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# SKY & TELESCOPE

THE ESSENTIAL GUIDE TO ASTRONOMY

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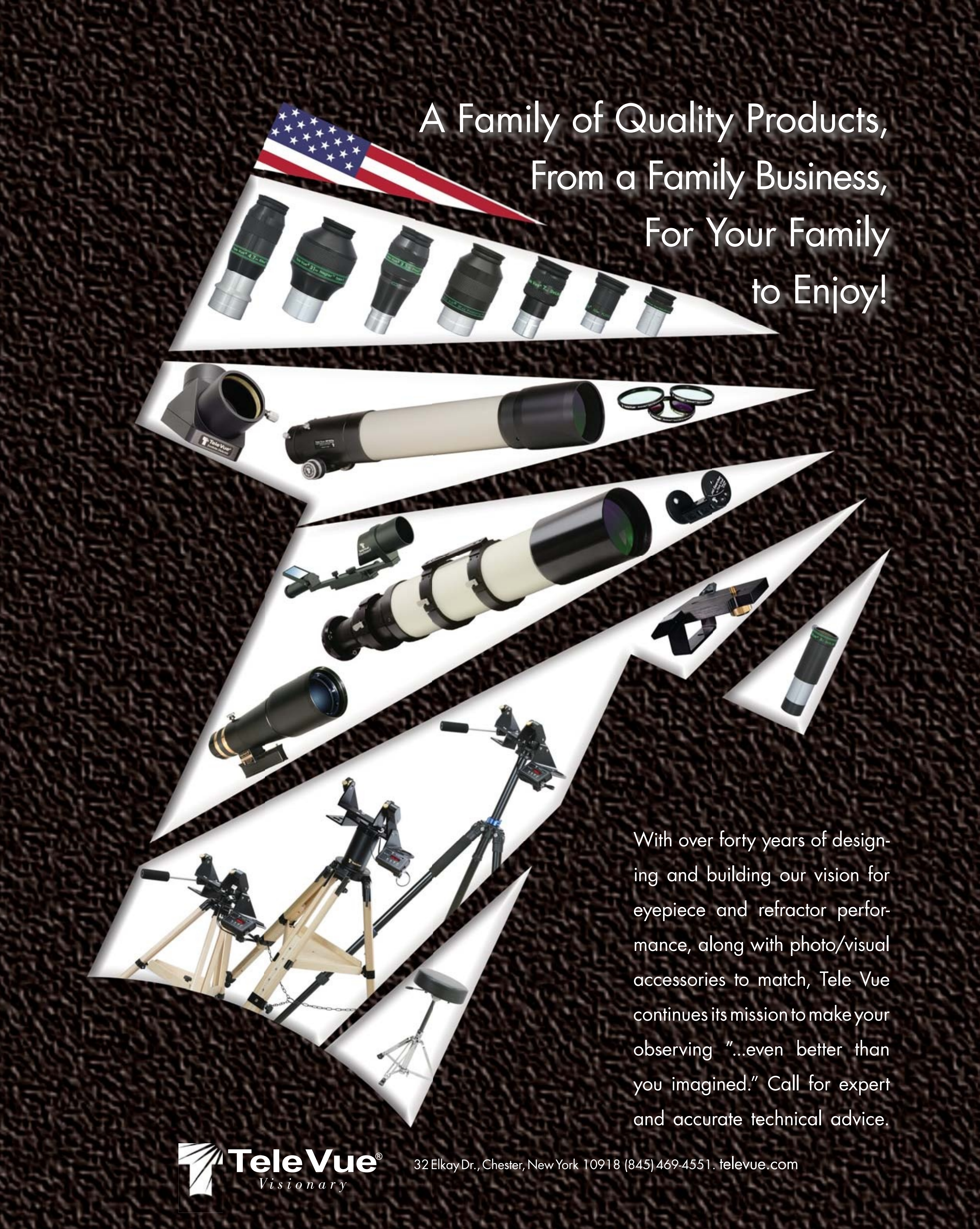

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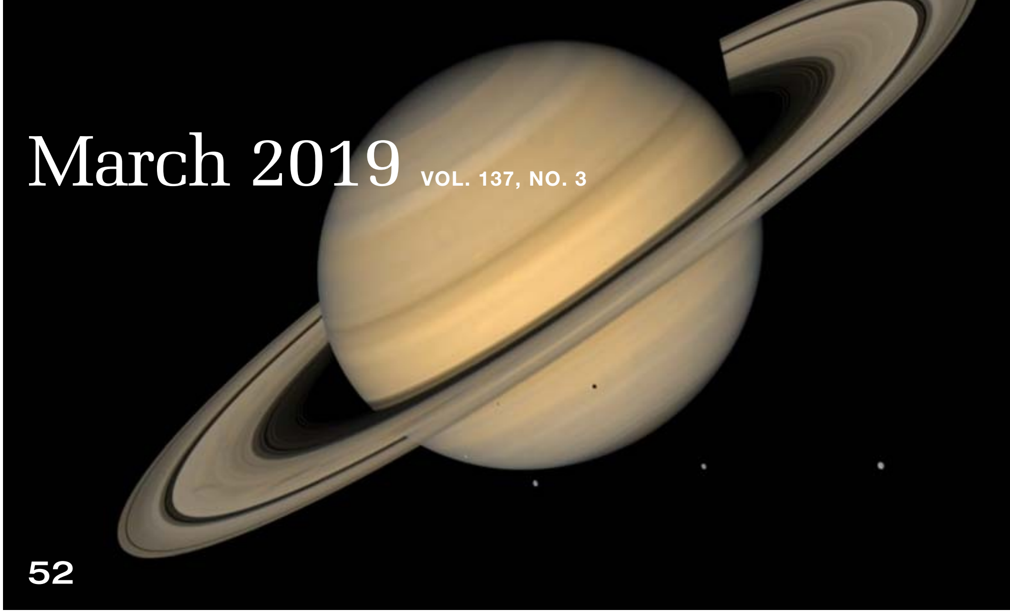


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Star trails over Anza-Borrego Desert State Park in California

PHOTO: DANIEL J BARR / GETTY IMAGES

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# Super Stars

**WITH THIS ISSUE** we kick off a three-part series on famous stars: Polaris, Alpha Centauri, and Betelgeuse.

Why did we choose these three over the thousands of others visible to the naked eye? Each holds abiding fascination not only for astronomers, both amateur and professional, but also for a broad swath of the enthusiastic public. Each is iconic in its own way. And each provides a keyhole glimpse into different sectors of cutting-edge science, from the formation of planets to how stars explode.

Artist's concept of the three-star Polaris system

NASA / ESA / G. BACON (STSCI)

Our first subject, Polaris, easily fits the bill. It's readily visible to observers in the Northern Hemisphere, even in light-polluted skies. A fixture of star-party outreach, it plays a fundamental role in familiarizing beginners with the constellations. ("See those two stars on the outer edge of the Big Dipper's bowl? They point to Polaris.") Owners of equatorial mounts generally rely on the North Star to align their telescopes, and astrophotographers cherish it as a centerpiece in their star-trails photos — just see our cover.

But Polaris's fame reaches beyond astronomy and into history and culture. Generations of seafarers knew that the star indicates the direction to true north, while its height in the heavens gives an idea of latitude. Our very notion of the "lodestar," a guiding principle or person, arose from the navigational utility of the North Star. Polaris became a lasting symbol of steadfastness: "I am constant as the northern star," boasts Shakespeare's Julius Caesar, "Of whose true-fixed and resting quality / There is no fellow in the firmament."

The irony, as Camille Carlisle notes in our cover story starting on page 14, is that "there is almost nothing constant about the North Star." Polaris is the nearest and brightest Cepheid variable, those exquisitely precise pulsating stars that serve as benchmarks for judging astronomical distances. Yet because of quirks in its pulsation, Polaris is useless for this. Recently astronomers discovered that the star emits X-rays, which it shouldn't be able to do. Even the pole star's much-vaunted fixity is an illusion: After March 24th, 2100, the North Star will begin moving away from the north celestial pole and will eventually cease altogether serving as the Northern Hemisphere's lodestar.

Which brings me to the final criterion to be chosen for our series: A star had to have *personality*. Polaris, that changeless changeling, certainly has it. And each of the two others in our triad — Alpha Centauri (the nearest star system to our own) and the red supergiant Betelgeuse (many people's favorite supernova progenitor) — has its own distinct charisma. But you'll have to wait till the April and May issues, respectively, to get the skinny on them.

Editor in Chief

**SKY&TELESCOPE**
The Essential Guide to Astronomy

Founded in 1941 by Charles A. Federer, Jr. and Helen Spence Federer



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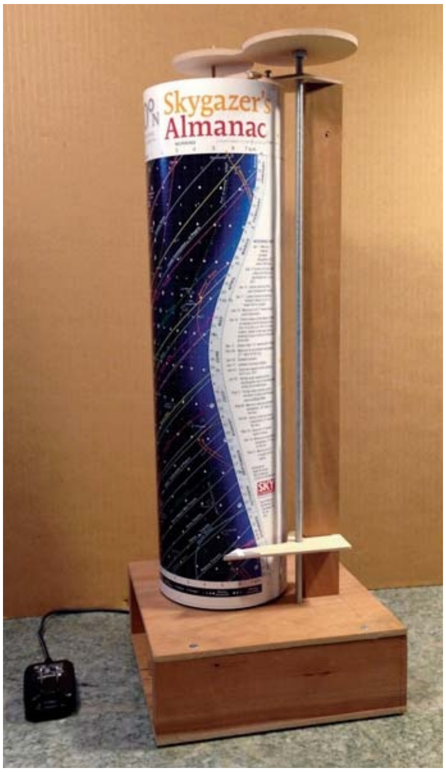



## Animated Almanac

I've built a device I call the SkyClock that animates *S&T*'s Skygazer's Almanac by pointing to sky events identified on the Almanac in real time.

The Almanac is mounted on a vertical cylinder that rotates once a day, driven by a stepper motor. A vertical screw connected to the cylinder with friction plates moves a pointer downward one day on the date scale per revolution of the cylinder. Thus, in one year the pointer moves down the Almanac from top to bottom.

It uses an inexpensive 5-volt stepper motor driven by a circuit board programmed with appropriate time delays between steps. The link between the rotating cylinder and the screw that moves the pointer downward consists of two spring-loaded plywood disks that supply a constant contact pressure. The ratio of their diameters provides the required rotation rate of the screw.

The SkyClock isn't intended to generate new information not already on the Almanac, but it's a real-time clock that's fun to watch and gives a visual sense of time and the events unfolding in the sky. The device gives a particularly interesting visual representation of the rising and setting times of the Sun and how the day and night times change throughout the year.

There is, of course, an inherent irony in this project: It takes a sophisticated computer-generated map based on physics and complex astronomical calculations and turns the information back into an 18th-century analog device!

**Bernd Enders • San Rafael, California**

◀ Bernd Enders's SkyClock updates the display on the Skygazer's Almanac on a daily basis.

BERND ENDERS

## A Deep-Sky Goodbye

It was with great sadness that I read of Sue French's retirement from her Deep-Sky Wonders column (*S&T:* Dec. 2018, p. 4). As someone who also writes — in my case a far more modest little astronomy column in the local newspaper — it's easy to feel a strange sense of not knowing if anyone is actually reading it. It's not a "live performance" where the audience claps at the end.

As this curtain closes let me assure you, Sue, of the applause from all of us. Your writing has inspired wonder, and your sense of joy has been spread far and wide. For me, and probably most, the guides you have provided are read and then re-read again and again as each view of the sky moves into place. You may not be writing any more columns, but Deep-Sky Wonders will live on as a timeless resource for observing the universe around us.

**William Maxwell**
**Camano Island, Washington**

I have just sat down to read this month's magazine, and I must say that the Spectrum editorial was moving. Sue French's columns back in the early 2000s were very important to me as I re-entered the world of astronomical observing after a hiatus of 30-plus years.

Amateur astronomy had changed so much from the late 1960s and early '70s. Living in northern New Jersey, I had almost despaired of what I could do with the small equipment I could afford. Sue's columns saved the day for me. She was the perfect instructor, always knowledgeable and encouraging. Her writing style encouraged me with a "you can do this" style of enthusiasm. It was an enthusiasm that also carried over in her public speaking, as when I heard her talks at NEAF.

I enjoyed her monthly columns and the published collections as well. It was her works that made me feel comfortable once again in this hobby. So, thanks so much, Sue. It has been a pleasure reading your columns. Enjoy your retirement, and may it be filled with clear skies.

**Dale Patterson**
**Washington, New Jersey**

## Home Sweet Hole

Michael Poll's letter (*S&T:* Dec. 2018, p. 6) describes Tswaing Meteor Crater in South Africa, which "must be one of the more easily accessed impact craters!" In Quebec, I actually live in one.

About 30,000 people live in the Charlevoix crater, in some 11 small towns and villages. The crater is referenced in the RASC's *Observer's Handbook 2019* on page 261. It's a 54-km semicircular crater, the missing half being buried under the St. Lawrence River and the Appalachian tectonic plate.

**Hugues Lacombe**
**Baie-Saint-Paul, Quebec**

## An Amazing Revelation

NGC 1514 in Taurus is sometimes called the "Crystal Ball Nebula," but I think the name "Herschel's Revelation" is far more significant. This is the object that convinced Sir William that nebulae are real and not, as was the belief then, just masses of unresolved stars. His profound insight came at seeing the clear separation of the surrounding nebula from the obvious central star. It was yet another of Herschel's many amazing observations based solely on the visual appearance of objects in his telescopes.

**James Mullaney**
**Rehoboth Beach, Delaware**

## Scaling the Void

Great article on the Local Void (*S&T:* Oct. 2018, p. 12)! But like all huge structures, I had difficulty visualizing it, so I tried scaling.

Make 1 million light-years equal 1 meter (3 feet): The Milky Way is now a disk 9 cm (3.6 inches) wide. If you're facing the Local Void with the Milky Way in front of you, Andromeda is off to your left 2.5 meters, a disk about 20 cm wide. M33, the Triangulum Galaxy, is a 2.5-cm disk to the left and below Andromeda, about 1 meter from it.

Have a friend hold the Milky Way while you go 1.5 meters past it and you pass Barnard's Galaxy (NGC 6822). Go another 2 meters and you pass the Sagittarius Dwarf Irregular Galaxy. Now for another 250 meters you walk through completely empty space.

Look back when you reach the end of the Local Void, and the Milky Way and Andromeda are very small and faint.

I've written an article using the solar system model in front of Griffith Observatory to show how far away the Oort Cloud and Alpha Centauri are. When you use my scale for the Local Void on this model, you come to realize just how large the void really is.

**Dave Nakamoto**
**Azusa, California**

## Moonset Moment

Eli Maor's justifiably reverent Focal Point (*S&T:* Dec. 2018, p. 84) overlooks the profound inspiration that humankind's first crewed visit to another world gave to my baby boomer generation.

I vividly remember that Christmas Eve in 1968 when Apollo 8's crew gave the first-ever "Live from the Moon" television broadcast. While the Moon's magnificently desolate features scrolled across my family's black-and-white TV screen and the astronauts read from the Book of Genesis, I looked out my window and saw the actual Moon setting outside in the wintry night.

So, besides the Apollo 8 crew's iconic Earthrise moment, my Moonset moment brought a little boy a profound awareness of our place in the universe.

**Daniel Costanzo**
**Locust Grove, Virginia**

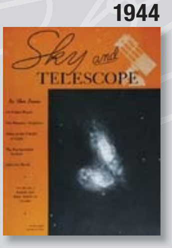
### FOR THE RECORD

- In "New Year's Eve Celestial Celebration" (*S&T:* Dec. 2018, p. 22), the actual distance for Altair is 17 light-years.
- In Gallery (*S&T:* Jan. 2019, p. 76), Nebula CTB-1 should be 36 arcminutes in diameter.

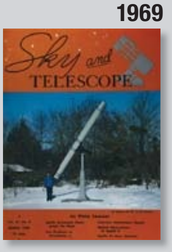
**SUBMISSIONS:** Write to *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, U.S.A. or email: letters@skyandtelescope.com. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

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

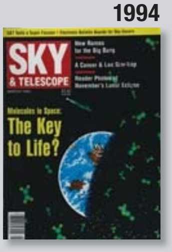
1944




1969




1994




◖ **March 1944**

**Titan's Air** "Titan [is] the principal satellite of Saturn. . . . Late in January, Dr. Gerard P. Kuiper . . . reported from the McDonald Observatory in Texas that he had obtained spectra of Titan in red and infrared light. These spectra reveal an atmosphere rich in hydrogen. It is much like the atmosphere of Saturn itself, containing methane (marsh gas) and possibly ammonia. . . . Life, as we know it, is as much out of the question on Titan as on Saturn."

*We now know Titan's atmosphere is largely nitrogen, but it does have some methane. Dorrit Hoffleit's final remark also needs a different emphasis. Astrobiologists think Titan could well harbor some exotic form of life.*

◖ **March 1969**

**Missing Mass** "A major discrepancy arises when astronomers try to determine the mass of a cluster of galaxies. Such a cluster is equivalent to more than 100 million million suns. The system's mass can be calculated from the motions of the galaxies in it, but when the individual masses of the member galaxies are added up, the sum is more than 10 times smaller! . . .

"This had been discovered for the giant cluster in Coma Berenices by Fritz Zwicky in 1933. [And at a 1961 meeting of astronomers in] Santa Barbara, cluster after cluster — both large and small — was added to the list."

*The curiosities cited by Herbert J. Rood (Van Vleck Observatory), plus other lines of evidence, have grown into the major cosmological problem of "dark matter."*

◖ **March 1994**

**Big Bang, or . . . ?** "The gauntlet thrown, *Sky & Telescope*'s challenge to rename the Big Bang immediately struck a chord among the public. [In the end we] processed 13,099 entries from persons in 41 countries. . . .

"*Creation* was submitted 124 times, followed closely by *Cosmogenesis. . . . Damaru* (the Hindu drum of creation) was suggested. . . . Those opting for modern-day English often resorted to terms that evoked a certain awe or puzzlement. A 90-year-old entrant submitted *Out of the Misty Mystery.* . . . But some contestants, and not just the professional astronomers, had a good grasp of the standard model. They pictured the universe as an expanding entity with such titles as *Super Seed*, . . . *Hawking's Hunch*, *Planck Point*, and *Hubble Bubble*. . . . And then there was *Bertha D. Universe*. . . .

"A small minority thought they might influence judges Timothy Ferris, Hugh Downs, and Carl Sagan [with a name like] *BS (Before Sagan)*. . . ."

*Sagan had predicted that no one would be clever enough to outdo Fred Hoyle's flawed and sarcastic term, Big Bang. And the judges' final verdict turned out to be: Leave it alone!*

MISSIONS

# Insight Lander Touches Down on Mars

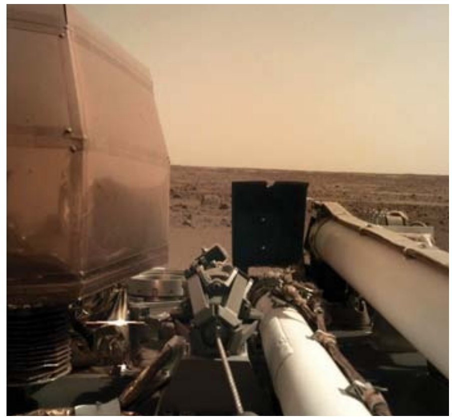
**AFTER A SEVEN-MONTH JOURNEY** of almost 500 million km (300 million miles) followed by just over eight minutes of nail-biting anxiousness by mission controllers, the Mars Insight lander has become NASA's eighth successful landing on the Red Planet. The lander touched down on November 26th at 2:52 p.m. EST in the Elysium Planitia region of Mars, 600 km (370 miles) north of Gale Crater, the stomping grounds of NASA's Curiosity rover.

As NASA's first dedicated geophysical mission to Mars, Insight will spend the next two years studying the deep interior of the planet by chronicling "marsquakes," geologic activity, and heat flow from the core (*S&T:* Dec. 2018, p. 34). The lander will attempt to address specific questions such as: How similar is the interior of Mars to that of other rocky planets? How does the interior of the planet affect what we see on the surface? What is the structural thickness of the crust and the size and density of the core?

Insight carries a host of science instruments. A seismic experiment will monitor for planetary rumblings and meteorite impacts. A heat flow package — known affectionately as "the mole" — will drill 5 meters (16 feet) below the surface as it measures heat dissipation from the planet's core. Radio signals will precisely measure the minute wobble in the rotation of Mars, building on data provided by previous missions.

The lander also carries a weather monitoring station, a laser retroreflector that future orbiters can utilize for measuring movement of the planet's surface, a suite of cameras, and a robotic deployment arm. Two small silicon chips brought the names of more than 2.4 million people to Mars.

Once Insight finishes scouting the landing site, researchers will select a location to deploy the surface experiments. Insight will use its robotic arm to grab and place the seismic experiment and the mole on the surface. The mole will then begin hammering away, digging into the surface of Mars about 1 mm at a time. Insight will use these taps to map the Martian crust directly under the lander. The probe will also stop every 50 cm (20 inches) during digging to take a measurement of the heat flowing out of the Martian interior. This will be a slow process, as the mole will have to pause for about four days between drilling sessions to allow heat from its own activity to dissipate.

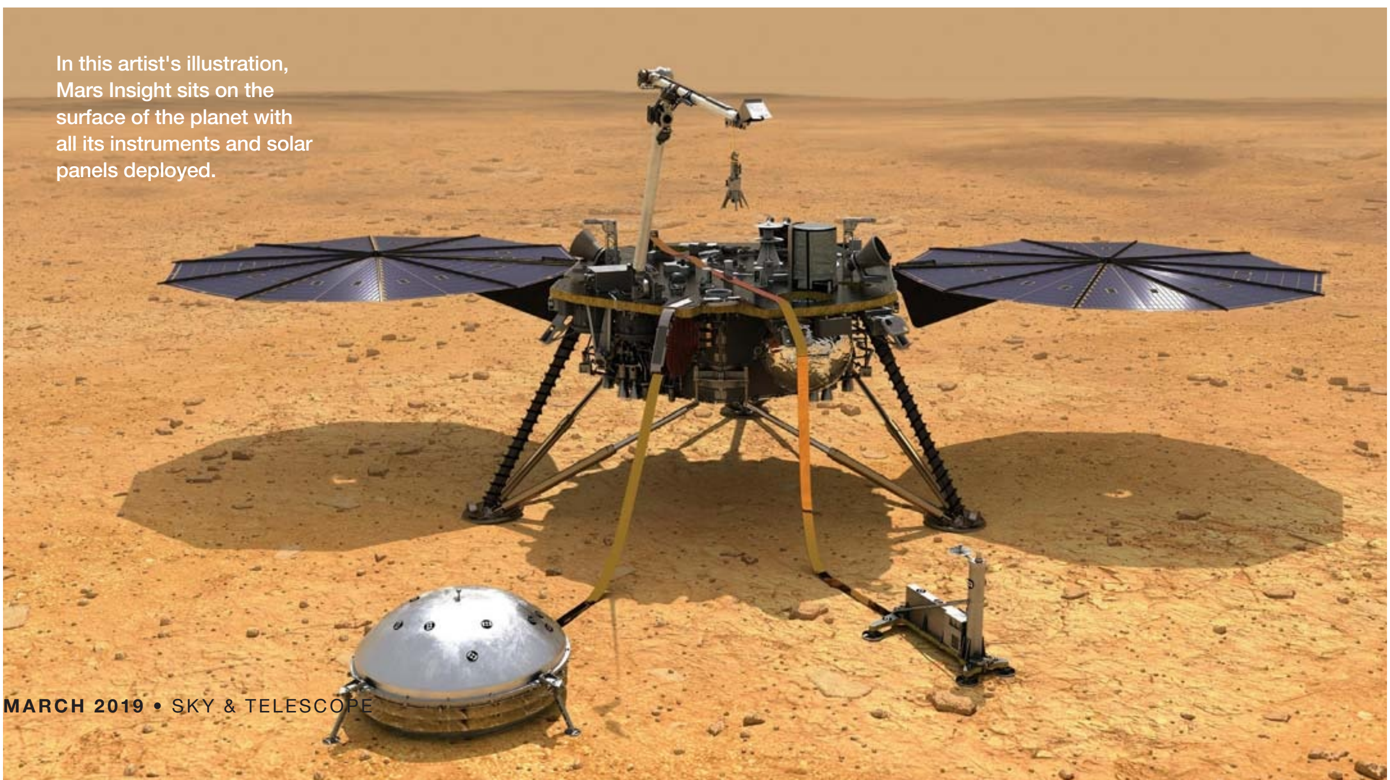


▲ The Mars Insight lander acquired this image of its landing site on November 26th, shortly after touching down on the surface.

The probe will hammer at the Martian soil an estimated 5,000 to 20,000 times en route to its 5-meter target depth. The entire digging process is expected to take anywhere from 30 to 40 days, and the mole must achieve a depth of at least 3 meters for good science results.

Then, Insight must sit silent to take delicate seismic measurements. To this end, the lander isn't even equipped with a steerable radio dish or anything that could induce vibrations in the deployed detector. Instead, Insight has fixed, opposing horn antennas for communication.

■ DAVID DICKINSON



In this artist's illustration, Mars Insight sits on the surface of the planet with all its instruments and solar panels deployed.

NASA / JPL-CALTECH (2)

GALAXIES

## Dwarf Galaxy Found by Amateur

**IN AN ERA OF GIANT** telescopes, one could be forgiven for thinking there wasn't much left for an enthusiastic hobbyist to discover. But with patience and the right equipment, even an amateur astronomer can stumble onto an undiscovered galaxy.

Beneath the dark skies of Pollino National Park in southern Italy, Giuseppe Donatiello had been investigating the Andromeda Galaxy with his home-built telescope. In images acquired late in 2010 and 2013, he noticed an unidentified smudge of light. That smudge turned out to be a dwarf spheroidal galaxy — now dubbed Donatiello I — lurking on the farside of Andromeda. "I literally jumped for joy," says Donatiello.

As far as galaxies go, Donatiello I is a runt. Assuming an estimated distance of about 10 million light-years, it appears to be roughly several thousand light-years across. The dwarf galaxy is faint, too. With a surface brightness of just 26.5 magnitudes per square arcsecond, it's barely visible against the night sky.

◀ The amateur-discovered dwarf galaxy Donatiello I is just a fuzzy blob in this composite image obtained with the discoverer's 127-mm refractor in Italy.

Astronomer David Martínez-Delgado (Heidelberg University, Germany) came across the discovery on Facebook, where Donatiello had posted his discovery image. Martínez-Delgado reached out and offered to collaborate on a paper, to appear in *Astronomy & Astrophysics*. The pros took a closer look with much larger telescopes. The dwarf galaxy appears to be old and on its own, just outside our Local Group of galaxies. Martínez-Delgado and colleagues hope to get a better look with the Hubble Space Telescope, which should provide them with precise measurements for the galaxy's distance, size, and mass.

Donatiello, meanwhile, plans to keep searching. "I have always had a great interest in dwarf galaxies, so I will continue in this direction," he says. "But more generally, I am interested in galactic archeology, so at the same time I will dedicate myself to the search for stellar streams around Milky Way-like galaxies."

■ CHRISTOPHER CROCKETT

EXOPLANETS

## Chilly Super-Earth May Orbit Barnard's Star

**IN THE CONSTELLATION OPHIUCHUS** lies Barnard's Star, one of the closest and most well studied red dwarf stars in the galaxy. Now, after more than two decades of searches, astronomers have found signs of an exoplanet hiding in its light.

Led by Ignasi Ribas (Institute of Space Sciences, Spain), this latest investigation combines new and archival observations spanning 20 years from seven different facilities across the globe. The data, which record the star's speed toward and away from Earth, suggest that a planet at least 3.2 times as massive as Earth orbits Barnard's Star every 233 days at a distance of 0.4 a.u. (60 million km). The team reports their find in the November 15th *Nature*.

The putative planet is a bit farther out from its star than Mercury's average distance from the Sun. But given the star's weak luminosity — less than 4% that of the Sun — this orbit puts the planet close to the system's snow line, where water exists only in its frozen form, making habitability unlikely.

At just under 6 light-years away, Barnard's Star is the fourth-closest star to the Sun (after the three stars of the Alpha Centauri system). This proximity means the separation between planet and star on the sky is large enough to make Barnard's planet an ideal candidate for direct imaging with next-generation observatories. The researchers say that the European Gaia satellite and even the Hubble Space Telescope might be able to directly measure the star's planet-induced wobble on the sky, which could help astronomers zero in on the planet's true mass.

■ SUMMER ASH

▼ A ruddy glow bathes the imagined surface of a putative rocky planet orbiting the red-hued Barnard's Star, in this artist's illustration.

DWARF GALAXY: G. DONATIELLO; PLANET: M. KORNMESSER / ESO

STARS

## Puny Star Might Be Survivor from Early Universe

**THE FIRST STARS** to light up the universe — known as *Population III stars* — were likely giants, hundreds of times heftier than the Sun. But a recently discovered puny star in our galaxy might be an ancient specimen that shows how the first stellar generation could have sprouted some runts that still live among us.

The star in question, estimated to be about 13.5 billion years old, contains few elements heavier than helium, a sign that it was born before other stars spewed lots of atoms such as carbon, oxygen, and iron into space. Astronomers know of similarly pristine stars, but two things make this one stand out. It's just 14% as massive as the Sun, barely weighty enough to ignite fusion, and it's the slimmer half of a binary system, which gives a clue about how it formed.

▲ The 13.5-billion-year-old binary system 2MASS J18082002–5104378 lies in the yellow box just off the plane of our galaxy.

Kevin Schlaufman (Johns Hopkins University) and colleagues report in the November 10th *Astrophysical Journal* that the star likely formed via *disk fragmentation* — gas clumping together in a disk that once swirled around the more massive of the duo. Researchers have debated whether or not this can happen around stars with a paucity of elements heavier than helium.

If disk fragmentation can happen for stars as pristine as these two — which aren't themselves from the first stellar generation — then it should also have been possible for Sun-sized stars to form in disks around gargantuan Population III stars, the team argues. Unlike first-generation behemoths, which would have shone briefly then exploded long ago, their low-mass bretheren might still be with us today.

"That's the reason we should keep looking for low-mass Population III stars in the galaxy," says Schlaufman. "We shouldn't despair. There's good reason to think they're still there."

■ CHRISTOPHER CROCKETT

COSMOLOGY

## Starlight Tally Reveals History of Star Formation

**FOUR THOUSAND** octillion octillion octillion — or $4 \times 10^{84}$. That's roughly the number of photons emitted by all the stars in all galaxies throughout time. Using this new tally, astronomers have pieced together an updated timeline of how the rate of star formation has waxed and waned over cosmic history, researchers report November 30th in *Science*.

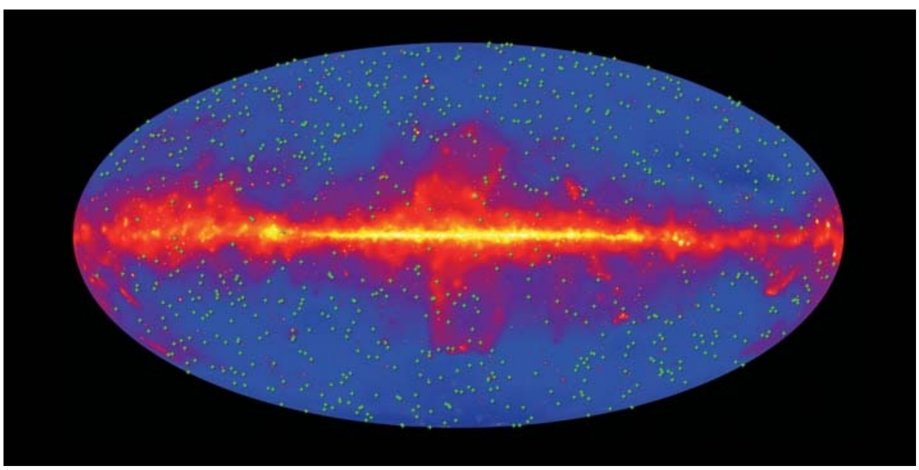
The new timeline jibes with earlier independent estimates: The cosmic star-forming factories were at their most prolific about 3 billion years after the Big Bang and have been gradually slowing down ever since. At its peak, the universe churned out 10 times as many stars per year as it does now. "Our galaxy and the entire universe were lit up like a Christmas tree," says coauthor Marco Ajello (Clemson University).

Starlight that escapes galaxies contributes to a haze of photons known as the *extragalactic background light*. This light is tricky to measure directly. So a team of researchers known as the Fermi LAT collaboration looked at how this light interferes with gamma rays emitted from blazars, wellsprings of radiation powered by supermassive black holes at the cores of galaxies.

To make their tally, researchers analyzed data on 739 blazars (and one gamma-ray burst) collected over 9 years by the Fermi Gamma-ray Space Telescope. The light from these blazars took anywhere from 200 million to 11.6 billion years to reach Earth. By measuring how specific wavelengths of gamma-ray light from each blazar have been suppressed, the team estimated the intensity of the extragalactic background light at various epochs. This in turn enabled the researchers to reconstruct the rate of star formation across most of cosmic time.

■ CHRISTOPHER CROCKETT

▼ This map of the entire sky from the Fermi Gamma-ray Space Telescope marks the location of 739 blazars (green crosses) used to estimate the extragalactic background light.



PUNY STAR: BELETSKY (ESO) / 2MASS / DIGITAL SKY SURVEY; STAR FORMATION: NASA / DOE / FERMI LAT COLLABORATION

STAR CLUSTERS

## Stars in M11 Hide Their True Colors

**THE WILD DUCK CLUSTER** — or Messier 11 (M11) — is one of the most enticing telescopic sights in the summer. There are some 2,900 stars here, a rich assemblage of suns that for some resembles a flock of ducks in flight. Astronomers have long believed that all the stars in an open cluster such as M11 were born in a single generation and therefore should be close in age. But the Wild Duck presents a mystery. Stars of similar brightness (and presumably similar mass and, thus, evolutionary stage) display different colors, which are generally a good indicator of age.

To get to the bottom of this mystery, Beomdu Lim (Kyung Hee University, South Korea) and colleagues examined the spectra of stars in M11. To their surprise, it isn't the stars' ages that cause the spectral variety but their rotation. Spectra revealed that the stars are spinning at different rates. This range of spins leads to differences in star color and ultimately stellar lifetimes.

"The effects of rotation on stellar evolution were often neglected in the past," says study co-author Yaël Nazé (University of Liège, Belgium). The team published their findings November 5th in *Nature Astronomy*.

Most of a star's life is spent on the *main sequence* burning hydrogen in its core (see page 14). When its core hydrogen is exhausted, the star switches to other fuels and burning strategies, causing it to expand, redden, and leave the main sequence.

But the faster a star spins, the better it mixes hydrogen into its core and the longer it can remain on the main sequence — 15% to 62% longer — compared to slower-rotating cousins of similar mass. Fast rotation also deforms a star's shape. As its diameter expands, the equatorial regions cool and redden. The fast rotators appear redder than slow rotators while still basking on the main sequence. So the Wild Duck Cluster mimics two stellar populations when only one exists.

■ BOB KING

▲ This picture of the open cluster M11, or the Wild Duck Cluster, was taken using the European Southern Observatory's 2.2-meter telescope at La Silla Observatory in Chile.

ESO

## IN BRIEF

### Landing Site Selected for Mars Rover

After a five-year selection process, NASA has chosen Jezero Crater in the Martian northern hemisphere as the landing site for its next Mars rover — dubbed Mars 2020 — scheduled to launch in July 2020. The 30-mile-diameter crater has landforms as old as 3.6 billion years and appears to have once been flooded with water early in the history of Mars. It also contains many promising geological targets, including at least five varieties of rock as well as an assortment of carbonates and clays. These are crucial, as the rover will specifically look for signs of life past and present on Mars. "Getting samples from this unique area will revolutionize how we think about Mars and its ability to harbor life," said Thomas Zurbuchen (NASA) in a November 19th press release. However, the site will be a challenging place for the rover to land and operate. Small craters and large boulders litter the terrain. There are also depressions filled with wind-driven sand, spots that could act as sand traps for the rover.

■ DAVID DICKINSON

### Quasar Cannibalizes its Neighbors

The most luminous known galaxy in the universe — a beast designated W2246 that blazes with the light of 350 trillion suns — appears to be feeding the gargantuan black hole at its center by cannibalizing three neighboring galaxies, researchers report in the November 30th *Science*. The galaxy hosts a quasar, a brilliant fountain of radiation likely powered by material falling onto the black hole. Astronomers have suspected that the most likely thing capable of feeding such voracious appetites is other galaxies, but evidence has been largely circumstantial. Now, Tanio Díaz-Santos (Diego Portales University, Chile) and colleagues have found rivers of dust streaming onto W2246 from three adjacent galaxies, indicating that the foursome is merging. The researchers argue that this quadruple merger is responsible for powering the quasar. And if W2246 is typical of similar behemoths, then perhaps all ultraluminous quasars in the early universe are powered by galaxies stripping each other for parts.

