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Target: Pelican Nebula
Photographer: Ron Brecher
OTA: Esprit 150ED Super Apo Triplet

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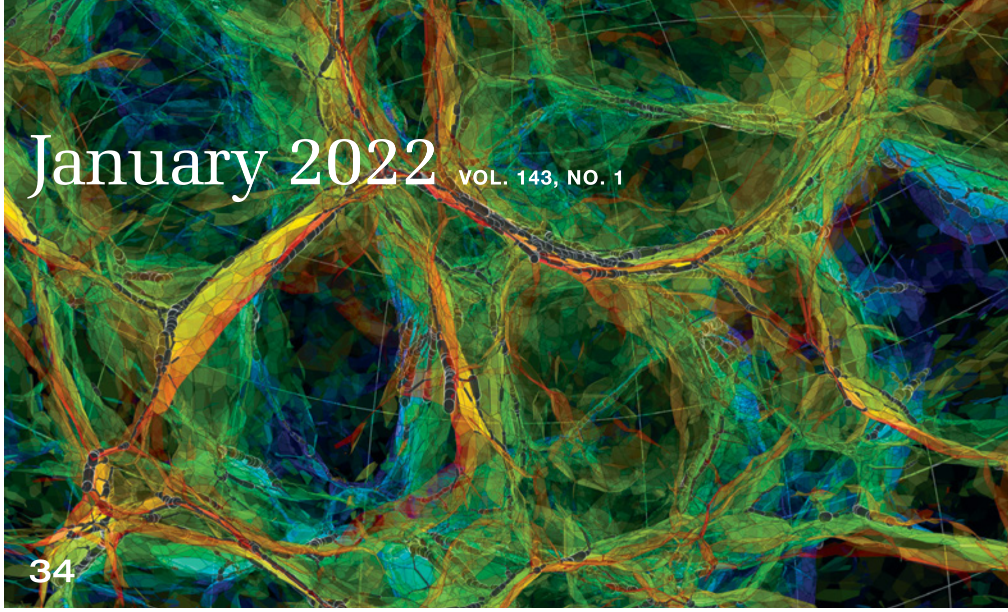

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Are You Sirius?

WHIMSY HAS LONG HELD an honored place in astronomy. We can thank ancient civilizations for setting the stage, placing all those fantastical creatures and heroes in the sky as they did. Many of them remain up there to this day, from Hydra to Hercules to the ultimate in whimsical, the Unicorn (though Monoceros was a 17th-century addition).

Even for active stargazers who use it all the time, the constellation menagerie is extravagant (and if you can see a Charioteer in the five-sided Auriga, more power to you). But imagine for a moment you knew nothing about astronomical history and were shown the chart of Orion and Taurus on page 59 and were told you could see that pair in the night sky right now. You could be forgiven for thinking, *A beefy guy with a club attacking a steer? It's a bunch of stars, friend!*

Of course, these figures — as for Ptolemy and other early astronomers who placed them there — serve a purpose for us: They help create order out of chaos. And as *S&T* readers well know, once you see certain of these figures overhead, you can't unsee them, such as the Teapot asterism in Sagittarius.

Sky & Telescope has long embraced our field's fanciful side, and this issue showcases that aspect. You can find it in titles, like "Bowling for Borrelly" (page 48) or "The Taming of the Slew" (page 72). You can recognize it in the writing, as when Ken Hewitt-White talks in his column about leaping minnows and "fraudulent fish" (page 54). We even pull out the stops on the frolicsome front and offer a scavenger hunt (page 20).

▲ Edward Lear illustrations of "The Owl and the Pussycat" and a scarlet macaw

PUBLIC DOMAIN (2)

Yet the whimsy is just a veneer. Beneath the lighthearted surface of each of these pieces you'll find the usual authority, the richness of scientific and historical detail, the best filters or lenses to use, the latest findings astronomers or the authors themselves have made. Our writers take their passion very seriously, even as they don't take themselves too seriously. It's a perfect balance: If it were all whimsy, it would be fluff; if it were all sober, it would be dry.

I'm reminded of the work of the 19th-century English artist and writer Edward Lear, whose work exemplifies this mix of the playful and the deeply serious. Lear is celebrated equally for his nonsense verse and drawings, and his exquisitely rendered illustrations of birds and other animals (see images above). Around the holiday season, and especially in these unsettled times, we can benefit from a healthy dose of both approaches.

Peter

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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Subscription Rates:
U.S. and possessions: $54.95 per year (12 issues)
Canada: $69.95 (including GST)
All other countries: $84.95, by expedited delivery
All prices are in U.S. dollars.

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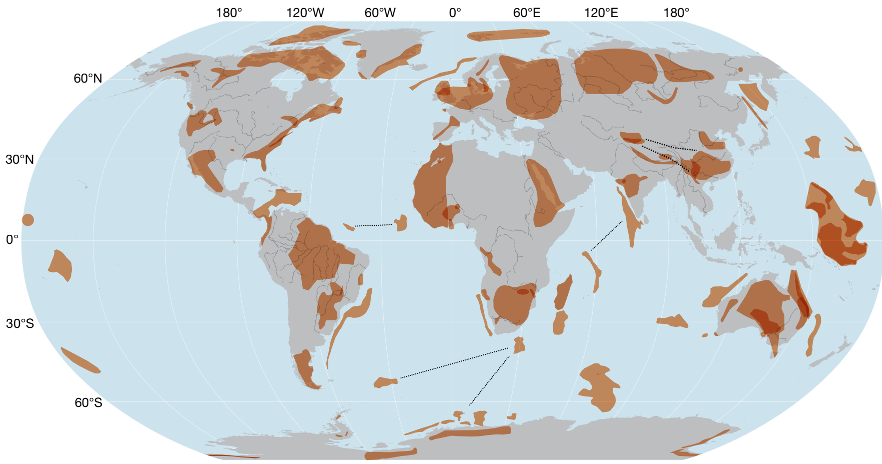


▲ The results of dozens of ample magma flows, known as large igneous provinces, cover the Earth. This map contains those from the past billion years, some of which scientists have linked to mass extinction events.

LIP COMMISSION MAP, UPDATED FROM R. E. ERNST AND N. YOUBI / *PALAEOGEOGRAPHY, PALAEOCLIMATOLOGY, PALAEOECOLOGY* 2017

Mass Extinction Events

I'm an amateur astronomer and an amateur volcanologist. Over the years, I've come to the conclusion that the discussion over the trigger of mass extinctions like the one in Shannon Hall's article "The Case of the Dead Dinosaurs" (*S&T:* Oct. 2021, p. 18) is not about what individual process caused them. Rather, the question is what combination of insults to the biosphere caused a mass extinction. We have to be careful about pointing fingers as the number of known mass extinctions is relatively small, only showing up with multicellular life and fossils present in, say, the last half billion years.

There is an outfit that calls itself the Large Igneous Provinces Commission (**largeigneousprovinces.org**). It maintains a database of massive volcanic eruptions, known as large igneous provinces (LIPs), stretching back nearly 3.5 billion years.

One logical conclusion would be that life on this planet evolved in the presence of LIP formations and is reasonably tolerant of them. The creation of every LIP formation does not coincide with a mass extinction, but every mass extinction seems to have a major volcanic eruption somewhere near in time.

What if a combination of massive environmental "insults" is what pushes the biosphere into a mass extinction event? For example, we know that the most recent mass extinction, roughly 65 million years ago, took place close to two events: a huge asteroid impact on the coast of what is now the Yucatán Peninsula, closely preceded by the enormous Deccan Traps eruptions in what is now central India.

Another approach would be to look at two known major insults that happened around the same time and try to figure out why a mass extinction event did not happen. A good example would be the end of the Eocene Epoch, when there was only a minor extinction event. At the time, three LIPs were in play: one in the Afar region of Ethiopia, and two poorly dated events in western and central Europe and in northern and central Africa. There were also multiple impact events around the same time — Popigai, Chesapeake Bay, and Toms Canyon. While there was a minor extinction event, it was not a major one, even though the planet cooled overall.

Perspective is everything. We may very well find that these events are not an either-or game. The investigation into them will be fascinating.

Alex Gimarc • Anchorage, Alaska

A Prehistoric Cold Case

Shannon Hall's article was much appreciated. If you pick up a globe of Earth, the Chicxulub impact site and the Deccan Traps are not quite antipodal but seemingly would have been more so 65 million years ago before the Indian continent drifted so far north. This has always seemed like an unlikely coincidence to me. The extreme violence of the impact would have been seismically concentrated at the antipode. So Paul Renne and Courtney Sprain's conjecture about the impact having "kicked the ongoing volcanism into high gear" seems to be the more likely scenario. Given the difficulty of dating past events accurately, perhaps the impact was even more causal in producing the Deccan Traps' enormous basalt flows.

Marcus Honnecke
North Park, Colorado

Shannon Hall presented a zesty debate on the mass extinction of the dinosaurs. Was it caused by an impact or a volcano? Both, I think. Representations of the shock wave propagating from the impact site often show an expanding ring of destruction that diminishes in strength as it widens. Halfway around the world, the ring begins to contract and intensifies in energy as it races to a focus point on the opposite side of Earth from the Chicxulub impact. However, it isn't a sharp focus because shock waves pass through each of the many geographic formations on Earth differently due to their varying densities.

The Deccan Traps had been pouring out lava for hundreds of thousands of years before the asteroid hit, but the propagated impact energy would have blown the volcanic vent wide open. This accounts for the fossil evidence, which shows earlier extinction events of varying severity around the globe and a massive spike in extinctions near the time of the impact.

David L. Koren
Sarver, Pennsylvania

Sabrina Garvin replies: *You both make good points. The theory that the massive lava flows at the Deccan Traps* *were the result of an antipodal reaction to an impactor was popular when astronomers first proposed the asteroid theory in the 1980s, but it fell out of favor after they discovered the Chicxulub crater in 1991. The paper by Mark Richards, Renne, Sprain, and colleagues (***https://is.gd/Chicxulub_Deccan***) details why, but the primary reason, they argue, is that 65 million years ago, the Chicxulub impact site's antipode was too far east of the Deccan Traps to cause that kind of reaction. Instead, they suggest that the asteroid shook the planet enough to ramp up the ongoing volcanism.*

I enjoyed reading Shannon Hall's article "The Case of the Dead Dinosaurs" but found myself wishing she had provided some more information. Among my questions were: What are the relative abundances of iridium and mercury in both Earth's mantle and different asteroid types, and what are the error bars in dating both the Chicxulub impact and the Deccan Traps events? (A graphic image superimposing these events would have been a nice inclusion.)

Douglas Warshow
Ann Arbor, Michigan

Camille M. Carlisle replies: *The recent paper* "The Chicxulub impactor: comet or asteroid?" (**https://is.gd/Chicxulub_Impactor**) *gathers together useful research on the evidence in favor of a carbonaceous chondrite asteroid being the impactor. According to that paper, scientists estimate that the total mass of iridium in the geologic clay layer is 2.0–2.8 $\times 10^{11}$ g, and a 10-km-wide carbonaceous chondrite–like asteroid would deliver about 2.3 $\times 10^{11}$ g — a very nice agreement. In contrast, a 7-km-wide comet (which would make the same size hole in Earth's crust since it would hit it at a faster velocity) would deliver less than a tenth as much iridium. To your second question: My original intention was to design a graphic timeline combining the Chicxulub and Deccan timeframes and lines of evidence. But I discovered that there is so much debate over the times and uncertainty ranges that it would have been a disaster of contradictions. Alas, I had to give up the idea.*

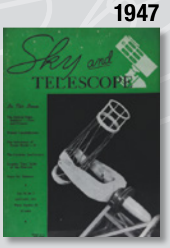
FOR THE RECORD

- The Chicxulub impactor was 10 km wide, not 200 km as stated in the graphic on page 20 of the October issue.
- In the info box on page 31 of the October issue, SagDIG is a member of the Local Group but isn't a satellite of the Milky Way.
- On page 23 of the August 2021 issue, all instances of NGC 7133 should read IC 5132/33.
- In "Mars Bumbles Through the Beehive" (*S&T:* June 2021, p. 50), the Beehive Cluster is almost 16 million times more remote than Mars.

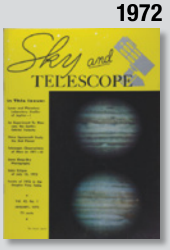
SUBMISSIONS: Write to *Sky & Telescope*, One Alewife Center, Suite 300B, Cambridge, MA 02140, USA or email: letters@skyandtelescope.org. Please limit your comments to 250 words; letters may be edited for brevity and clarity.

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

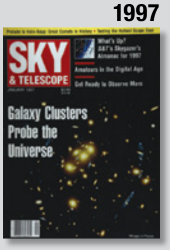
1947



1972



1997



January 1947

Far UV "[At] White Sands Proving Ground on October 10th, . . . the ultraviolet spectrum of the sun at wave lengths shorter than 3400 angstroms was obtained from a V-2 rocket at a height of 88 kilometers. The limit of the spectrograph was 1100 angstroms, [a region] normally absorbed by the ozone in the upper atmosphere. The new spectra clearly show the elimination of this absorption and the appearance of the spectrum in the ultraviolet as the rocket ascended above the ozone layer."

Captured German V-2 rockets continued to open new frontiers.

January 1972

Dwarf Unveiled "Sirius B is among the most important of the several thousand white dwarfs now known, since it forms a visual binary with Sirius A, the brightest star in the [night] sky. . . . But it is 10 magnitudes fainter than Sirius A, so its spectrum is exceedingly difficult to photograph without serious contamination from the brilliant primary. . . .

"During the past decade, the angular separation between the two components has been nearly the maximum possible, [letting astronomers] obtain the first 'clean' spectra of Sirius B at the coudé focus of the 200-inch telescope. . . .

"J. L. Greenstein, J. B. Oke, and H. L. Shipman [report] that Sirius B has an effective temperature of 32,000° Kelvin, radius 5,400 kilometers [, and is] a white dwarf consisting primarily of helium."

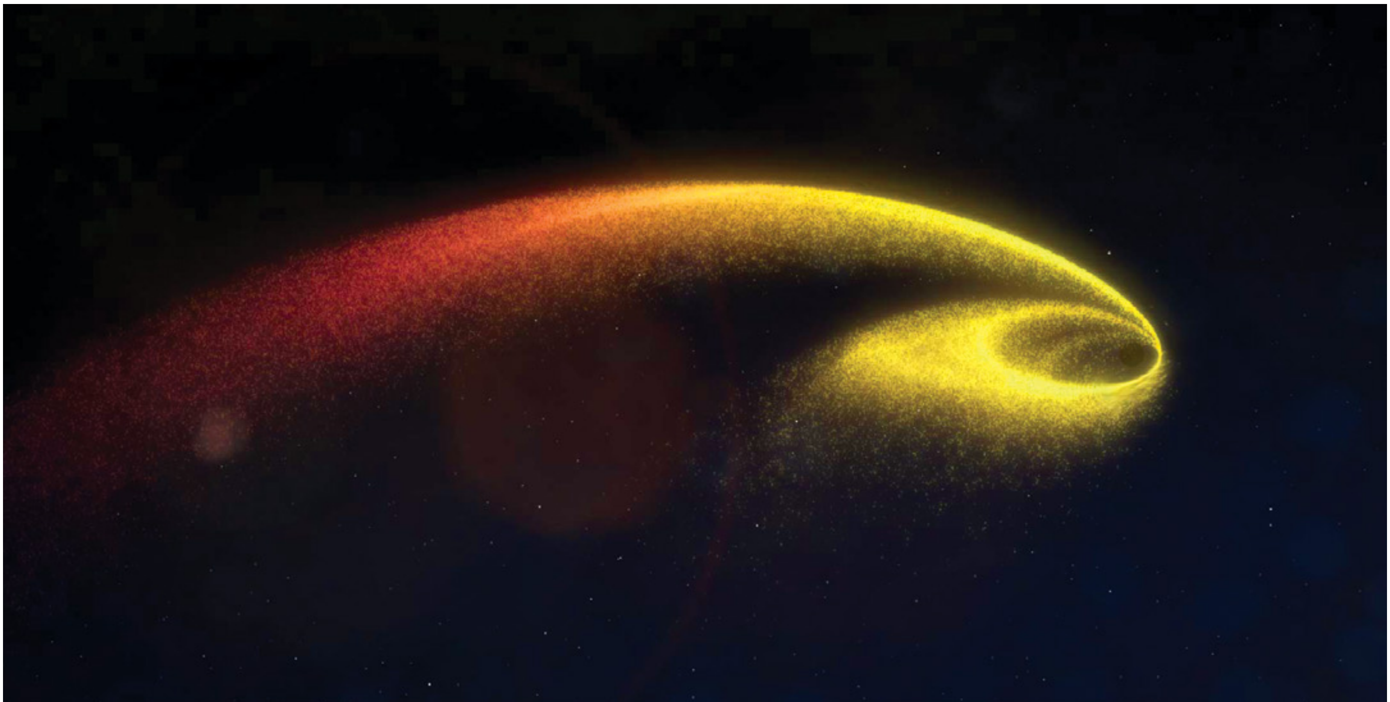
January 1997

CCD Charm "Unless you are very new to astronomy, you know about the astroimaging revolution. Amateurs are converting wholesale from conventional emulsion-based photography to digital imaging . . .

"During the 1980s backyard observers chalked up about 20 extragalactic supernovae. That number has more than doubled in the first six years of this decade, and most of the new finds were captured by CCDs. . . .

"Closer to home are countless asteroids waiting to be discovered. With rare exceptions, the sky has been swept clean of minor planets brighter than 16th magnitude (and thus within easy reach of conventional amateur astrophotography). But a CCD on even an 8-inch telescope can easily reach 18th magnitude in a few minutes. That opens a remarkably wide door to discovery. The experience of veteran observer Paul Comba in Arizona is a case in point. In the six months after connecting a CCD camera to his 18-inch reflector he discovered 39 asteroids between 18th and 20th magnitude."

As Dennis di Cicco anticipated, a new "golden age" of amateur asteroid discovery began. Today, however, large professional surveys are gobbling up asteroids at an astounding rate, and the sky has now been "swept clean" almost to magnitude 21.



BLACK HOLES

Shredded Star Reveals Elusive, Middle-Mass Black Hole

ASTRONOMERS HAVE USED the death of a star to uncover details about a black hole that weighs in between stellar-mass black holes and the leviathans that lurk in massive galaxies' centers.

Observers have found a few dozen candidate *intermediate-mass black holes*, with masses equivalent to tens to hundreds of thousands of Suns. But we know next to nothing about them.

Sixiang Wen (University of Arizona) and colleagues have now taken a closer look at one of those candidates. The middling black hole appears to sit in a star cluster near a galaxy about 740 million light-years away in the constellation Aquarius. Normally the black hole is invisible, but astronomers spotted it when it tore up and swallowed a star, skirting itself in the glowing debris and lighting up in an event dubbed 3XMM J215022.4−055108.

▲ Illustration of a star shredded by a black hole's tidal pull. The trailing part of the stream-that-was-a-star escapes the system, while the leading part swings back around.

As this tutu of hot gas swirled around and fell into the black hole, it heated up, emitting X-rays. The team used observations spanning 12 years from the XMM-Newton and Chandra X-ray space telescopes to watch the cataclysm unfold.

Using an approach originally designed for stellar-mass black holes, the team calculated this heftier black hole's approximate mass and spin: 20,000 Suns and 80% of the maximum, respectively. The results appear in the September 10th *Astrophysical Journal*.

Astronomers have used star-shredding calamities, called *tidal-disruption events*, to measure supermassive black holes' spins before — but they've never done it for an intermediate-mass black hole. What's truly curious about this result, though, is the value of the spin. A black hole's spin can tell us how it grew, but the team has no good explanation for the observed value.

The spin is slightly too high to match what's expected if the black hole was made by merging smaller ones, far too high for the black hole to have grown by munching intermittent gas snacks, yet too low to have grown by eating a steady stream of gas.

Wen personally favors either a runaway collision of stars or direct collapse, in which a large, pristine gas cloud crumples in on itself. The black hole has the right mass to fit in the direct-collapse scenario, which vies with a couple of others as a favored origin for black hole seeds in the early universe (*S&T:* Jan. 2017, p. 24).

Future eROSITA X-ray observations will help the team find more events like this one.

■ CAMILLE M. CARLISLE

NASA'S GODDARD SPACE FLIGHT CENTER / CHRIS SMITH (USRA / GESTAR)

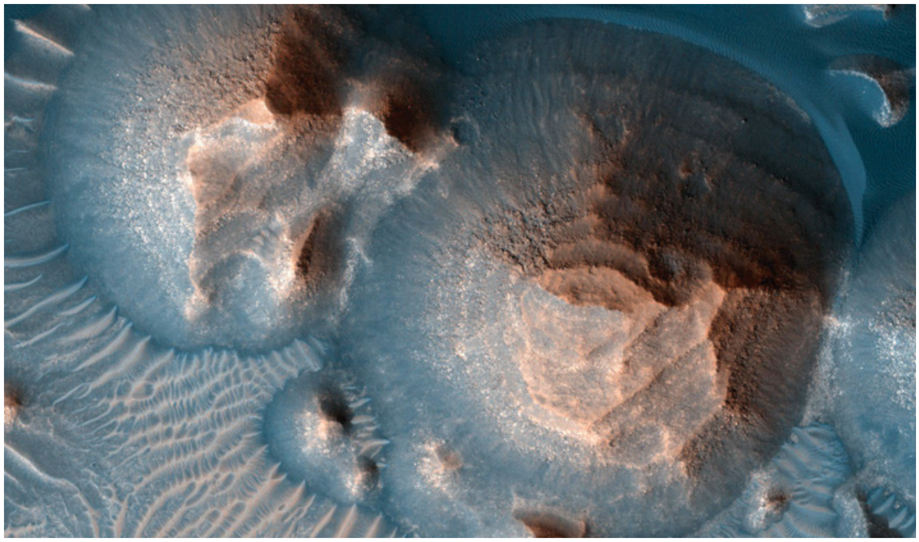
MARS

The Red Planet Hosted Ancient Supervolcanoes

ORBITAL IMAGES SUGGEST explosive volcanoes once tore apart the surface of Mars, spewing tons of ash and noxious gases into the atmosphere billions of years ago.

Scientists already knew that Mars was volcanically active early on, but evidence for explosive volcanoes was missing, leading some to think the planet only produced oozing, shield-type volcanoes.

Now, researchers examining the rugged terrain of Arabia Terra have found massive deposits of buried volcanic ash associated with giant craters in the area. Patrick Whelley (University of Maryland, College Park) and colleagues used NASA's Mars Reconnaissance Orbiter to study cliff faces, which revealed layers of minerals with the composition of chemically altered volcanic ash. Dispersion models confirmed that the distribution of the deposits matches that expected from explosive eruptions. The team describe their findings in the August *Geophysical Research Letters*.



▲ These craters in Arabia Terra on Mars are filled with layered rock, exposed in rounded mounds.

"They probably lasted for weeks to months at a time, where they're exploding and pushing out a bunch of material," Whelley explains. "So it's not just one explosion, but it's a series of sustained eruptions for many days up to months, perhaps."

The researchers estimate that between 1,000 and 2,000 individual super-eruptions occurred over a period of 500 million years.

Other researchers aren't fully convinced. "We still don't know for sure whether powerful volcanic eruptions took place in this region on early Mars," says Petr Brož (Institute of Geophysics of the Czech Academy of Sciences), who wasn't involved in the present study. "Erosion and younger resurfacing events could have destroyed or modified the evidence about such activity."

Nevertheless, Brož adds, "this work is bringing us a bit closer to such an answer. It is showing us that a powerful and repetitive process has to be responsible for the formation of these enigmatic deposits."

■ **JAVIER BARBUZANO**

MARS

Perseverance Snags First Samples

NASA'S PERSEVERANCE ROVER has collected two chalk-size cores from Jezero Crater, the first samples to be cached on Mars. The cores came from a large rock dubbed "Rochette," part of the long Artuby Ridge. The team announced the second successful collection on September 10th.

The process was suspenseful because Perseverance ran into problems on its first sampling attempt in August. Team members think the rock crumbled to pieces, which is why the tube came back empty. (It did, however, collect Martian atmosphere, so all was not lost.)

Based on images of the cores, scientists think the rocks are igneous, likely basalts from ancient lava flows. The presence of salts indicates that water percolated through this rock long ago. Once the sample caches are returned to Earth, scientists will look for liquid bubbles trapped in the salts called *inclusions*; they could provide a glimpse of Jezero Crater when it was wet and possibly capable of supporting life.

The Perseverance rover carries 43 containers, with the aim of collecting at least 30 samples for future return to Earth. About 14 of these will come from ancient rocks inside the crater. Then the rover will begin exploring the fan-shape delta, deposited by the ancient river that spilled into Jezero.

■ **DAVID DICKINSON**

▶ Perseverance drilled two holes in the rock dubbed "Rochette" (left of the rover) to collect a pair of igneous cores.

ARABIA TERRA: NASA / JPL-CALTECH / UNIVERSITY OF ARIZONA; SAMPLES: NASA / JPL-CALTECH

STARS

Supernovae Hollowed Out "Giant Cavity"

MILLIONS OF YEARS AGO, supernova blasts cleared a giant hollow in space, triggering the next generation of stars in their wake.

Shmuel Bialy (Center for Astrophysics, Harvard & Smithsonian), Reimar Leike (Max Planck Institute for Astrophysics, Germany), and colleagues pieced together this remarkable story based on dust.

Last year, Leike created an unprecedentedly sharp map of cosmic dust in the solar neighborhood using the distances to stars measured by the European Space Agency's Gaia satellite. By comparing stars' measured brightness with how bright they ought to be, given their spectral class, Leike could estimate the amount of dust dimming the light.

Now, Bialy and colleagues have used the dust map to disentangle two nearby star factories, the Perseus and Taurus molecular clouds. They publish the results in the September 20th *Astrophysical Journal Letters*.

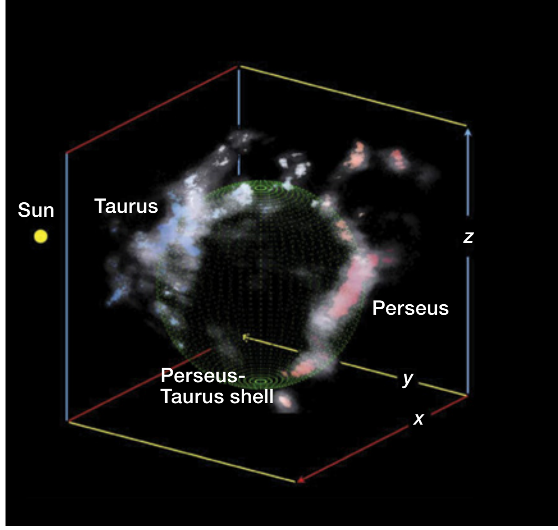
Astronomers have long suspected an association between the Perseus and Taurus clouds. Using tools that visualize the 3D dust distribution, Bialy's team showed that the clouds are actually on opposite sides of a giant, empty cavity — a supernova-blown superbubble 500 light-years across. Other data, including the emission of X-rays and an abundance of the aluminum-26 isotope, both coming from hot gas inside the shell, support the supernova scenario.

"I think that the [researchers] make a very convincing case for a cavity powered by a few supernova explosions," says Evangelia Ntormousi (Normal School of Pisa, Italy), who was not involved in the study.

The superbubble would have taken at least 6 million years to grow so large. However, if it were older than 22 million years, then the bubble would have dissipated into the interstellar medium. In other words, at some point after the existence of early apes but well before the first humans evolved, a series of supernovae lit up this area of the sky, and now we can see the long-term consequences of those blasts. As supernova-powered shock waves swept through the region, they compressed dust and gas into what are now star-forming clouds lining the cavity's edge. These new data provide the first 3D view of the long-held idea that the deaths of stars can trigger new generations.

■ MONICA YOUNG

Interactive map at https://is.gd/PerTau



▲ The Perseus and Taurus star-forming clouds lie on opposite sides of a large cavity.

S. BIALY ET AL. / *ASTROPHYSICAL JOURNAL LETTERS* 2021

SOLAR SYSTEM

Amateurs Spot Impact Flash at Jupiter

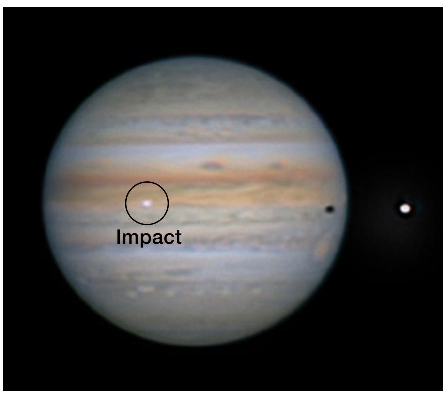
AMATEUR ASTRONOMER José Luis Pereira of Brazil discovered a probable impact at Jupiter on September 13th at around 22:39:30 UT (18:39:30 EDT). Weather conditions were poor at the time, but Pereira decided to search for possible flashes anyway using the *DeTeCt* software (see page 52). The program alerted him that there was a high probability that he'd caught a collision. He immediately sent a message to Marc Delcroix, who helped create the software, for confirmation. Several other observers independently saw or recorded the flash.

This is the 10th recorded impact at Jupiter, starting with the first one in July 1994, when fragments of sundered Comet Shoemaker-Levy 9 slammed into the planet and left a trail of prominent, dark impact scars.

Initial rough estimates put the new impactor's size at 100 meters (328 feet), but there were no reports of dark impact scars following the flash.

■ BOB KING

See more reports and images at https://is.gd/Jupiterimpact2021.



◀ This frame shows the moment of impact that German amateur astronomer Harald Paleske captured via recorded video.

IN BRIEF

Probe Passes Mercury

On October 1st, BepiColombo finally reached Mercury — and shot right past it. The joint mission of the European Space Agency (ESA) and Japan Aerospace Exploration Agency (JAXA) will ultimately whizz by the innermost planet five more times before finally entering orbit in December 2025. During this first encounter, BepiColombo approached the planet's nightside and viewed a gibbous Mercury on the outbound path. At its closest, the spacecraft's trajectory brought it within 200 kilometers (120 miles) of the surface. BepiColombo is a stack of three spacecraft: ESA's Mercury Planetary Orbiter, JAXA's Mercury Magnetospheric Orbiter (named "Mio"), and ESA's Mercury Transfer Module that propels them. Many of the MPO's instruments were facing Mio to protect against damage during the long cruise, so they can't see space at all right now. But all of Mio's fields-and-particles instruments were operating during the flyby and studying the planet's magneto-

SOLAR SYSTEM
"Mushballs" Might Fall on the Giant Planets

HAIL-LIKE, AMMONIA-RICH "mushballs" were first inferred to exist on Jupiter, plunging deep below the cloud bank in the giant planet's atmosphere. Now, new research suggests mushballs might also fall on Uranus and Neptune.

