 km, quickly decelerating from 16,000 km/h to 900 km/h (10,000 mph to 560 mph). Aeroshell-mounted instruments measured atmospheric gases, revealing the presence of life-enabling nitrogen (3% by volume) on Mars for the first time.

Some 6 km above the surface, the giant supersonic parachute opened. The aeroshell was discarded, and Lander 1's legs unfolded. The parachute slowed the rate of descent in just 45 seconds to 220 km/h. At an altitude of 1.4 km, the craft jettisoned its parachute, and Lander 1's three engines ignited.

To protect possible microbial life, the engines burned purified hydrazine. Standard hydrazine contains impurities, such as aniline, which can produce carbon-based exhaust products that scientists feared might obfuscate signs of Martian life. The craft also used 18 nozzles to disperse its exhaust, minimizing the impact on the ground: Mission planners intended to ensure Mars's surface was heated by no more than 1°C and that no more than 1 millimeter of soil was displaced.

Descending vertically at 8.7 km/h — as graceful as a returning skydiver — Lander 1 alighted with a slight jolt, honeycomb shock absorbers in its legs softening the impact. The 380-million-km gulf between the planets meant signals took 18 nail-biting minutes to reach the team back on Earth.

Astronomer Carl Sagan described the landing as "reasonably lucky." Viking Project Manager Jim Martin disagreed. "I don't plan on luck," he said. "It's people doing that extra job."

But luck did play a role for Lander 1: About 8 meters (30 feet) away lay a big rock, similar in size to the craft itself. "If we'd have landed on it, it would've destroyed the spacecraft," Young recalled.

Shortly after touchdown, Lander 1 transmitted its first image: a circular footpad on alien firmament, with a few light-hued, deeply pitted rocks dotted here and there. Later panoramic views also revealed sand dunes, low ridges, a curious cinnamon-red soil — and "Big Joe," the 2-meter-wide silt-covered rock.

It was a glorious moment for U.S. prestige. The *Chicago Tribune* called it "epoch-making," *The Philadelphia Inquirer* spoke of "another giant leap" — but legendary Flash Gordon actor Buster Crabbe was nonplussed. "I really do not know what the fuss is all about[,] landing on Mars," Crabbe quipped. "I landed there 40 years ago!"

The Life Question

Viking 2 entered Mars orbit soon after, on August 7th. Mission planners also shifted its landing site, from the broad Cydonia region to another northern plain called Utopia Planitia, a colossal impact basin formed about 4 billion years ago. On September 3rd, Lander 2 began its descent, but the orbiter's stabilization system temporarily lost power, and communications suffered a blackout for more than an hour.

When contact resumed, Lander 2 was already safely on Mars. One footpad touched down on a rock, producing a peculiar 8.2° tilt in the robot's view of the horizon. Utopia proved flatter and rockier than Chryse, with wind-whipped

NASA / JPL (2)

sand drifts, seasonal coatings of frost on nearby rocks, and a wide variety of boulders — some porous and spongy, others denser and more fine-grained.

Both landers behaved with recalcitrance. "We're not quite sure," recalled Young, "whether this thing is an obedient robot or a Frankenstein." Lander 1's seismometer jammed permanently, refusing to uncage its three sensing masses. The landers' sampling arms stuck as well, but the mission team eventually recovered both to successfully dig soil samples and deliver them to the milk-carton-size biology payload.

This instrument payload used different techniques to look for organisms. Scientists "fed" soil samples, whether with gases or nutrients, then watched for gases released by possible microbes as the organisms consumed the food.

The biology experiments returned odd results that continue to excite lively debate today. They found no definitive evidence for biological activity, but one experiment enigmatically delivered positive results. Researchers had added a broth of amino acids, vitamins, and organic compounds (nicknamed "chicken soup") to samples to see if any organisms metabolized it and the radioactive carbon it was tagged with. A subsequent steady flow of radioactive gases, higher than expected, suggested something — whether biological or non-biological in nature — might have consumed the nutrients. But with no conclusively biological materials found (even at vanishingly small parts-per-billion levels), scientists were skeptical.

NASA announced "enticing hints, but no firm answers" on the question of life from either Chryse or Utopia. *The Washington Star* glumly opined that the results "ended generations of fanciful imaginings" about Martian life.

"Many of us were very disappointed," wrote former NASA Langley Research Center Deputy Director Oran Nicks. "It had been a little like waiting for Christmas as a kid, only to find on Christmas morning that Santa didn't come through."

Scientific consensus came to regard the labeled-release result as a false positive, possibly induced by abiotic chemical reactions in Mars's soil. But proponents of life argued otherwise. They also suggested that the hydrazine retrorockets might have obliterated any microbes. The biology experiments might even have inadvertently snuffed out any organisms — drowning them in water or nutrients, perhaps, or accidentally cooking them in the landers' sampling ovens. Furthermore, the landers retrieved soil samples from a depth of only a few centimeters, likely too close to Mars's radiation-drenched surface for living organisms to survive.

There is another possibility. In 2008, NASA's Phoenix lander discovered perchlorate, a strong oxidant known to be toxic. Subsequent tests on Earth showed that perchlorate's byproducts after heating are chloromethane and dichloromethane, both of which were present in Viking data. We now know perchlorate is widespread on Mars. If it was present at Chryse or Utopia, it could have eradicated material from living organisms and further complicated the question of life.

The End of the Beginning

Circling overhead, the Viking orbiters contributed substantially to our understanding of Mars, producing high-resolution global maps and observing seasonal dust storms. On the surface, Lander 2's discovery of krypton and xenon suggested that, in its infancy, Mars's atmosphere was much thicker than it is today, a finding corroborated by later research.

Both orbiters also flew close by Mars's two moons, Phobos and Deimos, revealing groove-like surface striations, colossal crater chains, and low densities.

Orbiter 2 suffered a serious leak in early 1978 that quickly exhausted its remaining propellant and precipitated its shutdown that July. NASA deactivated Orbiter 1 in August 1980. Scientists expected both to orbit Mars into the 21st century before entering the atmosphere, although their current status is unknown.

On the surface, Lander 2 endured intermittent transmitter failings after October 1978, before NASA turned it off in April 1980 when its batteries could no longer hold charge. Its sister fared somewhat better, but by 1982 Lander 1's own

LANDER 1 MOSAIC: NASA / JPL

MARTIAN MORNING This mosaic combines images taken by one of Lander 1's camera systems over many days during the early morning hours, revealing the landscape in Chryse Planitia.

▲ **VALLES MARINERIS** Orbiter 1 took the images used to create this composite during its 701st orbit of Mars, on September 29, 1979. The canyon system stretches for roughly 4,000 km.

batteries had started to lose capacity. NASA set in motion a complex plan to prolong Lander 1's life, perhaps until 1994. But human error ultimately sounded the lander's death knell.

In November 1982, team members uplinked a new battery-charging command sequence to Lander 1, but they accidentally overwrote it on the computer memory location used by the mechanism that pointed the high-gain antenna. The result was that power and communications with the aging lander were permanently severed. Despite several months of efforts to revive Lander 1, the incident drew down the final curtain on Viking.

With that anticlimactic curtain call came the end of one of the most spectacular missions in the annals of planetary science. Between them, the Viking orbiters returned 52,663 photographs, mapping 97% of the planet's surface at 300-meter resolution, with some images revealing features as small as 8 meters wide. The landers transmitted another 4,000-plus photos and more than 3 million meteorological reports, revealing for the first time how another world's weather worked.

The Vikings' findings seized the imagination of a generation. Their photographs revealed the grandeur of Mars in unprecedented clarity, uncovering a world extremely unlike ours, yet with tantalizing hints of a very Earth-like past. And for the first time, they showed us Mars's surface with the same colors and textures as we humans might see it with our unaided eyes. In those heady weeks of 1976, NASA received 17,000 letters of support from an admiring public — amply demonstrating that, cost and complexity aside, Viking's lasting legacy was that it inspired an innate spirit of exploration.

Yet, despite these successes, Viking deterred future Martian exploration, at least for a while. The mission's inconclusive search for life contributed strongly to a harsh downturn in Mars funding. The demands of the hugely expensive Space Shuttle program aggravated the bleak fiscal outlook.

"We didn't find anything there that made us want to rush back right away," admitted former NASA Langley Research Center Director Edgar Cortright. "We found conditions not very conducive to life, and we found no life."

The U.S. didn't send another mission to the Red Planet until the 1990s. By then, with the *Challenger* disaster and its aftermath having sharply reinvigorated NASA's priorities, there came a renewed push to explore Mars. Several robots have gone to Mars since, but mission planners hope to eventually send humans.

And when the first people do set foot on the planet's ochre-hued surface, our next giant leap will owe a nod of thanks to Viking — the robotic mission that half a century ago unveiled Mars as never before.

■ **BEN EVANS** has been hooked on space exploration since childhood. He has written for several magazines, published several books for Springer-Praxis, and is currently working on his first novel. Quotes in this article come from NASA oral histories and publications, as well as Viking era news articles.

Explore Celestial Vistas Off the Beaten Path

Let's take a deep dive into the wondrous treasures of Vulpecula, Sagitta, Delphinus, and Equuleus.

The Northern Hemisphere summer Milky Way offers countless spectacular targets for stargazers, especially in the prominent constellations Cygnus, Aquila, and Sagittarius. But smaller constellations hold plenty of appealing sights, too. In this tour, we follow a scenic celestial side road that runs in a 35° arc from Albireo in Cygnus to Enif in Pegasus through the tiny constellations Vulpecula, Sagitta, Delphinus, and Equuleus. Here we'll find a satisfying assortment of star clusters, nebulae, and double stars to examine with a small telescope or binoculars on a warm summer night.

Into the Fox's Den

Let's begin in Vulpecula, the Fox. Polish astronomer and cartographer Johannes Hevelius conceived this constellation, and his wife, Elisabetha Koopman, herself an accomplished astronomer, featured it in an atlas published a few years after his death in 1687. I struggle to see a fox here, and from the suburbs I have difficulty seeing anything at all, since the constellation contains no stars brighter than 4th magnitude. But even modest optics will reveal the first stop on our tour: **Brocchi's Cluster**, also known as the Coathanger for its distinctive shape. Cataloged formally as Collinder 399, this asterism appears to the naked eye as a fuzzy patch about 8°

▲ **HOURGLASS IN THE SKY** M27, the Dumbbell Nebula, is one of the finest planetary nebulae in the sky. It appears almost rectangular through small telescopes at low magnification. Larger scopes will start to reveal its classic hourglass or apple-core shape and faint extensions on each side. Unless otherwise noted, north is up in all images.

STEFAN BINNEWIES / JOSEF PÖPSEL / RAINER SPARENBERG south-southwest of Albireo, Beta (β) Cygni. My 12×36 binoculars resolved the group into a straight line of six stars of magnitudes 5 to 7, spanning about 1.5° east-west, with four more stars forming a trapezoidal "hook" to the south. In my 85-mm refractor at 25× with a 2.7° field of view, I saw most of the stars as blue-white, save for an orange and a yellow star near the tip of the hook.

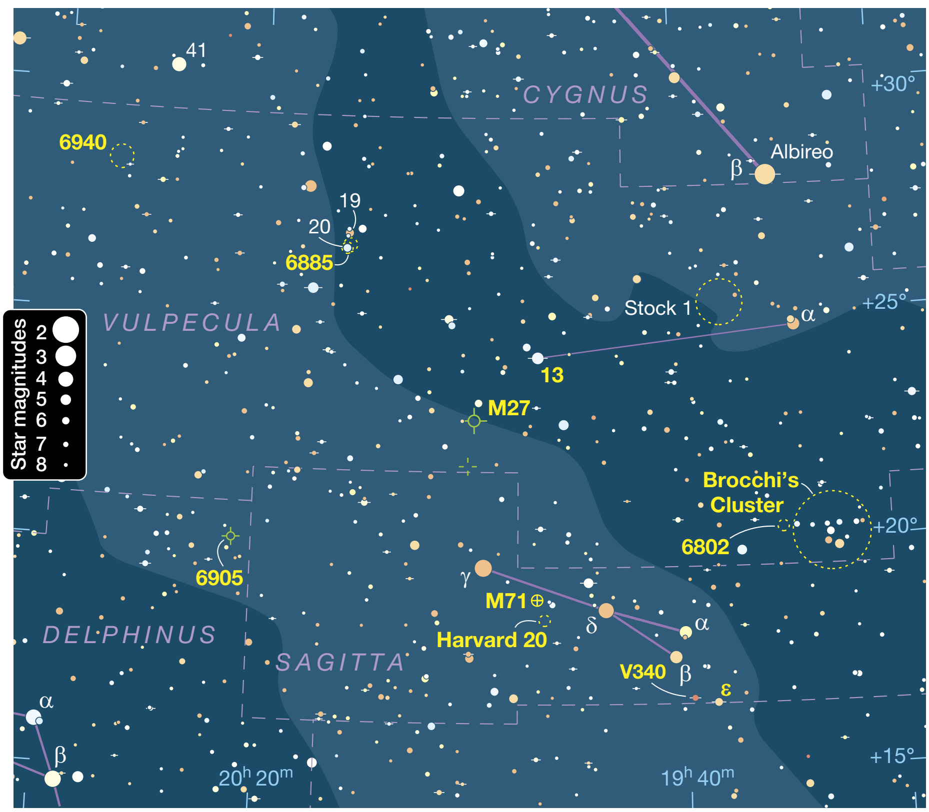
About 18′ east of 7 Vulpeculae, the easternmost star at the Coathanger's base, we find the open cluster **NGC 6802**. I easily saw its unresolved haze in my 85-mm refractor at 46× under dark sky. Just 5′ across, this 8.8-magnitude cluster profits from aperture and magnification. I partially resolved its tightly packed stars with my 10-inch Dobsonian reflector at 92×, and it appeared clearly rectangular, with its long axis oriented north-south. At a considerable distance of 3,700 light-years, this lovely cluster is dimmed and yellowed by the relatively thick dust in the plane of the Milky Way.

Now let's move on to **M27**, the Dumbbell Nebula, the showpiece of Vulpecula and one of the most magnificent objects in Charles Messier's catalog. It lies 3.2° north of Gamma (γ) Sagittae.

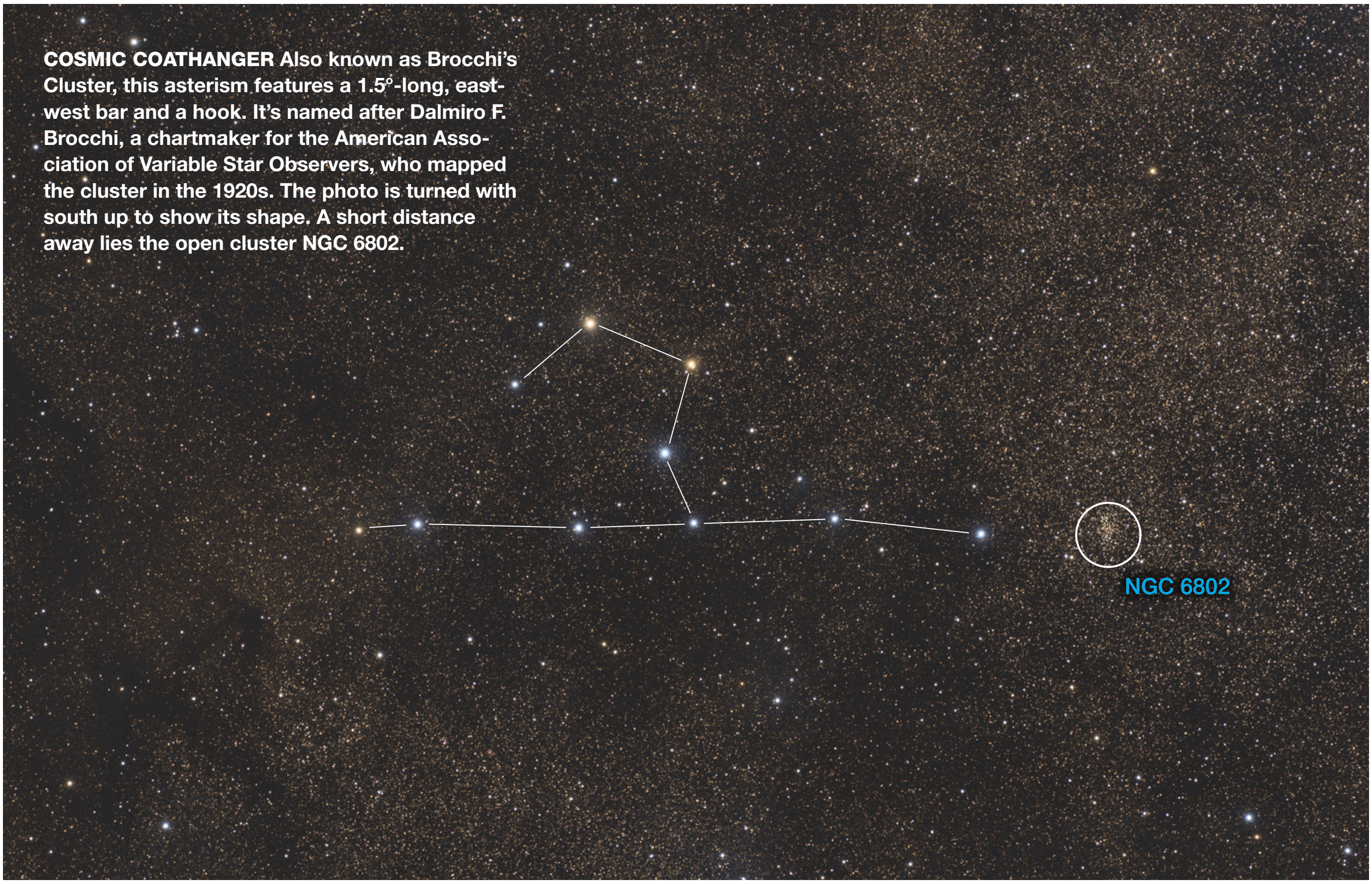
I first observed this hourglass-shaped planetary nebula as a youngster with a ramshackle 3-inch Tasco reflector, and it remains a favorite of mine. Arguably the finest of its class for visual observers, M27 shines at magnitude 7.1 and spans 8′ × 6′, enormous for a planetary. Its size is a consequence of its proximity (1,360 light-years) and age (about 9,000 to 14,000 years), which has given its gaseous envelope time to expand. M27 shows well in nearly any instrument. I saw hints of its telltale shape in 12×36 binoculars, while my 85-mm refractor at 75× and an ultra-high-contrast (UHC) filter revealed its pale-green hue and prominent end caps, as well as a bright diagonal bar running east-northeast to west-southwest. In my 10-inch at 92×, I detected traces of bright, knotty structure in the southwestern lobe along with foreground and background stars. A lovely star field envelopes the whole structure. The Dumbbell's central star, now emerging as a hot white dwarf, shines at 14th magnitude and lies beyond the reach of my 10-inch from my site.

Some 4.7° northeast of M27 lies the open cluster **NGC 6885**, anchored by the 6th-magnitude star 20 Vulpeculae. It spans about 18′ in diameter. In my 85-mm refractor at 46×, I saw three dozen or so 9th- to 12th-magnitude stars, most in a band running east to west with 20 Vulpeculae at its southern boundary. A few more scattered stars lie to the south of this irregular but attractive 8th-magnitude cluster. Across an ill-defined gap to the cluster's north lies the sparse NGC 6882, a putative open cluster dominated by three stars, including the 5.5-magnitude yellow-orange star 19 Vulpeculae. Both clusters framed nicely in a rich background at 75× in the 1.3° field of my 85-mm scope and 8-mm Ethos eyepiece. According to astronomy historian Harold Corwin, NGC 6882 is most likely a duplicate observation of NGC 6885, due to a positional error made by William Herschel when he discovered them in 1784.

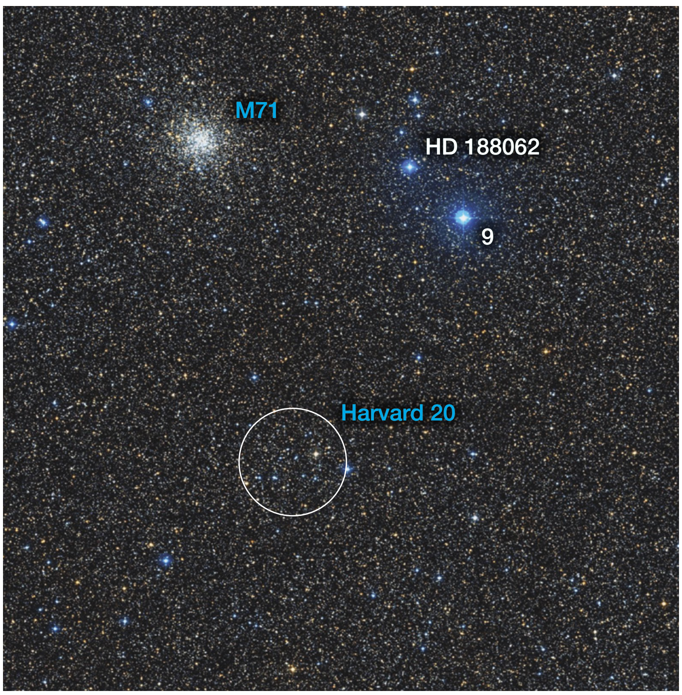
Now turn your telescope to the northeastern corner of Vulpecula, about 6.2° south-southwest of the star Epsilon (ε) Cygni near the southern wingtip of the Swan. Here lies the splendid but sometimes overlooked open star cluster **NGC 6940.** At magnitude 6.3 and 31′ in size, this beautiful aggregation lies only 2½° southeast of 4.0-magnitude 41 Cygni. In a telescope in dark sky, the cluster assumes the classic diamond-dust countenance that makes such objects appealing targets for visual observers. Even the finest astrophotos can't capture their appeal. In my 85-mm refractor at 75×, I saw perhaps 50 members from magnitude 11 down to my limit of visibility, along with red-orange FG Vulpeculae, a 9th-magnitude variable star near its center. The cluster appears uniform, slightly elliptical, and centrally compressed, with many outlying stellar assemblies of loops and chains. With some 170 members, NGC 6940



▶ **CELESTIAL FOX AND ARROW** Use this finder chart to plan the itinerary of your star-hopping. Unlike Sagitta, the Arrow, the stars of Vulpecula, the Fox, are relatively indistinct — use Albireo, Beta (β) Cygni, as a jumping-off point.



COSMIC COATHANGER Also known as Brocchi's Cluster, this asterism features a 1.5°-long, east-west bar and a hook. It's named after Dalmiro F. Brocchi, a chartmaker for the American Association of Variable Star Observers, who mapped the cluster in the 1920s. The photo is turned with south up to show its shape. A short distance away lies the open cluster NGC 6802.



▲ **A TALE OF TWO CLUSTERS** Use 6.2-magnitude 9 Sagittae and 7.7-magnitude HD 188062 as guideposts in locating the globular cluster M71 amid the rich Milky Way star field. About 30′ to its south-southwest is the loose, dim open cluster Harvard 20, the twentieth object listed in Harvard Observatory's 1930 catalog of star clusters.

contains sufficient mass to remain largely intact after a billion years of gravitational tugging and pulling by passing interstellar gas clouds.

Before we leave Vulpecula, let's power up and try to resolve the tight double star **13 Vulpeculae**. With components of magnitudes 4.6 and 7.4 separated by 1.5″, this physical double presented a challenge in my 102-mm f/11 ED refractor, even at 250× on nights of anything but rock-steady seeing. But when the air stabilized, I split it cleanly and saw the blue-white color of the primary and — with less certainty — a tinge of yellow-orange in the secondary.

Straight to the Arrow

We now journey southward along our celestial back road into the little constellation Sagitta, the Arrow. Claudius Ptolemy included Sagitta as one of the 48 constellations in his 2nd-century *Almagest*, and it's the third-smallest constellation by area, after Crux (the Southern Cross) and Equuleus (the Little Horse). The arrangement of Sagitta's brightest stars clearly resembles its name. Some ancient Greek legends feature Sagitta as the arrow Hercules used to kill Aquila, an eagle sent by Zeus to perpetually gnaw on the liver of Prometheus.

Sagitta sits in the plush star fields just off the summer Milky Way, making it ideal for sweeping aimlessly with a rich-field telescope for small star clouds and scattered patches of dark nebulae. Its showpiece is another personal favorite of

COATHANGER: RON BRECHER; M71 AND HARVARD 20: POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

mine, the globular cluster **M71**. It lies in a spectacular field halfway between Gamma and Delta (δ) Sagittae, 15′ east of a curious, Y-shaped asterism that resembles a mini-Sagitta, of which 6th-magnitude 9 Sagittae is the base. This small, loose globular spans about 7.2′. It appeared tiny, largely uniform, and partially resolved in my 85-mm refractor at 75×, with a hint of angularity to the southwest. My 10-inch at 150× resolved this 8th-magnitude cluster to the core and yielded a striking view of what appears to be a dense and slightly irregular open cluster rather than a globular. Astronomers have long debated whether M71 is an open cluster, but detailed photometric inspection confirms it's a globular with an unusually young age of 9 to 10 billion years.

While you're here, look 30′ south-southwest of M71 to see the sparse, scattered cluster **Harvard 20** spread over 8′. At magnitude 7.7, the cluster outshines M71 but is harder to discern against the starry background. With my 10-inch, I saw about 20 to 30 stars in a vaguely triangular shape. This indistinct cluster, along with M71 and the Y-shaped asterism, fits into a 1° field of view.

Now let's inspect the lovely double star **V340 Sagittae**, nearly 1° south-southwest of Beta Sagittae. The pair consists of a 6.4-magnitude red-orange primary and a 9.5-magnitude blue-white secondary separated by 28″. They were an easy split in my 85-mm scope with a 24-mm Panoptic eyepiece at 25×. To me, the primary looked ochre, while the secondary glowed a pale turquoise.

In the same field 31′ to the west, I saw another double star, **Epsilon Sagittae**. It featured a pale-yellow, 5.8-magnitude primary and an 8.4-magnitude secondary separated by 88″.

Dive into Delphinus

Shifting farther east, we arrive at Delphinus, the Dolphin. Its five brightest stars do resemble a little dolphin that spans about 6° from nose to tail. Four of the stars — Alpha (α) Delphini, Beta Delphini, Gamma Delphini, and Delta Delphini — form a diamond-shaped asterism known as Job's Coffin.