■ CHRISTOPHER CROCKETT

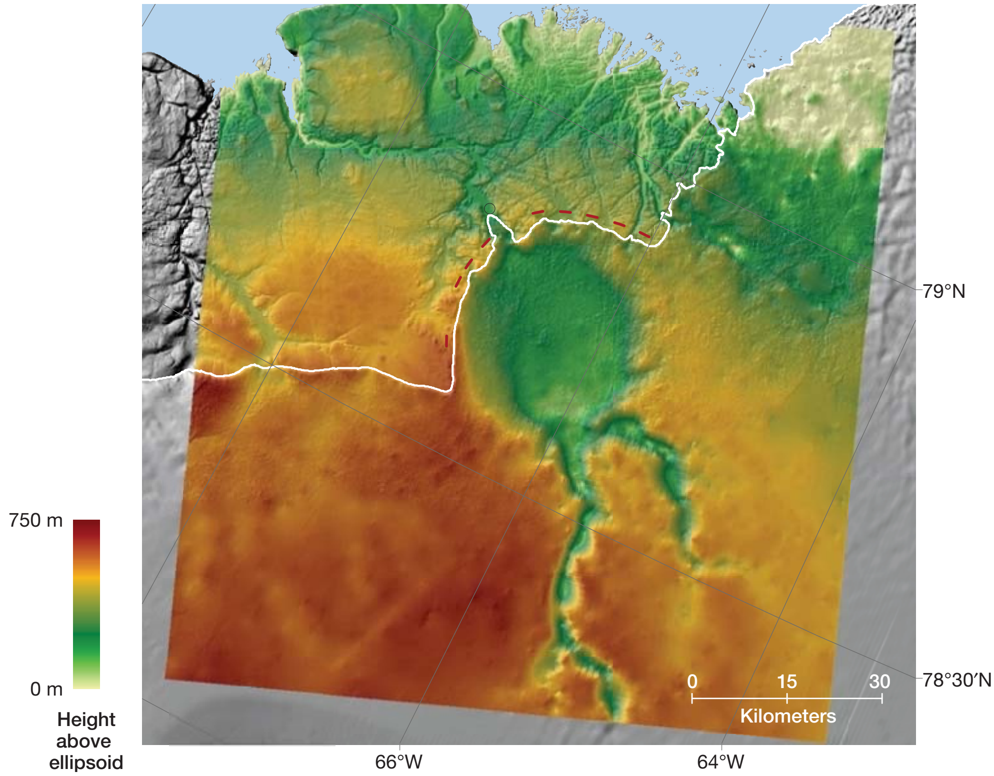
### Ghostly Galaxy Orbits Milky Way

A ghost of a galaxy has been lurking on the farside of the Milky Way, hiding this whole time behind the wall of stars that constitutes the disk of our galaxy. Dubbed Antlia 2, the ephemeral satellite sits about 420,000 light-years away and is almost as large as the Large Magellanic Cloud — our galaxy's biggest known companion — and yet about one four-thousandth as bright. Gabriel Torrealba (Academia Sinica, Taiwan) and colleagues discovered Antlia 2 while sifting through the most recent data from the European Gaia spacecraft, which is charting the positions and speeds of over a billion stars in and around our galaxy (see page 26). The newly discovered galactic satellite is an oddball. It's either too faint for its size or too large for its brightness — and it may hint at a whole population of tenuous dwarf galaxies around the Milky Way that have yet to reveal themselves. The researchers report their findings November 9th on the astronomy preprint site **arXiv.org**.

■ CHRISTOPHER CROCKETT

# Sudden Impact

*The discovery of a recent huge meteor crater beneath Greenland's ice sheet has reignited a debate over cosmic influences.*




**IN THE 1960s,** we took a giant leap forward in our understanding of the threat that meteors pose to our planet. In 1960, Eugene Shoemaker firmly established that a meteor — and not a volcanic eruption or other cause — created Arizona's Meteor Crater. A huge explosion by an iron meteorite slamming into Earth 50,000 years ago gouged out the 1.2-kilometer-wide pit. This confirmation, combined with detailed lunar photography that definitively showed that the Moon's craters arose from impacts, represented an important watershed in our comprehension of the profound connections between our planet and the rest of the solar system.

The father-and-son team of Luis and Walter Alvarez starkly illustrated these connections in 1980. That's the year they convincingly argued that an asteroid impact 65 million years ago triggered the mass extinction that wiped out the dinosaurs (and most other species). We realized then that occasional, monstrously violent celestial bombardments have repeatedly influenced biological evolution on Earth.

This ushered in what some called the "new catastrophism," whose exponents proposed impact events as the cause of many an unexplained and climactic change in our planet's history. The phrase is a nod to the old tension within geology between *catastrophism* and *uniformitarianism*. In the 19th century, it was a breakthrough when we realized that colossal transitions in Earth history did not require catastrophic happenings, just what we now call deep time. Slow changes acting over previously unimagined temporal expanses — millions of years or more — could raise mountain ranges and carve deep canyons.

Yet the evidence for impacts indicated that some important geologic changes are indeed sudden and catastrophic. The new catastrophists sometimes went a bit overboard, however, attempting to explain everything mysterious with large impacts. At worst, meteor strikes became a kind of *deus ex machina*, an explanation to invoke when evidence was lacking.

One example of this, arguably, was an attempt to assign blame to an impact for the Younger Dryas cooling episode around 12,000 years ago. This period roughly correlates with the extinction of many large mammal species and the possible disappearance of the Clovis people. Critics disputed the evidence, pointing out that no crater of the right age had turned up. The debates over this became quite heated and, regrettably, sometimes acrimonious.

The recent discovery in northwest Greenland of a large impact crater, 31 km across and possibly as young as 12,000 years, has predictably rekindled this controversy, with proponents of a Younger Dryas impact feeling vindicated and detractors digging in.

Certainly, it's a captivating possibility. If a crater that massive really is so young, then one would expect demonstrable effects on human and natural history at that time, perhaps matching the alterations that occurred then in North America. But the age of the impact is not precisely known. The 12,000-year number is a lower limit for the age; it could be much older.

The best and perhaps only way to determine when the impact took place will be to drill down through the area's nearly kilometer-thick ice, retrieve samples of melted rock from the crater itself, and determine their ages in a laboratory using radiometric isotopes.

It will be some time before this can happen. Until we know when this impact occurred, the smart attitude is to reserve judgment. Meantime, it will be fascinating to watch the debate play out — from a safe distance.

■ **DAVID GRINSPOON** is an astrobiologist who, for his PhD dissertation, modeled the effects of large impact events on the evolution of Earth-like planets.

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FAMOUS STARS, PART I by Camille M. Carlisle

# Secrets of Polaris

The North Star presents a façade of constancy, but it hides a capricious temperament.

It's arguably the most famous star in the sky — although more people have trouble finding it than would care to admit it. And truth be told, when it comes to the brightest stars, the 2nd-magnitude supergiant has nearly 50 stars ahead of it in line. But Polaris has been a guiding light for generations of seafarers and star-party goers alike, a haven of stability in a sky that whirls around it every night.

That stability is short-lived, however. Polaris has only reigned on its celestial throne for the last millennium, and in less than a century it will begin its abdication. Nor is the star itself stable: It wobbles in position as two companions waltz with it through space, and its light brightens and fades in a predictable pattern — except when it doesn't. In short, there is almost nothing constant about the North Star.

▲ **FINDING THE NORTH STAR** A stargazer demonstrates how to find Polaris: Follow the pointer stars at the end of the Big Dipper's bowl and extend the line between them about 5 times. The man's left hand points to Merak in Ursa Major, his right to Polaris.

MIGUEL CLARO

## The Pole Star

Polaris (Alpha Ursae Minoris) is a fat, bright, and aging yellow star. If you could put Polaris and the Sun side by side, Polaris would be 2,000 times brighter. It's roughly 45 times wider than our star, too, and if placed at the center of our solar system, its surface would reach more than halfway to the orbit of Mercury.

Alpha UMi sits less than a degree from the *north celestial pole*, the point on the sky that you'd hit if you extended

the line of Earth's rotation axis straight up from the North Pole. The width of your thumb held at arm's length is a good approximation for the separation between the star and the celestial pole. But this close kinship is a temporary one. The Sun and Moon tug gravitationally on the slight bulge around Earth's equator, and this combined effect makes our planet's rotation axis bob back and forth in a big circle, sweeping out an arc through the stars that takes 25,800 years to complete. The sweeping motion is called *precession*.

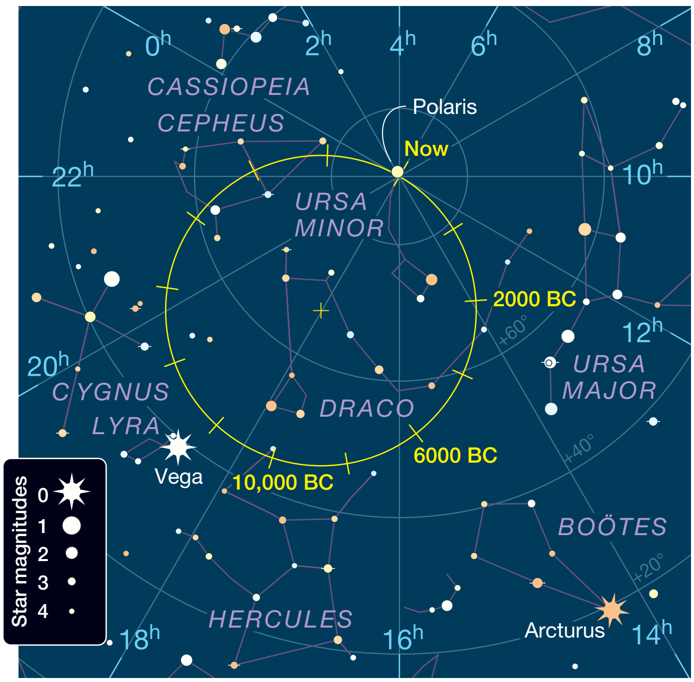
Back when Pharaoh Khufu was building the first Giza pyramid in 2550 BC, it was Thuban (Alpha Draconis), not Polaris, that shone closest to the north celestial pole. But Earth's axis was on the move away from Draco, and some 2,000 years later both Thuban and Polaris were each more

**If you could put Polaris and the Sun side by side, Polaris would be 2,000 times brighter.**

than 10° away from true north, Earth's axis skewering the sky nearly midway between them. During this era, the Phoenicians used the collection of stars that make up Ursa Minor as the northward marker.

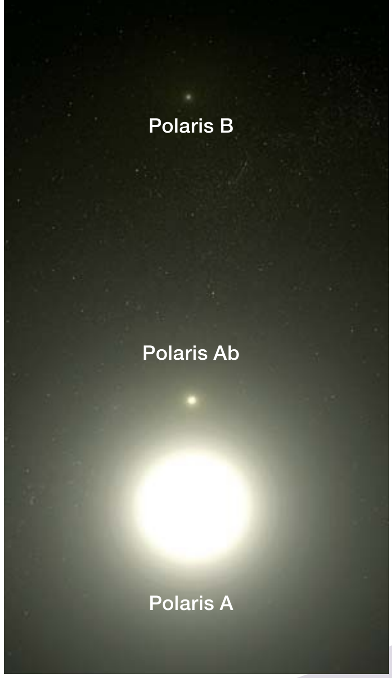
It's unclear exactly when navigators started using Polaris specifically. In his 1953 article "The Navigation of the Norsemen," nautical historian Geoffrey Marcus mentions a telling clue from an Anglo-Saxon poem dated circa AD 850, which stresses the importance of the *leiðarstjarna* or "guiding star." At that time, Polaris was about 7° from the north celestial pole, and at 2nd magnitude it was only rivaled by Kocab (Beta Ursae Minoris), which was a few degrees farther from true north.

The *leiðarstjarna* appears in several later Icelandic sagas, and in the early 1300s Dante equated the north celestial pole with a star in his unfinished *Il Convivio* ("The Banquet"); in *The Divine Comedy*, he also describes the sky as wheeling around the endpoint of the Little Dipper's stem. By the 15th century, Alpha UMi fell under the moniker *Stella Polaris* in European catalogs and globes. At that point, it was 3½° from




S&T ILLUSTRATION

▲ **ON THE MOVE** Due to the wobble of Earth's spin axis, the north celestial pole sweeps out a counterclockwise circle through the sky every 25,800 years. During the development of agriculture and animal domestication some 10,000 to 12,000 years ago, the pole was in Hercules. Right now, the pole points almost exactly at Alpha Ursae Minoris. To find the *north ecliptic pole* — essentially, the north pole of the solar system — look for NGC 6543, the Cat's Eye Nebula: Its coordinates are nearly identical to those of the ecliptic pole.




▶ **TRIPLE STAR** Artist's illustration of the three stars of the Polaris system. Just above Polaris is a smaller companion, Polaris Ab, which is 3 billion km (2 billion mi) from Polaris. Lying much farther away at some 390 billion km (240 billion mi) is the wide companion Polaris B.

the pole. It has continued closing the gap over the subsequent centuries, but its approach is nearly done: Polaris will reach its closest point to the pole around the year 2100, when it'll be less than half a degree away — closer than the breadth of the full Moon.

## A Merry Band of Fellows

The ponderous precession of Earth's axis isn't the only reason Polaris moves through the sky. Polaris is the brightest member of a triple-star system. The famed William Herschel first spotted the more distant of its companions, Polaris B, in 1780. The yellow, 8th-magnitude star lies 18 arcseconds from Polaris A, an easy split for small scopes. A and B take more than 40,000 years to circle each other on the celestial floor.

But Polaris proved more gregarious than astronomers thought. In 1929, astronomer Joseph Moore discovered a second, much closer companion using some three decades' worth of Lick Observatory data. This star, Polaris Ab, is also a yellow star and about half as bright as Polaris B. Yet because Polaris itself is more than 700 times brighter than Ab, the third star easily hid in its companion's glow. Moore only spotted Ab because it pairs with Polaris to create a *spectroscopic binary*, a stellar duo detectable by the wavelength shift in the primary star's light that's created as the two stars move around each other.

Polaris Ab follows a very elongated, 30-year orbit around Polaris. (In fact, it's making its closest pass this year.) Astronomers weren't able to see this third star directly until 2006, when Nancy Evans (Harvard-Smithsonian Center for Astrophysics) and colleagues nabbed it with the Hubble Space Telescope (*S&T:* Apr. 2006, p. 17). At the time, the researchers used the close companion's motion to pin Polaris's mass at the equivalent of 4½ Suns, give or take a Sun. They recently tried to refine the mass measurement, but with Ab so close to Polaris, even Hubble is hitting its limits. In order to improve the estimate, the team is now using Georgia State University's CHARA telescope array to watch Ab fly through its closest approach.

Astronomers think that all three stars in the system were likely born together about 70 million years ago — a blink compared to the 4.6 billion years the Sun has already lived (*S&T:* Oct. 2017, p. 22). Massive stars live fast and die young, and Polaris is already a puffy, aging star that has devoured the supply of hydrogen fuel in its core. Polaris B and Ab are lightweights in comparison, each maybe 1½ Suns or less. They're both still fusing their core hydrogen and will keep at it for another 5 billion years.

However, it's possible that Polaris A and B are *not* the same age. Based on two different distance calculations, Evans and collaborators recently estimated the stars' intrinsic brightnesses and combined those with the stars' surface temperatures to deduce how old each star is. Such work is possible thanks to the Rosetta stone of stellar astronomy, the *Hertzsprung-Russell diagram*. Astronomers use the H-R diagram to make sense of the breathtaking diversity of stars. The chart plots stars according to how hot and luminous they are. Where a given star falls on the H-R diagram depends on where it is in its life cycle, and a star will move across the plot — sometimes even back and forth multiple times — as it evolves. If you can peg a star's location on the H-R diagram, then you know its approximate mass, size, and age.

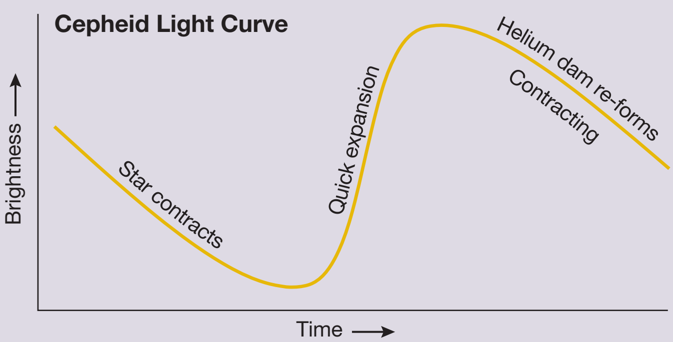
It turns out that B appears oddly bright for a 70-million-year-old sun. It could be that the star is actually a binary, but one tantalizing possibility is that it's actually more like 2 *billion* years old. If so, then Polaris itself might have reset its evolutionary clock by merging with a now-gone star. Which of the various scenarios is correct remains unclear.

## A Variable Star

At 70 million years old, Polaris falls in a special place in the life cycle of a star: the *instability strip*. This strip is a diagonal

### WHY "CEPHEID"?

**Cepheids take their name from Delta Cephei, the first of their kind to be discovered. English astronomer John Goodricke identified Delta Cep's periodic pulsations in 1794.**




▲ **CEPHEIDS** Due to an unstable helium layer deep within, Cepheids contract and expand in a regular pattern. As the star contracts, the helium layer compresses, until eventually the heat and pressure beneath it shove the layer outward in a rebound. Once the heat escapes through the now-tenuous layer, the star contracts again and the helium barrier forms anew.

TRIPLE STAR: NASA / ESA / G. BACON (STSCI); LIGHT CURVE: *S&T* ILLUSTRATION, SOURCE: EDWARD GUINAN slice of the H-R diagram (see page 18). Stars in the instability strip are variable, their light changing in predictable patterns. Almost all of them have moved out of the main sequence, the prime of life when stars fuse hydrogen in their cores, and have entered their golden years. This latter period splits into three sequential branches: *red giants* with inert helium cores surrounded by a shell of fusing hydrogen; *horizontal-branch giants*, when the helium core has reignited and is now transforming itself into carbon; and *asymptotic giant branch* (AGB) stars, those that have a carbon core surrounded by nested shells of fusing helium and hydrogen. The instability strip cuts a path through these stages.

Perhaps the most famous denizens of the instability strip are Cepheids. Cepheids are yellow and orange giants and supergiants, with masses of 3 to 18 Suns and girths 35 to 80 times larger than our star. They used to be big, bluish *B* stars, but such massive stars live short, frenetic lives, and at 50 to 200 million years they have already entered middle age.

Cepheids breathe in and out in a predictable pattern, controlled by a thin layer of ionized helium in their interiors. When this layer compresses, its temperature rises, and its helium atoms lose a second electron. The extra electrons prevent radiation from below from traveling freely through the layer. Heat that once passed through the helium is now trapped beneath it. The temperature and pressure below increase. As the pressure skyrockets, it shoves the layers above it outwards, and the helium expands and becomes more tenuous, permitting heat to pass through it again and lowering the interior pressure. But once the pressure below the layer drops, gravity takes over and the layer sinks and compresses again. This cycle repeats many times, causing the star to pulse.

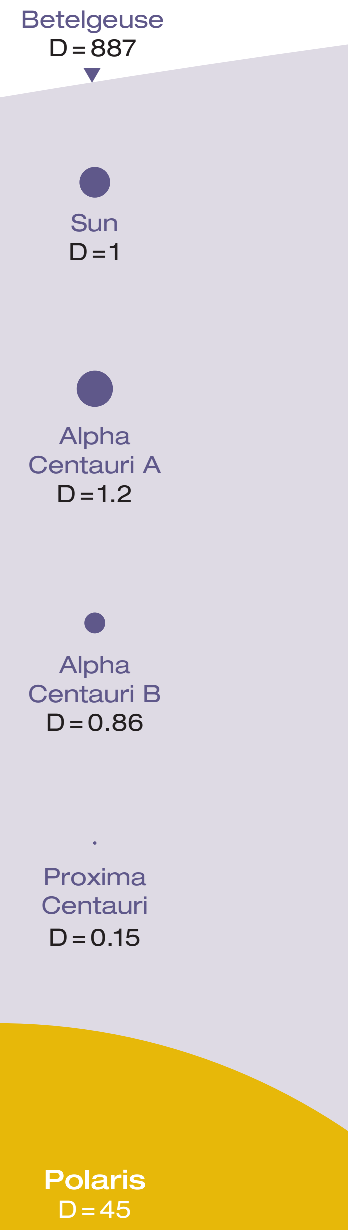
Polaris is the closest Cepheid, lying some 445 light-years away. For several years astronomers debated its precise distance — which is ironic, given that Cepheids derive most of their fame from their role as rungs on the cosmic distance ladder. In 1912 Henrietta Swan Leavitt discovered that the brighter a Cepheid is intrinsically, the longer it takes to cycle through a pulsation period. Because Leavitt was studying stars in the Small Magellanic Cloud dwarf galaxy, all the stars had roughly the same distance. Once astronomers calculated how far away one Cepheid variable lay, they could deduce the distance to any other Cepheid in the universe simply by measuring how quickly the star cycles through its pattern and how bright it appears. And because Cepheids radiate some 10,000 times more energy than the Sun does, they can be seen to very great distances indeed.

Depending on their mass, stars may cross the instability strip multiple times. A star of Polaris's mass will cross the Cepheid region thrice. But due to the previous disagreement about the North Star's distance, no one has been quite sure where Polaris is in its evolution. Part of the problem is, Polaris isn't your typical Cepheid. It has a more complicated jiggle than the simple breath-in-and-out pattern that most Cepheids follow, so astronomers don't use it in the distance ladder.

It also may be brightening 50 to 100 times faster than expected, explains Edward Guinan (Villanova University).

"It should not be doing this," Guinan says. Cepheids can brighten with time, but Polaris has shot up more than 10% in the last century. "Doesn't make any sense."

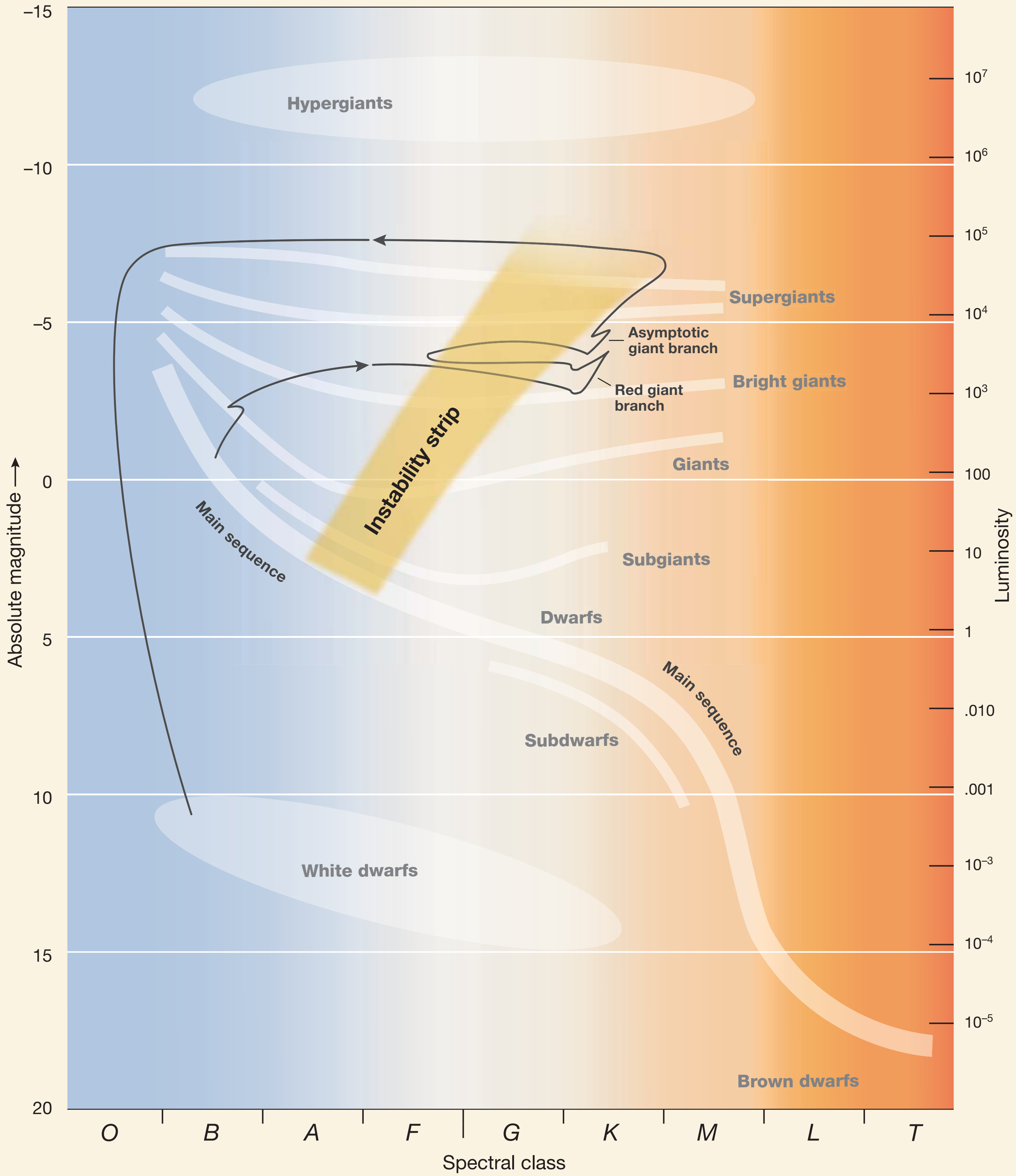
Guinan, Scott Engle (Villanova), and their colleagues discovered the change while gathering data for another Polaris project. They dug up measurements from previous centuries and traced the decline back to Johannes Hevelius in the 1600s. To be thorough, they decided to go even further back and check the data in two ancient star catalogs: Ptolemy's *Almagest* from around the year 150, and al-Ṣūfī's 964 *Kitāb al-Kawākib al-Thābitah* ("Book of the Fixed Stars"). Many assume al-Ṣūfī's book is a copy of Ptolemy's, but when Guinan looked at the




▶ **OUR STELLAR CAST** In our three-part series we'll discuss Polaris, the Alpha Centauri system, and Betelgeuse. These stars span a range of sizes, shown to scale. Listed diameters ("D") are approximate and given as multiples of the Sun's diameter. We've also included the Sun for visual reference.

TERRI DUBÉ / S&T

**Massive stars live fast and die young, and Polaris is already a puffy, aging star that has devoured the supply of hydrogen fuel in its core.**






▲ **LIFE OF A STAR** The Hertzsprung-Russell diagram plots stars according to their spectral class (related to color and temperature) and absolute magnitude (related to luminosity). Stars' locations depend on their mass and age, and they move across the H-R diagram as they evolve. Stars can experience one or more unstable periods, marked by the instability strip. The black line shows the approximate path a 5-solar-mass star will take across the diagram. When it enters the correct part of the strip, it becomes a Cepheid. (A star's behavior in the strip depends on its mass; the final crossing as the star dies won't create Cepheid pulsations.) The gray labels are luminosity classes (see *S&T:* Dec. 2018, p. 27) and their boundaries here are rough.

magnitudes listed for stars both in Ursa Minor and elsewhere in the sky, he discovered that al-Ṣūfī's values were a closer match for today's than Ptolemy's were.

Except, that is, for Polaris. Once Guinan and his colleagues had calibrated the ancient data to our current system, they discovered that both manuscripts record Polaris as some 2 to 4 times fainter than it is today.

"This is an entirely unexpected behavior for a Cepheid variable," the team wrote in 2014. They still don't have an answer.

## Nearly Gone, Then Back Again

A star remains in the Cepheid stage for thousands to hundreds of thousands of years, pulsating on time scales ranging from 1 to 70 days. But a star doesn't continue to pulse at the same rate throughout its sojourn in this part of the H-R diagram. As a star nears the end of its time in the instability strip, it becomes fluffier and larger, and its period lengthens. Polaris right now brightens and fades every four days, but that rate is lengthening by 4½ seconds each year, a much more rapid change than expected and one without clear explanation.

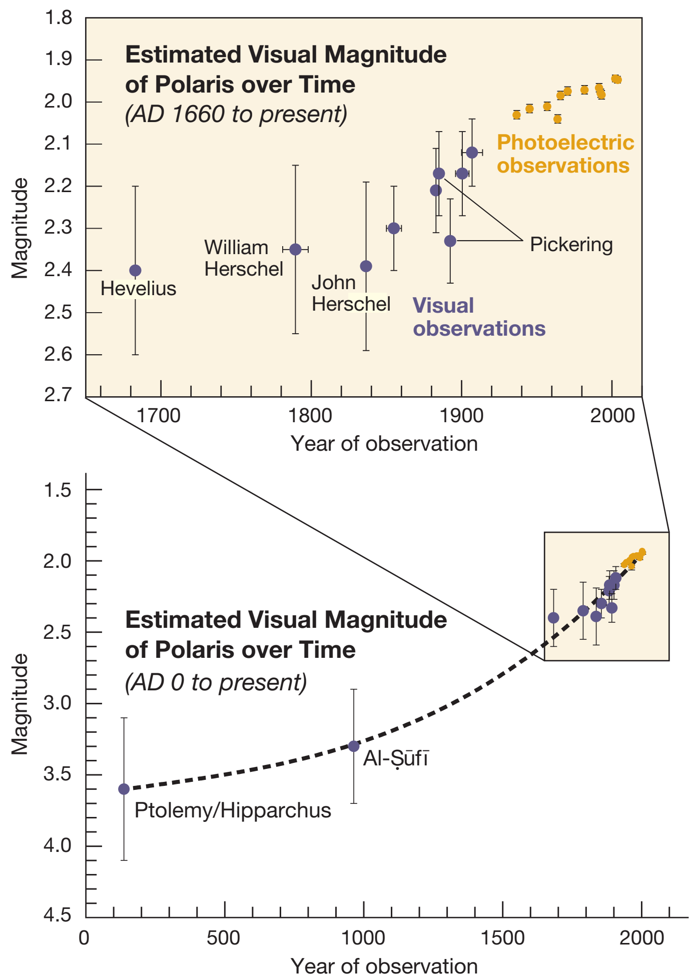
From when astronomers first identified Polaris as a Cepheid about 100 years ago to the 1990s, the difference between the star's brightest and faintest glow, or its *light amplitude*, decreased from 5% to 1%. (So no, it's not a change you can see with the naked eye.) Due to a calculation error, one team even predicted in 1993 that the pulsations were about to die out and that Polaris was going to become stable. Observers have seen one other Cepheid do that: V19, one of the stars Edwin Hubble used in the 1920s to calculate the distance to the galaxy M33.

But Polaris didn't stop pulsing. The plummet stalled. In 2008, three independent groups confirmed that the amplitude was *increasing* again and had been doing so since 1995, leading one team (in an obvious quip of the earlier prediction) to title their paper "Welcome Back, Polaris the Cepheid." The rebound now appears to be complete: Based on eight years' worth of methodical observations by Rick Wasatonic (Villanova) using an 8-inch and an 11-inch Schmidt-Cassegrain in his backyard observatory, Polaris's light amplitude is now back up to 5%, Guinan says.

## And Then There Were X-rays

Polaris has not finished giving up its secrets. Engle, Guinan, Evans, and their colleagues recently discovered that — much to astronomers' surprise — the star emits X-rays. They have since found a few other Cepheids doing the same thing. Even the original member of this stellar group, Delta Cephei, not only shines in X-rays but in a pattern that varies periodically. Most Cepheids are too far away for the current generation of space-based X-ray telescopes to pick them up, so the team doesn't know if this behavior is the norm or the exception, Engle says.

Other, non-pulsing supergiants have also proven to be X-ray emitters, bewildering observers. Astronomers didn't



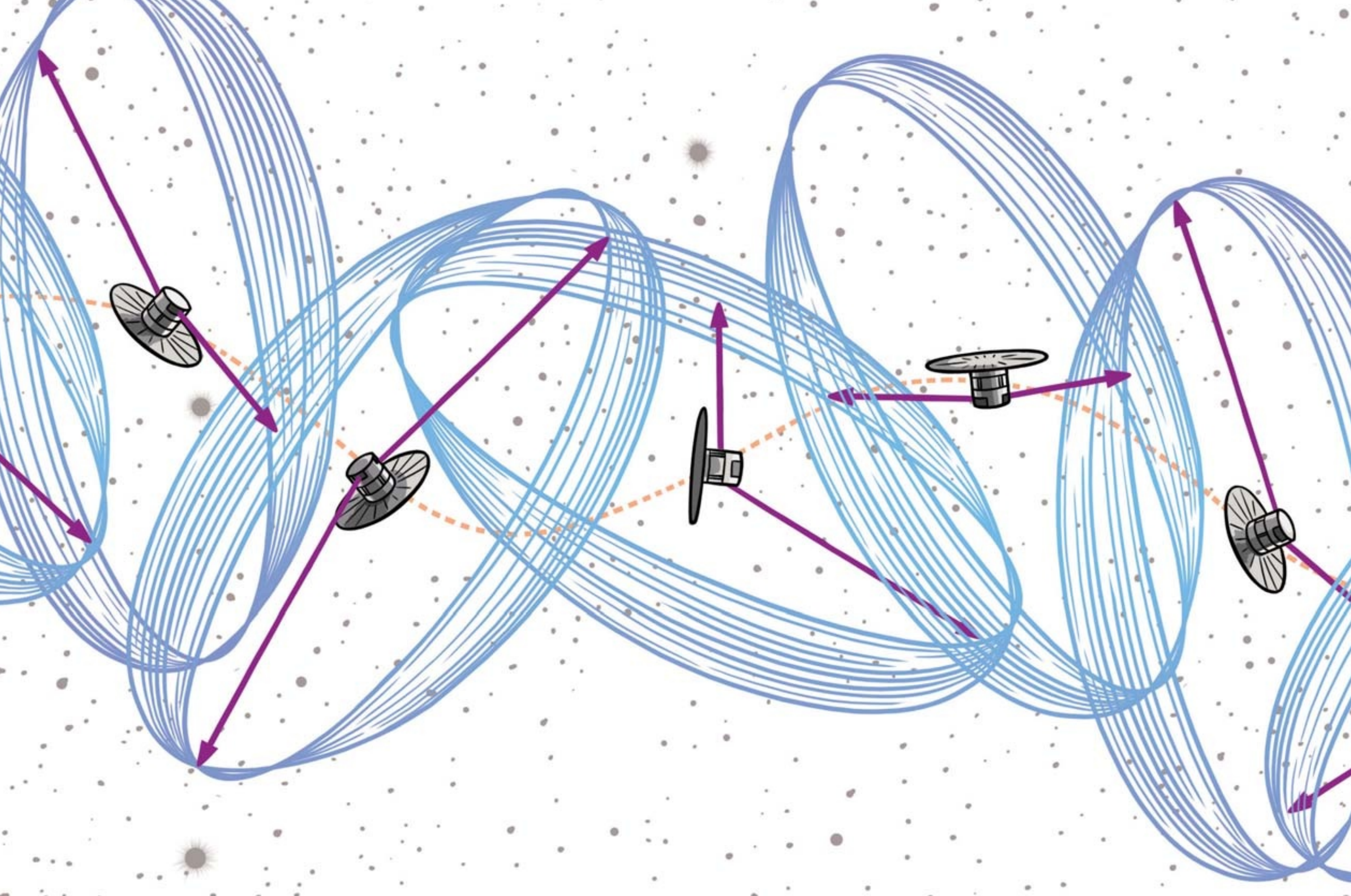

▲ **ON THE RISE** Comparison of observations taken over the last 1,800 years or so indicates that Polaris has unexpectedly brightened by a factor of two to four.

expect these stars to emit such fierce radiation, because the stars shouldn't have the necessary superheated plasma near their surfaces. This plasma is likely heated by tangled magnetic field lines, which release energy as they rearrange themselves. But giants and supergiants shouldn't be able to support the necessary strong magnetic fields — at least not ones that can poke out of the stars' bloated surfaces where we can see the X-ray-emitting plasma they produce, Engle explains. "There's something crazy going on," he says.

So our familiar beacon of stability in the sky has proved itself fickle. Polaris is not constant, but it is fascinating. Its quirks may tell us much about what the oddball members of the Cepheid class can do, and perhaps it will help us understand aging stars in general. In that way, it might reorient stellar astronomers just as effectively as it has the last millennium's travelers.

■ Science Editor **CAMILLE M. CARLISLE** admits that sometimes she second-guesses herself when looking for Polaris in the night sky.

S&T ILLUSTRATION, SOURCE: EDWARD GUINAN



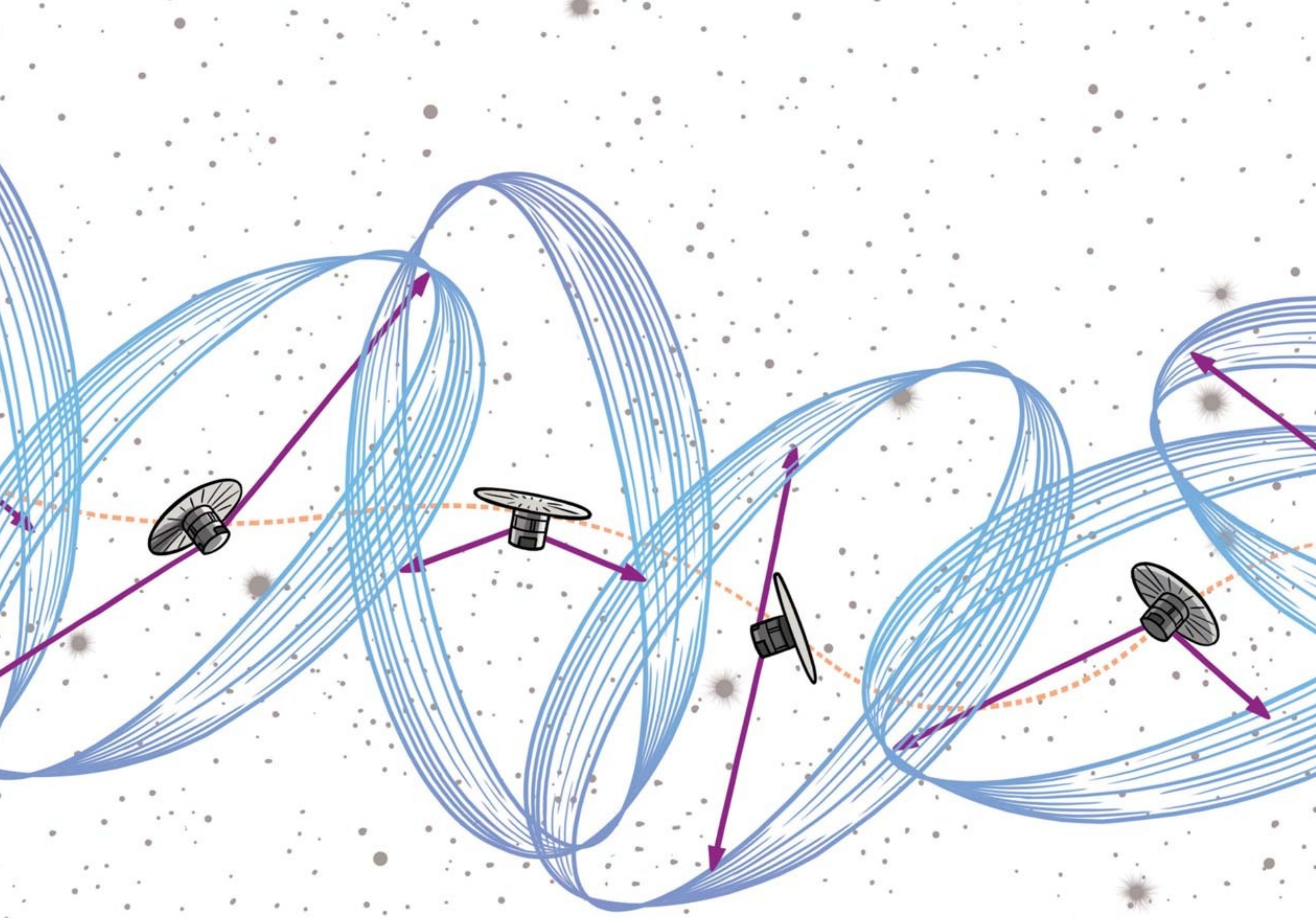
# *Spinning* Thr

**To capture our dynamic universe in all its glory, sometimes our telescopes need to show a little dynamism themselves.**

When asked to think of a space telescope, most people will immediately picture Hubble staring motionless into the distance. What they likely won't picture is a spacecraft twirling and writhing around the sky like a *Star Wars* TIE fighter after a fatal shot from the Rebel Alliance. Hubble and many other space telescopes — and amateur astronomers, for that matter — collect images of the cosmos by remaining as still as possible for as long as possible to collect as much light as possible. But a surprising number of space probes opt for the disabled TIE fighter strategy — albeit in a far more controlled way.