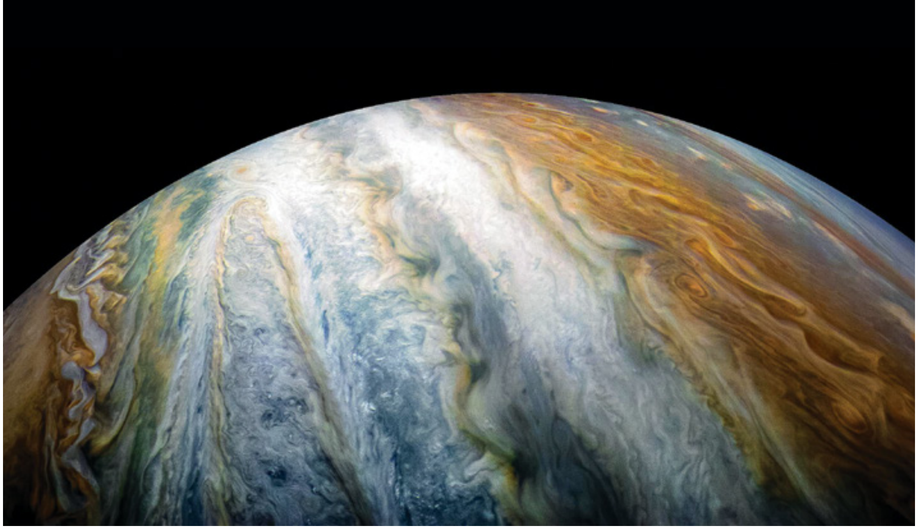
Key evidence for mushballs' existence on Jupiter came from NASA's Juno spacecraft. First it found an odd circulation pattern, with little ammonia anywhere in the atmosphere except along the equator (*S&T:* Dec. 2017, p. 14). Then came Juno's dramatic close-ups of violent thunderstorms, which showed lightning flashing in the upper atmosphere. Lightning requires the presence of a liquid, so astronomers were baffled to find it in a region where temperatures are colder than −88°C (−126°F).

But what if water mixed with antifreeze? Ammonia is "the best antifreeze you can get," explains Tristan Guillot (Côte d'Azur University, France). Last year, he and colleagues proposed that drops of two parts water to one part ammonia could remain slushy enough to allow lightning. This mixture would form hail-like mushballs as it fell, drawing ammonia underneath the cloud deck. This also explains why ammonia is more abundant in Jupiter's equatorial region, where there are fewer storms.

Recently, infrared observations have confirmed that ammonia is also rare on Uranus and Neptune, at least as far down as we can see from afar. At the Europlanet Science Congress 2021 in September, Guillot showed that mushballs could explain this phenomenon, too. In fact, mushball formation could be even more efficient on the ice giants than on Jupiter.

However, David Stevenson (Caltech) is cautious. He coined the term "mushballs" and worked with Guillot on the Jupiter research but not on the other planets. "In the case of Uranus and Neptune," he says, "the data admit alternatives."

■ JEFF HECHT



NASA / JPL-CALTECH / SWRI / MSSS / KEVIN M. GILL

▲ This enhanced-color image from Juno shows the swirling cloud deck of Jupiter's southern hemisphere.

sphere. The transfer module's three cameras, generally used for monitoring the solar panels, also glimpsed Mercury during the flyby.

■ EMILY LAKDAWALLA

Moon Landing Site Selected for VIPER Mission

NASA has announced that its VIPER rover, set for launch in 2023 (*S&T:* Jan. 2021, p. 34), will land just outside the western rim of Nobile Crater near the lunar south pole. The targeted study area covers 93 square kilometers (36 square miles); VIPER is expected to traverse 16 to 24 km during its primary, 100-day journey. NASA based the final site selection on four criteria: Earth visibility, which is necessary for direct line-of-sight communication; access to sunlight to charge the solar-powered rover; terrain that's suitable to traverse; and evidence for the likely presence of water ice. VIPER will search on and below the surface in at least six permanently shadowed regions, drilling and sampling in at least three of these locations. The rover carries three instruments to analyze volatiles (such as water ice) and mineral composition, as well as multiple cameras to capture the twilit landscape. The rover will follow several other lunar landers planned to launch in this time frame, including two NASA-funded landers and one each from Japan, Russia, and India.

■ DAVID DICKINSON

Sun-like Stars Eat Their Own

Some Sun-like stars that were born in the same gas cloud as their companions show unexpected differences — perhaps because some stars eat their own planets. To understand the chemical differences between such stars, Lorenzo Spina (INAF Astronomical Observatory of Padua, Italy) led a team in examining the composition of pairs of Sun-like stars. On August 30th in *Nature Astronomy*, the researchers report that in 33 of 107 pairs, one of the stars has more iron than expected. (The other stellar pairs are all chemically identical.) Iron is a refractory element that can survive engulfment by a star, and it's readily available in rocky planet cores. Furthermore, the stars with higher iron abundances also tended to have more lithium. Stars destroy lithium in fusion reactions, but it's plentiful in planets, so this finding also supports the planet-engulfment scenario. Based on the sample, Spina's team estimates that about a quarter of Sun-like stars eat from their own planetary buffet, speaking to the chaos — and carnage — of planet formation.

■ MONICA YOUNG

White Dwarfs Still Burn

When stars near the end of their lives, they stop burning. Most stars shed their outer layers before collapsing into white dwarfs. With no source of energy, these objects should slowly cool and dim. But ultraviolet Hubble Space Telescope observations of two globular clusters (M3 and M13) show that some white dwarfs still burn. While both clusters are both about 13 billion years old, Jianxing Chen (University of Bologna, Italy) and colleagues find that M13 has extra bright white dwarfs. That abundance, they show, originates in the cluster's larger fraction of weensy stars, with less than about half the Sun's mass. Even after they collapse, these stars retain a hydrogen envelope for later burning. About 70% of the white dwarfs in M13 are of the slow-burn variety. The finding upsets the notion of white dwarfs as forever-cooling embers.

■ MONICA YOUNG

Many Happy Returns

Venus's eight-year cycle has the author dreaming of 2029.

AS I WRITE THIS IN SEPTEMBER, Venus is wrapping up another magnificent appearance as the Evening Star. All summer and fall it has beamed through the dusk as the sky has darkened before following the Sun to exit, stage West. It's a stirring and comforting sight, and I always look forward to another visit from this stunning old friend.

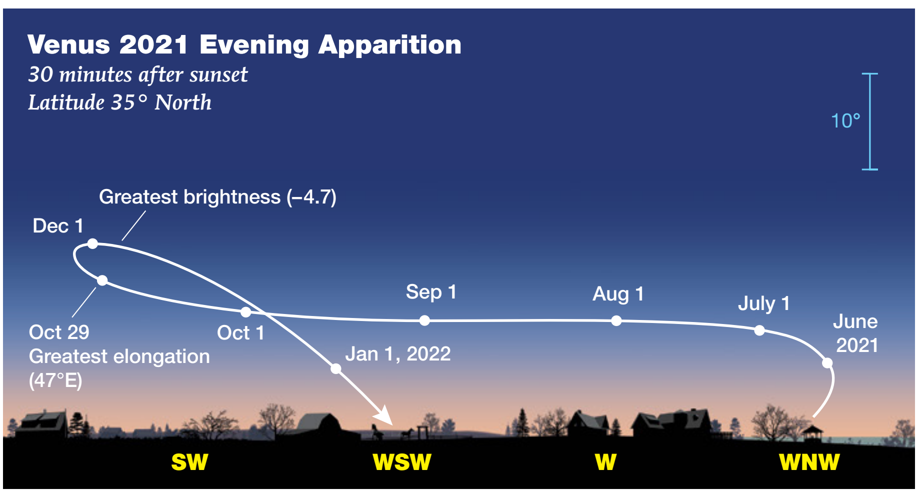
Venus repeatedly passes us on an inside lane, swinging between dawn and dusk in its never-ending 19-month cycle. It approaches Earth in the evening, pulls out in front of us in the morning, then races around to come up behind us again.

Our sister planet laps us almost exactly five times every eight years. (A Venusian would say the passing repeats every 13 Venus years.) This 8:13 mean-motion resonance is not perfect — it slips by two days every eight years — and its origin is not understood. But for millennia humans have observed and recorded this repeating cycle.

In any given year, Venus slowly traces out a peculiar shape against the sky. The exact pattern will depend on your latitude. Where I live at a mid-northern latitude (see diagram), Venus in its most recent apparition first appeared in late April 2021 about 20° north of due West. It rose higher each night for a few weeks before turning south in early June. In October it will reach greatest elongation, lingering for awhile into the darkness at the extremity of its orbit as seen from Earth. December will see it reverse course, heading north and plunging downwards into the solar glare, to finally disappear in January. The whole thing makes a sort of lopsided, tilted infinity sign, with the larger lobe disappearing over the horizon.

This month, Venus again becomes the Morning Star, and it will stay that way until its next evening apparition starting in November. But the pattern then will be markedly different from what you see below, as a result of the ecliptic's north-south seasonal tilt. The following three evening appearances will also be distinct, tracing new shapes over time.

Then something wonderful happens. The sixth appearance, beginning exactly eight years after the first, will repeat the first. And each successive return will imitate the one five cycles earlier. Thus, Venus outlines five distinct shapes in the sky, each of which repeats every eight years.



The Maya and Aztecs had different names and glyphs for each of the five appearances, which figured prominently in their origin stories and calendar cycles. Today, with our libraries full of planetary data and detailed imagery from spacecraft missions, we're distracted from these splendid patterns.

> When I see my brilliant companion, I know that, eight years hence, it will be right back in the same spot again.

But bright Venus, undiminished even in light-polluted skies, remains there for any of us to observe.

Having trained myself to be aware of these patterns, I often use Venus cycles to mark eight-year anniversaries. When I see my brilliant companion, I know that, eight years hence, it will be right back in the same spot again.

This year I'm aware of something new and to me tremendously exciting. My colleagues and I have worked for more than 3 Venus cycles (since the late 1990s) to send new missions to Venus. And now I'm finally on a team selected to do so. We'll build and fly a spacecraft called DAVINCI, which will be the first entry probe NASA has sent there since 1978 (*S&T:* Sept. 2021, p. 10).

The launch is tentatively planned for summer 2029 — one Venus cycle from now. This evening I'll look at the planet and know that, with luck and perseverance, the next time I see it at this same spot in the sky, our little machine will be on its way there.

DAVID GRINSPOON is author of *Venus Revealed: A New Look Below the Clouds of Our Mysterious Twin Planet*.

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SOFTWARE BISQUE

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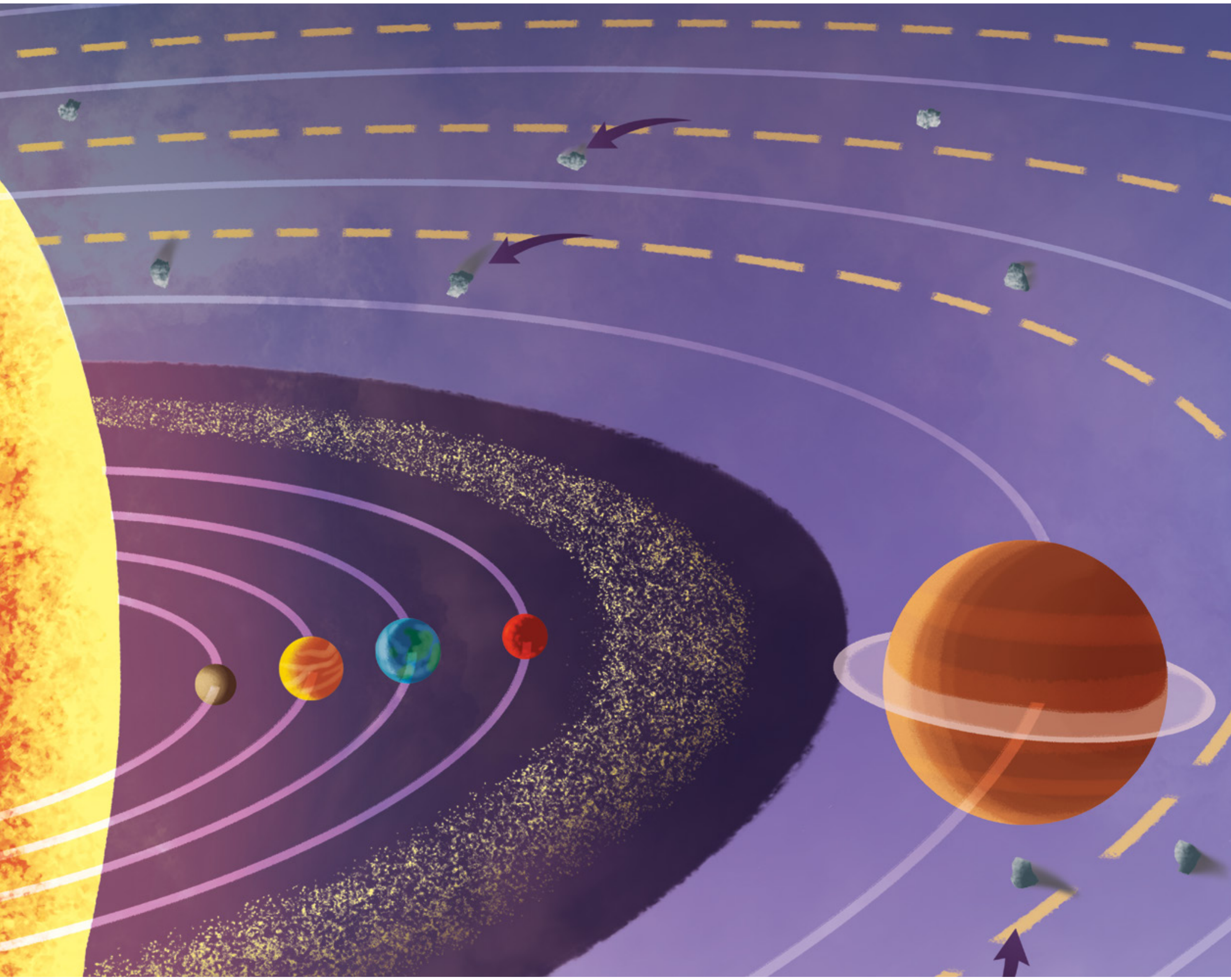
When talking about comets, we often refer to them as visitors from the outer solar system (or beyond). But not all comets hail from the same place. Some originate from the solar system's most distant region, the spherical cloud of debris loosely bound to the Sun called the Oort Cloud. Such objects include the memorable recent visitor Comet NEOWISE (C/2020 F3; *S&T:* Nov. 2020, p. 14), which will not return for another 7,000 years. Many other comets, though, originate in the relatively closer Kuiper Belt, a population of small, icy bodies beyond Neptune's orbit. These comets become more frequent repeat visitors to the inner solar system, with orbital periods ranging from a few to about 200 years.

Before we knew about the Kuiper Belt, a group of these short-period comets puzzled astronomers. Referred to as *Jupiter-family comets* (JFCs) due to Jupiter's dominant role in controlling their orbital evolution, these visitors have distinct properties. They generally take less than 20 years to complete a trip around the Sun, spending much of their time within the region encircled by Jupiter's orbit. A key trait, however, is the orientation of their orbits. While long-period comets zip

The Co

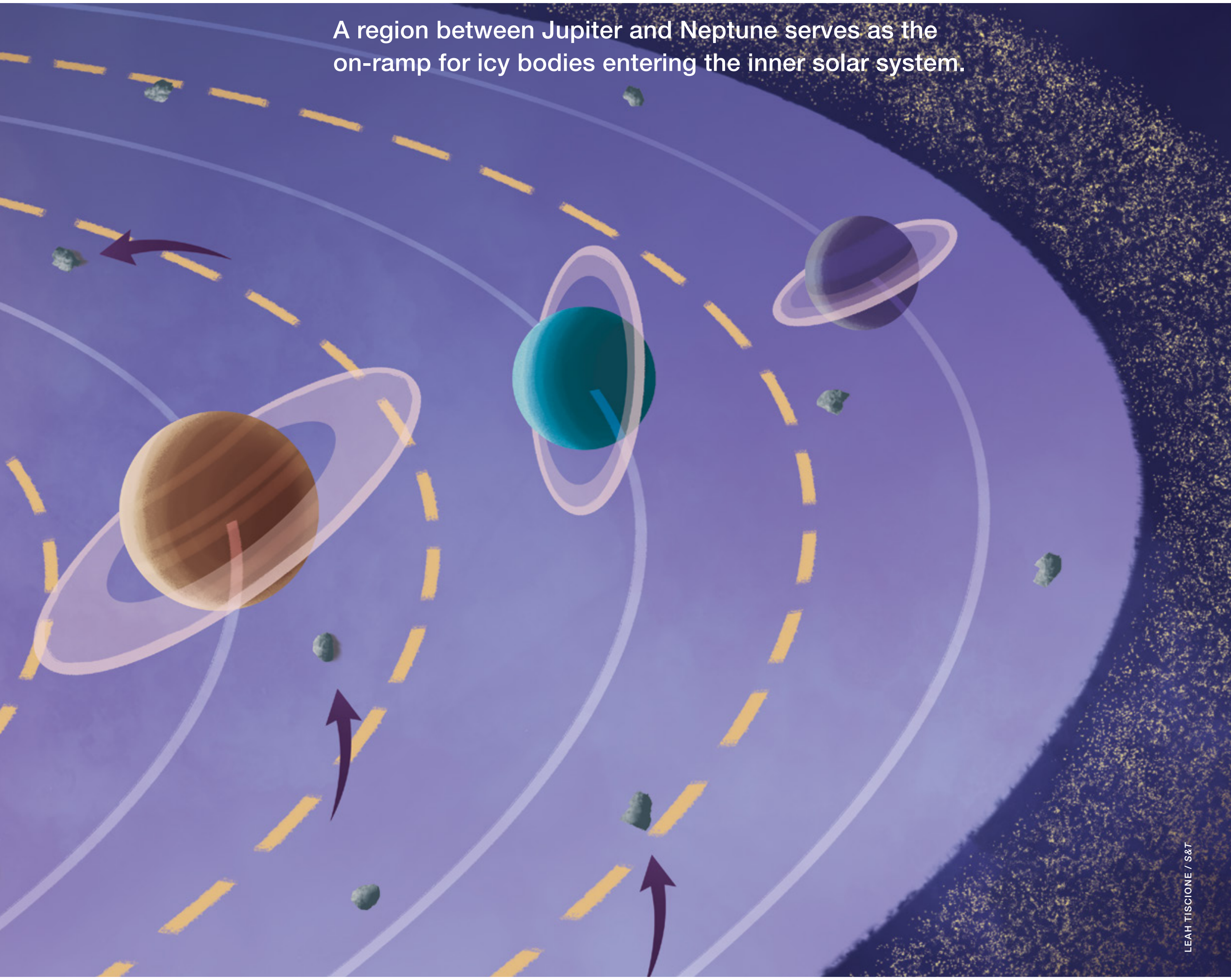


through the inner solar system from essentially all directions, JFCs overwhelmingly orbit the Sun on paths tilted less than about 30° from the planetary plane, and they travel in the same direction as the major planets, too. What could channel comets into the inner solar system like this? And where did these objects come from originally?

We now know the answers to these questions. Pristine bodies from the Kuiper Belt slowly feed into a transition region between Jupiter and Neptune. Then, over astronomically short periods of time, some objects make their way inward to become JFCs. The objects making this transition give us an exciting glimpse of icy worlds as they transform from distant, primordial frozen bodies into spectacular active comets.

met HIGHWAY

A region between Jupiter and Neptune serves as the on-ramp for icy bodies entering the inner solar system.



LEAH TISCIONE / S&T

The Cometary Cell Phone Lot

In the early 1970s, astronomers were still actively debating if Jupiter-family comets had been captured from the Oort Cloud or whether another, then-unobserved source region was needed. (At that time, the only member of the Kuiper Belt we'd found was Pluto.) In 1977, Charles Kowal discovered a harbinger of new outer-solar-system populations: 2060 Chiron. This little world is roughly 200 km (120 miles) across and follows an orbit with a perihelion near Saturn and an aphelion near Uranus. Early calculations showed that gravitational influences from the giant planets should relatively quickly alter its orbit and send it elsewhere. Further studies confirmed that most small-body orbits in the giant-planet region are only stable for about a million years, much shorter than the age of the solar system.

Dictionary: Centaur

A Centaur is a small object that spends some or all of its time in the region between Jupiter and Neptune. (Exact definitions depend on whom you ask.)

Some 15 years after Chiron's discovery, observers found 5145 Pholus, which has an orbit that spans from Saturn to Neptune. Discoveries of several more objects followed soon after. These so-called *Centaurs* are small bodies that, like Chiron, all reside within the giant-planet region on unstable orbits. Early observations of Pholus showed that its surface is extremely red compared with objects in the main asteroid belt, and subsequent measurements of its *reflectance spectrum* (a more detailed measurement of the brightness as a function of wavelength) also proved it to be uniquely red and missing features commonly seen in asteroid spectra. Other Centaurs also looked un-asteroid-like.

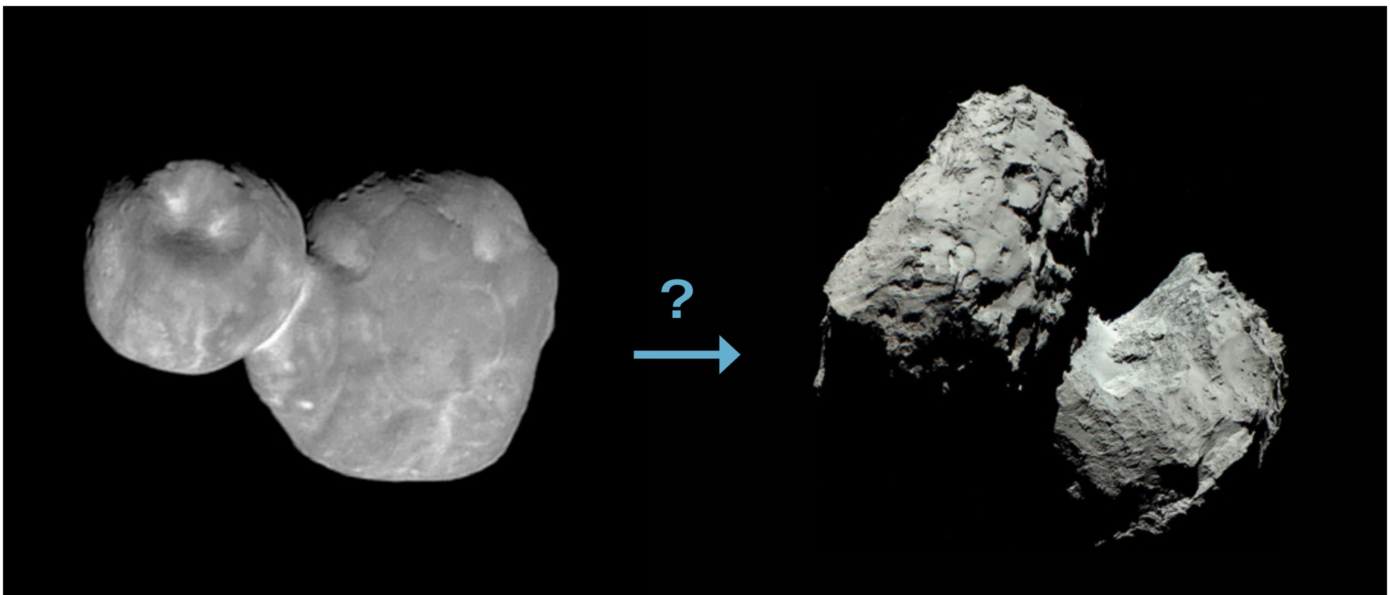
It was apparent that Centaurs are only temporary denizens of the giant-planet region, and their surface compositions don't match those in the asteroid belt. So where did they come from?

In the 1980s and early 1990s, researchers had returned to the idea of a comet belt beyond Neptune's orbit, using expanded computational capabilities and improved numerical tools to show how such a population could supply Jupiter-family comets. In 1992 — the same year that other observers found Pholus — David Jewitt and Jane Luu discovered the first Kuiper Belt object (KBO) residing entirely exterior to Neptune's orbit. This discovery, along with more than a dozen other KBO discoveries in the next three years, finally provided direct evidence of the hypothesized comet reservoir.

Follow-up observations of the newly discovered Centaurs and KBOs found more examples of distinctive red surfaces in both populations. This spectral information provided important compositional links between KBOs and Centaurs to back up the orbital modeling. It was becoming clearer that Chiron and Pholus represented a new population of objects closely related to the Kuiper Belt.

With these early KBO and Centaur discoveries, researchers were finally able to demonstrate the path objects take from the observed Kuiper Belt, through the giant planet region's Centaur population, and into the JFCs. Our understanding of the detailed orbital distribution and formation of the Kuiper Belt has expanded dramatically in the last 30 years, but this basic dynamical connection with the JFCs remains.

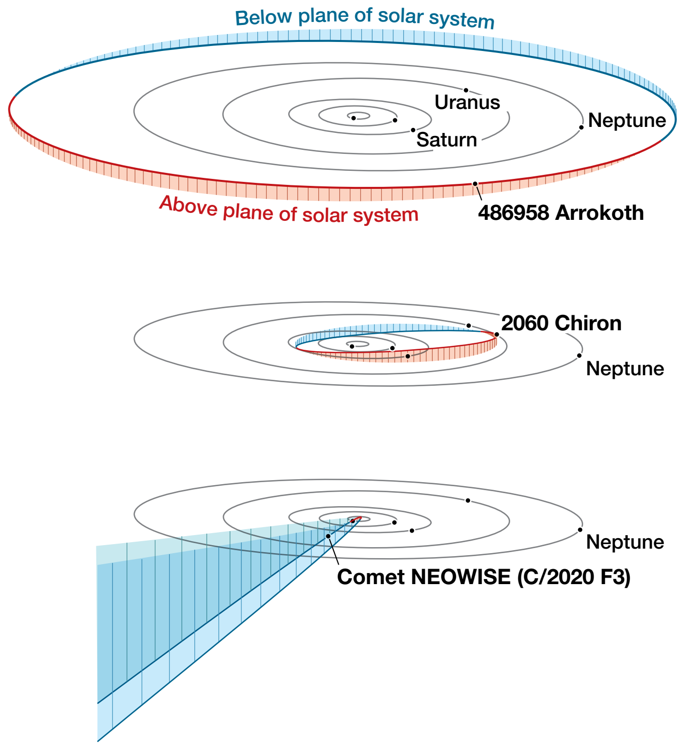
Although some KBOs have always lived beyond Neptune,



THE MAKING OF A COMET Years of observations and calculations led astronomers to deduce that primordial Kuiper Belt objects like Arrokoth (*left*) become Jupiter-family comets like 67P/Churyumov-Gerasimenko (*right*). The question is, what do the objects in transition look like?

ARROKOTH: NASA / JHU APL / SWRI; 67P: ESA / ROSETTA / MPS FOR OSIRIS TEAM MPS / UPD / LAM / IAA / SSO / INTA / UPM / DASP / IDA

Only about a third of Centaurs will make it through the entire giant planet region and past Jupiter to become JFCs in the inner solar system.



▲ **ENTRY** Many Kuiper Belt objects such as Arrokoth *(top)* follow paths minimally tilted with respect to the planets' orbits, as do Centaurs like Chiron *(center)*. But Oort Cloud comets such as C/2020 F3 *(bottom)* often zoom through on highly elongated orbits at steep angles.

GREGG DINDERMAN / S&T

many of the objects in today's Kuiper Belt were placed onto their orbits when the giant planets formed and then migrated to their current positions (*S&T:* Mar. 2021, p. 22). A variety of gravitational effects can change KBOs' orbits. On long timescales, the chaotic combination of orbital alignments with Neptune and the gravitational pull from all the giant planets can dramatically tilt or elongate a KBO's orbit, allowing it to make closer and closer approaches to Neptune. Smaller gravitational tugs from the most massive objects embedded within the Kuiper Belt might even contribute to changes in neighboring objects' orbits, too. All of these factors slowly feed KBOs onto Neptune-crossing orbits over many millions or even billions of years.

Close encounters with Neptune will then scatter these objects, sending some of them to more distant parts of the outer solar system and others onto smaller orbits in the Centaur region. Many Centaurs will interact with just our outer ice giants, Neptune and Uranus, before being tossed back into the Kuiper Belt. But about half will continue their journey inward and become Saturn-crossing Centaurs.

Every time a Centaur encounters a giant planet, its orbit either gets smaller or larger. The exact outcome depends on how closely the Centaur approaches the planet and the direction of that approach. Only about a third of Centaurs will make it through the entire giant-planet region and past Jupiter to become JFCs in the inner solar system. The time it takes an object to either traverse the giant-planet region or be kicked back out into the Kuiper Belt is typically a few million years.

Charting the Territory

Given that Centaurs represent a middle state in the continuum between the outer solar system's Kuiper Belt populations and the inner solar system's JFC population, it is perhaps unsurprising that there isn't one single agreed-upon definition for what a Centaur is. The commonly used definitions place Centaurs as spending some or all of their time in the giant-planet region, with their closest approach to the Sun lying exterior to Jupiter's orbit but interior to Neptune's orbit. Most definitions also require that their average distance from the Sun be in the giant-planet region; the strictest require that the object's orbit lies *entirely* inside that of Neptune.

Depending on which definition you use, the current census of observed Centaurs ranges from about 250 to 350 objects. On this list are objects discovered before Chiron, including 29P/Schwassmann-Wachmann 1, which was discovered in 1927 and classified as a comet due to its bursts of activity (*S&T:* Sept. 2021, p. 57). It wasn't until we had observations of more distant Centaurs and KBOs that we were better able to recognize the Centaurs as a distinct population.

The Centaurs provide a critical link between the nearly primordial icy bodies in the Kuiper Belt and the active, highly evolved comets in the inner solar system. Like their namesakes, Centaurs are hybrid creatures: part active comet, part frozen planetesimal. They offer us an opportunity to watch as objects experience their first significant thawing since they were tossed into outer-solar-system cold storage.

The partly cometary nature of Centaurs became apparent within a decade of Chiron's discovery. Large variations in its brightness over time suggested it was venting icy material from its surface; follow-up observations confirmed the presence of a coma. We now have many more examples of activity amongst Centaurs, ranging from relatively quiescent outgassing to extremely bright outburst events throwing off large amounts of dust and gas. Approximately 10% of the observed Centaurs have confirmed cometary behavior — and this is likely a lower limit, because not all Centaurs are amenable to a search for activity!

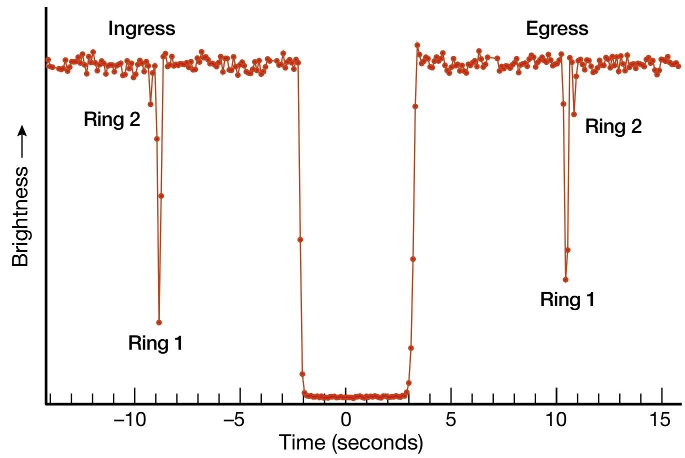
The sublimation of water ice largely drives activity on comets in the inner solar system, but for objects beyond Jupiter, the Sun is too far away to heat up the water ice they contain. Other ices that sublimate at lower temperatures, such as carbon dioxide and carbon monoxide, instead must contribute to Centaur activity — although some of the observed activity is

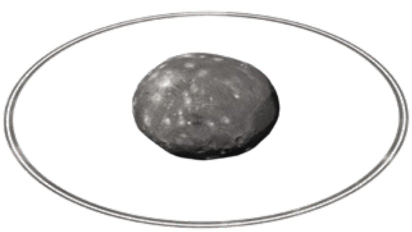
Discovering outer-solar-system objects requires more than a single night of observations. Objects must be tracked over months or years.

not well explained by just these ices. Astronomers are actively trying to understand the drivers of cometary activity in Centaurs, using both ground-based and space-based observations as well as modeling and laboratory work.