At the northwestern edge of Delphinus, near the border with Sagitta and Vulpecula and 6° northwest of Alpha Delphini, lies the lovely planetary nebula **NGC 6905**, nicknamed the Blue Flash. While dim overall at magnitude 10.9, it has sufficient surface brightness to punch through my light-polluted suburban skies. I easily spotted it with my 10-inch at 46×, appearing slightly extended and surrounded by a little triangle of 10th- to 12th-magnitude stars. The gray-green nebula is hemmed in by the triangle's two western

A Plethora of Summer Delights

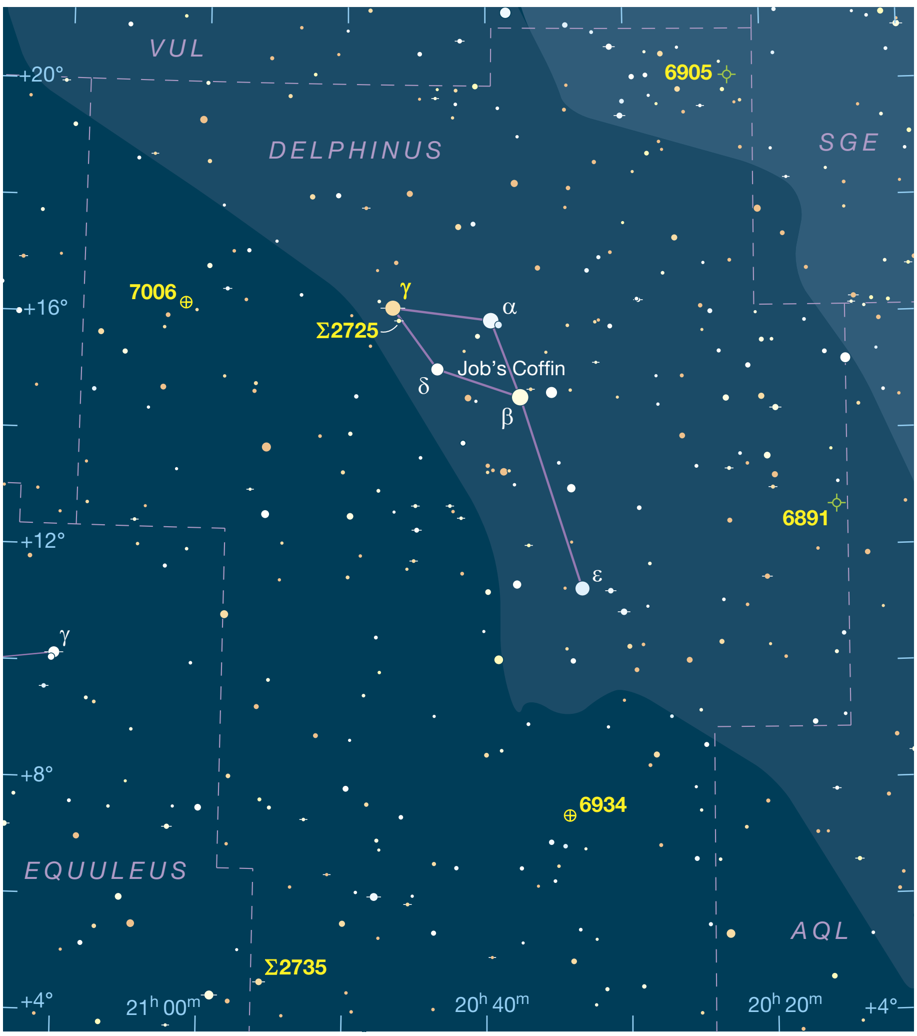
Object	Type	Constellation	Mag	Size/Sep.	RA	Dec.
Brocchi's Cluster	Open cluster	Vulpecula	3.6	90′	$19^h 26.2^m$	+20° 06′
NGC 6802	Open cluster	Vulpecula	8.8	3′	$19^h 30.6^m$	+20° 16′
M27	Planetary Nebula	Vulpecula	7.1	8′ × 6′	$19^h 59.6^m$	+22° 43′
NGC 6885	Open cluster	Vulpecula	8.1	18′	$20^h 12.0^m$	+26° 29′
NGC 6940	Open cluster	Vulpecula	6.3	31′	$20^h 34.5^m$	+28° 17′
13 Vulpeculae	Double star	Vulpecula	4.6, 7.4	1.5″	$19^h 53.5^m$	+24° 05′
M71	Globular cluster	Sagitta	8.1	7.2′	$19^h 53.8^m$	+18° 47′
Harvard 20	Open cluster	Sagitta	7.7	8′	$19^h 53.2^m$	+18° 21′
V340 Sagittae	Double star	Sagitta	6.4, 9.5	28″	$19^h 39.4^m$	+16° 34′
ε Sagittae	Double star	Sagitta	5.8, 8.4	88″	$19^h 37.3^m$	+16° 28′
NGC 6905	Planetary nebula	Delphinus	10.9	47″ × 37″	$20^h 22.4^m$	+20° 06′
NGC 6891	Planetary nebula	Delphinus	10.4	15″	$20^h 15.2^m$	+12° 42′
NGC 6934	Globular cluster	Delphinus	8.9	7.1′	$20^h 34.2^m$	+07° 24′
NGC 7006	Globular cluster	Delphinus	10.6	2.8′	$21^h 01.5^m$	+16° 11′
γ Delphini	Double star	Delphinus	4.4, 5.0	8.8″	$20^h 46.7^m$	+16° 07′
Σ2725	Double star	Delphinus	7.5, 8.2	6.2″	$20^h 46.2^m$	+15° 54′
Σ2735	Double star	Delphinus	6.5, 7.5	2.0″	$20^h 55.7^m$	+04° 32′
γ Equ, 6 Equ	Double star	Equuleus	4.7, 6.1	338″	$21^h 11.6^m$	+10° 14′
ε Equulei	Double star	Equuleus	5.3, 7.1	10.6″	$20^h 59.0^m$	+04° 18′
Σ2742	Double star	Equuleus	7.4, 7.6	3.0″	$21^h 02.2^m$	+07° 11′

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

stars. With a disk spanning 47″ × 37″, it took magnification well. A UHC filter at 180× showed the disk distinctly separated from the two stars along with barely perceptible hints of mottling in the nebula's interior. But it had far less structure than I saw in M97, the Owl Nebula in Ursa Major, to which NGC 6905 is sometimes compared. I saw no blue with my 10-inch scope, but I did see a "flash" of sorts when I averted my vision intermittently to optimize visual sensitivity.

Western Delphinus harbors another fine planetary, **NGC 6891**, about 4½° west-northwest of Epsilon Delphini. The nebula appeared smaller and brighter than the Blue Flash, which made it easier to distinguish from the background stars at low magnification with a UHC filter. With my 10-inch at 92× and a 1° field, I saw the starlike nebula at the southern end of a line of five stars ½° long, running north-south. At 150× it showed a tiny, featureless disk, and at 260× I saw hints of a bright halo around the disk. Unlike the Dumbbell Nebula, NGC 6891 easily revealed its central, 12.5-magnitude star in my 10-inch. Images from professional telescopes show that the nebula has several distinct shells, each expanding at different speeds, produced by separate outbursts from the dying central star over the last 28,000 years.

▼ **SWIM WITH THE DOLPHIN** The tiny constellation Delphinus is an easy-to-spot pattern of mostly 4th-magnitude stars. Despite its diminutive size, Delphinus resides in an area of the sky rife with deep-sky splendors.



Now let's examine a pair of distant globular clusters, starting with **NGC 6934**, a tightly packed stellar spheroid about 52,000 light-years away. With a diameter of 7′, this 8.8-magnitude cluster sits about 4° directly south of Epsilon Delphini (the tip of the dolphin's tail) and only 2′ east of a 9th-magnitude star. This dense stellar grouping features a number of *blue stragglers* — massive stars that burn faster, hotter, and bluer after the collision and merger of two smaller stars. They lie beyond the reach of a typical backyard telescope. In my 10-inch at any magnification, I saw nothing but a grainy outer halo of stars surrounding an impenetrable core. Even large, ground-based telescopes struggled to fully resolve the cluster's core until 1999, when the 8.1-meter Gemini North telescope on Mauna Kea cracked it using an adaptive optics system.

Smaller and dimmer still, the globular cluster **NGC 7006** lies some 135,000 light-years away, far out in the halo of the Milky Way. You can spot it 3.6° east of Gamma Delphini, the dolphin's snout. Glowing at magnitude 10.6 and with a diameter of 2.8′, the cluster was a dim smudge in my 85-mm refractor. My 10-inch offered a little graininess in its outer reaches along with a distinct but unresolved core. The cluster appeared slightly elongated east-west. While not much to look at, NGC 7006 is one of the most distant of the Milky Way's globulars and, along with NGC 6934, moves through the galactic halo in a highly elliptical orbit.

Now let's examine the superb Delphinus double-double: **Gamma Delphini** and Struve 2725 (**Σ2725**). Gamma features a golden, 4.4-magnitude primary separated by 8.8″ from a blue-white, 5.0-magnitude secondary. I easily split the components in my 102-mm refractor at 125× with an eyepiece that offers a ½° field of view. Some 14′ to the south-southeast, Σ2725 appears like Gamma Delphini's pale reflection. Its yellow components shine at magnitudes 7.5 and 8.2, with a 6.2″ gap. While both Gamma Delphini and Σ2725 are themselves physical doubles, the pair is not physically related.

The more challenging binary star **Σ2735** sits in the southeastern corner of Delphinus. This pair of distant suns of magnitudes 6.5 and 7.5 are separated by 2.0″. I split them easily under good seeing through my 102-mm refractor at 125×. The primary appeared canary yellow, while the secondary looked white.

▲ **MULTI-SHELLED PLANETARY** NGC 6891 exhibits a complex, asymmetrical structure, as revealed in this Hubble Space Telescope image. It features a dim, outer spherical halo surrounding a bright, inner core with at least two overlapping oval shells at different orientations. They indicate a series of outbursts from the 12th-magnitude central white dwarf star.

▲ **MAGNIFICENT DISTANT GLOBULAR** Lying about 52,000 light-years from Earth, 9th-magnitude NGC 6934, also known as Caldwell 47, was discovered by William Herschel in 1785. Globular clusters are large, spherical concentrations of ancient stars, typically numbering a few hundred thousand, residing on the outer fringes of galaxies.

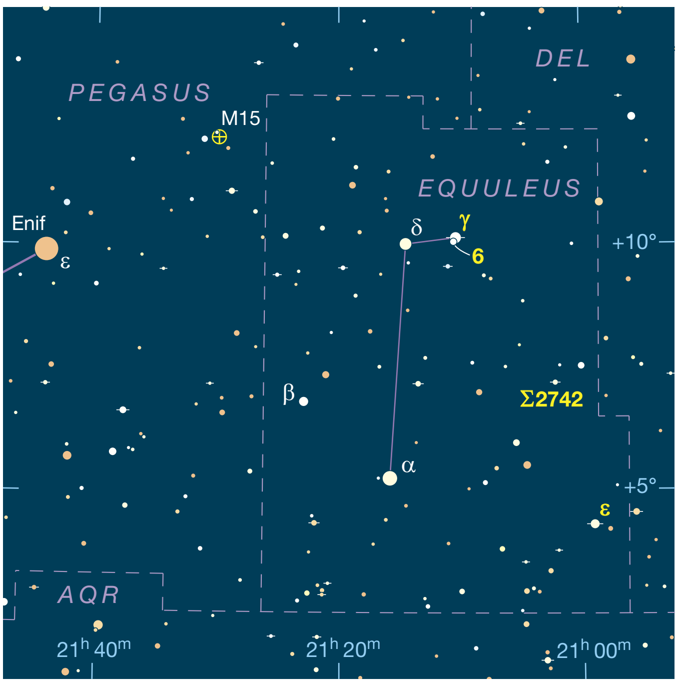
Galloping to Equuleus

Now let's jump over the fence of Delphinus to take in Equuleus, the Little Horse. This indistinct group was perhaps invented by Hipparchus in the 2nd century BC and included in Ptolemy's 48 constellations. In some Greek legends, its stars represent Celeris, a swift colt and the brother of Pegasus, the Winged Horse, although it takes a feat of imagination to see the shape of a little horse here.

As befits a constellation off the galactic plane, Equuleus contains many faint galaxies, too faint for my modest telescopes, but it also has a few interesting double stars. **Gamma Equulei** (magnitude 4.7) and **6 Equulei** (magnitude 6.1) form a wide binocular pair separated by 6′. I saw the two with plenty of sky between them in 12×36 binoculars. But I needed a telescope to split another double star, **Epsilon Equulei**, which consists of 5.3- and 7.1-magnitude components separated by 10.6″. They split easily in my 102-mm refractor at 47×. Boosting magnification to 125× increased the space between the yellow primary and blue-white secondary. Finally, the tidy double **Σ2742** features two solar-type stars of magnitude 7.4 and 7.6, split by 3.0″. They looked balanced and stately with their matching diffraction patterns in my 102-mm scope at 170×.

We're getting too far east now, nearly into Pegasus and the realm of galaxies, so it's time to end our ride down this celestial side road. While they may resemble characters in an illustrated children's book, the fanciful constellations of the Fox, the Arrow, the Dolphin, and the Little Horse offer us plenty to see and to return to during the slowly lengthening summer nights.

■ Contributing Editor **BRIAN VENTRUDO** enjoys surfing the Milky Way with wide-field telescopes from his home near Calgary, Canada (see his website **CosmicPursuits.com**).



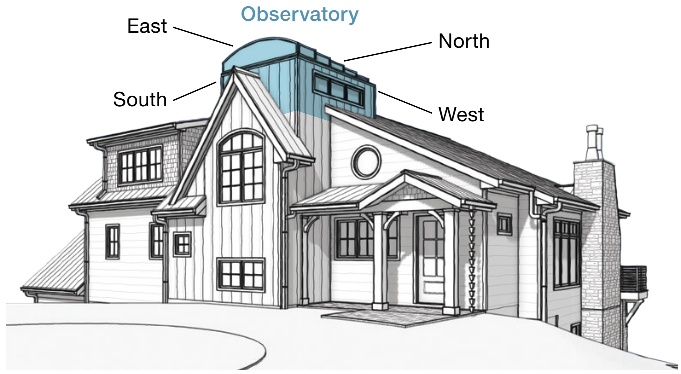
◀ **EQUINE ADVENTURE** You can use Enif, Epsilon (ε) Pegasi, the 2.4-magnitude star marking the nose of Pegasus, the Winged Horse, as your starting point in exploring the domain of Equuleus, the Little Horse.

The Clover Hollow Mountain Observatory

AERIAL VIEW Retired NASA engineer Paul Geithner and his wife, Carol, commissioned their three-story mountainside lodge to be crowned with a custom observatory to house his Celestron C11 Schmidt-Cassegrain telescope.

This residential rooftop facility puts unusual roof segments to good use.

Not long ago, I retired from my career as a deputy project manager for NASA. My wife, Carol, and I recently commissioned the design and construction of a custom lodge on a mountainside in southwestern Virginia. Before our designer, Marc Manley of Skia Design, unveiled the first draft of his plans, he asked, "Given your occupation, are you into astronomy as a hobby?" I curiously replied "Yes." We chatted for a while about telescopes and amateur astronomy, and then he told me his design lends itself to including a rooftop observatory. It's funny he mentioned it because my wife has said that if we ever commissioned a custom home, it should have a rooftop observatory. We were enthusiastic about Marc's design and the novelty of the observatory, and our builders Chris and Lydia Browne of C. R. Browne Construction were fully up to the task.



▲ **PEAK POSITION** The house was built with the front facing due east with the observatory atop, similar to 19th-century homes with a roof walk.

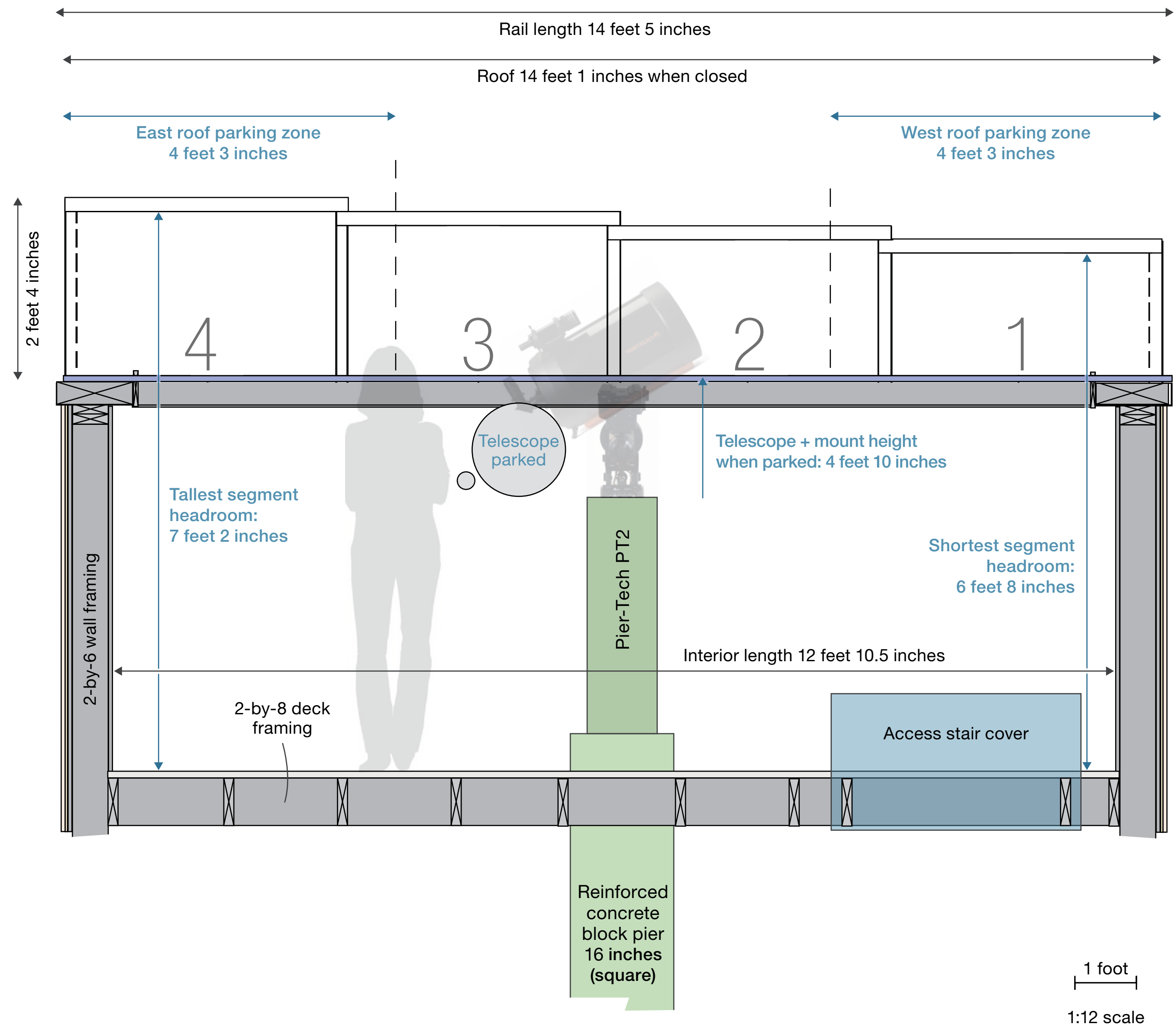
Challenges of a Rooftop Design

A rooftop observatory combines the requirements of an astronomical observatory with those of a house, which presents several challenges. An observatory needs to provide a stable mount for the primary instrument — in this case, my Celestron C11 Schmidt-Cassegrain telescope — as well as a means of access to the sky and exposure to the ambient environment. In addition, it also needs to protect the interior contents when not in use, not to mention mitigate sources of stray light.

As part of a dwelling, an observatory must meet residential building code requirements. Assuring a stable mount in the same structure where people and appliances generate mechanical disturbances can be difficult. Enabling access between the interior of the house and the observatory while protecting the integrity of the house are particular challenges, especially with a rooftop observatory.

With the telescope being at roof level, the first obstacle to surmount was pier design. Ours needed to be quite tall and proportionally slender, and we had to make it stable yet isolated from vibrations. Given the basic design of the house, the logical place to put the pier was through the three-story-tall column of open space between the basement slab and the underside of the observatory deck where the staircase is located. The placement of the pier determined the location of the observatory, which greatly influences the look of the house. The pier stands 30 feet tall (9 meters) above the basement slab, composed of 8-by-8-by-16-inch concrete blocks that are fully grouted with high-strength concrete

▲ **INNOVATIVE REPURPOSE** *Left:* The segmented roof panels of the observatory are a commercial product designed and marketed as retractable pool, spa, or outdoor bar enclosures but serve as excellent roll-off roofing. *Right:* Overlapping rubber skirts prevent rain or moisture from entering the building when the roof is closed. The folding stair enclosure's cover is visible to the right of the pier.



BEATRIZ INGLESSIS / S&T, AFTER PAUL GEITHNER

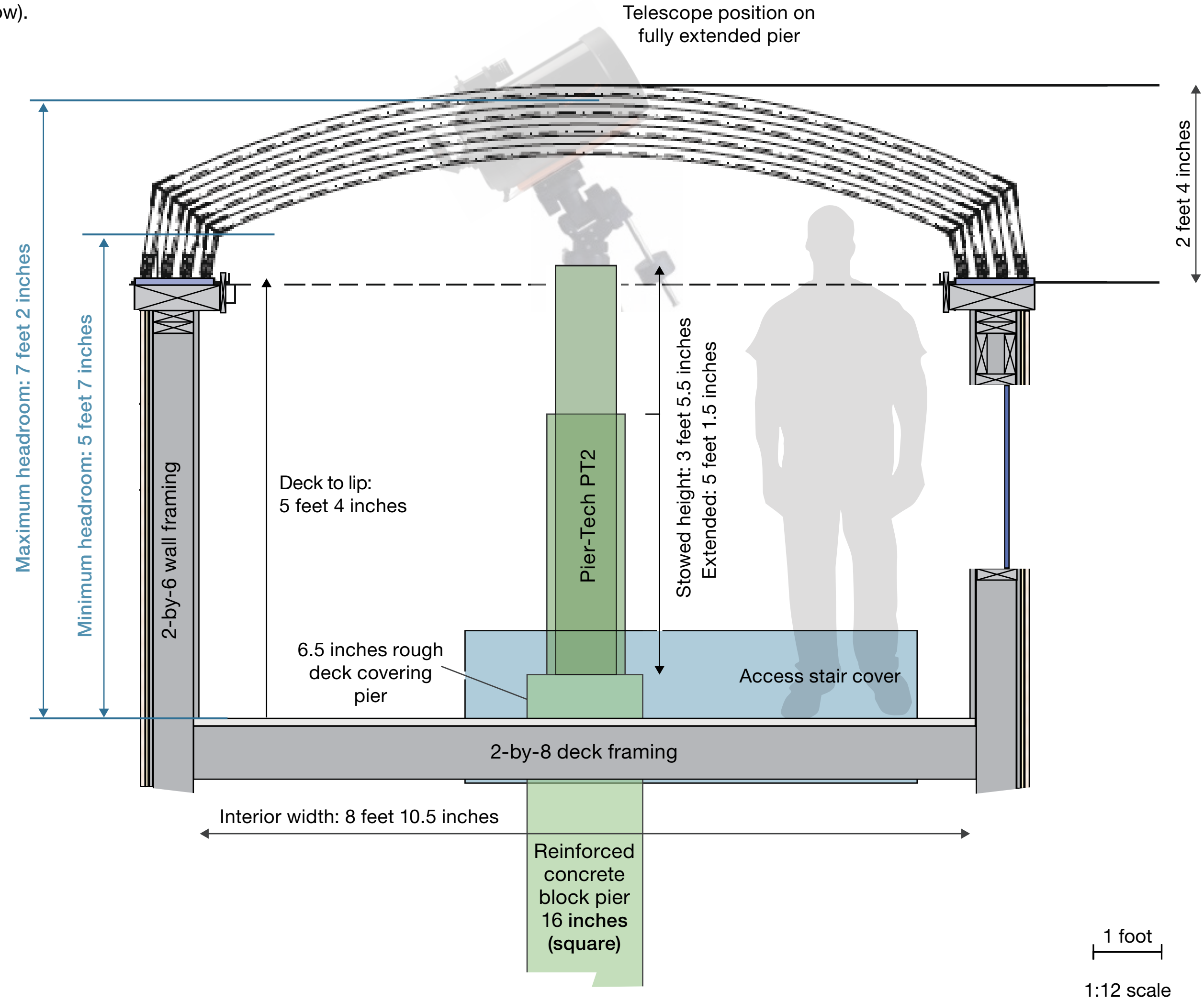
and reinforced with #5 steel rebar. It's anchored by a footer under the slab, about 10 feet below original grade, consisting of a cube of steel-reinforced concrete roughly 4 feet on each side. The footer weighs about 3.5 metric tons as does the pier itself, for a total combined mass of about 7 metric tons.

The pier is stout in compression of course, but given its height, it would deflect laterally at the top by nearly an inch if left unrestrained. To prevent this and to ensure its structural integrity, it's braced using the fewest number of points necessary. The restraints also need to isolate the pier from column shrinkage, potential foundation settling, or thermal expansion and contraction, as well as any vibrations from people moving around or unruly appliances without inducing tension loads into the column.

We chose to insert pins into the pier through vertically slotted holes in the home's structure at two orthogonal locations. A pair of ½-by-6-inch Tapcon concrete anchors are screwed into the pier through the stairway stringers at the first floor that act as shear pins to restrain the pier's north-south movement. A second pair of Tapcon anchors are attached at the second floor/loft level through the floor joist next to the pier to restrain any east-west movement.

The observatory deck is essentially a fourth level of the house like a roof walk, and the top of the pier protrudes through the deck and above the subfloor by about 7 inches. A roughly 1-inch-perimeter gap between the pier and the observatory deck framing is sealed with firebreak expanding foam as required by the building code. This material just happens to have the right mechanical properties to provide

◀▼ **CUTAWAY VIEW** These views show the dimensions of the observatory as seen from the north (facing page) and east (below).



BEATRIZ INGLESSIS / S&T, AFTER PAUL GEITHNER

good attenuation of shock from the deck and elastically limit motion of the top of the pier.

Walls and Flooring

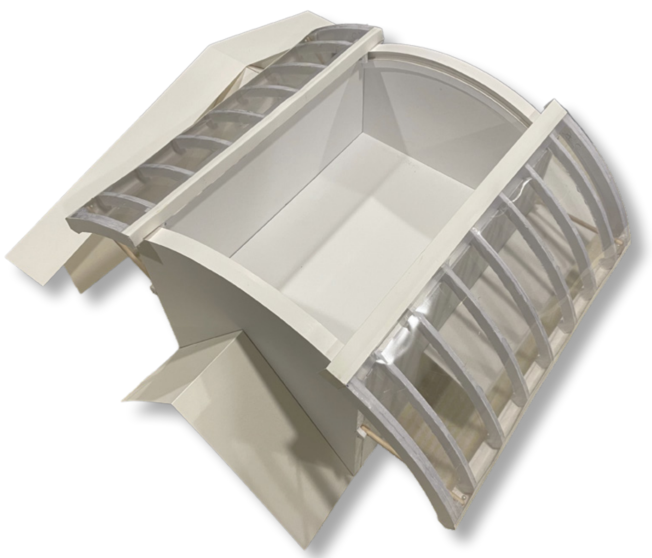
The observatory is essentially a parapet, roughly 10 by 14 feet, rising above a pitched roof. The volume of the observatory is considered an exterior space, which means it doesn't require HVAC or insulation between it and the outside but does necessitate environmental isolation from the home's interior to make it compliant with code. The observatory's deck is constructed of 23⁄32-inch subfloor over 2-by-8 joists spaced 16 inches apart with spray-foam insulation. The walls are 2-by-6 framing with 19⁄32-inch sheathing and board and batten exterior. There are only two fairly small areas where the walls overlap with living space and those are insulated.

A commercial insulated roof hatch in the deck provides access to the observatory from the loft below via a folding, steel attic ladder. The deck incorporates commercial flat-roof construction practice, with seam-sealed, 1⁄8-inch-thick rubber membrane adhered to the subfloor. This runs some 6 inches up the rough walls of the parapet, the sides of the hatch, and the sides of framing that surrounds the top of the pier. If some water could get in, it wouldn't damage the house.

The floor is finished off with vinyl plank over a layer of 11⁄16-inch-thick rubber horse-stall mats, and the top of the pier is capped with a sheet of stainless steel. The interior walls are sheathed in 1-by-6 tongue-and-groove pine with 1-by-6 pine baseboards and finished with exterior polyurethane. The parapet walls are capped with top plates of 4-by-12 PSL and rimmed on the inside with 1-by-6 PVC that protrudes above the top plates by 1¼ inches to form a water dam, and this is all sheathed in 22-gauge powder-coated roofing sheet steel. The north wall features three windows, the outer two being awning openings with screens, and the west wall includes an exhaust fan capable of moving 308 cubic feet per minute (sufficient to turn over the observatory volume about every 2.5 minutes) powered by a smart plug that's controlled remotely via a smartphone app.

Repurposed Retractable Roof

I had first considered a dome for the observatory but decided to go with a retractable roof for several reasons. The first was to be able to enjoy an expansive view of our Bortle 4 night sky in all its glory. Stray light also isn't a problem because dusk-to-dawn exterior lighting is prohibited and neighboring houses are hundreds of yards away. I also felt it was best to avoid the added complexity and expense of coordinating dome rotation with telescope slewing and tracking. Finally, reaching thermal equilibrium with the outside air is virtually instant when the roof is opened — there's no "chimney effect" of heat escaping through a narrow dome slit.



▲ **OPENING EXPERIMENTS** The author created scale models of several roof designs, though these revealed additional issues that inevitably come with untested ideas. In the end, the stock rails for the spa cover roof proved most economical and had a proven track record as a ready-made commercial product.

Marc and I considered various clamshell and roll-off-roof options. Neither of us wanted a traditional roll-off design given that the required rail support stanchions would create penetrations in the roof, as well as spoil the look of the roofline. I came up with a couple of enclosure designs and even made scale models that I shared with Marc and Chris. The first was a sliding, four-bar mechanism clamshell enclosure using garage-door hardware, plus support rods to offload and guide the two halves of the deployable roof. My other idea was a bifurcated sliding cantilevered deployment variant of the roll-off roof. The issues with both designs were that they would require costly custom fabrication and they would present the inevitable surprises and extra expenses that come with any new design.