Several of the earliest satellites spun to stabilize their orientations. Among them were NASA's Orbiting Solar Observatories series of satellites (OSO-1 to OSO-8) in the 1960s and 1970s. The exact design varied among models, but each

LEAH TISCIONE / *S&T*



# ough Space

had a "sail" section that always pointed toward the Sun and a "wheel" part that swiveled full circle every 2–10 seconds, like an Oreo twirling on a flag skewer. Both sections carried instruments, but the larger, more complex ones were housed in the stationary sail part of the telescope — after all, the main goal was to stare at a fixed target, the Sun.

## AGILE's Happy Accident

But spinning can provide much more than stability, as the experience of the Italian AGILE satellite team so vividly shows. Launched in 2007, Astrorivelatore Gamma a Immagini Leggero (AGILE) is a wide-field gamma-ray instrument that explores cosmic high-energy physics. The initial aim was for the telescope to point in one direction for a couple of weeks and then move on to another area until it covered a large swath of sky. This worked well until the end of 2009, when the team hit a snag: The telescope's inertia wheel keeping the platform stable malfunctioned.

Automatically AGILE switched into a safe mode: The spacecraft swiveled so that its solar panels constantly faced

◀ **THE CRAB** This composite of the Crab Nebula combines data from across the electromagnetic spectrum: radio waves (red), infrared (yellow), optical (green), ultraviolet (blue), and X-ray (purple). Fortuitous AGILE observations helped reveal that, much to astronomers' amazement, the Crab produces gamma-ray flares. Why remains unclear.

the Sun, while the rest of the craft started spinning very slowly (one revolution every 7 minutes) at right angles to the direction of the Sun.

"It created a lot of debate," recalls AGILE Principal Investigator Marco Tavani (National Institute for Astrophysics, Rome). "Some engineers said, 'It's finished, it's the end of AGILE,' but others said, 'No, it's the exact opposite'."

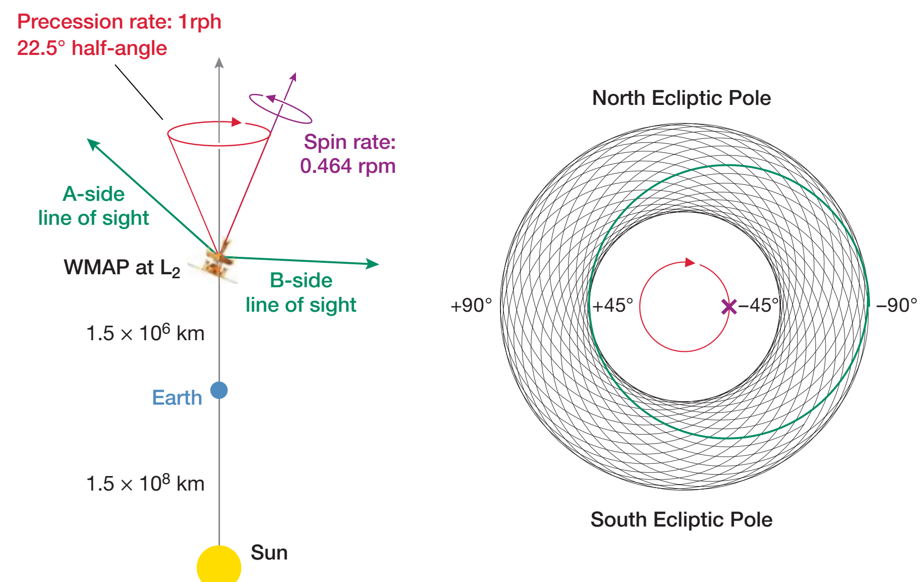
Although the telescope couldn't look as deeply as it could before, every 7 minutes it covered 80% of the sky. This took the blinders off the satellite and led to the team's greatest discovery. "We had looked at the Crab Nebula many times during the first two years for calibration purposes, because it is, or was supposed to be, a stable 'boring' source," explains Tavani. But forced to look again in 2010 due to being in a spin, the team noticed the Crab Nebula was far from a stable source: It was emitting gamma-ray flares. "The result was almost heretical, creating tremendous excitement in the community," he says. "We would have never discovered it if it were not for this spinning mode."

## To See and Survey

More commonly, spinning is less a happy accident and more an integral part of how the space telescope observes the sky. Just when NASA's Parker Solar Probe was setting off on its journey to "touch the Sun," scientists finally lost contact with another distinguished solar observatory called the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI). However, during its 16 years of operation RHESSI made a number of discoveries about solar flares and other aspects of solar physics and astrophysics. And none of it would have been possible without spinning.

RHESSI's aim was to make movies of solar flares in X-rays and gamma rays in order to understand solar-flare physics. But imaging X-rays — particularly high-energy or "hard" X-rays — is difficult. This is because they don't easily reflect off mirrors due to their sub-atom-scale wavelengths, which endow them with the ability to penetrate deeply into matter.

To get around this, a pair of grids known as a collimator was placed in front of each of nine detectors. On their own, these detectors couldn't create an image; they solely picked up the energy and arrival time of each detected photon. But by allowing the spacecraft to spin, the area of the detector visible through both grids from the Sun's perspective changed with time. When the solar source of the X-rays was slightly off-center, the X-ray photons were modulated, which the detectors registered as a variation in photon intensity with time. This difference encoded the location and size of the X-ray sources. Computers on the ground then decrypted this information to construct a series of snapshots of the Sun's flares.




▶ **WMAP'S STRATEGY** Orbiting at $L_2$, WMAP gyrated in three ways *(left)*. The spacecraft spun around its axis about every half minute, and this axis wobbled around in a circle every hour, tracing its two lines of sight through a complex crisscrossed pattern *(center)*. The craft continued this bobbing motion as it revolved around the Sun, enabling it to scan the whole sky *(right)*.

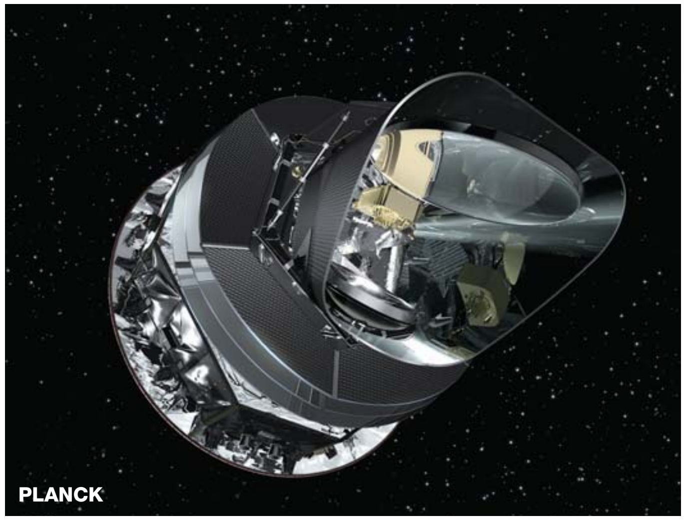
WMAP: NASA / WMAP SCIENCE TEAM; CRAB NEBULA: X-RAY: NASA / CXC / SAO, OPTICAL: NASA / STSCI, INFRARED: NASA / JPL / CALTECH, RADIO: NSF / NRAO / VLA, ULTRAVIOLET: ESA / XMM-NEWTON

Many all-sky surveys also spin to map the known universe. For example, the two most recent cosmic microwave background (CMB) space observatories, NASA's Wilkinson Microwave Anisotropy Probe (WMAP, 2001–10) and the European Space Agency's (ESA's) Planck (2009–13), each deployed very different scanning strategies to interrogate the faint heat left over from the Big Bang. Their insights have since been used to determine the proportions of the universe's fundamental constituents and establish the standard model of cosmology prevalent today.

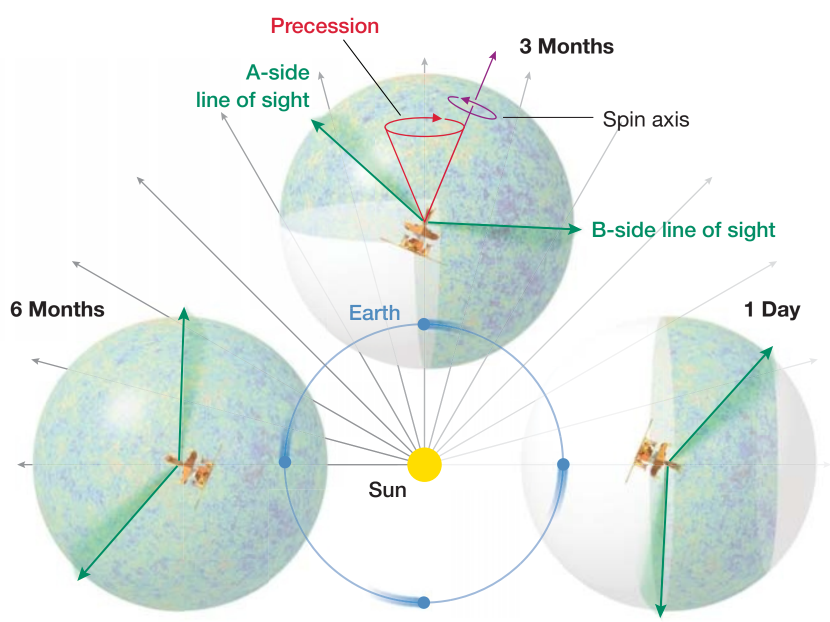
WMAP, orbiting about 1.5 million km from Earth's nightside at what is known as the $L_2$ point (see page 24), had two telescopes, one to either side of its spin axis. Each leaned about 70° away from the axis, which always pointed away from the Sun. Not only did the spacecraft rapidly spin on its axis once every 2.2 minutes, but it also slowly *precessed*, or wobbled on that spin axis like a spinning top, every hour. The scanning patterns WMAP's dance produced crisscrossed one another like the lines in a Spirograph drawing. It then moved this Spirograph donut around the sky as it orbited the Sun. To picture all of this movement together is difficult, but not impossible. One way is to imagine a bobblehead doll (precession) placed in a spinning hamster's wheel (spacecraft spin) set on a merry-go-round (orbit).

Why go to the trouble of gyrating your telescope in such a complex way when you could cover the whole sky by pointing and staring at different regions, and then piece them together? Former Planck Survey and Archive Scientist Xavier Dupac (ESA) has an answer: "One of the problems with these missions is that there is noise from what we call systematic effects." This could be any non-random error, like a temperature fluctuation in the spacecraft's electronics, or perhaps an error in calibrating the instrument. "You can't really average them out with statistics," he says. Precessing is the only way to reduce this type of unwanted noise.

**RHESSI**



**PLANCK**




RHESSI: NASA / RHESSI TEAM / SPECTRUM ASTRO, INC.; PLANCK: ESA / AOES MEDIALAB

Given this advantage, it might be surprising that WMAP's successor, Planck, followed a simpler path. Rotating once per minute with its instruments slightly off-axis and its base always pointed at the Sun, the spacecraft traced large rings on the sky that moved with the orbit about 1° per day to slowly build a picture of the sky. The benefit to Planck was that with minimal change in its angle to the Sun it could keep its instruments in cool shadow, helping to maintain a steady temperature — important when measuring tiny variations in the CMB.

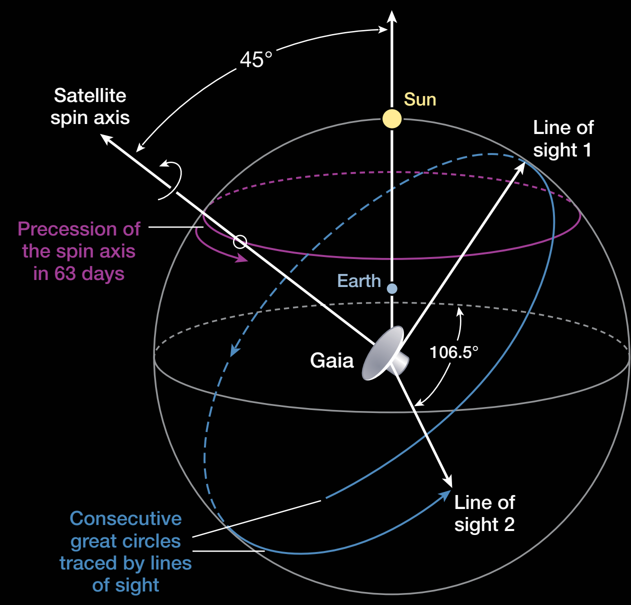
Without precession though, the team behind Planck knew it would have to tackle systematic effects and would also leave a large chunk of sky unobserved above and below the Sun as viewed from Planck's orbit. Hence, the ground team used the telescope's thrusters to tilt the craft's spin axis a little each hour to create a circular bobbing motion that moved the axis by up to 7.5° above and below the ecliptic over the course of six months. Going back to WMAP's merry-go-round analogy, everything was the same with Planck but for the bobblehead doll, which traced much smaller circles with its oversized head in jerky, discrete movements.

## When, Not Where

More recently, ESA's Gaia mission has taken spinning to a new level, capturing the entire sky, like the CMB scopes, and providing data that would be impossible to catch any other way, like RHESSI. Gaia is another sky mapper

## Gaia has no sky map to guide it . . .

**▶ GAIA'S PATH** The Gaia spacecraft whirls around on its axis 1° per minute, scanning the sky simultaneously along two lines of sight that trace great circles on the celestial sphere. The rotation axis also moves, maintaining a 45° angle from the Sun as it slowly precesses around the Sun-to-Earth direction. As the craft orbits the Sun, it observes long overlapping strips of sky, building an all-sky map *(far right)*.




like WMAP and Planck. But its mission is to build a detailed 3D map of our galaxy, plotting the positions and distances of stars in the sky.

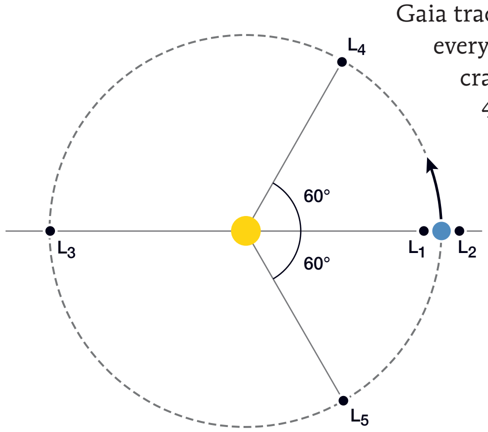
Before the 1990s astronomers could only estimate star positions and distances with ground-based telescopes. Yet this meant they had to deal with the confounding effects of the atmosphere, placing a limit on how accurate they could be. Gaia's predecessor Hipparcos, launched in 1989, solved this issue, managing to plot positions and distances to some 120,000 stars 100 times more accurately than ever before. Gaia's start in 2014 marked another jump: The second data release from the first 22 months of Gaia operation now gives astronomers a distance, or more precisely *absolute parallax* in astronomers' parlance, that is 100 times more accurate than Hipparcos to some 1.3 billion objects.

To collect this huge pot of data, Gaia has been performing a WMAP-esque dance around the Sun but much more slowly. Positioned at the now familiar $L_2$ point, Gaia traces large rings on the sky every 6 hours, with the spacecraft wobbling full circle at 45° from the direction away from the Sun every 63 days. These three types of rotation allow the spacecraft to scan every object it sees about 70 times over the course of five years.

Like a toddler trying to make sense of the world, the telescope makes no assumptions about the space around it. It has no sky map to guide it. All Gaia records is where a star shines in its field of view at a given point in time. In essence, Gaia doesn't measure where things are but just when they are seen during its careful dance.

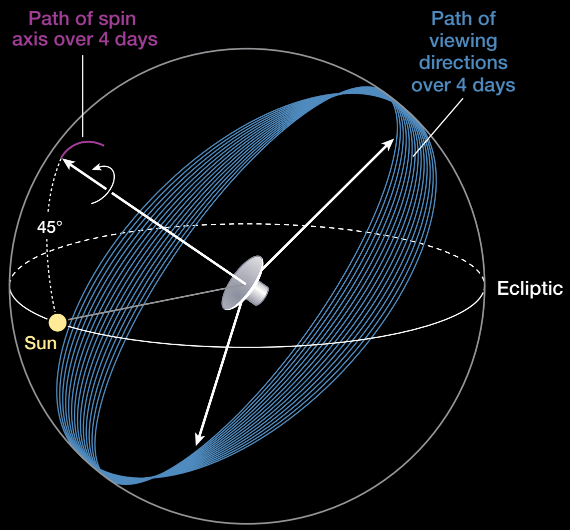
Gaia then fires these measurements down to Earth, where they are added to a vast calculation called the Astrometric Global Iterative Solution (AGIS), involving billions of parameters. AGIS gradually fits the data together like a jigsaw puzzle. "Gaia and Hipparcos are very, very elegant mathematical missions," explains Michael Perryman (University College Dublin, Ireland), a scientist who alongside Lennart Lindegren (Lund University, Sweden) proposed the Gaia mission. "They spin, but a lot of their beauty is in the mathematical methods that are actually used to reconstruct the data-analysis problem."

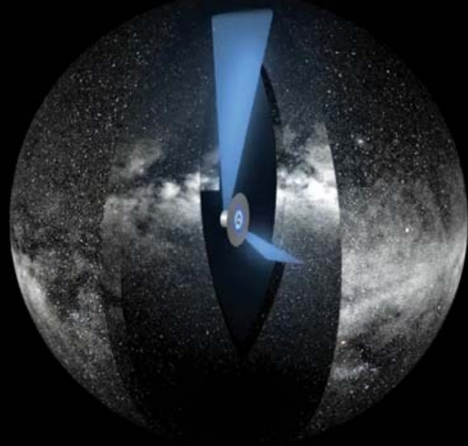
With repeated observations of the same objects at different times and from different perspectives, AGIS gradually makes deeper insights on the ground using what Gaia sees from space. Crucially, this includes the distance to every object — something astronomers using ground-based and non-spinning scopes could only ever dream of.




**◀ LAGRANGIAN POINTS** In a system of two massive bodies orbiting each other (such as the Sun and Earth), five gravitational "balance points" exist where a third, much smaller object can orbit in a constant pattern. $L_4$ and $L_5$ are stable if one of the two bodies is at least 24.96 times more massive than the other. On the other hand, $L_1$, $L_2$, and $L_3$ are unstable on a time scale of about 23 days, so spacecraft at these locations need regular course and attitude corrections (for this reason, they often circle the Lagrangian point). $L_1$ is ideal for solar observations, whereas a craft at $L_2$ can always keep Sun, Earth, and Moon behind itself and have a clear view of deep space.

GAIA IMAGES: C. CARREAU / ESA (2); GAIA PATH: *S&T* ILLUSTRATION, SOURCE: ESA; LAGRANGIAN: LEAH TISCIONE / *S&T*

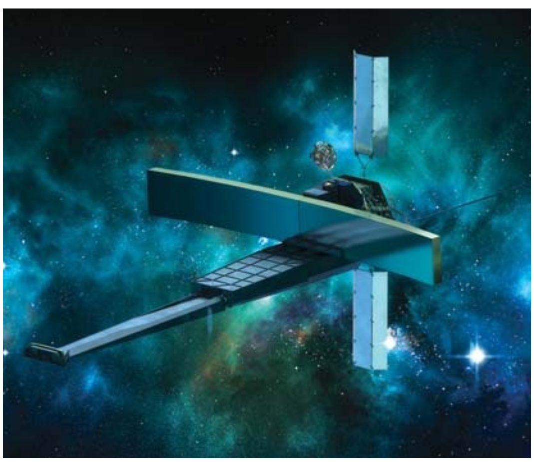


. . . All the telescope records is where a star shines in its field of view at a given point in time.

But how does AGIS figure out the distance to stars? Like any telescope, Gaia — through AGIS — can track parallax: the tiny apparent looping motion made by a star once a year that's caused by the spacecraft's moving viewpoint around the Sun (see page 26). However, the looping motions of stars in the same part of the sky will be synchronized, making it impossible to decipher their true distance — only their parallax relative to one another can be calculated. Gaia gets around this problem by having two fields of view separated by a wide angle. "If stars are widely separated on the sky, their looping motions will be out of sync, causing a variation in their angular separation over the year," explains Lindegren. "That variation contains the additional information needed to determine the size of the loops and hence the absolute parallaxes."

By spinning in such a way that both fields pass over the same stars within a short time, and by registering the stars' positions multiple times to disentangle a star's real and apparent motion, AGIS has all the data it needs to churn out the locations, drift across the sky, and distance of all stars at the same time, transforming the night sky jigsaw puzzle into a living 3D projection of the known universe.



▶ **MIRROR SPINNING** Artist's concept of Raytheon's rotating space telescope. Depending on mission requirements, the entire mirror and platform could rotate together (as shown here), or the mirror could spin on its own.

RAYTHEON COMPANY

## Skinny, Light, and Cheap

Turning to the future — please excuse the pun — spinning could hold the key to far more powerful space telescopes. Technology company Raytheon has been in discussions with NASA researchers on developing its Rotating Synthetic Aperture (RSA) concept. "As a professor of physics said of this technology, 'If Hubble sees toddler galaxies and the James Webb Space Telescope will see baby galaxies, RSA will see embryos,'" explains Raytheon Space Systems Vice President Wallis Laughrey. "But the best fit for the technology by far and away is direct imaging of exoplanets."

Curved like a canoe, the primary aperture of the telescope would spin like a wind turbine while taking a series of images. These pictures would then be combined using complex algorithms to produce a crisp final scene.

Although it would have reduced light-gathering power, a skinny, 20-meter-long RSA could provide the resolution of a full 20-m telescope at the cost and mass of an 8-m scope. This is crucial, because the 6.5-m aperture of JWST is near the limit of what can fit into current rocket nose cones.

With NASA's recent cost cap of between $3 billion and $5 billion on future space telescopes, ideas like RSA will be essential for pushing the boundaries of space-based astronomy and delivering new insights into our dynamic universe.

■ **BENJAMIN SKUSE** is a science writer based in Somerset, UK.

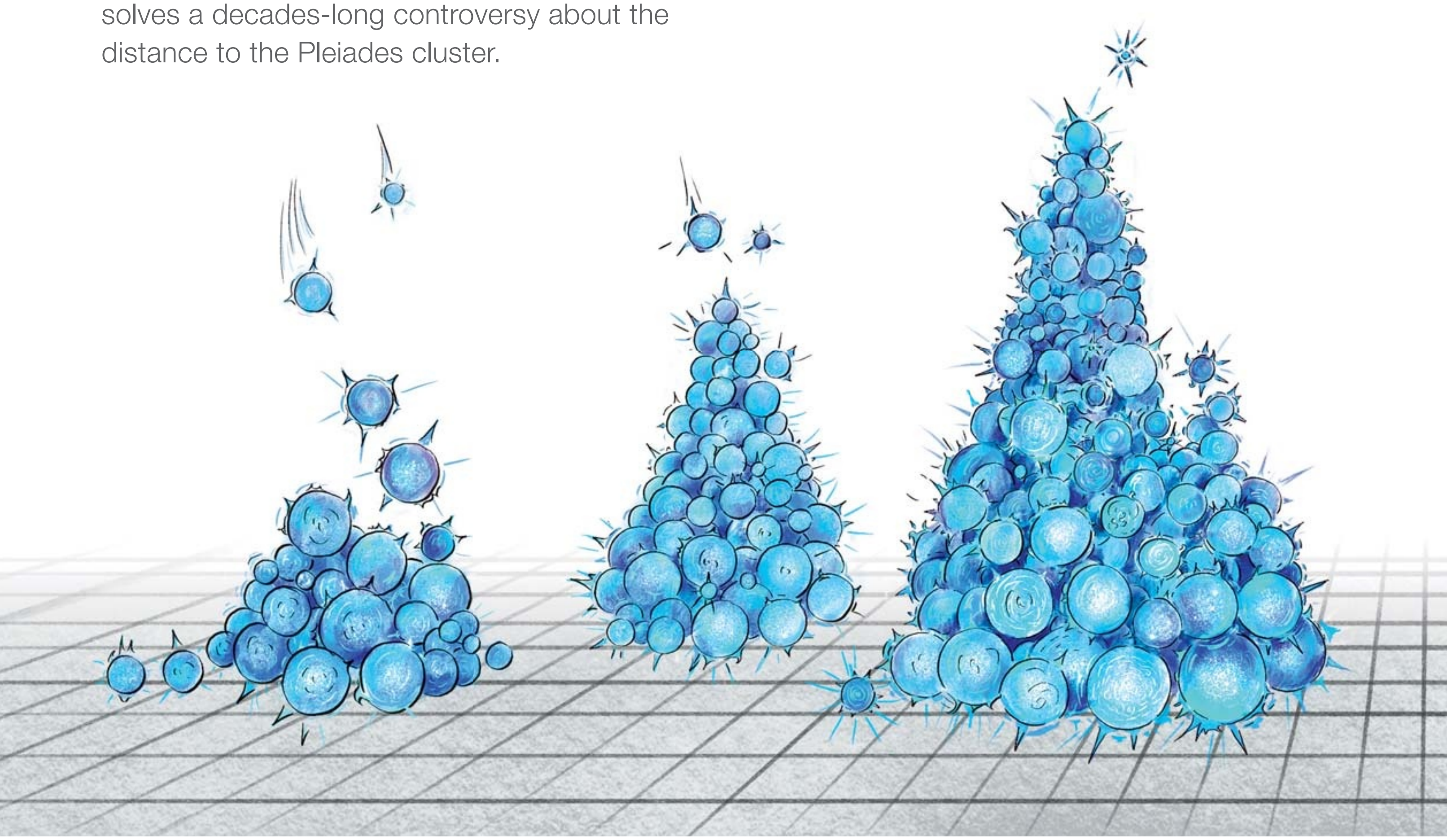
How far away are the stars? You might think that astronomers should know, but distances to the stars are something very difficult to figure out. In daily life, we estimate nearby distances using a trigonometric trick built into our bodies: Our eyes see the world from two slightly different perspectives, and our brain processes this difference to build a three-dimensional image of our environment. This shift in an object's apparent position, called *parallax*, enables us to complete a myriad of tasks, from threading a needle to catching a ball in mid-air.

Since classical antiquity astronomers have labored to use the same method on the stars, by observing the apparent shift of the position of a star while the Earth moves along its orbit. But the stars are so far away that it was only in the 19th century that astronomers finally succeeded in measuring a handful of stellar parallaxes. Measurements on a grand scale had to wait for modern technology.

Near the end of the 20th century, the European Space Agency (ESA) designed a space telescope to measure stellar parallaxes. The High Precision Parallax Collecting Satellite (Hipparcos, named in honor of the Greek astronomer Hipparchus of Nicaea from the 2nd century BC), observed a predefined set of stars over four years. The result was the Hipparcos Catalogue, published in 1997 and containing precise

# PLACING the Pleiades

The second data release from the Gaia mission solves a decades-long controversy about the distance to the Pleiades cluster.

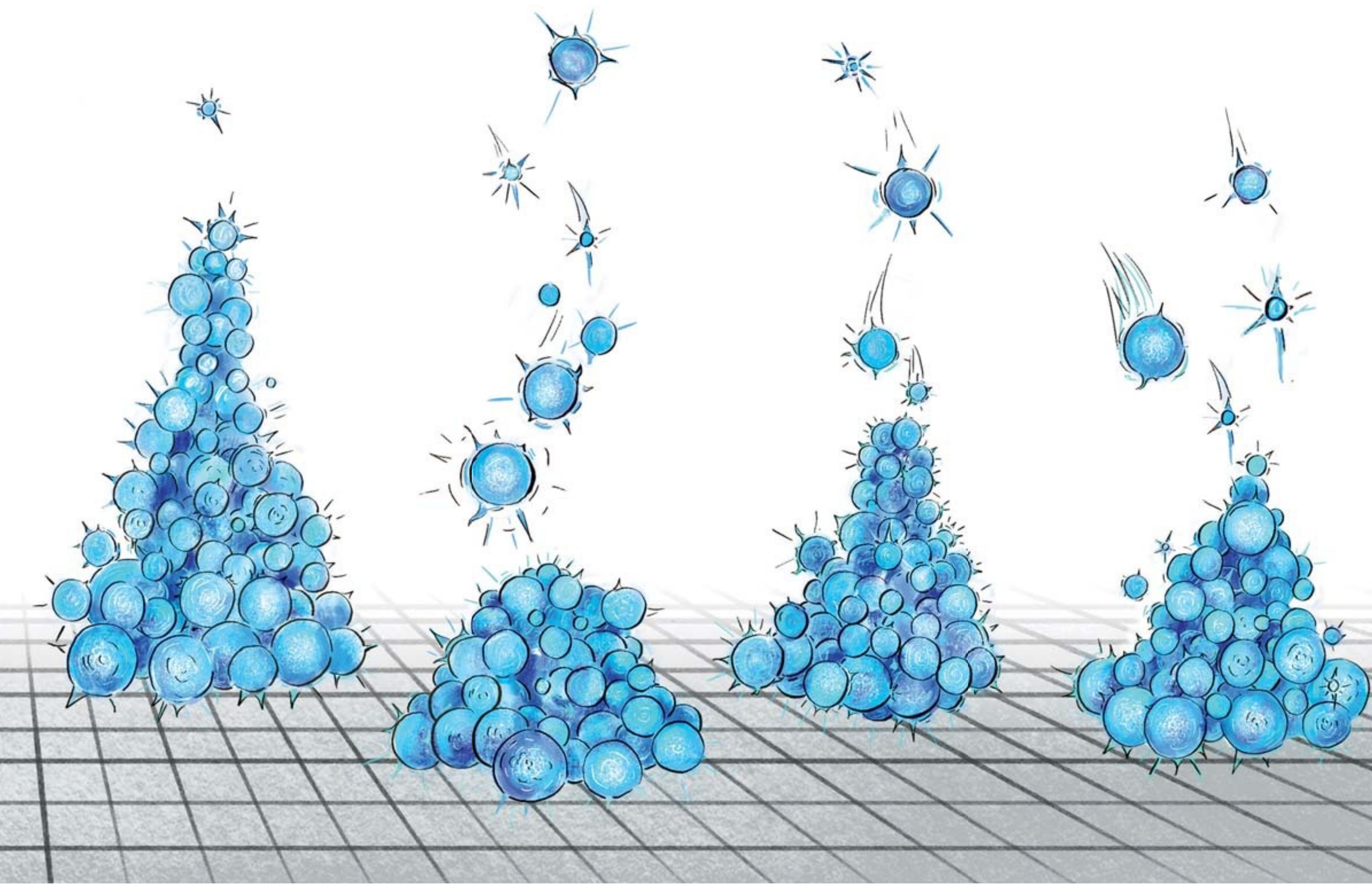


▲ **THE PLEIADES** Perhaps the most famous star cluster in the sky, the bright stars of the Pleiades — often called the Seven Sisters — can be seen without binoculars even from a city. The cluster lies roughly 450 light-years away toward the constellation Taurus.

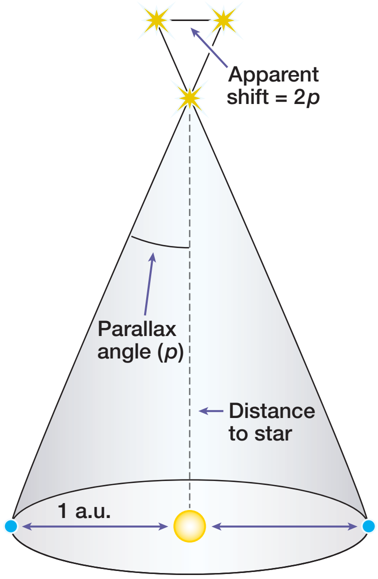
parallaxes for a little more than 100,000 stars, all within 300 light-years of Earth. The precision achieved was about 1 milliarcsecond (1 mas), which is 1⁄1,000 of an arcsecond or 1⁄3,600,000 of 1°. That is like seeing an astronaut standing on the Moon from Earth.

Along with its expected successes, the Hipparcos mission delivered several surprises. The most notable was the distance to a famous stellar cluster, the Pleiades (Messier 45, in Taurus). This group of bluish stars is easily visible by eye in dark autumn skies — although there are many more members than your naked eye can discern. Hipparcos found a distance of roughly 380 light-years, rather less than the 440 light-years of previous calculations, which were based on the stars' brightnesses and considerations of stellar physics (see *S&T:* June 1999, p. 40).

This was an embarrassing problem. On the one hand, if astronomers had been using the wrong distance for the Pleiades, then it could have implications on a much larger scale: The Pleiades are a nearby open cluster and for this reason are frequently used to test our models of stellar evolution and to calculate the distances to farther stars. On the other hand, if Hipparcos were wrong, then the dubious result might challenge the entire Hipparcos catalog. Was there some



NICOLLE R. FULLER / SAYO-ART LLC; PLEIADES PHOTO: DAVIDE DE MARTIN & THE ESA / ESO / NASA PHOTOSHOP FITS LIBERATOR




▶ **WHAT IS PARALLAX?** Parallax is the shift in an object's position against the background scene when viewed from two different locations. Nearby stars have measurable parallaxes due to Earth's motion around the Sun, which astronomers can use to calculate the stars' distances. However, calculating the true distance using the parallax requires eliminating all sources of error in the angle measurement.

instrumental or systematic error astronomers had overlooked? Was there a problem with just the Pleiades, or also with other measurements? Or were the Pleiades really closer and thus didn't fit into our models of stellar formation and evolution?

Astronomers now have an answer.

## The Importance of Being Clumped

Open clusters play a crucial role in astronomy. Because a cluster's stars formed together from the same interstellar cloud, we know that they are the same age. As such, they are excellent laboratories to test physical models of stellar evolution. What's more, by knowing their distance and using it to derive their intrinsic brightness, astronomers can then use these models to calculate the distances to farther stars, those that are removed from the reach of direct geometrical methods like parallax.

In this regard, the Pleiades play a keystone role in the calibration of the cosmic distances ladder, which proceeds step by step, from the Sun to the nearest stars, then to farther stars, and so on and so forth, changing methods along the way until we reach the confines of the observable universe. Much of modern astronomical knowledge, from stellar physics to the structure and evolution of the universe, depends on a good calibration of this distance ladder — and thus on knowing the distances to nearby stars to a T. Controversy over the Pleiades' distance was therefore disconcerting.

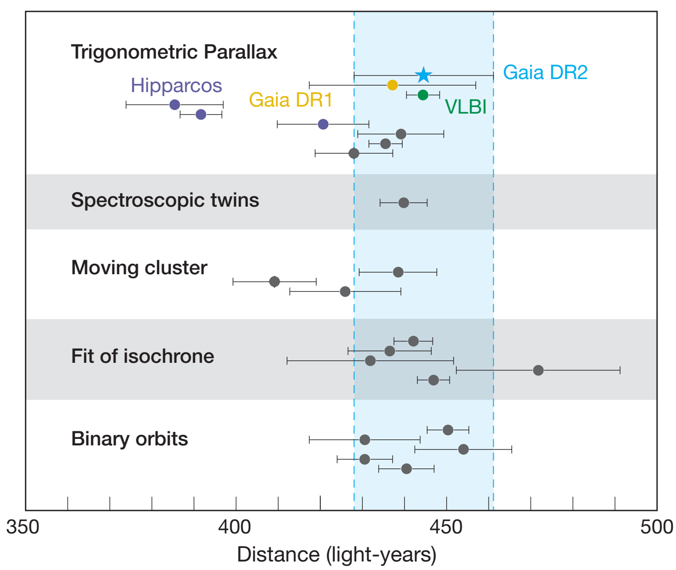
Suspicion quickly fell on Hipparcos, as additional measurements made with other instruments and methods contradicted its result. In 2004, observations of three Pleiads done by the Hubble Space Telescope gave a distance of 435 light-years. In 2014, an extremely precise measurement made by combining data from radio telescopes all over the world gave a result of 444 light-years. Measurement after measurement agreed with the greater distance, making the one from Hipparcos look anomalously small, even though successive reassessments of the spacecraft's data only narrowed in on the smaller value.

It took many years to solve the mystery. The issue is apparently a matter of instrument calibration, due to Hipparcos's intricate observing method. Instead of looking at a fixed spot in the sky, the telescope rotated about itself and changed the orientation of its rotation axis over time, a common strategy for all-sky surveys (see page 20). Using this method, Hipparcos built up a map of the celestial sphere by determining the relative angular distances between stars and how those distances changed with time. Calculating a particular star's parallax required distinguishing the star's motion from those around it. But closely packed stars — like those in a cluster — gave tightly correlated measurements. This called for different calibrations at different spatial scales and resulted in an unexpected source of error for the important and compact open clusters.

But even when they knew what the problem likely was, astronomers had trouble correcting Hipparcos's data to produce a distance that agreed with the others. It could be that there were multiple sources of error. So, what scientists wanted was confirmation of the larger distance from an instrument that worked as Hipparcos did.

## Putting the Pleiades in Their Place

Hipparcos's successor, the hat-shaped Gaia, provided the opportunity astronomers needed. Like Hipparcos, Gaia is an ESA satellite of unusual design: It also looks sideways as it spins, its two telescopes scanning the same strip of sky one after the other as the spacecraft slowly rotates its view. Its second data release contains the positions, parallaxes, and proper motions of more than 1.3 billion sources and reaches as faint as magnitude 21. The uncertainty of its parallaxes is around 40 microarcseconds (40 µas) for objects brighter than




▲ **HIPPARCOS'S ANOMALY** Shown are distances to the Pleiades according to a variety of methods. Note the anomalous distance measured by Hipparcos (purple), the precise result of radio interferometry (green), and the early result given by the first Gaia data release (DR1, yellow). The article uses Gaia's second data release (light blue).

PARALLAX: LEAH TISCIONE / *S&T*; HIPPARCOS ANOMALY: *S&T* ILLUSTRATION.
SOURCE: C. MELIS ET AL. / *SCIENCE* 2014

magnitude 15. So while Hipparcos could spot an astronaut on the Moon from Earth, Gaia would be able to see a penny.