Another startling discovery is the presence of rings around at least one Centaur. In 2014 Felipe Braga-Ribas (now at Paris Observatory) and others announced the detection of a ring system around 10199 Chariklo. Astronomers usually estimate the size and shape of an object based on how much sunlight it reflects. Yet these estimates are uncertain because they rely on assumptions about the *albedo*, or reflectivity, of the surface, which varies due to composition and other factors. Braga-Ribas's team, on the other hand, waited for Chariklo to pass between a background star and us, briefly blocking out the light from that star in what's known as a *stellar occultation*. If we know the orbital position and speed of the small body, we can measure its physical size by timing how long it blocks out the star. If we measure this "shadow" from multiple positions, we can even measure its shape (as was done for the KBO Arrokoth prior to its visit from the New Horizons spacecraft). For Chariklo, the occultation showed equally spaced dips in starlight on either side of the central body's shadow created by its ring system, the first to be detected around a solar system object that isn't a giant planet!

There is some evidence that Chiron also possesses a ring system. Researchers are still debating how such rings could form, and how old they are. Is formation more likely early in the solar system's history, meaning that rings can survive the trip into the Centaur region from the Kuiper Belt? (We've observed a ring around another KBO dwarf planet called Haumea, for example.) Or did the rings form after the objects became Centaurs, perhaps due to their activity?





▲ **RINGS** *Top:* When the Centaur Chariklo passed in front of a 12.4-magnitude star, observers in South America watched the star wink out (central dip). But they also saw a pair of much smaller fades both before and after Chariklo's, indicating that the small object has two rings. *Above:* A 3D model of what Chariklo and its rings might look like. Chariklo is roughly 300 km wide.

CHART: F. BRAGA-RIBAS ET AL. / *NATURE* 2014; CHARIKLO WITH ITS RINGS: M. KORNMESSER AND L. CALÇADA / ESO

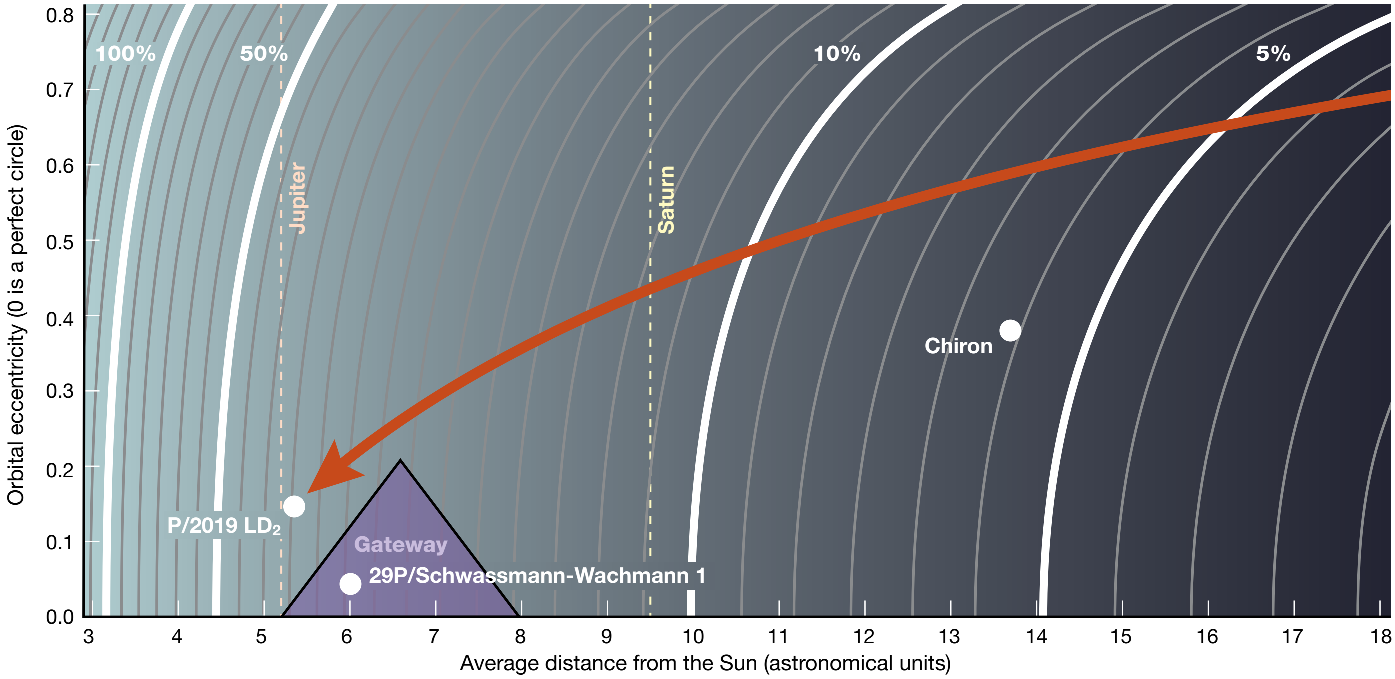
Road Trip?

There are undoubtedly many more discoveries waiting to be made about Centaurs. Even at a very basic population level, there are a lot of things we simply don't know. Centaurs' wide range of heliocentric distances (from 5 to 30 astronomical units) has made them a challenging group of targets. Many of them are too distant and therefore faint for existing all-sky surveys to spot. Even the brighter Centaurs move too slowly against the background stars to be easily picked up by surveys optimized for faster-moving near-Earth objects — though archival searches through these surveys have yielded some distant detections.

At the opposite end, KBO surveys don't detect Centaurs easily either because they're designed to catch the slower-moving Kuiper Belt populations. Discovering outer-solar-system objects requires more than a single night of observations. Objects must be tracked over months or years so that their orbital path (and thus the population to which they belong) becomes apparent. But Kuiper Belt surveys often cover small sky areas, meaning faster-moving Centaurs can move out of the search fields before observers can determine their orbits if special efforts are not made to track them.

It is thus quite difficult to tell if our current Centaur census accurately represents the whole population, especially in terms of how many objects there are of different sizes. (We have to know what we can and can't detect in order to make accurate estimates!) Measuring the size distribution of Centaurs would help us bridge the gap between observed JFCs — which have typical diameters less than 10 km — and observed KBOs, which are typically at least 50–100 km in diameter. This, combined with a better understanding of activity in Centaurs, will provide critical insights into the physical evolution of cometary nuclei from their primordial start to their end states.

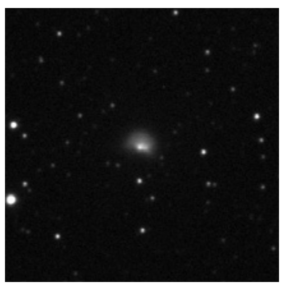
In the coming years, the Vera Rubin Observatory's Legacy Survey of Space and Time (LSST) should dramatically improve our observational census of Centaurs. Over a 10-year period, LSST will cover a large percentage of the sky down to limiting magnitudes much deeper than previous all-sky surveys. It



▲ **THE ROAD TRAVELED** Over time, Centaurs can migrate through the outer solar system to near Jupiter, experiencing more intense sunlight (shown here as lighter shading) as they travel sunward. Their orbits also circularize (y-axis). The arrow shows the likely path that ATLAS (P/2019 LD$_2$) has taken in the last few thousand years, and the white dots mark current orbits of the Centaurs Chiron and S-W 1, the latter of which orbits in the so-called Gateway (purple triangle) and is en route to becoming a Jupiter-family comet. The white contour curves indicate how the amount of solar heating in a particular orbit compares to that received by a Jupiter-family comet.

should detect Centaurs at sizes that overlap with the observed JFC sizes in a systematic way that allows us to better estimate the intrinsic population. The long time scale of the survey should also help identify brightness variations that indicate activity, yielding a new set of active Centaurs that astronomers can then study in more detail with other observatories.

LSST's increased sensitivity compared to current surveys should turn up more examples of Centaurs on the cusp of transitioning to JFCs. Recent dynamical studies of the Centaur-to-JFC transition identified a region just exterior to Jupiter's orbit, dubbed the *JFC Gateway*, that the vast majority of inbound JFCs traverse. Gateway objects have temporary, nearly circular orbits in between Jupiter and Saturn that allow Jupiter to scatter them inward. This orbital region, expected to contain several hundred objects larger than 1 km, coincides with the solar distance at which we expect significant cometary activity to begin in earnest. The recently discovered active Centaur ATLAS (P/2019 LD$_2$), which should enter the JFC population mere decades from now, is likely just the first of many transitional objects we can look forward to discovering. These will help us better understand the early stages of cometary activity.



29P/Schwassmann-Wachmann 1 July 2016 outburst

Future spacecraft missions could also help reveal the secrets of Centaurs. After the New Horizons mission's initial exploration of the Kuiper Belt at Pluto and Arrokoth, and Lucy's upcoming tour of the Jupiter Trojans, the Centaurs remain a key unexplored outer-solar-system population. In 2019, researchers proposed two missions to Centaurs for the latest round of NASA Discovery missions. They were not selected (this time!), but perhaps Centaurs will fare better in the future, especially if they are featured in the next decadal recommendations from the planetary science community, expected in 2023.

Whether through spacecraft or additional ground- and space-based observations, exploration of the Centaurs will continue to provide critical insights into how primordial icy bodies formed and are transformed as they journey into the inner solar system as comets.

■ **KAT VOLK** is a planetary scientist at the University of Arizona's Lunar and Planetary Laboratory. She studies the dynamics and evolution of small solar-system bodies.

JOIN THE CAMPAIGN: Astronomers have begun a pro-am campaign to catch as many outbursts from the Centaur 29P/Schwassmann-Wachmann 1 as they can. Read page 57 of our September 2021 issue or go to **https://is.gd/observing29p** for more information. You'll need access to at least a 6-inch scope; imaging capabilities are a plus.

A WINTER SCAVENGER HUNT

Transform your observing sessions by adding a new sense of adventure.

If you have ever been on a scavenger hunt, you know that the challenge is to collect a number of common objects from a list of cryptic clues. In this journey through January's night sky, we'll add a touch of whimsy by concealing our targets in a scavenger hunt.

First, let's consider our list of clues. Your task is to find:

1. **A Concealed Planetary:** It hides in plain sight on a shoulder.
2. **A Sidekick Cluster:** It's a bright showpiece's little companion.
3. **Headgear for a Norse God:** You'll have to filter your expectations.
4. **The Unicorn's Other Fan:** It's smaller than its variable cousin.
5. **A Holiday Icon:** It's a popular adornment for the winter season.
6. **A Bodybuilder:** This cluster is buff.
7. **A Row in a River:** It's quite a lineup.
8. **A Rose within a Hare:** Seeing red where you wouldn't expect to.
9. **An Enumerated Cluster:** It's more than just a number of stars.
10. **A Frozen Toe:** Look for it opposite an armpit.
11. **A Triple Wonder:** Sir William was impressed.
12. **An Orbuculum:** It's a bull's bauble.
13. **A Capricious Demon:** Nothing eclipses its fame.

Before reading on, take a moment to contemplate the list and see if you can guess all the stops on our journey.

YAO XIAO, ILLUSTRATOR

1 A Concealed Planetary. Hidden in the glare of 4th-magnitude Mu (μ) Orionis is the faint planetary nebula **Abell 12**, discovered by George Abell on photographic plates in 1966. In the line of stars representing the Hunter's raised arm, Mu is the next bright one up from Betelgeuse. The adjacent planetary, at a distance of about 6,900 light-years, is much farther away than the star, which is only at around 150 light-years.

Abell 12 is just 50″ northwest of Mu, which makes it quite difficult to observe — but an O III filter will dim the star enough to allow the planetary to materialize. In my 18-inch Dob with filter employed, Abell 12 is quite apparent. Under a dark sky, I've even detected Abell 12 in my 8-inch SCT using an Ultra High Contrast (UHC) filter. It appears as a ghostly disk of mostly even brightness about 30″ in diameter with a slightly brighter rim.

In optimal observing conditions, if you place Mu Orionis just outside your field of view, you might even glimpse Abell 12 without a filter.

2 A Sidekick Cluster. From comic books to the "B" Westerns of the 1940s and '50s, the sidekick has been an endearing character: a faithful companion to a more important personage. The secondary position that the open cluster **NGC 2158** takes to the brighter, more famous M35 always puts me in mind of such a partnership. The two clusters aren't actually associated at all: NGC 2158 is at least 4½ times more distant than its flashier neighbor. If they were at the same distance, the situation would be reversed, since NGC 2158 has more than twice the number of stars than does M35. As it is, though, M35 appears 25 times brighter than its little sidekick. NGC 2158 is 5′ in diameter and shines at magnitude 8.6. It appears rather concentrated and is even listed as a globular cluster in both the *Revised New General Catalog of Nonstellar Astronomical Objects* (*RNGC*) and the Lund catalog of open clusters. However, Brent Archinal and Steven Hynes in their book *Star Clusters* point out that NGC 2158 has none of the properties of a globular. To find the smaller cluster, aim a bit less than ½° southwest of the bright Messier object at the foot of Gemini and look for a dense puffball of stars.

▲ **HIDDEN PLANETARY** Kick off your quest for celestial treasures in Orion, the Hunter, by playing peekaboo with Abell 12.

DEREK SANTIAGO

3 Headgear for a Norse God. Imagine a line connecting the two brightest stars in Canis Major, Alpha (α) and Beta (β), more familiar to us as Sirius and Mirzam. Then extend that line eastward about 1½ times its length and point your scope a little north of that spot. At low power with a UHC or O III filter, you'll be treated to a remarkable nebula. **NGC 2359** is known as Thor's Helmet due to the two horn-like extensions that protrude out of a dome-shaped nebula. In photographs (such as the one on page 24), it truly does resemble the iconic horned Viking headdress of mythology. In the eyepiece, I see it more as a snail or a rabbit, as one of the "horns" is rather faint.

NGC 2359 is a vast emission nebula powered by a Wolf-Rayet star, an extremely hot giant thought to be in a pre-supernova stage. It lies about 12,000 light-years from us and is approximately 30 light-years across. Unfiltered, NGC 2359 is a faint, barely detectable haze. The view through a narrowband filter, though, is spectacular, and gets more so with increasing aperture.

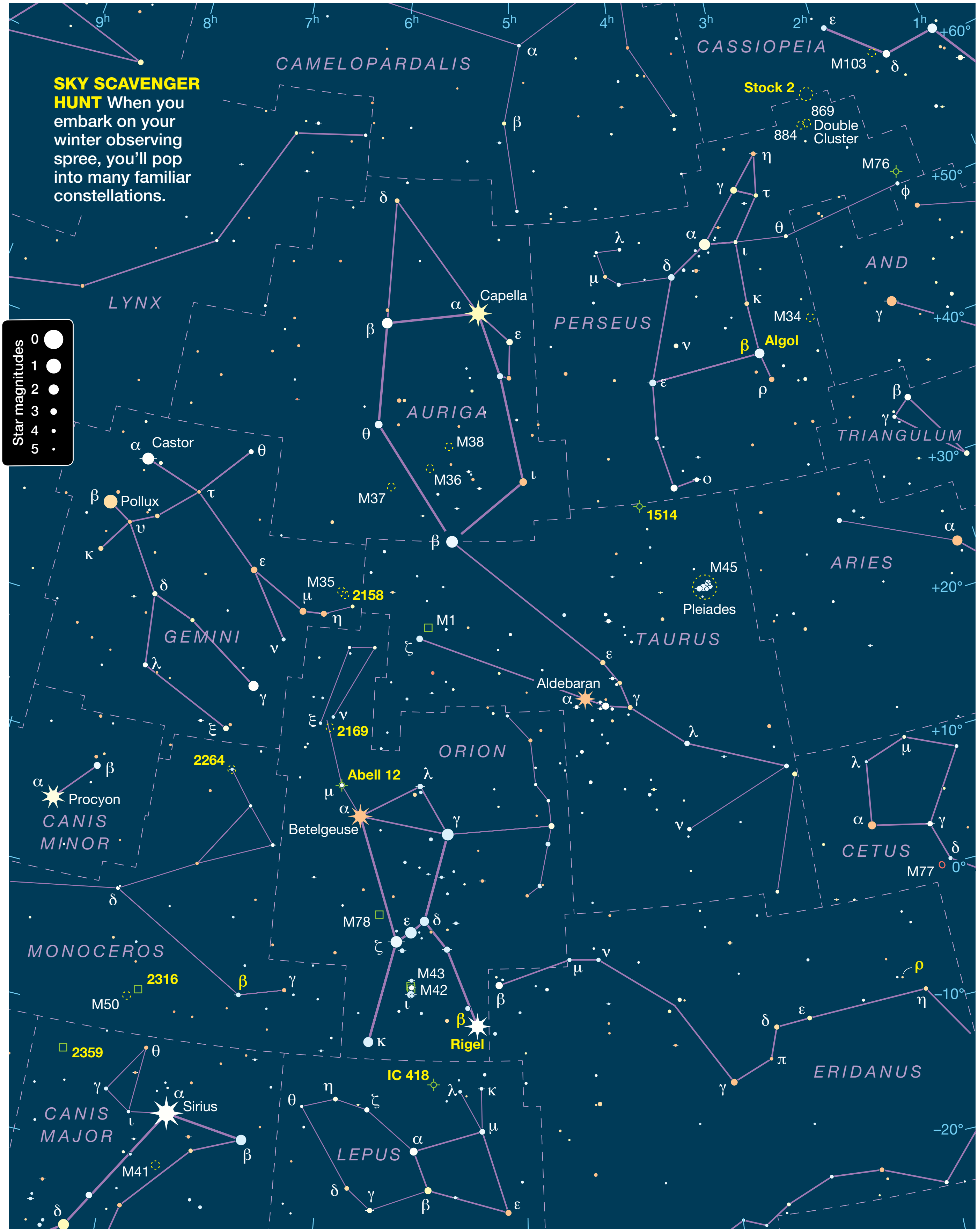
4 The Unicorn's Other Fan. Fan-shaped nebulae are sometimes called *cometary nebulae* due to their resemblance to stubby-tailed comets. Today, the modern term is generally applied to objects illuminated by T Tauri stars (young variable stars akin to the prototype, T Tauri). Monoceros is home to perhaps the most famous cometary nebula, Hubble's Variable Nebula (NGC 2261), but it also houses another often-overlooked fan. **NGC 2316** is a small emission/reflection nebula about 1° northwest of the open cluster M50.

According to *S&T* Contributing Editor Steve Gottlieb's "Adventures in Deep Space" website (see link on page 27), William Herschel discovered NGC 2316 in March of 1785. Irish engineer and astronomer Bindon Stoney observed the nebula in February 1851 and reported a second nucleus that John Louis Emil Dreyer subsequently recorded as NGC 2317 in his *New General Catalogue of Nebulae and Clusters of Stars* (published in 1888). The *RNGC* lists NGC 2317 as nonexistent, and several modern references assume that 2316 and 2317 refer to the same object.

To find the nebula, look for a small, cone-shaped glow spreading toward an arc of three stars. You'll need at least a 10-inch scope, and a light-pollution filter, such as the Lumicon Deep Sky, will enhance the view. Use moderate magnification to separate the nebula from the stars.

5 A Holiday Icon. The open cluster **NGC 2264** is also known as the Christmas Tree Cluster and is associated with

SKY SCAVENGER HUNT When you embark on your winter observing spree, you'll pop into many familiar constellations.



VIKING VISIONS
NGC 2359 floats like the helmet of a Norseman of yore in the northeastern reaches of Canis Major.

the Cone Nebula, an H II emission nebula similar in structure to the Pillars of Creation in M16, the Eagle Nebula.

The cluster is visible to the naked eye as a 4th-magnitude haze. A wide-field eyepiece will show the 40 or so cluster stars arranged in the distinctive shape reminiscent of a Christmas tree cookie spanning about 40′. The bright star S Monocerotis (15 Monocerotis) forms the trunk of the cookie's tree (as in the image on page 25). At the top of the tree is the Cone Nebula, which in larger scopes (20-inch or greater) is somewhat visible as a dark void in the subtle glow of the bright nebula that permeates the area.

William Herschel discovered the cluster and the associated nebulosity in January 1784. On his website, Gottlieb notes that prior to 1861 William Parsons, the Third Earl of Rosse, and other observers at Birr Castle examined the region around S Monocerotis a number of times without detecting the nebulosity that Herschel had recorded. German astronomer Heinrich d'Arrest also failed in his attempt in 1862. Only a year later, however, Birr Castle announced a positive detection, followed by several other successful observations by others thereafter. Many modern observers, myself included, have noted a subtle nebulosity around the base of the tree. While S Monocerotis is a variable star, it fluctuates in magnitude only marginally, and the nebula it illuminates isn't recognized as variable. As Lord Rosse wondered in the 1860s: "Has there been a change here?"

6 A Bodybuilder. The beautiful Perseus Double Cluster is the starting point for finding **Stock 2**, the Muscleman Cluster. From the western member of the pair (labeled h-Persei or NGC 869 on star maps), follow the string of about 10 stars ranging in magnitude from 6 to 10 arcing north in a gentle curve about 2° long, and you'll land at the base of the cluster. Once you're there, check the view in your finderscope to see the Muscleman, a stick figure reminiscent of a bodybuilder with raised arms in the classic flexed-bicep pose. Admittedly, it takes a bit of imagination to see him. You'll need a wide field to take in the whole cluster, which spans a degree.

This family of stars is about 990 light-years from Earth and has been extensively studied. Earlier sources list around 166 cluster stars, but recently the Gaia satellite has identified more than 1,300 members, making it a rather massive open cluster.

GERALD RHEMANN / CCDGUIDE.COM

FESTIVE SIGHT The Christmas Tree Cluster and the Cone Nebula nestle together in Monoceros. The cluster stars are arranged in an upside-down tree shape, and the bright star S Monocerotis — representing the trunk — is therefore at the top of the asterism.

JIM THOMMES

7 A Row in a River. Spanning about 46′ and marking the northernmost bend in Eridanus, three stars, all designated by the Greek letter *rho* (ρ), line up to form an interesting fuzzy-object asterism that's visible to the naked eye. But the three stars are unrelated. The westernmost star, **Rho¹** (8 Eridani), is a 5.7-magnitude *K*0 giant about 300 light-years distant. In the middle of the arc is **Rho²** (9 Eridani), another *K*0 giant, that shines at magnitude 5.4. Rho² is actually a binary star with an 8.9-magnitude companion around 1.4″ away. The pair is about 260 light-years from Earth. **Rho³** (10 Eridani), the closest to Earth of the trio at 140 light-years, is magnitude 5.3.

8 A Rose within a Hare. Sometimes while observing, one has to bear in mind that deep-sky objects might be tinged with faint colors so as to actually perceive them. I'd never noticed the reddish-pink hue of the planetary nebula **IC 418** in Lepus until I read an observing report by the late veteran observer Barbara Wilson. At a Texas Star Party, Wilson detected a red tint in the planetary's disk. Bearing this in mind, I examined IC 418 carefully on my next visit to the planetary. I did indeed see a pink envelope, and averted vision brought the color out even more. I've shown this pretty planetary to many observers in my 18-inch, and I always ask them to describe the color. They usually invoke blue-green until you suggest that there may be a tinge of red in the object. Then, like a revelation, the color becomes apparent to them. The power of suggestion is at play, perhaps. The remarkable Hubble image of the object inspired the moniker Spirograph Nebula, but its other nicknames are the Raspberry Nebula and the Red Planetary. Those of us seeing red are obviously not alone.

9 An Enumerated Cluster. The small open cluster **NGC 2169** is a favorite object at outreach events. The arrangement of the 15 or so brightest stars in the group uncannily resemble the number 37 in a 4-inch or larger scope. The pattern is quite obvious once it's pointed out and makes for added interest in an otherwise unremarkable cluster of some 30 stars. Look for it in Orion's raised arm: It forms the apex of a triangle pointing southwest, the base of which is defined by Xi (ξ) and Nu (ν) Orionis. The 37 Cluster, lying at a distance of some 3,000 light-years, is young — probably about 10 million years old or less, which makes it an important laboratory for the study of stellar evolution.

SEEING NUMBERS To many observers the first sight of NGC 2169 in the eyepiece often elicits a chuckle or two.

10 A Frozen Toe. For many of us, the sky lore we're most familiar with largely consists of stars with Arabic names that reside in the characters of Greek mythology. It's fun, however, to explore the vision of the sky expressed in other cultures. In Norse legend, the star **Rigel** (Beta Orionis) represents the big toe of Orwandil (Orion), who got frostbite while crossing a river. Thor, Orwandil's traveling companion, snapped off the frozen digit and hurled it into the sky. In some versions of the myth, the severed toe became the star Alcor (Mizar's fainter companion in the Big Dipper), while Rigel represents the remaining big toe. Rigel is a blue supergiant around 60,000 times more luminous than the Sun (with some estimates leaning toward even greater figures). Hiding in the glow of this brilliant, magnitude-0.3 star at a separation of a bit more than 9″ is a tiny, 6.8-magnitude companion — the view in a 10-inch scope makes for a spectacular contrast with the bright, white primary. The secondary is itself a binary comprising two main sequence stars that are too close to split. The pair orbits Rigel at a distance of about 2,000 a.u. Spectroscopic observations suggest that a fourth star might belong to the Rigel system as well.

11 A Triple Wonder. William Herschel described **Beta Monocerotis** as "one of the most beautiful sights in the heavens." Today, many call it Herschel's Wonder Star. This lovely system consists of three nearly equal-magnitude white stars. The primary is magnitude 4.6 and is separated by about 7″ from a very close pair of nearly identical beauties of magnitudes 5.0 and 5.3. Use at least a 4-inch scope to enjoy this sight. Beta Monocerotis represents a hoof of the Unicorn and is the brightest object between Sirius and Betelgeuse.

12 An Orbuculum. This obscure word is another name for a crystal ball, which is the nickname given to **NGC 1514** in Taurus. The planetary nebula, with its bright central star surrounded by a translucent spherical shell, is indeed reminiscent of a crystal ball. And somewhat like the sphere fortunetellers employ, it also has a way of foretelling the future — specifically, it might divine the future quality of your observing night by how well this mercurial orb shows up without a filter. If you can detect the planetary's faint disk without a filter, you can grade the night's transparency as excellent. On less-than-perfect nights, you'll need a narrowband filter to observe the disk.

13 A Capricious Demon. Rounding out this baker's dozen of celestial gems is the most famous variable star in the sky. **Algol** (Beta Persei) is an eclipsing variable and the first of its kind ever discovered. The hero, Perseus, is depicted as carrying the severed head of the Medusa, a mythical snake-haired monster. Algol represents that head and so earned its nickname the Demon Star. It's a triple-star system, with the inner close binary responsible for the object's periodic dimming. Fainter Algol B eclipses brighter Algol A every 2.87 days, dropping the magnitude from 2.1 to a minimum of 3.4, where it stays for about two hours before brightening again. The difference between the maxima and the minima are plainly visible to the naked eye. The star is usually equal in brightness to

TENHO TUOMI

▶ **ETHEREAL BALL** Located around 7′ almost due north of 8th-magnitude HD 26125, the planetary nebula NGC 1514 in Taurus can serve as a barometer of the night's observing conditions.

Gamma (γ) Andromedae, which lies about 4° to the west. But during the minima, it fades to become dimmer than Epsilon (ε) Persei, which you'll find 9.5° degrees to the east. A simple glance at those stars can alert you as to whether the system is in or out of eclipse. Turn to page 50 for a chart showing Algol and the comparison stars; during the months when Perseus is above the horizon, the magazine also lists Algol's minima in both the Sky at a Glance and Celestial Calendar columns. Or you can go to **skyandtelescope.org/algol** and enter the date to find the times of the next eight minima.

The winter sky is well-known territory for most *Sky & Telescope* readers. It contains the largest collection of bright stars and familiar constellations in the northern sky. Maybe it has even become a little too familiar to engender any real excitement among more seasoned observers. Finding novel ways to explore it might just re-energize your observing group. Why not design a scavenger hunt for your next star party or outreach event?

■ Contributing Editor **TED FORTE** resides in southeastern Arizona, where he enjoys the sky at outreach events along with fellow members of the Huachuca Astronomy Club.

USEFUL LINK Steve Gottlieb's website is at **astronomy-mall.com/Adventures.In.Deep.Space**.

Treasures in the Sky

Scavenger Hunt Hint	Name	Type	Mag(v)	Size/Sep	RA	Dec.
A concealed planetary	Abell 12	Planetary nebula	12.0	37″	$06^h\ 02.3^m$	+09° 39′
A sidekick cluster	NGC 2158	Open cluster	8.6	5′	$06^h\ 07.4^m$	+24° 06′
Headgear for a Norse god	NGC 2359	Bright nebula	—	9′ x 6′	$07^h\ 18.6^m$	–13° 12′
The Unicorn's other fan	NGC 2316	Bright nebula	—	4′ x 3′	$06^h\ 59.7^m$	–07° 46′
A holiday icon	NGC 2264	Open cluster	4.1	40′	$06^h\ 41.0^m$	+09° 54′
A bodybuilder	Stock 2	Open cluster	4.4	60′	$02^h\ 14.7^m$	+59° 29′
A row in a river	Rho$^{1,\,2,\,3}$ Eridani	Asterism	5.7, 5.4, 5.3	—	$03^h\ 02.7^m$	–07° 41′
A rose within a hare	IC 418	Planetary nebula	9.3	12″	$05^h\ 27.5^m$	–12° 42′
An enumerated cluster	NGC 2169	Open cluster	5.9	6′	$06^h\ 08.4^m$	+13° 58′
A frozen toe	Rigel	Multiple star	+0.3, 6.8	9.4″	$05^h\ 14.5^m$	–08° 12′
A triple wonder	Beta Monocerotis	Multiple star	—	—	$06^h\ 28.8^m$	–07° 02′
		AB	4.6, 5.0	7.1″	—	—
		BC	5.0, 5.3	2.9″	—	—
An orbuculum	NGC 1514	Planetary nebula	10.9	132″	$04^h\ 09.3^m$	+30° 47′
A capricious demon	Algol	Variable star	2.1–3.4	—	$03^h\ 08.2^m$	+40° 57′

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.

MICHAEL DEGER / CCDGUIDE.COM

Choosing the Best Lenses for Nightscapes

When nightscape photos fall short of expectations, chances are the problem is the lens.

After a solid tripod, a good-quality, fast lens is the best investment an aspiring astrophotographer can make. It need not be an expensive purchase. But it does require research, as the lens market has become rather complex in the past few years, to say the least.

With a focus on choosing wide-angle lenses for nightscapes, here's my guide to buying the best lens, whether it be for your old faithful digital single lens reflex (DSLR) or for one of the newer digital single lens mirrorless (DSLM) cameras.