While we searched for existing and reasonably priced commercial alternatives, I stumbled upon a couple of examples of segmented sliding enclosures used as covers for spas, pools, and as retractable roofs over open-air bars and restaurants. I chose Pool & Spa Enclosures, LLC, in New Jersey as my vendor. Manufacturing is done in the Czech Republic by Alukov, and the enclosure footprint can be specified to virtually any size to the millimeter.

The four enclosure segments are powder-coated structures of extruded aluminum, riveted and screwed together and fitted with bronze-tinted, 10-mm twin-wall polycarbonate panels. Each segment slides independently back and forth on wheels that ride on the aluminum tracks fastened to the tops of the north and south parapet walls. The segments, which glide effortlessly with the push of a finger, can each travel the full length of the tracks, and they nest under one another to enable a nearly fully open enclosure wide enough so that trees, rather than the roof segments, are what limit access to the sky. The segments lock in their closed positions with spring-loaded, stainless-steel pins, and incorporate stainless-steel L-brackets that are captured within grooves in the tracks to keep them from lifting off.

My enclosure is qualified for more than 32 kg (70 pounds) per square foot of snow load and is practically weather-tight. No rain gets past the overlapping rubber seals between the roof segments, and I've seen only a minuscule amount of dry snowflakes get through in the worst blowing-snow conditions. Only the tracks get wet, and that water drains away and is prevented from dripping inside by virtue of the 1¼-inch lip around the inner perimeter of the top of the parapet.

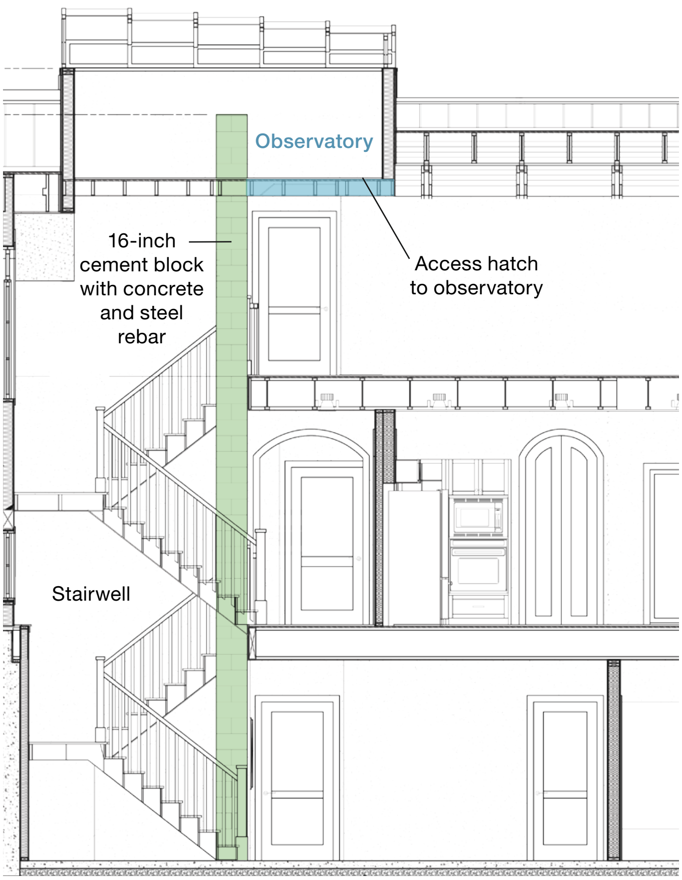
The only issue that I still needed to address was the greenhouse effect produced by the translucent enclosure. It would get uncomfortably warm in the observatory during the day, especially in summer. To reflect most of the sunlight, I attached 3-mm-thick SmartSHIELD radiant barrier foam that's aluminized on one side to the interior ceiling of the roof segments. While this helped a lot by reflecting most sunlight, it would still get warmer inside than I liked, so I added 3-mil-thick (76 micron) 1100 aluminum sheeting over the exterior top surfaces. (I left the enclosure side windows as is.) This reflected all sunlight hitting the top of the enclosure and made a dramatic difference, mitigating most of the thermal buildup.

Power and Instrumentation

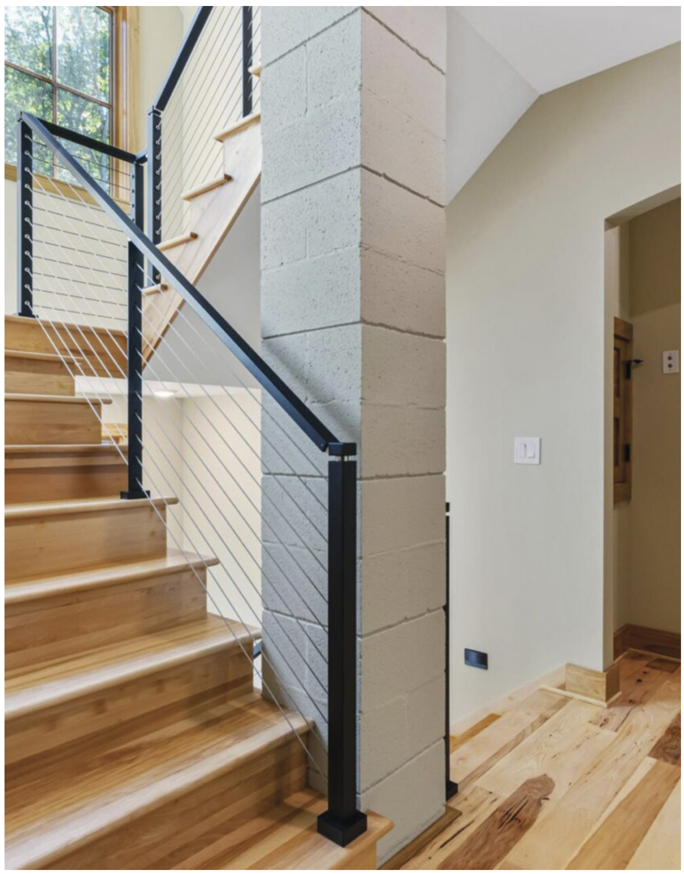
One thing that's easy with a new build is adding power and data connectivity. We included a 115 VAC 20-amp outlet on a dedicated circuit breaker at the pier cap, while the east and south walls each have 115 VAC 15-amp outlets on a separate circuit. The exhaust fan is on the wall outlet circuit and its smart plug is hidden in the wall and accessible via a removable panel. On the south interior wall are two sconces on three-way switches with one switch in the observatory and another in the loft below. Valent RGBW wet location LED color strip lighting is installed under the interior lip of the parapet wall top plates, which I've set to deep red at low luminosity for nighttime ambient lighting. All receptacles and lamps are protected from weather and rated for exterior use. For networking, there is Cat 5e ethernet cable running to the pier cap, though wireless connectivity from the house router on the main level is good.

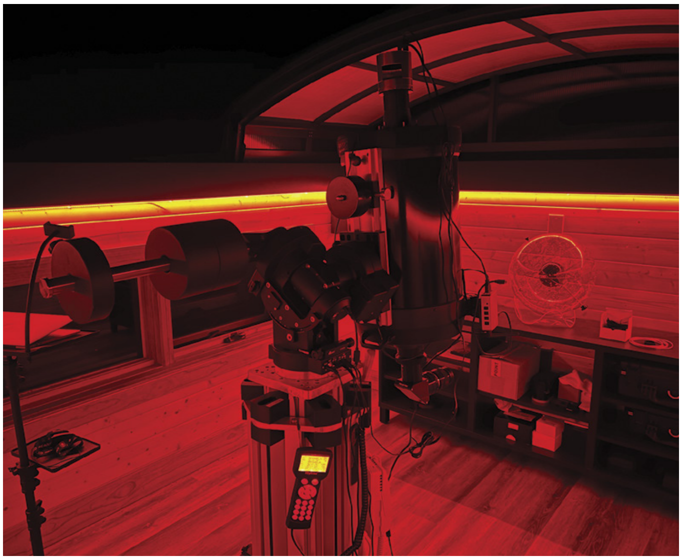
▶ **ATTIC ACCESS** The observatory is accessed with steel pull-down attic stairs.

▼ **STAIRWELL PIER** The three-story-tall, 15.7-inch-square steel-reinforced concrete-block telescope pier is surrounded by the home's stairwell. It's anchored by four shear pins at two locations — two on the second level and a pair on the third — to restrain its motion and isolate it from vibrations from people or appliances within the home.



CUTAWAY RENDERING: COPYRIGHT MARC MANLEY / SKIA DESIGN LLC





▲ **EASE OF OPERATION** The observatory houses a Celestron C11 that rides atop an iOptron CEM70 center-balance equatorial mount fastened to a Pier-Tech PT2 Electric Height Adjustable Pier. In typical use, the pier is extended to place the eyepiece at a comfortable height for observing. It can also elevate the scope above the roof segments if needed.

▲ **OPENING OPTIONS** The segmented roof panels move independently of each other and can be opened in three different ways. Here they are set to provide a central opening, with the panels secured to both the east and west parking positions. They all can be pushed to one side or the other if needed.

The concrete pier is topped with a Pier-Tech PT2 adjustable-height pier fastened to its four J-bolts and base plate that were set in the pier's concrete grouting as the last of it was poured. My mount is an iOptron CEM70 center-balance equatorial mount connected to an aluminum adapter plate and bolted to the PT2. Atop the iOptron mount rides the Celestron C11 SCT. The observatory is furnished with a BESTÅ TV shelf unit from IKEA for storage of accessories. There's also a telescoping tripod stand on casters to hold a laptop to interface with a ZWO ASIAir Plus controlling my equipment.

Easy Access to the Stars

I'm very happy with the performance of Clover Hollow Mountain Observatory. I don't experience any discernable polar alignment shift or jitter because the pier is stable and sufficiently isolated from vibrations. Still, I take care to minimize disturbances when recording images, particularly at plate scales when small deflections can result in image motion across multiple detector pixels, regardless of setup.

The interior stays dry and my equipment is safe from the elements. I typically open only the middle two segments of the roof for sky access as my total viewable area is ultimately limited by trees, and I can also raise the scope on the PT2 to have a clear line of sight above the entire roof if necessary. Moreover, the PT2 is really handy for positioning the telescope so that the eyepiece is at a comfortable height for visual observing. Access to the observatory from the loft below is a matter of pulling down the attic ladder, and once everyone is up on the deck, I close the hatch for safety. The temperature and humidity inside are pretty much whatever they are outside, so rising room air and tube currents within the scope aren't an issue. I typically keep the awning windows cracked a few inches and run the exhaust fan during peak heating hours on summer days.

A potential problem with a rooftop observatory is degraded seeing due to convective air currents driven by the surrounding roof surface that's much hotter than the air above it. Thankfully, I haven't had any issues with this while observing at night. Infrared thermometer measurements show that the roof responds very quickly to match the temperature of the ambient environment after sunset due to its design. The house has vaulted ceilings and features "hot roof" construction — that is, there's no attic space but rather the roof's asphalt shingles, underlayment, and sheathing are nailed to 2-by-16 wood I-beam rafters insulated with spray-on foam and finished on the interior. Additionally, the high heat emission of the shingles makes them cool quite rapidly.

The situation during the day is different than at night with sunshine heating the roof up to several tens of degrees above that of the surrounding air. Nonetheless, I've had success observing the Sun from my observatory, with the seeing being similar to observing at ground level on various surfaces.

It's such a convenience having an observatory as part of our home. I can simply open it up, turn everything on, and start observing. The equipment is all there, everything is aligned and at a known location, and the optical tube assembly is already near or at ambient temperature, so setup and settling times are minimal. And I can easily and quickly retreat to the interior of the house and continue operations remotely if I want or need to.

■ **PAUL GEITHNER** is a former NASA engineer and deputy project manager (technical) who worked on the Hubble and James Webb Space Telescopes.

1 DAWN: The month opens with Mars in Taurus hanging some 4½° lower right of the Pleiades, while Aldebaran twinkles farther to the lower left. This scene graces the east-northeastern horizon before sunrise.

6 EARTH is at aphelion, farthest from the Sun for the year (around 3.4% farther than it was at perihelion in January).

9 DUSK: Face west to see Venus about 1° above Regulus, the brightest star in Leo, the Lion. Catch the duo before it sinks out of sight. Turn to page 46 for this and other events listed here.

11 MORNING: Early risers can spot the waning crescent Moon, Mars, and Aldebaran forming a delightful line above the east-northeastern horizon. About 5° separates the crescent from the planet, while Aldebaran shines some 5½° below right of Mars and the Pleiades glitter to the upper right.

16 DUSK: Low in the west, the two-day-old crescent Moon sets with Regulus about 1¼° to its upper right, while blazing Venus trails farther to the upper left.

17 DUSK: Look to the west to see the waxing crescent Moon with Venus a bit less than 6° to the right.

20 DUSK: The Moon, one day shy of first quarter, hangs some 2¾° below Virgo's shining light, Spica. Face southwest to take in the view.

24 DUSK: Turn to the south to see the waxing gibbous Moon 2½° lower left of the celestial Scorpion's smoldering heart, the supergiant Antares

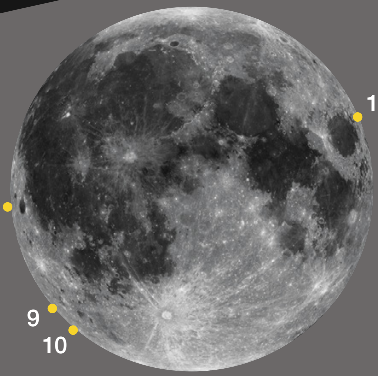
30–31 ALL NIGHT: The Southern Delta Aquariid meteor shower is expected to peak, but light from the Moon, just one day past full, will severely hamper viewing.
—DIANA HANNIKAINEN

▲ Messier 71 is a sparse globular cluster in the constellation Sagitta, the Arrow. In the image, north is to the lower left. Turn to page 28 for more on this and other targets in small constellations. ESA / HUBBLE / NASA

JULY 2026 OBSERVING

Lunar Almanac

Northern Hemisphere Sky Chart



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

NASA / LRO

MOON PHASES

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

LAST QUARTER

July 7
19:29 UT

NEW MOON

July 14
09:44 UT

FIRST QUARTER

July 21
11:06 UT

FULL MOON

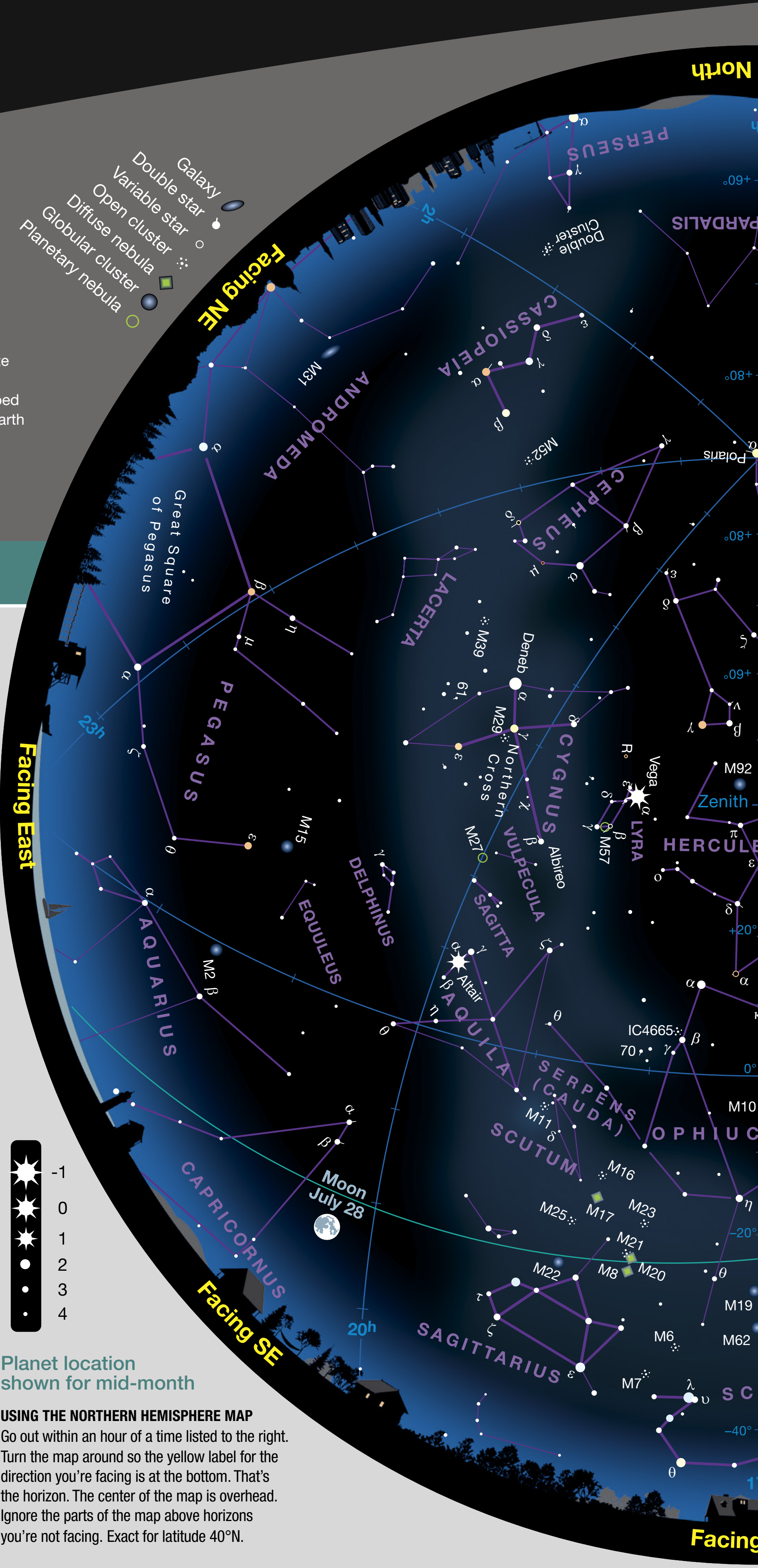
July 29
14:36 UT

DISTANCES

Perigee	July 13, 08^h UT
359,114 km	Diameter 33′ 16″
Apogee	July 25, 17^h UT
405,547 km	Diameter 29′ 28″

FAVORABLE LIBRATIONS

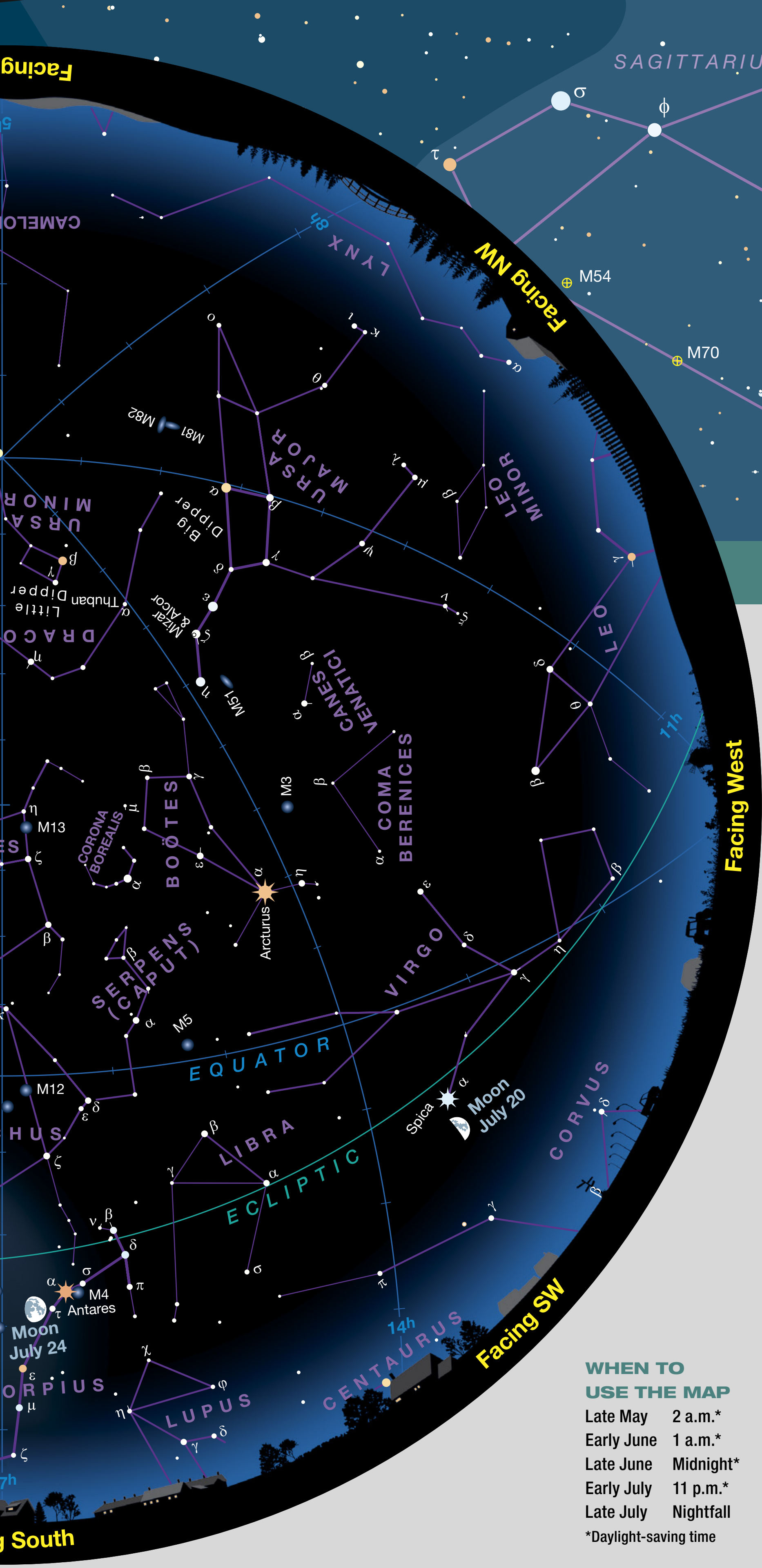
• Schluter Crater	July 5
• Mare Orientale	July 9
• Andersson Crater	July 10
• Joliot Crater	July 19

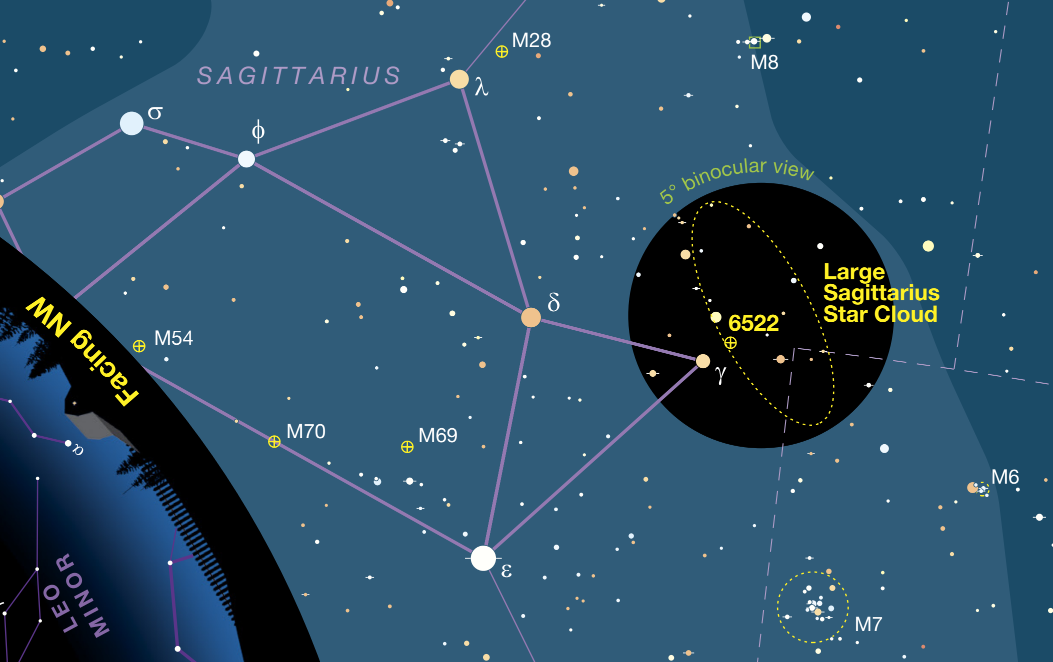


Planet location shown for mid-month

USING THE NORTHERN HEMISPHERE MAP

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





Binocular Highlight by Mathew Wedel

The Good Kind of Cloud

In 2017, I was invited to a star party in north-central Texas. The dark skies there were spangled with so many stars that picking out the familiar constellations was sometimes a challenge. On a predawn observing run, I saw to my disappointment that some clouds were coming up in the eastern sky. Then I did a double-take — these weren't atmospheric clouds, they were the star clouds of the central Milky Way, bright enough to cast faint shadows. I stood frozen, entranced by the galaxy as I'd never seen it before.

I can't wave a magic wand and conjure skies that dark for everyone, but I can at least point you in the right direction. The brightest part of the Milky Way as seen from Earth is the **Large Sagittarius Star Cloud**. This immense star cloud is a roughly 5° oval located immediately northwest of Gamma (γ) Sagittarii, forming the first puff of "steam" from the Teapot asterism in Sagittarius, the Archer. What we're seeing is part of the central bulge our galaxy, about 25,000 light-years away near the galactic center.

To understand the structure of the Milky Way, I prefer the wide views in low-power binoculars like 7×35s. But it's nice to have 10×50 and even 15×70 binos for deeper dives. One target for the bigger glass is the 8.5-magnitude globular cluster **NGC 6522**, which lies about the same distance from us as the Large Sagittarius Star Cloud. NGC 6522 is centered in Baade's Window, an area largely free of interstellar dust that affords professional astronomers a relatively clear view into the galactic core. I find it both awe-inspiring and empowering to plumb the depths of our galaxy with binoculars, and I hope you will as well.

■ MATT WEDEL figures that as fixations go, "Milky Way addict" is a pretty safe one to have, even if it does lead to some groggy mornings.

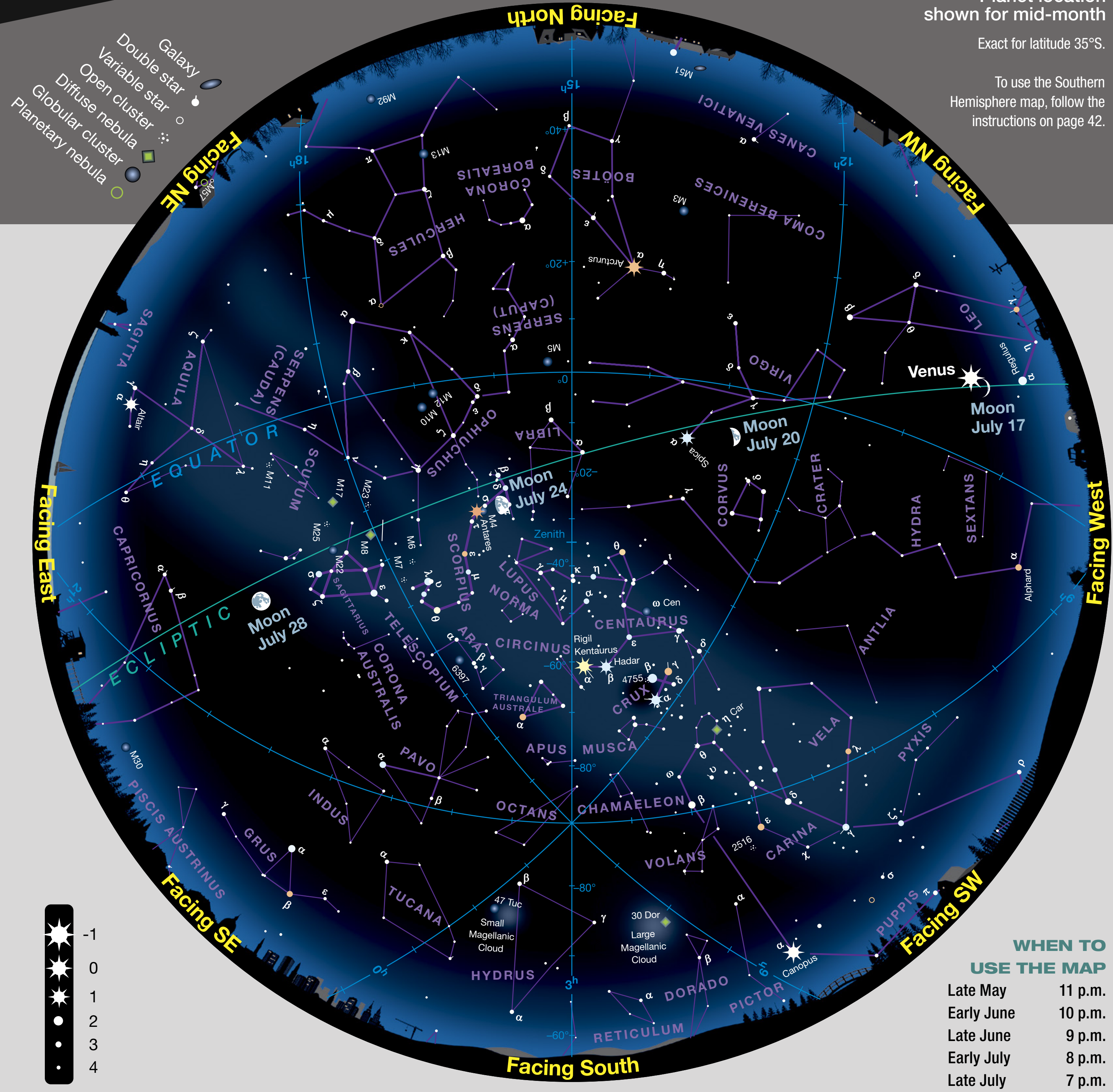
WHEN TO USE THE MAP

Late May	2 a.m.*
Early June	1 a.m.*
Late June	Midnight*
Early July	11 p.m.*
Late July	Nightfall

*Daylight-saving time

Southern Hemisphere Sky Chart

by Jonathan Nally



WHEN TO USE THE MAP

Late May	11 p.m.
Early June	10 p.m.
Late June	9 p.m.
Early July	8 p.m.
Late July	7 p.m.