What value would Gaia find for the distance to the famous cluster? Using the first data release from 2016, one team calculated that the 164 cluster stars they included in their analysis gave a distance of 437 light-years. It was a clear confirmation that Hipparcos's value was wrong.

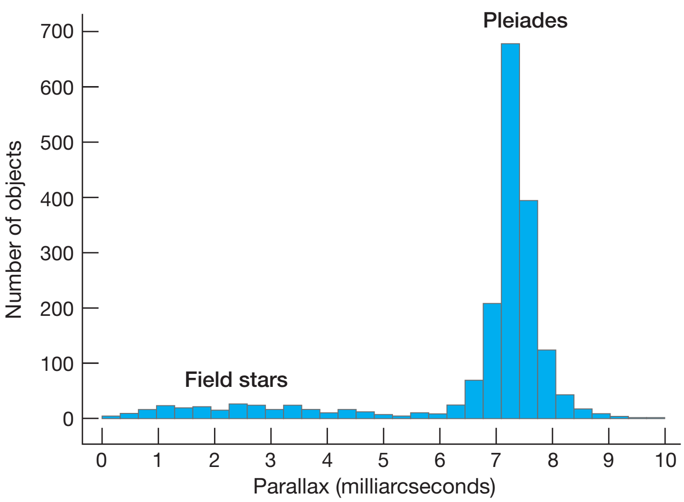
How does this analysis work? Using the same method, we can calculate the distance to the Pleiades based on Gaia's second data release, announced in April 2018:

First we have to pick the Pleiades out from everything else that shines in the same part of the sky. A download of all the (nearly 700,000!) sources lying within 5° of the Pleiades' position gives a cone of observations, with its tip in the solar system and extending indefinitely into space. Somewhere inside that cone lie the Pleiades, as well as many field stars in front of and beyond the cluster.

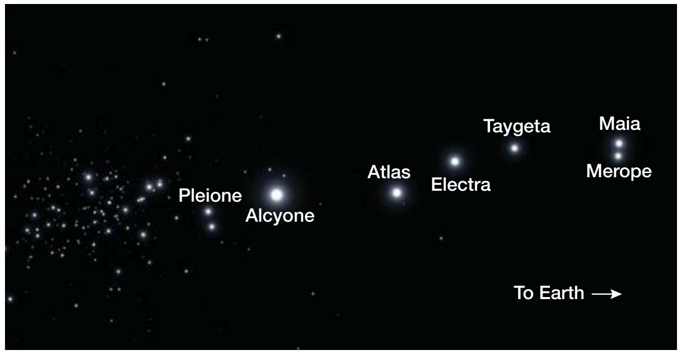
The extraction of the Pleiades from such a large stellar population is, fortunately, quite simple. The stars of an open cluster move together and therefore share the same proper motion across the sky. Gaia records a proper motion for the Pleiades of around 6 mas per year, in a particular southeastern direction. This leaves 1,876 stars of our original 700,000. Almost all of them belong to the cluster.

If we sort these remaining stars based on their parallaxes, we find that the vast majority are clumped together, with an average shift in their apparent positions of 7.3 mas. Selecting those stars with parallaxes between 5 and 9.5 leaves 1,594 stars, most of them surely belonging to the cluster. When we factor in various sources of error, we are left with a very precise final result of 7.317 ± 0.002 mas, which corresponds to a distance of 445.8 ± 0.1 light-years.

It comes almost as a relief: The Pleiades are where they should be, and stellar physics is all right.




▲ **SORTING PARALLAXES** There are nearly 2,000 sources that both lie within 5° of the Pleiades and share the cluster's proper motion across the sky. To tease out the stars that belong to the Pleiades, we plot all the sources' parallaxes. The cluster's members clump together.




▲ **UNUSUAL STREAM** When you plot the positions of the cluster's members in 3D, the brightest stars form a string stretching away from the swarm and pointing toward the solar system (on the right side of this image). The effect might be a byproduct of the data analysis, but other research has seen similar patterns in open clusters.

The Pleiades have not relinquished all their mysteries, however. The precise determination of the positions allows us to plot the cluster in 3D. When doing so we can see that the brightest stars (the traditional Seven Sisters, with proper names after the Pleiades of mythology) form a string stretching away from the swarm and pointing toward our solar system. This is, frankly, bizarre. What are the chances that the brightest, most massive stars are not only on the same side of the cluster but form a tail?

It's highly likely that this feature is an artifact of the measurement. The parallaxes of these brightest stars have particularly large errors, because Gaia is fine-tuned for stars between magnitudes 6 and 15, and the Seven Sisters are much brighter. It's also possible that at least some of these bright stars are not actually part of the cluster: The closest ones, Maia and Merope, are moving faster across the sky than the bulk of the cluster's members.

Then again, it could be that the cluster is simply elongated. And it's not a wild idea: Other research has seen similar patterns in open clusters across the Milky Way. We can only hope that further analysis and refinements in the catalog will shed light on these matters.

■ **GUILLERMO ABRAMSON** is a physicist at the Statistical and Interdisciplinary Physics Group of the Bariloche Atomic Center and Balseiro Institute, in Bariloche, Argentina. This work made use of Gaia mission data processed by the Gaia Data Processing and Analysis Consortium.

**FURTHER READING:** To learn the fascinating history of stellar parallax, read *Parallax: The Race to Measure the Cosmos*, by Alan W. Hirshfeld (W. H. Freeman, 2001). "Hipparcos: The Stars in Three Dimensions" (*S&T:* June 1999, p. 40) recounts the results of the Hipparcos mission, including the mystery of the Pleiades. The paper "Gaia Data Release 2: Using Gaia Parallaxes" by Xavier Luri (University of Barcelona, Spain) and colleagues (*Astronomy & Astrophysics* 2018) discusses the methods to obtain distance from parallax in the context of Gaia DR2.

SORTING PARALLAXES: *S&T* ILLUSTRATION, SOURCE: GUILLERMO ABRAMSON; 3D PLOT: GUILLERMO ABRAMSON / *CELESTIA*

# The Hersc

# hel Hustle

Are you up for the ultimate observing challenge? Take a page out of the author's logbook and endeavor to observe the whole Herschel catalog.

In May of 1975 I completed my observations of all 110 Messier objects and received the certificate of the Astronomical League's (AL) Messier Observing Program. There weren't any other deep-sky programs within the reach of an amateur astronomer with a 6- or 8-inch reflector until James "Jim" Mullaney of Pittsburgh, Pennsylvania, in a letter to *Sky & Telescope* (*S&T:* April 1976, p. 235) soon proposed a new observing challenge: a list of the brightest objects culled from William Herschel's *Catalogue of Nebulae and Clusters of Stars*. The Ancient City Astronomy Club of St. Augustine, Florida, reacted to Jim's letter, and the AL's Herschel 400 Observing Program took off (**https://is.gd/Herschel400**).

◀ **TWO OBJECTS UNDER ONE NUMBER** The Cone Nebula and the Christmas Tree Cluster are both cataloged under a single designation: NGC 2264. These double (or even multiple) designations have led to confusion in the past. The nebula and the cluster lie at a distance of about 2,600 light-years in Monoceros. This image, taken with the European Southern Observatory's Wide Field Imager at the La Silla Observatory in Chile, spans some 30 light-years.

ESO

## Herschel's Categories

William Herschel categorized eight classes of object as shown at right. Also tabulated are the lower and upper limits of number of objects in each category that the author collated from various publications, as well as the total.

### Herschel's Classes of Objects

| Class | Type | Lower Limit | Upper Limit |
|---|---|---|---|
| I | Bright Nebulae | 288 | 289 |
| II | Faint Nebulae | 907 | 912 |
| III | Very Faint Nebulae | 978 | 987 |
| IV | Planetary Nebulae, Stars with Burs, with Milky Chevelure, with Short Rays, Remarkable Shapes, etc. | 78 | 80 |
| V | Very Large Nebulae | 52 | 53 |
| VI | Very Compressed and Rich Clusters of Stars | 42 | 43 |
| VII | Pretty Much Compressed Clusters of Large (Bright) or Small (Faint) Stars | 67 | 67 |
| VIII | Coarsely Scattered Clusters of Stars | 88 | 89 |
| **Totals** | | **2,500** | **2,520** |

Omitting duplicated Messier objects in Herschel's catalogs, I observed my first Herschel object — or should I say objects — on the night of October 6, 1974, with a 3-inch f/10 Newtonian at 45×. They were **NGC 869** and **NGC 884**, the Double Cluster in Perseus. I completed the Herschel 400 in 1981 and received the certificate in June that year. I never thought about observing all 2,500+ deep-sky objects identified by Herschel at that time or even after I finished a second set of 400 objects 25 years later. And yet, 42 years, 6 months, and 20 nights later I bagged the last one, **NGC 5592** in Hydra, on the night of April 26, 2017, at the Amateur Astronomers Association of Pittsburgh's (AAAP) observing site in Greene County, Pennsylvania, using my 16-inch f/4.5 Dobsonian.

The question many of us have been asking for years is, "How many observable objects are there in Herschel's catalog?"

## Tackling the Observing

I purchased a used 16-inch f/4.5 Meade reflector in 1987. In 1998 the AAAP replaced the 20-inch mirror on the Manka Memorial Telescope at Wagman Observatory with a 21-inch f/4.75 mirror donated by L3 Brashear. The performance of these larger scopes was improved when both the 16- and 21-inch were resurfaced to 98% reflectivity several years ago.

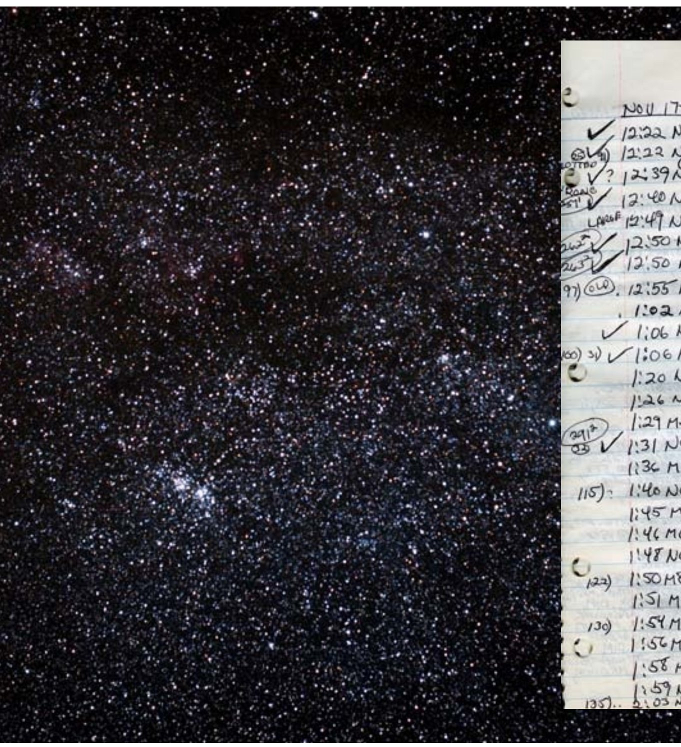
▼ **FORTY-TWO YEARS, SIX MONTHS, AND 20 NIGHTS** Tom Reiland bagged his last Herschel source, NGC 5592 (*below, far right*), in 2017. He estimates he's recorded more than 153,000 observations (amounting to 5,665 hours) on several thousand pages in 15 logbooks since 1974. The first source he observed was the Double Cluster in Perseus (*below*), and his most successful night pursuing the AL 400 was in 1979.

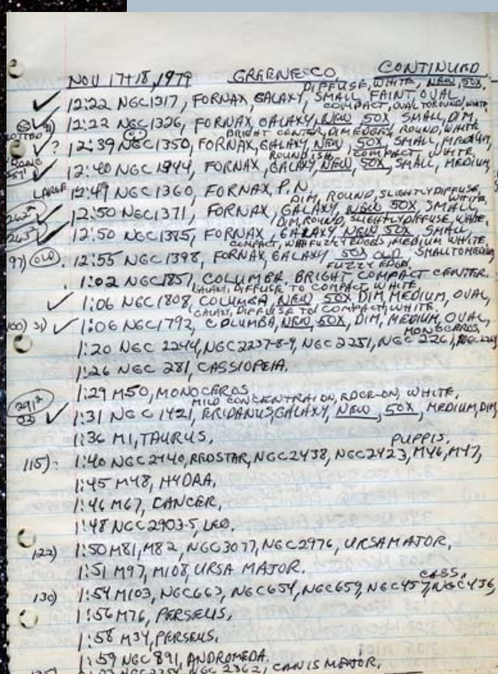
You have to be obsessed, crazy, or both to attempt this. **I feel I was both.**

This helped with my search for faint to very faint deep-sky objects. However, there's one problem with larger scopes that we often forget: They may gather more light, but that light can include glow from homes and street lights. This light pollution reduces the darkness of the background when trying to spot faint, diffuse objects in suburban and even some rural areas. In addition to these larger scopes, I also used a 3-inch f/10, a 6-inch f/6.6, and an 8-inch f/5, with magnifications ranging from 31× to 508×. All were Newtonians.

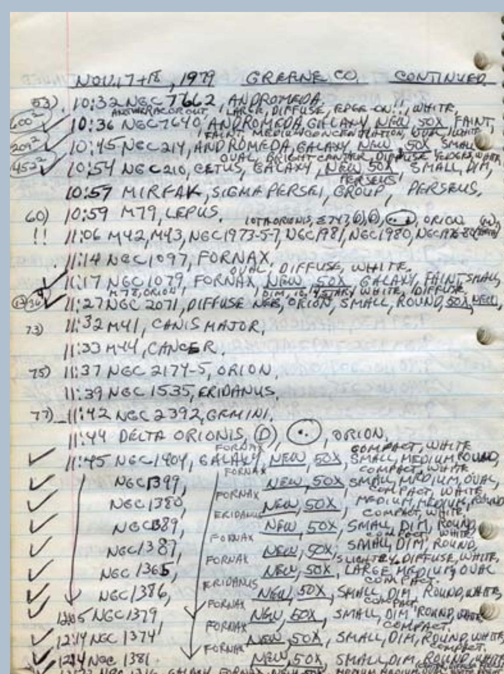
All of my observing is done via star-hopping. I wouldn't consider using a Go To system, as I personally feel no sense of accomplishment using a computer to move my scopes to the objects on my search lists. Also, I wonder whether the Go To systems include the "nonexistent" objects listed in the catalogs. I didn't use setting circles, either, but that doesn't mean you shouldn't support your search with either of these. Herschel "swept" the sky — he'd study the sky for an hour or more with a telescope aimed at the meridian mounted on a transit circle, pausing only if clouds interfered or if he had to reset his telescope — to acquire each object for his catalog without any extra aid, and I feel that star-hopping is the closest that I can get to following his sweeping system.

SOURCES AND LOGBOOKS: ESO / S. BRUNIER / POSS-II / CALTECH / STSCI / PALOMAR OBSERVATORY / TOM REILAND





NOV 17+18, 1979 GREENE CO CONTINUED
12:22 NGC 1317, FORNAX, GALAXY, SMALL FAINT OVAL
12:22 NGC 1326, FORNAX, GALAXY, NEW 50X SMALL, DIM,
12:39 NGC 1350, FORNAX, GALAXY, NEW, 50X, SMALL, MEDIUM,
12:40 NGC 1344, FORNAX, GALAXY, NEW, 50X, SMALL, MEDIUM,
12:49 NGC 1360, FORNAX, P.N.
12:50 NGC 1371, FORNAX, GALAXY, NEW 50X, SMALL,
12:50 NGC 1385, FORNAX, GALAXY, NEW 50X SMALL,
12:55 NGC 1398, FORNAX, GALAXY, 50X OLD, SMALL TO MEDIUM,
1:02 NGC 1851, COLUMBA. BRIGHT COMPACT CENTER.
1:06 NGC 1808, COLUMBA, NEW 50X DIM MEDIUM, OVAL,
1:06 NGC 1792, COLUMBA, NEW, 50X, DIM, MEDIUM, OVAL,
1:20 NGC 2244, NGC 2237-8-9, NGC 2251, NGC 2261,
1:26 NGC 281, CASSIOPEIA.
1:29 M50, MONOCEROS
1:31 NGC 1421, ERIDANUS, GALAXY, NEW, 50X, MEDIUM, DIM,
1:36 M1, TAURUS,
1:40 NGC 2440, REDSTAR, NGC 2438, NGC 2423, M46, M47,
1:45 M48, HYDRA,
1:46 M67, CANCER,
1:48 NGC 2903-5, LEO.
1:50 M81, M82, NGC 3077, NGC 2976, URSA MAJOR,
1:51 M97, M108, URSA MAJOR.
1:54 M103, NGC 663, NGC 654, NGC 659, NGC 457, NGC 436,
1:56 M76, PERSEUS,
1:58 M34, PERSEUS.
1:59 NGC 891, ANDROMEDA.
2:03 NGC 2354, NGC 2362, CANIS MAJOR,



NOV 17+18, 1979 GREENE CO. CONTINUED
10:32 NGC 7662, ANDROMEDA.
10:36 NGC 7640, ANDROMEDA, GALAXY, NEW, 50X, FAINT,
10:45 NGC 214, ANDROMEDA, GALAXY, NEW, 50X, SMALL,
10:54 NGC 210, CETUS, GALAXY, NEW, 50X, SMALL, DIM,
10:57 MIRFAK, SIGMA PERSEI, GROUP, PERSEUS,
10:59 M79, LEPUS.
11:06 M42, M43, NGC 1973-5-7, NGC 1981, NGC 1980,
11:14 NGC 1097, FORNAX.
11:17 NGC 1079, FORNAX, NEW, 50X, GALAXY, FAINT, SMALL,
11:27 NGC 2071, DIFFUSE NEB, ORION, SMALL, ROUND, 50X, NEW,
11:32 M41, CANIS MAJOR,
11:33 M44, CANCER.
11:37 NGC 2174-5, ORION.
11:39 NGC 1535, ERIDANUS.
11:42 NGC 2392, GEMINI.
11:44 DELTA ORIONIS, ORION,
11:45 NGC 1404, GALAXY, NEW, 50X, SMALL, MEDIUM, ROUND,
NGC 1399, NEW, 50X, SMALL, MEDIUM, OVAL,
NGC 1380, NEW, 50X,
NGC 1389, NEW, 50X, SMALL, DIM, ROUND,
NGC 1387, NEW, 50X, SMALL, DIM, ROUND,
NGC 1365, NEW, 50X, LARGE, MEDIUM, OVAL
NGC 1386, NEW, 50X, SMALL, DIM, ROUND, WHITE,
12:05 NGC 1379, NEW, 50X, SMALL, DIM, ROUND,
12:14 NGC 1374, NEW, 50X, SMALL, DIM, ROUND, WHITE,
12:14 NGC 1381, NEW, 50X, SMALL, DIM, ROUND, WHITE
12:22 NGC 1316, GALAXY, FORNAX, NEW 50X, MEDIUM,

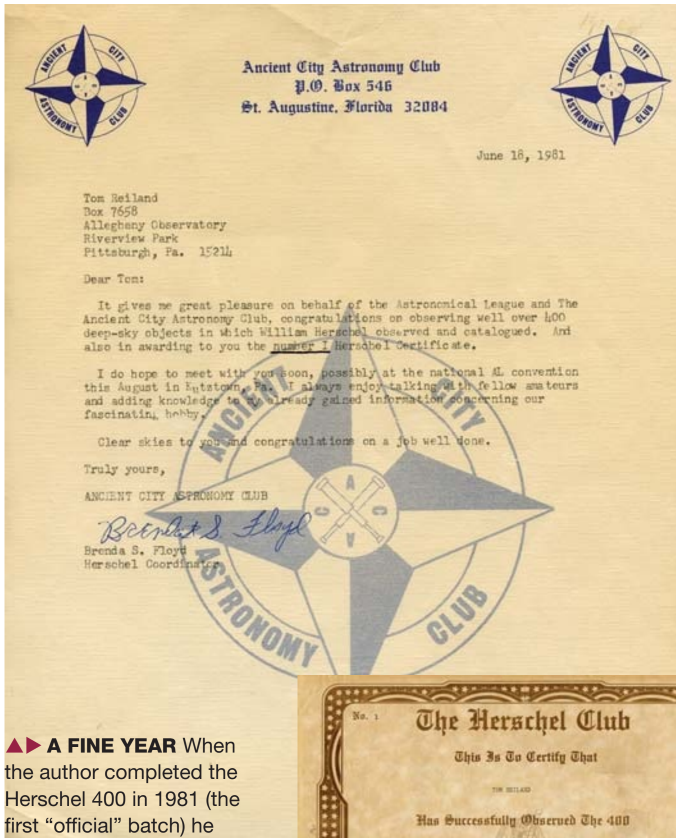
I used *Uranometria 2000.0*, the *Millennium Star Atlas*, and the *Sky Atlas 2000.0* in addition to printing images from the Space Telescope Science Institute (STScI) website to help find some of the more difficult targets. *Norton's Star Atlas* used Herschel numbers instead of NGC numbers in its early editions, but it charted only the brightest objects.

Obviously, it's more difficult keeping track of 2,500+ objects than the AL's list of 400 or the Messier 110. In order to avoid confusion, I kept four separate records of my observations. The first were my logbooks, fifteen of them, dating back to 1974. Second, I checked off each object listed in the NGC 2000.0 catalog. Next was a printout of objects in the catalog in order of NGC numbers. And last was my own printout of the Herschel objects grouped into each of the eight categories of deep-sky objects. I trusted this would eliminate mistakes or omissions.

## Stepping Up to the Challenge

I decided to tally all my observations of Herschel objects after I completed the second 400 list and found they amounted to more than 1,400. My next step was to top the 2,000 mark and, possibly, even expand to more than 2,400 Herschel objects. Which I did.

And that's where I planned to end my search. I figured the increased light pollution near Wagman Observatory and at the nearby dark-sky sites that I frequented would limit my ability to get the more difficult objects: the very faint, very small galaxies near the north pole at +70° to +80° and galaxies and other objects in the southern portion of the sky from –20° to –29°.


Ancient City Astronomy Club
P.O. Box 546
St. Augustine, Florida 32084

June 18, 1981

Tom Reiland
Box 7658
Allegheny Observatory
Riverview Park
Pittsburgh, Pa. 15214

Dear Tom:

It gives me great pleasure on behalf of the Astronomical League and The Ancient City Astronomy Club, congratulations on observing well over 400 deep-sky objects in which William Herschel observed and catalogued. And also in awarding to you the number 1 Herschel Certificate.

I do hope to meet with you soon, possibly at the national AL convention this August in Kutztown, Pa. I always enjoy talking with fellow amateurs and adding knowledge to my already gained information concerning our fascinating hobby.

Clear skies to you and congratulations on a job well done.

Truly yours,

ANCIENT CITY ASTRONOMY CLUB

Brenda S. Floyd
Brenda S. Floyd
Herschel Coordinator


No. 1

The Herschel Club

This Is To Certify That

Tom Reiland

Has Successfully Observed The 400 Deep-Sky Objects As Designated By The Herschel Club.

Awarded This Day of June, 1981

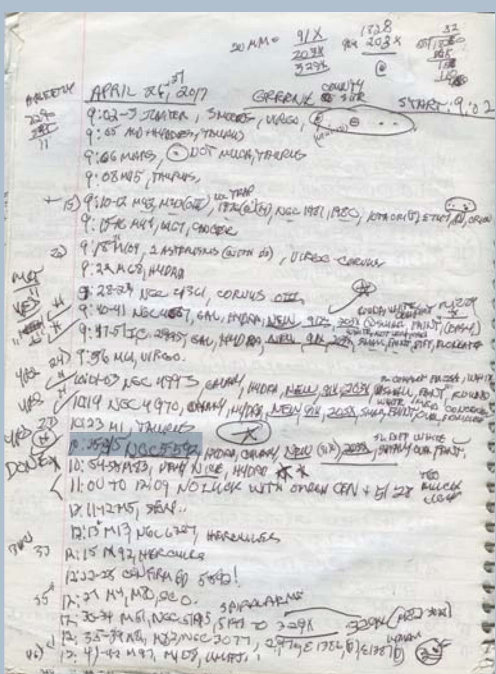
Astronomical League President

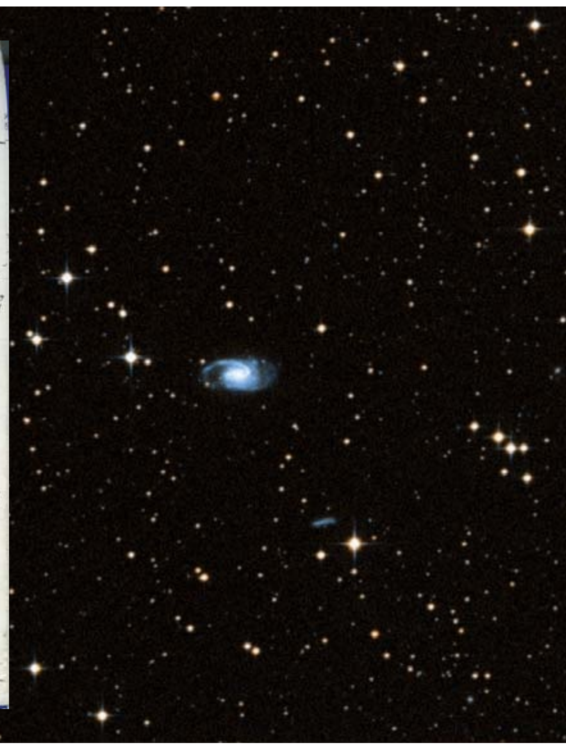
Herschel Club Coordinator

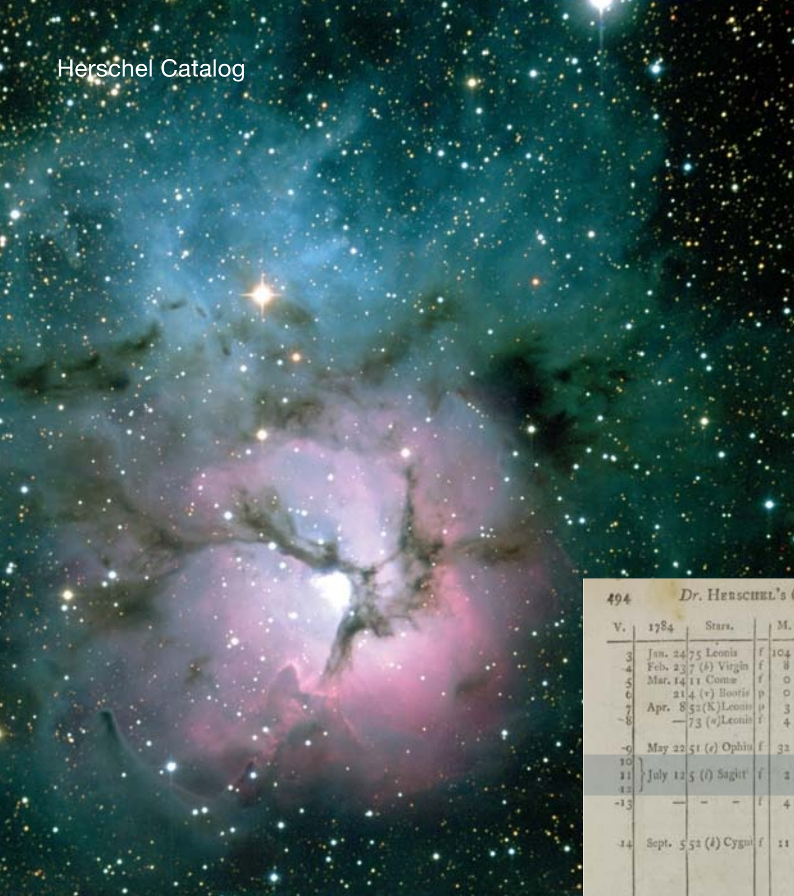
Brenda Floyd

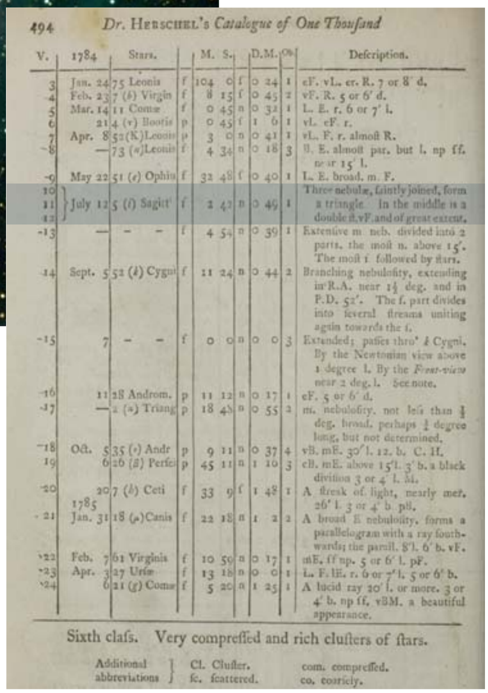
**A FINE YEAR** When the author completed the Herschel 400 in 1981 (the first "official" batch) he received this certificate (*right*) along with a letter from the Ancient City Astronomy Club's president at the time (*above*). The author went on to observe all Herschel objects.

LETTER AND CERTIFICATE: TOM REILAND







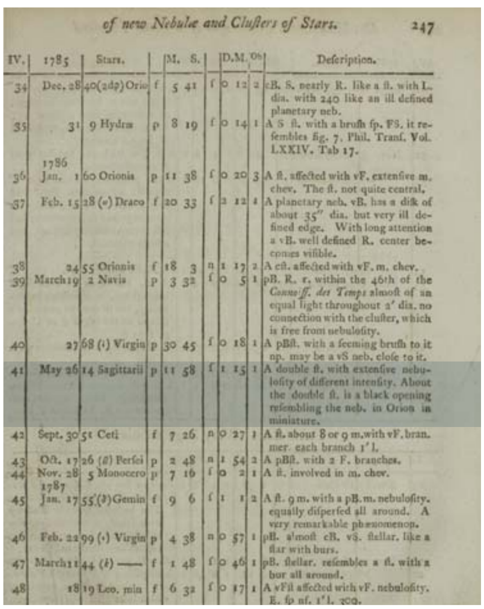


494 *Dr. Herschel's Catalogue of One Thousand*

| V. | 1784 | Stars. | | M. S. | | D.M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|
| 3 | Jan. 24 | 75 Leonis | f | 104 0 | f | 0 24 | 1 | eF. vL. er. R. 7 or 8′ d. |
| -4 | Feb. 23 | 7 (*b*) Virgin | f | 8 15 | f | 0 45 | 2 | vF. R. 5 or 6′ d. |
| 5 | Mar. 14 | 11 Comæ | f | 0 45 | n | 0 32 | 1 | L. E. r. 6 or 7′ l. |
| 6 | 21 | 4 (*τ*) Bootis | p | 0 45 | f | 1 6 | 1 | vL. eF. r. |
| 7 | Apr. 8 | 52 (K) Leonis | p | 3 0 | n | 0 41 | 1 | vL. F. r. almost R. |
| -8 | — | 73 (*n*) Leonis | f | 4 34 | n | 0 18 | 3 | B. E. almost par. but l. np ff. near 15′ l. |
| -9 | May 22 | 51 (*e*) Ophiu | f | 32 48 | f | 0 40 | 1 | L. E. broad. m. F. |
| 10<br>11<br>12 | July 12 | 5 (*l*) Sagitt | f | 2 42 | n | 0 49 | 1 | Three nebulæ, faintly joined, form a triangle. In the middle is a double st. vF. and of great extent. |
| -13 | — | — — | f | 4 54 | n | 0 39 | 1 | Extensive m. neb. divided into 2 parts, the most n. above 15′. The most f. followed by stars. |
| 14 | Sept. 5 | 52 (*k*) Cygni | f | 11 24 | n | 0 44 | 2 | Branching nebulosity, extending in R.A. near 1½ deg. and in P.D. 52′. The f. part divides into several streams uniting again towards the f. |
| -15 | 7 | — — | f | 0 0 | n | 0 0 | 3 | Extended; passes thro' *k* Cygni. By the Newtonian view above 1 degree l. By the *Front-view* near 2 deg. l. See note. |
| -16 | 11 | 28 Androm. | p | 11 12 | n | 0 17 | 1 | eF. 5 or 6′ d. |
| -17 | — | 2 (*α*) Triang | p | 18 45 | n | 0 55 | 2 | m. nebulosity, not less than ⅓ deg. broad, perhaps ½ degree long, but not determined. |
| -18 | Oct. 5 | 35 (*ν*) Andr | p | 9 11 | n | 0 37 | 4 | vB. mE. 30′ l. 12. b. C. H. |
| 19 | 6 | 26 (*β*) Persei | p | 45 11 | n | 1 10 | 3 | cB. mE. above 15′ l. 3′ b. a black division 3 or 4′ l. M. |
| -20 | 20 | 7 (*b*) Ceti | f | 33 9 | f | 1 48 | 1 | A streak of light, nearly mer. 26′ l. 3 or 4′ b. pB. |
| -21 | 1785<br>Jan. 31 | 18 (*μ*) Canis | f | 22 18 | n | 1 2 | 2 | A broad E. nebulosity, forms a parallelogram with a ray southwards; the paral. 8′ l. 6′ b. vF. |
| -22 | Feb. 7 | 61 Virginis | f | 10 59 | n | 0 17 | 1 | mE. ff np. 5 or 6′ l. pF. |
| -23 | Apr. 3 | 27 Ursæ | f | 13 18 | n | 0 0 | 1 | L. F. lE. r. 6 or 7′ l. 5 or 6′ b. |
| -24 | 6 | 21 (*g*) Comæ | f | 5 20 | n | 1 25 | 1 | A lucid ray 20′ l. or more. 3 or 4′ b. np ff. vBM. a beautiful appearance. |

Sixth class. Very compressed and rich clusters of stars.

Additional abbreviations } Cl. Cluster. sc. scattered. com. compressed. co. coarsely.



*of new Nebulæ and Clusters of Stars.* 247

| IV. | 1785 | Stars. | | M. S. | | D.M. | Ob | Description. |
|---|---|---|---|---|---|---|---|---|
| 34 | Dec. 28 | 40 (2d*φ*) Orio | f | 5 41 | f | 0 12 | 2 | cB. S. nearly R. like a st. with L. dia. with 240 like an ill defined planetary neb. |
| 35 | 31 | 9 Hydræ | p | 8 19 | f | 0 14 | 1 | A S. st. with a brush sp. FS. it resembles fig. 7. Phil. Trans. Vol. LXXIV. Tab 17. |
| 36 | 1786<br>Jan. 1 | 60 Orionis | p | 11 38 | f | 0 20 | 3 | A st. affected with vF. extensive m. chev. The st. not quite central. |
| 37 | Feb. 15 | 28 (*ω*) Draco | f | 20 33 | f | 2 12 | 1 | A planetary neb. vB. has a disk of about 35″ dia. but very ill defined edge. With long attention a vB. well defined R. center becomes visible. |
| 38 | 24 | 55 Orionis | f | 18 3 | n | 1 17 | 2 | A cst. affected with vF. m. chev. |
| 39 | March 19 | 2 Navis | p | 3 32 | f | 0 5 | 1 | pB. R. r. within the 46th of the *Connoiss. des Temps* almost of an equal light throughout 2′ dia. no connection with the cluster, which is free from nebulosity. |
| 40 | 27 | 68 (*i*) Virgin | p | 30 45 | f | 0 18 | 1 | A pBst. with a seeming brush to it np. may be a vS neb. close to it. |
| 41 | May 26 | 14 Sagittarii | p | 11 58 | f | 1 15 | 1 | A double st. with extensive nebulosity of different intensity. About the double st. is a black opening resembling the neb. in Orion in miniature. |
| 42 | Sept. 30 | 51 Ceti | f | 7 26 | n | 0 27 | 1 | A st. about 8 or 9 m. with vF. bran. mer. each branch 1′ l. |
| 43 | Oct. 17 | 26 (*β*) Persei | p | 2 48 | n | 1 54 | 2 | A pBst. with 2 F. branches. |
| 44 | Nov. 28 | 5 Monocero | p | 7 16 | f | 0 2 | 1 | A st. involved in m. chev. |
| 45 | 1787<br>Jan. 17 | 55 (*δ*) Gemin | f | 9 6 | f | 1 1 | 2 | A st. 9 m. with a pB. m. nebulosity, equally dispersed all around. A very remarkable phænomenon. |
| 46 | Feb. 22 | 99 (*ι*) Virgin | p | 4 38 | n | 0 57 | 1 | pB. almost cB. vS. stellar, like a star with burs. |
| 47 | March 11 | 44 (*k*) —— | f | 1 48 | f | 0 46 | 1 | pB. stellar, resembles a st. with a bur all around. |
| 48 | 18 | 19 Leo. min | f | 6 32 | f | 0 17 | 1 | A vFst affected with vF. nebulosity. E. sp nf. 1′ l. 300. |

▲▶ **FOUR PARTS TO A WHOLE** The Trifid Nebula (M20, NGC 6514), a star-forming region in Sagittarius, was initially assigned three entries by Herschel. He added a fourth designation — in a different class — later (entries highlighted at right).

TRIFID NEBULA: TODD BOROSON / NOAO / AURA / NSF; CATALOGS: PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON (2)

However, some years ago I read that several amateur astronomers had actually accomplished the feat of tallying all 2,500+ Herschel objects, including *Sky & Telescope* Contributing Editor Rod Mollise (see *S&T:* Aug. 2012, p. 60). Sue French also let me know by email that Larry Mitchell logged 2,508 Herschel objects. While I was corresponding with Jim Mullaney about these achievements, he suggested that I contact deep-sky expert Wolfgang Steinicke about tackling the remaining objects in the Herschel catalogs.

Wolfgang shared details with me on his observations of the so-called nonexistent objects (largely open clusters) confirming to me that most of them did, in fact, exist. This left only a handful of objects that have not been found, some of which may or may not have been comets. Once I knew how many galaxies, clusters, and nebulae definitely remained in my quest, I was able to plan my program for the last 100+ Herschel objects. My conversations with Wolfgang and the recoating of my 16-inch and the 21-inch Manka scope encouraged me to go for it.

## True Source or Not?

Confusion in transcribing across various catalogs has led to some objects being listed with wrong NGC numbers. Depending on the source, there are 36 to 50 duplicate observations by Herschel himself of objects that are listed under two or more Herschel numbers. The **Trifid Nebula** and **NGC 2264** together account for six Herschel numbers: Four numbers are assigned to sections of the Trifid Nebula and two to NGC 2264, which consists of the Cone Nebula and the Christmas Tree Cluster.