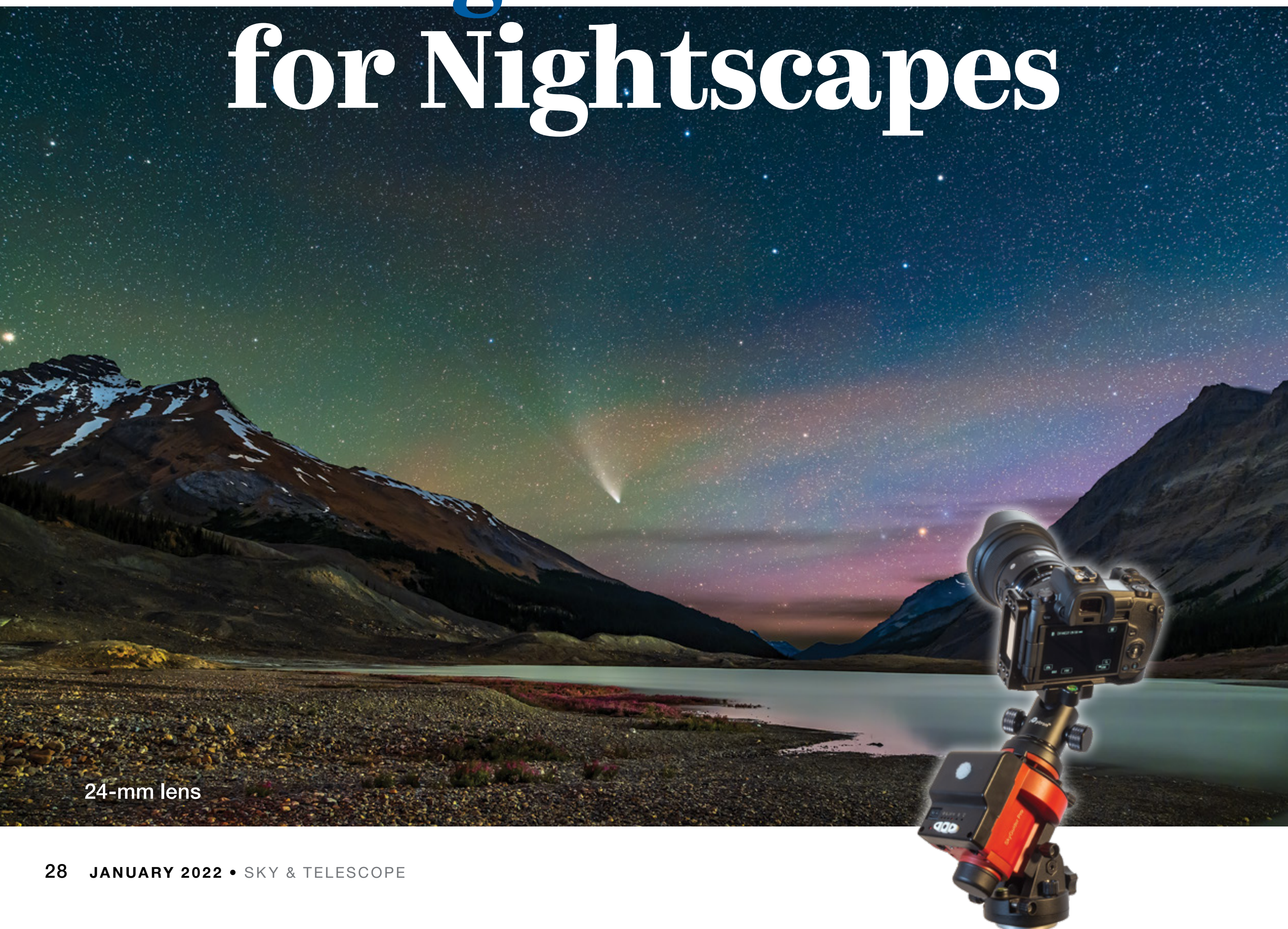
Aperture Is Key

While daylight photography is bright and forgiving, at night we need speed. The photographically faster the better. This "speed" refers to the focal ratio, or "f-ratio" of the lens, which is its focal length divided by the maximum diameter of the internal iris of the lens (not to be confused with the size of its front element).

Twilight scenes, conjunctions, eclipses, noctilucent clouds, star trails, and even bright, moonlit nightscapes are captured well with f/4 to f/5.6 lenses. However, the subjects astrophotographers most want to capture — the Milky Way, meteor showers, and aurorae — demand a lens with a maximum aperture of f/2.8 or faster.

They are called "fast" lenses because they let in more light during a given exposure than lenses with larger f-ratios, allowing shorter, faster shutter speeds. Those are important

▼ **COMET AT THE ICEFIELDS** A 24-mm lens is one of the most useful for nightscapes, worth investing in for the highest quality. To capture Comet NEOWISE at the Columbia Icefields in Alberta, the author used a 24-mm Sigma Art lens made for a Nikon F-mount, attached to a Canon EOS Ra DSLM via a Metabones lens adapter, all on an iOptron Sky-Guider Pro tracker, as shown.



for preventing star trails, freezing the motion of an active aurora display, or recording a fleeting meteor. (Photographing meteors is particularly at the mercy of your lens speed.) Attempting those subjects using typical kit zooms with f/5.6 focal ratios usually yields dark, disappointing results or excessively trailed and noisy images. And no meteors!

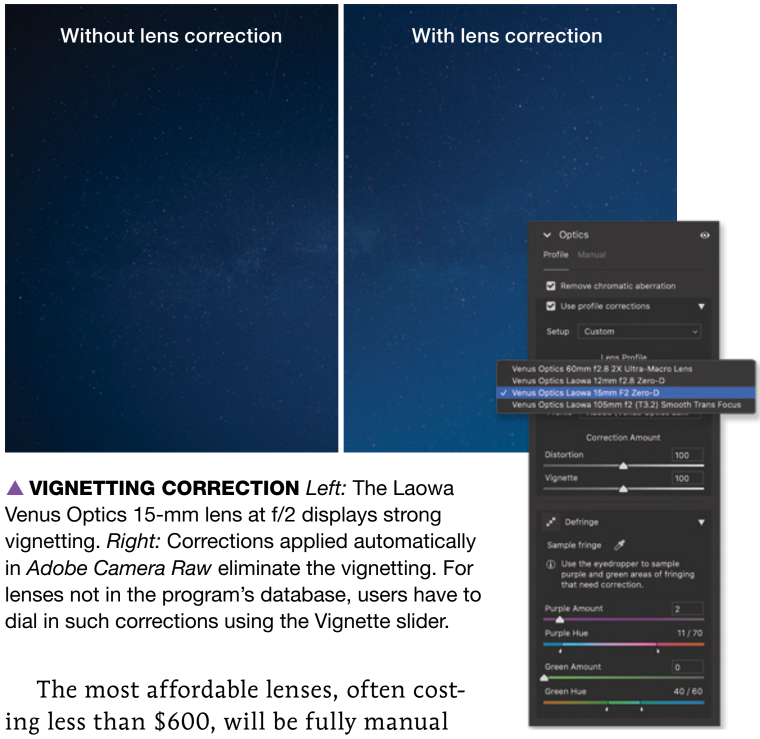
Aberrant Behavior

Of course, there are downsides to photographic speed. The first is cost. Fast lenses are more expensive, though selecting a no-frills, manual-focus lens somewhat eases the price pain. The second downside is aberrations. Stars, which offer the most demanding test of a lens, can look bloated and distorted in a fast lens used "wide open" at its maximum aperture.

Spherical aberration enlarges star images across the frame, turning them into soft blobs. *Coma* turns stars at the corners into comets; *tangential astigmatism* turns stars into radial streaks, while *sagittal astigmatism* distorts stars into concentric arcs. *Longitudinal chromatic aberration* adds blue or magenta glows around stars everywhere in the field, while *lateral chromatic aberration* spreads stars into tiny rainbows at the corners. As a general rule, the faster — and cheaper — the lens the worse the aberrations, with most lenses showing a mix of imperfections.

An ill effect even the best lenses can exhibit is vignetting. The corners look dark, sometimes by as much as two to three f-stops dimmer compared to the center. Like chromatic aberrations (but not spherical, coma, or astigmatism), vignetting can be corrected in raw-image processing.

However, if the corners of an image are too dark out of camera, then boosting their brightness in post-production often reveals ugly noise, magenta tints, and banding artifacts. Vignetting is generally worse the faster and wider the lens.



▲ **VIGNETTING CORRECTION** *Left:* The Laowa Venus Optics 15-mm lens at f/2 displays strong vignetting. *Right:* Corrections applied automatically in *Adobe Camera Raw* eliminate the vignetting. For lenses not in the program's database, users have to dial in such corrections using the Vignette slider.

The most affordable lenses, often costing less than $600, will be fully manual models. You have to focus and set the aperture by hand. That's just fine. While the newest cameras are capable of autofocusing on stars and dimly lit landscapes, at night the best method is to manually focus on a star at high magnification using the Live View feature in your camera to zoom in on a star.

The lowest-cost manual lenses offer no electrical communication with the camera. The camera doesn't know what lens is attached nor its aperture. That's a slight inconvenience when documenting what gear and settings you used.

Manual vs. Auto Focus

For nightscapes, lenses with 14-mm, 20-mm, or 24-mm focal lengths are the most useful, certainly on full-frame cameras. When shopping for one you'll encounter a bewildering selection of lenses within that range of focal lengths. For example, you can find 14-mm f/2.8 lenses, a favored size, selling for as little as $250 to as much as $2,000.

▶ **EDGE ABERRATIONS** This image series compares the extreme upper left corner of a premium Sigma 14-mm Art lens at its maximum aperture of f/1.8 and stopped down to f/2.8 and f/4. Astigmatism and vignetting improve markedly at f/2.8, less so at f/4. Most fast lenses improve similarly when stopped down.

ALL IMAGES COURTESY OF THE AUTHOR

▲ **ULTRA-WIDE ENSEMBLE** Lenses in the 14-mm to 15-mm range are great for nightscapes. Seen from left to right are the Sigma 14-mm f/1.8 Art, the Rokinon 14-mm f/2.4 SP, the Laowa Venus Optics 15-mm f/2, and the Irix 15-mm f/2.4 Firefly, which has a handy click stop at infinity. All but the Sigma are manual lenses.

▲ **AFFORDABLE ULTRA-WIDE** The most popular nightscape lens has long been the no-frills Samyang or Rokinon 14-mm f/2.8 ED, available for many lens mounts, including mirrorless. It costs about $300.

More advanced manual lenses (sometimes called “chipped” models) have electronics to communicate with the camera, so it automatically records the information in the image file metadata. This information about the lens model and aperture setting makes it much easier to correct distortions and vignetting during post-processing. Programs including *Adobe Lightroom* can automatically read this information and apply corrections to a large series of images — particularly handy when processing hundreds of frames to assemble into a time-lapse video.

Fully automatic lenses will autofocus when switched to AF mode and also permit the camera to automatically set the aperture. If you expect to use the lens for normal daytime photos, then autofocus and autoexposure become important features.

While all autofocus lenses also include the ability to manually focus, it’s now often performed via what’s called “focus by wire.” Turning the focus ring doesn’t directly move the lens elements but instead sends a signal to the lens’s internal motors, which perform the adjustments. Many such lenses lack a focus scale, which we’ve relied upon in the past to preset focus to infinity. Precise focusing is possible but has to be done for each shoot, which is the best practice anyway.

While low-cost manual lenses can be great values, I advise purchasing from a dealer who allows for easy returns for exchanges or refunds. Lenses can suffer from de-centered elements, creating asymmetric and exaggerated aberrations that often cannot be identified until you shoot the night sky. And it can be days or even weeks before the weather cooperates to test out the lens.

▼▶ **CHOOSE YOUR FIELD** *Left to right:* A 14-mm lens on a full-frame camera is great for imaging wide swaths of the Milky Way. Many photographers favor a 20-mm lens for its balance of wide field and low distortion. A 35-mm lens frames the photogenic Milky Way core. An 85-mm is suitable for tracked “deepscapes” that isolate choice deep-sky fields above a foreground.


14-mm lens


20-mm lens

Cropped vs. Full Frame

Once you narrow your choice of lens, the next step is to check if it will work with your camera. It has to fit your brand of camera, but it also has to fit your type of camera within that brand.

For example, Canon has four different types of lenses: EF (for all its DSLRs), EF-S (for just its cropped-sensor DSLRs), EF-M (for its M series of mirrorless, cropped-sensor cameras), and RF (for its R-series of mirrorless, full-frame cameras). Got that?

Nikon has its decades-old F-mount from the film SLR days and carried over to its DSLRs, as well as the new Z-mount lenses for its mirrorless cameras. Sony offers E-mount lenses, Leica and Panasonic require L-mount lenses, Fujifilm uses its X-mount and medium-format G-mount, while the Pentax standard is called the K-mount. Yes, we have standards. Lots of them!

The other spec to check is if the lens will work with your camera sensor. That appealing fast lens might be only for cropped-frame cameras. Sometimes you have to dig into the specs to see if that's the case. It might say it's for DX or APS-C, terms camera manufacturers use for their cropped-frame sensors. Even if it can physically connect to your brand of lens mount, such a lens won't project an image circle large enough to fill a full-frame sensor. The vignetting will be extreme, and no amount of post-processing will fix it!

If yours is a cropped-frame camera, then a cropped-frame lens will be just fine. Nevertheless, be mindful of two considerations. First, the smaller sensors of cropped-frame cameras provide a narrower field of view with any given lens or focal length. It takes a 12-mm lens to provide the same actual field of view as a 20-mm lens does on a full-frame camera. For example, Samyang (aka Rokinon in North America) has a fast 12-mm f/2 in several versions, but it's only for cropped-sensor cameras.

Second, keep in mind that if you invest in a lot of lenses that work only on your cropped-frame camera, they'll be obsolete if you later upgrade to a full-frame camera. Industry pundits expect Canon and Nikon will introduce few, if any, new DSLRs in coming years. As with Sony, which discontinued its DSLRs in 2021, all new cameras will be mirrorless, with most of those being full-frame. Only Pentax bravely remains as the manufacturer of just DSLRs, both cropped and full-frame.

Lens Field of View (FOV)*

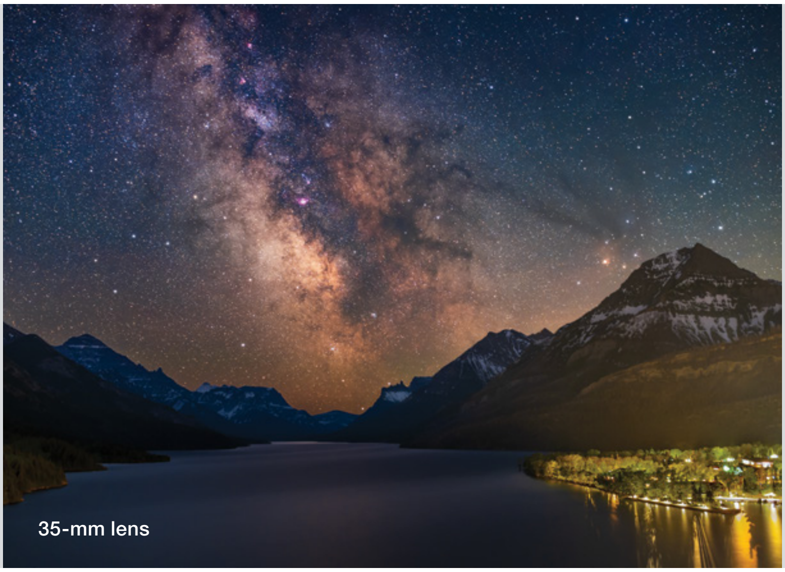
Focal Length	Full-Frame (35-mm) Camera	Lens for Similar FOV with Cropped-Frame Camera
8-mm Circular Fisheye	180°	4-mm to 6.5-mm
11-mm to 12-mm Rectilinear Fisheye	117° × 95°	7.5-mm to 9-mm
14-mm	104° × 81°	8-mm to 10-mm
20-mm	84° × 62°	12-mm
24-mm	74° × 53°	14-mm
35-mm	54° × 38°	20-mm to 21-mm
50-mm	40° × 27°	30-mm to 35-mm
85-mm	24° × 16°	50-mm to 55-mm

*Approximate dimensions

DSLR vs. DSLM

DSLRs have vast catalogs of lenses available for them. The lens selection for the new generation of DSLMs is limited but growing, both from the original manufacturers and from third parties. Established lens manufacturers such as Sigma, Tamron, and Tokina now must compete with names such as Samyang/Rokinon and Laowa, and most recently by previously unknown brands such as Irix, Meike, 7artisans, TTArtisan, Viltrox, and Yongnuo, to name a few.

Many of these startups specialize in lenses just for mirror-



35-mm lens

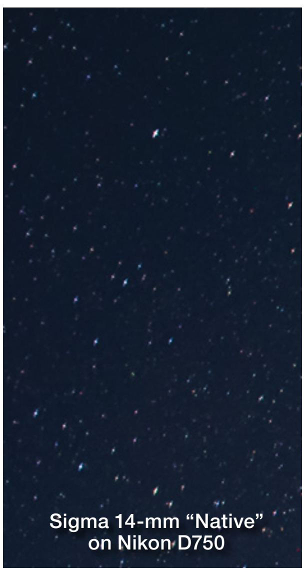
85-mm lens

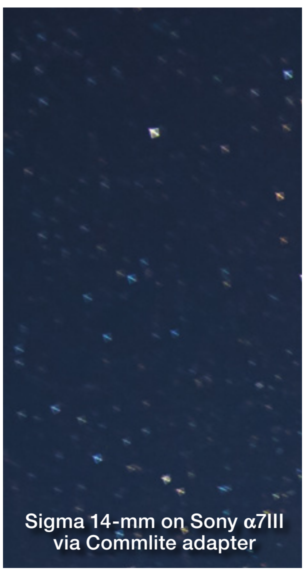

11-mm full-frame fish-eye lens

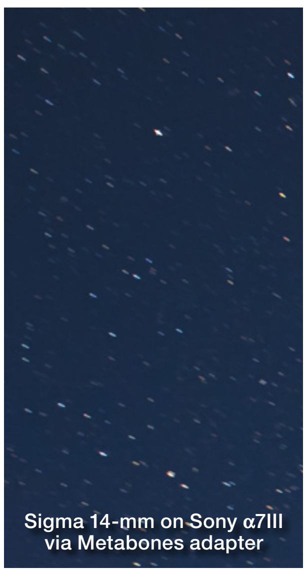
FISHEYE FRAMING Very short-focal-length lenses encompass a full 180 degrees diagonally, but with a curved horizon. These fisheye lenses (a TTArtisan 11-mm f/2.8 was used at left) are specialized lenses ideal for wide sweeps of the Milky Way, aurorae, or, in this case, both at once.


14-mm rectilinear lens

RECTILINEAR DISTORTION Most lenses 14-mm and longer are rectilinear designs, which present straight horizons but introduce a leaning-in distortion on vertical structures. The effect is more pronounced on wider lenses. This image was taken with a Rokinon 14-mm SP at f/2.4.


Sigma 14-mm "Native" on Nikon D750


Sigma 14-mm on Sony α7III via Commlite adapter


Sigma 14-mm on Sony α7III via Metabones adapter

ADAPTED ABERRATIONS At far left is a blowup of the frame corner from a 14-mm Sigma Art lens at f/1.8 mounted directly to a Nikon D750. At center is the same lens on a Sony a7III using a Commlite adapter and at near left with a Metabones adapter. The slightly incorrect lens spacing introduced by some third-party adapters increases off-axis aberrations.

less cameras, with Leica/Panasonic's L and Sony's E-mounts the most widely supported. Canon and Nikon have so far been reluctant to open up their R and Z systems to third-party lens manufacturers.

For example, as of late 2021, Samyang's new 24-mm f/1.8 AF, with a unique infinity-focus light and marketed to astrophotographers, is available only for Sony's E-mount. The same is true of Tokina's 20-mm f/2 from its FiRIN series.

Lenses for DSLMs will fit only on those mirrorless cameras. However, lenses made for DSLRs can be adapted to work with DSLMs. Some lens adapters, such as those Canon and Nikon sell, offer full electrical connectivity, which permit older autofocus lenses to fully operate on the respective company's new mirrorless cameras.

Third-party adapters from brands such as Metabones expand the flexibility to allow DSLR lenses of one brand to fit on a mirrorless camera from another brand, though usually with some loss of functionality.

The lowest-cost lens adapters are mechanical only. They are best used only with fully manual lenses that have an aperture ring, because with no data communication between lens and camera, the camera cannot control the lens aperture.

Zoom vs. Prime

Another important question to consider when shopping for nightscape lenses is why buy several lenses when a single quality zoom can cover the range? Zooms simplify your lens kit for travel and, once onsite, make it easy to compose the scene.

Canon, Nikon, and Sony all have f/2.8 wide-angle zooms covering the 12-to-24-mm or 16-to-35-mm range. The 15-35-mm Canon RF (reviewed in the April 2020 issue), Nikon's Z 14-24-mm S, and Sony's FE 12-24-mm G-Master are enjoying rave reviews from nightscape photographers, with those new mirrorless lenses offering significantly better image quality over the older DSLR versions, though at premium prices. The improvement is sufficient to overturn the old wisdom that zooms have inferior optical quality to fixed-focal-length, prime lenses.

For a traditional DSLR zoom, Sigma has its 14-24-mm f/2.8 DG Art, Tokina its 16-28-mm f/2.8 Opera, while Tamron's SP 15-30-mm f/2.8 has long been a favorite of nightscapers. For use on cropped-frame cameras, Tokina's 11-20-mm f/2.8 CF is another popular choice.

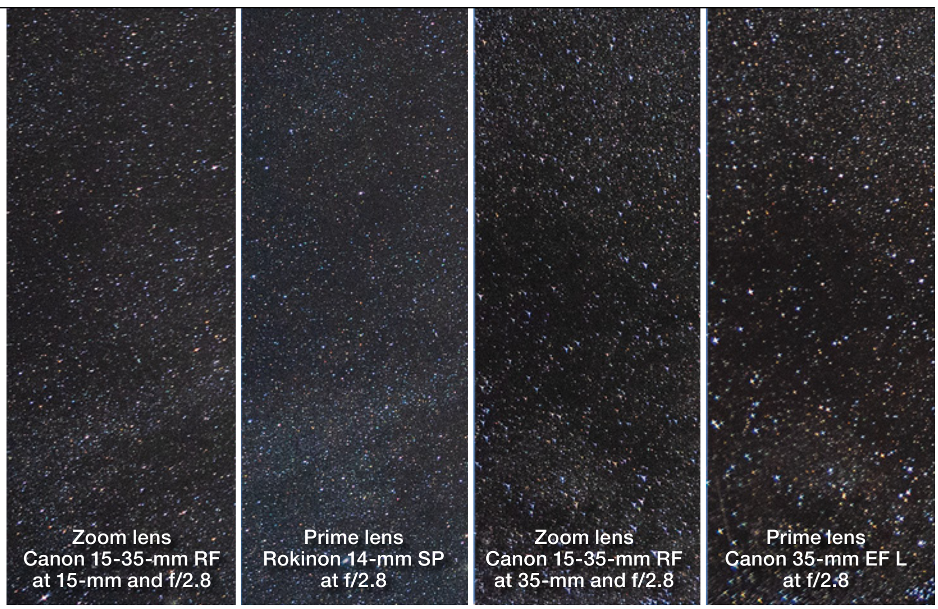
So why buy a prime? The advantage over an f/2.8 zoom is that the faster f/2 to f/1.4 apertures of most primes brighten the live view image by two to four times, making it much easier to focus and frame a scene. The faster the lens — we're even seeing some f/0.95 lenses now — the lower the ISO can be, reducing noise, which for older, noisier cameras might be a fair tradeoff against any added aberrations. For time-lapse photography, the shorter shutter speeds made possible by a fast lens let you capture more frames during a shoot, for a slower, more graceful movie in the final render.

With video-centric DSLM cameras, fast apertures also make real-time movies at night possible. The Sigma 20-mm f/1.4 Art and the Venus Optics Laowa 15-mm f/2 have been my "prime" choices for 4K movies of aurorae.

As with zooms, older DSLR prime lenses, such as the well-respected Sigma Art series, are being outclassed by smaller and lighter mirrorless primes, like Nikon's 20-mm f/1.8 S and 24-mm f/1.8 S, and Sony's 14-mm f/1.8 and 24-mm f/1.4 G-Masters.

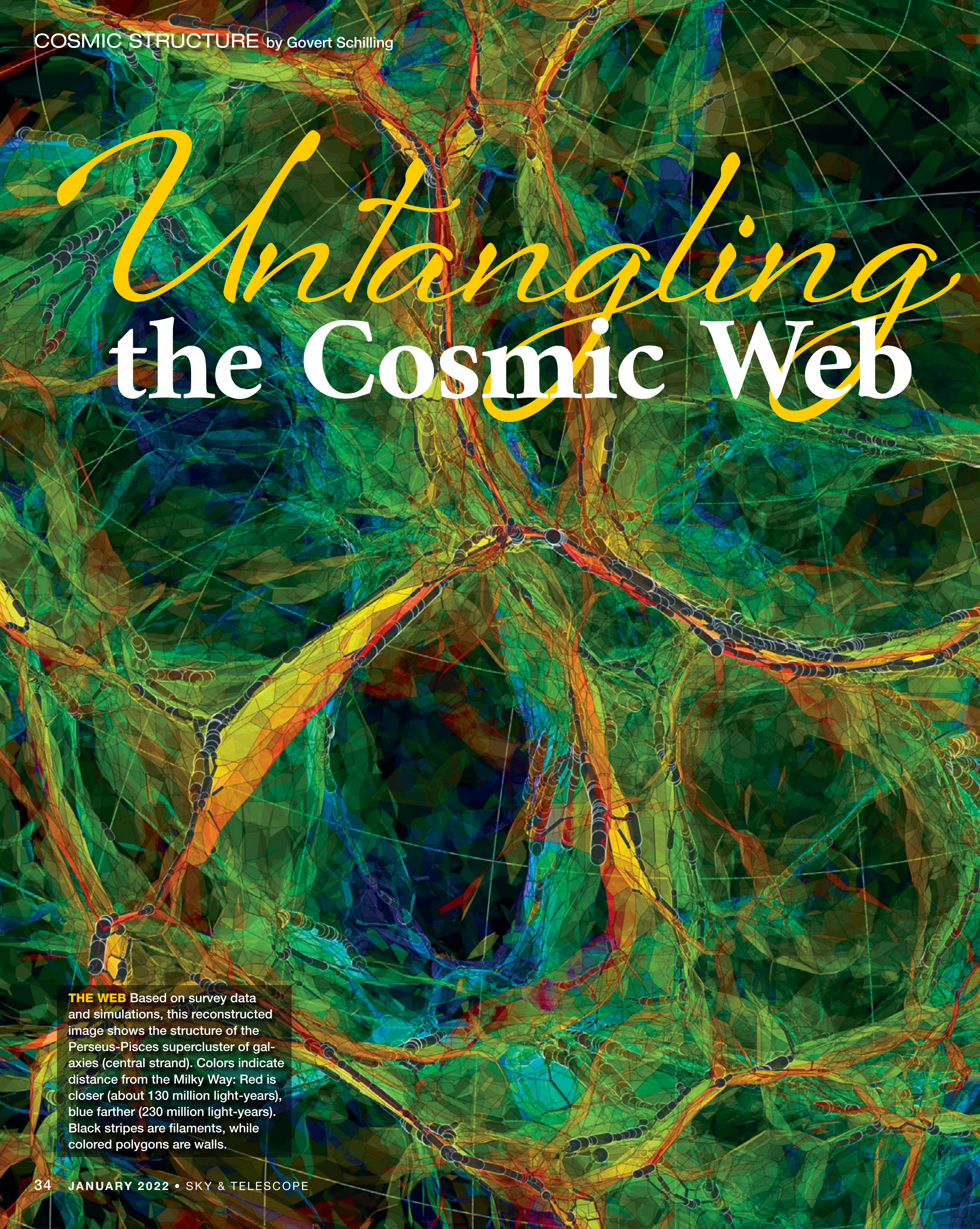
The camera world is in rapid transition, as are lenses, making selecting the best lens a challenge. However, the latest lenses offer much better performance, a trait we can appreciate when shooting under the stars.

■ **ALAN DYER** is coauthor with Terence Dickinson of the new fourth edition of *The Backyard Astronomer's Guide*, described at **BackyardAstronomy.com**.

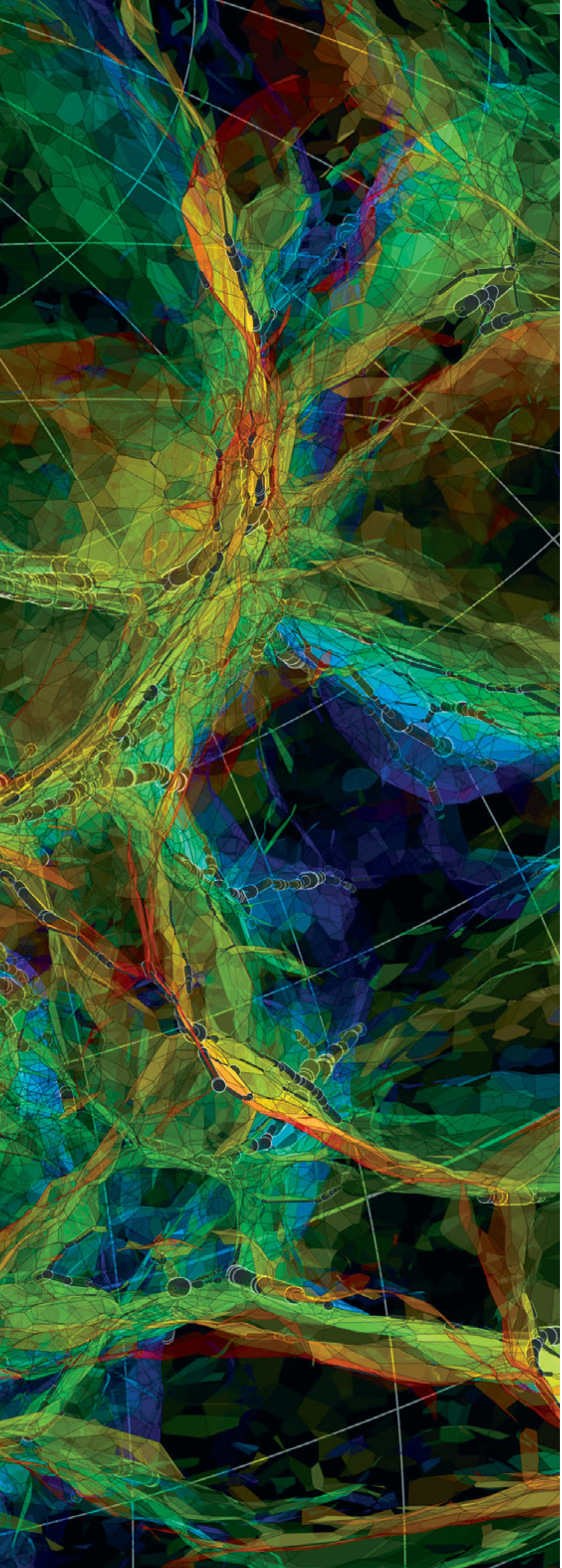


▼▶ **PRIMES MEET THEIR MATCH** This compares the extreme corners of a current top-of-the-line zoom, the Canon 15-35-mm RF (inset), wide open at f/2.8, with 14-mm and 35-mm prime lenses, also at f/2.8. The Canon zoom is marginally softer than the Rokinon SP prime but slightly better than the older Canon 35-mm L-series prime.

Untangling the Cosmic Web



THE WEB Based on survey data and simulations, this reconstructed image shows the structure of the Perseus-Pisces supercluster of galaxies (central strand). Colors indicate distance from the Milky Way: Red is closer (about 130 million light-years), blue farther (230 million light-years). Black stripes are filaments, while colored polygons are walls.



Astronomers are slowly mapping the long-hidden filaments that connect galaxies.

We live in a hierarchical cosmos. Earth is one of eight planets orbiting a middle-of-the-road star in a spiral arm of the Milky Way, which, in turn, is in the outskirts of a cluster of similar galaxies. Galaxies are often seen as the "building blocks" of the universe. But the truth is that galaxies and their groups and clusters are interconnected by hard-to-observe tendrils, just like towns and cities are interconnected by roads and highways. And although mysterious dark stuff is the main component of this cosmic web, the structure also contains at least 30% of all "normal" (so-called *baryonic*) matter in the universe.

The web-like, large-scale structure of the universe was first predicted by renowned Soviet theorist Yakov Zeldovich, back in 1970. That same decade, astronomers made the first crude 3D maps of our cosmic surroundings, confirming that galaxies are indeed distributed unevenly throughout space. As has been revealed over and over again by ever-larger survey programs, galaxies are concentrated in thin walls and more prominent filaments, interspersed by large voids that may well be a few hundred million light-years across (*S&T:* Oct. 2018, p. 12). Massive clusters mark the nodes where three or more filaments meet.