LUPUS, THE WOLF, is a fairly large constellation sandwiched between Centaurus and Scorpius in the southern Milky Way. Its prime location means it contains many stars of naked-eye visibility, the brightest of which is 2.3-magnitude Alpha (α) Lupi, a blue giant almost eight times the size of our Sun, 10 times as massive, and intrinsically 18,000 times as bright. It's about 460 light-years from Earth.

The next brightest are 2.7-magnitude Beta (β) Lupi, a bluish giant that's a little hotter than Alpha, and 2.8-magnitude Gamma (γ) Lupi, a triple-star system made up of a tight binary and a more distant companion. Alpha, Beta, and Gamma Lupi are members of the Scorpius-Centaurus *OB* association, a group of about 460 young, hot, bright stars moving together through space. ■

Stars of Independence and Hope

Celebrate America's independence this July 4th with Venus, Saturn, and Virgo.

On the evening of July 4, 1776, when American colonists celebrated the adoption of the Declaration of Independence (see page 12), Saturn was the only known planet visible when night fell. Shining at 1st magnitude, the straw-colored planet was only 15° above the southwestern horizon, roughly 7° (a little more than the width of three fingers held at arm's length) upper right of similarly bright blue-white Spica in Virgo, the Virgin. What a befitting pairing for this celebratory occasion, at least symbolically speaking!

Saturn, the most powerful and prominent of the Titans — an elder generation of deities who were the children of Caelus (Uranus) and Terra and ruled the cosmos before the Olympians — is most often associated with time and agriculture. But his role in the Roman religion was more complex. Among the deity's lesser-known affiliations were renewal, liberty, and change — all fundamental causes of the American Revolution.

We can also envision the planet's location in Virgo as symbolic. In one of her more well-known guises in Roman mythology, Virgo was Astraea, the goddess of justice (*S&T:* May 2026, p. 45). And it was due to significant issues of justice under British rule — such as unfair trials and oppressive laws — that kindled America's fight for independence. Furthermore, that Saturn and Spica were "side by side" and equal in brightness seems fitting, as the leaders of the revolution championed the cause of equality for all.

This July, though you'll be able to see the constellation as it looked 250 years ago, Saturn won't be perched among its stars. Still, a similarity exists. As in July 1776, only one planet is visible in the sky after sunset. Furthermore, it lies only about 5° northwest of another blue-white 1st-magnitude star; that planet is Venus, and the star is Regulus in Leo, the Lion.

Venus was not directly associated with the events that occurred on July 4, 1776, but it indirectly played a role four days later. On July 8, 1776, during a planned election-campaign event, a large crowd gathered at the Pennsylvania State House to hear Colonel John Nixon of Pennsylvania give the first public reading of the Declaration of Independence. This he did while standing on a platform that had been erected by the American Philosophical Society for Philadelphia astronomer David Rittenhouse to observe the transit of Venus on June 3, 1769. Rittenhouse's observations enabled him to measure the distance from Earth to the Sun and contributed to international recognition of American scientific achievement.

Let's return our attention to Virgo as Astraea, as it may prove hopeful to ponder her mythology. In his poem *Metamorphosis*, the Roman poet Ovid (43 BC – circa AD 17) tells us how, in the beginning, Astraea lived among mortals. That was during humanity's First Age, the Golden Age — a time when everyone "of their own accord, without threat of punishment, without laws, maintained good faith and did what was right." But by the Final Age, the Iron Age, iron had been discovered, "to the hurt of [humankind], and gold, more hurtful still than iron. War made its appearance, using both those metals in its conflict, and shaking clashing weapons in bloodstained hands. Men lived on what they could plunder: friend was not safe from friend, nor father-in-law from son-in-law, and even between brothers . . . All proper affection lay vanquished."

And so, the "last of the immortals, the maiden Justice, left the blood-soaked earth." Astraea ascended into the heavens, so we can look upon her purity in the visage of Virgo, as a reminder of how things were, with the hope that she keeps her promise to one day return and usher in a new era of truth and justice for all.

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

▶ An 1889 print of Astraea, the last immortal to abandon Earth. She left our planet in the Iron Age because humanity forsook modesty, truth, and loyalty, for treachery, deceit, violence, and criminal greed. We see her embodied in the stars of Virgo, the Maiden.

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

A Month for Naked-Eye Planets

July offers the chance to view five (or six!) planets without the aid of optics.

SATURDAY, JULY 4

Just five planets are usually regarded as naked-eye objects: Mercury, Venus, Mars, Saturn, and Jupiter. However, a sixth world is also within reach under the right conditions. **Uranus** currently shines at magnitude 5.8, which places it just a shade brighter than 6th magnitude — the (slightly arbitrary) dividing line between naked-eye and not. The trouble with spotting Uranus is that it's often difficult to identify without optics. Not so this morning when **Mars** passes just 7′ below it in the east-northeastern sky. Binoculars easily show the sixth planet, but try with your eyes alone, too. You just might be surprised. (Turn to page 48 for more on this close conjunction.)

THURSDAY, JULY 9

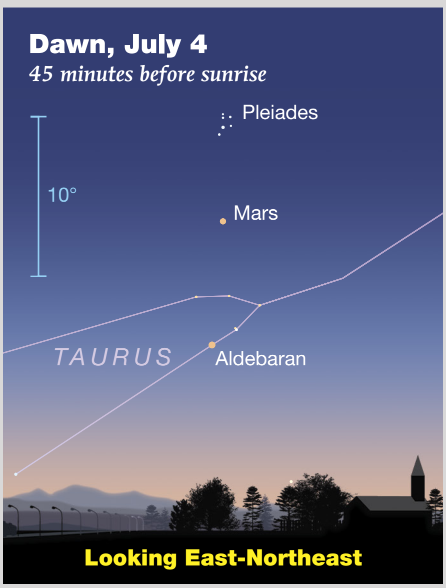
The sky's two brightest planets both feature in noteworthy events at dusk today. Let's begin with the brightest of all, **Venus**. The reigning Evening Star is past the peak of its current apparition but will remain a prominent evening sight until early October. Tonight, it's positioned a bit less than 1° upper right of **Regulus**, the Alpha star in Leo, the Lion. The pair are quite a luminosity mismatch — Venus gleams at magnitude –4.1 while Regulus shines at magnitude 1.4. That's nearly 160 times fainter! Indeed, in twilight you might struggle to catch the star's glint next to the brilliant planet. Binoculars make the task much easier, even after the sky darkens. Both objects set roughly two hours after the Sun.

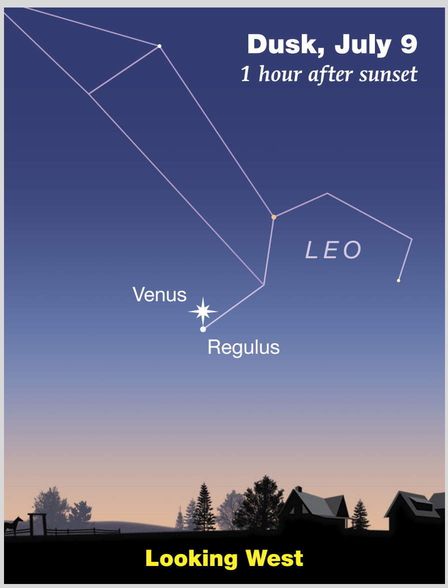
Our second notable planet event involves **Jupiter**. It's time to say goodbye to Big Jove, as this evening may well mark your last chance to spot it without optical aid. And it's not going to be easy. The planet sets less than an hour after the Sun, so it's going to take some effort to fish it out in early twilight. But Jupiter is bright: magnitude –1.8. Try sweeping for it just above the west-northwestern horizon with your binoculars. If you succeed, try again with your eyes alone using prominent landmarks to guide you. Jupiter has its conjunction with the Sun on July 29th and re-emerges at dawn around August 10th, so it won't be gone for long.

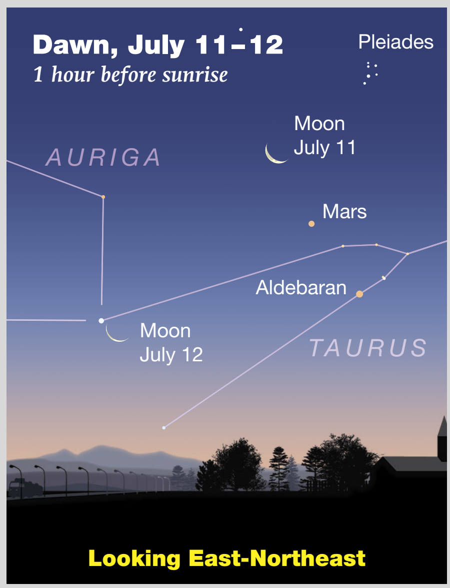
SATURDAY, JULY 11

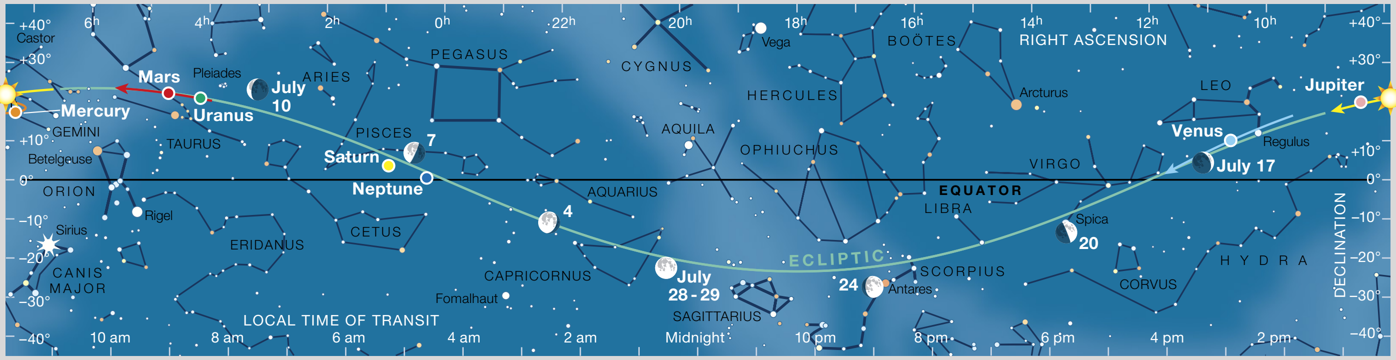
An attractive tableau awaits early risers this morning. Cast your gaze toward the east-northeast around 3:30 a.m. local daylight time to watch the **Moon**, **Mars**, and **Aldebaran** rising together in Taurus. The trio are arranged in a neat line with the Moon on top, Mars in the middle, and Aldebaran at the bottom.

▼▶ These scenes are drawn for near the middle of North America (latitude 40° north, longitude 90° west). European observers should move each Moon symbol a quarter of the way toward the one for the previous date; in the Far East, move the Moon halfway.





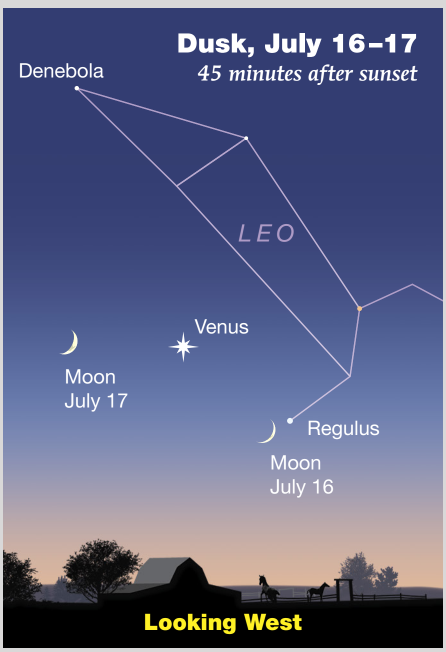




▲ The Sun and planets are positioned for mid-July; the colored arrows show the motion of each during the month. The Moon is plotted for evening dates in the Americas when it's waxing (right side illuminated) or full, and for morning dates when it's waning (left side illuminated). "Local time of transit" 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 Red Planet is positioned roughly 5° from the 13%-illuminated lunar crescent and 5½° from Aldebaran. You'll also note that the Moon is some 6½° lower left of the alluring sparkle of the **Pleiades**. (They were similarly close the previous morning.)

Aldebaran, or Alpha (α) Tauri, shines at +0.9 magnitude — the brightest star along the ecliptic. By comparison, Mars presently glows slightly fainter at magnitude 1.3. The planet is slowly brightening as it draws nearer to Earth, and by mid-November it will outshine Aldebaran. This morning and the next Mars is as close to the star as it gets during its current apparition, which reaches its opposition climax in February 2027.

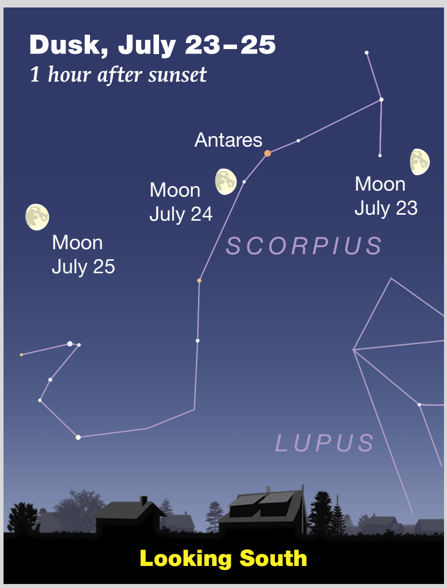


THURSDAY, JULY 16

The closest encounter between the **Moon** and a bright star in July takes place tonight when the 10%-illuminated waxing lunar crescent sits less than 1¼° lower left of **Regulus**, in Leo. The best time to look is late into twilight when the two are side by side above the western horizon. Because Regulus is the faintest of the 1st-magnitude ecliptic stars (barely making the cut at magnitude 1.4), it pairs up best with a thin crescent Moon. When the duo meets again in August, Regulus will be too near the Sun to be visible.

FRIDAY, JULY 17

This month's meet-up between the **Moon** and **Venus** isn't a particularly close one, but tonight's conjunction is still well worth viewing. (Of course, nothing is going to top last month's encounter when the Moon passed right in front of Venus!) The lunar crescent has grown since its meeting with Regulus on the previous evening and is now about 18% illuminated. Venus beams brightly 6¼° to its right.



MONDAY, JULY 27

If you're trying for all five (or six) naked-eye planets this month, dawn today likely represents your first shot at bagging **Mercury**. The innermost planet never strays far from the Sun's glare, and its apparitions are always brief and often challenging. This morning marks the start of the second of its three 2026 dusk appearances and is considerably more favorable than the most recent one in March/April. Mercury climbs a little higher and grows a little brighter and farther from the Sun each passing morning as July winds down and August begins. Today the little planet shines at magnitude 1.1 and rises roughly 75 minutes before the Sun (the exact amount depends on your latitude). Mercury will be at its best for this apparition on August 5th, when it clears the east-northeastern horizon 90 minutes before sunrise and glows at magnitude –0.4. Congratulations if you managed to spot both Uranus *and* Mercury this month!

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

▲ Mars and its close "companion" Uranus (center) appear in the eastern sky below the Pleiades cluster at the start of morning twilight, seen here from 40° north latitude. They'll be exceptionally close but still separable in a pair of binoculars. A telescope will reveal each planet's color and minute disk.

Close Shave on July Fourth

Distant siblings meet at dawn.

Whether you're a U.S. citizen or not, everyone can start the fireworks early this holiday with a squeaky-close conjunction of Mars and Uranus. They'll be just 7′ apart low in the northeastern sky, about 5.5° below the Pleiades cluster at the start of morning twilight. Rarely do two planets get this tight. For comparison, the gap between the famous Mizar-Alcor double in the Big Dipper is nearly twice as wide.

Binoculars will split the pair cleanly and may even reveal their striking color contrast. A telescope certainly will. Clay-colored Mars at magnitude 1.3 will gleam southeast of cool, blue Uranus (5.8). Mars's hue is due to a ubiquitous blanket of fine, iron-oxide-rich dust covering its surface, while methane in the Uranian atmosphere gives the planet an almost Earth-like color.

The most recent sub-degree conjunction of two planets occurred on April 23rd, when Venus and Uranus nestled 46′ apart at dusk. The current one is the closest observable planetary pairing in several years. Through a telescope magnifying around 200×, both planets will be tiny, colorful disks only a short distance apart in the same field of view — Mars with an apparent diameter of 4.5″ and Uranus a close second with 3.5″. Despite their small sizes, I can't wait to see this red-headed kid and his hipster blue-haired sister in juxtaposition. The next sub-degree conjunction happens on November 24, 2027, between Venus and Mars.

Funny how distance distorts our perception of size in astronomy. Uranus is 7.5 times larger than Mars but almost 10 times as distant. Directly between them you'll see an interloper, the 8.3-magnitude spectroscopic binary HD 284146.

As the United States celebrates the 250th anniversary of the Declaration of Independence, it just so happens that the same two planets met in a similar close conjunction (14.5′ apart) in Taurus on June 15, 1776, just weeks before the document was signed.

Minor-Planet Hunting

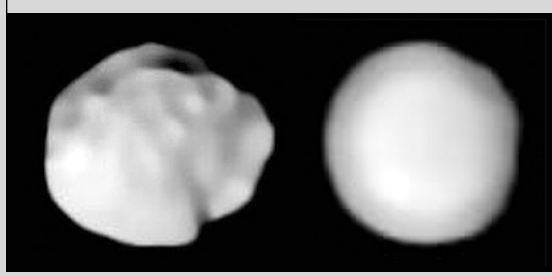
TWO BRIGHT MAIN-BELT asteroids reach opposition this month: 3 Juno on July 9th and 8 Flora on July 27th. Both will peak around magnitude 9.0, bright enough to find and track in the smallest telescope. If you're fortunate enough to have access to rural skies, you might even spy them on tripod-mounted 10×50 binoculars.

As both asteroids loop west in retrograde motion, a telescope will clearly show their movement from one night to the next (two nights if you're using binoculars). Like the outer planets, asteroids appear to reverse course for a time as the speedier Earth laps them around the time of opposition.

It's a thrill and challenge to hunt a moving target among the static stars, especially when they look so similar. Finding an asteroid satisfies our inner hunter, sharpens observing skills, and gives us a sense of accomplishment. Planets capture most of the attention, leaving asteroids and their cycles underappreciated. Like the intimate knowledge of a flower or insect gained through close attention, these stellar lookalikes have much to offer.

Being virtually featureless to the eye, asteroids may seem remote and inaccessible, save through spacecraft

▼ Images made with the Spectro-Polarimetric High-contrast Exoplanet Research (SPHERE) adaptive optics system on the Very Large Telescope (VLT) reveal subtle details on asteroids 3 Juno (left) and 8 Flora (right). Both are irregularly round, typical for small solar system bodies not crushed into spheres by gravity, and display depressions and contours that hint at impact craters.



missions. But they are remnants of the same materials that clumped together eons ago to form our solar system, and their shards continually pelt Earth as meteorites. Examination of the spectra of Flora and Juno — both S-type (stony) asteroids — indicates that both are related to the most common types of meteorites found in terrestrial collections, the ordinary chondrites.

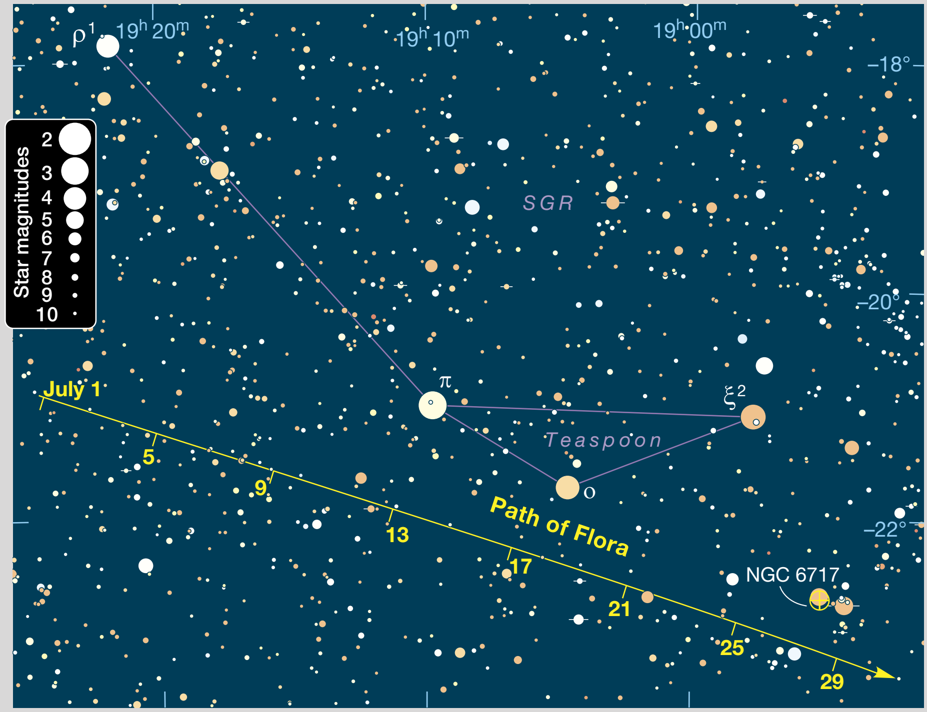
Chondrites are composed of silicates peppered with iron and nickel, containing peppercorn-like spheres called chondrules. Flora and the Flora-family asteroids are likely candidates for the L-chondrites (low-iron), one of the most abundant classes of space rocks.

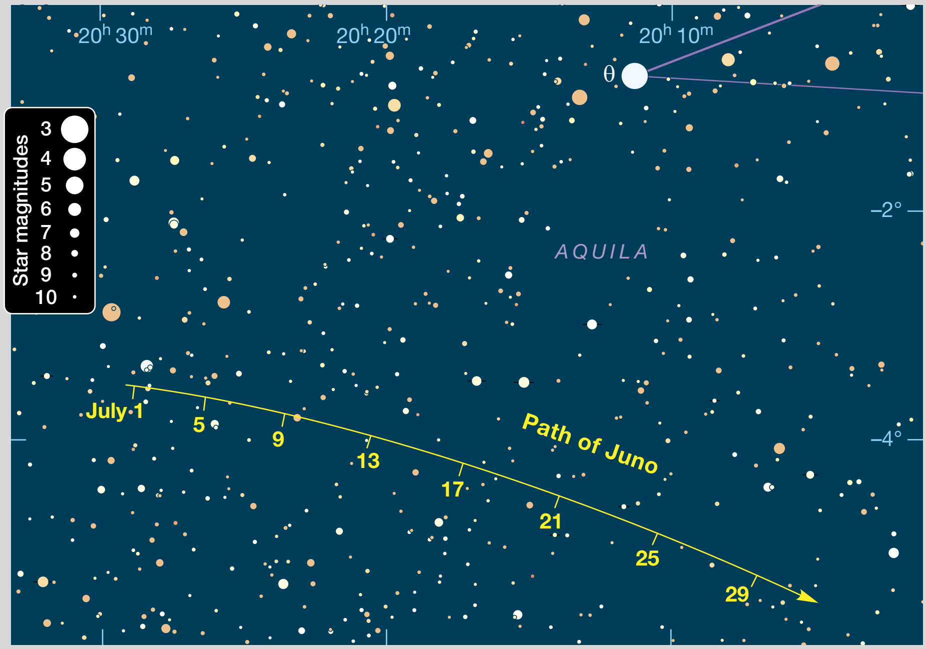
These days, anyone can go on Facebook (search for Meteorite Club) or eBay, and for a reasonable price purchase a stony meteorite. It's like putting an asteroid in your pocket and a wonderful way to make what you observe real.

When German astronomer Karl Harding discovered 3 Juno in 1804, people still called these objects planets. By the mid-1800s, as the number of asteroid discoveries started to increase exponentially, astronomers began calling them "minor planets," and then asteroids. Each received a numerical prefix indicating its order of discovery.

One of the largest main-belt asteroids, Juno has a diameter of about 250 km (160 miles) and orbits the Sun every 4.4 years. Its distance from Earth varies at each opposition due to its elliptical orbit. The next couple of favorable oppositions occur in January 2028 (magnitude 8.0) and October 2031 (7.4). This time around it will be easily accessible, but not nearly as bright, as it wings westward across southeastern Aquila.

English astronomer John Russell Hind first spotted 8 Flora in a 10-foot refractor with a 7-inch lens on October 18, 1847. Hind was a passionate hunter of minor planets, discovering 10 of them between 1847 and 1854. Astronomer John Herschel, famous for his detailed survey of the Southern Hemisphere sky, named this one Flora after the Roman goddess of flowers and gardens.





▲ Tag along with two bright main-belt asteroids this summer. Flora (*top*) travels just below the Teaspoon in Sagittarius, not far from the ecliptic. Juno (*bottom*), located in Aquila about 25° northeast of Flora, keeps near 3rd-magnitude Theta (θ) Aquilae. Both minor planets move westward about ¼° each night around mid-month.

Flora orbits within the inner part of the main belt, circling the Sun every 3.3 years. It's about 146 km across. Look for it above the Sagittarius "Teaspoon" asterism. On July 26–27, it will pass just ½° southeast of the 9th-magnitude globular cluster NGC 6717. Both it and fellow traveler Juno will be well placed for observation in the southeastern sky around 11 p.m. local time. If the summer sky is a fruit salad of star clusters and nebulae, our two featured asteroids are the nuts that add that extra crunch.

Young Moon and a Jovian Farewell

YOUNG LUNAR CRESCENTS are best seen in the Northern Hemisphere at dusk from February through April. That's when the ecliptic, the Sun's annual path around the sky, intersects the western horizon at a steep angle after sunset. Since the Moon sticks close to this path as it orbits Earth, the ecliptic's near-vertical orientation vaults the Moon straight up into the sky soon after new Moon at that time. July isn't the best month to catch a super-thin crescent because the angle is less, which lowers the Moon's altitude and visibility.

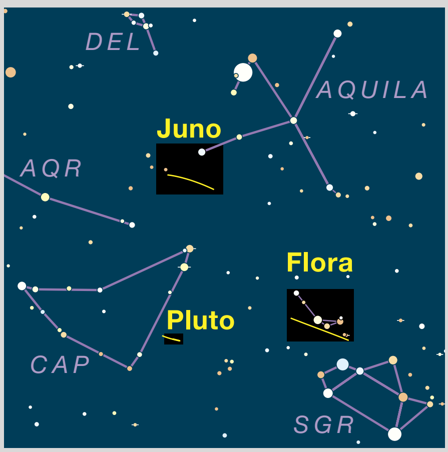
But when timing and location dovetail, good viewing opportunities are possible even in off months. Such is the situation on July 14th, when observers in the southern U.S. will have a shot at spotting an exceptionally young crescent. Lunar perigee occurs the day before and works to our advantage. Not only will the Moon be a little brighter and larger than normal, but it distances itself from the Sun more quickly. Its location 1.5° north of the ecliptic provides an additional boost in altitude.