One example of an object listed under the wrong designation is NGC 5570. I tried to observe it one night in the spring of 2016 but couldn't see anything at the location marked in *Uranometria 2000.0*. I did see other galaxies near that spot, but nothing where NGC 5570 was supposed to be as shown on the chart. As it turns out, NGC 5519, and not NGC 5570, is the true Herschel Class III object 12.

One of the nonexistent objects that I was able to eliminate on my own is **NGC 6847** in Vulpecula. I used the STScI page to scan the area near it and found that the planetary nebula **NGC 6842** fits the description of Herschel Class II 202. The only objects that I consider truly nonexistent are either NGC 420 or NGC 421 (depending on which of these two objects is taken to be the false detection), NGC 3401, and possibly NGC 5621 (but it may have been observed by John Herschel). Some might consider NGC 1908 to be nonexistent, but I believe that the field of NGC 1908 does show a pattern of stars that could be mistaken for a cluster — and I was able to find it.

I wanted to make sure that I had covered all possibilities and so I decided to observe other deep-sky objects in the field of view of Herschel objects, in case one of them might be the object that Herschel actually observed. Another questionable object is **NGC 4317**, which is listed as a faint star. On the STScI image of the field of NGC 4317, I noted several faint galaxies. I was able to locate three of them through the 21-inch scope: **PGC 1929454**, **PGC 1924297**, and **PGC 40071**. They are all within 15′ of the star. **IC 4470** near **NGC 5712** (both galaxies) is an example of a possible Herschel object that I observed, though it's not on the original list of 2,500. In fact, I found that IC 4470 was actually easier to spot than NGC 5712.

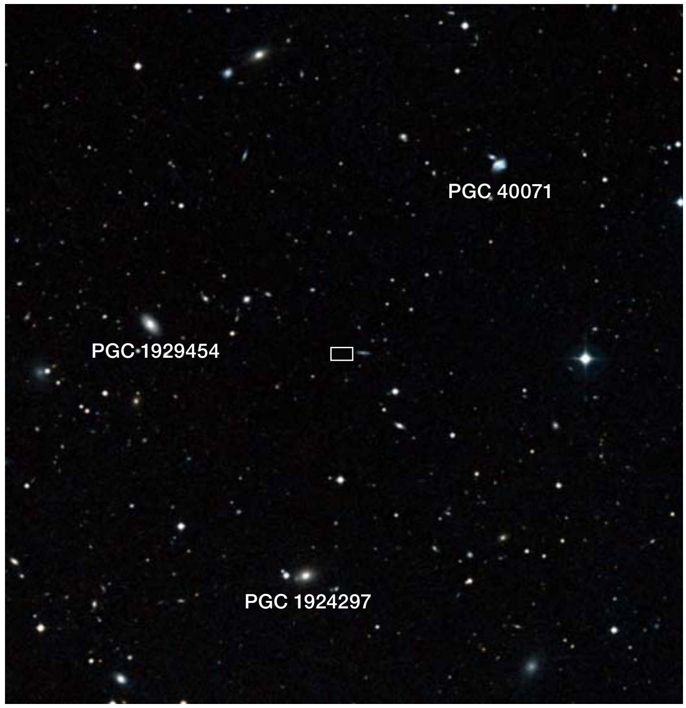
## Final Tally

Do I believe that I've spotted all of the visible Herschel objects? Probably, but I'm not sure that any of us who went on this quest can say that with complete certainty. One difficulty arises from of the method of recording object positions by astronomers in the 18th and early 19th centuries. Charles Messier, Pierre Méchain, William Herschel, and others didn't use coordinates consistently in their catalogs. They also gave positions in relation to nearby stars or other deep-sky objects. Mistakes were made when later astronomers tried to match the descriptions of the object positions to right ascension and declination — M91 and possibly M103 are examples of Messier objects with mistaken identities.

How many Herschel objects are observable? I've found that the totals vary from 2,397 to 2,520. How many have I logged? I counted 2,517. Subtracting the duplicates and multiple listings for NGC 2264 (cluster and nebula) and M20 (four sections of the Trifid Nebula), my total number of actual galaxies, clusters, nebulae, stars, multiple stars, and asterisms is 2,477.

Besides these 2,500+ objects, Wolfgang Steinicke has identified 55 more objects that Herschel observed but didn't include in his three separate catalogs that eventually became his complete listing of 2,500 objects. I checked Wolfgang's list and noted that I had observed 27 of them. I haven't decided yet whether I will try for the remaining 28. I need a rest from searching for what some of us call *faint fuzzies*.

I estimate that someone with experience, good vision, a dark-sky observing site, and the desire for the hunt can find all of William Herschel's deep-sky objects with scopes of 14 to 16 inches. Good luck to all who try this quest. You have to be obsessed, crazy, or both to attempt this. I feel I was both.




▲ **COULD IT BE?** NGC 4317 was listed as a faint star by Herschel. Tom Reiland couldn't find the star when he observed the field but did spot three galaxies, all within 10′ of the given position (box). Could one of the galaxies be the actual object Herschel observed?

POSS-II / CALTECH / STSCI / PALOMAR OBSERVATORY

■ **TOM REILAND** has been observing the night sky for more than 45 years. He worked at the Allegheny Observatory as the Assistant Astronomer for 22 years and Senior Observer 10 of those years, and then founded and became director of the Wagman Observatory. Along with Tom Hoffelder, Tom is one of several independent originators of the Messier Marathon in 1975. In July 1985 Tom discovered an open cluster subsequently named Reiland 1 (see *S&T:* Nov. 1988, p. 582), and in 2004 he was honored with the naming of asteroid (10320) Reiland. He was also the first to report the discovery of SN 2011dh in M51.

**FURTHER READING:** See "The Herschel Sprint" by Mark Bratton in the April 2015 issue of *Sky & Telescope* (page 34) for an account of an extraordinary night of observing by William and Caroline Herschel.

**HERSCHEL CATALOG RESOURCES:** Jim Mullaney, Wolfgang Steinicke, and David Bishop all supplied the author with useful information in his searches. Here are some links:
**messier.seds.org/xtra/similar/herschel.html**
**www.klima-luft.de/steinicke/index_e.htm**

### Tracking Down Designations

The Space Telescope Science Institute (STScI) Digitized Sky Survey website (**https://is.gd/stsci_dss**) locates objects by their designations. This is useful for identifying sources' true names. Just input the object designation in the search bar, and the website will return results indicating whether or not the object is truly known by that name or if it goes by another one (for example, if it has another NGC number other than the one entered). You can also retrieve an image of the field.

Another useful website for this purpose is the SIMBAD database maintained by the University of Strasbourg: **simbad.u-strasbg.fr/simbad/**

**ALL MIRRORS ARE EQUAL** Whether you use a tabletop reflector or a giant Dobsonian, all Newtonian reflector mirrors require a good cleaning eventually.

# Nurture YOUR NEWT: Bathing Mirrors

Cleaning your reflector's optics ensures top performance.

Newtonian telescopes are amazingly robust devices. With two mirrors that need to be accurate to within ¼-wavelength of light and aligned within millimeters, you might expect them to be fussy, temperamental beasts that require constant attention and adjustment. Some people do seem to fiddle with their scopes more or less continually, but others let them go for years without so much as a dusting or a twist of a collimation knob. The famous Edmund Astroscan, one of the best-selling Newtonian designs in history, wasn't even built to be adjustable.

Yet while it's true that the Newtonian is tolerant of neglect and even some abuse, it's also true that a little care and fine-tuning can keep your scope operating at peak capacity. Two of the simplest and most effective maintenance tasks are surprisingly easy: keeping it clean and keeping it collimated. We'll talk about cleanliness here and collimation next month.

## Dust Prevention

Regarding cleanliness, the main thing you need to concern yourself with is dust on the mirrors. It's surprising how much they can collect and still provide a decent view (by "surprising," I really mean "Holy, cow, you've got to be kidding!"), but there's a limit. Every speck of dust adds a little diffraction to the image, and eventually all that diffraction adds up to become a distraction.

ALL PHOTOS COURTESY OF THE AUTHOR

Unfortunately, when using the scope, its primary mirror is facing upward, so any dust in the air can settle on it. With closed-tube scope designs this isn't a big problem, but with open-truss scopes, whose primary mirrors are right next to your feet as you scuffle around in the dark, you can put on a hefty coat of dust in a single night. The trick, then, is to not kick up so much dust in the first place. That means setting up on grass or a hard surface if possible, or laying down a ground cloth if you can't.

It also means not letting the mirror dew up if you can help it. Dew moistens the dust particles and effectively glues them to the mirror so they can't simply be blown off later. It's not a disaster if the mirror dews up, but you'll need to clean it more often if it happens frequently.

How you store the scope will also have a big effect on how clean the mirrors stay. Obviously, use a dust cap, but also put a bag or a shower cap around the base of the scope so dust can't enter around the mirror cell. A full-length cover is even better. If possible, store solid-tube scopes sideways or top-down so no dust that does get inside can fall on the primary. Store any scope in as dust-free an environment as possible. In the shop next to the table saw is probably not the best place.

When your mirrors do become dusty, the first step is to gently blow them off with compressed air. Be careful when using mechanical air compressors; the air coming out of them can sometimes be oily or wet, which will make matters worse. Use a can of compressed air instead. Compressed air won't get everything off, especially if it was dew-glued on, but it'll help considerably. Eventually your mirrors will need cleaning, but with a little preventative care that won't happen for several years.

Figuring out when it's necessary is the real trick. Any telescope that's been used more than a couple of times will fail the flashlight test, in which you shine a light straight down the tube and gasp at all the dust on that once-pristine surface. By the time it's truly ready to clean, the flashlight test will make you want to use a chisel.


▲ **CELL PROTECTION** A simple shower cap prevents dust from entering through the bottom of the telescope around its mirror cell.

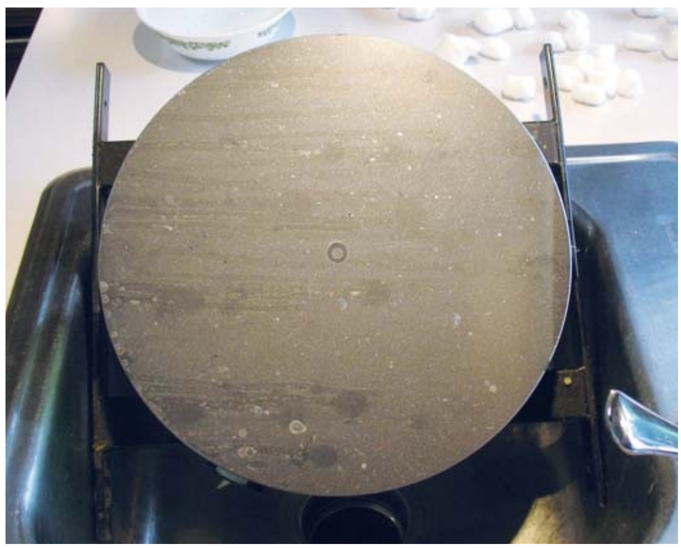
Your best indicator isn't by examining the primary mirror at all, at least not directly. You're better off looking at a bright star through a clean medium- to high-power eyepiece. Is there a lot of flare around the star? If so, then that's probably from dust on the primary. (Be sure to check your eyepiece first — the view through a dirty eyepiece mimics that of a dirty mirror.) The scope may have a dirty secondary mirror, but since secondaries point downward most of the time, that's less likely. If so, though, the following procedure will work for cleaning a secondary just as well as a primary.

## Hands-on Cleaning

Many people (maybe even most) are afraid of their primary mirror. It is, after all, a precision instrument, and the coating is on the front surface where it can be easily scratched. While this is true, it's not as fragile as you might think. The aluminum coating is overcoated with a layer of silicon dioxide, which is basically glass.

I have a fond memory of Bill Atwood, owner of Uvira, Inc., holding my very first mirror casually in his hands as he admonished me not to be afraid of its shiny new surface. "It's coated with glass," he said. "I could clean it with my tie."

▼ **HAZY REVELATION** *Left:* When it's time to clean your Newtonian's primary mirror, be careful removing it from its sling or cell. Here, the author dons new gloves in order to avoid adding fingerprints and other contaminants to the coated surface. *Right:* This mirror is definitely ready for cleaning.



SCANDALOUSLY FILTHY MIRROR PROVIDED BY ANDY EDELEN

I've never had quite the courage to do that, but I believe he's right. I have cleaned mirrors with Glass Plus and Kleenex without harming them. But there's a tried-and-true method that's safer, and it's easy enough that it should be your standard method, too.

First, remove the mirror from its cell if possible. If you can't, then you'll have to clean it in the cell, as I've done in the illustrations here.

Next, blow off any dust that you can. Don't use a high-pressure air jet; just puff away whatever is loose.

Get a couple dozen cotton balls ready. You'll want to be able to pick them up one at a time with wet hands.

Have some distilled or deionized water ready, too.

Take off your rings.

Trim your fingernails. Seriously.

Prepare a bowl of warm, soapy water. Add just a couple drops of Dawn, Ivory, or some other gentle dish soap. Unscented is best (fewer additives), but that's not critical. Wash your hands first to get most of the oils off, then soak the fingertips of your dominant hand for a few minutes in the mirror-washing water. This will soften up your skin and get it squeaky clean.

Next, rinse the mirror under warm running water. From this point on, don't let any water dry on the mirror. Tap water leaves mineral deposits when it dries, and those are hard to get off.

◀ **FIRST BATH** *Top:* Flooding the mirror with warm tap water will remove a lot of the dirt. *Middle:* Gently swipe a soapy wet cotton ball across the mirror. Use a fresh cotton ball for each pass to avoid scraping grit particles across the mirror again and again. *Bottom:* Use your soapy, softened fingertips to feel for any remaining grit particles.

Rinse off all the dirt you can. Use your sink sprayer if it has one. You might even soak the mirror for a while if you have stubborn spots.

Once you've gotten off everything you can with running water, start in with the cotton balls. Take a single cotton ball, dip it in the soapy water, and, starting at the top of the mirror, wipe it gently across the mirror in one steady, light swipe from one edge to the other. Now throw that cotton ball away. If the cotton picked up any grit, you don't want to be scraping it across the surface on your next pass.

Work your way down with overlapping horizontal motions, using one cotton ball per swipe. (Yes, if you're careful you can rotate the cotton ball and get a second clean swipe out of it.)

When you've done the entire mirror, rotate it 90° and do it again.

Now take a deep breath and touch the mirror with your fingertips. (This is why you trimmed your fingernails — you just want the fleshy parts of your fingers to

## Mirror COATING SERVICES

Here's a list of companies that currently provide aluminization services for amateurs in North America.

**Aluminum Coating**
807 Rutherdale Ave.,
San Carlos, CA 94070
650-868-5035
**alcoat.net**

**Evaporated Coatings Inc.**
2365 Maryland Rd.,
Willow Grove, PA 19090
215-659-3080
**evaporatedcoatings.com**

**Evaporated Metal Films**
239 Cherry St.,
Ithaca, NY 14850
800-456–7070
**dynasil.com**

**Galaxy Optics**
P.O. Box 2045,
Buena Vista, CO 81211
719-395-8242
**galaxyoptics.com**

**H. L. Clausing, Inc.**
8038 N. Monticello Ave.,
Skokie, IL 60076
847-676-0330
**clausing.com**

**North American Coating Laboratories**
9450 Pineneedle Dr.,
Mentor, OH 44060
866-216-6225; **nacl.com**

contact the surface.) This part is optional, but it's worth doing if you can work up the courage, because your fingertips are so sensitive that you can feel any grit particles that might still be stuck to the mirror. Gently feel around with your soapy, wet fingertips to make sure the mirror is truly clean. If you find a grit particle, gently knock it free and rinse it off the mirror so you won't drag it around. If you see a stubborn stain, it's okay to rub it a little — lightly — with your fingertips to clean it off. A fresh cotton ball would work, too, but unless you're a guitarist and you're using your fretting hand to wash the mirror, your fingertips are gentler than the cotton fibers.

When the mirror is clean to your satisfaction, rinse off all the soapy water with warm tap water, then rinse off all the tap water with distilled or deionized water. This last step ensures that no mineral deposits will be left on the mirror when it dries.

Water will sheet off a truly clean mirror, so odds are you'll only have a few drops remaining. You can dry these drops by blotting them with a soft towel, but there's no need. The distilled/deionized water will dry perfectly clean.

## When to Recoat a Mirror

If you notice a lot of splotches on a clean mirror, it's possible that your coating is going bad. Pinholes in the glass overcoating let oxygen and other contaminants reach the aluminum layer, and that can eventually lead to corrosion. These spots usually look like an irregular patch of algae on a rock or an ice cream cone splat on the pavement, and they won't clean off. When more than a small percentage of the mirror is affected with this corrosion, it's time to have it recoated. (See below for a list of coating vendors.)

Assuming your mirror is in good shape, though, you're done! Put it back in its cell, remembering not to overtighten the mirror clamps. You want them to *just* hold the mirror from tipping forward when the scope is tilted horizontal, not push down on it (not even a little bit). Too much pressure will pinch the optics.

Now reassemble the scope and collimate it. We'll cover the finer details of collimation in the next installment.

◀ **ROUND TWO** *Top:* Rinse off the soapy water with lots of warm tap water. *Middle:* Flood the mirror with distilled water to prevent mineral stains. *Bottom:* The cleaned mirror may still have some defects. This one is beginning to have coating issues but is still perfectly useable.

Contributing Editor **JERRY OLTION** loves cleaning mirrors, especially other people's.

**Majestic Optical Coatings**
152 Willow Way,
Clark, NJ 07066
888-278-8308
**majestic-coatings.com**

**Optical Mechanics Inc.**
2224 Heinz Rd.,
Iowa City, IA 52240
319-351-3960
**opticalmechanics.com**

**Precision Optical**
320 Kalmus Dr.,
Costa Mesa, CA 92626
949-205-7346
**precisionoptical.com**

**Spectrum Thin Films**
135 Marcus Blvd.,
Hauppauge, NY 11788
800-815-8184
**spectrumthinfilms.com**

**Optiques Fullum**
1111 Rt. Harwood #6,
Vaudreuil-Dorion,
QC J7V 8P2 Canada
**optiquesfullum.com**

**Ostahowski Optics**
P.O. Box 390440,
Anza, CA 92539
951-763-5959
**ostahowskioptics.com**

**Reynard Corporation**
1020 Calle Sombra,
San Clemente, CA 92673
949-366-8866
**reynardcorp.com**

**Spectrum Coatings**
1165 Ring St.,
Deltona, FL 32725
386-561-9779
**spectrum-coatings.com**

**1–3 DAWN:** Venus, Saturn, and Jupiter arc across the southeastern sky with the waning crescent Moon initially some 3° right of Saturn. Follow the ever-thinning Moon over the next two mornings as it first moves to 4½° right of Venus and then 7° lower left of the planet.

**1 EVENING:** Algol shines at minimum brightness for roughly two hours centered at 7:19 p.m. EST; see page 50.

**10 DAYLIGHT-SAVING TIME STARTS** at 2 a.m. for most of the United States and Canada.

**11 EVENING:** After sunset, follow the waxing crescent Moon and Mars, some 7° apart, as they drop lower in the west. They set together around midnight.

**12 EVENING:** The growing Moon is in the outskirts of the Hyades, the open cluster in Taurus.

**13 EVENING:** Find the Moon, still in Taurus, about halfway between Aldebaran and Zeta Tauri.

**18–19 ALL NIGHT:** The waxing gibbous Moon and Regulus traverse the night sky together, starting only 2° apart at dusk, with the gap between them widening to 5½° before dawn.

**18–19 NIGHT:** Algol shines at minimum brightness for roughly two hours centered at 10:15 p.m. PDT (1:15 a.m. EDT).

**20 SPRING BEGINS** in the Northern Hemisphere at the equinox, 5:58 p.m. EDT (2:58 p.m. PDT).

**21 EVENING:** The soft glow of the zodiacal light is visible at mid-northern latitudes from dark sites during the next two weeks. Look toward the west in deepening twilight for a hazy pyramid of light stretching up through Taurus to Gemini, tilted slightly to the left.

**21 EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:04 p.m. EDT (7:04 p.m. PDT).

**23–24 NIGHT:** The waning gibbous Moon, in Libra, traverses the sky some 4° from Alpha Librae.

**26–29 MORNING:** Around 25° separates Jupiter and Saturn in the southeast. Watch over the next four mornings as the waning gibbous Moon moves from 9° upper right of Jupiter, to in between the two planets for the following two mornings, and finally 3° left of Saturn.
— DIANA HANNIKAINEN

▲ The zodiacal light tilts up over Lake Superior near Duluth, Minnesota, at dawn on October 18, 2018. The cone of light is composed of comet and asteroid dust in the plane of the solar system. BOB KING

**MARCH 2019 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 | | | | | | |

**NEW MOON**

March 6
16:04 UT

**FIRST QUARTER**

March 14
10:27 UT

**FULL MOON**

March 21
01:43 UT

**LAST QUARTER**

March 28
04:10 UT

**DISTANCES**

| | |
|---|---|
| Apogee | March 4, 11$^h$ UT |
| 406,390 km | Diameter 29′ 24″ |
| Perigee | March 19, 20$^h$ UT |
| 359,377 km | Diameter 33′ 15″ |

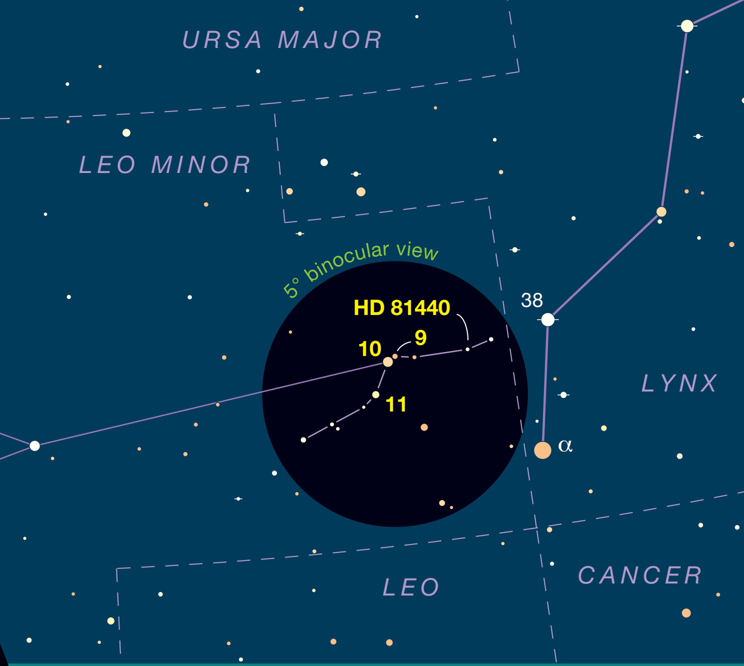
**FAVORABLE LIBRATIONS**

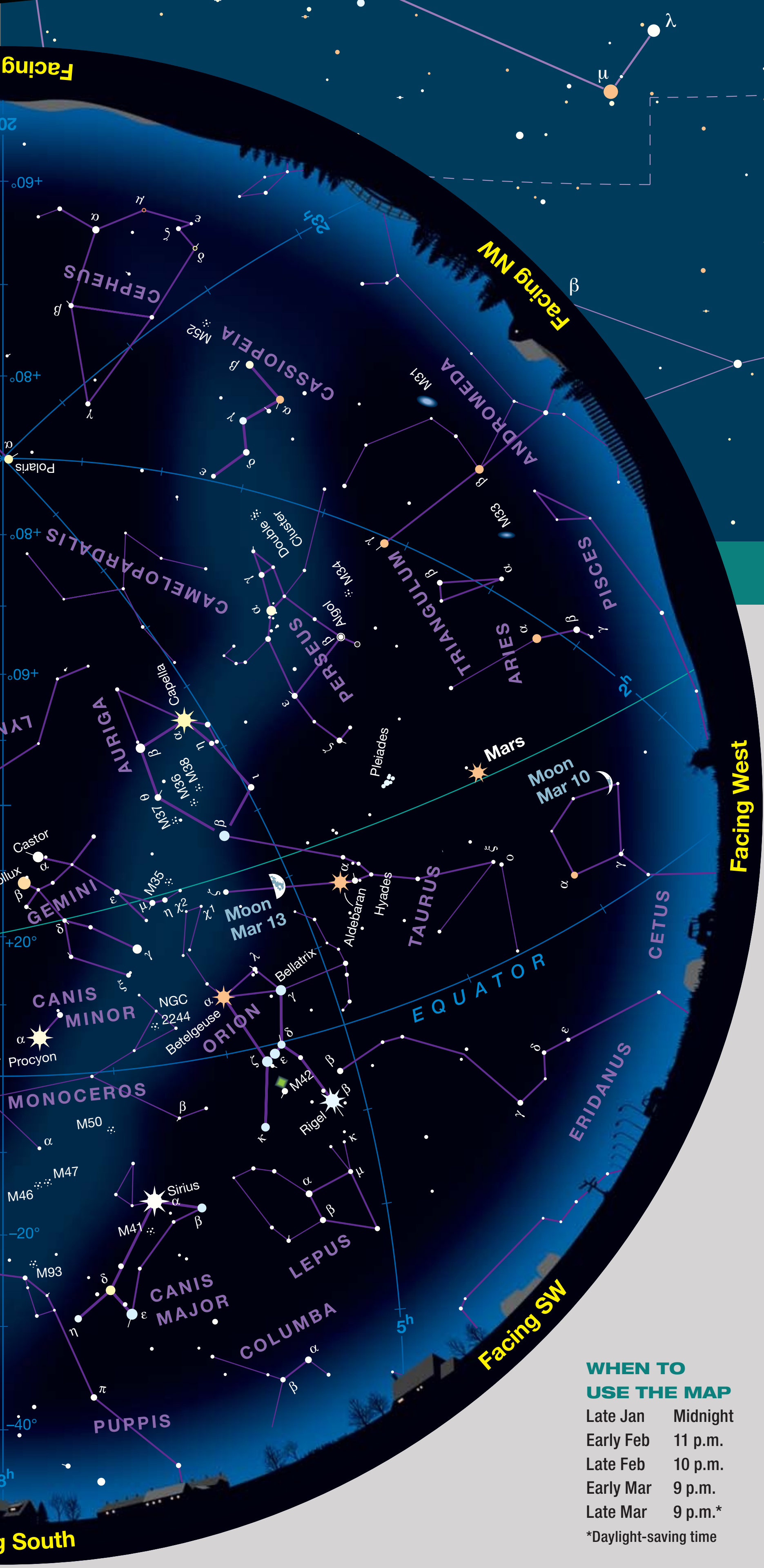
| | |
|---|---|
| • Bailly Crater | March 19 |
| • Demonax Crater | March 20 |
| • Neumayer Crater | March 21 |
| • Gill Crater | March 22 |


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.




**WHEN TO USE THE MAP**

| | |
|---|---|
| Late Jan | Midnight |
| Early Feb | 11 p.m. |
| Late Feb | 10 p.m. |
| Early Mar | 9 p.m. |
| Late Mar | 9 p.m.* |

*Daylight-saving time

**Binocular Highlight** by Mathew Wedel

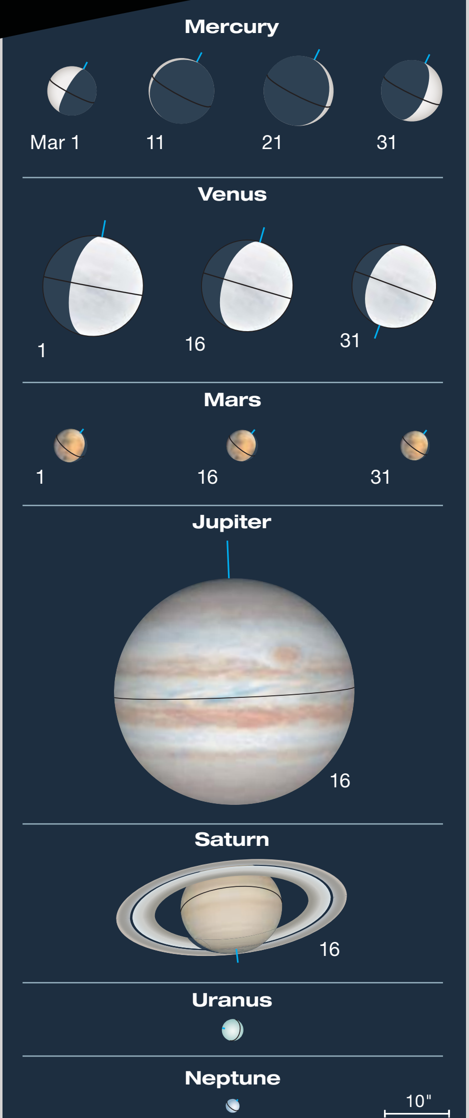
# Fly By Night

Here's something I stumbled upon last spring: a winged asterism at the western end of Leo Minor. The anchor star is **10 Leonis Minoris**, which forms an isosceles triangle with Alpha (α) and 38 Lyncis about 3° farther west. I initially sketched the asterism as a seagull, but on subsequent visits **9 Leonis Minoris** and 10 LMi struck me as the yellow eyes of a bat. Whatever you call it, this night flyer is above the horizon before midnight between November and July, but it only flies right-side up when the bright stars Pollux and Procyon are crossing the meridian (see chart at left). Hang on to Pollux and Procyon, we'll have need of them in a minute.

The "eyes," 9 and 10 Leonis Minoris, are both giant stars, larger, cooler, and more yellow-orange than the Sun. The stars that form the wings are mostly yellow-white main-sequence stars, with a few orange giants thrown in. A couple of them make for interesting comparisons. The star nearest the bird's body in the eastern "wing," **11 Leonis Minoris**, is a *G*-type main-sequence star very similar to our own Sun. It gives us a pretty good idea of what the Sun would look like from 37 light-years away. Pollux, 25° southwest in Gemini, the Twins, is about the same distance from Earth, 34 light-years, but as a *K*-type orange giant it's much brighter.

Now have a look at **HD 81440**, the middle star in the western "wing." It's an *F*-type yellow-white main-sequence star. In terms of size and spectral class it's a close match with Procyon, which lies 40° away in Canis Minor, the Little Dog. The difference in apparent brightness is down to distance: HD 81440 lies 350 light-years away, versus a mere 11 light-years for Procyon.

■ **MATT WEDEL** is gazing into the starry abyss and having fun cataloging whatever gazes back.



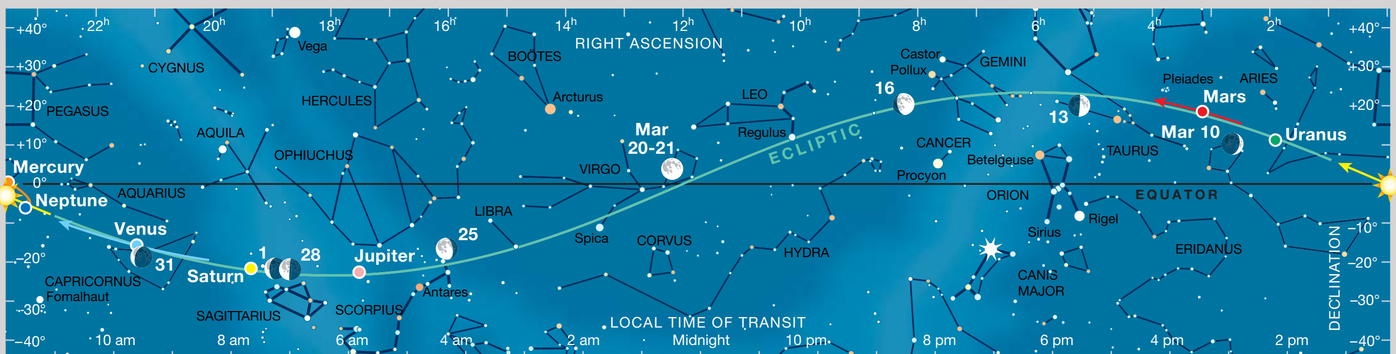

**PLANET DISKS** have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.

**PLANET VISIBILITY Mercury:** visible at dusk through the 6th • **Venus:** visible at dawn all month • **Mars:** visible at dusk, sets late evening • **Jupiter:** rises early morning, visible through dawn all month • **Saturn:** visible at dawn all month

## March Sun & Planets

| | Date | Right Ascension | Declination | Elongation | Magnitude | Diameter | Illumination | Distance |
|---|---|---|---|---|---|---|---|---|
| Sun | 1 | $22^h 45.6^m$ | −7° 53′ | — | −26.8 | 32′ 17″ | — | 0.991 |
| | 31 | $0^h 35.8^m$ | +3° 51′ | — | −26.8 | 32′ 02″ | — | 0.999 |
| Mercury | 1 | $23^h 48.2^m$ | +0° 52′ | 18° Ev | −0.2 | 7.7″ | 39% | 0.876 |
| | 11 | $23^h 44.8^m$ | +2° 17′ | 8° Ev | +3.6 | 10.2″ | 4% | 0.658 |
| | 21 | $23^h 14.4^m$ | −2° 13′ | 11° Mo | +3.2 | 10.9″ | 6% | 0.615 |
| | 31 | $23^h 08.9^m$ | −5° 29′ | 24° Mo | +0.9 | 9.5″ | 27% | 0.705 |
| Venus | 1 | $20^h 03.5^m$ | −19° 33′ | 41° Mo | −4.1 | 15.6″ | 72% | 1.070 |
| | 11 | $20^h 52.7^m$ | −17° 20′ | 39° Mo | −4.0 | 14.7″ | 75% | 1.138 |
| | 21 | $21^h 40.9^m$ | −14° 17′ | 37° Mo | −4.0 | 13.9″ | 78% | 1.204 |
| | 31 | $22^h 27.8^m$ | −10° 34′ | 35° Mo | −3.9 | 13.2″ | 81% | 1.268 |
| Mars | 1 | $2^h 27.7^m$ | +15° 17′ | 60° Ev | +1.2 | 5.3″ | 91% | 1.767 |
| | 16 | $3^h 07.7^m$ | +18° 24′ | 55° Ev | +1.3 | 4.9″ | 93% | 1.892 |
| | 31 | $3^h 48.6^m$ | +20° 57′ | 50° Ev | +1.4 | 4.7″ | 94% | 2.012 |
| Jupiter | 1 | $17^h 23.6^m$ | −22° 33′ | 78° Mo | −2.0 | 36.2″ | 99% | 5.445 |
| | 31 | $17^h 33.6^m$ | −22° 40′ | 106° Mo | −2.2 | 39.7″ | 99% | 4.963 |
| Saturn | 1 | $19^h 15.5^m$ | −21° 52′ | 52° Mo | +0.6 | 15.6″ | 100% | 10.632 |
| | 31 | $19^h 24.3^m$ | −21° 37′ | 80° Mo | +0.6 | 16.3″ | 100% | 10.178 |
| Uranus | 16 | $1^h 53.1^m$ | +11° 04′ | 35° Ev | +5.9 | 3.4″ | 100% | 20.656 |
| Neptune | 16 | $23^h 10.9^m$ | −6° 19′ | 9° Mo | +8.0 | 2.2″ | 100% | 30.920 |

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




**The Sun and planets** are positioned for mid-March; 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). "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.

# In the Ship's Keel

## There's more to learn about Canopus, the night sky's second-brightest star.


▲ **ARGO NAVIS** Once a single large constellation, Argo Navis was divided into three smaller ones. Canopus, now shining in Carina, the Keel, is the large star highlighted in blue.

JOHANNES HEVELIUS / *ATLAS COELESTIS*

Last month we began our discussion of the second-brightest of all the night's stars, Canopus. This star is visible considerably farther north — at least to latitude 37°N — than any of the other 1st-magnitude and brighter stars that are always below the horizon from the traditional latitude 40°N line. Yet Canopus seems to get less publicity than almost any of the sky's 21 brightest stars, including those I call the "Far-South Six," save for lonely Achernar (the other members of the Six, besides Canopus, are Alpha and Beta Centauri and Alpha and Beta Crucis).

Could Canopus be relatively lacking in fame because the only thing fascinating or distinctive about it is its great brightness? Nothing could be further from the truth. Let's continue our study of this star that everyone who lives in northern lands should strive to see on some southward trip.

**The thrice past and once future king.** Legend says that King Arthur will someday return, and so he has been called the "once and future king." But Canopus earns a more impressive title. In the 10-million-year period spanning from 5 million years ago to 5 million years in the future, Canopus is the only star that appears brightest in Earth's skies many times — thrice in our past and once in our future. The main reason is the star's great intrinsic brightness. Other stars, like Sirius and Vega, usurp the title of brightest in our skies when they pass quite close to us. But Canopus has an absolute magnitude of –5.7 and therefore can sometimes appear brighter than any star in Earth's night sky even from several hundred light-years away.

**The rudder of the great ship Argo.** Today, Canopus is Alpha Carinae, the brightest star in the constellation Carina, the Keel. But before the establishment of the 88 official constellations by the International Astronomical Union in 1930, Canopus was the brightest star in the biggest constellation of all in Western classical culture: Argo, the ship of Jason and his crew in Greek mythology. Argo was split into Carina, the Keel; Vela, the Sails; and Puppis, the Poop Deck. Vela and Puppis are rich, fascinating constellations that are pretty easily visible from latitude 40° north, but Carina is more southerly. Oddly, only about half of Argo was ever portrayed by stars in the heavens, and the ship as pictured sails backwards in its nightly journey across the sky. So Canopus, which marks the rudder at the back of the ship, actually leads Argo (or today the three constellations that were parts of Argo) in the journey across the sky each night.

**The pilot or navigator of ships and spaceships.** In Greek legend, Canopus was the name of the man who piloted the fleet of Menelaus when that red-haired king and husband of Helen tried to sail home from the Trojan War. The story goes that when the ships landed in Egypt, Canopus went ashore and was killed by the bite of a venomous snake. In his honor, Menelaus named after his pilot not only the harbor there but also the bright star that rose during his dedicatory speech.

At least 3,000 years after the reputed time of the Trojan War, the star Canopus became a new kind of navigator. The star was used along with the Sun, Earth, and other planets to guide interplanetary spacecraft. Why? For a reason I figured out playing with my *Norton's Star Atlas* as an adolescent: Canopus is the really bright star farthest from the ecliptic in the heavens.

**How much yellow do you see in the heavens' second-brightest star?** Historical claims that Canopus appears yellow or even orange are probably based on the reddening of the star when seen near the horizon. But Canopus is most likely an *F*-type star, possibly even a supergiant. What do you readers who observe the star high in the sky say about its color?

■ Contributing Editor **FRED SCHAAF** welcomes your letters and comments at **fschaaf@aol.com**.