But initially, no one knew whether or not the space between the galaxies in the filaments was truly empty.

That changed in the 1980s, with the first computer simulations of the growth of cosmic structure over time. Dominated by the gravity of mysterious dark matter, which comprises some 85% of all gravitating stuff, such simulations predicted that the nearly homogeneous post-Big Bang universe of 13.8 billion years ago should indeed have evolved into an expanding cobweb- or soapsuds-like pattern. So yes, if cosmic matter condenses into galaxies, you would expect those to be arranged in filamentary configurations, as shown by observations. But according to the simulations, large amounts of matter — both dark and baryonic — should still be present in the underlying cosmic web.

Today, state-of-the-art simulations like IllustrisTNG (The Next Generation) and Evolution and Assembly of Galaxies and Their Environments (EAGLE), run by international collaborations on some of the most powerful supercomputers in the world, reveal the process in detail, taking into account not only the gravitational pull of dark matter but

Filaments

The cosmic web comprises voids, filaments, walls, and nodes. Filaments make up only about 5% of the cosmic volume, but they may contain half of all baryonic mass (estimates vary).

JOHAN HIDDING

also the "push" of dark energy — the mysterious force behind the observed acceleration of cosmic expansion (*S&T:* May 2018, p. 14). According to Joop Schaye (Leiden University, The Netherlands), the principal investigator of the EAGLE simulation, no one questions the existence of intergalactic material in the cosmic web. "But of course, observers always want to really see it first," he says.

10%
Fraction of the universe's baryons in galaxies

Background Beacons

While the web-like pattern is clearly visible in large 3D galaxy surveys, observing its intergalactic content is a real challenge. Remember that most of it is dark matter, which is invisible by definition. In the early universe, the baryonic gas in the filaments has a very low density (in a terrestrial laboratory, we would call it a perfect vacuum), and temperatures are on the order of 10,000 kelvin. Over time, the structures grow larger and more massive, and shocks further heat the gas. But even at temperatures of millions of degrees, this plasma is generally much too tenuous to be easily seen.

Only at the endpoints of the tendrils, close to galaxy clusters and individual galaxies (where it's more commonly known as the *circumgalactic medium*), the cosmic web has a significantly higher density, up to hundreds of times the average density in the universe. Here, primordial gas flows into galactic halos and disks, ultimately feeding the birth of new stars. Through stellar winds and supernova explosions, galaxies also blow processed gas back into space. Some of this material ends up in the cosmic web again, enriching the filaments with heavy elements (*metals* in astronomical parlance) that are produced by stellar nucleosynthesis. "The details of this feedback mechanism are still not well understood," says Schaye. "We don't know how far these metals can end up from their parent galaxy."

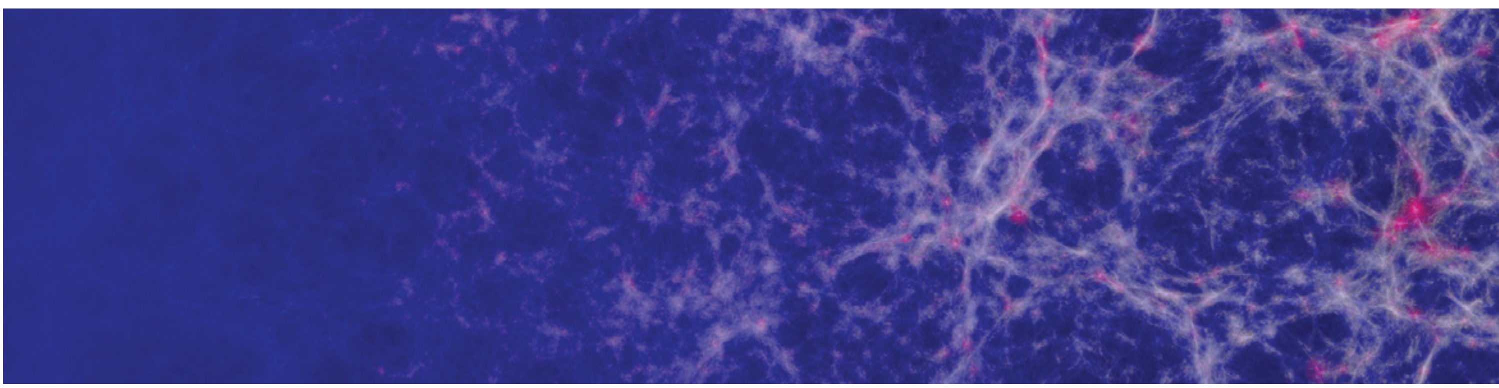
One way to detect relatively cold, tenuous gas in intergalactic space is by looking at the absorption fingerprint it leaves in the light of background beacons, such as bright quasars. Neutral hydrogen atoms preferentially absorb ultraviolet photons with a wavelength of 121.6 nanometers, which provide the right amount of energy to help the atom's single electron jump from its ground state to the next quantum level up. The resulting absorption line in the quasar's spectrum will be observed at a longer wavelength here on Earth, depending on the distance to the absorber and the corresponding redshift due to cosmic expansion. Usually, quasar spectra contain a "forest" of these *Lyman-alpha lines*, produced by a large number of absorbers at various distances along the line of sight.

The problem is figuring out the true nature of the absorbers. Most of the detectable ones are probably individual galaxies or galactic halos (indistinguishable because of their remoteness), which produce a relatively strong absorption signal. Because only neutral (that is, cool) hydrogen produces the Lyman-alpha line, the approach only works as a way to detect the cosmic web at very large distances, corresponding to early times when the web's temperature was still really low. Closer to home, in more recent cosmic epochs, the tendrils of the cosmic web are expected to be much hotter — astronomers sometimes call it the *warm-hot intergalactic medium*, or WHIM — and thus there's little neutral hydrogen. Here, at distances of a few billion light-years, other detection techniques are needed.

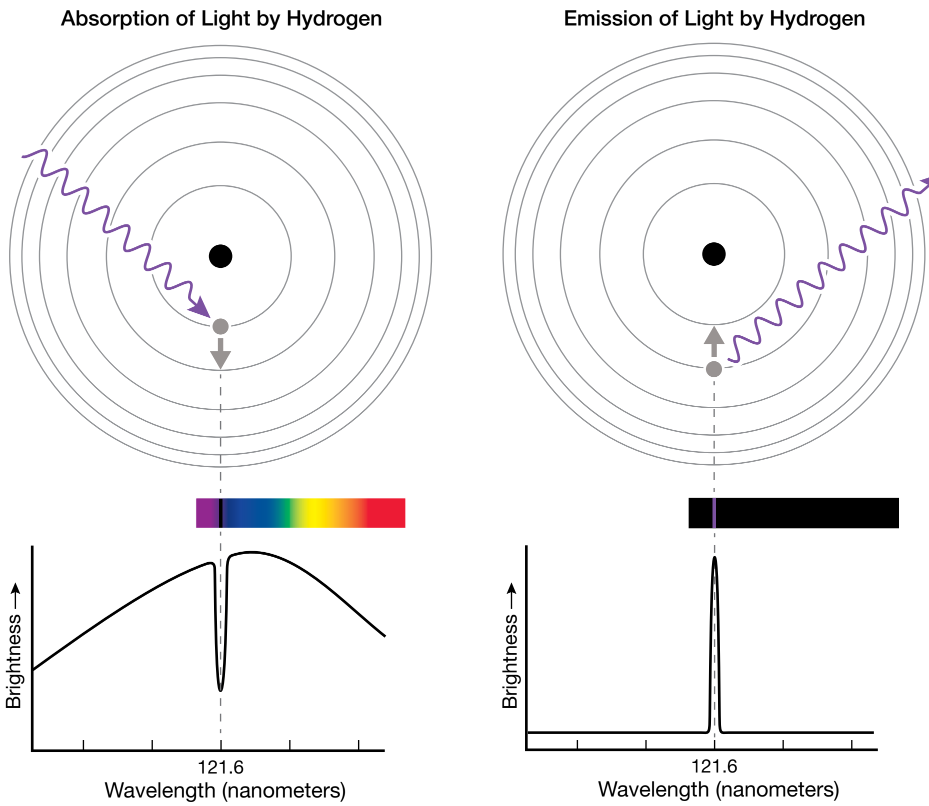
That's where X-ray astronomy comes in. As mentioned above, the evolved cosmic web contains a smattering of heavy elements, including oxygen atoms — the most abundant metal in the universe. Because of the gas's high temperature, the oxygen atoms are highly ionized: Many of them have only one or two of their original eight electrons left. Ionized oxygen absorbs X-ray photons at a handful of particular energies, leaving characteristic dips in the brightness of background X-ray sources.

Because this technique focuses on the relatively nearby universe, it's easier to check whether intervening galaxies cause the absorption features. If not, the features may be due to tenuous patches of the cosmic web. Using NASA's Chandra X-ray Observatory, launched in 1999, astronomers made the first tentative WHIM detections more than 20 years ago. "But it's incredibly hard," notes cosmic-web expert Rien van

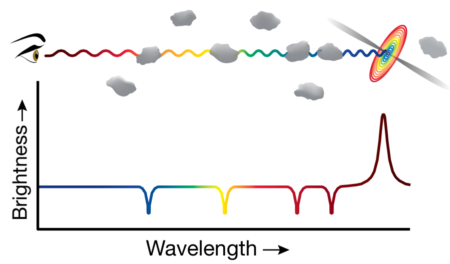
▼ **GROWING WEB** Over time (left to right), matter in the universe has collected in a web-like structure. Redder colors indicate hotter gas temperatures, while more intense color indicates higher gas density. The strip spans about 300 million light-years vertically.



EAGLE PROJECT



◀ **LYMAN ALPHA** *Left:* To move to a higher energy level in the atom, an electron must absorb a photon; to move to a lower level, it must emit a photon. The transition between the first and second energy levels involves an ultraviolet photon of wavelength 121.6 nm, known as Lyman alpha. *Below:* Quasars emit strongly at visible and ultraviolet wavelengths (including Lyman alpha), and that light is absorbed by hydrogen clouds between the quasar and us. But because all the clouds and the quasar lie very far away, the Lyman-alpha lines are redshifted to longer wavelengths. The more distant the absorber or emitter, the redder the wavelength. The numerous clouds between us and a quasar create a comb-like pattern in the quasar's spectrum called the *Lyman-alpha forest*.



GREGG DINDERMAN / *S&T*, SOURCES: EDWARD WRIGHT AND NASA / ESA / LEAH HUSTAK (STSCI)

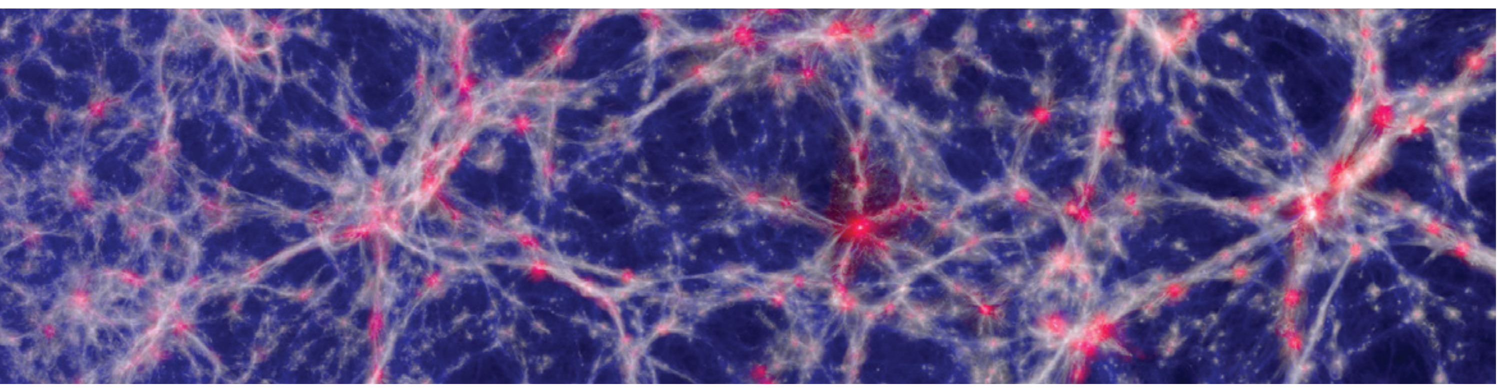
de Weijgaert (University of Groningen, The Netherlands). The universe makes far more low-energy photons than high-energy ones, and X-ray photons are rare. "You need an extremely energetic or very nearby quasar as a background source, and even then, X-ray astronomy is really about counting individual photons."

Alternative Approaches

Little wonder, then, that people have tried other means to detect the elusive intergalactic filaments. For instance, Jörg Dietrich (now at University Observatory Munich) and his colleagues found evidence for an invisible but massive bridge between galaxy clusters Abell 222 and 223 (some 2½ billion light-years away), using a technique known as weak gravitational lensing. In their 2012 *Nature* paper, they described how tiny distortions in the shapes of tens of thousands of remote background galaxies reveal the existence of a 60-million-light-year-long filament between the clusters, weighing in at some 80 trillion solar masses. The find has been hailed as "the first robust detection of a dark matter filament."

Later that year, Mathilde Jauzac (now at Durham University, UK) and her colleagues published a similar result in *Monthly Notices of the Royal Astronomical Society*. Through weak lensing, they were able to make a crude 3D reconstruction of what appears to be a huge filament, funneling matter into the massive cluster MACS J0717.5+3745, which is so far away that its light took more than 5 billion years to reach us.

And weak lensing isn't the only alternative game in town to track down cosmic-web filaments. In a 2013 paper in *Astronomy & Astrophysics*, the Planck Collaboration described



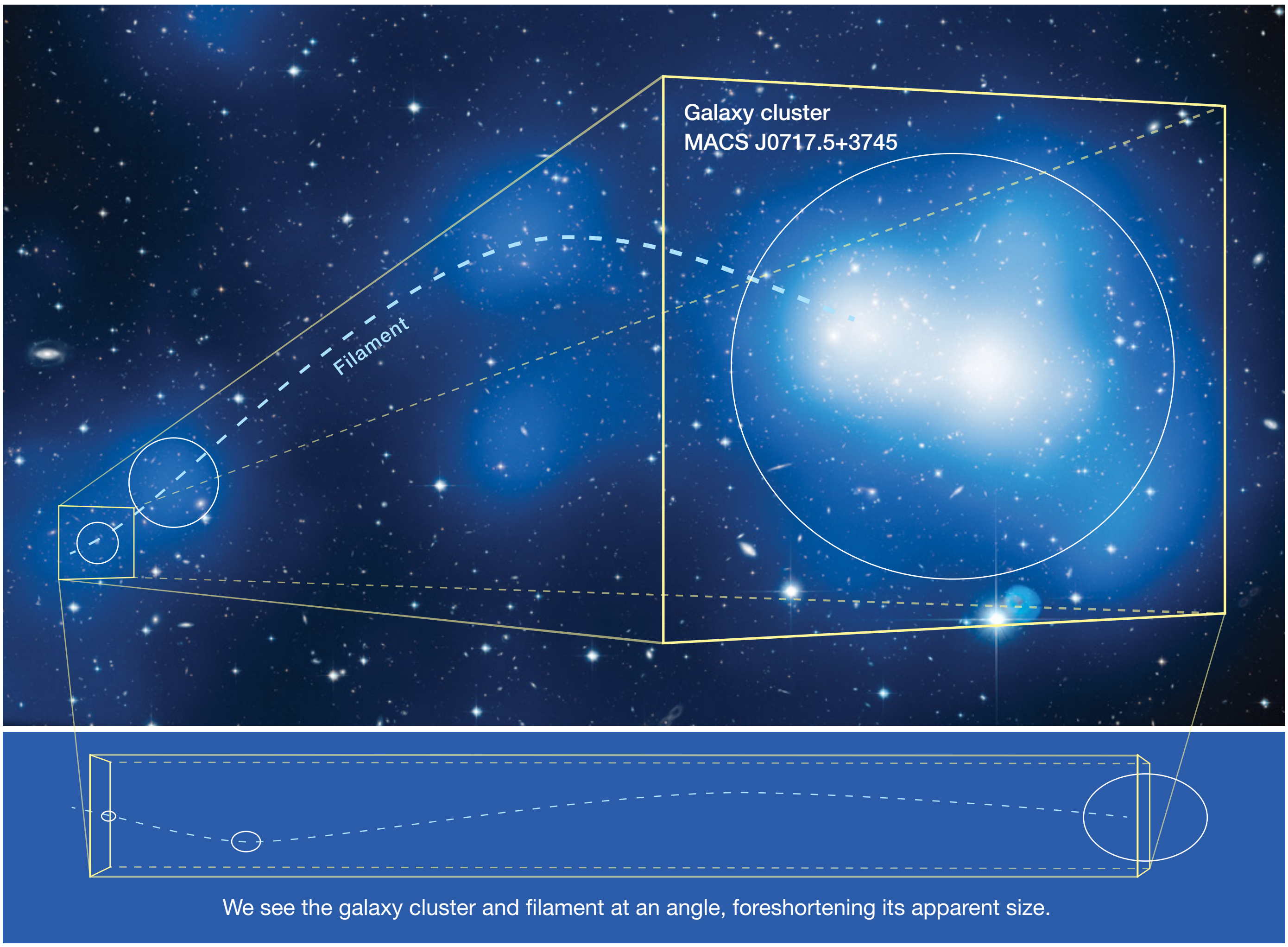
how the cosmology probe found evidence for a bridge between the merging cluster pair Abell 399 and 401. Photons in the cosmic microwave background receive an energy kick from interactions with free electrons in the cosmic web, slightly distorting the observed spectrum — a process known as the (thermal) *Sunyaev-Zeldovich* (SZ) *effect*, after the two scientists who first described it.

Astronomers have also applied both cosmic-web detection techniques — weak lensing and the SZ effect — to observations of many tens of thousands of galaxy pairs. After scaling and rotating the observations to the correct degree, they can be stacked and analyzed as an ensemble. Thus, over the past five years, several teams of researchers found statistically significant evidence for the existence of large-scale inter-galaxy filaments that contain a huge fraction of all the baryonic matter in the universe.

Which is not to say that the interest in more direct detections or real images has declined. While X-ray astronomers such as Fabrizio Nicastro (National Institute of Astrophysics, Italy) still make incidental "pencil-beam" detections by studying absorption features in quasar spectra — which can provide useful information on gas temperatures — others have begun to create real maps of the cosmic web, albeit over relatively small regions of the sky. As an example, the German eROSITA telescope, mounted on the Russian Spectrum-Roentgen-Gamma spacecraft, may have detected the very weak X-ray *emission* of hot gas in between the galaxy clusters Abell 3391 and 3395. In the March 2021 *Astronomy & Astrophysics*, Thomas Reiprich (University of Bonn, Germany) and his colleagues cautiously describe the result as "tantalizing hints" of hot gas in a cosmic-web filament.

The First Real Image

Lyman-alpha detections are also very much back in vogue. For many years now, Khee-Gan Lee (now at the Kavli Institute for the Physics and Mathematics of the Universe, Japan) has been constructing huge maps of the distribution of neutral gas in the cosmic web by using sky positions and distances



▲ **DARK FILAMENT** By carefully measuring how the dark matter in and around the galaxy cluster MACS J0717.5+3745 warped the apparent shapes of background galaxies, astronomers were able to map the invisible matter's location (blue). Additional observations revealed the filament's 3D structure and that the part farther from the cluster extends away from us *(bottom)*.

NASA / ESA / HARALD EBELING (UNIVERSITY OF HAWAI'I, MANOA) / JEAN-PAUL KNEIB (LAM) of hundreds of Lyman-alpha absorbers in the COSMOS field — an area in the constellation Sextans that many major telescopes have studied in detail in order to explore galaxy evolution. Thanks to their instrument's sensitivity, Lee and his colleagues do not restrict themselves to bright quasars as background beacons. Instead, they also use fainter star-forming galaxies, which are much more numerous. "This [provides] an unprecedented view of the cosmic web, which has never been mapped at such vast distances," Lee said in a 2014 press statement.

Because of the huge distances and corresponding large redshifts of the absorbing systems, the Lyman-alpha absorption lines are conveniently shifted from the ultraviolet into the visible part of the spectrum, where astronomers can measure them with the Low Resolution Imaging Spectrometer (LRIS) on the 10-meter Keck I telescope at Mauna Kea, Hawai'i. Using special-purpose computer algorithms, the data are then converted into 3D maps. Eventually, Lee's CLAMATO survey (for COSMOS Lyman-Alpha Mapping And Tomography Observations) is expected to cover a remote region of the universe some 230 million light-years wide and almost a billion light-years in depth.

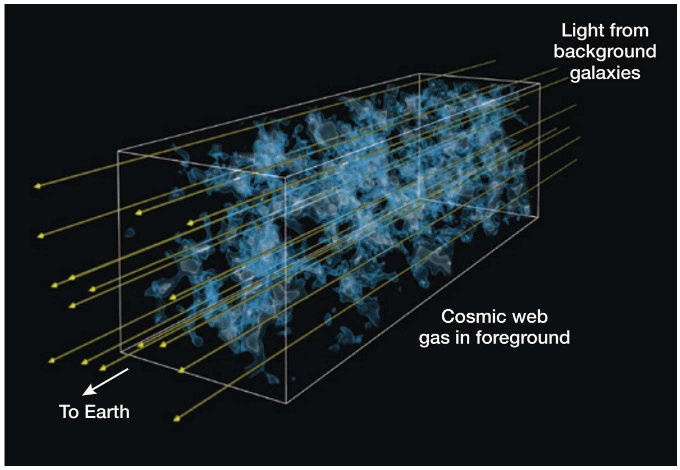
Most recently, in another March 2021 study, scientists revealed what they described as the first real image of intergalactic matter in the cosmic web. Not that anyone doubted its existence anymore, "but really seeing an image is of course much more convincing," says study leader Roland Bacon (University of Lyon, France).

Bacon and his colleagues used the sensitive Multi-Unit Spectroscopic Explorer (MUSE) spectrograph of the European Southern Observatory's Very Large Telescope in Chile to map the incredibly faint Lyman-alpha *emission* of remote swirls of intergalactic hydrogen gas in the Hubble Ultra Deep Field. "This is the most well-known part of the universe," says Bacon, "so there's a lot of interesting science you can do here with long observing times."

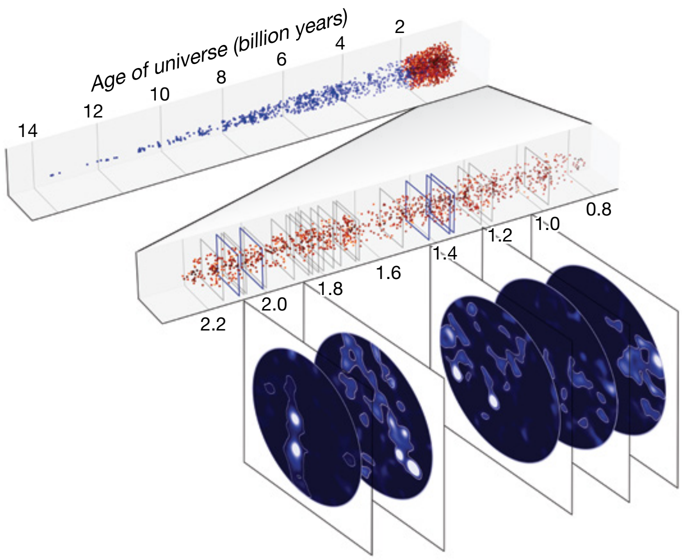
Between August 2018 and January 2019, MUSE was trained on this small area (in the southern constellation Fornax, the Furnace) for a total of no less than 140 hours. According to Bacon, getting awarded so much observing time was the biggest challenge. "Of all the instruments on the VLT, MUSE is the one most in demand," he says.

The faint glow of the cosmic web's hydrogen gas is a form of fluorescence. As mentioned before, neutral hydrogen atoms get excited when they absorb ultraviolet photons with a wavelength of 121.6 nm. But eventually, the electrons fall back to their lowest energy level, emitting photons of the same wavelength in the process. Since these are emitted in all possible directions, the Lyman-alpha *emission* signal is much fainter than the *absorption* signal. However, while studying absorption lines in the spectrum of a single background source only gives you information on one tiny part of the cosmic web, the emission signal can provide you with an image (albeit extremely faint) of the whole structure.

Bacon and his colleagues were not the first to detect



▲ **3D MAPPING** The CLAMATO project uses distant background galaxies to look for intervening hydrogen clouds that absorb some of the galaxies' light. The imprint enables astronomers to reconstruct the cosmic web that the light traversed.



▲ **COSMIC SLICE** Astronomers picked up the signal of Lyman-alpha emission from hydrogen at different times in the first 2 billion years of cosmic history (red, top). They found 22 notably dense regions (gray rectangles, center), five of which contained especially prominent filaments (blue rectangles and bottom row).

Lyman-alpha emission from intergalactic gas. It had already been observed in 2014, in the proximity of a luminous quasar that acted as a flashlight. Not much later, the Cosmic Web Imager — a dedicated instrument pioneered by Christopher Martin (Caltech) — started to reveal ever-stronger hints of filamentary structures. And in 2019, a team led by Hideki Umehata (University of Tokyo) used the MUSE spectrograph to detect structures between individual galaxies in a remote protocluster. But the new observations are the first to reveal cosmic-web filaments in the early universe, 1 to 2 billion years after the Big Bang. The structures have lengths of up to 15 million light-years.

A Bright Future

The most surprising part of Bacon's work is that the photons exciting the hydrogen gas appear to come from large numbers of extremely small, star-forming galaxies hidden in the filaments. According to Bacon, the dwarf galaxies weigh in at just a million solar masses or so. "If our interpretation is correct," he says, "the number of galaxies in the early universe that are forming stars is huge." Billions of these tiny galaxies may have been responsible for re-ionizing the universe at the end of the so-called Dark Ages, a few hundred million years after the Big Bang.

The new results provide additional observational constraints to cosmologists like van de Weijgaert, who try to model the evolution of the large-scale structure of the universe. "But don't forget that dark matter is the main component of the cosmic web," he says. "The big question is to what extent the gas distribution is representative for the web as a whole." Building on work by Francisco-Shu Kitaura (now at the Institute for Astrophysics in the Canary Islands, Spain), van de Weijgaert's PhD student Johan Hidding has reconstructed the dark matter distribution in the local universe out to some 300 million light-years by meticulously "tweaking" supercomputer simulations until they exactly reproduce the

▼ **FILAMENT** One of the hydrogen filaments (blue) discovered using the MUSE instrument in the Hubble Ultra-Deep Field (background image). The structure stretches across 15 million light-years.

▲ **XRISM TELESCOPE** Scheduled to launch in 2022, this X-ray telescope may help astronomers explore cosmic structure.

observed distribution of real galaxies. Eventually, his eye-catching reconstructions (see page 34) may provide much more detailed information on the evolution and the current locations of cosmic-web filaments and on the density of intergalactic gas in the local universe, Hidding says.

Massive galaxy surveys will also yield a wealth of detailed information about the cosmic web, enabling cosmologists to explore the precise way in which dark matter and dark energy have shaped the large-scale structure of the universe. Prime examples are the recently completed Dark Energy Survey (DES), the ongoing Dark Energy Spectroscopic Instrument (DESI) survey, the upcoming Legacy Survey of Space and Time (LSST), and the future space-based galaxy surveys of ESA's Euclid and NASA's Nancy Grace Roman Space Telescope. Next-generation ground-based telescopes like the European Southern Observatory's 39-meter Extremely Large Telescope, outfitted with sensitive integral-field spectrographs, will vastly surpass the recent achievements of the VLT's MUSE instrument. And future X-ray observatories — in particular the Japanese-American X-Ray Imaging and Spectroscopy Mission (XRISM) and the European Advanced Telescope for High-Energy Astrophysics (Athena) — have high enough sensitivity and spectral resolution to detect hundreds of tenuous intergalactic filaments.

As theories and simulations become more sophisticated over time, and observations ever more detailed, the study of the elusive cosmic web will likely remain a fecund interaction between the two approaches for quite some time to come. In the past, theoretical insights have usually guided cosmologists' interpretation of their sparse observational data. But in the end, the real universe has the last word. Before long, we could be witnessing how theories follow observations, instead of the other way around.

■ Contributing editor **GOVERT SCHILLING**'s new book on the search for dark matter, *The Elephant in the Universe*, will be published this spring by Harvard University Press.

FILAMENT: ROLAND BACON / DAVID MARY / ESO / NASA; XRISM TELESCOPE: NASA

OBSERVING
January 2022

1 DUSK: Jupiter, Saturn, Mercury, and Venus are arranged in a line above the southwestern horizon. If you want to see all four planets, you'll have to be quick to catch the sight before Venus and Mercury set.

2 EVENING: Algol shines at minimum brightness for roughly two hours centered at 7:01 p.m. EST (see page 50).

3 DUSK: Look very low in the southwest to espy the thinnest sliver of a Moon hanging some 4° below Mercury. Turn to page 46 for more details on this and other events listed here.

3–4 ALL NIGHT: The short-lived Quadrantid meteor shower peaks for North America at 3:40 p.m. EST on January 3rd (go to page 49). The Moon is one day past new and won't interfere for more favorably placed viewers in Asia and Eastern Europe.

4 EARTH passes through perihelion, its closest point to the Sun for 2022 (just 3% nearer than at aphelion in July).

4 DUSK: The Moon, still in the southwest, is now higher in the sky with Saturn around 5° upper right.

5 DUSK: The waxing crescent Moon and Jupiter are some 5° apart in Aquarius.

12 DUSK: Mercury and Saturn grace the southwestern horizon; a smidgen more than 3° separates the pair before they set. Higher up in Taurus, the waxing gibbous Moon is closing in on the Pleiades and will be less than 4° away by mid-evening.