That evening, it will be a tad more than 15 hours old from the Central Time Zone and 17-plus hours old for observers on the West Coast. From New Orleans the Moon will be 15.3 hours old shortly after sunset, 16.2 hours from Dallas, 17.0 hours from Albuquerque, and 17.8 hours from Los Angeles. While the crescent will be even younger from the East Coast, it will likely be hidden in the solar glare.

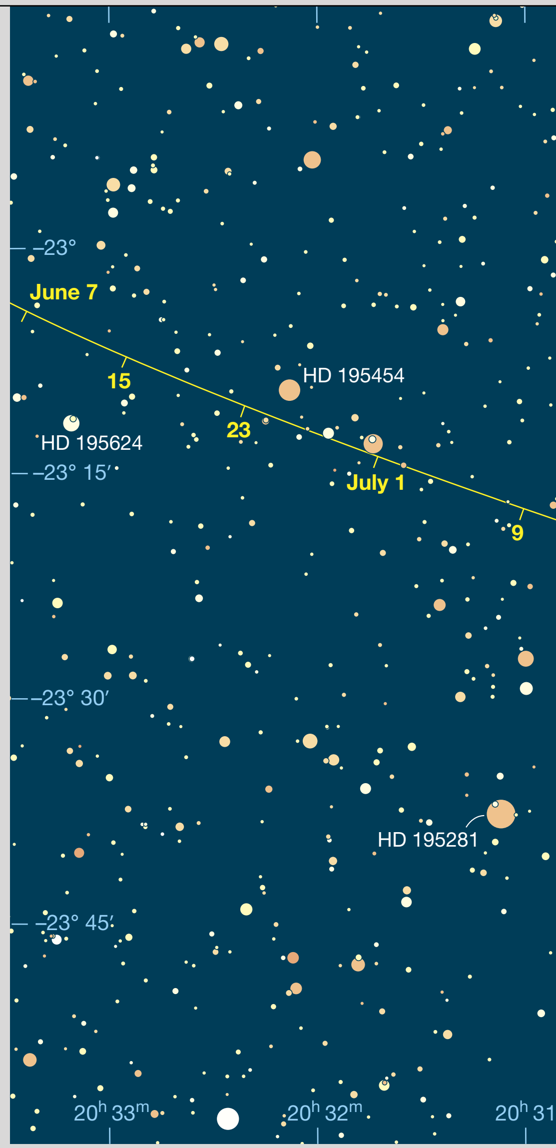
Assuming the sky in the sunset direction is clear and haze-free, here's

Pluto in 2026

IN RECENT YEARS, Pluto has exchanged the dense star fields of Sagittarius for the wide-open spaces of western Capricornus. For visual observers that's a good thing — a less crowded field makes targets easier to find. Every little bit will help when Pluto reaches opposition on July 27th at magnitude 14.5. Although the ecliptic bends northward in the region of Capricornus, Pluto's 17° orbital tilt will carry it southward until 2030. Stuck in the sky's basement and fading, it will only become more difficult to view from the Northern Hemisphere. Pluto reaches its greatest distance south of the ecliptic in the late 2080s before heading back north towards the plane of the solar system. At the same time, Pluto's light is fading as it heads toward aphelion in 2113. But an 8-inch under rural skies should still catch it, as will a smart telescope in the city. Happy hunting!



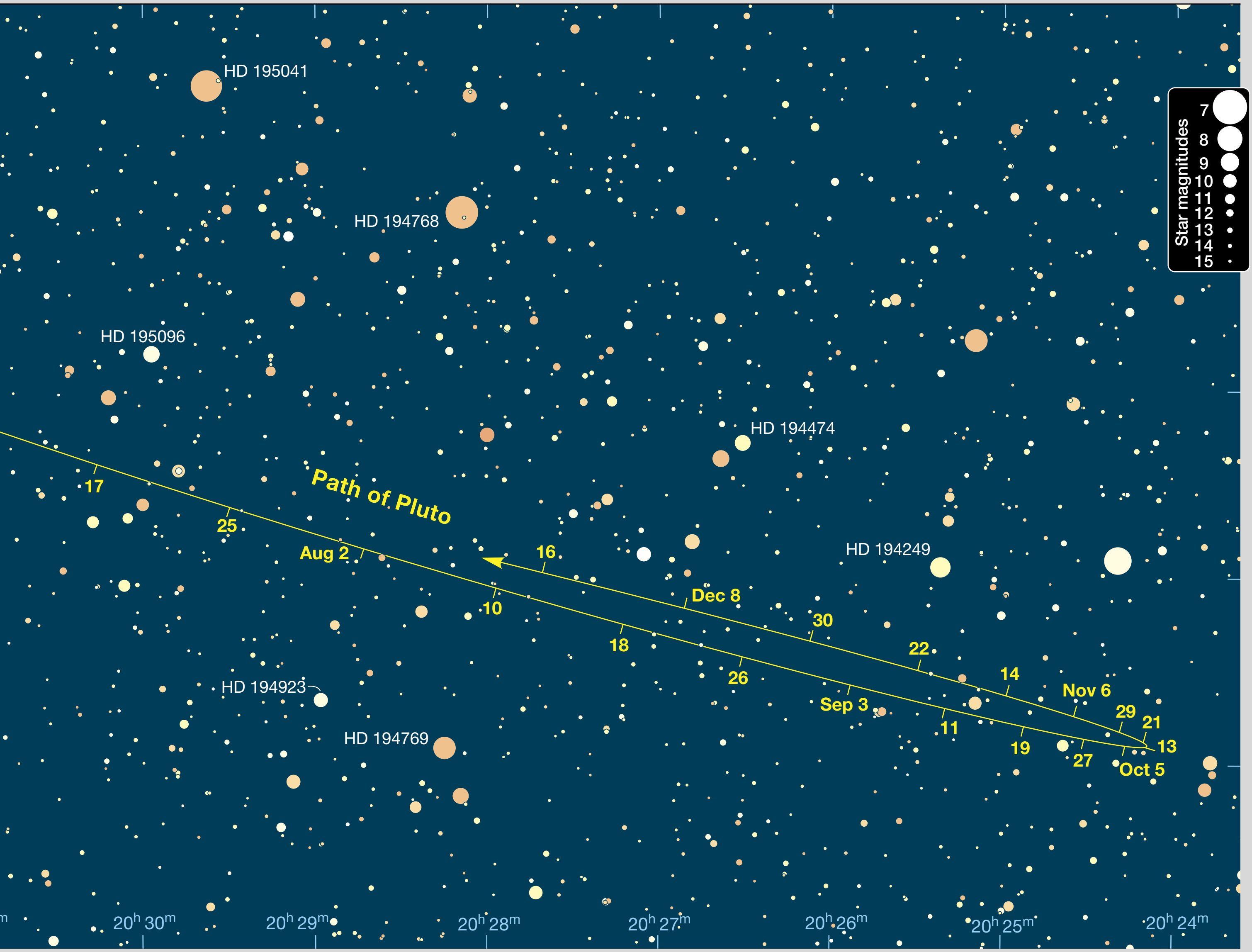
▲▶ Pluto *(left)* is a kaleidoscope of color in this high-resolution image captured by NASA's New Horizons spacecraft on July 14, 2015. It combines blue, red, and infrared photos taken by the Ralph/Multispectral Visual Imaging Camera. Each hue identifies distinct landforms and compositions that illuminate the dwarf planet's complicated geological and climatological history that scientists are just beginning to understand. In the constellation chart *(above)*, the larger Pluto chart at right is marked as a black rectangle, as are the charts for Juno and Flora, currently in the same region of the sky, on page 49.



PLUTO: NASA / JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY / SOUTHWEST RESEARCH INSTITUTE / ZLDOYLE a checklist to prepare for your skinny Moon adventure.

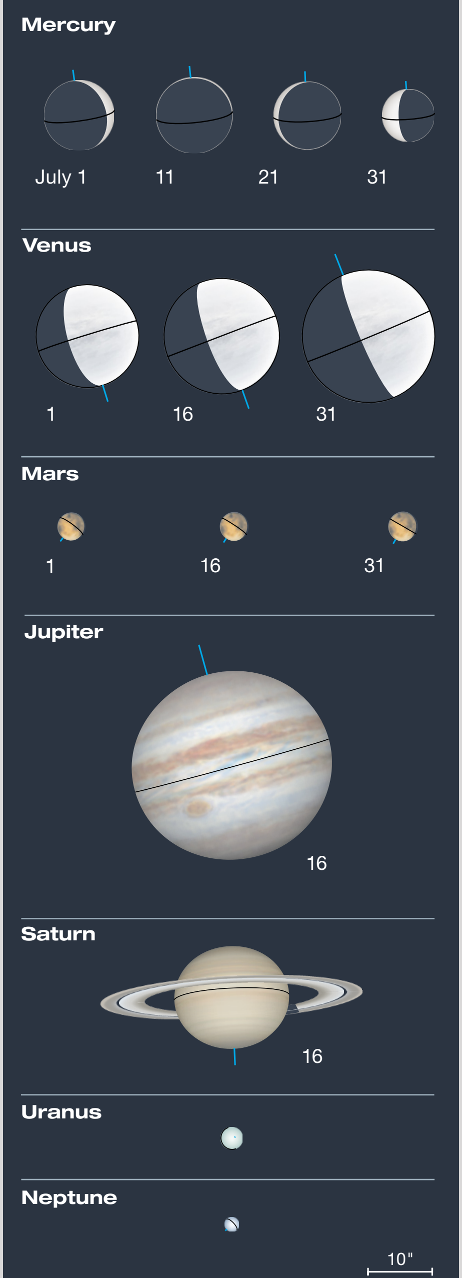
- Find a site with an unobstructed view to the west-northwest; arrive shortly before sunset. The crescent will lie a short distance to the left of the sundown point, about 2.5° to 3° high 20 minutes after sunset.
- Bring binoculars that you've focused in advance on a celestial object. If they're not prefocused at infinity, the Moon will be blurry and impossible to see. Clouds are essentially infinitely distant, so if there are some around, focus on them.
- Set up a tripod-mounted camera, also pre-focused at infinity, to take multiple images of the Moon's location. You might capture the event photographically even if you struggle to see it. A successful photo will also aid in knowing exactly where to look.
- Starting about 15 minutes after sunset, place the horizon near the bottom of your binocular field of view and make slow sweeps from the bright glow that marks the Sun's location below the horizon to about 10° to its left (south). Be alert to anything that catches your eye. The Moon will be a pale, tenuous arc of light.
- If you sight the crescent, note its location relative to a nearby or distant landmark, and then lower the binoculars to see if you can spot it without optical aid.
- Bonus! Jupiter, at magnitude –1.8, will shine just 2.3° to the left (southeast) of the Moon from New Orleans and 1.3° from Los Angeles. Will you see the gas giant's last gasp before its July 29th solar conjunction?

For context, Contributing Editor Steven James O'Meara holds the record for the youngest Moon sighted with the naked eye — a 15-hour, 32-minute crescent in May 1990. Mohsen G. Mirsaeed of Tehran, Iran, holds the record for the youngest Moon observed with optical aid. He used 40×150 binoculars to spy an 11-hour, 40-minute sliver on September 7, 2002. Observing the newborn Moon will be challenging. Please let us know if you succeed!



Planetary Almanac

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dawn starting on the 27th • **Venus** visible at dusk • **Mars** visible at dawn in the east-northeast • **Jupiter** visible at dusk very low in the west-northwest to the 10th • **Saturn** rises around midnight and visible to dawn.



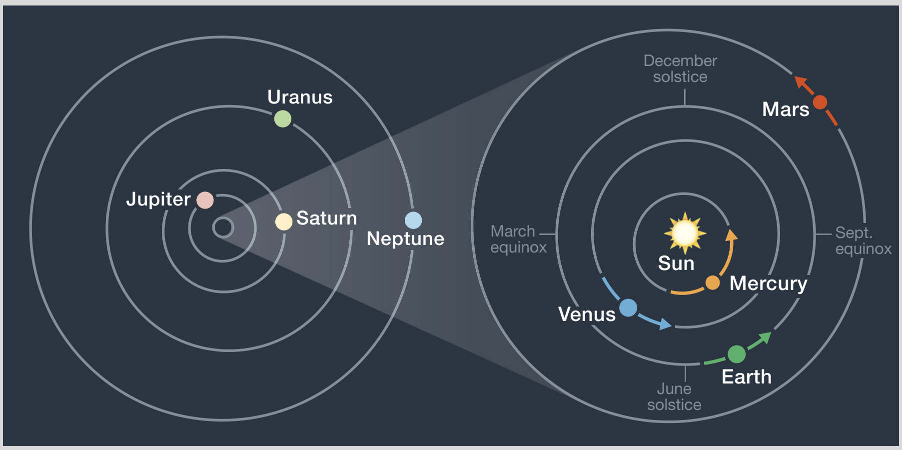
▲ **PLANET DISKS** are presented north up and with celestial west to the right. Blue ticks indicate the pole currently tilted toward Earth.

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

July Sun & Planets

	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$6^h 38.5^m$	+23° 08′	—	–26.8	31′ 28″	—	1.017
	31	$8^h 39.5^m$	+18° 24′	—	–26.8	31′ 31″	—	1.015
Mercury	1	$7^h 49.3^m$	+18° 31′	17° Ev	+2.4	10.9″	12%	0.614
	11	$7^h 30.6^m$	+17° 07′	6° Ev	+5.3	11.8″	1%	0.569
	21	$7^h 08.6^m$	+17° 55′	12° Mo	+3.0	10.5″	7%	0.639
	31	$7^h 18.3^m$	+19° 47′	19° Mo	+0.5	8.1″	31%	0.825
Venus	1	$9^h 31.3^m$	+16° 33′	41° Ev	–4.1	16.0″	69%	1.043
	11	$10^h 14.4^m$	+12° 24′	43° Ev	–4.2	17.3″	65%	0.966
	21	$10^h 54.9^m$	+7° 49′	44° Ev	–4.2	18.8″	61%	0.888
	31	$11^h 33.1^m$	+2° 59′	45° Ev	–4.3	20.6″	56%	0.808
Mars	1	$3^h 56.5^m$	+20° 06′	38° Mo	+1.3	4.4″	95%	2.107
	16	$4^h 40.9^m$	+22° 05′	41° Mo	+1.3	4.5″	94%	2.058
	31	$5^h 25.2^m$	+23° 17′	45° Mo	+1.3	4.7″	94%	2.002
Jupiter	1	$8^h 08.3^m$	+20° 37′	21° Ev	–1.8	31.7″	100%	6.213
	31	$8^h 35.5^m$	+19° 08′	1° Mo	–1.8	31.3″	100%	6.301
Saturn	1	$0^h 54.6^m$	+3° 15′	85° Mo	+0.8	17.5″	100%	9.497
	31	$0^h 56.8^m$	+3° 20′	113° Mo	+0.6	18.4″	100%	9.009
Uranus	16	$4^h 08.3^m$	+20° 48′	49° Mo	+5.8	3.5″	100%	20.105
Neptune	16	$0^h 17.0^m$	+0° 20′	109° Mo	+7.9	2.3″	100%	29.532

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



Border Denizens

A short star-hop across the Serpens-Ophiuchus boundary reveals a handful deep-sky treasures.

If, like me, you're an avid observer who views on clear nights from a suburban site, you'll likely have a warm feeling for open star clusters. Numerous prominent or even just average open clusters are observable from brightly lit backyards and balconies. I enjoy exploring them with even the smallest of my telescopes — an equatorially mounted 4¼-inch f/6 Newtonian reflector.

For this month's tour, I have in mind a pair of modest targets sitting a few degrees apart in a strip of sky where the constellations Aquila (the Eagle), Serpens Cauda (the Serpent's Tail), and Ophiuchus (the Serpent Bearer) meet. Join me as I enter this border region at its extreme eastern end, where northern Serpens Cauda joins western Aquila.

ALAN DYER

▲ **STRADDLING THE BORDER** This 23°-wide field shows two open clusters (at upper left): IC 4756 (left) in Serpens Cauda and NGC 6633 (right) in Ophiuchus. The star at far left is 4.6-magnitude Alya, Theta (θ) Serpentis; at far right is 2.1-magnitude Rasalhague, Alpha (α) Ophiuchi. To its lower left is 2.8-magnitude Beta (β) Ophiuchi and the open cluster IC 4665. North is at upper right.

A Serpens Star-Hop

I'm a dedicated (read: stubborn) star-hopper. My starting point here is 4.6-magnitude **Theta (θ) Serpentis**, also known as Alya. If I can't detect Alya with my unaided eyes (full disclosure: I can spot it only on the very best nights), I orient myself first by sighting +0.8-magnitude Altair, Alpha (α) Aquilae, then casting my gaze 8.5° southwestward to 3.3-magnitude Delta (δ) Aquilae. From Delta Aquilae, I'll use my reflector's 6×30 finderscope to scan slowly west-northwestward a bit more than 7° to Alya. The finder picks it up instantly.

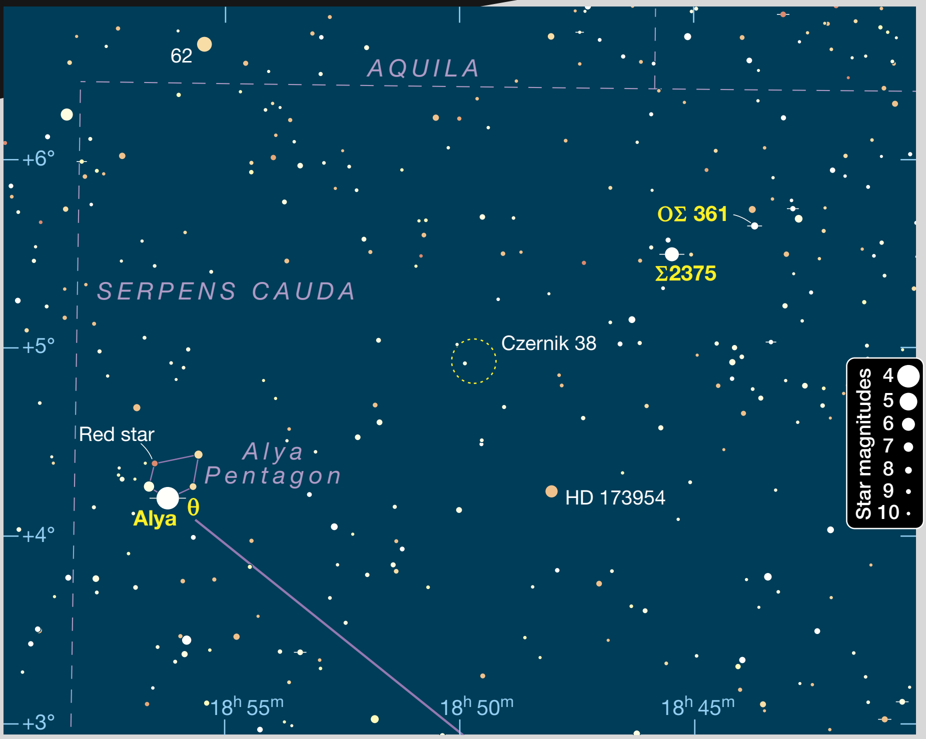
Alya is a superb binary star. My little Newtonian at 27× easily splits its 4.6- and 4.9-magnitude components 22″ apart. The pure-white stars also anchor the southern corner of a five-sided asterism, which I call the Alya Pentagon. The figure was apparent to me right away at low power, as it's fairly large (17′ × 20′) and bright (the asterism's other points range from magnitudes 6.7 to 8.5). On the pentagon's northeastern corner, the faintest star glows with a dull, yet unmistakably reddish hue. Immediately east of this dim red light is a small scatter of six dimmer dots. In all, this isn't a flashy field, but it's attractive.

From Alya, I make a 2° westward hop to the orangey, 6.2-magnitude star HD 173954, then veer sharply northwestward for not quite 1.5° to a challenging binary, Struve 2375 **(Σ2375)**. The 6.3- and 6.7-magnitude components of Σ2375 are just 3″ apart; I needed (gulp!) 194× to resolve them cleanly.

Less than ½° to the west-northwest is an easy double listed as **OΣ 361** in Otto Struve's first catalog. Like Alya, the 8.2- and 9.4-magnitude components of OΣ 361 have a generous gap of 23″.

Pushing 1.5° westward, we arrive at the first open cluster on our tour: **IC 4756**. It's officially listed in catalogs at a very impressive magnitude 4.6, but that brightness is mysteriously misleading. A coarse clump of nearly 500 stars about 1° wide, IC 4756 doesn't pack a lot of visual punch. It overflows the northern half of an asterism I've dubbed the Keystone, a miniature version of its Hercules namesake. My Serpens Keystone is only about 1° across and it's outlined by 6th- and 7th-magnitude stars. My scope at 27× showed the entire figure, plus three dozen members of IC 4756 — a few of them 8th magnitude, the rest fainter than magnitude 9. I'm sure the IC label stands for "Insignificant Cluster." The Keystone struggled in my blighted suburban sky, yet it did register at low power.

When I boosted the magnification to 72×, a few stellar bonuses came



◀ **CHOCK-FULL OF BORDER DOUBLES** Use the following finder charts to plan your star-hopping adventure across the rich star fields of the Serpens-Ophiuchus border. You can also refer to the text for additional star-hopping tips. For this tour, the author has highlighted optical doubles and binary stars suitable for small telescopes and binoculars.

into focus along the southern side of the Keystone, a roughly east-west line of three stars. A tad more than 6.5′ southwest of the easternmost star, 6.7-magnitude HD 172190, is a pairing not listed in double-star catalogs but exhibits 9.6- and 10.2-magnitude stars separated by 24″. I nicknamed it **Ken 1**, after yours truly. The westernmost sun on the southern side, 6.5-magnitude HD 171586, is a strongly uneven duo. Cataloged as **Σ2342**, its 9.6-magnitude companion stands 34″ to the north. Barely 4.5′ west of Σ2342 is a 6th-magnitude, low-amplitude variable star designated **FR Serpentis**. It's nearly as red as the faintest point in the Alya Pentagon. The star varies in brightness from magnitude 6.3 to 6.5 over a period of 2.1 days.

Border Crossing Catches

Object	Type	Mag	Size/Sep.	RA	Dec.
θ Serpentis	Double star	4.6, 4.9	22″	$18^h\,56.2^m$	+04° 12′
Σ2375	Double star	6.3, 6.7	3″	$18^h\,45.5^m$	+05° 30′
ΟΣ 361	Double star	8.2, 9.4	23″	$18^h\,43.7^m$	+05° 39′
IC 4756	Open cluster	4.6	~1°	$18^h\,38.9^m$	+05° 26′
Ken 1	Double star	9.6, 10.2	24″	$18^h\,38.5^m$	+04° 45′
Σ2342	Double star	6.5, 9.6	34″	$18^h\,35.6^m$	+04° 56′
FR Serpentis	Variable star	6.3–6.5	—	$18^h\,35.6^m$	+04° 56′
NGC 6633	Open cluster	4.6	~0.5°	$18^h\,27.3^m$	+06° 31′
Ken 2	Double star	10.8, 11.0	23″	$18^h\,26.5^m$	+06° 23′
ΟΣΣ 170	Double star	7.0, 8.8	100″	$18^h\,30.7^m$	+04° 31′
Ken 3	Double star	7.7, 10.5	128″	$18^h\,31.1^m$	+04° 38′
ΟΣΣ 168	Double star	7.7, 8.8	47″	$18^h\,28.6^m$	+04° 51′

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

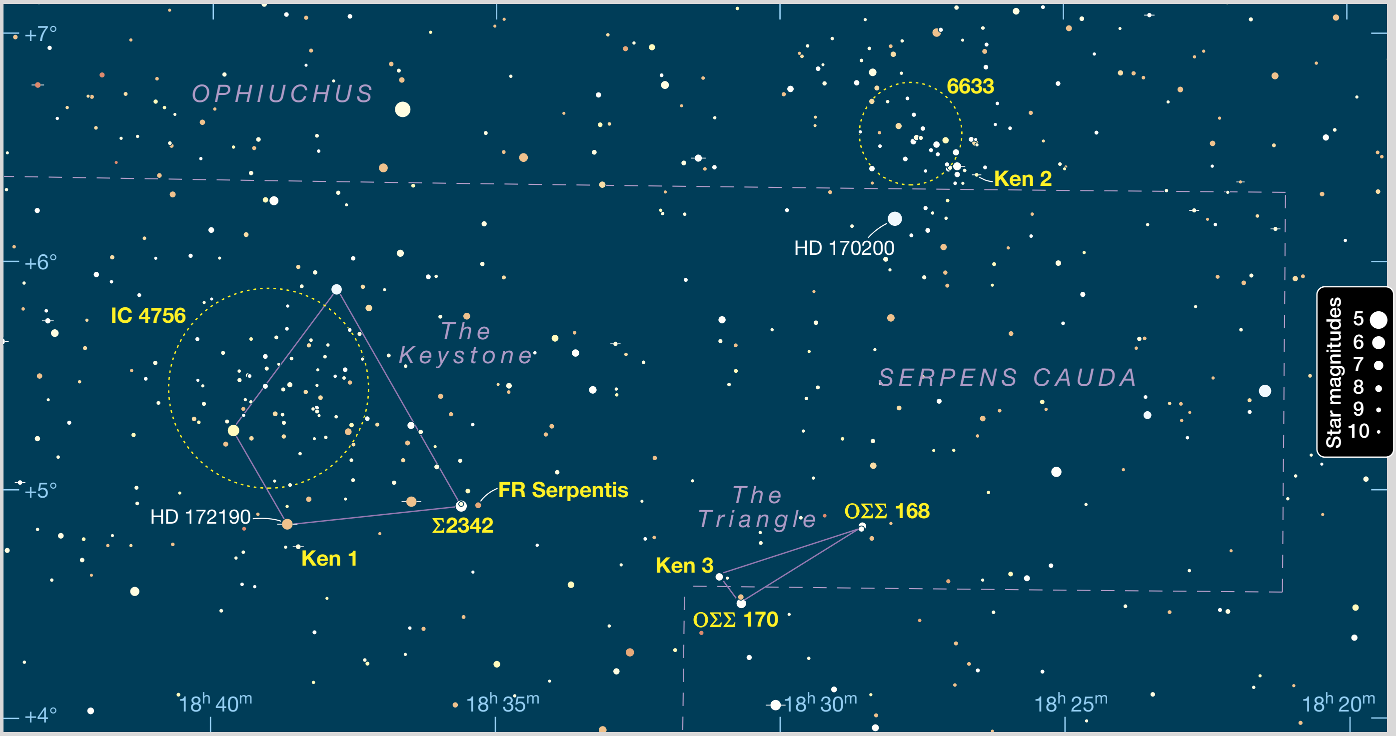
Across the Line

Looking through the finderscope, I head 2¼° northwestward to 5.7-magnitude HD 170200 (it's the only 6th-magnitude star in the area). I then nudge my scope north-northwestward just 20′ farther to get across the constellation boundary into Ophiuchus. Bingo! Right there lies the second cluster on our itinerary: **NGC 6633**.

NGC 6633 is officially cataloged as a grouping of about 160 stars together shining at magnitude 4.6. However, as with IC 4756, its listed brightness is misleading, and I have no idea how the experts arrived at that 4.6 number. NGC 6633 comprises no sparks brighter than magnitude 7.7 and presents no obvious central concentration. This coarse collection is elongated, spanning less than ½° on a northeast-southwest slant. Harrumph. The acronym NGC must mean "No Good Cluster."

This isn't to say observing NGC 6633 is a waste of time. My scope at 27× showed about two dozen cluster members, including a teensy triangle lying above NGC 6633's southwestern end. Focusing on the triangle at 72× added an adjacent, westward row of three fainter stars to make it a six pack. The higher magnification picked up perhaps another dozen stars throughout the cluster. Among them, marking the extreme southwestern end of NGC 6633, is another undesignated dim duo. The anonymous pair, **Ken 2**, musters 10.8- and 11.0-magnitude stars 23″ apart.

To wrap up the tour, I'll share a serendipitous "discovery" I made when I accidentally swept south of the two clusters. A 2° hop south-southeast



▲ **TARGET-RICH ENVIRONMENT** Star clusters and asterisms make ideal targets for suburban stargazers. The open clusters IC 4756 and NGC 6633, situated 3° apart against the rich Milky Way background, are best viewed with low-power, wide-angle instruments. Try to see if you can recognize the star patterns described by the author, namely the Alya Pentagon, the Keystone, the Triangle, and the tiny triangle in NGC 6633 (see below).

of NGC 6633 or west-southwest of IC 4756 lands on a narrow asterism outlining an isosceles triangle that measures 9′ × 40′, its long dimension pointing northwestward. The slim triangle caught my attention because it's formed by three wide stellar pairs. The widest ones establish the base of the triangle — **ΟΣΣ 170**, listed in the appendix to Otto Struve's first catalog, offers 7.0- and 8.8-magnitude stars 100″ apart, while an unofficial set, **Ken 3**, serves up 7.7- and 10.5-magnitude stars separated by 128″. The triangle's vertex is adorned by **ΟΣΣ 168**, which features 7.7- and 8.8-magnitude components 47″ apart. All three pairs fit in my telescope's 54× field of view.