To find out what's visible in the sky from your location, go to skypub.com/almanac.

# Three Worlds at Dawn

During the night's second half, three planets come into view.

After the first week of March, Mercury disappears into the Sun's afterglow. That yet again leaves dimming Mars as the only bright planet visible in the evening sky — but at least it beautifully drifts up near the Pleiades by month's end. A few hours after the late-evening setting of Mars, Jupiter rises. It's followed about two hours later by Saturn. Still later, Venus rises, near dawn's first light. By late March, Mercury, having passed into the morning sky, is creeping into view below Venus around the time Jupiter is highest in the south.

## DUSK ONLY

**Mercury** was at greatest eastern elongation in the evening sky on February 27th. It starts March still setting about 1½ hours after the Sun and shining at magnitude +0.1 with its 8″-wide disk about 35% lit. But this innermost planet is fading rapidly as its phase thins and by about March 6th is fainter than magnitude 2.0 and no longer readily detectable. Mercury reaches inferior conjunction with the Sun on March 15th — just two inferior conjunctions before the one in which it will transit across the face of the Sun for the last time in 13 years (the transit this November 11th will be visible in the Americas, Europe, and Africa).

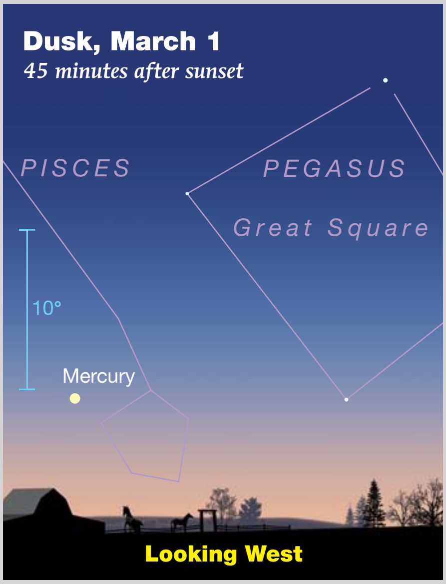
**Neptune** is at conjunction with the Sun on March 7th and not viewable this month. **Uranus** can still be observed when the last of evening twilight fades, though it appears lower and lower at that time with each passing week in March (see the September 2018 issue, pages 48–49, for a finder chart).

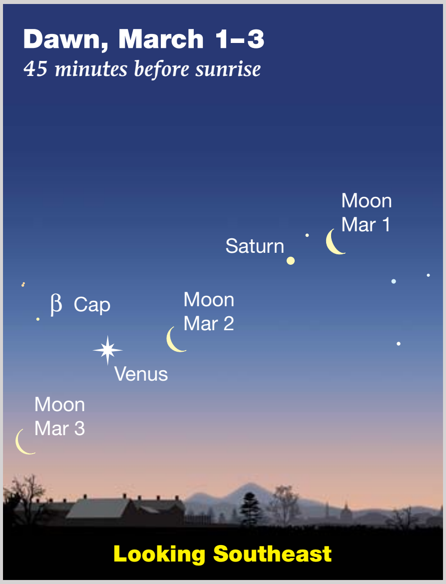
## DUSK AND EVENING

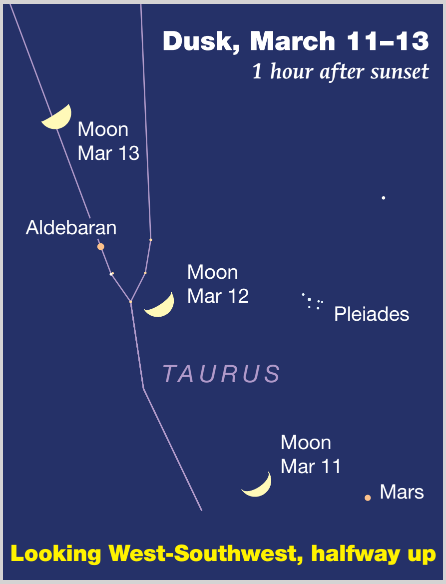
**Mars** is almost halfway up the southwest sky an hour after sunset this month and doesn't set itself until near midnight daylight-saving time. Unfortunately, the Red Planet dims even further in March — from magnitude 1.2 to 1.4 — with its disk decreasing from 5.3″ to 4.6″ wide. At least Mars passes through a lovely section of the zodiac in March, appearing some 3° below the Pleiades at month's end.

## PRE-DAWN AND DAWN

**Jupiter** rises around 2 a.m. standard time on March 1st but not too long after 1 a.m. daylight-saving time on March 31st. Its magnitude brightens from –2.0 to almost –2.3 this month, its equatorial diameter increasing from 36″ to almost 40″. Jupiter passes through western quadrature (90° west of the Sun) in March, improving views of some of the phenomena of its Galilean satellites (see page 51). The best time to get a sharp view of Jupiter's many



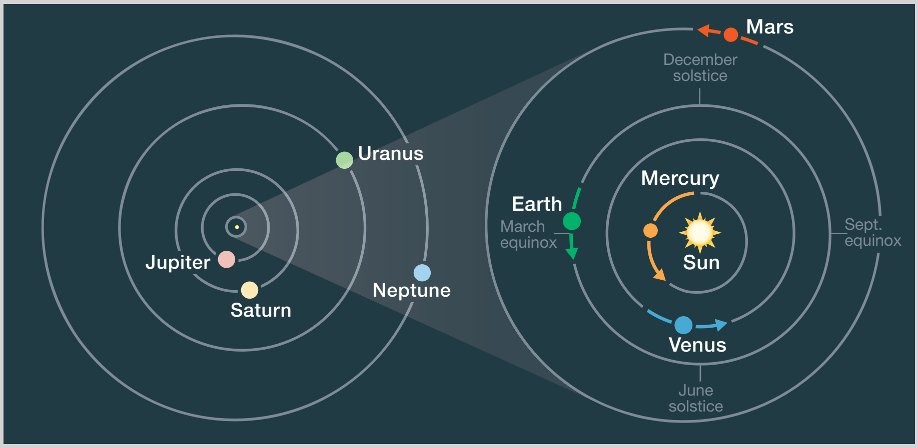



cloud features is when it's at its highest before sunrise. Jupiter culminates a bit earlier each day, reaching the meridian a little after sunrise at the beginning of the month but almost an hour before sunrise at the end.

**Saturn** clears the horizon about two hours after Jupiter at the start of March. Once Saturn is high enough we can see it and Jupiter shine to either side of the Teapot asterism of Sagittarius (Saturn to the left or upper left and Jupiter to the upper right of the pattern). Jupiter is ever so gradually catching up to Saturn. The long-awaited next conjunction of these two slow-moving giants will occur fairly low in the evening sky in December 2020 — and will be a historically close one. In March 2019 Saturn is at a minimum in brightness — magnitude +0.6 — and its equatorial diameter is 16″. The wondrous rings are tilted close to 24° from edge-on.

## DAWN

**Venus** begins March rising about 2 hours before the Sun, but the interval gets a little shorter by the end of the month. Venus fades from magnitude –4.1 to –3.9 during March, its disk shrinking from 16″ to 13″ wide as its illuminated fraction increases from 72% to 81%. But Venus stands only about 10° above the southeast horizon at 45 minutes before sunrise as the month opens.




**ORBITS OF THE PLANETS**

The curved arrows show each planet's movement during March. The outer planets don't change position enough in a month to notice at this scale.

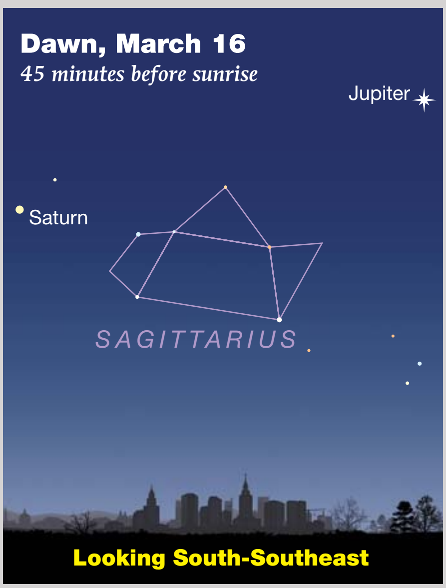
At month's end **Mercury** rises about an hour before the Sun. But the planet appears very low in the southeast and is a difficult sight for observers at mid-northern latitudes.

## SUN AND MOON

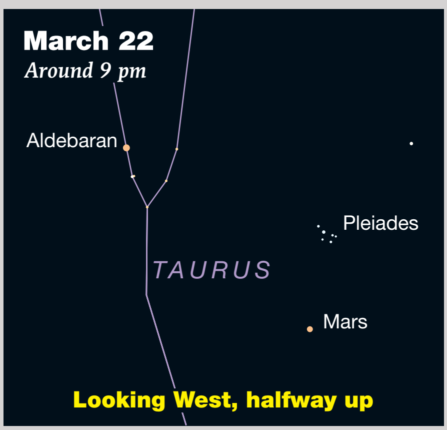
**The Sun** reaches the March equinox at 5:58 p.m. EDT on March 20th. This event marks the beginning of spring in the Northern Hemisphere and start of autumn in the Southern Hemisphere.

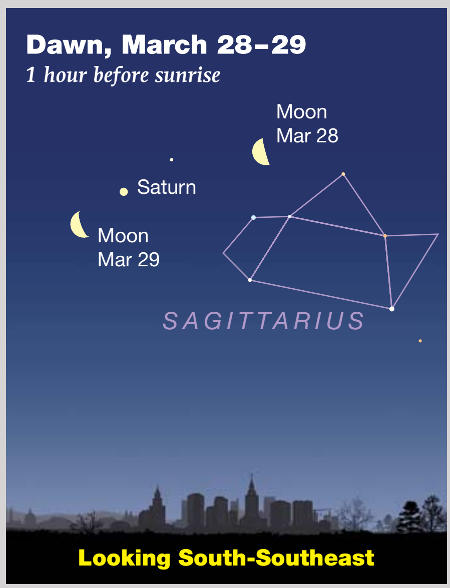
**The Moon** hangs as a waning crescent 3° right or upper right of Saturn on the morning of March 1st (a daytime occultation of Saturn by the Moon is visible from Texas, Central America, and large swathes of the Pacific Islands). At dawn on March 2nd a slender lunar sliver is 4° right of bright Venus. On the evening of March 11th the waxing crescent Moon is around 7° upper left of Mars, and the next evening lower right of the Hyades. On the night of March 18th, the waxing gibbous Moon shines near Regulus. The waning Moon is 4° left or lower left of Jupiter at dawn on March 27th and some 3° lower left of Saturn on the morning of March 29th.

■ Contributing Editor **FRED SCHAAF** has been writing about the skies above us for more than 40 years.




◀▼▶ 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.




Charles Messier detected the open cluster M93 on the night of the spring equinox, March 20, 1876. The field of view of this image is 30′. Messier estimated the cluster's width at 8′ while William Herschel pegged it as almost twice as wide.

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# Starfish and Stragglers

Celebrate spring by recreating Messier's historic discovery of a striking star cluster.

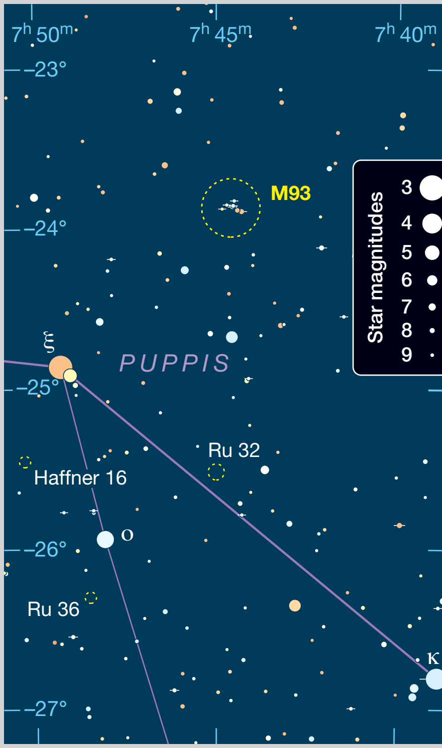
The third week of March 1781 was particularly busy for Charles Messier, the famed French comet hunter. Prompted by the discovery of a faint object in Virgo by his interlocutor Pierre Méchain, Messier spent the night of March 18th observing eight new deep-sky objects in what we now know as the Virgo Cluster. (The number bumps to nine if you include the lenticular galaxy detected by Méchain on March 4th but drops to six if you discount both Méchain's discovery and a galaxy previously logged by Johann Elert Bode.) The temperatures in Paris were slightly warmer than typical that week, so we can imagine Messier was feeling comfortable and possibly excited by the potential for further discoveries as he settled in with his 100-mm refractor at the Naval Observatory on Paris's Left Bank on March 20th.

Messier discovered only a single object that night, a modest open star cluster. He duly entered the cluster into the fourth edition of his "Catalogue of Nebulae and Star Clusters" as No. 93, laconically describing it as "a cluster of small stars, without nebulosity, between the Greater Dog [Canis Major] and the prow of the ship [Puppis, once part of Argo Navis]." He estimated it to be about 8′ (arcminutes) across.

Was Messier disappointed that he logged just one deep-sky object on March 20th? It must have been a bit anticlimactic after the long list he'd written two nights earlier. As it turned out, M93 was one of his last original discoveries (excluding comets), and the fourth edition of his catalog, which was published in the *Connoissance des Temps* for 1784, would be the final version. Since he didn't include his feelings along with the positional data for the modest open cluster, we can only guess as to his mindset, but I suspect he was relieved to have the majority of what he considered nuisance objects cataloged so he could get back to the real task at hand, hunting comets.

Nothing in Messier's commentary suggests that M93 offered anything particularly special to the observer, but words can be deceptive. In fact, the open cluster boasts a lengthy observational history, partly because it's visually interesting and partly because it's an easy target, hovering at the edge of naked-eye visibility. Even the most modest scope can pick up the 6th-magnitude cluster, and if you're well away from light pollution, you should be able to spot it without optical aid 1½° northwest of the yellow supergiant Xi (ξ) Puppis.

As astronomers following Messier soon noted, M93 looks good in the eyepiece. Caroline Herschel made the next recorded observation of the cluster after Messier's, sweeping it up with her small scope on February 26, 1783. She invited her brother, William, to examine it under more magnification, and they found it consisted of perhaps 100 or 150 stars that were "very beautiful, nothing nebulous among them." William revisited M93 in November 1784 and described it as "a cluster of scattered stars, pretty close and nearly of a size, the densest part of it about 15′ diam., but the rest very extensive."




◀ Follow William Henry Smyth's directions to find the general location of M93: ". . . a line from Orion's sword-cluster, led through Sirius, strikes upon it 16° beyond, where it will be intersected by a ray from Castor through Procyon." M93 is 1½° northwest of Xi Puppis.

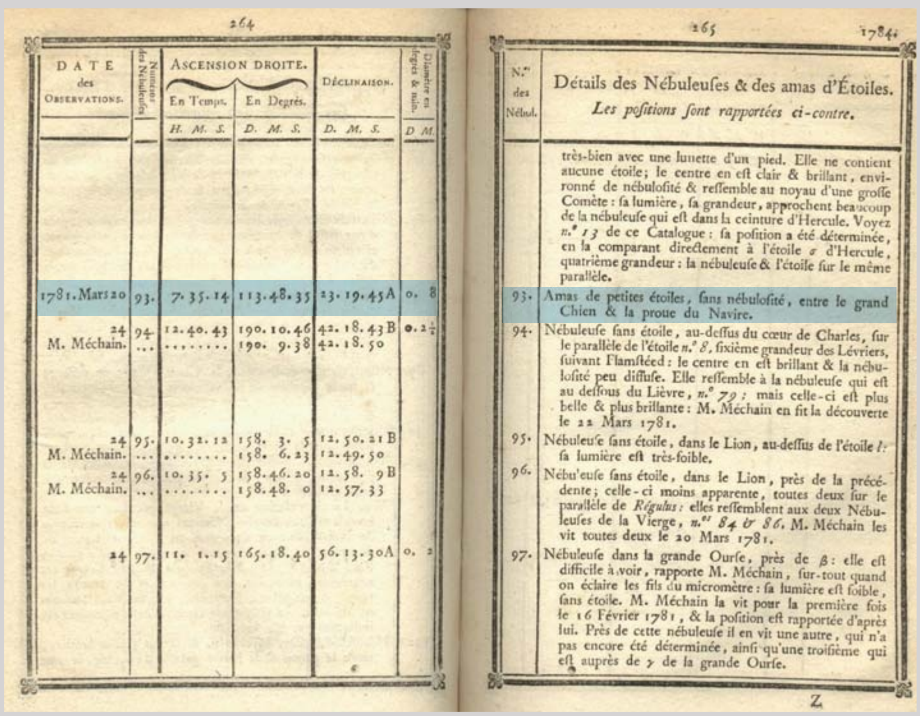
A more imaginative take on the cluster had to wait for the pen of Admiral William Henry Smyth. In the second volume of *A Cycle of Celestial Objects*, now known by amateur astronomers as "The Bedford Catalogue" after Smyth's town of residence in the United Kingdom, he directed readers to imagine two rays, one shooting from Castor through Procyon, another from Orion's sword through Sirius. The cluster, "a neat group . . . of a star-fish shape" shines at the intersection of the two rays.

It's an oddly shaped starfish, though. Through 10×50 binoculars, M93 looks more like a fat squid or a jellyfish floating across the sky, its body angled northeast-southwest. More magnification strengthens the illusion. Tentacles fill out with fainter stars, and a 8.2-magnitude orange-yellow star, HD 62679, caps the body.

Smyth mocked a fellow astronomer who mistook M93 for a comet, but once you've imagined the cluster as a sea creature with two arms, it's not difficult to see how this could happen.

The stars comprising M93 formed around the same time from the same molecular cloud, so they're the same composition, age (approximately 400 million years old), and distance from Earth (about 3,600 light-years). As a star cluster ages, more and more of its higher-mass stars move off the main sequence, evolving into red giants. With an aged cluster, we'd expect a Hertzsprung-Russell (H-R) diagram to show fewer stars at the top of the main sequence, with a large group of red giants clumped at the top right (see page 18). This holds true for M93 for the most part, as the majority of the cluster's 16 known red giants sit where they're expected to on the diagram. But three cluster stars, #26, #38, and #42, aren't in their "proper" place; rather, they've moved toward the *Hertzsprung gap*, the less populated area of the diagram between the main-sequence and red giant branches and above the subgiant branch. Spectral data obtained with the Fibre-fed Extended Range Optical Spectrograph at the European Southern Observatory's 2.2-meter telescope at La Silla reveal these three as *yellow stragglers*, red giants whose color may be affected by the presence of a bluer main-sequence companion. Instead of hanging out with their buddies on the right side of the H-R diagram, these binary systems appear more centrally located because the primary appears more yellow in color thanks to "contamination" by its secondary. A fourth red giant, cluster star #25, is also a suspected binary, but since its color hasn't shifted toward the yellow, astronomers think its companion is probably a very a faint main-sequence star. Successful detection of straggler stars can help astronomers check their predictive simulations on binary stellar evolution in clusters.

While professional astronomers study these straggler stars spectroscopically, amateur visual observers can follow in the footsteps of Messier, the Herschels, and Smyth. A 5- or 6-inch reflector at low magnifications will easily provide enough separation in the cluster stars for you to detect #25, #26, #38, and #42. Whether you see a starfish or a squid, M93 is a worthy object to include on your springtime observing list.



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| DATE des OBSERVATIONS. | Numéros des Nébuleuſes | ASCENSION DROITE. En Temps. H. M. S. | En Degrés. D. M. S. | DÉCLINAISON. D. M. S. | Diamètre en degrés & min. D M. |
|---|---|---|---|---|---|
| 1781. Mars 20 | 93. | 7. 35. 14 | 113. 48. 35 | 23. 19. 45 A | 0. 8 |
| 24 | 94. | 12. 40. 43 | 190. 10. 46 | 42. 18. 43 B | 0. 2½ |
| M. Méchain. | ... | ........ | 190. 9. 38 | 42. 18. 50 | |
| 24 | 95. | 10. 32. 12 | 158. 3. 5 | 12. 50. 21 B | |
| M. Méchain. | ... | ........ | 158. 6. 23 | 12. 49. 50 | |
| 24 | 96. | 10. 35. 5 | 158. 46. 20 | 12. 58. 9 B | |
| M. Méchain. | ... | ........ | 158. 48. 0 | 12. 57. 33 | |
| 24 | 97. | 11. 1. 15 | 165. 18. 40 | 56. 13. 30 A | 0. 2 |

265 1784.

| N.os des Nébul. | Détails des Nébuleuſes & des amas d'Étoiles. *Les poſitions ſont rapportées ci-contre.* |
|---|---|
| | très-bien avec une lunette d'un pied. Elle ne contient aucune étoile; le centre en eſt clair & brillant, environné de nébuloſité & reſſemble au noyau d'une groſſe Comète : ſa lumière, ſa grandeur, approchent beaucoup de la nébuleuſe qui eſt dans la ceinture d'Hercule. Voyez *n.° 13* de ce Catalogue : ſa poſition a été déterminée, en la comparant directement à l'étoile σ d'Hercule, quatrième grandeur : la nébuleuſe & l'étoile ſur le même parallèle. |
| 93. | Amas de petites étoiles, ſans nébuloſité, entre le grand Chien & la proue du Navire. |
| 94. | Nébuleuſe ſans étoile, au-deſſus du cœur de Charles, ſur le parallèle de l'étoile *n.° 8*, ſixième grandeur des Lévriers, ſuivant Flamſtéed : le centre en eſt brillant & la nébuloſité peu diffuſe. Elle reſſemble à la nébuleuſe qui eſt au deſſous du Lièvre, *n.° 79* : mais celle-ci eſt plus belle & plus brillante : M. Méchain en fit la découverte le 22 Mars 1781. |
| 95. | Nébuleuſe ſans étoile, dans le Lion, au-deſſus de l'étoile *l* : ſa lumière eſt très-foible. |
| 96. | Nébuleuſe ſans étoile, dans le Lion, près de la précédente; celle-ci moins apparente, toutes deux ſur le parallèle de *Régulus* : elles reſſemblent aux deux Nébuleuſes de la Vierge, *n.os 84 & 86*. M. Méchain les vit toutes deux le 20 Mars 1781. |
| 97. | Nébuleuſe dans la grande Ourſe, près de β : elle eſt difficile à voir, rapporte M. Méchain, ſur-tout quand on éclaire les fils du micromètre : ſa lumière eſt foible, ſans étoile. M. Méchain la vit pour la première fois le 16 Février 1781, & la poſition eſt rapportée d'après lui. Près de cette nébuleuſe il en vit une autre, qui n'a pas encore été déterminée, ainſi qu'une troiſième qui eſt auprès de γ de la grande Ourſe. |

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▶ Charles Messier included M93 in the fourth edition of his "Catalogue of Nebulae and Star Clusters," published in 1781.

PUBLIC DOMAIN

# Lunar Occultation

**THERE ARE NO OCCULTATIONS** of 1st-magnitude stars by the Moon visible from North America in 2019. The brightest stars to be hidden by the Moon (at least for our continent) range only from magnitudes 2.9 to 3.9: Delta$^1$ Tauri; Zeta Tauri; Delta, Eta, and Mu Geminorum; Gamma Librae; and Gamma Capricorni. The next 1st-magnitude event involves Antares in 2023, with visibility limited to Florida.

In the meantime, we enjoy the dimming of lesser lights. On the night of March 12–13, the Moon passes in front of Delta$^1$ (δ) Tauri (HD 27697) in the Hyades for western North America. The waxing crescent will be heading toward its set, standing only 20° or 25° high when the dark leading limb slips across the 3.8-magnitude star. Delta$^1$ disappears at the Moon's northeastern edge near or after $6^h$ UT and reappears at the west-northwestern edge less than an hour later. The reappearance may be difficult to detect as it occurs at the Moon's bright limb. The Moon is only 10° or 15° above the horizon at most at that point, so atmospheric effects add to the challenge.

About 25 or 30 minutes after Delta$^1$ goes missing, the Moon occults Delta$^2$ (HD 27819). The 4.8-magnitude star disappears behind the Moon's eastern, dark limb. We won't see the star again this night, as the Moon sets before the star reappears at its bright limb.

Observers near Seattle, Salt Lake City, and other places along the northern limits of the occultation path should watch for a grazing event, when Delta$^1$ seems to skim by the Moon's northern limb, very near the terminator. Look for the star to blink on and off as it's covered and revealed by the moving Moon's valleys and mountains. A few minutes after the graze event, the Moon's leading edge covers Delta$^2$.

Delta$^1$ is a known double, and observations of the occultation are highly desired by the International Occultation Timing Association (IOTA). Timetables are available from the IOTA website (**https://is.gd/IOTApredict**). You can also calculate predictions for your observing site using IOTA's free software program, Occult (**https://is.gd/IOTAoccult**).

Here are some times for a few major cities. For Delta$^1$: **Sacramento,** *disappearance* 10:56 p.m., *reappearance* 11:45 p.m. PDT; **Los Angeles,** *d.* 10:58 p.m., *r.* 11:53 p.m. PDT; **Seattle,** *graze* 11:13 p.m. PDT; **Denver,** *d.* 12:11 MDT, *gr.* 12:20 MDT; **Salt Lake City,** *gr.* 12:18 a.m. MDT.

For Delta$^2$: **Seattle,** *d.* 11:16 p.m. PDT; **Sacramento,** *d.* 11:22 PDT; **Los Angeles,** *d.* 11:27 p.m. PDT; **Salt Lake City,** *d.* 12:23 a.m. MDT; *d.* **Denver,** 12:25 a.m. MDT.

## Minima of Algol

| Feb. | UT | Mar. | UT |
|---|---|---|---|
| 1 | 8:06 | 2 | 0:19 |
| 4 | 4:55 | 4 | 21:09 |
| 7 | 1:45 | 7 | 17:58 |
| 9 | 22:34 | 10 | 14:47 |
| 12 | 19:23 | 13 | 11:36 |
| 15 | 16:13 | 16 | 8:26 |
| 18 | 13:02 | 19 | 5:15 |
| 21 | 9:51 | 22 | 2:04 |
| 24 | 6:41 | 24 | 22:54 |
| 27 | 3:30 | 27 | 19:43 |
| | | 30 | 16:32 |

These geocentric predictions are from the recent heliocentric elements Min. = JD 2445641.554 + 2.867324*E*, where *E* is any integer. For a comparison-star chart and more info, see **skyandtelescope.com/algol**.

# Action at Jupiter

**JUPITER SHINES** on in Ophiuchus in March, rising about 2 a.m. local standard time as the month opens. By the 31st, its rise time has crept forward only to about 1:30 a.m., thanks to daylight-saving time.

Jupiter stands highest in the south as the Sun rises. You may notice an improvement in visibility as the planet brightens from magnitude –2.0 to –2.2 over the course of the month. Jupiter broadens in March as well, its equatorial diameter increasing from 36″ wide to 40″ wide by the 31st.

Any telescope shows the four big Galilean moons, and binoculars usually show at least two or three. Use the diagram on the facing page to identify them at any date and time.

The March interactions between Jupiter and its satellites and their shadows are tabulated on the facing page. Find events timed for when Jupiter is at its highest in the early morning hours.

Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Daylight Time is UT minus 4 hours.)

**Feb. 1:** 4:01, 13:57, 23:53; **2:** 9:48, 19:44; **3:** 5:40, 15:36; **4:** 1:31, 11:27, 21:23; **5:** 7:19, 17:14; **6:** 3:10, 13:06, 23:02; **7:** 8:57, 18:53; **8:** 4:49, 14:45; **9:** 0:40, 10:36, 20:32; **10:** 6:28, 16:23; **11:** 2:19, 12:15, 22:11; **12:** 8:06, 18:02; **13:** 3:58, 13:53, 23:49; **14:** 9:45, 19:41; **15:** 5:36, 15:32; **16:** 1:28, 11:24, 21:19; **17:** 7:15, 17:11; **18:** 3:06, 13:02, 22:58; **19:** 8:54, 18:49; **20:** 4:45, 14:41; **21:** 0:36, 10:32, 20:28; **22:** 6:24, 16:19; **23:** 2:15, 12:11, 22:06; **24:** 8:02, 17:58; **25:** 3:54, 13:49, 23:45; **26:** 9:41, 19:36; **27:** 5:32, 15:28; **28:** 1:23, 11:19, 21:15

**Mar. 1:** 7:11, 17:06; **2:** 3:02, 12:58, 22:53; **3:** 8:49, 18:45; **4:** 4:41, 14:36; **5:** 0:32, 10:28, 20:23; **6:** 6:19, 16:15; **7:** 2:10, 12:06, 22:02; **8:** 7:57, 17:53; **9:** 3:49, 13:45, 23:40; **10:** 9:36, 19:32; **11:** 5:27, 15:23; **12:** 1:19, 11:14, 21:10; **13:** 7:06, 17:01; **14:** 2:57, 12:53, 22:48; **15:** 8:44, 18:40; **16:** 4:35, 14:31; **17:** 0:27, 10:22, 20:18; **18:** 6:14, 16:09; **19:** 2:05, 12:01, 21:56; **20:** 7:52, 17:48; **21:** 3:43, 13:39, 23:35; **22:** 9:30, 19:26; **23:** 5:22, 15:17; **24:** 1:13, 11:09, 21:04; **25:** 7:00, 16:56; **26:** 2:51, 12:47, 22:43; **27:** 8:38, 18:34; **28:** 4:30, 14:25; **29:** 0:21, 10:17, 20:12; **30:** 6:08, 16:03; **31:** 1:59, 11:55, 21:50.

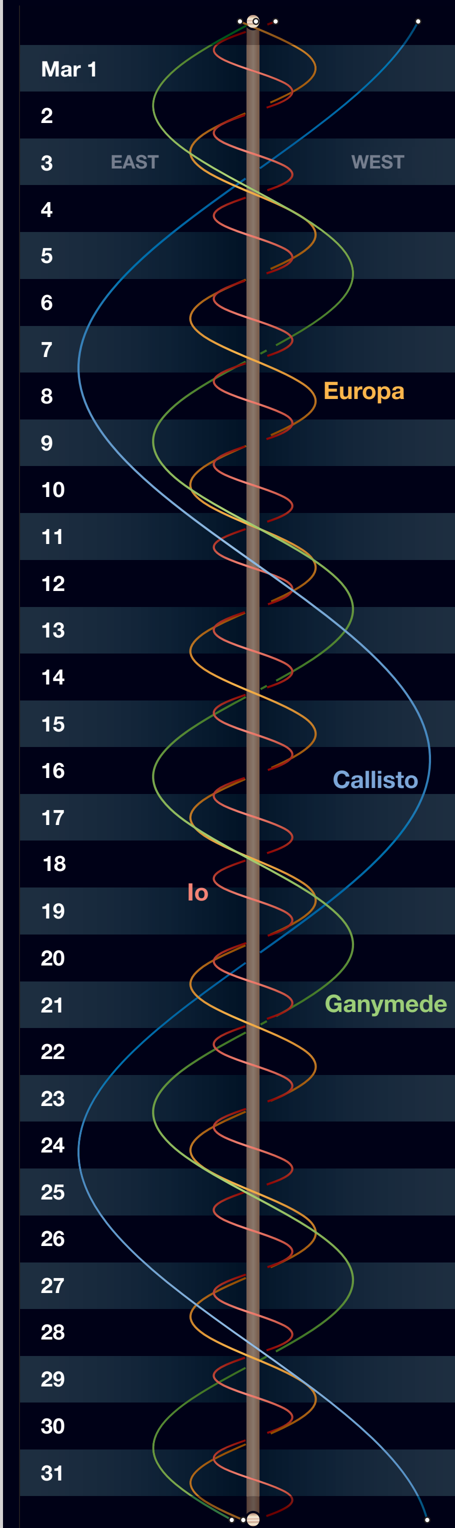
These times assume that the spot will be centered at System II longitude 298°. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 298° and 1⅔ minutes later for each degree more than 298°.

## Phenomena of Jupiter's Moons, March 2019

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 4 hours ahead of Eastern Daylight Time). Next is the satellite involved: **I** for Io, **II** Europa, **III** Ganymede, or **IV** Callisto. Next is the type of event: **Oc** for an occultation of the satellite behind Jupiter's limb, **Ec** for an eclipse by Jupiter's shadow, **Tr** for a transit across the planet's face, or **Sh** for the satellite casting its own shadow onto Jupiter. An occultation or eclipse begins when the satellite disappears **(D)** and ends when it reappears **(R)**. A transit or shadow passage begins at ingress **(I)** and ends at egress **(E)**. Each event is gradual, taking up to several minutes. Predictions courtesy IMCCE / Paris Observatory.

## Jupiter's Moons




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

# Expectation and Observation

Amateurs can benefit greatly by approaching the eyepiece without preconceived notions.

Even as the 20th century drew to a close, visual observers of the planets continued to make unexpected discoveries. Two sterling examples were the work of Stephen James O'Meara.

In 1976 O'Meara reported the presence of dusky radial "spokes" in Saturn's B ring — delicate, ephemeral features that had been independently recorded in 1887 by Thomas Gwyn Elger in England and Charles-Émile Stuyvaert in Belgium. Five years later, O'Meara was able to determine an accurate rotation period of features in the temperate latitudes of distant Uranus (*S&T*: Sept. 2012, p. 54).

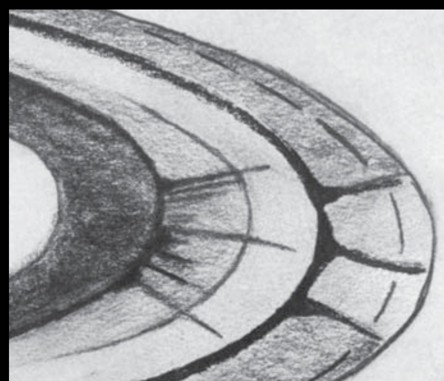
These remarkable feats of visual acuity, both accomplished using a surprisingly modest aperture (the 9-inch Clark refractor at the Harvard-Smithsonian Center for Astrophysics), were initially greeted with skepticism and even derision. The credibility of visual observers had been irreparably damaged early in the 20th century by the bitter debate that raged for decades over the presence of canals on Mars.

In a 1967 address to the Arizona Academy of Sciences, Gerard Kuiper (1905–1973), the leading American planetary scientist of his generation, complained about the lingering effects of the Martian canal debate:

> *The careful observers with better telescopes who continued to denounce the "canals" as optical illusions were castigated. This controversy brought disrepute to planetary science and weakened its status in universities. To this day the effects have not been overcome and affect even the NASA programs adversely through inadequate academic scientific support.*

Kuiper went on to attribute the longevity of the canals myth to a perverse rating system that emerged among the amateur community of Mars observers during the 1920s:

> *[I]t is instructive to see how the cult was perpetuated in semi-professional literature for decades. For many years W. H. Pickering, the brother of the famous Harvard astronomer E. C. Pickering, collected amateur observations of Martian canals and published the results in 44 reports in* Popular Astronomy. *The amateur observers were "rated" by the number of "canals" they had noted. Thus, there was a premium on reporting many canals.*



▲The presence of radial "spokes" like those in the left ansa of Saturn's rings in this Voyager 2 image (top) were seen and sketched years earlier by Stephen James O'Meara (above).

NASA / JPL / USGS; SATURN SKETCH: STEPHEN JAMES O'MEARA

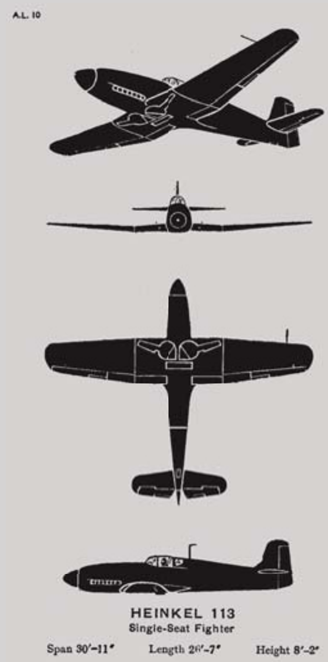
The notion that under good atmospheric conditions any observer worth his salt and equipped with a decent telescope should be able to see canals on Mars persisted well into the 1960s. The Cave Optical Company's 1962 catalog enticed prospective customers with the claim that "Mars is seen in a wealth of very fine maria and canal detail" through the firm's 10-inch Astrola reflectors. Readers of the 1964 Optical Craftsmen telescope catalog were assured that "much of the subtle canal network of Mars can be observed at favorable oppositions" using their 8-inch "Connoisseur Series" telescope.

The history of astronomy is rife with examples of the phenomenon that cognitive psychologists call "expectation bias." When William Herschel discovered Uranus in 1781, he initially mistook the pale green orb for an approaching comet. For several weeks he reported that its diameter was steadily increasing even though the apparent size of the receding planet was actually decreasing. Yet Herschel was the greatest observational astronomer of his era.

A cautionary tale of the interplay of expectation and observation from the annals of military history is worth recounting here. Fifteen months before the outbreak of World War II, an experimental fighter plane known as the Heinkel He-100 captured the world air speed record for Germany. Plagued by overheating engines, a fragile cooling system, and a rash of landing gear failures, the design was rejected by the German Air Ministry in favor of the Messerschmitt Me-109, which would serve as the Luftwaffe's principal single-engine fighter throughout the coming war. The 12 He-100 prototypes were relegated to the defense of the Heinkel factory at Rostock on the Baltic coast. Manned by factory test pilots, they would never fire a shot in anger.

In the spring of 1940 the German Propaganda Ministry decided to put the idle He-100s to good use. Re-christened the Heinkel He-113, the aircraft were painted with the insignia of fictitious squadrons and staged on several airfields. Heinkel factory workers posed as Luftwaffe pilots and ground crewmen in a series of photographs that appeared in German newspapers and magazines to accompany the announcement that a sleek new fighter of unrivalled performance was beginning to enter Luftwaffe service.

The ruse was a resounding success. The British military intelligence services warned pilots and anti-aircraft gunners that they would soon be encountering the He-113. Within a month Royal Air Force pilots began to report dogfights with He-113s over the English Channel. Some pilots even contrasted the He-113's appearance and performance with those of the Messerschmitt Me-109, the aircraft they had actually encountered.