13 EVENING: Still in Taurus, the Moon is now some 6° from Aldebaran.

17 MORNING: Before the Sun rises, the full Moon gleams in the west in Gemini, a bit more than 4° from Pollux.

19 EVENING: Algol shines at minimum brightness for roughly two hours centered at 11:56 p.m. EST (8:56 p.m. PST).

20 DAWN: The waning gibbous Moon is above the western horizon in Leo; 4° separates it from Regulus.

22 EVENING: Algol shines at minimum brightness for roughly two hours centered at 8:46 p.m. EST.

24 DAWN: It's Virgo's turn for a lunar visit, where the Moon (one day shy of last quarter) is 5° upper right of Spica.

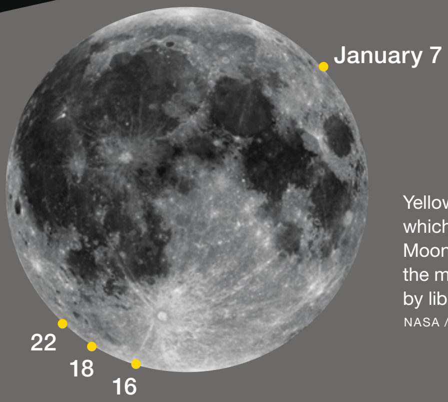
29 DAWN: The pretty trio of the waning crescent Moon, Mars, and Venus rises in the south-southeast. The Sun follows soon thereafter, but you'll have about an hour to enjoy this sight.
— DIANA HANNIKAINEN

▲ The winter Moon rises above Lastoi del Formin in the Dolomites in northern Italy.
GIORGIA HOFER

JANUARY 2022 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
January 2
18:33 UT

FIRST QUARTER
January 9
18:11 UT

FULL MOON
January 17
23:48 UT

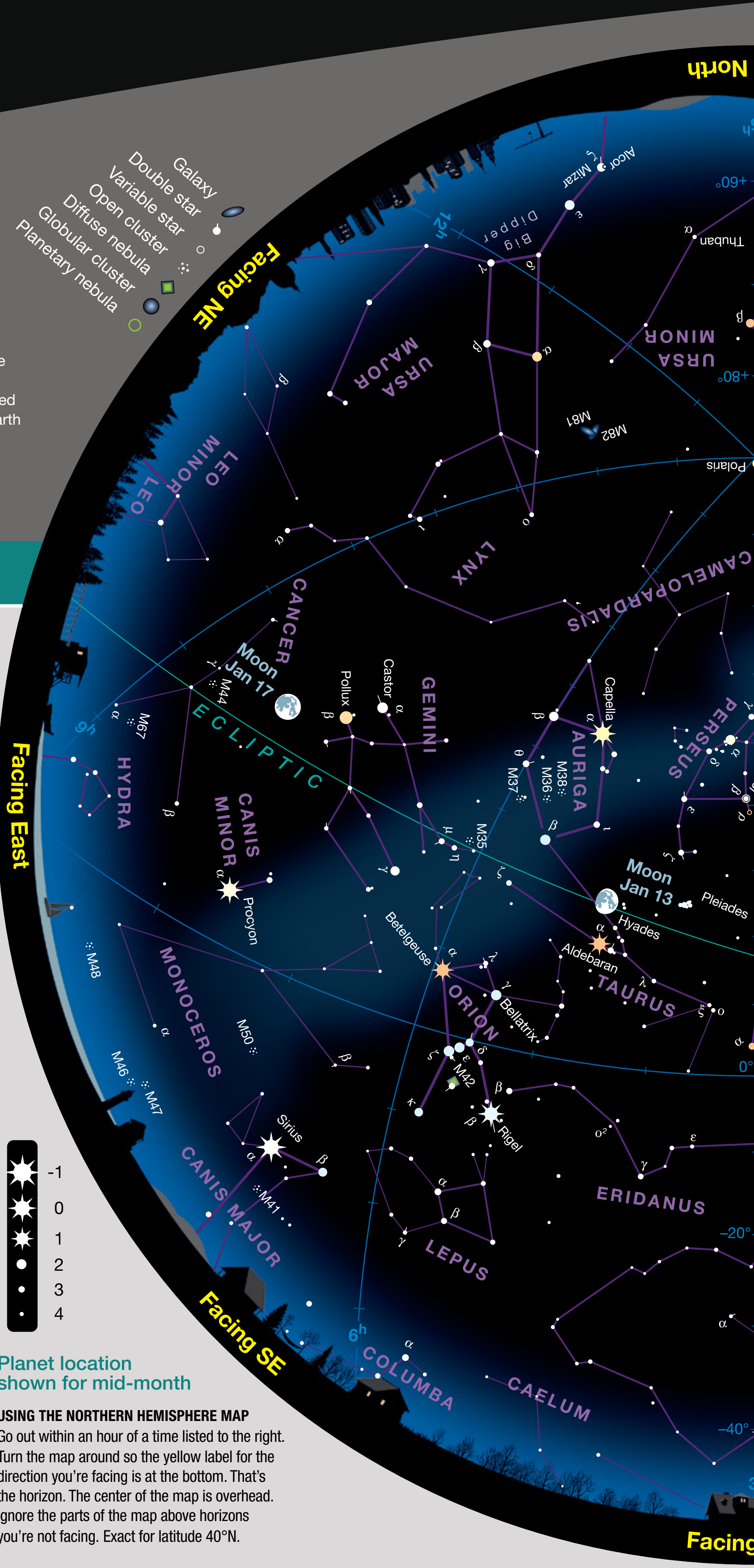
LAST QUARTER
January 25
13:41 UT

DISTANCES

Perigee	January 1, 23^h UT
358,033 km	Diameter 33′ 23″
Apogee	January 14, 09^h UT
405,805 km	Diameter 29′ 27″
Perigee	January 30, 07^h UT
362,252 km	Diameter 32′ 59″

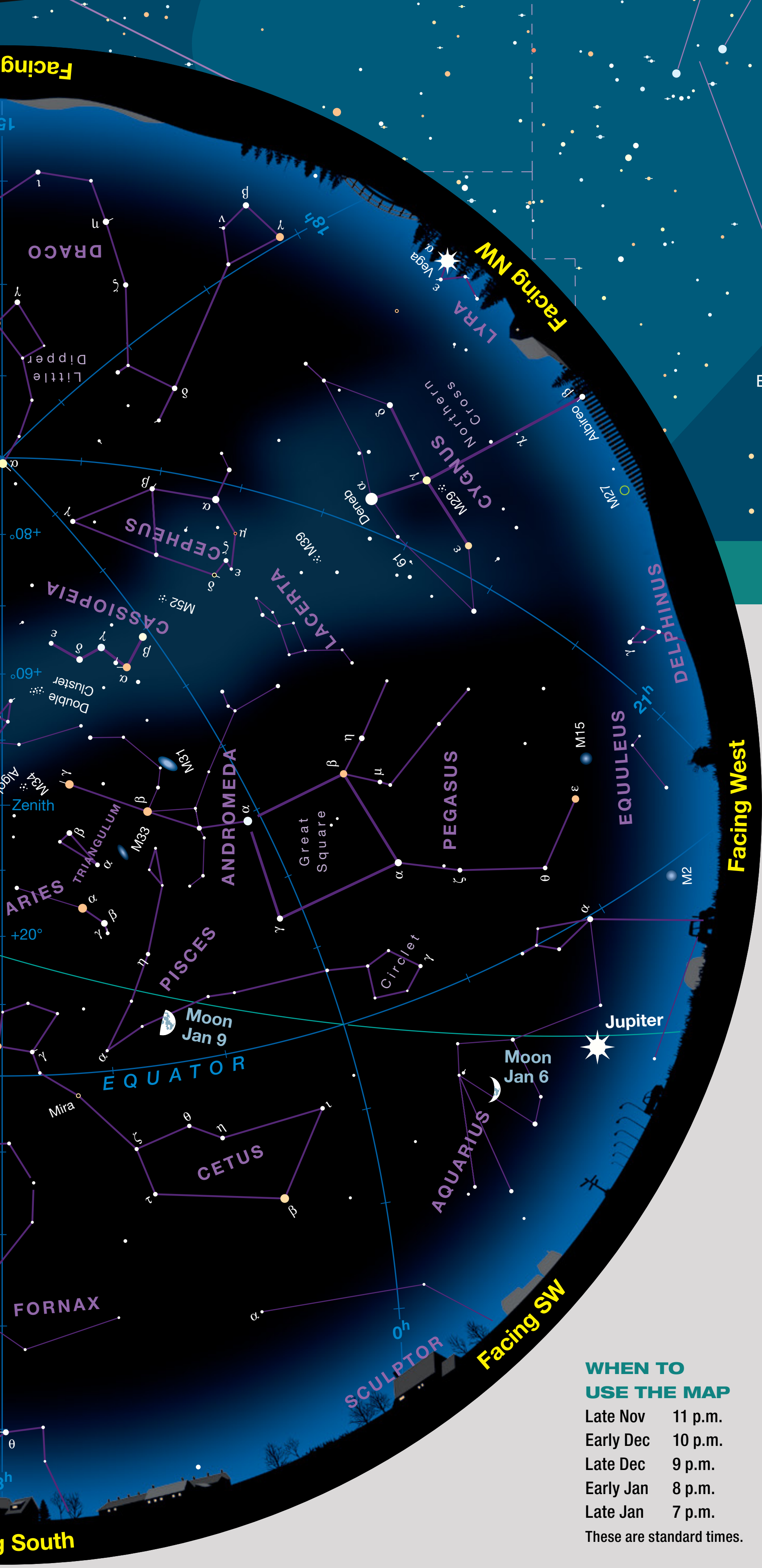
FAVORABLE LIBRATIONS

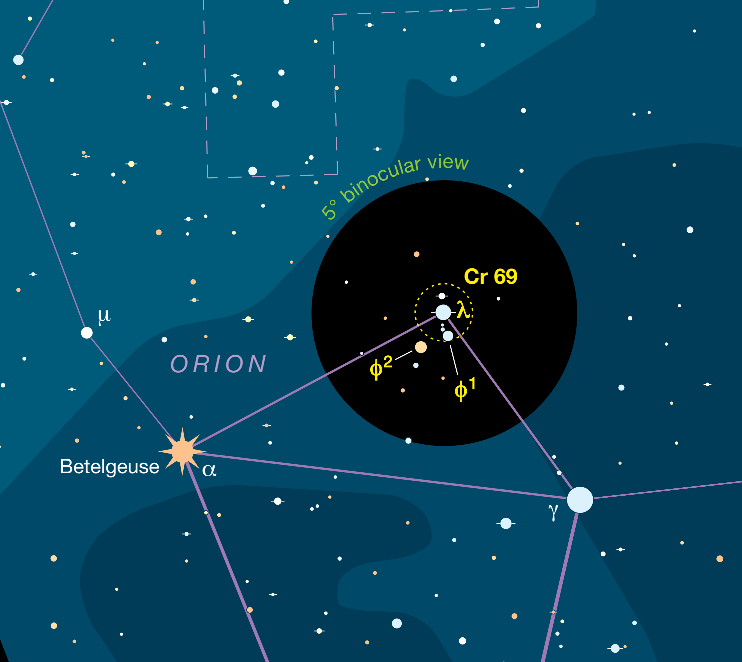
• Vashakidze Crater	January 7
• Wilson Crater	January 16
• Pilâtre Crater	January 18
• Baade Crater	January 22



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. Exact for latitude 40°N.





Binocular Highlight by Mathew Wedel

The Head of the Hunter

Befitting the constellation's name, Orion, the Hunter always seems to sneak up on me. Somehow it creeps over the horizon unannounced, and then I see it soaring in the eastern sky and I know that winter is upon us.

One winter jewel worth checking on at any magnification is **Lambda (λ) Orionis**, also known as Meissa. Together with **Phi^1 (ϕ^1)** and **Phi^2 (ϕ^2)** Orionis and the open cluster **Collinder 69**, Lambda forms the head of the imaginary hunter. Lambda itself is a double star, but with a separation of only 4.5″ it's too tight to be split with binoculars. It sits near the visual center of Collinder 69, a loose open cluster of approximately 100 stars, of which perhaps 10 or 20 are resolvable in binoculars. The rest contribute to a general brightening or fuzziness that seems to envelop Orion's head.

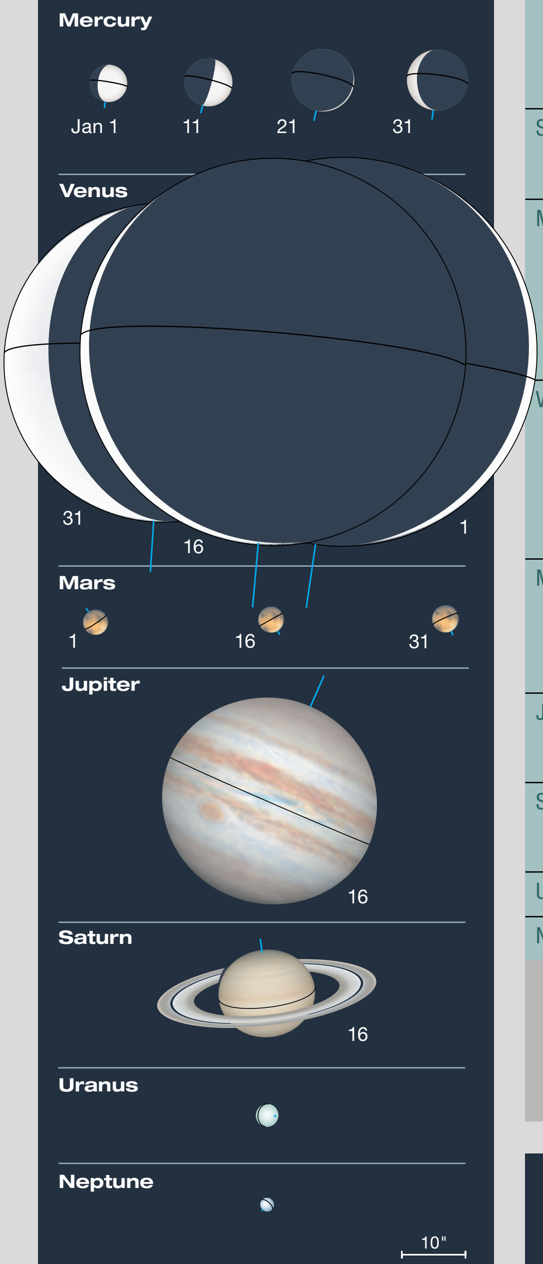
In fact, it's that apparent fuzziness that makes Lambda and its neighbors so interesting, especially at different magnifications. Stars in close proximity can fool you into thinking that nebulosity is present when none exists. To the naked eye, the light of Lambda Orionis, Phi^1 and Phi^2 Orionis, and the brighter cluster members combine to make Orion's head almost as misty as his sword. Binoculars resolve quite a few stars and dispel much of the unfocused glow in this area, but take a close look: You might spot some remnant brightening — the star-forming nebula Sharpless 264 occupies the same region of space. Although the nebula is generally regarded as too faint for small amateur optics, veteran observer Stephen James O'Meara thinks that it might just be possible to catch in averted vision under extremely dark conditions. Comparing the view with naked eyes, binoculars, and a telescope might prove enlightening.

■ **MATT WEDEL** finds that exploring the heavens with binoculars helps clear the fuzziness from his head.

WHEN TO USE THE MAP

Late Nov	11 p.m.
Early Dec	10 p.m.
Late Dec	9 p.m.
Early Jan	8 p.m.
Late Jan	7 p.m.

These are standard times.



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

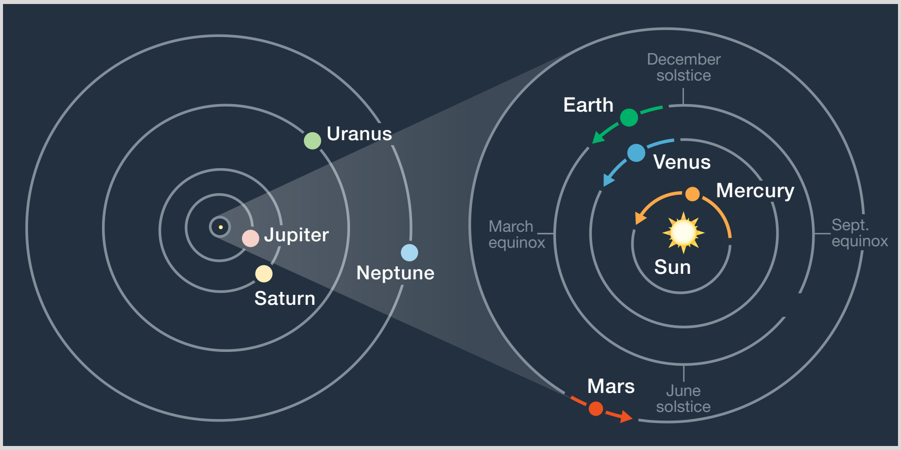
▶ **ORBITS OF THE PLANETS** The curved arrows show each planet's movement during January. The outer planets don't change position enough in a month to notice at this scale.

PLANET VISIBILITY (40°N, naked-eye, approximate) **Mercury** visible at dusk until the 15th • **Venus** visible at dusk until the 5th and then at dawn starting on the 10th • **Mars** visible at dawn all month • **Jupiter** visible at dusk all month • **Saturn** visible at dusk until the 19th.

January Sun & Planets

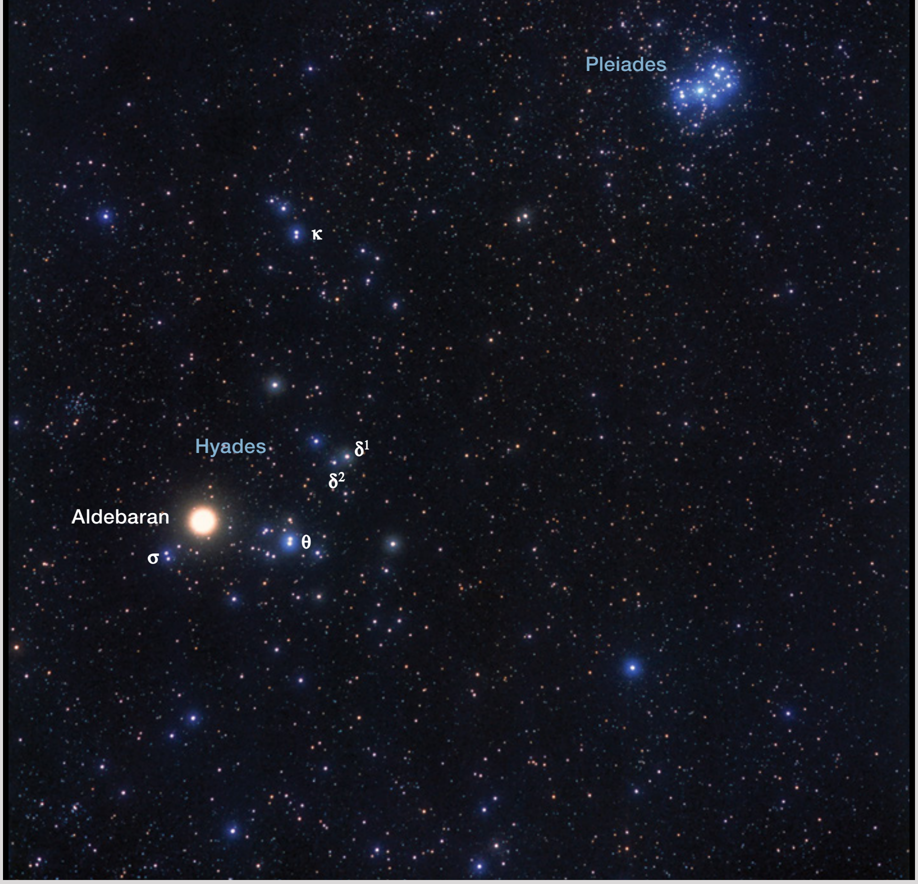
	Date	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$18^h\ 44.5^m$	–23° 03′	—	–26.8	32′ 32″	—	0.983
	31	$20^h\ 52.9^m$	–17° 32′	—	–26.8	32′ 28″	—	0.985
Mercury	1	$20^h\ 01.5^m$	–22° 22′	18° Ev	–0.7	5.9″	78%	1.142
	11	$20^h\ 45.6^m$	–18° 06′	19° Ev	–0.3	7.5″	43%	0.891
	21	$20^h\ 30.9^m$	–16° 01′	6° Ev	+4.0	9.9″	3%	0.681
	31	$19^h\ 46.3^m$	–17° 50′	16° Mo	+1.5	9.6″	16%	0.703
Venus	1	$19^h\ 37.3^m$	–18° 38′	13° Ev	–4.3	60.9″	2%	0.274
	11	$19^h\ 11.9^m$	–17° 07′	6° Mo	—	62.5″	1%	0.267
	21	$18^h\ 50.6^m$	–16° 18′	19° Mo	–4.5	57.8″	6%	0.289
	31	$18^h\ 44.8^m$	–16° 15′	31° Mo	–4.8	50.0″	14%	0.334
Mars	1	$16^h\ 45.4^m$	–22° 28′	27° Mo	+1.5	4.0″	98%	2.341
	16	$17^h\ 31.8^m$	–23° 35′	32° Mo	+1.5	4.1″	97%	2.259
	31	$18^h\ 19.2^m$	–23° 50′	36° Mo	+1.4	4.3″	96%	2.172
Jupiter	1	$22^h\ 10.7^m$	–12° 19′	50° Ev	–2.1	35.4″	99%	5.567
	31	$22^h\ 35.1^m$	–9° 58′	26° Ev	–2.0	33.7″	100%	5.854
Saturn	1	$20^h\ 57.2^m$	–18° 06′	31° Ev	+0.7	15.5″	100%	10.746
	31	$21^h\ 11.2^m$	–17° 07′	4° Ev	+0.7	15.3″	100%	10.896
Uranus	16	$2^h\ 32.9^m$	+14° 36′	105° Ev	+5.7	3.6″	100%	19.443
Neptune	16	$23^h\ 27.5^m$	–4° 44′	55° Ev	+7.9	2.2″	100%	30.471

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



The Noble Hyades

The nearest open cluster is a naked-eye delight.



▲ **TAURUS TWOSOME** Riding high on January evenings is the constellation Taurus, the Bull, which features two superb open clusters: the Pleiades and the Hyades. Of the two, the Hyades is arguably the more "noble" naked-eye sight.

AKIRA FUJII

Last month I called the Pleiades the loveliest of all naked-eye star clusters. But a friend of mine asked, "What about the Hyades?" I thought about my lifelong love of that collection of stars and quickly came to this personal judgement: The Pleiades are the loveliest naked-eye star cluster, but the Hyades are the *noblest*.

The most prominent members of the Hyades outline the face of Taurus, the celestial Bull. Depending on the time of night (and your latitude) these stars appear as a glittering V or arrowhead. The southeastern arm of the V would be shorter without the presence of magnitude +0.9 Aldebaran, but the star isn't actually a member of the Hyades. In fact, at a distance of 65 light-years, Aldebaran is considerably closer than the cluster, which is roughly 150 light-years away. Nonetheless, the Hyades is the nearest true star cluster and three times closer than the Pleiades.

The Hyades also appears bigger and brighter than the Pleiades. This can be considered as both a good and a bad thing. Why bad? The stars of the Pleiades are close enough to Earth to appear reasonably bright, yet far enough away to crowd together in a marvelously compact grouping. The key stars of the Pleiades can fit into the low-power field of a small, wide-field telescope. By contrast, you need binoculars capable of showing a 5½° field to contain the expansive Hyades.

But when it comes to naked-eye observing, the number of stars easily visible in the Hyades is much greater than in the Pleiades. The five brightest Hyads shine between magnitudes 3.4 and 3.8, and another 11 cluster members are brighter than magnitude 5.0. That's 16 stars that you should be able to see without optical aid even from a small city or a moderately light-polluted suburb. A total of 26 Hyades stars are brighter than magnitude 6.5, the traditional naked-eye limit for really dark skies. More than 130 Hyads are brighter than 9th magnitude and hence within reach of binoculars under clear, dark skies.

Not all the stars of the Hyades are crowded inside the V pattern. The brightest Hyad farthest from the main flock is Kappa^1 (κ^1) Tauri, a 4.2-magnitude star lying north of the ecliptic and the V. A scant 5.6′ from Kappa^1 is 5.3-magnitude Kappa^2, also known as 67 Tauri. The Kappa pair are one of several naked-eye doubles in the cluster. The brightest duo includes the yellow, 3.8-magnitude star Theta^1 (θ^1) Tauri, which shines 5.6′ from the orange, 3.4-magnitude Theta^2. This pair is the next stop down from Aldebaran in the southeastern arm of the V. In the other branch of the V, the Delta^1 (δ^1) and Delta^2 pair are much farther apart (18′) and shine at magnitude 3.8 and 4.8, respectively. About 1° southeast of Aldebaran you'll find Sigma (σ) Tauri, comprised of blue-white stars of magnitudes 4.7 and 5.1, separated by a little more than 7′. How many of these pairs can you split without optics?

When I view the cluster, my eye is drawn to an extra line of Hyads extending south-southwest of the V, transforming it into a Z or N. I was gratified to see Stephen James O'Meara also mentioned this configuration in his book *The Caldwell Objects* (the Hyades cluster is listed as Caldwell 41).

The middle-aged Hyades are much older than the young, blue Pleiades — indeed, many Hyads have already evolved into red (and orange) giants. In about 50 million years the receding Hyades will be a ½°-wide telescopic cluster positioned a few degrees east of where Betelgeuse is now.

■ **FRED SCHAAF** was delighted that asteroid 7065 Fredschaaf was passing through the Hyades just a few months after it was named for him.

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

Mercury, Venus, and Saturn Slip Away

A quartet of bright planets crowd the southwestern horizon at dusk.

SATURDAY, JANUARY 1

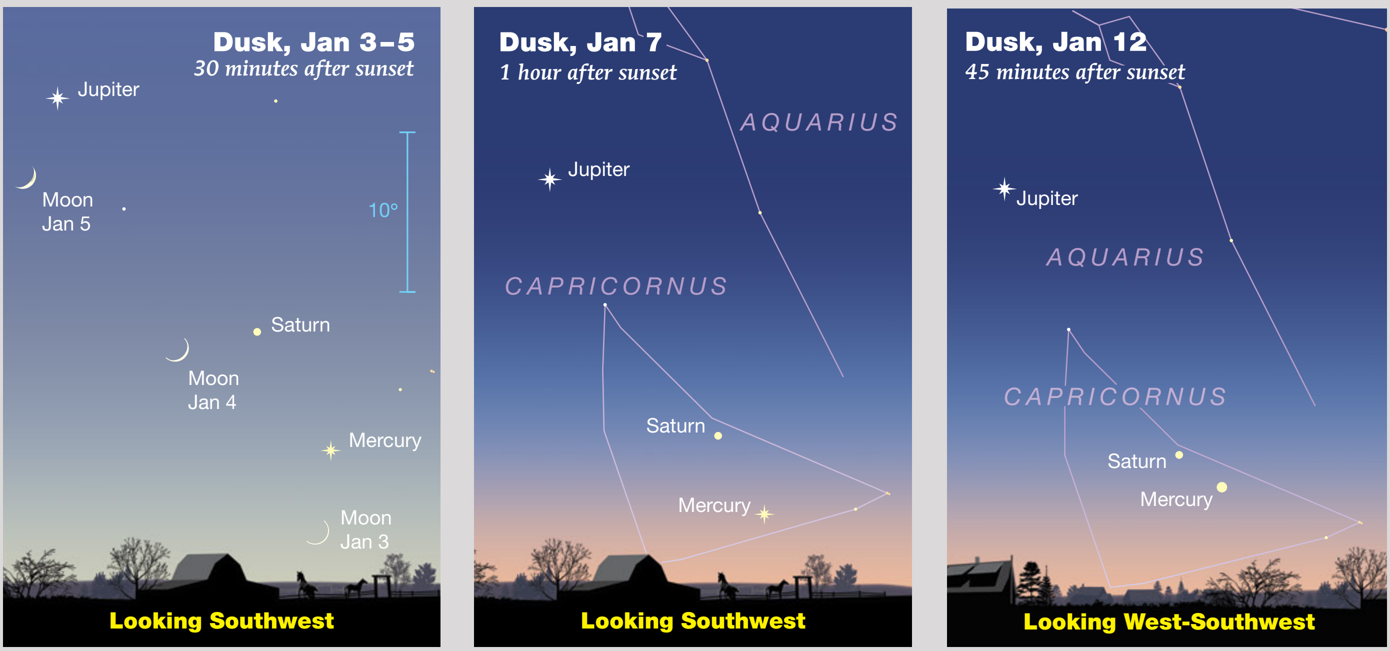
As the month gets underway, early risers can watch **Mars** continue its journey past **Antares**, in Scorpius. Antares is a notable conjunction mate for two reasons. First, it's the third brightest star near the ecliptic (only Aldebaran and Spica are marginally brighter), and second, its color is a close match for the Red Planet. On this particular morning, however, Antares outshines its "rival" by roughly half a magnitude. Can you see the difference? And if you have a particularly unobstructed view towards the southeast, try to catch the razor-thin (2%-illumined), crescent **Moon** lower left of Mars and Antares. The warm-hued planet-star duo were actually closest as December drew to a close, and now Mars is gliding away from Antares at a rate of about ½° per day. This rapid eastward motion is one reason why the planet remains stubbornly mired in the haze near the dawn horizon. On January 1st, Mars rises about two hours ahead of the Sun, and by the 31st that figure grows by only a couple of minutes. Talk about slow progress!

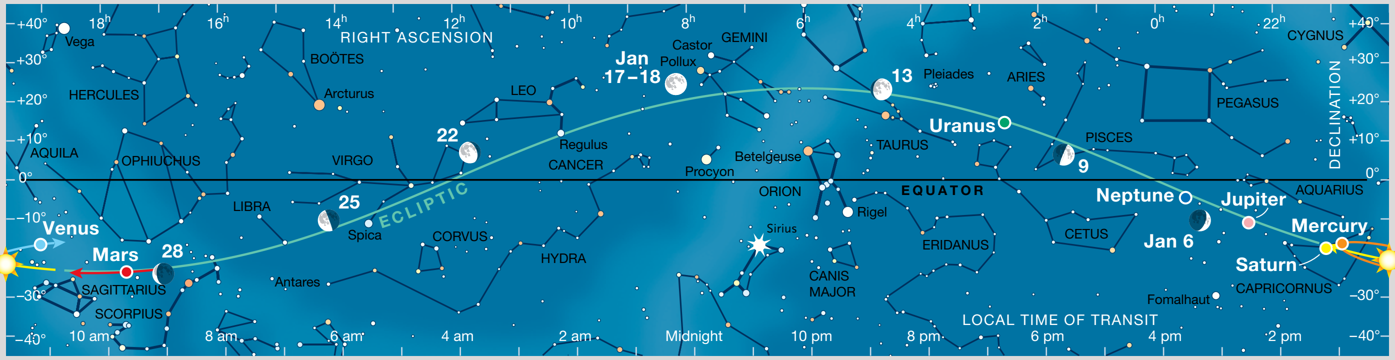
MONDAY, JANUARY 3

Fresh from its dawn meetup with Mars and Antares, the **Moon** returns to the dusk sky where it forms a triangle very low in the west-southwest with the two innermost planets, **Venus** and **Mercury**. Of the three, the Moon may prove to be the toughest to spot, sitting about 12° left of the brilliant Evening Star. If you can't spot the thin lunar crescent this evening, try again tomorrow when it'll be fatter and much higher — the trio still form a triangle, just a different one.

Mercury currently shines at magnitude –0.7, and Venus gleams at magnitude –4.2. However, the two planets are moving in opposite directions — Mercury is climbing higher, while Venus is losing altitude as it heads toward its January 8th conjunction with the Sun. Don't worry — Venus won't be gone for long. You should be able to spot it at dawn starting on the morning of the 10th, when it begins an apparition that will continue on through the end of next summer. As interesting as triangles are, more eye-catching is the luminous line spanning 40° that includes Saturn

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





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

and Jupiter as well as Venus and Mercury. Think of it: in a single view you can see four of the five bright naked-eye planets. Impressive! Saturn glows at magnitude +0.7 from its perch near the middle of Capricornus, while Jupiter is roughly 20° away and, at magnitude –2.1, utterly dominates Aquarius.

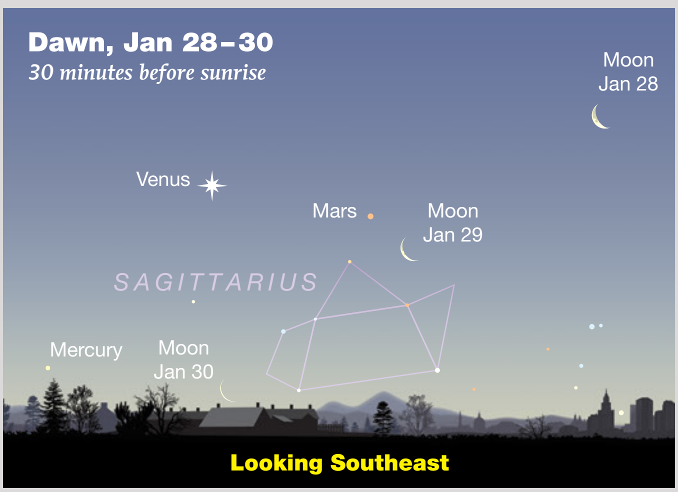
FRIDAY, JANUARY 7

Today **Mercury** reaches its greatest elongation from the Sun, when it sits 19° east of our home star. This marks the climax of an apparition that began in December and is the first of four evening showings in 2022. Catch Mercury while you can because you'll have to wait until April for another shot at it at dusk. (That apparition will be the planet's finest for the year.) And though the date of greatest elongation tends to be the one that gets the most attention, more often than not Mercury is higher above the horizon a few days before or after that date. In this case, the difference is small. For observers at mid-northern latitudes, Mercury is very slightly higher at dusk on the 9th than this evening.