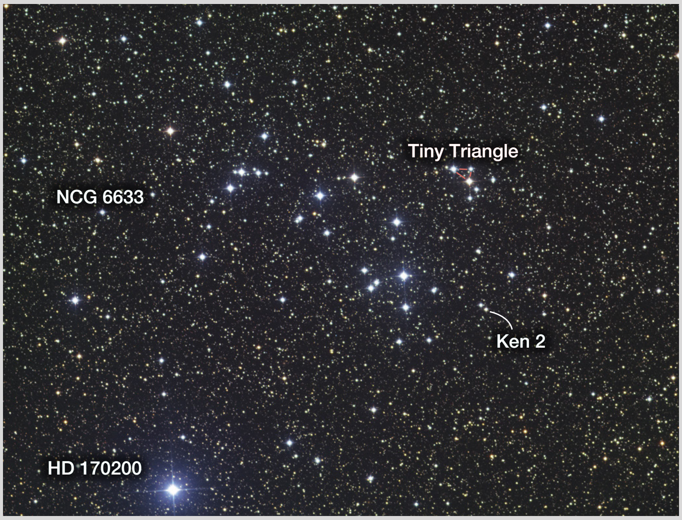
Binoculars, Too!

Despite working under a badly light-polluted sky, I enjoy exploring this area with binoculars. I could split ΟΣΣ 168 and ΟΣΣ 170 using my tripod-mounted 10×50s. The sturdy mount (merely an L-bracket on a camera tripod) steadies the 10-power binos well enough to clearly resolve the petite Alya Pentagon. IC 4756 appeared as a pale mist, salted with a few very faint pinpoints. Neighboring NGC 6633 was better, displaying many stars, though a bit too close together to count. Both clusters fit easily into one binocular field. Nice!

None of the targets I described are prizewinners, but I'll take anything I can get in my suburban sky. Whatever telescope (or binoculars) you have, I hope you give these fair-to-middling treasures a try. Don't be satisfied with a quick, low-power peek — a longer look at any star cluster, using a range of magnifications, can be rewarding. Stirring up the stardust, you never know what you might find.

■ Contributing Editor **KEN HEWITT-WHITE** has never met a star cluster he didn't like, even if it's dimmer than advertised.

▶ **SPARSE GROUP** Discovered in 1745 by Jean-Philippe Loys de Chéseaux, NGC 6633 lies about 1,040 light-years away. It's bright enough to be seen with the unaided eye under a dark sky. Together with IC 4756, the pair is referred to as the S-O Double Cluster, or Tweedledee and Tweedledum, after the twins in Lewis Carroll's 1871 classic *Through the Looking-Glass.* North is up.



Sole Author

A historical curiosity leads to a discovery.


Contributing Editor Scott Harrington enjoys the views through his vintage 10-inch scope.

SCOTT HARRINGTON

Amateur astronomers have long contributed to research papers, with their names appearing in the (often) lengthy list of coauthors. They've done everything from providing crucial long-term brightness measurements of sources using backyard telescopes to trawling through data as members of citizen-science projects. These contributions often involve large collaborations across several disciplines, continents, and, more often than not, years of work.

But sometimes, solo discoveries still happen. Contributing Editor Scott Harrington recently experienced that delight — an unexpected find that has led to an equally rare occurrence in scientific publishing: a single-author journal article.

Curiosity calls. At 14 years old, the astronomy bug bit Scott hard. He lives under the seriously dark skies of northern Arkansas (something he's very appreciative of!). He enjoys using his 10- and 16-inch telescopes to snag a wide variety of celestial objects, from nebulae to galaxies, but he readily admits that he particularly relishes binocular and naked-eye observing. He's an enthusiastic observer, sometimes star-hopping through a menagerie of targets in individual constellations.

Scott penned his first article for *S&T* in the May 2021 issue. In it, he provides tips on how to observe star-forming regions in distant galaxies. Since then, Scott has written another nine feature articles, as well as two Focal Point essays and one Going Deep column. (You might also have seen his various letters in the From Our Readers department.)

Scott works closely with Contributing Editor Steve Gottlieb — and for the regular readers among you, you might know Steve for his meticulous attention to historical detail. In fact, Steve co-founded the Adventures in Deep Space website, which, among other things, painstakingly outlines the discovery histories of each and every NGC and IC target in great detail. Inspired by Steve (and his colleagues') expertise in this field, Scott has developed a keen sense of what it means to research a topic thoroughly.

In fact, while working on his article on the brightest stars and clusters in M33, the Triangulum Galaxy (*S&T:* Nov. 2024, p. 22), Scott stumbled upon something that aroused his curiosity. And he couldn't let it go.

Publishing a peer-reviewed paper. During his research, Scott turned to the drawings of M33 that were made in the years 1850–1851 and 1857 using the 72-inch speculum-mirror reflector built and owned by William Parsons, the Third Earl of Rosse. Scott noted that one of the plotted stars perfectly matched the position of a *luminous blue variable* that he was researching for his *S&T* article. These stars, as their name implies, are very bright and can exhibit even brighter outbursts during periods of instability, which they undergo at random intervals.

As Scott dug deeper, he noticed that a *second* luminous blue variable matched a star in those historical drawings! Further research revealed that Var 83 and Var B, as they're known today, were undergoing outbursts at the time. Realization dawned, and Scott was mildly astonished to find that he had stumbled upon evidence that those observations signaled the first time an astronomer had observed luminous blue variables outside the Milky Way.

Scott didn't merely stop at that realization, however — the thrill of this discovery prompted him to investigate how he could share his discovery with a wider public. That vehicle proved to be the peer-reviewed *Journal for the History of Astronomy*, where you'll find Scott's article starting on page 43 of the February 2026 issue.

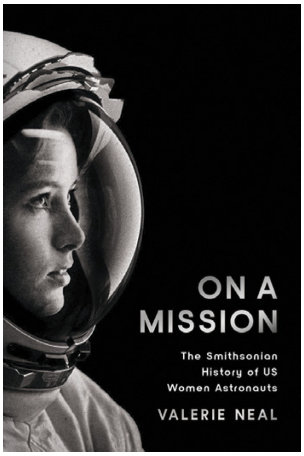
Please join me in congratulating Scott on his enterprising feat. And, who knows, maybe this will serve as inspiration for you to explore wider horizons when observing. In the meantime, bravo, Scott!

■ Editor in Chief **DIANA HANNIKAINEN** continues to be impressed by amateurs' dedication to research astronomy.

Women Who Touched the Stars

ON A MISSION: *The Smithsonian History of US Women Astronauts*

Valerie Neal
Smithsonian Books, 2025
360 pages, ISBN: 978-1-58834-776-3
US $29.95, hardcover.



THE NASA GROUP 24 astronaut class was announced in September 2025, and they made history: Six of the 10 AsCans, or astronaut candidates, were women. A month later, Valerie Neal published her newest book, and it was extremely timely — *On A Mission: The Smithsonian History of US Women Astronauts*.

Now a Curator Emerita, Neal began her work with the Department of Space History at the Smithsonian's National Air and Space Museum in 1989. She supervised the human spaceflight collections from the shuttle program and the International Space Station, giving her a unique window into these programs and the people involved.

Women have served in every position in the NASA astronaut corps and have flown on every spacecraft since the '80s — but it hasn't always been that way. It wasn't until nearly 20 years after the first astronauts were introduced that NASA announced the initial six female AsCans in 1978. Neal points out that the terms "women astronauts" and "female astronauts" are problematic. They aren't a formal subset of astronauts: Women are subject to the same standards as the men. They just happen to be women, and they prefer to be known simply as astronauts. During interviews, Neal asked her subjects about the descriptor, and they tolerated the term solely for the purpose of the book. They don't identify or like being referred to as such. As Neal writes, "the women presented in this history have an emphatic answer: 'We are astronauts. Period.'"

On a Mission provides an overview of women at NASA, a general history of the agency and human spaceflight, as well as the personal story of each individual. The book opens with a chapter about the early Space Age, which recounts the development of the American astronaut. The initial requirements excluded women by default, since military test pilots were seen as the ideal candidates. As the role expanded to scientists and civilian pilots, things started to change. We learn about the Lovelace Women in Space research program (commonly referred to as the Mercury 13) and programs like the 1970 aquanaut Tektite II mission — which, as Neal writes, "was the first-ever extended women-scientists-in-the-sea mission. Arguably, it was also the first NASA mission to include women and its only all-woman mission crew to date."

In the following chapters, Neal breaks down the history of women astronauts into three generations: the astronauts chosen between 1978 and 1990, whom she calls the Trailblazers; those chosen 1992 through 2000, labeled the Inspired; and the Empowered, those selected starting in 2004. She also covers the selection of 18 astronauts (nine men and nine women) in 2020 — "the Artemis generation" — which later expanded to all those on active duty (47 astronauts, 20 of whom are women). The Artemis generation may get even larger, and eventually they will be followed by a Mars generation.

Within each chapter, Neal summarizes the generation, along with any changes to NASA's selection process and the stated goals put forth at the time. She lists the women in each class and then describes their paths to NASA, as well as their duties while there. There's a summary at the end of each entry listing the number of flights they took, notable statistics about their astronaut career, and their cumulative time in space. It's not meant to be comprehensive, but the book manages to pack a lot of information into each entry, leaving the reader with a good sense of each astronaut as well as the desire to learn more about them. The final chapter describes the risks and rewards of being an astronaut of any gender, addressing topics like reproductive health and pregnancy in the context of spaceflight.

On A Mission conveys an incredible amount of information without overwhelming the reader. With so many stories to be told, Neal has crafted a cohesive history that is also highly readable. It's a wonderful homage to these astronauts, and one that every space nerd should have on their shelf.

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

▶ SMARTSCOPE

Dwarflab announces the DWARF mini Smart Telescope ($399). The system includes two lenses: a 30-mm f/5 telephoto and a 3.4-mm wide-angle lens. The larger optic is paired with a Sony IMX662 CMOS color sensor that has a 1,920 × 1,080 array of 2.9-micron-square pixels, while the wide-angle lens is paired with a Sony OS02K10 sensor of similar specs. The telephoto includes built-in, selectable filters to mitigate light pollution and enhance nebulosity. Both cameras are capable of recording images or video. The DWARF mini is built into a compact alt-azimuth Go To mount that weighs only 840 grams (1.85 pounds). Users can control the device with a smartphone or tablet through the DWARFLAB app connected via Wi-Fi. Images and videos are saved on 64GB of internal memory. An internal, rechargeable lithium-ion battery powers the device for up to four hours. Each purchase includes a USB-C charging cable, a solar filter, and a carrying case.

Dwarflab
dwarflab.com

▶ ORIGIN UPGRADE

Celestron now offers a camera upgrade for owners of its Origin Intelligent Home Observatory. The Celestron Origin 678C Camera ($499.00) is designed around the Sony IMX678-AAQR1 color, back-illuminated CMOS detector, which has a 3,856 × 2,180 effective array of 2-micron-square pixels. This 8.4-megapixel camera replaces the original Origin camera, offering increased sensitivity and resolution. Purchasers can replace the camera themselves following the step-by-step instructions on the company's website. Or they can visit Celestron's premium installation service page for directions on shipping their Origin for installation and calibration by the company's expert technicians.

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

▶ ROBOTIC FOCUSER

PrimaLuce Lab unveils the SESTO SENSO 3 robotic focusing motor for external focusers ($299). The device attaches to most rack-and-pinion or Crayford-style focusers with a unique, self-centering clamp. It connects to your computer either through a USB-C cable or its built-in Wi-Fi via the Virtual HandPad app for smart devices. The focuser incorporates an integrated position encoder that allows manual focusing without losing motor position. It provides 0.7-micron-per-step resolution on focusers with 1:10 reduction gears and is ASCOM compatible. The SESTO SENSO 3 also includes a port that accepts a temperature sensor and an additional port to connect with the company's ARCO instrument rotators. Purchase includes the USB-C cable, 12-volt DC power cable, and several knob adapters.

PrimaLuce Lab
1108 Championship Rd., Oceanside, CA 92057
442-218-4507; primalucelab.us

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.

 by Trudy E. Bell

The 19th century in the United States was the golden age of the "great refractor." Famously, during the century's last four decades, self-taught master optician Alvan Clark and his sons (George Bassett Clark and Alvan Graham Clark) built five of the world's largest refracting telescopes in their workshop in Cambridge, Massachusetts.

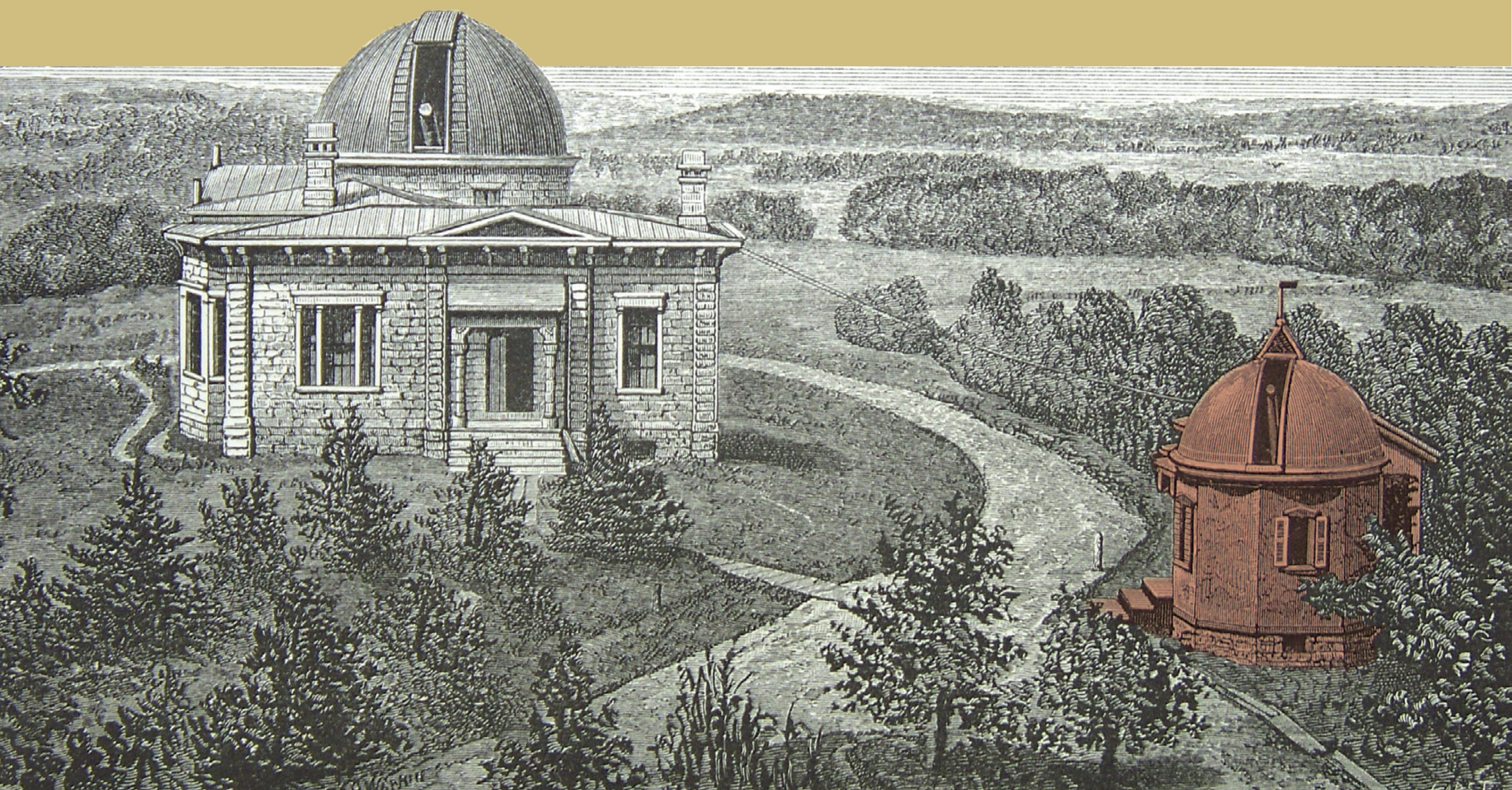
Four of these marvels of glass and steel were erected in the U.S.: the 18½-inch of Dearborn Observatory (mounted in 1866 at its first site in Chicago), the 26-inch of the U.S. Naval Observatory (1873; at its first Washington, DC, site), the 36-inch of Lick Observatory (1888; Mount Hamilton, California), and the 40-inch of Yerkes Observatory (1897; Williams Bay, Wisconsin). Since the 1980s, the histories of these observatories have been extensively researched and recounted in books and articles (*S&T:* June 2011, p. 28).

However, the unique and extraordinary extent of the broader observatory-building movement that swept America during the same era has been largely unfathomed. It had three underappreciated aspects.

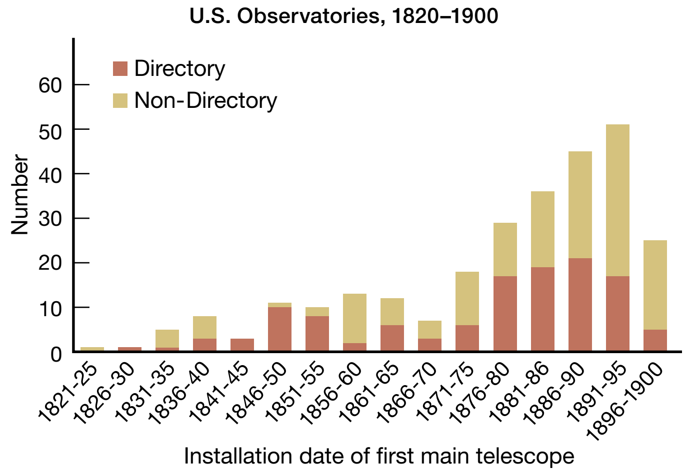
First was its sheer magnitude. The actual number of 19th-century U.S. observatories built is more than double any previous estimate.

The Big Role of Small Observatories

More than 300 U.S. observatories, many now forgotten, pioneered 1800s education and outreach.



STAR SCHOLARS The University of Wisconsin at Madison built a student observatory (smaller dome at right) across the road from the larger, better-known Washburn Observatory; both were completed in 1881. The student observatory sheltered a 6-inch Clark equatorial refractor. An adjoining transit house (mostly hidden behind the dome) contained a 3-inch Fauth combined transit instrument and zenith telescope. This student observatory was one of only two listed in any 19th-century directory (the other was at the University of California, Berkeley).



▲ **MAGNITUDE OF MOVEMENT** U.S. observatories grew in number from 1820 to 1900. Observatories described in a published 19th-century directory are shown in orange; additional observatories (most discovered since 2000) are shown in yellow. The chart clearly shows the interruption of the Civil War 1861–1865 and a sharp decline after 1895.

Second was a strong demand for smaller and mid-size telescopes from educational institutions and individuals. This demand stimulated the growth of an industry of specialized and regional astronomical-instrument makers.

Third was the movement's pervasive cultural appeal. For pulpit ministers, grade-school pupils, and grieving families alike, an observatory's value was not primarily in advancing the science of astronomy. Often its founders and funders were motivated by societal, spiritual, or emotional imperatives.

So strongly were Americans impelled to build observatories that in January 1859, *The New York Times* envisioned a future in which "the cities and hillsides of our land from ocean to ocean shall be crowned with noble Observatories, where *people by the thousands* as well as the *men of science,* may enjoy the *telescopic* view of the most wonderful and glorious objects that creation presents to the mind of man."

Untapped Sources

Until about 2000, historians' best guess for the number of astronomical observatories built in 19th-century America was around 144. This number appears to have originated with British astronomical historian Agnes M. Clerke, in her influential 1885 book, *A Popular History of Astronomy During the Nineteenth Century.*

Her 1882 estimate, never updated in subsequent editions, was likely based on one of a score of descriptive directories of observatories compiled and published irregularly by the Smithsonian Institution and other organizations between 1844 and 1902. Since then, Clerke's number has been cited as fact. However, recipients of these compilers' mailed questionnaires varied in their responsiveness. All the directories were therefore incomplete and sometimes even contradictory.

Several historians from the 1930s through the 1980s ascertained details about U.S. observatories founded by 1850. But none extended their analysis through the second half of the 19th century, thereby missing the observatory-building movement's full magnitude and peak.

During the past 25 years, previously unavailable 19th-century primary sources have come online. These new sources establish that at least 350 observatories were built in 19th-century America. (Many also closed in the same century, so at no time did all exist at once.) More than 200 were never included in any observatory directory, even though some instruments were large for the time and some observers well known to contemporary astronomers.

In this article, I report on 318 observatories; documentation for them ranges from rich to sparse. I am in the process of examining nearly 50 additional observatories.

The 318 investigated already fall into tantalizing patterns. At least 189 — fully 60% — were affiliated with educational institutions. Most (at least 153) were built for universities or colleges. At least another 36 were built for high schools or even for private academies serving younger grades.

For consistency throughout this article, I have defined *foundation date* as the date an observatory's first main telescope was installed, the one event that was common to all completed observatories (regardless of when, or if, an observatory was formally dedicated).

Observatory Hardware

Most commonly, an observatory's first main instrument was a permanently mounted *equatorial*, an achromatic, visual-focus refractor on a German equatorial mount. Often the equatorial was housed under a revolving dome, cylindrical turret, or conical structure, although a few were under roll-off roofs.

Many observatories were structures built by schools or individuals with limited space or financial means. Especially earlier in the century, some were economical, open-air wooden platforms affixed to a roof or in a yard, sometimes equipped with a permanent pier to which a portable telescope was carried for nightly observations. Such were the early personal observatories of (among others) the prolific comet-hunters William R. Brooks and Lewis Swift in upstate New York.

Most observatories also had at least one fixed *instrument of precision*. Usually, it was a transit instrument, used

Observatory

Not everything called an "observatory" in the 19th century was for celestial study or appreciation. Some were facilities dedicated to magnetic, meteorological, or seismological observations. Others were rooftop or hilltop structures for admiring the view, spotting approaching merchant ships, or keeping a military lookout. Still others were temporary government "astronomic" observing stations from which latitudes and longitudes were determined for mapping the new nation's vast and expanding territory. All such "observatories" are outside the scope of this research.

primarily for determining accurate local time: a relatively small-aperture refractor attached to a horizontal axis so that the telescope moved only in the plane of the meridian. Most transit instruments were mounted in a flat-roofed "transit house" with a closable north-south meridian slit, either as a wing of the main, circular observatory or as a separate outbuilding.

Many Motivations

The nation's first college, Harvard, was founded in 1636. By 1776, eight of the 13 original colonies had chartered colleges; after independence, they became the foundation of America's higher education system in those states.

The 19th century was a religious era. Astronomical study had a strong spiritual connection: beholding God's wondrous works in the heavens complemented reading His Word in the Bible. Most U.S. colleges were founded primarily to train ministers, overwhelmingly Protestant. An observatory was viewed in part as a moral institution, uplifting and "purifying" the mind and directing it to the Creator.

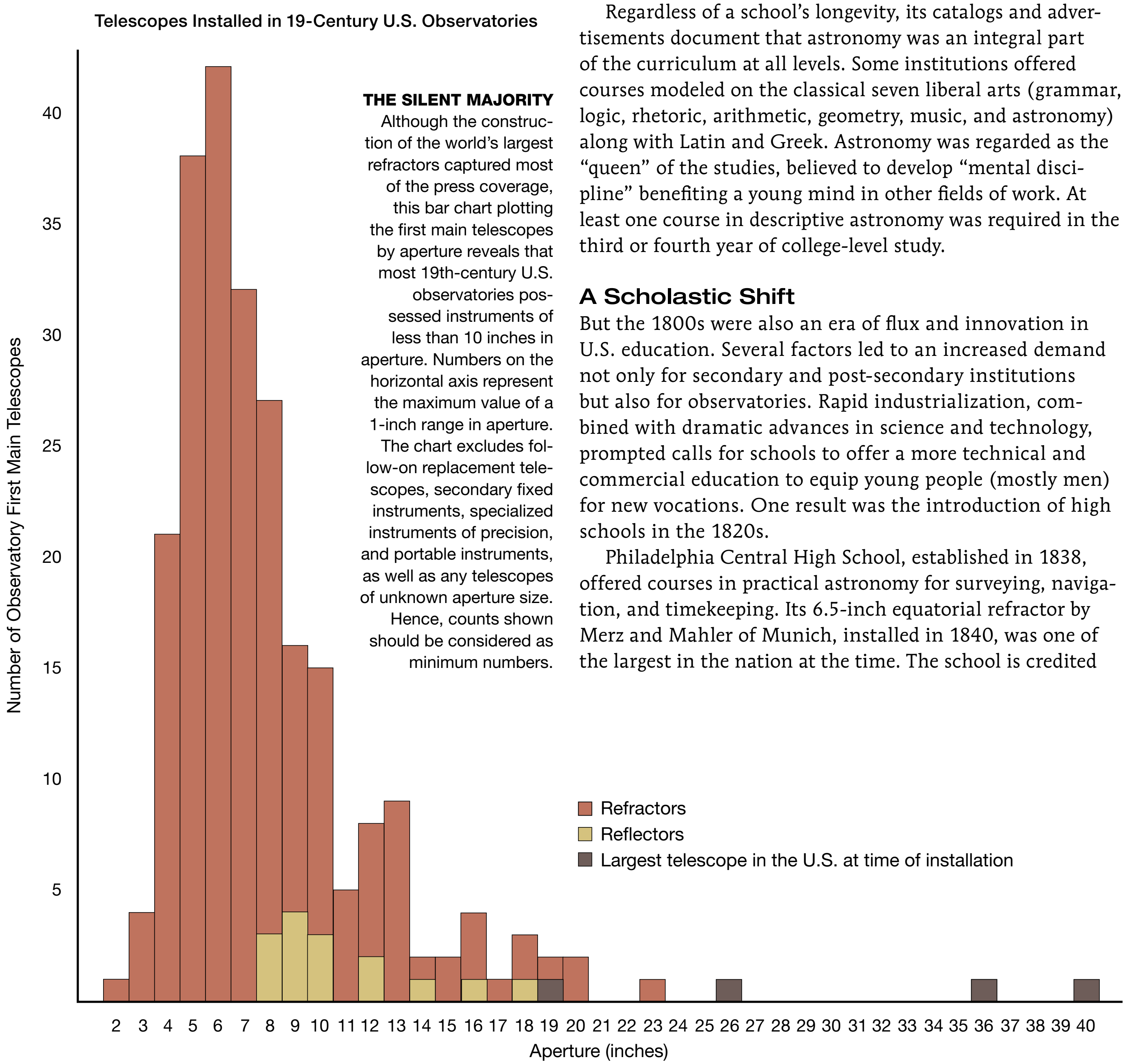
The westward expansion of the nation led to new towns, whose settlers founded more schools and colleges — and observatories. Such humble first observatories were often forgotten by history, however, if the college subsequently built a bigger observatory at the same location, sometimes with a different name; moved to a new campus, where it erected a new observatory; or financially failed — an all-too-common fate.

Regardless of a school's longevity, its catalogs and advertisements document that astronomy was an integral part of the curriculum at all levels. Some institutions offered courses modeled on the classical seven liberal arts (grammar, logic, rhetoric, arithmetic, geometry, music, and astronomy) along with Latin and Greek. Astronomy was regarded as the "queen" of the studies, believed to develop "mental discipline" benefiting a young mind in other fields of work. At least one course in descriptive astronomy was required in the third or fourth year of college-level study.

A Scholastic Shift

But the 1800s were also an era of flux and innovation in U.S. education. Several factors led to an increased demand not only for secondary and post-secondary institutions but also for observatories. Rapid industrialization, combined with dramatic advances in science and technology, prompted calls for schools to offer a more technical and commercial education to equip young people (mostly men) for new vocations. One result was the introduction of high schools in the 1820s.