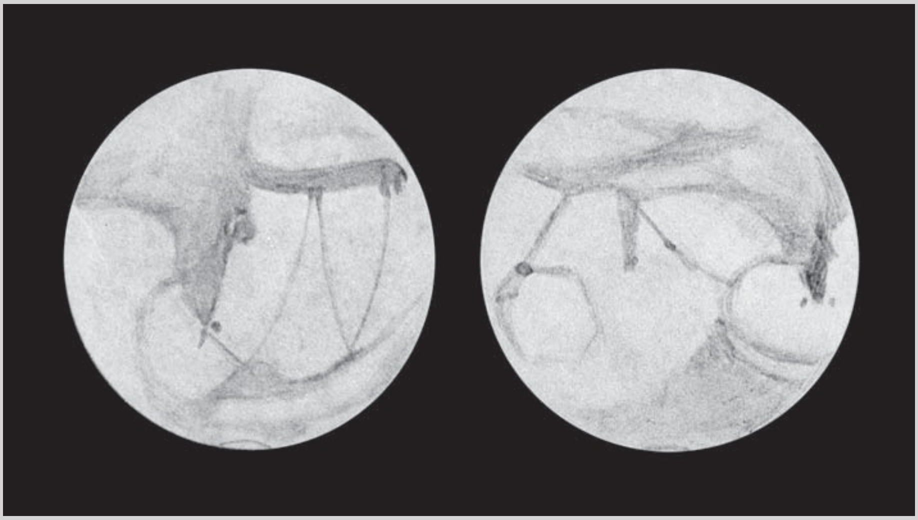

▶ During World War II scores of Allied pilots reported encounters with the Heinkel He-113 despite the fact that the handful of prototypes were never used in combat.

Pilots, anti-aircraft gunners, and aircraft spotters on both sides received extensive training in aircraft recognition. The ability to rapidly and accurately identify both friendly and enemy aircraft was literally a matter of life and death. Posters and flash cards featuring aircraft silhouettes were widely employed to foster the ability to recognize aircraft at a glance.

Although the He-113 did bear a superficial resemblance to the Me-109, it had salient differences that should never have eluded a trained eye. Yet reports of encounters with He-113s continued for years. It was only after the war that the British realized the extent to which they had been hoodwinked. More than a twinge of embarrassment may account for the fact that the Air Ministry's files on the He-113 were only declassified almost 30 years after the end of the war.

How were such highly trained observers repeatedly deceived? The answer is really quite simple — they "saw" what they were led to expect to see, just like the host of observers who "saw" a network of canals on Mars. The same interplay of expectation and observation has no doubt contributed to the controversial reports of the ashen light of Venus and Transient Lunar Phenomena ("TLPs"). The story of the He-113 is worth recalling if only momentarily whenever we look through a telescope. As any trial lawyer will attest, eyewitness testimony can be very unreliable.

■ Contributing Editor **TOM DOBBINS** is a lifelong student of astronomy as well as military history.



▶ These 1969 drawings by the well-known optician and observer Thomas Cave demonstrates that skilled observers continued to depict Martian canals until their existence was conclusively disproved when NASA's Mariner 9 orbiter mapped the Red Planet from pole to pole in 1971. South is up.

MARS DRAWING: THOMAS A. CAVE; FIGHTER ID CARD: WIKI COMMONS


# The Great Twin Brethren

The Roman brothers stand high these spring nights.

▲ Supernova 2015I was discovered by T. Noguchi of Chiba Prefecture, Japan, on February 5, 2015, in the spiral galaxy NGC 2357. The Type Ia supernova peaked at magnitude 14.0.

MARK WALTERS

*Back comes the Chief in triumph,*
*Who, in the hour of fight,*
*Hath seen the Great Twin Brethren*
*In harness on his right.*
*Safe comes the ship to haven,*
*Through billows and through gales,*
*If once the Great Twin Brethren*
*Sit shining on the sails.*
— Thomas Babington Macaulay, *Lays of Ancient Rome*, 1842

High in our evening sky, the constellation Gemini depicts Castor and Pollux, the great twin brethren of Roman mythology. During their voyage with Jason on the great ship Argo, a star alit on each of their heads as a raging storm calmed. When later mariners saw dual flames of electrical discharge, now known as St. Elmo's Fire, dance on their ship's masts and rigging, they said it was the twins protecting them. A single light was an ill omen — a visit from Helen, the sister of Castor and Pollux, who was the ruin of Troy.

The star **Castor** is an amazing triple double, three sets of close pairs orbiting each other in an intricate ballet. Through my 130-mm refractor at 37×, brilliant Castor AB is dazzling white with much dimmer C glowing orange and very widely separated to the south-southeast. Boosting the magnification to 102× pries A and B apart with room to spare. The A component looks white, but its companion to the northeast seems to have a touch of yellow.

Although that's as far as a telescope can take us, our mind's eye introduces us to the rest of the crew. Each visible star is a close binary, a revelation made clear by its spectra. All six components are main-sequence stars heated by hydrogen fusion in their cores. Components Aa and Ba are both spectral type *A* and about 2 to 2½ times the mass of our Sun, while Ca is a red dwarf. Their inseparable companions (Ab, Bb, and Cb) are also red dwarf stars, each about half the mass of our Sun. The C pair is the eclipsing binary YY Geminorum. Its brightness drops 0.7 magnitudes twice during each 19.5-hour orbit, each eclipse taking 82 minutes. This incredible star system tantalizes us from a distance of 52 light-years.

Southwest of Castor, we'll find the intriguing bipolar planetary nebula **NGC 2371/72**. When discovered in 1785, William Herschel logged it as:

"Two faint of an equal size, both small within a minute of each other; each has a seeming nucleus, and their apparent atmospheres run into each other." The halves received consecutive numbers in the *New General Catalogue of Nebulae and Clusters of Stars* (NGC).

In the 130-mm scope at 102×, NGC 2371/72's oblong mist shines brighter in the southwest. At 164× I can just tell that the nebula is bipolar and a little less than 1′ long. Adding a narrowband filter brings out a bright spot in the northwest end of the southwest lobe. Through my 14.5-inch scope at 276×, the lobes are detached with faint nebulosity between them and some fluff to their sides. The nebula is brightest around the southwest lobe's spot. Although not as bright, there's a corresponding spot in the southeast end of the northeast lobe, such that a line between the two spots would run diagonally across the nebula and through the dim central star. Images display outrigger arcs bracketing the main body of NGC 2731/32, making the nebula resemble a candy in a cellophane twist-wrap. Visually I see a short piece of the northwest arc, and with a narrowband filter I can glimpse a bit of the southeast arc with difficulty. The lobe's spots stand out very well with an O III filter.

The bright spots in NGC 2371/72 are knots of gas ejected by the central star, which is growing ferociously hot as it collapses to eventually become a white dwarf, its surface currently blazing about 23 times as hot as our Sun's. As with most planetary nebulae the distance is poorly known, but recent estimates give about 4,000 or 5,000 light-years.

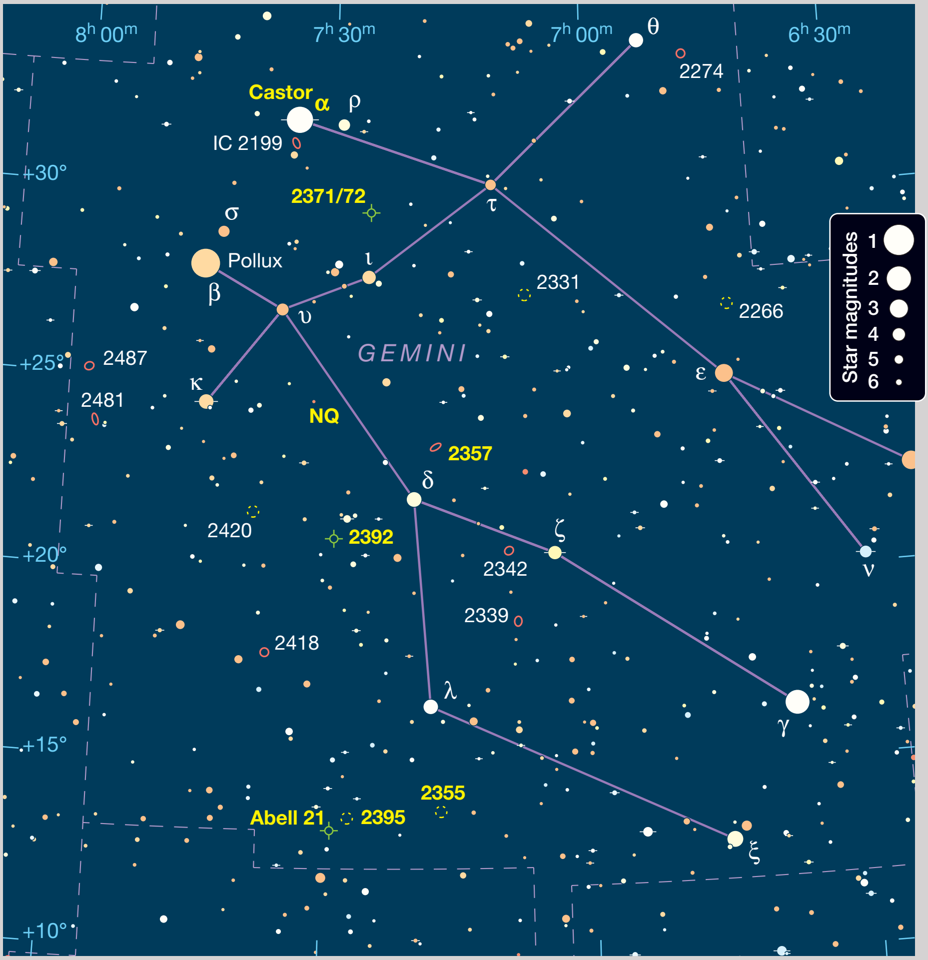
West of Kappa (κ) Geminorum, the carbon star **NQ Gem** offers us a nice color comparison with HD 60336 (HIP 36883), a normal red giant star 44′ to its east-southeast. Seen in the same field of view through the 130-mm scope at 37×, the "red" giant is only orange, while NQ Gem is distinctly red-orange. A carbon star's atmosphere is rich in carbon-bearing molecules that absorb the shorter wavelengths of visible light, leaving only ruddy colors to reach our eyes. NQ Gem exhibits low-amplitude brightness variations caused by intrinsic pulsations of the star and interactions with its white dwarf companion.

Resting north-northwest of Delta (δ) Gem, the flat galaxy **NGC 2357** is a challenging target. Flat galaxies are disk-like galaxies that have little or no central bulge and are seen edge-on from our vantage point, making them look very slender. My 10-inch reflector at 299× shows a very faint needle of light with a slightly brighter center and a 13th-magnitude star perched north of its north-northwestern end. It's easier to capture with my 15-inch scope at 216× but still dim enough to be best studied with averted vision. It's hard to tell exactly where the needle's tips fade into the background sky, but I'd put the length at at least 2′. NGC 2357 has hosted two supernovae: One peaked at magnitude 14.0 in the year 2015 and the other at magnitude 15.3 in 2010.


▲ Most amateur scopes reveal the central region of the bipolar planetary nebula NGC 2371/72; the outer arcs are difficult to see and call for more aperture. Look for the bright knot of gas — likely a jet — in the northwest end of the southwest lobe of the nebula. A similar but less vivid knot lies in the southeast end of the northeast lobe. An O III filter can help.

JIM MISTI

The planetary nebula **NGC 2392** sits east-southeast of Delta Gem and is easily recognized in the 130-mm scope at 37×. It's small, bright, and bluish, with its central star plainly visible. At



▲ *Left:* Like NGC 2371/72, the planetary nebula NGC 2392 is bipolar. William Herschel discovered the nebula in 1787, describing it as "A star 9th magnitude with a pretty bright middle, nebulosity equally dispersed all around. A very remarkable phenomenon." *Right:* French observer Serge Vieillard drew this view of NGC 2392 as seen through his 24-inch (620-mm) f/14.5 Cassegrain telescope at a magnification of 1,875×.

164× the interior sports a beautiful aquamarine color, has dimmer patches around the central star, and is shaped much like a face — wider and flatter at the forehead and narrower at the chin, which points a little east of north. The face is brightest around the rim and surrounded by a wide, bluish fringe.

On some images, the brightness variations near the central star resemble facial features, while the fringe looks like the fur of a parka's hood. In the 15-inch scope at 345×, the encircling fur is round and about 45″ across. On a good night I can vaguely see how the dim areas within might suggest eyes and a mouth, but on one night of exceptional seeing, I was stunned to see NGC 2392 looking very much like those familiar photos when seen through Alex Langoussis's 24-inch reflector at magnifications of 914× to 1280×. As seen in the sketch above, Serge Vieillard was treated to even more marvelous detail through Saint-Véran Observatory's 24-inch Cassegrain at 1875×, a view I'm sure we all covet.

On our way to our final target, let's drop in on the open cluster **NGC 2355**, south of Lambda (λ) Gem. It's only visible as a moderately faint, hazy patch with a 10th-magnitude star in its eastern side through the 130-mm scope at 23×, but at 164× it becomes an attractive, rich group of faint to extremely faint stars. The densest concentration resides within the central 5′, while more loosely scattered stars extend the group to about 8′. The 15-inch scope at 216× reveals more than 55 moderately faint to very faint stars in a ragtag assembly bridging at least 9′. The bright star gleams yellow-orange.

Sweeping eastward from NGC 2355 with the 130-mm scope at 48× brings me to **NGC 2395**, a 15′ × 10′ loose group of at least 20 faint stars in the shape of a triangle with a stem to the northwest. Sticking an O III filter in the eyepiece makes the planetary nebula **Abell 21** materialize 35′ to the southeast in the shape of a fat, 8′ arc concave toward the northwest. The nebula looks very nice with the 15-inch scope and filter at 79×. The arc is bright in the northeast, pinned by a superimposed star. It dims in the southeast and becomes bright and narrower in the southwest. The wide areas appear vaguely filamentary. These snaky filaments are much more obvious on photos and most likely the inspiration behind its nickname, the Medusa Nebula, bestowed by Soviet astronomer Boris Vorontsov-Vel'yaminov in 1960.

## Targets in the Twins

| Object | Type | Mag(v) | Size/Sep | RA | Dec. |
|---|---|---|---|---|---|
| Castor | Multiple star | 1.9, 3.0, 9.8 | 5.3″, 70″ | $7^h\ 34.6^m$ | +31° 53′ |
| NGC 2371/72 | Planetary nebula | 11.2 | 62′ | $7^h\ 25.6^m$ | +29° 29′ |
| NQ Gem | Carbon star | ~8 variable | — | $7^h\ 31.9^m$ | +24° 30′ |
| NGC 2357 | Flat galaxy | 13.3 | 4.3′ × 0.4′ | $7^h\ 17.7^m$ | +23° 21′ |
| NGC 2392 | Planetary nebula | 9.9 | 54″ | $7^h\ 29.2^m$ | +20° 55′ |
| NGC 2355 | Open cluster | 9.7 | 9′ | $7^h\ 17.0^m$ | +13° 45′ |
| NGC 2395 | Open cluster | 8.0 | 15′ | $7^h\ 27.2^m$ | +13° 37′ |
| Abell 21 | Planetary nebula | 10.3 | 11.3′ | $7^h\ 29.1^m$ | +13° 15′ |

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.

■ Contributing Editor **SUE FRENCH** welcomes your comments at **scfrench@nycap.rr.com**.

# SkyRaider DS10cTEC is Here

**MALLINCAM**

Introducing the new MallinCam DS10cTEC – designed from the ground up to accommodate the most demanding astronomical video imaging applications. Since most CMOS sensors cannot be directly cooled via a cold finger without causing damage and delamination with time, which will ultimately shorten their life, a new cooling system had to be developed. MallinCam developed a unique cooling system that provides no direct physical contact between the Peltier cooler and the sensor. Instead, the Peltier cooler creates a convection system (refrigerator-like) environment that cools the sensor without actually contacting it. This cooling system is unique to MallinCam and not found on other astronomical imaging cameras.

Since the back illuminated IMX294 class 1 CMOS sensor of the MallinCam DS10cTEC is cooled via convection, thermal shock to it and its associated circuitry is reduced. CMOS sensors have other components mounted on the same wafer with the imaging section which do not require or can be adversely affected by cooling. This includes the digital logic circuitry (interface, timing, processing, output amplifiers, pad rings and associated oscillators), clocks and timing controls, analog signal processing, analog-to-digital converter (which when under cooling from direct cold finger and Peltier results in instability). These parts of the CMOS sensor do not need to be direct cooled from a cold finger application.

MallinCam has successfully designed a working alternative – a cooling chamber called refrigeration cooling – which subjects the CMOS sensor to cooling inside a triple-sealed vacuumed sensor chamber controlled with a heating element mounted around the internal optical window to control and avoid dew formation on the optical window and surroundings. A vacuumed sealed chamber is used to eliminate the use of desiccant material and keep a dew-free environment permanently.

The result of this new technology, the SkyRaider DS10cTEC, will not require a dark frame for live application or imaging in most cases. It is built to laboratory specification, where CNC machining is used throughout to provide the rigid tolerances needed to provide precise component matching. The chamber has six stainless steel screws securing the chamber cover under 100 pounds of pressure to avoid possible air leaks into the chamber.

The internal electronics use Grade 1 components with tolerance of 0.5%, a military and aerospace standard. The camera contains 4Gb DDR3 internal memory to insure the smooth flow of data to the computer. The DS10cTEC also has a built-in USB2 hub that can support a guider or a USB type focuser.

Each camera is subjected to a 24-hour burn-in prior to being ready for shipment to insure proper operation. It is these details that set MallinCam apart from everyone else.

**KEY FEATURES**

- Convection Cooling
- Refrigeration Chamber
- Vacuumed-Sealed Chamber
- Built-in Heater for Optical Window Dew Removal and Chamber Temperature Control
- 100 Pound Chamber Plate Pressure Held with 6-Stainless Steel Screws
- Built-In USB2 Hub for Guider, Focuser, Filter Wheel etc.
- Four Blue LED Status Indicators (power, system, cooler, fan)
- High Velocity Ultra Quiet Fan With Dual Air Output
- High Grade Carrying Case
- 4Gb DDR3 Internal Memory for smooth operation
- Sony IMX294 Back Illuminated, Class 1 Hand Picked CMOS Sensor (Scientific grade)
- 1900 mv Output
- Spectral Range: 350nm to 1100nm.
- Light Pollution Electronic Reduction System using the White Balance Feature
- HCG and LCG Mode (High Conversion Gain, Low Conversion Gain Selectable)
- Correlated Double Sampling
- High S/N ratio
- No Amp Glow (when used in live mode)
- 21.63mm Diagonal Sensor Size
- Resolution Sizes:
  - 4096 X 2160, 38 FPS @0.100ms
  - 3704 X 2778, 35 FPS @ 0.100 ms
  - 2048 X 1080, 70 FPS @ 0.100ms
  - 1360 X 720, 100 FPS @ 0.100ms
- Digital Binning Mode: 1x1, 2x2, 3x3, 4x4 All in Color
- Global Shutter
- Image Format, FITS, JPEG, BMP, PNG
- Full Video Mode: AVI, SER
- Vacuumed-Sealed Optical Window
- T-Mount
- USB3 Operation
- One 12 Volt DC Power Cable for Cooler
- Precision All Aluminum Construction and Stainless Steel Hardware
- 10.0 cm X 8.00 cm (3.93 inches X 3.14 inches)
- 534 Grams/1.17 Pounds
- High Speed USB 3.0,
- 5 Volts Operation @900 ma
- 12 Volts DC Cooling via Supplied A/C Power Supply

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# Daystar's Solar Scout 60C

*Explore the Sun's chromosphere with this dedicated hydrogen-alpha telescope.*

## 60mm Daystar Solar Scout

U.S. Price: $1,295

daystarfilters.com

### What We Like

Compact size

Etalon can be used on other scopes

### What We Don't Like

Image-shift when focusing

Band tuning slow to respond

**WHEN DAYSTAR'S 60-MM** Solar Scout arrived for review, it was a cloudless day.

It was also a sunspotless day . . . not even a tiny one visible.

For two weeks in July when I had hoped to enjoy views of the Sun through this special hydrogen-alpha (Hα) solar telescope, there were no sunspots! According to **spaceweather.com**, you'd have to go back to 2009 for a longer stretch of spotless days. We are currently in the midst of solar minimum, the lowest point of activity in the Sun's 11-year cycle.

But as users of properly equipped solar instruments know, a blank Sun in white light doesn't mean there isn't an exciting view to be had of the chromosphere. This second layer of the Sun's atmosphere is normally hidden from view, with the exception of brief periods during a total solar eclipse. But telescopes equipped with a special filter reveal the chromosphere in the light of Hα, that tiny slice of the solar spectrum around 656.3 nanometers.


▼ The Daystar 60mm Solar Scout (SS60C) is a compact solar telescope with an integrated Fabry-Pérot etalon used to observe the Sun in hydrogen-alpha light.


▲ Both SS60C and SS60P models come with a heavy-duty waterproof carry case with plenty of space for storing additional accessories.

Until recently, my experience with observing the Sun through Hα filters was limited to peering into eyepieces at amateur gatherings and on solar-eclipse tours. I was awed by those direct views of intricate detail on the solar disk and dramatic prominences at the Sun's limb. But back home I settled for white-light views using Mylar-like filters. That all changed with the arrival of the Daystar Solar Scout.

This dedicated 60-mm solar scope is built strictly for observing the Sun in Hα light. The Solar Scout is also available in an 80-mm model (SS80) as well as the less-expensive SS60-ds. Apart from the SS60-ds, each Solar Scout is available in two versions. The chromosphere models (SS60C and SS80C) incorporate a narrow 0.6- to 0.3-angstrom bandpass that shows filaments and active regions around sunspots on the solar disk as well as prominences along the limb

ALL PHOTOS BY THE AUTHOR

of the Sun. The prominence versions (SS60P and SS80P) use a wider 0.8- to 0.6-angstrom bandpass, which displays prominences a bit brighter than the chromosphere model does, though at the expense of other details across the Sun's disk. I tested the SS60C.

The Solar Scout is a nearly complete observing kit that incorporates a removable Quark filter — a Fabry-Pérot etalon Hα filter that was reviewed in the November 2014 issue, p. 38. The scope comes with a waterproof, foam-lined hard case, a solar "bullet" finder, an AC-to-DC power supply, and a mounting foot threaded for ¼-20 standard tripods that also doubles as a short Vixen-style dovetail plate.

Optics in the SS60C are an f/3.75 doublet objective in a carbon-fiber OTA, which, when combined with an integral Barlow lens within the Quark filter, extends the effective focal length of the system to approximately 930-mm (f/15.5) in a 16-inch-long package. Users will need to provide a star diagonal and eyepiece. The scope's focus travel is sufficient to accommodate most standard 1¼-inch diagonals combined with a range of eyepieces.

One useful aspect of the SS60C is that its Quark filter is removable (an option not available on the SS60-ds), and, with the addition of an optional adapter and appropriate energy-rejection filter, it can be used safely on other refractors. This is particularly helpful for users hoping to image the Sun, as I'll explain later.

The Quark is a temperature-regulated Hα solar etalon that's powered by a supplied wall transformer with a generous 9½-foot cable, which plugs into a USB-micro port on the side of the filter. Plug adapters are included for other types of international wall outlets. This power heats the Quark's etalon cavity to between 100° and 150°F, precisely regulating the filter's passband.

As an electrically stabilized filter, the Quark needs to be powered up for about 10 minutes before an observing session begins in order for its temperature to stabilize. An LED located near the power port changes from yellow to green when it's ready. The LED is tiny but bright enough to be seen in full sunlight. While it isn't dangerous to view through the filter while it is reaching operating temperature, the views are extremely low-contrast and off-band before stabilizing, appearing like a white-light view, except colored red.

The power transformer provides 5 VDC at 2 amps. The Quark can also be powered with most DC power supplies that have a USB output, though you'll need to ensure the power supply can output 2 amps.

An included 14-page manual is extremely helpful and directly answered any questions I had whether I was using the instrument visually or with an imaging setup.

## Under the Sun

Although the filtering system that isolates the Hα band does permit viewing and imaging of solar features, the quality of the view with the SS60C depends on several factors.

The seeing or steadiness of our atmosphere is one big consideration. Daytime seeing is generally much worse than nighttime and can blur fine detail associated with active solar regions. Local conditions significantly help or worsen the quality of the image viewed through any solar telescope. My best seeing almost always came in the early morning hours, even though the Sun was lower in the sky than when at its midday position. I experienced slightly better seeing when I used the SS60C outside on my lawn, rather than attaching the scope piggyback on my observatory telescope in its domed building.

Users can loosen a thumbscrew on top of the scope to allow the filter to be rotated to place the power input and tuning knob in a convenient position.

The tuning knob has 5 click-stops on either side of a center position, with each click changing the transmitted wavelength by 0.1 Å. When adjusting the knob, even slightly, the LED changes from green back to yellow. It takes several minutes to stabilize and turn green again after each adjustment. I couldn't see much difference when changing one click-stop, but contrast improved slightly when moving several stops at a time. The manual states that turning the knob clockwise increases (redshifts) the center wavelength of the filter, while counter-clockwise decreases (blueshifts) its central passband. This is useful when looking at prominences along the limb, which can sometimes be blue- or red-shifted, revealing details that were fainter or even invisible before changing the filters' tuning.

Unlike a white-light view of the Sun, observing in the dimmer, deep-red Hα


▲▲ Placing the Sun in the telescope's field of view is easy using the bullet finder. Focusing the SS60C is accomplished by turning the large, red anodized collar.

▲ The SS60C's peak passband can be adjusted +/- 0.5 angstroms in 0.1-Å increments using the tuning knob. While most features across the solar disk looked best at the mid-position, prominences sometimes changed appearance when turning the knob 2 or 3 clicks. It took several minutes for the filter to stabilize each time the knob was adjusted.

band is less straightforward. Details are often subtle and less defined compared to white-light views. The image at the eyepiece needs more sustained scrutiny, requiring roughly a minute or so for your eye to adjust to the contrast differences across the monochromatic red solar disk, similar to viewing, say, festoons in Jupiter's cloudtops. The manual recommends a 40-mm Tele Vue Plössl eyepiece for a full-disk view, and that eyepiece did indeed excel when I took a first look at the entire solar disk. Shorter-focal-length eyepieces and a 2× Barlow allowed me to zoom in on fine details. Contrast was best on days with clear, deep-blue skies, since even slight haze or high cirrus clouds tended to rob the view of detail-defining contrast.


▲ The exit aperture of the Quark filter is large enough to display the entire solar disk using a 40-mm Tele Vue Plössl.

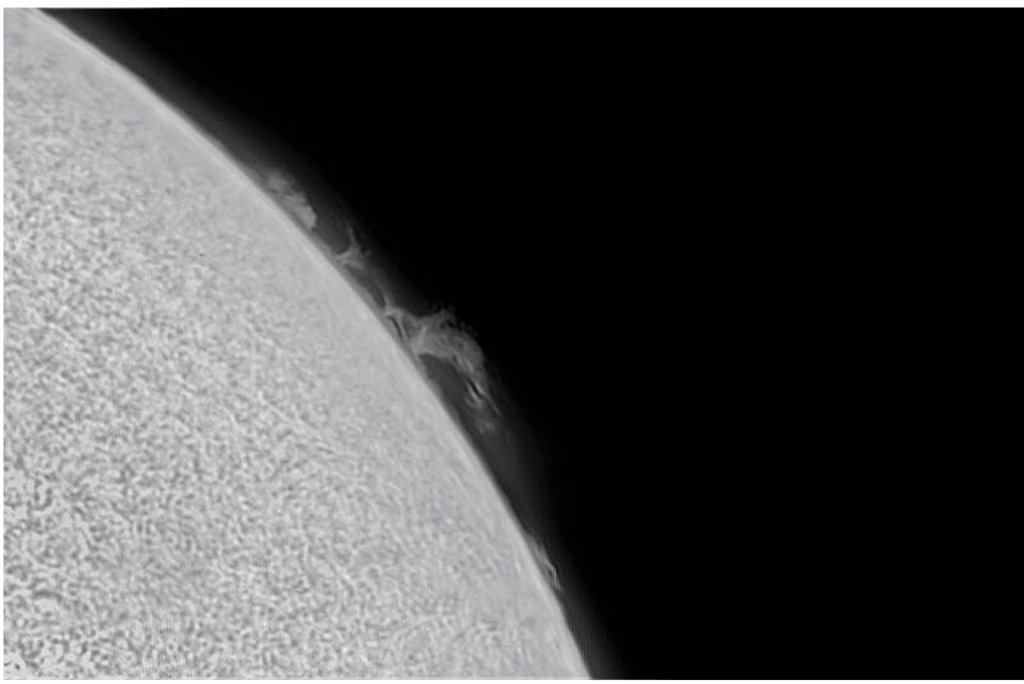
When observing with the Solar Scout, it's best to assume a comfortable position so that your eye becomes adjusted to the deep-red view. I set up a chair, and a makeshift cardboard shade around the scope provided me with additional comfort on many 90°+ summer days here in North Carolina. A black cloth draped over my head at the eyepiece helped too, though I don't recommend it on scorching hot days. The "bullet" finder mounted on the right side of the tube is helpful for aiming the scope at the Sun, though its pinhole-projected image of the Sun is fuzzy on the finder's rear crosshair screen.

The more time you spend observing with the scope, carefully scrutinizing prominence activity at the limb and churning activity on the solar disk, the more detail you'll see. Adjusting the tuning knob position requires a few minutes of waiting for results, which were sometimes very subtle, if noticeable at all.

One feature of the Solar Scout I questioned is its permanently extended "dew shield" in front of the objective lens. (Why would a telescope used to look exclusively at the Sun be concerned with dew?) A call to Daystar clarified that this extension is no dew shield, but is actually meant to both protect the front element from dust and act as an additional baffle in the optical train, helping to increase contrast. While it is black, it doesn't radiate enough heat during use to noticeably degrade the view.

Focusing the SS60C is performed by twisting the large, red anodized collar around the middle of the telescope tube. This rotates the entire front portion of the carbon-fiber tube and objective but does not rotate the eyepiece holder. The length of the tube remains constant for the full focusing travel. There is considerable image movement when focusing, which was inconsequential when observing visually at low powers. But this movement of the image, combined with having to essentially grab the entire scope to focus, was an annoying problem at high powers. It was


▲ The mounting shoe on the SS60C is threaded to attach to most photo tripods, and its base is formatted to fit in any Vixen-style dovetail saddles. Users need to supply their own star diagonal and eyepieces.



▶ Prominences were easy to see and record through the SS60C with the author's Celestron Skyris 236M monochrome video camera, though focusing the instrument with a camera attached is difficult using the large, red anodized helical focuser.

▶▶ Filaments, sunspots, and active regions containing plages and field transition arches are easily visible through the SS60C.


▲ *Left:* Attaching video or deep-sky astronomy cameras can be accomplished using the 1¼-inch eyepiece adapter, though a better option is Daystar's Interference Eliminator mount (**https://is.gd/cmount**), which permits users to slightly tilt the camera to correct for interference banding that often appears when using monochrome cameras. *Right:* The Quark unit of the SS60C can be removed and used on most small refractors with the addition of a 1¼- or 2-inch nosepiece adapter (above).

especially problematic when I attached a camera to the telescope, making it virtually impossible to achieve perfect focus. This is where the versatility of the SS60C's removable etalon comes into play. Users of the Solar Scout hoping to take sharp images of the Sun would be most successful by moving its Quark filter to another, similar-sized refractor with a traditional focuser.

After some time using the SS60C, I settled into a routine of observing with it coupled with my Astrovid StellaCam 3 video camera. This monochrome camera has a small chip, but after spending a lot of time focusing, I was able to enjoy close-up, contrasty views on a small monitor of many prominences, with occasional filaments, arches, and active regions visible even during this period of solar minimum. Likewise, I tried imaging with the SS60C using a Celestron Skyris 236M video camera. The 236M's small 5.44 × 3.42-mm chip could capture only about 25% of the solar disk with no additional focal reducers. For increasing the field of view, the manual recommends the addition of a 1¼-inch-format, screw-on focal reducer offered by several third-party manufacturers when imaging with video cameras. Using one I already own enabled the camera to see about 75% of the Sun using the Skyris 236M.

With the versatility of the Solar Scout 60C, there's no need to be discouraged when a spotless Sun is the rule around times of deep solar minimum like we're experiencing now. The lack of sunspots doesn't mean there isn't a dark, sinuous filament stretching across the Sun's disk or dramatic prominences dancing along the limb. We just have to be tapped into the hydrogen-alpha world to see and image those very compelling solar attractions within the chromosphere.

■ Though he didn't lose sleep reviewing the Daystar Solar Scout, Contributing Editor **JOHNNY HORNE** may have lost some weight using the SS60C in the hot summer Sun at his home in southeastern North Carolina.

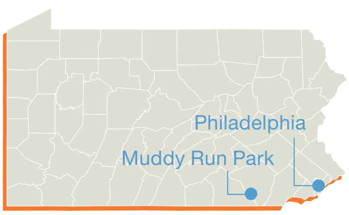
# MUDDY RUN OBSERVATORY by Robert Naeye

Growing up in the 1960s in Daytona Beach, Florida, Alfred "Al" Ryan watched NASA rockets climb above the horizon and head toward the stars. This was the dawn of the Space Age, when almost anything seemed possible. For Ryan, NASA kindled a passion for astronomy that waxed and waned but never vanished. These early launches initiated a chain of events in Ryan's life that culminated in October 2017 when the Muddy Run Observatory opened its doors to the public.

This high-tech amateur facility in southeastern Pennsylvania represents an innovative partnership between a large corporation and three astronomy clubs. The company provided the funding to make the observatory possible. The clubs fulfill the company's vision by hosting stargazing sessions that draw hundreds of visitors. The amateurs are now readying Muddy Run's two 14-inch telescopes for scientific research, and they plan to make them available to citizen scientists around the world.

As one of Muddy Run's founding fathers, Ryan selected the location and much of its equipment. But the observatory's origins date back decades earlier to his childhood fascination for the stars.

Ryan started observing through telescopes in grade school, hanging out with friends who shared his interest. But he decided to go in another direction for his career, earning a law degree from the University of Florida in 1976. He trained and practiced as a trial lawyer before entering public service, moving up the ladder until he attained the lofty position of chief environmental attorney for the State of Illinois. Despite focusing on his career, he maintained his interest in astronomy. He built his own telescope and ground its 4-inch mirror at Chicago's Adler Planetarium.

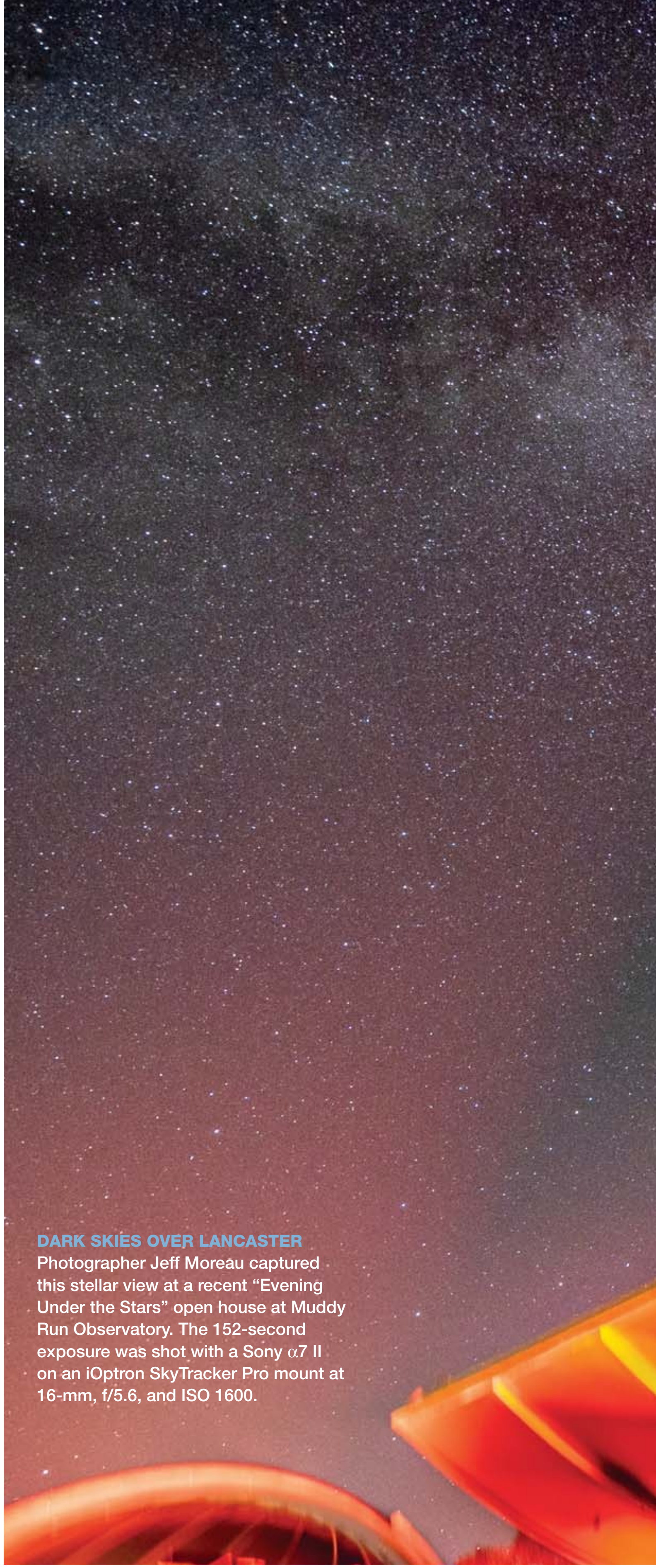



**▲ SHORT DRIVE FROM THE CITY** Muddy Run Recreation Park is about 15 miles south of Lancaster, Pennsylvania. The observatory stands near the Muddy Run Reservoir, which feeds into the Susquehanna River.