WEDNESDAY, JANUARY 12

If you've been watching **Mercury** regularly, you'll have noticed that it's been getting closer and closer to **Saturn**. Mercury has been climbing higher while Saturn has been sinking lower, and at dusk today the two worlds are at their closest with a little less than 3½° separating them. (They'll be nearly as close tomorrow evening, too.) The two are similarly bright, with Mercury shining at magnitude 0.0 and Saturn at magnitude +0.7. Given the pair's low altitude (45 minutes after sunset it's just 6°), you'll probably find that binoculars make spotting them much easier. After this meet-and-greet, Mercury will pull away as it plunges sunward for its solar conjunction on the 23rd. Saturn is moving at a more leisurely pace and won't have its date with the Sun until February 4th.

Later this evening turn your attention toward the waxing gibbous **Moon**, riding high in the south. About 4° above the bright lunar disk is the clutch of stars known as the **Pleiades**, or M45. (The cluster is also known as the Seven Sisters, as readers of Fred Schaaf's December column will recall.) Glare from the 80%-illuminated Moon will make the cluster stars a bit harder to notice, so don't be afraid to pull out your binoculars again.



SATURDAY, JANUARY 29

Let's wrap up the month the way we started — in the dawn sky with the **Moon** and **Mars**, which are now joined by a post-solar-conjunction **Venus**. Of all the January solar-system gatherings, this is probably the most striking. Certainly, it's the easiest one to see, apart from the bit about having to get up early in the morning. Any time you have the Moon and Venus together, it's going to attract attention — even if they're quite far apart, as they are on this occasion when they're separated by about 13°. The scene is enhanced by the Morning Star's extreme brightness (magnitude –4.8) and the subtle beauty of earthshine lighting up the "dark" portion of the lunar disk. And let's not forget Mars, shining gamely at magnitude 1.4, upper left of the Moon. When we last looked in on the Red Planet it was visiting Antares, but since then it has motored eastward more than 20°.

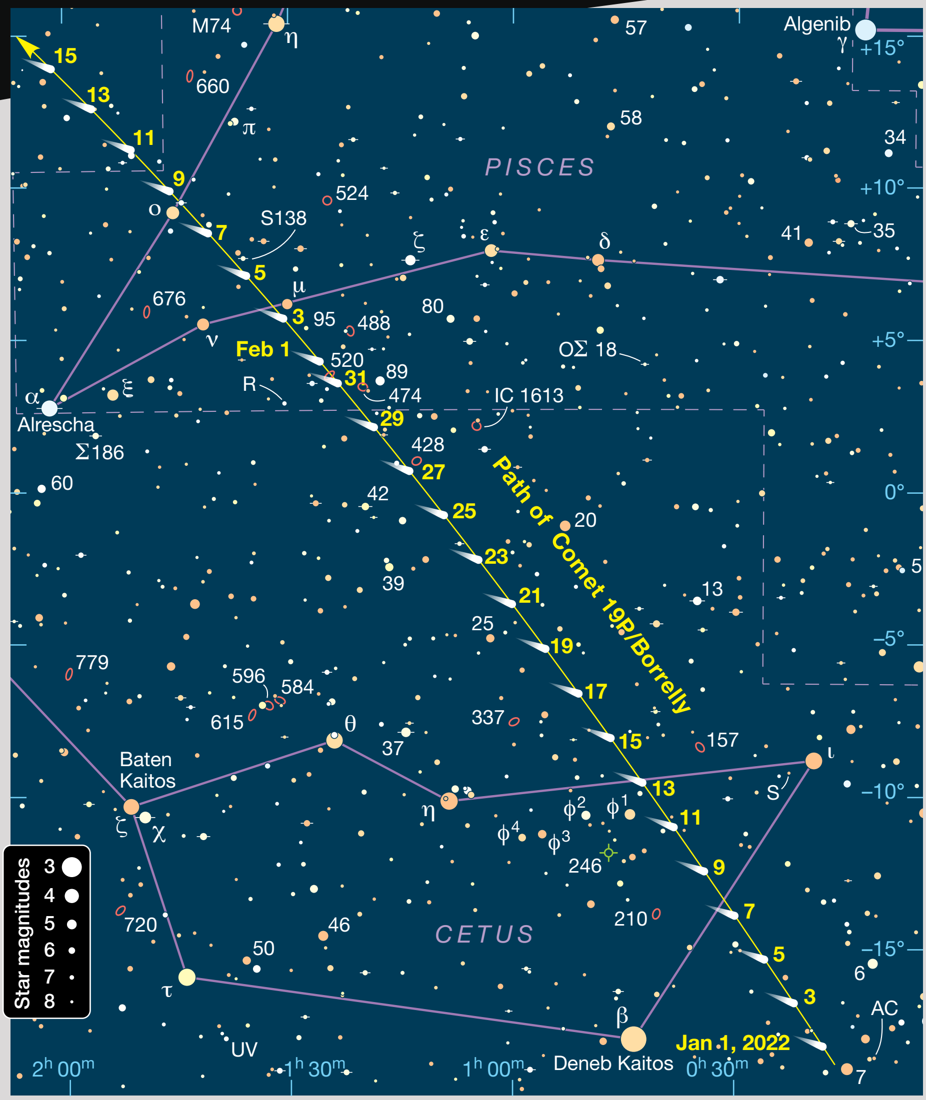
■ Consulting Editor **GARY SERONIK** is more than happy to greet the new year with his solar system friends.

Bowling for Borrelly

January has a bite to it, but you can bite back by checking out a periodic comet.

If you've ever gone bowling, you have a pretty good idea of what the nucleus of Comet 19P/Borrelly looks like. Up close, it's shaped like a bowling pin except that it's composed of ice and dust and stands 8 kilometers (5 miles) tall. We last got a good look at this periodic comet in our telescopes when it came to perihelion in May 2015. It does so again on February 1st.

Borrelly passed closest to Earth last December but will reach its peak brightness of around 9th magnitude in early January, dimming slightly by month's end. Southern skywatchers got their first good look at this dusty visitor last autumn, and now the rest of us can share in the icy bounty as the comet ascends from western Cetus into Pisces in the evening sky. Your best views will come at the end of twilight,



▲ Throughout January, Comet 19P/Borrelly will be an early evening target as it traverses Cetus on its way into Pisces. (The comet's positions are plotted for 0^h UT.)

which coincidentally is the warmest part of January nights. Based on past apparitions, the comet should exhibit a moderately compact coma and a short, eastward-pointing tail. A 6-inch scope will fish it out, but an 8- or 10-inch instrument will better show Borrelly's classic cometary form.

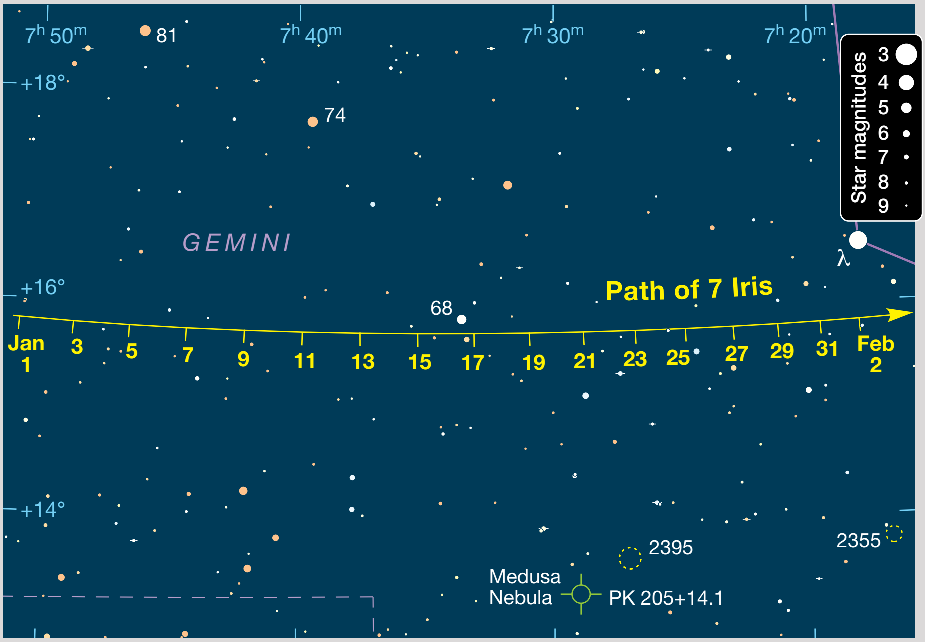
French astronomer Alphonse Borrelly discovered the object on December 28, 1904, when it was also in Cetus and moving northward. Borrelly worked at Marseilles Observatory and discovered 18 asteroids and several more comets in his lifetime. Comet 19P/Borrelly orbits the Sun every 6.9 years and is a member of the Jupiter-family of comets — a passel of frozen leftovers with orbital periods of fewer than 20 years and molded by gravitational interactions with the giant planet.

Borrelly became the second comet (after 1P/Halley) to be imaged up close, when NASA's Deep Space 1 spacecraft flew just 2,170 kilometers from its nucleus in September 2001. Laurence Soderblom, who headed the Deep Space 1's camera team, noted at the time that the photographs recorded "rugged terrain, smooth, rolling plains, deep fractures, and very, very dark material."

The comet remains visible well into spring, though it gradually fades as it proceeds northeastward through Pisces, Aries, Taurus, and Auriga. On the evening of January 10th, Borrelly sweeps 2.3° northwest of the 10.9-magnitude planetary nebula NGC 246, also known as the Skull Nebula. The Moon stays largely out of the picture from December 21st to January 6th, and again from January 19th to February 3rd.

▼ Comet Borrelly displays a small coma and short tail in this photo taken during its most recent apparition, on August 12, 2015. According to comet expert Alan Hale, Borrelly's current return is the "best one it will have had in over two decades."

ALFONS DIEPVENS

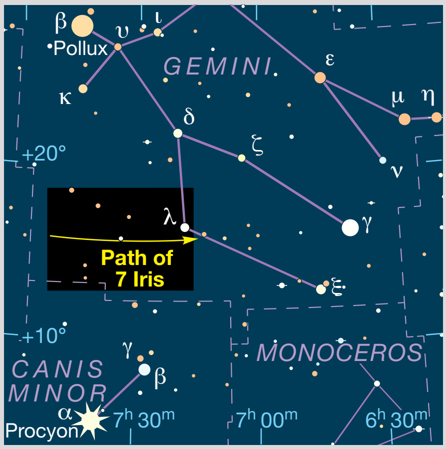


Eye on Iris

BINOCULARS ARE OFTEN underappreciated. Many skywatchers leap from naked-eye observing to a telescope and bypass the humble handheld instrument. I've learned to utilize binoculars more and more over the years and can't think of a better way to put them to good use this month than by tracking down the asteroid 7 Iris. It comes to opposition on January 13th in southern Gemini, where it glows at magnitude 7.7. That's a little brighter than Neptune, which means Iris is well within reach of 50-mm binoculars from a moderately dark site.

Around opposition, Iris advances westward about ¼° each night and ends the month ¾° south-southeast of the 3.6-magnitude star Lambda (λ) Geminorum. If you watch closely, you can perceive its night-to-night motion even in binoculars by carefully noting its changing position against the background stars.

English astronomer John Russell Hind discovered Iris from London, England, in August 1847 during a systematic search following the discovery of Neptune the previous year. Named for the Greek rainbow goddess, Iris is the fourth-brightest minor planet and has a mean diameter of 214 kilometers. Its



reflective surface is pocked by craters, eight of which are between 20 and 40 kilometers across and bear Greek names for the colors of a rainbow, such as Chloros (green) and Cyanos (blue). These features were discovered with the Very Large Telescope's SPHERE instrument.

Iris orbits the Sun every 3.7 years and rotates once every 7.1 hours. Remote examination of its surface reveals similarities to LL-chondrite (low-iron) meteorites. Familiar examples include the Chelyabinsk meteorite fall of February 2013 as well as the asteroid Itokawa, which the Japanese probe Hayabusa visited in 2005, returning samples of the asteroid to Earth in June 2010.

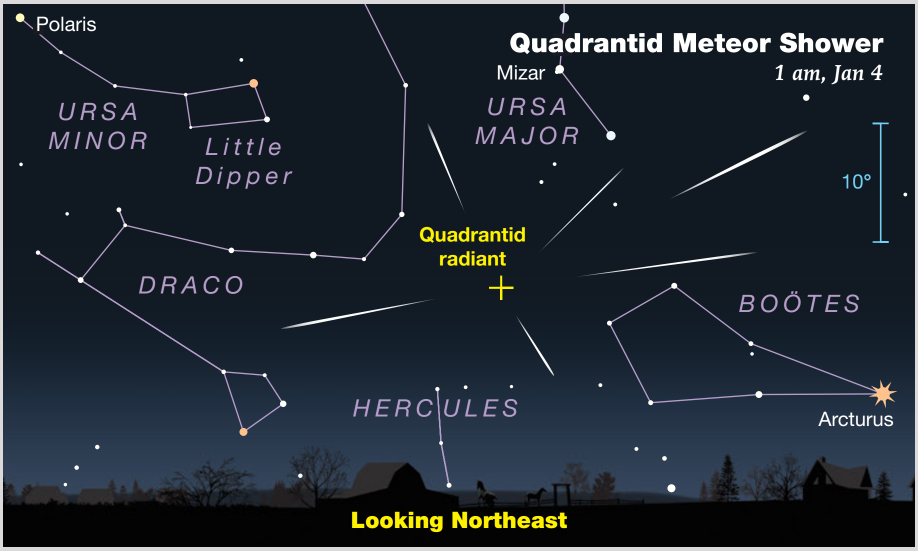
And now you can grab your own retinal "sample" of Iris photons.

Moonless Quads

NORMALLY, MOONLESS CONDITIONS for any meteor shower would be cause to celebrate, but the annual Quadrantids are fussy. While up to 120 meteors per hour *could* be visible under ideal conditions, the shower's peak lasts only about 4 hours. If you miss that brief window, the rate plummets to about 25 per hour — though that's still a bit better than a typical Lyrid or Orionid display.

This year the Quads are expected to peak around 20:40 UT (3:40 p.m. Eastern Time) on January 3rd, which favors observers in Asia and at eastern European longitudes. North American skywatchers will still see a shower, but one with the volume turned down. Because of the timing of the peak, it's likely the mornings of the 3rd and 4th will both offer good viewing. Watch between 3 a.m. and dawn when the radiant stands highest in the northeastern sky.

▲ Astrophotographer Petr Horálek captured this composite photo of the 2020 Quadrantid meteor shower above a snowy Slovakian landscape. The peak of this year's display favors observers (and photographers) in Eastern Europe and Asia.



Quadrantid meteors derive from fragments shed by the small, near-Earth asteroid 2004 EH_1. It's thought the asteroid is actually an extinct comet that still exhibits occasional activity. Quads travel at 41 kilometers per second, and the display isn't stingy with fireballs.

The annual cosmic sprinkle gets its name from the former constellation Quadrans Muralis (Mural Quadrant), named for an instrument once used to measure the altitudes of celestial objects. French astronomer Jérôme Lalande created the figure from a smattering of "unused" stars between Draco and Boötes. It never gained wide acceptance and soon entered the domain of defunct constellations. But once a year, like Santa Claus, Quadrans Muralis returns to gift us a meteor shower.

Minima of Algol

Dec.	UT	Jan.	UT
2	11:00	3	0:01
5	7:49	5	20:50
8	4:38	8	17:39
11	1:27	11	14:28
13	22:16	14	11:18
16	19:05	17	8:07
19	15:54	20	4:56
22	12:44	23	1:46
25	9:33	25	22:35
28	6:22	28	19:24
31	3:11	31	16:14

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

▲ Perseus is positioned at the zenith during evening hours throughout January. Every 2.7 days, Algol (Beta Persei) dips from its usual magnitude 2.1 to 3.4 and back. Use the chart above to estimate Algol's brightness in respect to comparison stars of magnitude 2.1 (Gamma Andromedae) and 3.4 (Alpha Trianguli).

Action at Jupiter

JANUARY IS THE FINAL COMPLETE month of the current Jupiter apparition and offers your last chance for decent telescopic views of the planet before its conjunction with the Sun in early March. On the 1st, Jupiter has an altitude of roughly 35° at sunset, but by month's end that figure is down to 21°. As January begins, the gas giant shines at magnitude –2.1 and spans just 35″.

Any telescope reveals the four big Galilean moons, and binoculars usually show at least two or three. Use the diagram on the facing page to identify them by their relative positions on any given date and time. All the observable interactions between Jupiter and its satellites and their shadows are tabulated on the facing page.

Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. Here are the times, in Universal Time, when the Great Red Spot should cross Jupiter's central meridian. The dates, also in UT, are in bold. (Eastern Standard Time is UT minus 5 hours.)

December 1: 1:44, 11:40, 21:35; **2**: 7:31, 17:27; **3**: 3:23, 13:19, 23:14; **4**: 9:10, 19:06; **5**: 5:02, 14:58; **6**: 0:54, 10:50, 20:45; **7**: 6:41, 16:37; **8**: 2:33, 12:29, 22:24; **9**: 8:20, 18:16; **10**: 4:12, 14:08; **11**: 0:04, 09:59, 19:55; **12**: 5:51, 15:47; **13**: 1:43, 11:39, 21:34; **14**: 7:30, 17:26; **15**: 3:22, 13:18, 23:13; **16**: 9:10, 19:05; **17**: 5:01, 14:57; **18**: 0:53, 10:49, 20:44; **19**: 6:40, 16:36; **20**: 2:32, 12:28, 22:24; **21**: 8:20, 18:15; **22**: 4:11, 14:07; **23**: 0:03, 09:59, 19:54; **24**: 5:51, 15:46; **25**: 1:42, 11:38, 21:34; **26**: 7:30, 17:25; **27**: 3:21, 13:17, 23:13; **28**: 9:09, 19:05; **29**: 5:01, 14:56; **30**: 0:52, 10:48, 20:44; **31**: 6:40, 16:36

January 1: 2:30, 12:26, 22:21; **2**: 8:17, 18:13; **3**: 4:09, 14:05; **4**: 0:01, 9:57, 19:52; **5**: 5:48, 15:44; **6**: 1:40, 11:36, 21:31; **7**: 7:28, 17:23; **8**: 3:19, 13:15, 23:11; **9**: 9:07, 19:02; **10**: 4:59, 14:54; **11**: 0:50, 10:46, 20:42; **12**: 6:38, 16:33; **13**: 2:30, 12:25, 22:21; **14**: 8:17, 18:13; **15**: 4:09, 14:04; **16**: 0:01, 09:56, 19:52; **17**: 5:48, 15:44; **18**: 1:40, 11:36, 21:31; **19**: 7:27, 17:23; **20**: 3:19, 13:15, 23:10; **21**: 9:07, 19:02;

22: 4:58, 14:54; **23**: 0:50, 10:46, 20:41; **24**: 6:38, 16:33; **25**: 2:29, 12:25, 22:21; **26**: 8:17, 18:12; **27**: 4:09, 14:04, 23:59; **28**: 0:00, 9:56, 19:52; **29**: 5:48, 15:43; **30**: 1:40, 11:35, 21:31; **31**: 7:27, 17:23

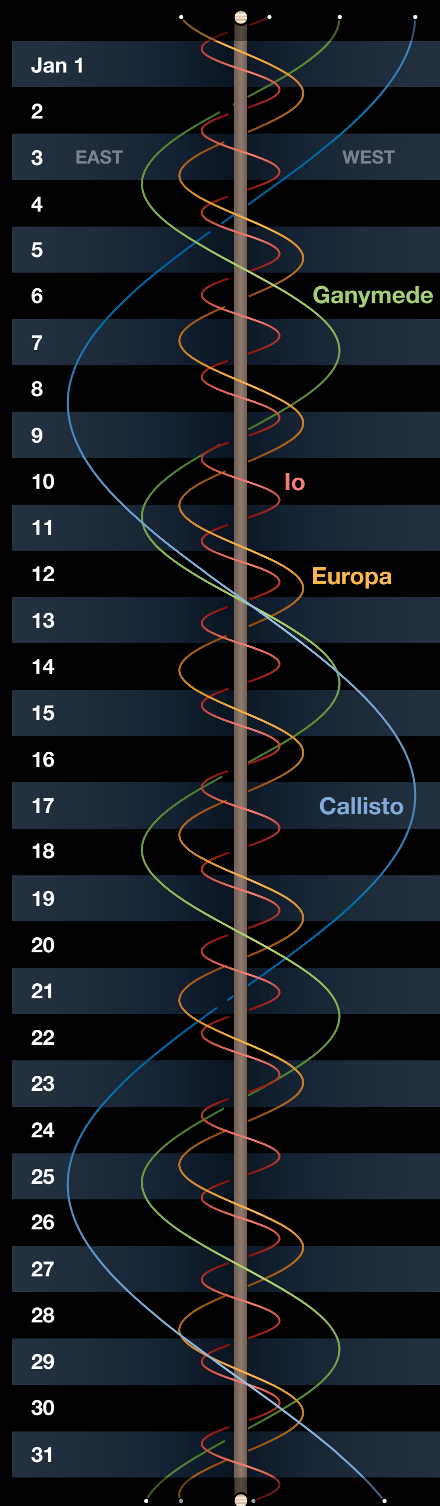
These times assume that the spot will be centered at System II longitude 9° on January 1st. If the Red Spot has moved elsewhere, it will transit 1⅔ minutes earlier for each degree less than 9° and 1⅔ minutes later for each degree more than 9°.

Phenomena of Jupiter's Moons, January 2022

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

Every day, interesting events happen between Jupiter's satellites and the planet's disk or shadow. The first columns give the date and mid-time of the event, in Universal Time (which is 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.

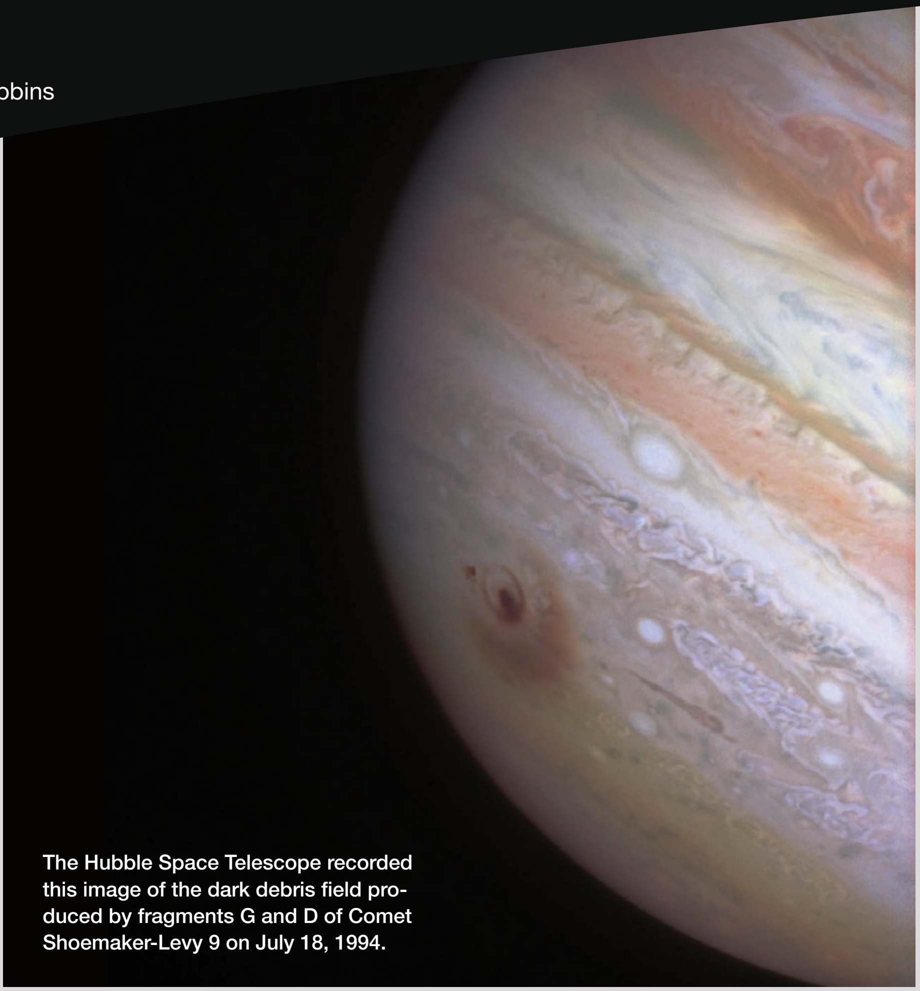
Jupiter's Moons



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.

Monitor Jupiter for Planet Strikes

Amateurs keep catching objects hitting Jupiter, and you can, too.



The Hubble Space Telescope recorded this image of the dark debris field produced by fragments G and D of Comet Shoemaker-Levy 9 on July 18, 1994.

H. HAMMEL / MIT / NASA, PROCESSING: JUDY SCHMIDT

For eight days in July of 1994 the fragments of Comet Shoemaker-Levy 9 smashed into Jupiter, producing huge clouds of sooty particulates that encircled the planet and lingered for months. Arguably the most impressive spectacle ever witnessed by astronomers, these events drove home the grave danger to Earth posed by comet and asteroid impacts (*S&T:* June 2018, p. 12) and added a new urgency to determining the frequency of cosmic collisions. In recent years a series of serendipitous discoveries by amateur astronomers has provided vital clues.

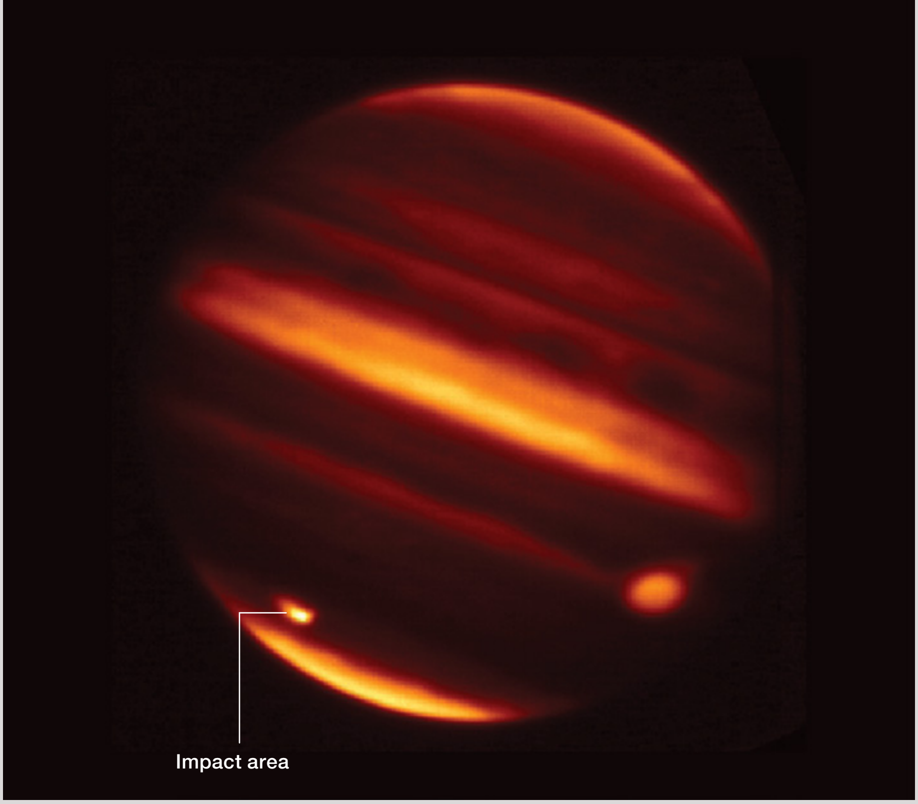
Despite its lack of a solid surface, Jupiter is the ideal place to look for asteroid and comet impacts. With a diameter over 11 times greater than Earth's, Jupiter is a big target. And at two and a half times the mass of all the other planets combined, it is the solar system's major attractor for impacting bodies. Jupiter's powerful gravitational pull also accelerates objects to high speeds. Ignoring orbital velocities, objects strike Jupiter with roughly five times the velocity of those that strike Earth, resulting in impact energies that are 25 times higher.

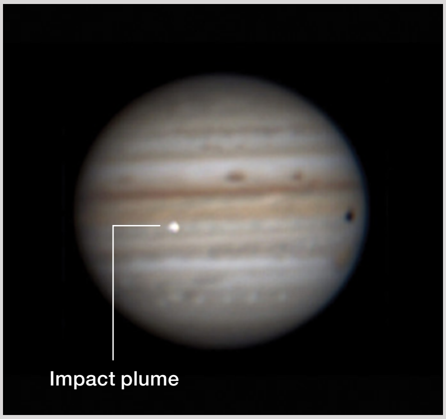
On July 19, 2009 — almost 15 years to the day after the Shoemaker-Levy 9 events — Australian amateur Anthony Wesley captured images of a fresh impact "bruise" as it rotated into view over Jupiter's morning limb. (The impact itself was unobserved because it occurred on Jupiter's averted night hemisphere.) Less than two days later, NASA's Infrared Telescope Facility obtained the first images of this feature through an 890-nanometer methane band filter in the near-infrared region of the spectrum. Methane filters effectively block the sunlight reflected off clouds deeper in the Jovian atmosphere, so the presence of material high above the main cloud deck stands out. A dark appearance in visible light combined with a bright appearance in the near infrared is the hallmark spectral signature of impact scars. The methane pictures showed the spot to be much brighter than its surroundings.

In June of the following year, Wesley and others recorded the flash of a bright bolide above Jupiter's clouds that left no detectable mark on the face of the planet. A similar event followed only 10 weeks later, and a third occurred in September 2012. Four more have been recorded in recent years. All seven of these events were confirmed in videos acquired by at least two geographically separated observers, all amateurs.

In the past, small impacts producing flashes lasting for a second or two were widely regarded as undetectable with all but the largest ground-based telescopes. But the modest instruments that today's amateurs wield have proven to be remarkably powerful tools. In recent years, the sensitivity, frame rates, and signal-to-noise ratio of high-speed video cameras employed by amateurs have improved dramatically. Higher sensitivity makes it possible to detect impact flashes using smaller telescopes, while faster frame rates (>30 frames per second) provide better temporal resolution of the light curves of the events, permitting astronomers to infer the nature of the impacting object (stony, metallic, icy compact, or icy porous) through its fragmentation behavior.

With these impacts in mind, French amateur Marc Delcroix, Spanish physi-





▲ Brazilian amateur José Luis Pereira captured the most recent impact event at 22:39 UT on September 13, 2021, using his 10.8-inch Newtonian reflector and a QHY5III462C video camera (see page 10).

◀ The debris field of an impacting object in 2009 appears bright when seen through a 890-nanometer methane filter.

cist Ricardo Hueso, and Jon Juaristi Campillo of the Center for Astronomy at Heidelberg University in Germany wrote software that searches for impact flashes in video recordings. Employing a fast and efficient algorithm based on differential photometry, *DeTeCt* (**https://is.gd/DeTeCt**) is an open-source application that planet imagers can use on their own computers to identify impacting events. The program eliminates the need to perform a very tedious and time-consuming frame-by-frame hunt for bright spots of fleeting duration by searching for localized brightness anomalies and automatically generating a detection image and report.

Using *DeTeCt* is one of the core activities of the Europlanet Planetary Space Weather Services. The project's website (**https://is.gd/europlanet**) provides a tutorial for using the program, a download link, and an up-to-date list of results. The group has also analyzed data acquired during almost two decades of Jupiter observations containing more than five months of continuous video recordings. Scrutinizing this long span of data allows more accurate estimates of the frequency of impacts, though considerable uncertainties remain because it's difficult to make a statistical analysis of events that have been observed only a few times.