Philadelphia Central High School, established in 1838, offered courses in practical astronomy for surveying, navigation, and timekeeping. Its 6.5-inch equatorial refractor by Merz and Mahler of Munich, installed in 1840, was one of the largest in the nation at the time. The school is credited



THE SILENT MAJORITY Although the construction of the world's largest refractors captured most of the press coverage, this bar chart plotting the first main telescopes by aperture reveals that most 19th-century U.S. observatories possessed instruments of less than 10 inches in aperture. Numbers on the horizontal axis represent the maximum value of a 1-inch range in aperture. The chart excludes follow-on replacement telescopes, secondary fixed instruments, specialized instruments of precision, and portable instruments, as well as any telescopes of unknown aperture size. Hence, counts shown should be considered as minimum numbers.

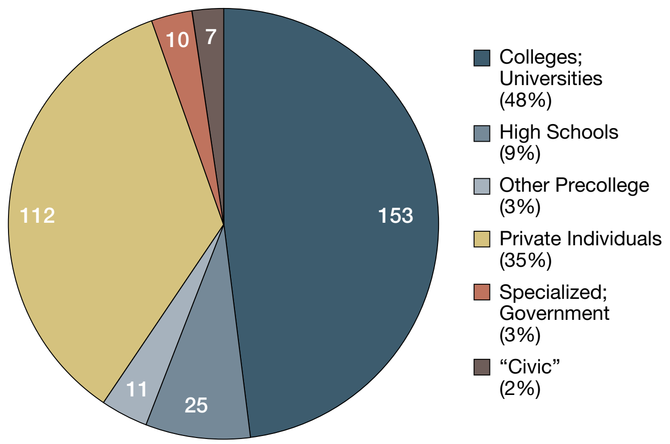
BEATRIZ INGLESSIS / *S&T*, SOURCE: TRUDY E. BELL with introducing German instruments and rigorous observational and mathematical techniques to the U.S.

The period spanning the 1830s through the 1880s was also the heyday of a widespread "female seminary" movement, which advocated that girls should receive an intellectual education equal to that of boys. Hundreds of pre-college female institutions were established, some later becoming colleges. Curricula often included use of a portable telescope or access to an observatory.

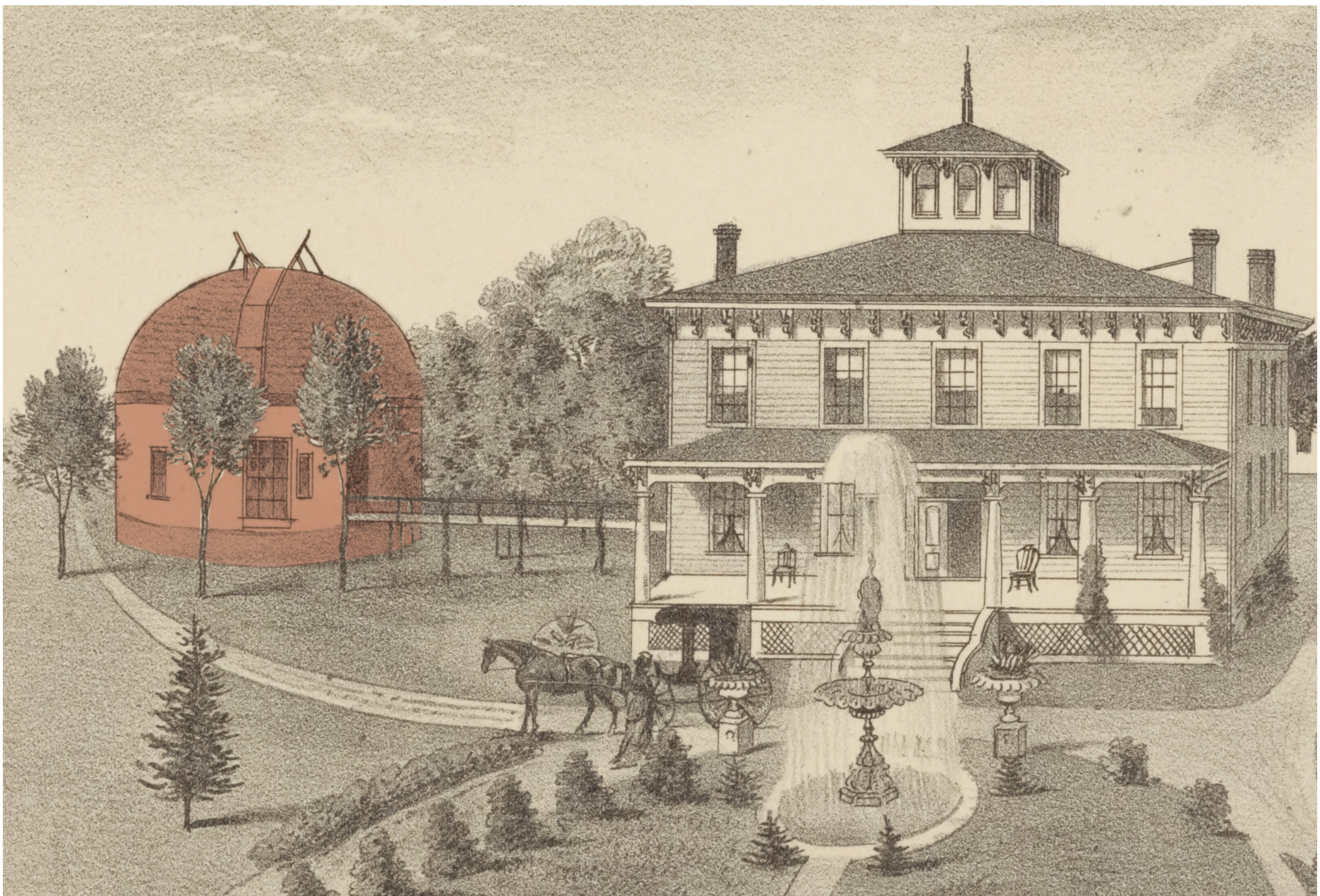
The federal Morrill Act of 1862 funded land-grant colleges and universities to provide post-secondary instruction in agricultural and industrial skills. Subsequent federal legislation broadened the mandate to include research and more institutions, technical disciplines, and students. Among the original 57 colleges, many built astronomical observatories; examples include the University of California (then only at Berkeley), Iowa State, Michigan State, and Ohio State.

A major educational change was the introduction of a hands-on, learn-by-doing "laboratory model" for teaching physics, chemistry, and practical astronomy. Then profes-

Affiliations of 19th-Century Observatories



▲ **OBSERVATORY PROPRIETORS** Fully 60% of 19th-century U.S. observatories were affiliated with educational institutions: Colleges and universities, high schools, and primary-grade academies are all shown in shades of blue. Another 35% were built by or for independent observers (yellow).



OVERLOOKED GIANT Willow Dale Observatory in Lancaster, New York, was William Sanford Van Duzee's second observatory, built around 1875. When originally installed in Van Duzee's first observatory in Buffalo in 1863, the 16-inch was the largest refractor then mounted in the United States. Despite its size, it was not included in any observatory directory.

CHART: BEATRIZ INGLESSIS / S&T; SOURCE: TRUDY E. BELL; WILLOW DALE: LIONEL PINCUS AND PRINCESS FIRYAL MAP DIVISION / NEW YORK PUBLIC LIBRARY DIGITAL COLLECTION / PUBLIC DOMAIN, COLOR: BEATRIZ INGLESSIS / S&T

sor of physics at the Massachusetts Institute of Technology, Edward C. Pickering articulated this philosophy in his 1876 textbook *Elements of Physical Manipulation*. At least 13 student observatories or "astronomical laboratories" were founded after 1880, mostly at large research universities, so that students could master instruments and conduct their own investigations.

These student observatories were often separate from colleges' "main" observatories. Yet most had equally good equipment: equatorial refractors of 6 to 9½ inches in aperture, plus instruments of precision. Indeed, some student observatories originally had been the campus observatory before a larger facility was built. For example, the Perkins Observatory of Ohio Wesleyan University (completed in 1896) was renamed the Student Observatory after a larger, off-campus Perkins Observatory was completed in the 20th century.

Independent Observers

Of the 318 observatories examined so far, 112 (35%) — the second-largest category — were built and operated by private individuals. Vigilant and careful self-taught independent observers using telescopes of modest aperture (by today's standards) could make fundamental advances in our knowledge of the solar system and beyond. They counted and mapped daily sunspots; discovered asteroids, comets, and novae; monitored variable stars; and identified double-star systems.

Until very late in the 19th century, distinctions between "professional" and "amateur" observers were fairly fluid; skilled measurements mattered more than paper credentials. Well-known astronomers who started as amateurs with private observatories included (among others) Edward Emerson Barnard, Charles Burckhalter, Sherburne W. Burnham, Seth Carlo Chandler, George Ellery Hale, and Maria Mitchell.

An innovator who recognized the potential of marshaling an army of skilled independent observers into a systematic program for observing a sky full of relatively bright objects was, once again, Edward C. Pickering. In 1882, Pickering (by then Harvard College Observatory director) published a pamphlet inviting amateurs — including "graduates from women's colleges" — to join a corps of variable-star observers.

Another well-known astronomer who recognized the value of professional-amateur collaboration was Edward Singleton Holden, founding director of Lick Observatory. He famously used the occasion of the total solar eclipse on January 1, 1889 — which attracted many independent observers and photographers to northern California — to found the Astronomical Society of the Pacific.

Unsung Artisans

Most 19th-century educational and private U.S. observatories were outfitted with instruments having apertures smaller than 10 inches, most commonly 5 to 7 inches. Even at the

▲ **REGIONAL MAKER** Prolific instrument maker, engineering instructor, and Methodist minister Rev. Hiram G. Sedgwick built equatorial telescopes and instruments of precision principally for Midwestern clients. This display ad in the January 1893 issue of *Astronomy and Astro-Physics* shows the refractor mounted in 1891 at the Underwood Observatory at Lawrence University in Appleton, Wisconsin. The instrument had a 10-inch Clark lens, but Sedgwick and his students built all the mechanical components.

ASTRONOMY AND ASTRO-PHYSICS, 1893 / PUBLIC DOMAIN

Some 19th-century U.S. Commercial Instrument Makers

Equatorials	
John A. Brashear	Josiah Lyman
John Byrne	William & David Mogey
John Clacey	John Peate
Alvan Clark & Sons	Benjamin Pike
William Carey Edgecomb	James W. Queen & Co.
Henry Fitz	George W. Ritchey
Henry G. "Harry" Fitz	George N. Saegmuller
William Gaertner	Hiram G. Sedgwick
Richard Brown Gans	Charles A. Spencer / Spencer & Eaton
William T. Gregg, Sr. and Jr.	Herbert R. Spencer
Amasa Holcomb	Warner & Swasey
C. A. R. Lundin	

▲ ▶ **COMMERCIAL U.S. OBSERVATORY** The astronomical equipment makers shown here ranged from specialists to generalists, although some were both. Not shown are about an equal number of additional makers who fashioned only portable instruments or who made instruments primarily for their own use or experimentation.

few major research observatories, most specialized instruments of precision were of similar apertures.

Moreover, scores of American schools and individuals unable to afford an observatory building still wanted high-quality instruments. Not yet included in my statistics are upwards of 270 telescopes for which I have not yet found evidence of an observatory building, despite some refractors having apertures exceeding 6 inches. Hence in the 1880s and 1890s, some thriving instrument makers fashioned smaller, possibly portable, instruments specifically for the educational and amateur markets. Among those most widely known were John Byrne (former apprentice of Henry Fitz) in New York City and William & David Mogey in New Jersey. Others, including Benjamin Pike in New York City and James Queen in Philadelphia, imported modest-size instruments from Europe. Still others focused on crafting specialized instruments of precision, notably the German-American "dynasty" of William Würdemann, Camill Fauth, and George N. Saegmuller (*S&T:* Aug. 2020, p. 26).

Some craftsmen designed and built essential auxiliary observatory equipment. Nathaniel M. Lowe in Boston designed, patented, and fabricated inexpensive, lightweight, but durable domes for school and private observatories. Bridge-builder William Scherzer also built large observatory domes, including those of the Cincinnati, Chamberlin, and Dearborn observatories.

A few observational astronomers collaborated with artisans to invent, design, and build new instruments for special investigations. In the 1860s, U.S. Coast Survey cartographer-astronomer George Davidson and Yale astronomer Chester S. Lyman independently designed a combined transit instrument/zenith telescope, subsequently widely adopted in U.S. observatories. Two decades later, Harvard astronomer Seth Carlo Chandler teamed with instrument maker John Clacey to develop a workable *almucantar*, a tool for measuring variation of latitude (polar motion).

Founders and Funders

The time-honored method of funding colleges was *subscription* — an appeal to the community at large, or to a wealthier subset, for resources. For observatories, donors were sometimes promised occasional viewing through the telescope; the largest donor might even be accorded naming rights.

Famously, Lick Observatory was named after James Lick, then the richest man in California, who wanted to establish an enduring monument as his legacy; he even specified that his body be interred at the base of its 36-inch refractor. Yerkes Observatory took its name from its principal donor, Chicago streetcar magnate Charles T. Yerkes, who wanted to redeem an unsavory reputation for shady business dealings.

But rich men seeking immortality or redemption were the exception. Statistically, nearly half of observatories were named for their town or host institution. In other cases, a school grateful for the gift of an observatory chose to name it after a donor, or to honor a long-serving professor.

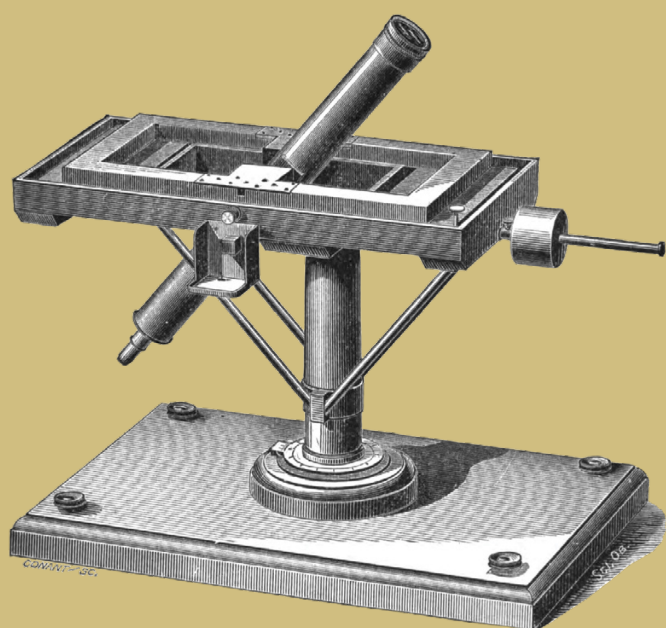
In at least a dozen instances, a mourning family financed the building of a college observatory as a memorial to a deceased loved one. Wealthy widow Blandina Dudley funded

Instruments of Precision (IOPs)

Ballou Mfg. Co.	Edward Kahler
John Bliss & Sons	Edward Kübel
E. & G. W. Blunt	Phelps of Troy / Phelps & Gurley
J. Brown & Son	George N. Saegmuller
Brown & Sharpe Mfg. Co.	Stackpole & Bro.
Buff & Berger	Stendicke of New York City
Fauth & Co.	John Hapgood Temple
Gregg & Rupp	William Würdemann
W. & L. E. Gurley	William J. Young
Jones of Philadelphia	Warner & Swasey

Domes

Nathaniel M. Lowe (lightweight domes)
William Scherzer (large domes)
Waters & Son (paper domes)
Warner & Swasey



▲ **COLLABORATIVE DESIGN** This 1880 prototype was the first of three very different designs of an *almucantar* invented by independent observer Seth Carlo Chandler and instrument maker John Clacey, both of Boston. This prototype had a 1.75-inch refracting telescope kept level by floating on a shallow rectangular channel of mercury.

SCIENCE OBSERVER, 1880, PUBLIC DOMAIN

About Time

Before the adoption of standard U.S. time zones in 1884, observatories determined accurate local solar time using transit instruments. A surprising number of observatories — both academic and private — earned income by transmitting daily time signals by telegraph to local or regional jewelers, railroad stations, and other subscribers.

and named the Dudley Observatory in Albany, New York, to memorialize her late husband. The largest donor to the Dearborn Observatory gave it the maiden name of his beloved late wife.

A few wealthy individuals sought to be patrons of science, building observatories for unrelated amateur astronomers. One famous example was the Warner Observatory in Rochester, New York, that patent medicine entrepreneur H. H. Warner constructed for the use of comet-hunter Lewis Swift. Similarly, the Smith Observatory in Geneva, New York, with a 10-inch Clacey refractor, was underwritten by nurseryman William Smith for the use of comet-hunter William R. Brooks.

▲ **COMET HUNTER** William R. Brooks stands with his 10⅛-inch refractor. John Clacey built the optical assembly; the equatorial mount and dome are by Warner & Swasey. Mounted in 1888, it is still the main telescope of the Smith Observatory in Geneva, New York.

COLLECTION OF TRUDY E. BELL

For the People

From the outset, many major research observatories — including Cincinnati, Harvard, Lick, and Washburn at the University of Wisconsin — offered public observing nights. Some private observatories did as well, such as the Brooklyn Heights observatory of Stephen Van Culen White, with its 12-inch Fitz/Clark refractor (now housed at the Whitin Observatory of Wellesley College).

Moreover, at least two observatories — Chabot in Oakland, California, and Frick in Mount Pleasant, Pennsylvania — were built specifically for the benefit of schoolchildren and were donated to local school systems. And the first successful U.S. periodical on astronomy, *The Sidereal Messenger* (founded by Carleton College Observatory director W. W. Payne in 1882), was initially intended for teachers and amateurs.

Such public outreach was unique to U.S. observatories. During a visit to Lick Observatory in March 1891, astronomer William Parsons, the Third Earl of Rosse, was "astonished to see the number of people visiting the observatory" because "in England, no such interest is manifested." In an 1887 U.S. Bureau of Education report, the author quoted an unidentified British astronomer who asserted, "There is no such thing in England as an observatory to which the public is admitted."

On the other hand, the sheer popularity of owning or visiting observatories baffled and dismayed some professional astronomers. "Our country has very many excellent observatories," lamented American physicist and spectroscopist Henry Rowland in 1883,

> *and yet little work is done in comparison because no provision has been made for maintaining the work of the observatory; and the wealth, which, if concentrated, might have made one effective observatory which would prove a benefit to astronomical science, when scattered among a half-dozen, merely furnishes telescopes for the people in the surrounding region to view the moon with.*

But to a sizable minority of the 19th-century American public, an observatory was akin to a cathedral or monument — a tangible symbol of spiritual renewal, cultural attainment, local or national pride, or eternal personal love and devotion.

Thus, historical records sometimes convey a sense that astronomers and funders were talking past each other. That disconnect could lead to dissension about where to site an observatory (James Lick's original wish was for his to be built in downtown San Francisco instead of atop a distant mountain), or to perennial difficulties with securing ongoing support for the observatory's astronomical work, often leading to underfunding of research and maintenance, and even decommissioning.

A New Golden Age

In the 1890s, several coinciding, unrelated factors precipitated a decline in the American observatory-building movement. Reasons cited by many historians include the rise of astrophysics, which needed costly, specialized equipment and PhD-graduate researchers, and the growing "professionalization" of astronomy in the 1890s, which tended to divide the observing community. Suburban observing sites became progressively degraded by urban light pollution and smoke. The newer technologies of spectroscopy and long-exposure photography necessitated remote, dark, fine-weather sites.

Other simultaneous, less-recognized external factors likely exacerbated the decline. For example, a severe worldwide recession began in 1893 and lasted some five years, ruining many financiers.

Recommendations to standardize high-school curricula were published by the U.S. Bureau of Education in 1893 and the National Education Association in 1894. High schools accordingly instituted a more career-oriented curriculum, still prevailing today, with its familiar silos of biology, chemistry, and physics. Simultaneously, belief was faltering in the value of the "mental discipline" of astronomical study.

Such wholesale changes reverberated throughout colleges. One lasting effect was demoting astronomy from an academic requirement to an elective subject as an adjunct to physics, reducing the incentive to build campus observatories.

Meanwhile, a new telescope technology was showing promise: large silver-on-glass reflectors. With the Yerkes 40-inch, large refractors were widely viewed as having reached their physical limit. Since the 1880s, some independent observers had been experimenting with reflectors of 8- to 22-inch aperture. The first significantly large silver-on-glass reflector installed at a major U.S. observatory was the 36-inch Crossley made by A. A. Common in England, mounted at Lick Observatory in 1895.

Lasting Heritage

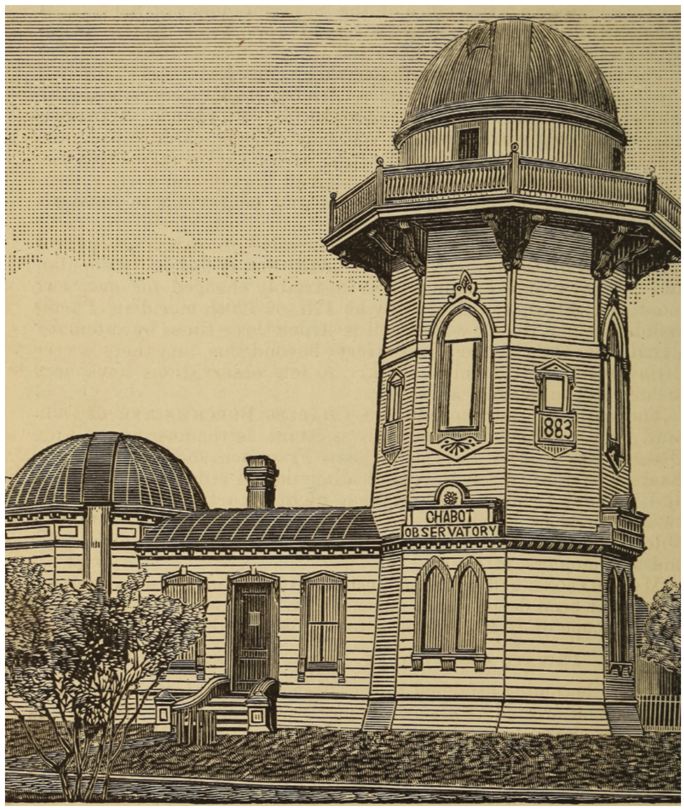
Fortunately for research astronomers, several major philanthropists understood perfectly that the "New Astronomy" of astrophysics demanded large, novel research facilities. They financed the construction of high-altitude, fine-climate, and Southern Hemisphere observing stations, as well as the publication of observational data and results. Thus began the 20th century's new golden age of the giant reflector.

After reflector apertures exceeded 100 inches, what happened with comparatively small 19th-century observatories? For the first half of the 20th century, they held their own as both research and teaching tools. But by the 1970s and 1980s, high-flying aircraft and satellites were enabling research at wavelengths inaccessible from the ground. Simultaneously, the Hipparcos satellite and interplanetary spacecraft were revolutionizing positional and solar system astronomy, formerly the provinces of the largest long-focal-ratio refractors. Today, more than 90% of 19th-century observatories have been razed — an irreplaceable loss of our astronomical heritage.

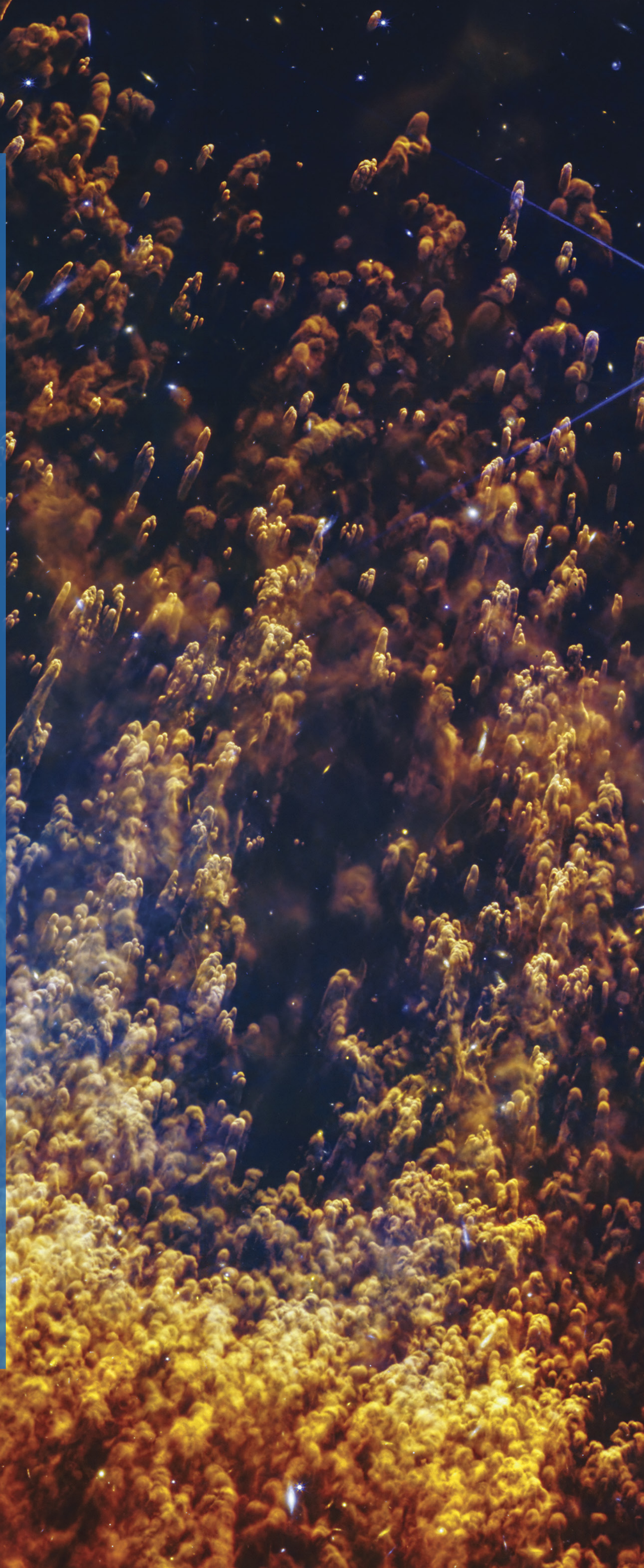
But one cultural priority from the 19th century remains to this day: dedication to education and outreach. Many large U.S. research observatories, as well as many college observatories (some dating from the 19th century), include visitor centers, tours, and public observing nights, welcoming, to quote the visionary *New York Times* in 1859, "*people by the thousands*."

■ Contributing Editor **TRUDY E. BELL** has a Master of Arts degree in American intellectual history and has been researching 19th-century U.S. observatories, telescopes, telescope makers, and philanthropists since the late 1960s, when she worked three student jobs for Lick Observatory at the University of California, Santa Cruz. She thanks manuscript reviewers Bart Fried (founder of the Antique Telescope Society), Roger Hutchins (author of *British University Observatories, 1772–1939*), and Philip Shoemaker (Ormsby MacKnight Mitchel biographer).

FURTHER READING: You can find more information on timekeeping with transit instruments in the 19th century in Ian R. Bartky's *Selling the True Time: Nineteenth-Century Timekeeping in America*, Stanford University Press, 2000.



▲ **GIFT TO PUBLIC SCHOOLS** In 1883, Anthony Chabot donated $15,000 to the city of Oakland, California, to build an observatory for the public school system. Completed in 1886 at its first site (shown here) in Lafayette Square in downtown Oakland, its main instrument was an 8-inch Alvan Clark & Sons equatorial refractor. Today, the Chabot Observatory (now at its third site) also includes a 20-inch Brashear refractor for public outreach.



As Below, So Above

The James Webb Space Telescope team released this stunning close-up view of the Helix Nebula, the expanding shell of a dying star 650 light-years away in Aquarius, the Water Bearer. Yet, despite the image's drama, the physics is the same as what we see much closer to home.

It's no surprise to us today that physics on Earth is reproduced in the heavens. Isaac Newton's theory of universal gravitation first solidly united the celestial and earthly realms in the 17th century. In formulating gravity, Newton was proposing that the same force that pulls an apple to Earth also applies to the planets and stars.

In the case of the Helix Nebula, we're looking not at things falling down but at light and particles conquering gravity. The central star (not visible here) is dying, having puffed off its outermost layers as the core collapsed to make a white dwarf. Now that incandescent ember has set the nebula's gases alight.

The intense radiation packs a punch, pushing thin gas away and leaving denser clumps behind as thousands of comet-like knots. Known as *radiation pressure*, the effect is the same one that we see push on dust in comet's tails, pointing them away from the Sun. If you had access to high-power lasers, you could even reproduce this phenomenon in a laboratory.

Radiation pressure works together with another phenomenon to shape these knots. The white dwarf's tenuous wind of charged particles helps sculpt clumps into pillars via *Rayleigh–Taylor instabilities*, which create swirls where fluids of different densities meet. You can watch similar swirls on Earth when pouring milk into coffee (or tea, if you prefer) — no telescope required.