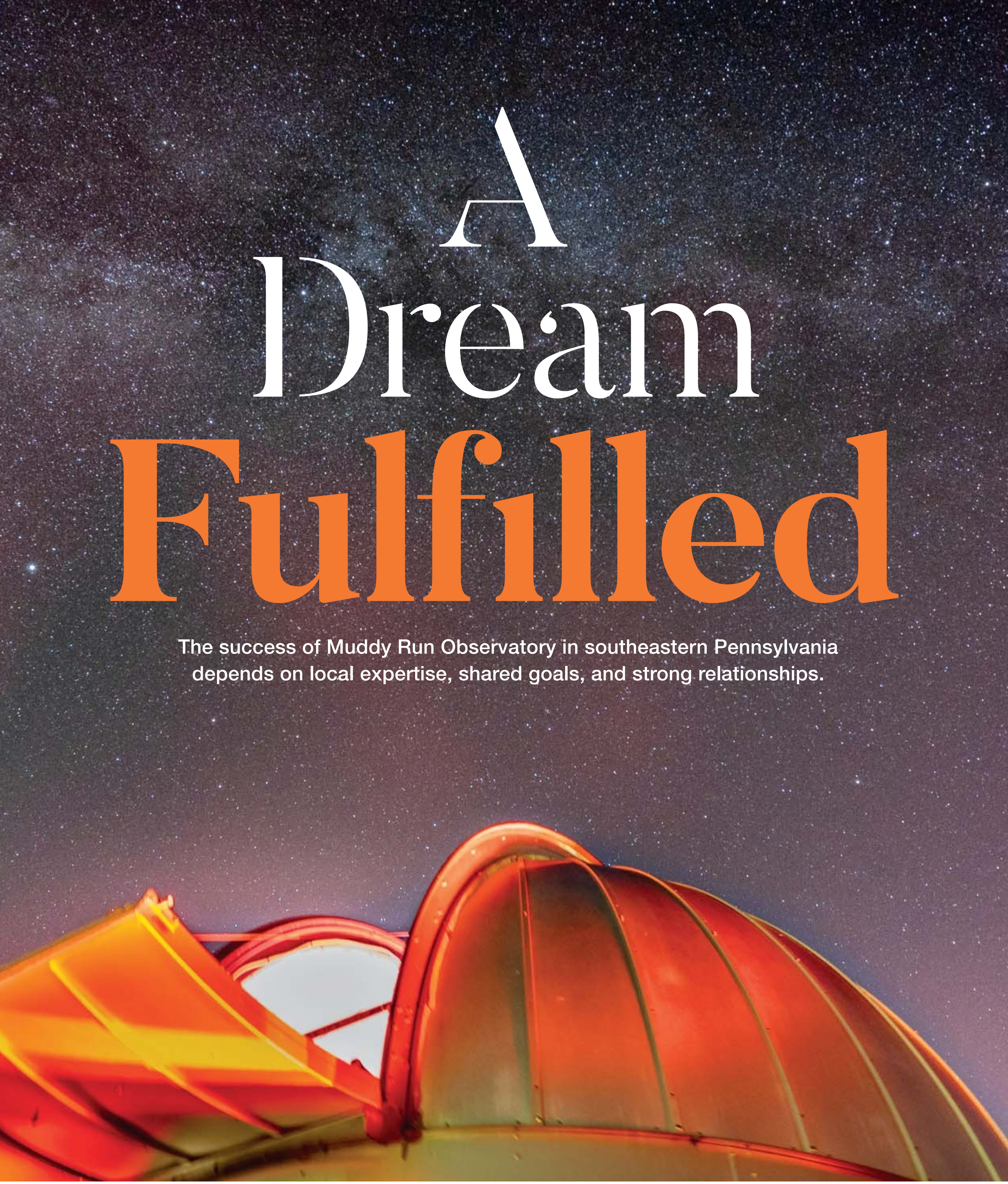
MAP: FREEVECTORMAPS.COM

After leaving state government, Ryan practiced corporate law for five years, then started his own law firm in Chicago. He enjoyed the freedom that came with company ownership, but his income varied widely from year to year. With two daughters to raise and educate, his wife Barbara Siegel encouraged him to seek a position that would provide more financial stability. In 1998 Ryan accepted a job offer from the Philadelphia Electric Company, which subsequently merged with a Chicago utility. The new firm, Exelon, is one of America's largest energy providers.

The younger of Ryan's two daughters, Layla, followed in his footsteps by developing an interest in astronomy. But unlike her father, she pursed it as a possible career, majoring in astrophysics at the University of Illinois. Layla motivated her father to raise his interest in astronomy to the next level.



**DARK SKIES OVER LANCASTER** Photographer Jeff Moreau captured this stellar view at a recent "Evening Under the Stars" open house at Muddy Run Observatory. The 152-second exposure was shot with a Sony α7 II on an iOptron SkyTracker Pro mount at 16-mm, f/5.6, and ISO 1600.



# A Dream Fulfilled

The success of Muddy Run Observatory in southeastern Pennsylvania depends on local expertise, shared goals, and strong relationships.

After moving to Glenside, Pennsylvania, a suburb of Philadelphia, he constructed a backyard observatory that now houses a 10-inch Ritchey-Chrétien telescope that sits atop an Astro-Physics 1100 GTO mount. He owns three other telescopes, including his homemade 4-inch reflector. His favorite activity is to use an SBIG STXL-16200 camera for narrowband imaging, a project well-suited for his light-polluted suburban skies.

◀ **THE BIG EVENT** Although Muddy Run Observatory officially opened in October 2017, the observatory played host to a solar eclipse party on August 21, 2017. The observatory domes were installed just weeks before the big event.

Al and Layla frequently visited the Muddy Run Recreation Park, a 700-acre nature preserve owned and managed by Exelon. The park is situated 15 miles south of the city of Lancaster near the eastern shore of the Susquehanna River. Layla noticed a helicopter landing pad inside the park and suggested that it would be an ideal location for an observatory. Al wasn't contemplating such a facility at that time, but Layla had planted a seed that would germinate a decade later.

In a devastating blow for the Ryan family, Layla died of a long-term illness in 2006 at the tender age of 24. To honor their daughter, Al and Barbara established a scholarship fund for University of Illinois astronomy majors. Remembering Layla's strong commitment to education and outreach, the Ryan family stipulated that recipients must have an established track record of public service in addition to high academic scores. Preference is given to female or minority students.

Ryan forged a harmonious partnership between a large company with no experience in running an observatory and one of America's oldest astronomy clubs.

Toward the end of 2015, Exelon started toying with the idea of building a public observatory. Looking to the future, company managers realized they would need employees with a solid background in science, technology, engineering, and mathematics.

"Exelon is a strong supporter of anything that has to do with STEM programs. So we were looking for ways to involve the local community to get them interested in math and science, along with space and dark skies," recalls Edward "Archie" Gleason, one of Exelon's general managers at that time.

Knowing of Ryan's interest in astronomy, the company turned to him for expert advice on where to build the observatory and what equipment to install. Ryan was the perfect choice. As a member of Philadelphia's Rittenhouse Astronomical Society (RAS), Ryan forged a harmonious partnership between a large company with no experience in running an observatory and one of America's oldest astronomy clubs. RAS was involved in the planning from day one. Among other contributions, RAS members came up with the idea for a large outdoor amphitheater.

Ryan recalled Layla's idea of building an observatory on the Muddy Run helipad. Besides the helipad, the park already had a visitor center, accessible facilities, and hundreds of parking spaces. The night sky is reasonably dark for the northeastern United States, reaching a limiting magnitude of about 4.5 to 5 on moonless nights. And yet the site is close enough to Lancaster, Harrisburg, and York that public events can draw from sizable metro areas.

Muddy Run seemed like an ideal location, but Ryan needed to convince Exelon management. To test this idea, he partnered with the RAS to hold a stargazing event in the park on Friday, October 2, 2015. For speakers, Ryan invited Derrick Pitts, Chief Astronomer at the Franklin Institute in Philadel-

AERIAL VIEW: EXELON GENERATION COMPANY, LLC; MUDDY RUN RECREATION CENTER; RITTENHOUSE ASTRONOMICAL SOCIETY / MUDDY RUN OBSERVATORY (3)


▶ **RESEARCH READY** *Top:* Muddy Run Observatory plans to offer time to researchers, both amateurs and professionals, on a modified Dall-Kirkham scope. The observatory's science operations team is currently working on scheduling and protocol systems, and will soon be accepting research proposals from astronomers. *Bottom:* Ted Williams, president of the Rittenhouse Astronomical Society, checks out Muddy Run's 14-inch Schmidt-Cassegrain. The scope is equipped with a video camera that allows captured images to be projected onto a large outdoor screen.

phia, as well as the 2010 recipient of the Ryan family's astronomy scholarship, Coralie Jackman (now Coralie Adam). At the time, Jackman was working on the navigation team for NASA's New Horizons mission to Pluto and the Kuiper Belt. "This was three short months after the Pluto encounter, so I got to show some great images and talk about my role as a navigator on the mission," she says.

"Ms. Jackman was a real-life example not only of what we can do in science, but what young women can do given the resources and encouragement a STEM agenda can provide," says Ryan.

Even though thunderstorms passed through the area, the stargazing session turned out 100 to 125 people, which impressed company management. The success of this initial event on a cloudy night convinced Exelon's top brass that Muddy Run was indeed the right place for their astronomical

RITTENHOUSE ASTRONOMICAL SOCIETY / MUDDY RUN OBSERVATORY; TELESCOPES: ROBERT NAEYE (2)

◀▼ **BREAKING GROUND** *Left:* Construction at Muddy Run began in April 2016. It took four months to regrade a slope for the amphitheater, pour the concrete pad for the observatory, install a large outdoor screen, and finish the landscaping. *Below:* Ash-Dome visited the site in July 2017 to install the observatory's two domes, moving the construction project almost to completion.

facility. The company invested more than $300,000 to build the observatory, and Exelon will continue to provide annual financial support for the foreseeable future.

Construction began in April 2016. The amphitheater, large screen, and landscaping were completed by August. The project was then delayed for many months because the original dome manufacturer failed to deliver on its promises. The RAS turned to Ash-Dome in Illinois, which installed two domes in July 2017, just in time for a solar eclipse party on August 21st. The Muddy Run Observatory officially opened about two months later.

For equipment, Ryan decided to install two 14-inch scopes: a Celestron EdgeHD SCT and a PlaneWave instrument featuring a modified Dall-Kirkham design. Ryan chose the 14-inch EdgeHD scope because it's a popular model for public observatories. The team uses a MallinCam Xterminator video camera to take images, which can be projected onto the large outdoor screen for public viewing. And with the EdgeHD's flat field, there are no distorted stars from center to edge. The astronomers can also transmit images from a piggybacked 60-mm Lunt solar scope. They can employ ZWO color and monochrome video cameras with either scope or with an 80-mm refractor piggybacked onto a 9.25-inch Celestron EdgeHD scope.

For the other dome, Ryan wanted a telescope more suited for research. "The Dall-Kirkham design, engineering, and reputation seemed to fit the bill for the skies we have at this location," he explains.

**The observatory is a godsend for the RAS, which is based in the severely light-polluted environment of one of America's largest cities.**

The PlaneWave scope has built-in heaters and coolers for the primary and secondary mirrors, preventing dew formation. The scope also comes equipped with an electronic focuser that is regulated by changes in ambient temperature. The team has attached other equipment to the scope: an SBIG AO-X adaptive optics unit, an SBIG self-guided filter wheel with LRGB and narrowband filters, and an SBIG SXTL 16200 monochrome camera.

The RAS has assumed the primary role of running the observatory, but it receives considerable assistance from the Astronomy Enthusiasts of Lancaster County (AELC) and the Harford County Astronomical Society in Maryland, whose members helped install the equipment. Whereas most RAS members have to drive 90 minutes or longer to reach Muddy Run, these other clubs are considerably closer. All three clubs now benefit from having a private, dark observing site with two excellent telescopes.

**SHOW TIME** While observing under dark skies is the big draw for Muddy Run, even cloudy nights offer quality programming. Members of the Rittenhouse Astronomical Club, the Harford County Astronomical Society in Maryland, and the Astronomy Enthusiasts of Lancaster County provide equipment and support for the observatory, as do volunteers from nearby colleges and universities.

"We welcome support from other clubs and individuals," confirms Ryan. "In fact, we have folks from the Harrisburg club and local colleges and universities who are regular volunteers. Nobody wanted the observatory to be dominated by Philadelphia."

The observatory is a godsend for the RAS, which is based in the severely light-polluted environment of one of America's largest cities. RAS president Ted Williams credits Muddy Run for giving club members access to a much darker site. But he is also deeply thankful for the support of the other two clubs, whose members provide telescopes and educators that are essential for large public events.

Muddy Run is now hosting open houses on a monthly basis. These star parties include talks by scientists and amateurs, and astrophotography workshops will soon be underway. Recent events have attracted hundreds of attendees, who are now enjoying an observatory in full operation.

AELC president Lane Davis says that three to six of his club's members volunteer for every public open house. They bring along their telescopes to shorten the lines at the two domed scopes. Members also contribute by operating the two 14-inch telescopes or by pointing out constellations with green lasers.

"AELC was running its own public outreach programs until a year and a half ago, when we decided to put all our effort into Muddy Run," says Davis. "It's tough for a small club to run something like that, but in the case of Muddy Run, we have at least three astronomy clubs involved, so there are a lot more volunteers. There's no trouble getting full coverage every month."

To further its goal of educating the public about space science, Exelon modified the visitor center to include an astronomy hallway of astronomical photos and models. The visitor center also has several large rooms that are used for astronomy classes.

From the outset, scientific research was a major motivating factor for constructing the observatory. Ryan says that it

▼ **GAME ON** Club members gathered early to prepare for Muddy Run's grand opening. While skies were cloudy for the October 2017 celebration, attendees were able to tour the completed facilities, which include twin domes and a renovated visitor center.

RITTENHOUSE ASTRONOMICAL SOCIETY / MUDDY RUN OBSERVATORY (2); RYAN: ROBERT NAEYE

▲ **MOVER AND SHAKER** Al Ryan, Assistant General Counsel at Exelon and a member of the Rittenhouse Astronomical Society, spearheaded Exelon's effort to build an astronomical observatory at its Muddy Run Recreation Park. Here Ryan addresses the crowd gathered at the observatory in July 2018 to listen to a talk on 'Oumuamua (1I/2017 U1) by the author and another on astrophotography by John Yecker.

has taken a bit longer than expected to get science operations up and running. The team is developing a protocol system for research proposals and a scheduling system for operator assistants. It's still working to resolve a few technical glitches as well. Ryan hopes science operations will commence in the spring or summer of 2019.

The research will focus on whatever projects appear to be of value to students and citizen-scientists, as long as they're consistent with the equipment's capabilities. Possible projects include the photometric monitoring of variable stars, asteroid occultations, and stars hosting transiting exoplanets. Research won't be limited to local amateurs and students; anyone with a valid proposal will be awarded observing time.

Whatever happens with research programs, Lane Davis says the observatory has met all of its short-term goals. Speaking for the company, Archie Gleason remarks, "Exelon is very proud of the facility, the way it came out, and the way it's being used."

For his part, Ryan dreams of bigger and better things. He hopes the RAS can find ways to bring in even more funding, which will allow the team to extend its range of equipment and activities. "Make big plans if you want to get meaningful results" is one of Ryan's mottos.

With all of its initial success, and with the promise of more to come, it's not far-fetched to wonder if the Muddy Run Observatory will one day inspire some child to accomplish great things in astronomy, just as NASA lit a fire under the youthful Al Ryan.

■ Former *Sky & Telescope* Editor in Chief **ROBERT NAEYE** was the featured speaker at the Muddy Run Observatory's July 14, 2018, open house.

# Brent's Light Bucket

*You can make a telescope out of practically anything.*

**I'M A BIG PROPONENT** of what I call "found object engineering." There's a special kind of delight in creating something with stuff that's been cluttering up your shop for years, or in going to the hardware store and wandering the aisles in search of the perfect gadget that can be repurposed for your project.

Washington ATM Brent Burton has taken that concept to a perhaps ridiculous extreme, building a telescope out of a 5-gallon bucket, two 1-gallon buckets, two soft drink cups, some plumbing fixtures, and bungee cords.

We last saw Brent's handiwork in our May 2017 issue, when I wrote about the beautiful wood-inlaid telescope and hand-carved accessory tray he built. This project occupies the opposite end of the refinement spectrum, but it conveys a certain beauty all its own: the beauty of a project that's simple, inexpensive, functional, and unconventional.

Why did Brent build such a crazy telescope? Besides the obvious desire to build a "light bucket," he says, "I was always intrigued by small, portable scopes. Like most people, however, I didn't have the money to go out and custom machine individual parts to build my own, so I decided to improvise and build one using cheap building materials that I could source from the local hardware store." Well, that plus Olive Garden for the drink cups and his own garage for the outer bucket.

◀ Brent Burton holds what might be the world's most portable "light bucket."

For the optics, he cannibalized a 4½-inch Orion StarBlast tabletop scope that he picked up secondhand. He kept the primary, secondary, and spider assembly from the StarBlast and made everything else himself.

The OTA is two 1-gallon buckets with their open ends held together with bungee cords. Brent cut the bottom out of one to make the front opening and mounted the primary mirror cell in the bottom of the other. The mirror cell is just a circle of medium-density fiberboard held together with thumbscrews and small springs for collimation. The helical focuser is made from a toilet valve.

The altitude bearings really make this scope. They're just plastic cups from an Olive Garden restaurant with plastic reinforcing disks on the outer ends. The threaded rod that attaches them to the OTA goes through the plastic disks, the bottom of the cups, and the lid on the top that came with the cups. I suspected that the cups had to be filled with plaster or something to keep them from collapsing, but Brent says that wasn't necessary. He did have to be careful with the tension on the bungees that go over the cups and provide friction in the altitude direction, but he was able to find a sweet spot that gave him the proper stiffness of motion and didn't crush the cups.

The lid of the big bucket becomes the ground board, with hex-bolt heads against the bottom of the "rocker bucket" providing the right amount of friction in azimuth. Brent had to cut a flap in the side of the outer bucket for the rear of the OTA to clear when aimed at the horizon. He hinged the flap so

BRENT BURTON (4)

▶ *Left:* Everything nestles inside the outer bucket. *Right:* The scope parts laid out for assembly show how simple a telescope can be.

nothing would fall out during transport.

That's right: Everything fits into the outer bucket! When it's disassembled and stowed away, you can pick up the bucket by its handle and carry it like five gallons of fun.

Brent says the scope took him about a month to build: "An hour after work and a few hours on the weekend here and there."

How well does it work? "Surprisingly, not too bad. Although it works as a larger-footprint tabletop scope, I actually enjoyed taking the OTA by itself and using it as a sky sweeper while sitting in a chair." The scope doesn't need a finder, since it's such a wide-field scope on its own.

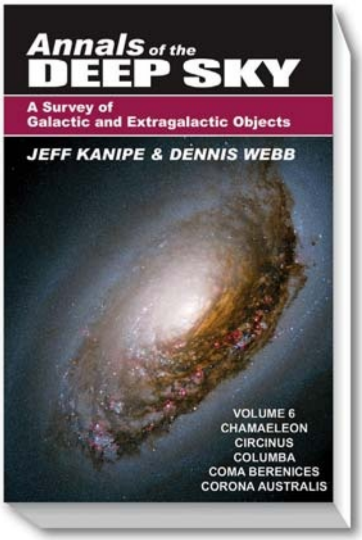
▲ Brent screws on one of the altitude bearings. The 1¼-inch helical focuser is made from a plastic toilet valve.

Brent and his son, Blake, enjoyed the scope for a while, but they also enjoy watching a YouTube variety show called Good Mythical MORE, so Brent sent the scope to them, and they featured it in an episode you can find here: **https://is.gd/bucketscope**.

The scope makes its appearance at about the 9:30 minute mark. The show's hosts don't seem particularly adept at telescope assembly, but I'm confident that a single look at the photos Brent has provided here will reveal all to a serious telescope maker. Everybody should have a light bucket. Go forth and make one for yourself!

For more information, contact Brent Burton at **brebur1@juno.com**.

■ Contributing Editor **JERRY OLTION** sometimes uses 5-gallon buckets as secondary cages, too.




## ◄ DEEP-SKY COMPENDIUM

Willmann-Bell announces the latest volume of its popular series *Annals of the Deep Sky: A Survey of Galactic and Extragalactic Objects* by Jeff Kanipe and Dennis Webb ($24.95). Volume 6 covers the constellations Chamaeleon through Corona Australis, providing the most up-to-date and comprehensive information on the prominent stars, deep-sky objects, and other celestial exotica within each region. This richly illustrated volume uses the latest findings in astrophysics and cosmology, paired with extensive historical and observational information for each object. Volume 6 is softbound and includes 223 illustrations. 6 by 9 inches, 334 pages.

**Willmann-Bell**
P.O. Box 35025, Richmond, VA 23235
804-320-7016 and 1-800-825-7827; willbell.com

## ▲ SUPER-WIDE BINOS

Omegon rolls out a unique pair of binoculars. The Omegon 2.1×42 wide-field binoculars ($179) allow you to see entire constellations and sprawling star fields in the Milky Way all at once. Its 20° field of view and low magnification bring out stars up to 2 magnitudes fainter than is possible with the naked eye. The lens cells are threaded to accept standard 2-inch filters (not included), permitting views of extended nebulosity like never before. The binoculars are threaded to attach to standard ¼-20 tripods and include individual lens and eyepiece covers, a wrist strap, and a nylon carrying bag.

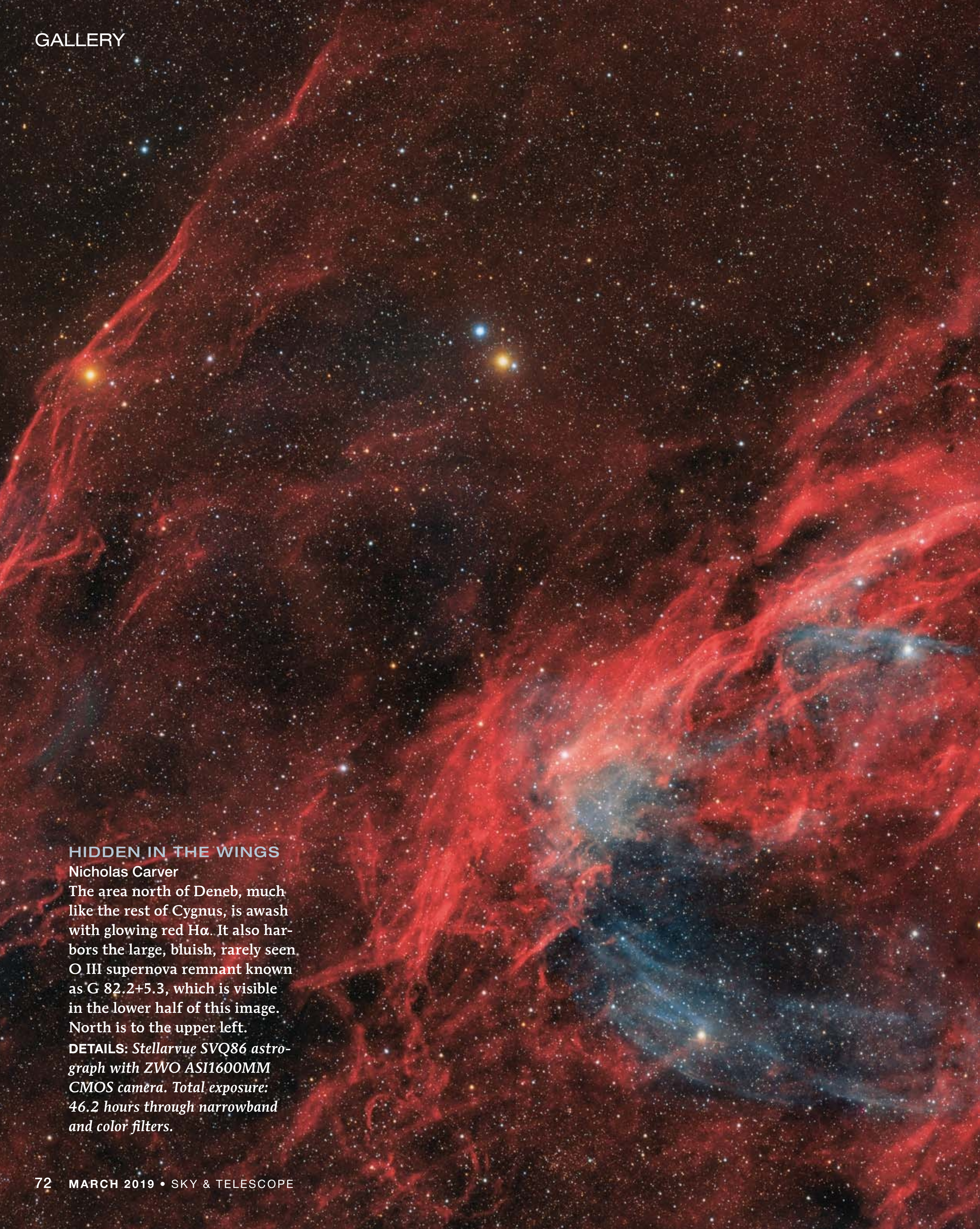
**Omegon**
+44-203-8688042; omegon.com


## ▲ OBSERVING FILTER

Lumicon now offers an improved O III filter for visual observing. The Generation 3 Lumicon 2-inch Oxygen III filter ($200) passes 97% and 98% of light at 496 and 501 nanometers, respectively, at the dual passbands where doubly ionized oxygen emits light while blocking many sources of light pollution. This helps to enhance the view of planetary nebulae, supernova remnants, and other diffuse nebulosity within the Milky Way by darkening the sky around these faint objects, making them stand out in the eyepiece even under dark skies. Each filter is threaded to fit standard 2-inch eyepieces and includes a transmission sheet.

**Optical Structures Inc.**
11371 Pyrites Way, Suite A, Rancho Cordova, CA 95670
916-638-2003; farpointastro.com

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



### HIDDEN IN THE WINGS

Nicholas Carver

The area north of Deneb, much like the rest of Cygnus, is awash with glowing red Hα. It also harbors the large, bluish, rarely seen O III supernova remnant known as G 82.2+5.3, which is visible in the lower half of this image. North is to the upper left.

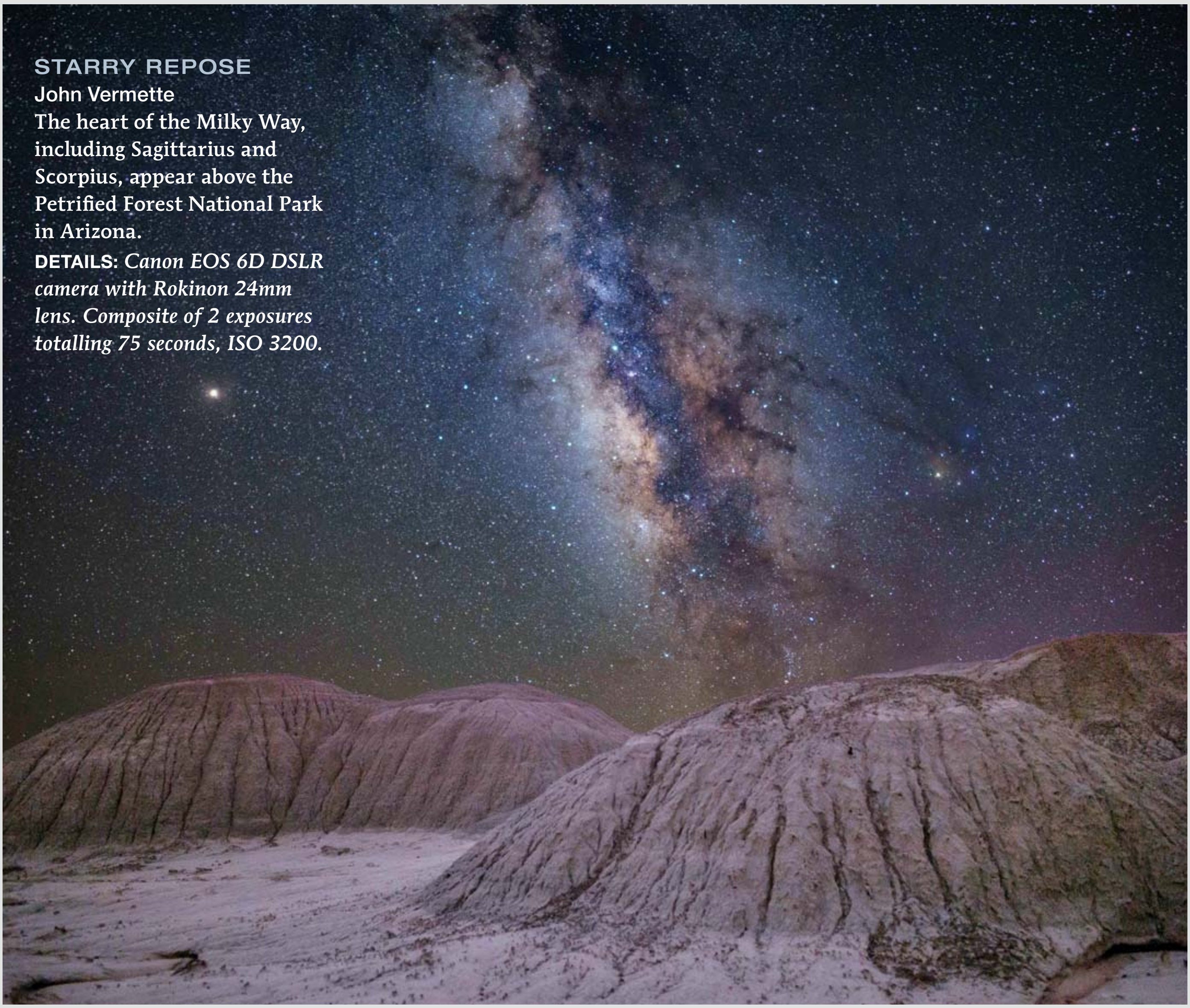
**DETAILS:** *Stellarvue SVQ86 astrograph with ZWO ASI1600MM CMOS camera. Total exposure: 46.2 hours through narrowband and color filters.*

◁ YOUNG MOON

Jamie Cooper

A dramatic crescent Moon sports several distinctive craters near the sunrise terminator days before first quarter, including the striking pair of Atlas and Hercules at upper right, and giant Janssen at bottom left.

**DETAILS:** *8-inch Sky-Watcher Newtonian reflector with Canon EOS 6D DSLR camera. Total exposure: 1/125 second at ISO 400.*



STARRY REPOSE

John Vermette

The heart of the Milky Way, including Sagittarius and Scorpius, appear above the Petrified Forest National Park in Arizona.

**DETAILS:** *Canon EOS 6D DSLR camera with Rokinon 24mm lens. Composite of 2 exposures totalling 75 seconds, ISO 3200.*

## ▷ GALACTIC MERGER

Kfir Simon

The Antennae Galaxies (NGC 4038/4039) are a pair of colliding galaxies in Corvus. Their interaction has kicked off a furious epoch of starbirth while ejecting two streams of stars.

**DETAILS:** *6-inch f/8 Hypergraph with FLI PL16803 CCD camera. Total exposure: 4 hours through color filters.*

## ▽ OPTICAL DOUBLE

Jamie Cooper

Alberio is one of the most striking pairs of stars in the night sky, though recent observations by the ESO Gaia spacecraft have determined it to be a chance alignment and not a true binary.

**DETAILS:** *8-inch Sky-Watcher Newtonian reflector with Canon EOS 6D DSLR camera. Total exposure: 30 minutes.*

## ▷ AVIAN GHOST

Jason Guenzel

The faint reflection nebula vdB 152 lies at the end of the long dark nebula Barnard 175 in Cepheus. This remarkably deep image brings out additional wisps of reddish Hα in the region.

**DETAILS:** *Celestron EdgeHD 8 Schmidt-Cassegrain with ZWO ASI1600MM camera. Total exposure: 26.1 hours through color filters.*

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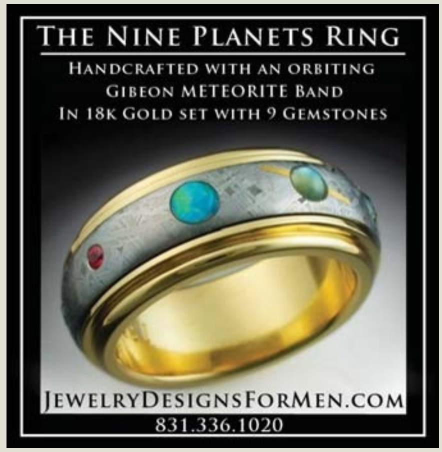


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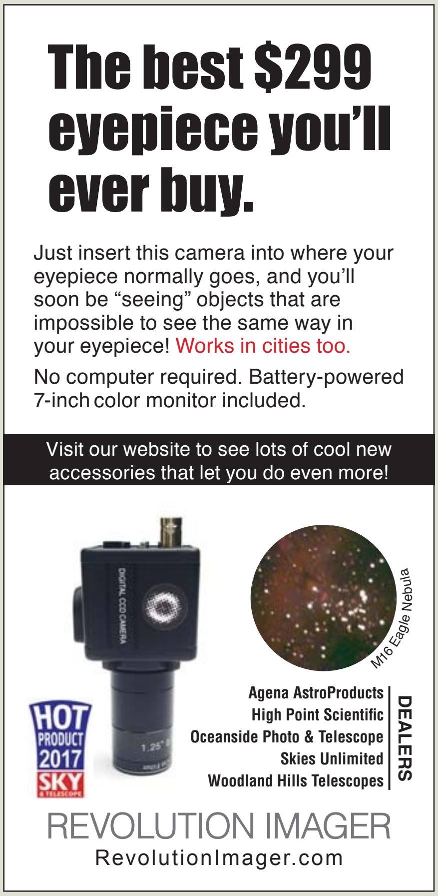


## EYEPIECES


## MOUNTS


## OBSERVATORIES/DOMES



## OBSERVATORIES/DOMES (cont.)


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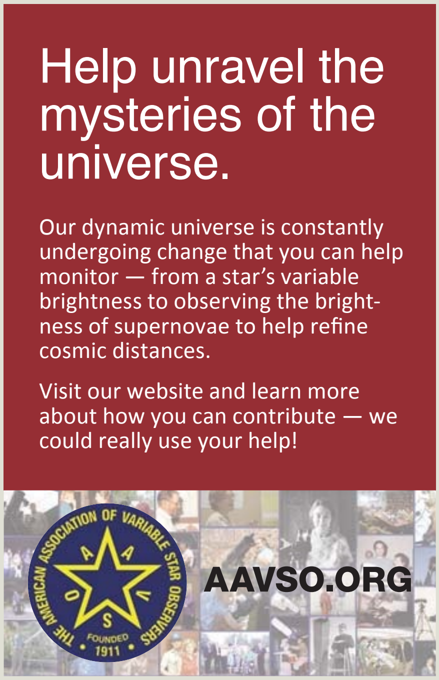



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# INSIDE This Issue

Specialty astronomy equipment dealers and manufacturers are an important resource for amateur and professional astronomers alike — patronize our advertising dealers in this issue and enjoy all the benefits of their expertise.

# Event Calendar

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

*February 4–10*
**WINTER STAR PARTY**
Scout Key, FL
**scas.org/home/winterstarparty**

*March 31–April 7*
**INTERNATIONAL DARK SKY WEEK**
Everywhere!
**https://is.gd/darkskyweek2019**

*April 3–6*
**MIDSOUTH STARGAZE**
French Camp, MS
**rainwaterobservatory.org/events**

*April 4–7*
**SOUTHERN STAR**
Little Switzerland, NC
**https://is.gd/southernstar2019**

*April 6–7*
**NORTHEAST ASTRONOMY FORUM**
Suffern, NY
**rocklandastronomy.com/neaf.html**

*April 28–May 5*
**TEXAS STAR PARTY**
Fort Davis, TX
**texasstarparty.org**

*May 11*
**ASTRONOMY DAY**
Events across the continent
**https://is.gd/AstronomyDay**

*May 30–June 2*
**CHERRY SPRINGS STAR PARTY**
Coudersport, PA
**astrohbg.org/CSSP**

*June 22–29*
**GRAND CANYON STAR PARTY**
Grand Canyon, AZ
**https://is.gd/GCSP2019**

*June 26–30*
**ROCKY MOUNTAIN STAR STARE**
Gardner, CO
**rmss.org**

*June 29–July 3*
**GOLDEN STATE STAR PARTY**
Adin, CA
**goldenstatestarparty.org**

*July 26–August 4*
**SUMMER STAR PARTY**
Plainfield, MA
**rocklandastronomy.com/ssp.html**

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

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

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

*September 19–22*
**RTMC ASTRONOMY EXPO**
Big Bear City, CA
**rtmcastronomyexpo.org**

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

# The Night I Forgot My Telescope

*And what a night it was.*

**THERE I WAS AT LAST,** under a clear, dark sky far from city lights. The air was steady, the mosquitoes mercifully subdued, the only intrusive light bulb miles away. Venus, Jupiter, and Saturn framed the deep twilight, and a waning gibbous moon wouldn't rise for a couple of hours. Lists of long-neglected sky sights assembled themselves in my mind, like children lining up at an ice-cream truck.

Too bad I'd forgotten my telescope.

Well, "forgotten" is a stretch. I'd chosen to leave it at our Vermont vacation rental, an hour away on winding Green Mountain roads, because I'd been tasked with driving teenagers to a fireworks display. But room was found for my charges in other cars, leaving me with sole dominion over an inviting hillside lawn — an hour away from my scope. I pulled my night-driving glasses from my glove box and lay down to await the arrival of night.

"If only I'd brought that telescope!" Who among us stargazers hasn't felt a pang of remorse when rooting about for a missing eyepiece case or forgotten counterweight? This ached even more.

Fortunately, I was able to see this celestial glass as half full: a quiet evening with a galaxy full of stars to call my own. I ran my gaze along the silhouettes of distant trees against a slowly (oh, how slowly!) darkening pink-to-purple sky. Ruddy Arcturus popped into view when I relaxed my upward gaze, soon to be joined halfway across the sky by sparkling Vega.

As successive waves of ever-fainter stars declared their presence, I found myself recalling myriad star-hops of evenings long past. I regarded with longing the faint star dangling from the Big Dipper's handle (a mile marker en route to the Whirlpool Galaxy), the angled star pair bisecting Sagitta (a signpost for the Dumbbell Nebula), and the keystone denoting Hercules' trunk (the path to Messier 13, a glittering star-sphere where true night never falls). Oh, to have that telescope on hand!

And yet . . . without it, I was inspired to give myself a gift I hadn't enjoyed in many years: the simple experience of watching a star-filled night take over from a sun-splashed day. Without the distractions of operating a telescope, I gazed upon star clouds and ghostly glows that I'd hardly noticed before, even though the Cygnus-to-Scorpius Milky Way is prime hunting ground at the star parties I attend. Never had the Small Sagittarius Star Cloud or the Lagoon Nebula stood out in such bold relief. Never had the Coathanger so vividly adorned the hinterlands of Vulpecula. Never had I been better able to follow the stellar steppingstones along the Swan's neck or amidst the locks of Berenice's hair.

Never, in other words, had I so fully embraced the journey in lieu of the destination.

All because I'd forgotten my telescope.

■ **JOSHUA ROTH** was an *S&T* editor from 1995 to 2006. He now curates online learning experiences for Cengage.

RACHEL HARRIS