Whenever we look up at the sky, whether with professional telescopes or our own, we witness the same science we see on Earth. Only in the knots of the Helix Nebula, the science is not of apples but of coffee and milk.

—MONICA YOUNG

Photograph by
NASA / ESA / CSA / STScI,
Image processing: Alyssa Pagan (STScI)

Explore Scientific's 8-inch Dobsonian Telescope

This Newtonian reflector could help redefine the idea of a beginner's scope for visual observers.

ES-ON20859 8-inch Dobsonian Reflector Telescope

U.S. Price: $549.99
explorescientific.com

What We Like

Very good optics

Quality construction

Very easy to set up and use

What We Don't Like

Dark window on red-dot finder (see text for details)

**Prices subject to change*

H. G. WELLS HAD HIS Victorian time machine; Mr. Peabody and Sherman had their Wayback Machine; and Doc Brown had his plutonium-powered DeLorean. Stories of time travel have long fascinated us in books, cartoons, and movies. Too bad time travel isn't real even though sometimes it almost feels like it is.

That's what happened the first night I turned Explore Scientific's 8-inch Dobsonian skyward. It was like being whisked from my suburban driveway back a half century to the yard of my boyhood home. This was where I excitedly began scanning the heavens with a new, homemade 8-inch reflector after having my observing appetite whetted with a 60-mm refractor.

While my time-travel fantasy was strictly personal, it makes an important point about the potential of an 8-inch reflector. It's a scope that can show a lot, from the Moon and planets to star clusters, nebulae, and galaxies. It offers views that can fuel a lifelong interest in astronomy and observing, and I'm obviously speaking from experience.

After several months using Explore Scientific's 8-inch Dob, which we borrowed from the manufacturer for this review, I began seeing the scope as a serious option for a beginning visual observer. The scope is easy to set up and use for just about everyone, from older children to aging adults. The assembled base and telescope tube sections each weighs less than 9 kg (20 pounds). On numerous occasions I carried the separate pieces from my garage to the driveway, placed the scope on the base, connected the tensioning springs on the altitude trunnions, and was ready to observe in less than two minutes.

This level of convenience, coupled with only a few minor issues that I had with the scope, made it a delight to use. And the views through the eyepiece were very satisfying and a significant step up from those afforded by many smaller scopes that are often recommended for beginners.

◀ Explore Scientific's 8-inch f/5.9 Dobsonian Reflector is especially easy to set up and use. The motions on the altitude and azimuth axes are smooth, and the eyepiece stands 114 cm (45 inches) above the ground when the scope is pointed at the zenith.

ALL IMAGES ARE BY THE AUTHOR

Out of the Box

The telescope arrived in two boxes. One for the fully assembled telescope tube (all you need to do is attach the red-dot finder), and the other for the unassembled base shipped like a piece of flat-pack furniture, including all the tools needed to put it together. The scope's optics were so nearly perfectly aligned on arrival that there was no need to make any adjustments to the collimation. The primary mirror has a center mark to help with collimation, but it would also be nice if the dust cap for the focuser had a small center hole that would keep your eye properly positioned when checking and adjusting the collimation. Users should consider picking up a collimation tool like a Cheshire eyepiece or laser.

Before putting the base together it's a good idea for even experienced do-it-yourselfers to scan the instruction manual (which anyone can download for free from the Explore Scientific website), paying heed to the bold type that explains why the identical-looking side panels must be assembled only one way for proper orientation. It should take most people less than an hour to complete the one-time assembly of the base.

Speaking of the manual, it's very well written, nicely illustrated, and contains a lot of straightforward information for first-time telescope owners. It's no surprise that the manual has abundant warnings about never aiming the scope at the Sun, but new to me was the somewhat dubious request that you "not use [the telescope] to look into people's homes."

The scope comes with a good-quality 25-mm Plössl eyepiece, which provides a magnification of 49× and a 1°-wide field of view (twice the Moon's apparent diameter). I used it exclusively for my first night of observing last December. The eyepiece is only 114 cm (45 inches) above the ground when the scope is aimed at the zenith, so many people will find it convenient using the scope while seated in a chair (I often used an overturned 5-gallon bucket).

To enjoy my time-travel fantasy on that first night, I set about looking at some of the sights I best remember from my youth, beginning with the Great Globular Cluster, M13, in Hercules, which was sliding down my northwestern evening sky. What often appears as little more than a soft glow in small telescopes was, even at this modest altitude, a dramatic splash of well-resolved stars in the 8-inch. It seemed even better than how I remembered those long-ago views with my 8-inch reflector. Observing experience played a role, but

▲ Springs on each altitude trunnion provide enough friction to keep the telescope from slipping while paired with a modest range of different-weight eyepieces. Heavier ones, however, often required some form of counterweight on the mirror end of the tube.

I suspect today's better optical coatings for mirrors and eyepieces helped too.

Next up was the Ring Nebula, M57, in Lyra, which appeared as a perfect little smoke ring with a subtle haze across its center. The light grasp of the 8-inch made the nebula instantly visible as it swept into the field while I was aiming the scope.

The double star Albireo in Cygnus was a treat with its beautiful, contrast-

▲ The Crayford-style focuser is solidly made and operates smoothly, making precise focusing easy, but it provides only 20 mm of travel. The scope comes with a 37-mm-long, screw-on extension tube and a 2-inch-to-1¼-inch adapter seen here, both of which were needed for the supplied eyepiece to reach focus.

▲ Rather than fiddling with the supplied threaded extension tube in the dark, the author found it easier to use extension tubes of his own that slipped into the scope's 2-inch focuser. The 2-inch-to-1¼-inch adapter has standard M42 threads on its top that accept T rings and camera accessories.

ing gold and blue colors. Brighter stars appear with four diffraction spikes surrounding them caused by the telescope's secondary-mirror support vanes. While some observers don't care for these diffraction artifacts inherent in views through a classical Newtonian reflector, others find them an enjoyable bit of the observing experience. "It wouldn't seem right if stars didn't have little spikes on them," one person told me as she looked up from the eyepiece while I was explaining that the spikes were caused by the telescope's optics.

A Few Details

The accompanying photos and captions highlight some of the scope's features that I especially liked, including the smooth-operating Crayford-style focuser and the extended rim on the primary-mirror cell that allows setting the telescope tube down on the ground without worrying that the collimation knobs will be disturbed.

One thing about the scope that disappointed me, however, is its red-dot finder. This type of inexpensive finder is adapted from those made for air rifles and BB guns. And the one supplied with this scope has a strong neutral-density coating on its front "window." It's like putting sunglasses on the finder — okay for daytime use, but terrible at night.

▲ A dark coating on the "window" of the scope's supplied red-dot finder (right) is seen here next to a far-more transparent finder from a 20-year-old Meade Lightbridge telescope. [Editor's note: After this review was completed, Explore Scientific announced that a different red-dot finder will be supplied with this scope in the future.]

Except for pointing the scope at the Moon, the bright planets, and a scattering of the brightest stars, I found it pretty much useless.

A telescope of this aperture, which can show so many deep-sky objects, really needs a finder that can help you hunt them down. I realized this immediately on my first night, and I quickly replaced the supplied finder with a 6×30 optical finder commandeered from one of my own scopes. If you Google "6×30 telescope finder," for less than the price of a modest eyepiece you'll find a large selection of suitable finders, complete with hardware that fits the mounting shoe on the Explore Scientific Dobsonian (similar to most coming from Asia these days.)

Another purchase for this scope that almost goes without saying for a first-time telescope owner is a few eyepieces and perhaps a Barlow. I tested the scope with a wide range of eyepieces from my own collection — from a 35-mm Tele Vue Panoptic with a 2-inch barrel providing 32× and a 1.8° field of view to a 10-mm Meade UHD model yielding 122× and a 0.6° field.

While I had no issues using my eyepieces with some combination of the scope's focuser, screw-on extension tube, and 2-inch-to-1¼-inch adapter, I did find it a bit inconvenient to fiddle with the extension tube in the dark. It was far easier and faster to use a couple of extension tubes of my own that *slipped* into (rather than *screwed* onto) the scope's 2-inch focuser. Such extension tubes are readily available from online sources.

Higher magnifications are more challenging to use with a Dobsonian that lacks motorized tracking. The trick is to focus the eyepiece carefully for the center of the field and then move the scope to position your target at the edge so that it drifts across the field while not touching the scope. This worked great for my views of Jupiter, which

▲ *Left:* A tight-fitting plastic cover protects the telescope optics from dust and pollen during transport and storage. *Right:* The scope's primary-mirror cell has a rim that extends farther out than the mirror's collimation knobs and locking thumbscrews, allowing the tube to be placed upright on the ground without fear of disturbing the collimation. The rim also served as a convenient place for the author's small, clip-on counterweights that he needed for balancing the scope when using heavy eyepieces.

was riding high near the zenith in last winter's sky.

Something Unexpected

The 25-mm eyepiece that came with the scope reached focus almost at the limit of travel available with the supplied extension tube and 1¼-inch adapter. From many years of testing telescopes, I've found that a manufacturer's specified focal length for reflectors can easily vary by 20 mm or more, which is insignificant for a Newtonian's performance.

Because the scope reached focus near the outermost limit of its focuser, I simply assumed that the primary mirror's focal length was a bit longer than the specified 1,219 mm. To satisfy my curiosity, I pulled the mirror from the scope and put it on my workshop test stand. The measured focal length turned out to be only 1,214 mm. Had it been the claimed 1,219 mm, the supplied eyepiece wouldn't have reached focus. This really isn't an issue since the telescope did reach focus, but it did surprise me a bit.

On the plus side, with the scope's primary mirror on the test stand, I could see that its optical surface was very smooth and free of any zones or detrimental edge defects. It also had a peak-to-valley wavefront error just shy of ⅛ wave, confirming what I already knew from using the scope that it was a great mirror for visual observing.

With so many positive features and so few negative ones apart from my criticism of the red-dot finder, I can heartily recommend the Explore Scientific 8-inch Dobsonian for today's visual observers, especially those just getting into the hobby. I've rarely seen an 8-inch reflector recommended for a first-time telescope owner, but that shouldn't stop anyone from considering this scope. And an 8-inch provides enough aperture to fulfil a lifetime of observing enjoyment.

■ In recent years **DENNIS DI CICCO** has been returning to his roots as a visual observer and enjoying his nights under the stars more than ever.

In the deepening evening twilight of March 24th, the author captured this snapshot of the Moon passing by the 1.7-magnitude star Elnath, Beta (β) Tauri (above). He used a Nikon D850 camera attached directly to the 8-inch Dob's focuser.

Build a Custom Bino-Chair

This comfort-focused binocular recliner will have you cruising the Milky Way in style.

◀ Dave Selinger's bino-chair is aimed at the zenith. The reclining zero-gravity chair controls altitude while the adjustable, counter-weighted binocular cradle keeps the optics aligned with the observer's eyes.

ONE OF MY FAVORITE things in writing this column is when amateur telescope makers prove me wrong. I first stumbled upon the idea of a binocular married to a chair while digging into the provenance of my first large telescope mirror made by Pierre Schwaar. The late master scope-builder had also made a beautiful 8-inch f/4 binocular Newtonian built around a lounge chair. I had largely written off such contraptions as the domain of expert inventors and woodworkers, off-limits to most hobbyists. Enter Vermont ATM Dave Selinger, who has created such a bino-chair around a pair of 16×70 binoculars and a common, commercially made zero-gravity recliner. The steering mechanism for his setup won awards for innovation and mechanical design at the 2023 Stellafane Convention.

It's often said that two eyes are better than one when it comes to observing. In a true binocular, the use of two lenses matches a true aperture gain of 1.4×. But the real benefit is something harder to quantify: Binocular summation is a fuzzy magic that happens in our brain when we watch something with two eyes. It intensely increases contrast and perceived brightness. The drastic improvement in contrast — alongside the intrinsic increase in light gathering — is often compared to a substantial increase in aperture. And any regular bino-observer will swear up and down that it simply feels better.

Another phenomenon improving the observing experience is having a "happy butt." My predecessor, Jerry Oltion, argues that "comfortable seated viewing is like adding aperture" (*S&T:* Dec. 2016, p. 70), a sentiment I strongly agree with. It was on a Wood Wonders Catsperch chair that I managed some of my best observing feats: I sat staring at the swirling arms of M101 through my 16-inch for nearly an hour, picking out puffs of star-forming regions and detecting stars down to 16th magnitude.

Dave says a bino-chair brings both ideas to their limits. Sitting in a reclining observing chair is the comfiest I've ever been at a star party (better than the car, sleeping bag, or cafeteria). And large binoculars are the most straightforward way to stargaze with the power of both eyes. Binoscopes work, but they're often bulky and require frequent collimation. Binoviewers tend to have limitations in terms of exit pupil and image circle size, as well as lower light transmission. A pair of large-aperture binoculars and a zero-gravity chair are a natural pairing to maximize comfort and light throughput.

Dave's bino-chair first started when he got his hands on the 16×70 binos. They were excellent for stargazing, but their size and weight made them difficult to hold steady for extended periods. So, he dug into binocular mounting methods in online forums, finding posts that discussed modifying a zero-gravity chair. He picked up some hardware supplies and went down to his basement. A few days later, his design emerged: A chair mounted on a turntable azimuth bearing as seen in many commercial Dobsonians and fitted with a single, large manual friction drive in the form of a hand-turned wheel. It also incorporates an adjustable, counter-weighted cradle for the binoculars and a simple mechanical link that raises the cradle as the chair reclines to keep the binoculars' aim fixed.

ALL PHOTOS ARE COURTESY OF DAVE SELINGER

Steering in azimuth is done by turning a bicycle wheel, not unlike maneuvering with a wheelchair. Dave says the prototype's steering was so smooth that one or two fingers were enough to turn the whole thing. He even had to add a friction mechanism to keep the viewing stable. And to change altitude, the user simply reclines with the action/altitude locks that come with the commercial chair. The binocular cradle is adjustable to accommodate most heights, as is the bino's eyepiece distance for observers with eyeglasses.

In practice, the bino-chair delights. At stark odds with handheld binoculars, looking straight at the zenith is the most comfortable viewing position. Users enjoy full access to 360° × 90° of sky. And with the adjustments being so easy, they sometimes forget they're even steering something.

Backyard assembly is straightforward. First, Dave sets down the octagonal base with the friction track and levels it. Then the rectangular chair platform with the azimuth turntable bearing sits on top of this, and the chair mounts onto the platform. A pair of wingnuts secures the steering wheel to the side of the chair. And from here, he just attaches the binoculars to the cradle, calibrates the chair to the user, and then it's time to stargaze.

Dave's design philosophy is to make the project easy to build with only modest woodworking skills and tools. It should also be easy to set up at night to offer a great viewing experience.

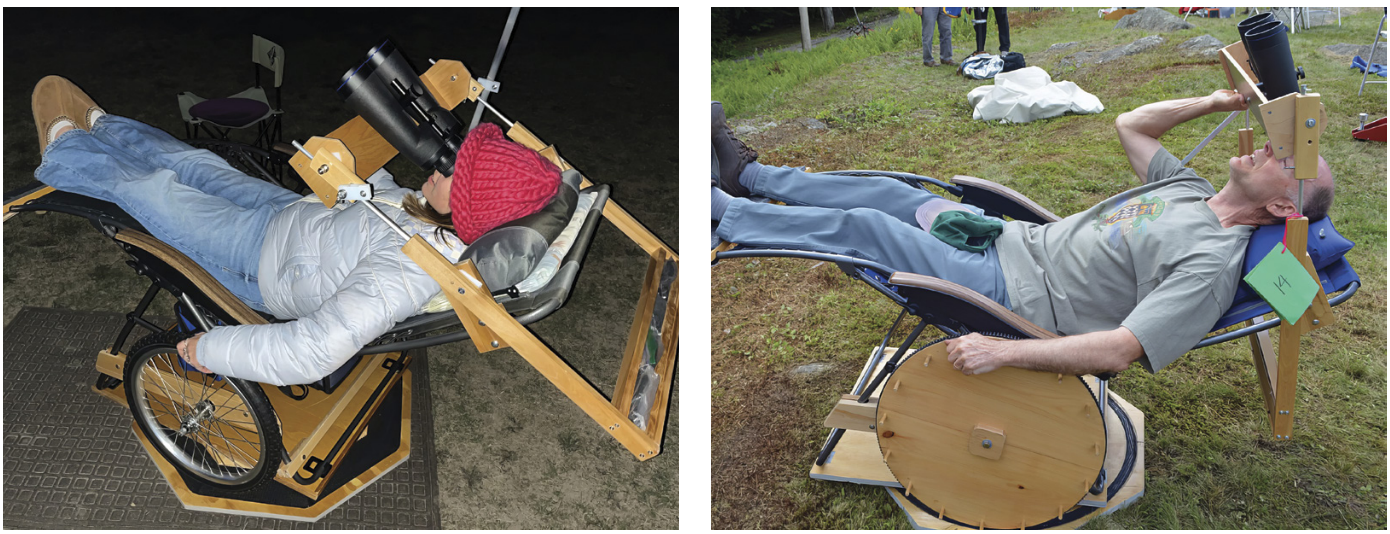
▲ The bino-chair transports and stores in compact, flat sections. Dave demonstrates how the setup assembles in just a few minutes in videos on his blog at **https://is.gd/bino_chair_demo**.

"Real DIY means the eventual achievement of an optimal result, done at relatively low cost," Dave says. "A store-bought bino-chair, even if one were readily available, would undoubtedly have been full of performance compromises."

Iteration helps, and it was only after feedback from friends on the field that he perfected his idea. The result of all this effort is a piece of observing gear that all but disappears when you use it, leaving just the magnified sky and the comfort of a cozy chair.

You can find detailed plans and documentation for Dave's build at **milkywaylounge.com**.

■ Contributing Editor **JONATHAN KISSNER** has a comfy butt but is still fussing with his linear bino-viewer.



▲ *Left:* Reclining the chair raises the binoculars toward the zenith while preserving eye alignment, making overhead observing unusually easy and comfortable. The user moves in azimuth by turning the steering wheel mounted on the side of the chair. *Right:* Dave demonstrates the bino-chair at the 2023 Stellafane Convention in Vermont. (To see another design variation, using a car bucket seat, see the August 2024 issue, page 74.)

GALACTIC ENHANCEMENT

Kfir Simon

NGC 55 is a Magellanic-type barred spiral galaxy located some 6.5 million light-years away in Sculptor. This enhanced-color image highlights vast clouds of hydrogen nebulosity that permeate its single spiral arm. Many galaxies that are even farther away dot the surrounding field.

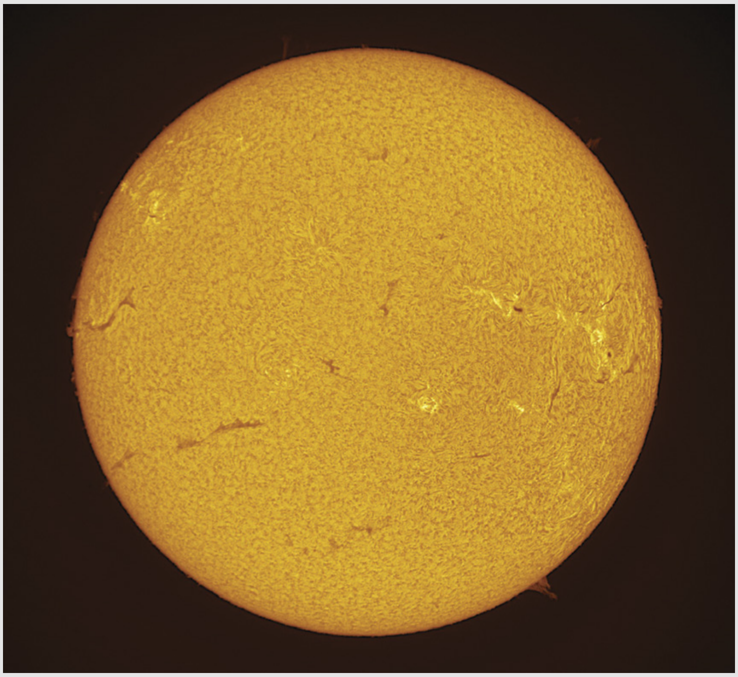
DETAILS: *ASA600 24-inch Ritchey–Chrétien operating at f/4.5 with Moravian G3 61000 Pro camera. Total exposure: 2 hours through hydrogen-alpha and color filters.*

INTERSTELLAR BOOGEYMAN

John Vermette

Dark nebula LDN 1622 in eastern Orion is a dense clump of gas that resembles a menacing figure to some. The brightest area in its upper right is the reflection nebula vdB 62. North is to the left.

DETAILS: *Sky-Watcher Esprit 100 refractor with ZWO ASI6200MC camera. Total exposure: 11 hours from Starfront Observatories in Rockwood, Texas.*



◁ SNAKING FILAMENTS

Eric Africa

Despite being past solar maximum, the Sun is still quite active, particularly in the chromosphere. This full-disk image records several filaments transitioning into prominences along the eastern (left) limb and a bright prominence at lower right.

DETAILS: *Lunt Solar Systems LS80MT with ZWO ASI1600MM camera. Stack of multiple video frames.*

▽ BARNARD'S GALAXY

Chris Schur

A member of the Local Group of galaxies, NGC 6822 resides roughly 1.6 million light-years away in the direction of Sagittarius. This deep image highlights the tenuous streams of dust in our own galaxy that imagers typically overlook.

DETAILS: *11-inch Celestron Rowe-Ackermann Schmidt Astrograph with ZWO ASI6200MM camera. Total exposure: 2 hours through LRGB filters.*

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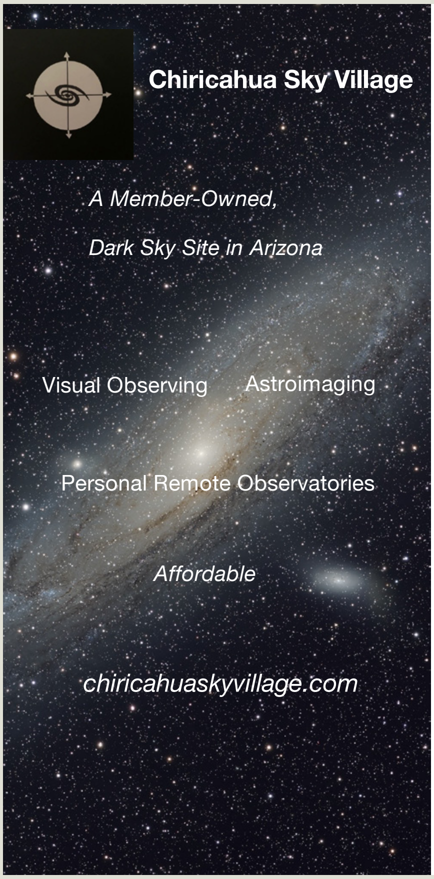

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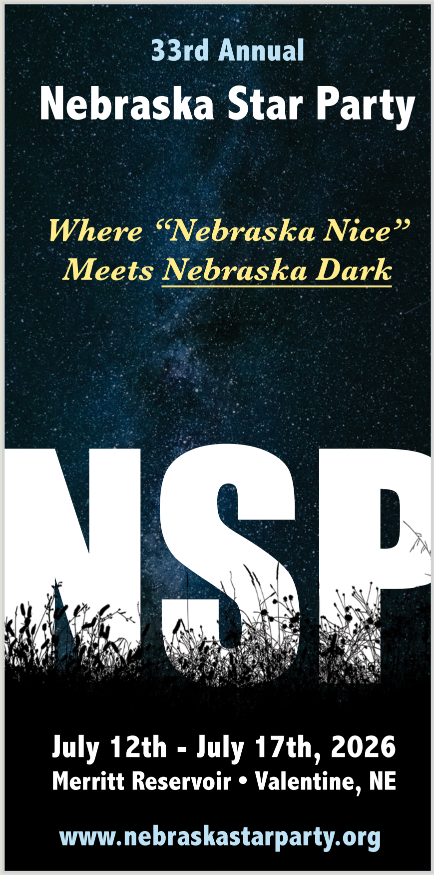

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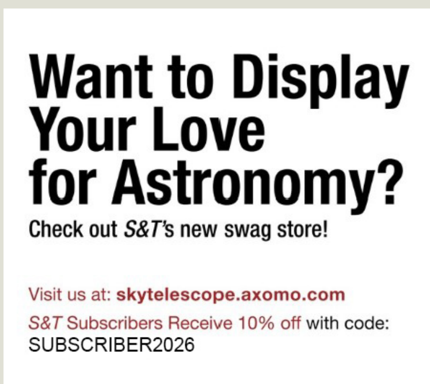

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Insight Cruises 3, 57
Knightware 81
Lunatico Astronomia 80
Nebraska Star Party 81
Nine Planets Ring 80
QHYCCD C2
Sky & Telescope 1, 83
Sky-Watcher C4
Software Bisque 5
Special Interest Tours 13
Stellafane Convention 81
Stellarvue C3
William Optics 80

Event Calendar

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

GALILEOMOBILE / ESO

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

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

June 11–13
BRYCE CANYON ASTRO FESTIVAL
Bryce Canyon National Park, UT
https://is.gd/brca_astrofest

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

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

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

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

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

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

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

August 12–15
ALCON
Covington, KY
alcon2026.org

August 11–16
SASKATCHEWAN STAR PARTY
Maple Creek, SK
sssp.saskatoon.rasc.ca

August 13–16
STARFEST
Ayton, ON
nyaa.ca/starfest.html

August 13–16
STELLAFANE CONVENTION
Springfield, VT
stellafane.org/convention

August 12–16
NOVA EAST
Smileys Provincial Park, NS
novaeast.rasc.ca

September 3–6
THEBACHA & WOOD BUFFALO DARK SKY FESTIVAL
Fort Smith, NT
tawbas.ca/dark-sky-festival

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

Taking Life's Scenic Route

Sometimes the detours life takes become the road itself.

WHAT DO YOU THINK of when you hear "Nevada"? The quirkiness of Reno and the bright lights of Las Vegas might readily come to mind. Yet, nestled in the valleys north of the City of Lights are charming towns, dark skies, and even a national park. The entire state is essentially a geological feature, with rolling mountain ranges and flat valleys. Towns with gas stations and Wi-Fi are often hundreds of miles apart along U.S. Route 50, the "loneliest road in America." Drives in this region are striking and worth a detour in ways that are surprising, especially if you love the night sky.

I enjoy driving places, but whether or not I choose a pretty, scenic route depends on how much time I can spare. As a graduate student on observing trips to the Big Island of Hawai'i, I rarely passed up an opportunity for a delightful drive like the one from Pepe'ekeo to Onomea north of Hilo, and I often sought interesting detours.

Sometimes, though, life's roads lead one on paths that are unavoidable. What brought me out West was one such path. External forces, professional choices that I could only see as wrong turns in hindsight, and a need for change led me to Nevada.

I've stayed here, fueled by the hope of experiencing something new and beautiful. On a clear, moonless night, I can see the Milky Way. I take comfort in spotting the constellations I learned as a kid, and I track the passage of time as they come and go. Research has felt like a Sisyphean task of late, but I'm learning firsthand about other routes to joy while sharing my love of astronomy.

One of those routes took me to Ely (ee-lee). For amateur and/or professional astronomers, the town's surroundings are rife with opportunities for nighttime observing and astrophotography. I've found one of them in the Nevada Northern Railway, which runs a set of astronomy-focused train rides during the summer months. They enable people to leave the lights of town behind for a spell, to marvel at the Milky Way, observe objects with an 8-inch telescope, then ride back to the comfort of their stay.

If you ever take one of these trips, I might be your guide. I'll answer your astronomy questions, trace out constellations with my green laser pointer, and occasionally drift into conversations about the meaning of life under the Milky Way while bumping along at 8 mph. An hour southeast, the Great Basin National Park hosts daily astronomy programming with knowledgeable Rangers, who often are on their own scenic route, pre- or post- graduate school. Next door to Ely's Steptoe Valley is Spring Valley, where Caltech's Deep Synoptic Array — part of the Eric and Wendy Schmidt Observatory System — will soon begin construction of a 1,650-element radio camera. The facility will take advantage of the region's isolation to probe the radio sky.

While here at 6,400 feet (2,000 meters), I'm both further away from the path that I thought would lead me directly toward stereotypical success as an astronomer and yet closer to what captured my fascination as a child — the sky. I couldn't have predicted my present in my past, but I'll see where this path takes me.

■ **AMY STEELE** is an astronomer who studies material around stars and enjoys sharing the night sky through observing and public outreach.

AMY STEELE


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