Analysis of the light curves of the five flashes recorded between 2010 and 2017 indicates they were produced by impactors measuring less than 20 meters in diameter (assuming a modest density typical of cometary material). The energy released by these events is comparable to the February 13, 2013 "superbolide" airburst over the Russian city of Chelyabinsk, which was 30 times more powerful than the atomic bomb dropped on Hiroshima.

A recent estimate by Spanish astronomer Agustin Sánchez-Lavega of the impact rate of objects in this size span striking Jupiter ranges from 10 to 65 per year. He notes that only a fraction of these can be observed from Earth for several reasons:

Impact sites are evenly distributed over Jupiter's visible day and averted night hemispheres.

There's only an eight-month observing window each year when Jupiter is readily visible.

Most observations tend to cluster around the date of opposition.

The visibility of impacts at high latitudes on Jupiter's oblate globe is poor.

Impactors larger than about 300 meters, like the one that produced Wesley's 2009 scar, yield dark debris fields observable with amateur instruments that persist for weeks. According to Sánchez-Lavega, these events probably occur once every 3 to 16 years and should be observed about once every 7 years.

Jupiter has long been known as "the amateur's planet" due to its rich legacy of discoveries by backyard astronomers (*S&T:* Nov. 2021, p. 52). Professional astronomers find it easier to collaborate with this worldwide amateur network than to persuade the committees that allocate telescope time to allow a round-the-clock, long-term vigil for sporadic events.

A growing band of dedicated amateurs continues to provide monitoring of Jupiter during each apparition. Thanks to *DeTeCt* software, imagers can analyze video recordings of the planet long after the end of the annual Jupiter observing season. So make time to scan your unprocessed planetary videos — you may have an unnoticed impact event in your possession awaiting discovery. The opportunity to collect valuable data and make real contributions to planetary science has never been greater.

■ Contributing Editor **TOM DOBBINS** has yet to witness an object hit Jupiter himself, but he enjoys vicarious views provided through the internet.

2009 IMPACT: NASA / IRTF / JPL-CALTECH / UNIVERSITY OF OXFORD

A Milky Way Chariot Ride

Have a cool time touring the Leaping Minnow region of southern Auriga.

Winter can be tough on astronomers. Across much of the northern United States and Canada, the "Orion months" tend to be pretty darn cold. My situation in southwestern British Columbia, a few snowdrifts north of the 49th parallel, is typical — the night sky above my frosted suburban home is compromised by light pollution *and* chimney smoke.

Fortunately, even modest telescopes can pull in a variety of celestial treasures throughout the winter. I'm especially attracted to the cluster-filled portion of the Milky Way that spills through Auriga, the Charioteer. Join me as I take my 4¼- and 8-inch Newtonian reflectors for a short journey into the Auriga Milky Way.

Fishing for Minnows

The constellation's pentagon-shaped pattern is outlined by a half-dozen 2nd- and 3rd-magnitude stars, plus zero-

▲ **WINTER'S CHARIOTEER** The pentagon-shaped constellation of Auriga, the Charioteer, sits astride the winter Milky Way. Dominated by zero-magnitude Capella, Auriga is easy to locate high in the east on January evenings.

ALAN DYER

magnitude Capella. On the moonless evenings of early January, 2022, the big, bold Charioteer is well placed halfway up the eastern sky. Let's get in there.

Our tour begins at the pentagon's southern end, where an optical finderscope or binoculars will reveal a 1.6°-long asterism of 5th- and 6th-magnitude stars dubbed the Leaping Minnow. The slender Minnow swims in a northeasterly direction — a parallelogram of four stars at the top forms the Minnow's head, while two loners — one at the center, another at the bottom are its body and tail. The sextet dominates a large, coarse clump of three-dozen suns called **Melotte 31**, or Mel 31, for short.

My 4¼-inch reflector operating at 20× captures Mel the Minnow with room to spare. I love aiming the scope at the Minnow's tail, marked by 5th-magnitude 14 Aurigae, a lovely double star also known as **Struve (Σ) 653**. Upping to 72× snares a 7.3-magnitude blue-white companion 14″ southwest of the 5.0-magnitude yellow primary. Last winter, I turned to my 8-inch reflector and discovered that Σ653 is a *triple* treasure — 100× picked up a 10.9-magnitude tertiary star a scant 10″ north of the gleaming primary.

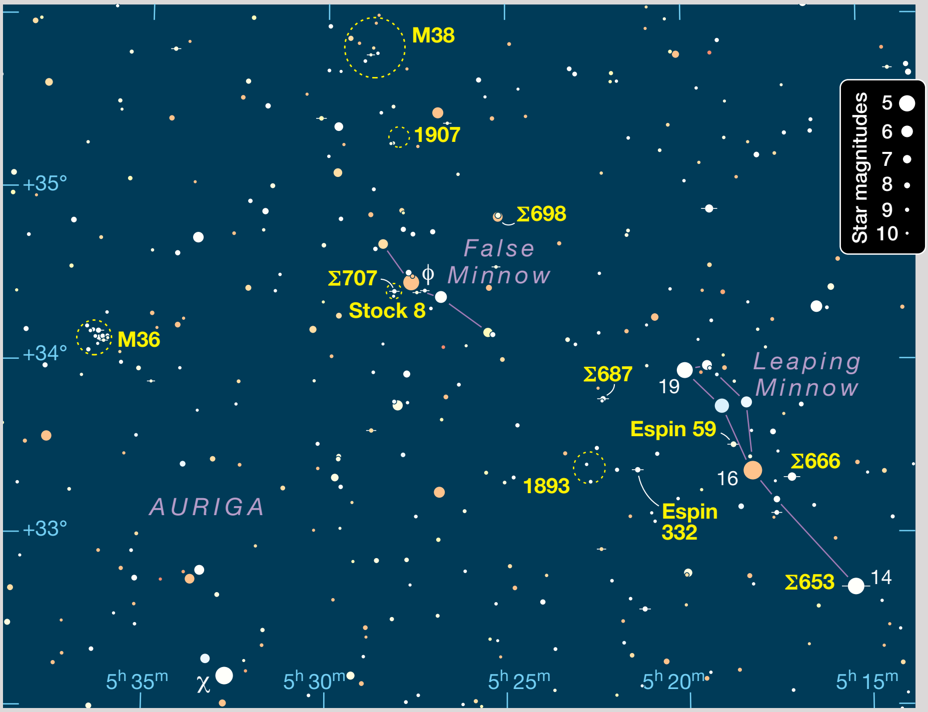
The brightest star in the Minnow, 4.5-magnitude 16 Aurigae, is a kind of guidepost. Slightly more than 11′ northeast of this orangey beacon is a double named **Espin 59**, whose 8.5- and 9.6-magnitude components are separated by 14″. Less than 14′ west-southwest of 16 Aurigae is a much tougher tandem. **Σ666** features 7.9-magnitude twins 3.2″ apart. In the 4¼-inch at 93×, the sibling suns appear as two dots almost in contact, while in the 8-inch at essentially the same power they're a nicely spaced set of headlights.

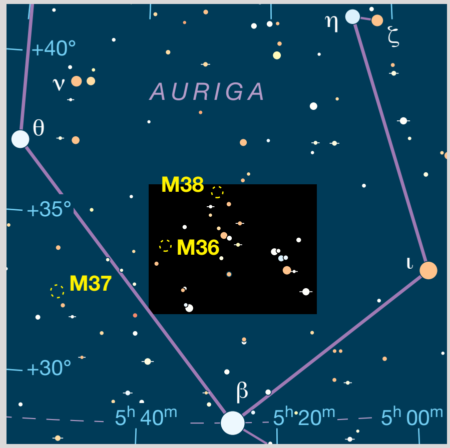
Finally, I always cast my gaze 40′ east of orangey 16 Aurigae to locate **Espin 332**. Consisting of 8.9- and 9.6-magnitude components nearly 15″ apart, Espin 332 is just another garden-variety double — indeed, a virtual copy of Espin 59. But I consider the easterly Espin helpful because it's the easy-to-spot doublet centering a bent row of three 9th-magnitude stars that lead right into our next target.

Subtle Pleasures

The target in question is **NGC 1893**, an ill-defined cluster half-submerged in the Milky Way. The scattered members of this 10′-wide group are faint — I can detect only the central half of NGC 1893 from my suburban observing site. Conveniently, a triangle of 9th-magnitude stars, roughly 13′ wide, neatly frames the visible loot.

In my 4¼-inch at 20×, NGC 1893 is a teasingly granular haze surrounding a 9.8-magnitude lucida. The 72× view suggests a loose crowd of very weak stars inside the triangle. My larger scope produces 20 participants, some in teeny pairs. Revved up to 135×, the





◀▼ **MEET THE MINNOWS** In the constellation Auriga, a large, loose "cluster" (its categorization is uncertain) called Melotte 31 is dominated by an asterism of a half-dozen 5th- and 6th-magnitude stars dubbed the Leaping Minnow by *S&T* Senior Editor Alan MacRobert. The region is also home to several notable open clusters, including M36, 37, and 38. All three can be viewed with binoculars.

8-inch snares a dim duo identified in the Washington Double Star Catalog as **FYM 376**. The 10.3- and 11.3-magnitude stars, 14″ apart, lie northwest of the lucida. There's also an unlisted tighter set southeast of the lucida.

North-northwest of NGC 1893, three 9th- and 10th-magnitude stars form a tiny isosceles triangle. A line extended from 18 through 19 Aurigae in the Leaping Minnow grazes the trio. Measuring 17″ by 48″, the wee wedge is listed as **Σ687**, a triple system. In the 4¼-inch at 20×, STF 687 is a blur easily missed. However, 72× creates an eye-catching geometric figure — the vertex of which points directly at NGC 1893.

The Leaping Minnow leaps toward the False Minnow, 2° northeastward. Our fraudulent fish is established by a handful of stars, led by 5.1-magnitude Phi (φ) Aurigae. Like 16 Aurigae in the Leaping Minnow, orangey Phi is a handy guidepost. For example, a 40′ hop northwest of Phi lands on the colorful double **Σ698**, which boasts a yellowy 6.7-magnitude primary and a blue-white 8.3-magnitude secondary about 31″ apart. Simply put, Σ698 is a beauty.

A few arcminutes east of Phi is an oblong open cluster called **Stock 8**. Although officially 15′ in extent, in my

RON BRECHER

▲ **MINNOW TERRITORY** The Auriga Milky Way is resplendent with glittering star clusters and delicate emission nebulae. (Use the chart above to identify the targets displayed in this photo.) Surrounding the coarse open cluster NGC 1893 is a faint but enticing cloud of hydrogen called IC 410. Although wonderfully photogenic, the nebula isn't visible in the author's backyard telescopes.

8-inch the cluster is a mere sprinkle of stars, 6′ long. Ah, but the leader is a triple star! At 94× the 9.4-magnitude primary and 10.8-magnitude secondary of **Σ707** are 18″ apart and obvious. The 11.5-magnitude tertiary (part of a pair designated **BU 889**, which shares the 9.4-magnitude star) emerges at 135×, turning Σ707 into a delicate triangle.

Beyond the Minnows

Three Messier clusters add glitter to the Auriga Milky Way. Starting at Phi in the False Minnow, a 1.5° arc of 7th-magnitude stars trends northward toward **M38**. In my smaller Newtonian at 20×, M38 is an easy if unspectacular catch. The 15′-wide agglomeration contains 160 members, but they're mostly below 10th magnitude. That said, a moderate increase in power morphs M38 into a ragged letter X. My 8-inch working at 94× brings out many additional suns without diminishing the "X-factor." An 8.4-magnitude star hugs the cluster's northeastern edge. Xcellent stuff — and there are still two Messiers to go!

Hold on. A tiny cluster sits ½° south of M38. Barely 5′ in diameter, **NGC 1907** hides more than 100 faint stars — none brighter than mag 11. In the 4¼-inch at 20×, M38's shy neighbor is a compact, grainy glow somewhat overpowered by two 9.8-magnitude field stars (separated by 52″) that guard the cluster on its southern periphery. Higher magnification intensifies the glow and supplies partial resolution of the "grain." In my 8-inch at 94×, NGC 1907 becomes a tiny hive of stars.

Let's shift a couple of degrees southeast to **M36**. About 10′ across, M36 lays claim to 60 stars, none better than magnitude 9. Even so, this little guy makes a brighter splash than M38. In my smaller reflector, the cluster is thin and relatively unconcentrated. Happily, though, M36 offers an embedded binary. **Σ737** sports 9.1- and 9.4-magnitude stars 11″ apart. The petite pairing is fuzzy at 20× but unmistakable at 72×.

My favorite cluster in the area, though, is **M37**. Lying just outside the Auriga pentagon, it packs a population of approximately 1,800 stars, all but one dimmer than magnitude 10. In the 4¼-inch at 20×, I get a powdery mass, 15′ wide, enveloping a reddish, 9.2-magnitude lucida. M37 magnifies well — 72× resolves the powder into pinpoints, provided I cup my hands around the eyepiece to protect my dark-adapted eye from stray light. When I take the same precaution with the 8-inch at 94×, I perceive M37 as an intricate starry maze cut by narrow lanes. Sublime!

■ Contributing Editor **KEN HEWITT-WHITE** loves everything about winter except the clouds, wind, snow, and subzero temperatures.

▲ **TWO FOR THE PRICE OF ONE** Open cluster M38, in Auriga, greatly outshines its celestial neighbor, NGC 1907. In truth, the clusters only *seem* like neighbors. M38 is 3,750 light-years from Earth, while NGC 1907 is 4,336 light-years away.

RON BRECHER

Charioteer Treasures

Object	Type	Mag(v)	Size/Sep	RA	Dec.
Mel 31	Open cluster	—	—	$5^h\ 19.6^m$	+33° 36′
Σ653AC	Double star	5.0, 7.3	14.3″	$5^h\ 15.4^m$	+32° 41′
Σ653AB	Double star	5.0, 10.9	9.8″	$5^h\ 15.4^m$	+32° 41′
Espin 59	Double star	8.5, 9.6	13.8″	$5^h\ 18.7^m$	+33° 31′
Σ666	Double star	7.9, 7.9	3.2″	$5^h\ 17.1^m$	+33° 20′
Espin 332	Double star	8.9, 9.6	14.7″	$5^h\ 21.4^m$	+33° 23′
NGC 1893	Open cluster	7.5	10.0′	$5^h\ 22.7^m$	+33° 25′
FYM 376	Double star	10.3, 11.3	13.9″	$5^h\ 22.7^m$	+33° 26′
Σ687AB	Double star	8.7, 9.8	17.3″	$5^h\ 22.3^m$	+33° 48′
Σ687A,CD	Double star	8.7, 10.2	48.2″	$5^h\ 22.3^m$	+33° 48′
Σ698	Double star	6.7, 8.3	31.4″	$5^h\ 25.2^m$	+34° 51′
Stock 8	Open cluster	—	15′	$5^h\ 28.1^m$	+34° 26′
Σ707AC	Double star	9.4, 10.8	18.3″	$5^h\ 25.2^m$	+34° 51′
BU 889AF	Double star	9.4, 11.5	27.8″	$5^h\ 28.1^m$	+34° 25′
M38	Open cluster	6.4	15.0′	$5^h\ 28.7^m$	+35° 51′
NGC 1907	Open cluster	8.2	5.0′	$5^h\ 28.1^m$	+35° 20′
M36	Open cluster	6.0	10.0′	$5^h\ 36.3^m$	+34° 08′
Σ737AB	Double star	9.1, 9.4	11.0″	$5^h\ 36.4^m$	+34° 08′
M37	Open cluster	5.6	15.0′	$5^h\ 52.3^m$	+32° 33′

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

Nosing Around NEOs

Your asteroid observations may provide space missions with valuable data.

Near-Earth asteroids might conjure images of our annihilation. But they're so much more than menacing bits of rubble — they're brimming with information on the early solar system. Spacecraft have rendezvoused, orbited, and touched down on them, and even brought samples back to Earth for scientists to poke and prod. Interest in these rugged, rocky relics remains high, and several science missions are either under way or in the making. But mission designers need your help.

Target NEOs! Near-Earth Objects (NEOs) include asteroids such as 101955 Bennu, the quarry of the OSIRIS-REX mission that launched in 2016 (*S&T:* May 2020, p. 14). The spacecraft "tagged" the asteroid in October 2020, snatching some regolith to bring back to Earth in September 2023. In support of the mission, Dolores Hill and Carl Hergenrother (both University of Arizona) tapped into the amateur community for observations of possible parent asteroids to Bennu — 142 Polana and 495 Eulalia. Hill and Hergenrother wanted to expand on these initial successes and teamed up with the Astronomical League (AL). And thus, Target NEOs! took off.

▶ **HELP TAG AN ASTEROID** The OSIRIS-REX spacecraft descends towards Bennu's surface in this artist's rendering.

Why amateurs? Observing time on large telescopes (think Keck) is limited, which makes it especially challenging to secure sky time for projects that rely on regular, frequent sightings of large numbers of targets. Most professional astronomers only get a few nights — or hours — per year. And that's just not enough for in-depth NEO research. "For some studies, long-baseline observations are vital," says Hill. Amateur astronomers can fill in the gaps, since they can observe anytime, anywhere.

Two other NASA missions are expected to benefit from amateurs' input: Psyche, scheduled to arrive at the giant metal asteroid 16 Psyche in 2026, and the Double Asteroid Redirection Test (DART), which will slam into the "moonlet" of 65803 Didymos. Data from ground-based observations — via *photometry* and *astrometry* — will better characterize these two targets. And both techniques are doable with small scopes. Photometry provides estimates of an asteroid's rotation rate, shape, and color, while astrometry enables the crucial calculation of the target's orbit and thus a prediction of its future path.

Gear up. Psyche and Didymos aren't the only objects in Target NEOs!'s crosshairs; several more await. And many are bright enough for backyard scopes, but you'll still need at least an 8-inch (the bigger the better). Imaging requires an astronomical camera, ideally one with a monochrome sensor equipped with photometric or color filters. A DSLR camera works, too, for the brighter targets (magnitude 14–16). You should also arm yourself with a broadband filter, but if you're using a DSLR, its "green channel" is akin to the V-band, so you won't need a filter. Data reduction software is a must for both photometry and astrometry (several free packages are available online).

To register for the project, send an email to the coordinators: **meteorite@cox.net** or **carlhergenrother@gmail.com** (this step verifies serious inquiries and identifies observers' locations). You'll receive a "welcome to the program" email that includes the list of targets, and you'll be added to the project's mailing list.

Once you've acquired your data, submit your images and a Minor Planet Center–type report to the coordinators (**https://is.gd/TargetNEO** has instructions). You don't need to be affiliated with the AL to participate. And although the coordinators don't require an MPC code for observers, they highly encourage it.

Hill, Hergenrother, and other NEO enthusiasts eagerly await your observations. "More data are always better, of course," Hill says. "It turns out that some of our most prolific observers have been those with smaller telescopes who just get out there and give it a try."

NASA / GODDARD / UNIVERSITY OF ARIZONA

■ Observing Editor **DIANA HANNIKAINEN** would love to hitch a ride to an asteroid.

The First Deep-Sky Atlas

Can a classic star atlas still work for modern observers?

From earliest times astronomers were aware that among the fixed stars there were a few, equally fixed but un-star-like objects which appeared to them as 'misty patches' or 'little clouds'. These were the nebulae and their unique appearance and comparative rarity exercised the imagination of all who enquired into the nature of the universe.

Kenneth Glyn Jones, *The Search for the Nebulae* (1975)

We 21st-century amateur astronomers are fortunate to have wonderfully detailed and accurate printed and computer-generated star charts to aid us in our explorations of the heavens. When I started observing in 1984, I was thrilled with Wil Tirion's *Sky Atlas 2000.0*, published in 1981. Although I didn't know it at the time, Tirion's atlas was modeled on Antonín Bečvář's *Atlas of the Heavens: Atlas Coeli 1950.0* (the 1958 edition). Before this, *Norton's Star Atlas*, first published in 1910, was a favorite of many amateurs.

Most beginners start by hunting for the Messier objects and then graduate to more challenging deep-sky wonders. Accurate and detailed charts make star-hopping much easier, and there's even the option of computerized Go To telescopes complete with extensive self-contained databases. Experienced observers can log *thousands* of deep-sky targets in the course of a lifetime. But it wasn't always this way.

Starting with the invention of the telescope in the early 17th century, astronomers scanned the night sky with little guidance, slowly discovering "nebulae" (misty objects of all kinds) and logging each new find. These discoveries were shared as lists of objects that usually included coordinates and descriptions for each one. Charting these nebulae in star atlases progressed rather slowly over several centuries.

So, imagine yourself a novice amateur astronomer transported back in time, seeking a star atlas to aid you in your

▶ **CLASSIC COMBINATION** Johann Elert Bode's *Uranographia* from 1801 beautifully combined artistry and astronomy. The work includes more than 2,000 deep-sky objects, several of which are easy to spot on this chart covering Orion and Taurus. Today's amateur astronomers could easily use this atlas to star-hop to deep-sky wonders.

DETLEV VAN RAVENSWAAY / SCIENCE SOURCE


Auriga
Lac tea
Perseus
Caput Me dusae
TAURUS
Eclipitica
ORION
HARPA GEORGII
Aequator
Eridanus
Sceptrum
Brandenburgi cum

search for deep-sky treasures. When did a suitable set of charts first appear? We can't know to what extent astronomers of the 17th to 19th centuries relied on star atlases in their quest to explore the heavens, but we can certainly determine if any of those available would be helpful to today's amateurs.

◀ **THE BEAST OF SLOUGH** British astronomer William Herschel discovered more than 2,000 deep-sky objects using several telescopes, the largest of which was this monster with a 48-inch (122-cm) aperture and "forty-foot" focal length erected in Slough, England. It ceased operation in 1815.

Bode and *Uranographia*

One obvious candidate is the wonderful *Uranographia*, which was produced by the German astronomer Johann Elert Bode. Published in 1801, *Uranographia* represents the high point of celestial cartography's marriage of art and science, which soon thereafter parted ways. Later works that featured artistic depictions of the constellations never matched the astronomical accuracy of Bode's masterpiece — those atlases that focused on the science of the heavens generally abandoned fanciful constellation figures altogether.

Uranographia contained very large charts (31 by 23 inches, or 79 by 58 cm) and used special symbols and Roman numerals to plot deep-sky objects and indicate their appearance. Bode included more than 2,000 nebulae and hundreds of double stars based on the observations of British astronomer William Herschel, who surveyed the heavens in the late 18th century from England with reflector telescopes of 6, 12, 18.7, and (ultimately) 48 inches in aperture.

Herschel categorized deep-sky objects as follows:

I Bright nebulae
II Faint nebulae
III Very faint nebulae
IV Planetary nebulae
V Very large nebulae
VI Very compressed and rich clusters of stars
VII Compressed clusters of faint and bright stars
VIII Coarsely scattered clusters of stars

▲ **EARLY NEBULAE** Johannes Hevelius's 1687 atlas was the first to show the open cluster M7 (indicated) in the correct location. The cluster was misplotted by Gallucci in 1588, and it appears that Bayer (1603) and Schiller (1627) may have simply perpetuated Gallucci's error.

Bode's charts were the first to incorporate these designations, and they persisted in modern works, including many editions of *Norton's Star Atlas*.

Modern-day amateurs clearly could use *Uranographia*, even though the giant atlas might be somewhat unwieldy, to locate double stars and deep-sky objects. But was it the first such work? Bode himself created a smaller version in 1782, and other celestial cartographers produced earlier efforts. Could one of these take the prize instead? To answer this, it's helpful to decide what a deep-sky atlas *should* be.

Here are the features that I consider most important: First, the charts should be reasonably detailed — every observer knows the frustration of trying to find targets when there aren't enough stars presented, or the chart scale is too small. Second, the atlas should include dozens of deep-sky objects, represented with symbols that make them easy to distinguish from stars. Third, the atlas should be as error-free as possible, with a minimum number of "false nebulae" to mislead users. Fourth, each chart should cover a small enough area of sky to avoid severe projection distortion at the edges. And finally, the charts should use an equatorial coordinate system and not some other, less useful scheme.

Discovering the Deep Sky

Of course, for an atlas to feature deep-sky objects, those objects first have to be discovered and cataloged. Lists of nebulae were usually compiled by adding new discoveries to previously known ones. Progress was slow. Only 19 such objects were widely known prior to 1700, and by 1750 that total had increased to just 35. In 1755, French astronomer Nicolas-Louis de Lacaille tabulated 42 objects that included 24 new finds. Working from the Cape of Good Hope in South Africa, Lacaille made discoveries that were out of reach for European observers. In 1771, French comet hunter Charles Messier presented the first installment of his now-famous catalog, which included 45 entries — many of which he discovered.

Bode himself produced a list of 75 objects in 1777, but he only discovered 5 of these and, according to Kenneth Glyn Jones in his book *The Search for the Nebulae* (1975), Bode's selection "contains far too many errors and misprints and one of the worst features is that the list is greatly inflated by numerous asterisms and 'non-objects.'"

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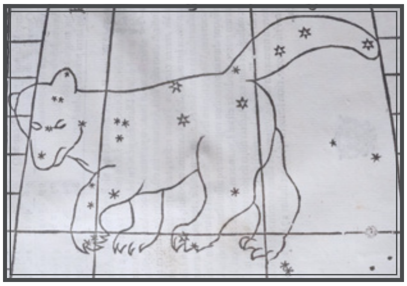
Fortunately, Messier was busy updating his catalog, and in 1780 he extended his original list from 45 objects to 68. Four years later, he published his final tally of 103 entries in the 1784 edition of the French almanac *Connaissance des Temps*. Since Messier himself verified every object on his list, he mostly avoided including false nebulae.



◀ **BIG BEAR** Giovanni Paolo Gallucci's atlas of 1588 was based on Ptolemy's 2nd-century *Almagest*. Gallucci included all seven of Ptolemy's "nebulae," including one below the tail of Ursa Major. The object is now charted as Coma Berenices — a constellation in its own right.

Early Star Atlases

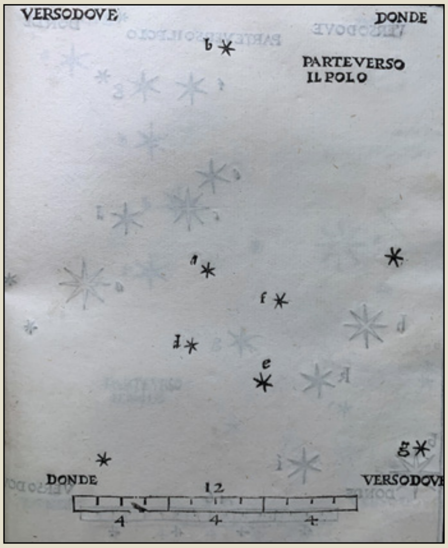
How did star atlases of the 16th, 17th, and 18th centuries generally deal with deep-sky objects? Mostly in ways that wouldn't meet the needs of today's deep-sky observers. Here's a brief survey of pre-telescopic atlases:

De le stelle fisse by Alessandro Piccolomini (1540). This was the first star atlas ever printed and contains 47 small woodcut charts (6.5 by 5.5 inches) depicting Ptolemy's constellations (as described in the *Almagest*, which hails back to the 2nd century), but it doesn't display any deep-sky objects, it only shows stars to 4th magnitude, and it lacks a coordinate system. *De le stelle fisse* portrays the sky from a "normal" perspective, that is, as seen from Earth's surface.

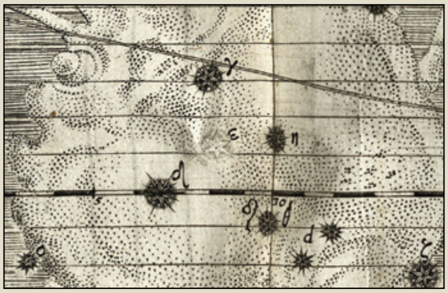
Theatrum Mundi by Giovanni Paolo Gallucci (1588). Consisting of 48 small woodcut charts (6.5 by 5 inches) showing Ptolemy's constellations, this atlas uses a coordinate grid system based on the ecliptic (defined by Earth's orbital plane), rather than the more familiar equatorial coordinate system used on modern charts. Gallucci plotted Ptolemy's seven

▼ **DEEP-SKY BEGINNINGS** Julius Schiller's celestial atlas, published in 1627, was the first to appear after the invention of the telescope. It depicts the Pleiades with 10 stars on the chart-left shoulder of Saint Andrew the Apostle (who replaced Taurus in this atlas) but included only a few other deep-sky objects. Note the chart's "mirror-reversed" perspective — as if the constellatons were viewed from outside the celestial sphere.

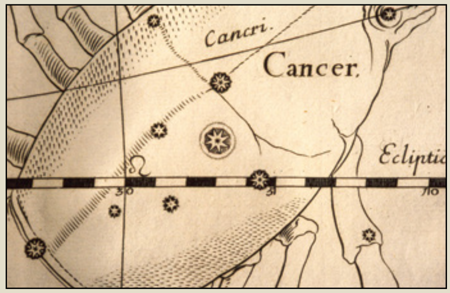
COLLECTION OF RAY HARRIS (2)



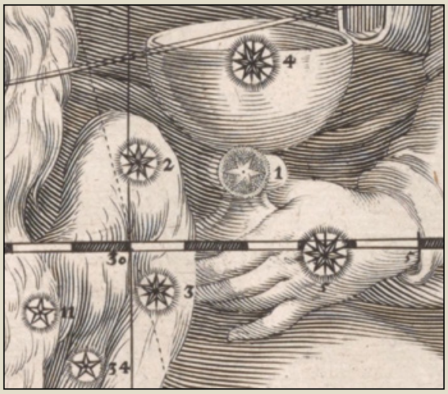
De le stelle fisse (1540)



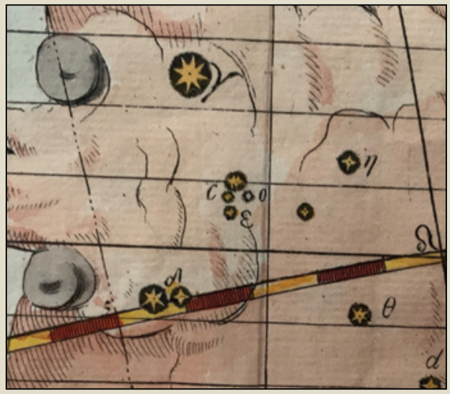
Uranometria (1603)



Firmamentum Sobiescianum (1687)



Coelum Stellatum Christianum (1627)



Atlas Coelestis (1729)

▲▶ **PRAESEPE COMPARED** These closeups of the constellation Cancer show how the Beehive Cluster (Praesepe, M44) was represented in various star atlases over time. Note that the cluster is absent in 1540, and that the 1627 and 1687 charts are mirror-reversed.

naked-eye "nebulae," of which only three were true deep-sky objects: M7, M44, and the Double Cluster. Gallucci's charts use an external perspective to mimic looking at a celestial globe from the outside. Such a representation gives a "mirror-reversed" view, which might appeal to observers using telescopes that match this orientation.

Uranometria by Johann Bayer (1603). This star atlas introduced copperplate charts, which show finer detail and don't degrade as rapidly in the printing process compared with woodcut blocks. Bayer utilized Tycho Brahe's meticulous observations to position the stars more accurately than any previous atlas and introduced the use of Greek letter designations for the brightest stars. *Uranometria*'s 48 constellation charts (15 by 11 inches) have a very sparse coordinate system based on the ecliptic. In addition to M7, M44, M45 (the Pleiades, shown as six stars), the Double Cluster, and a few false nebulae, Bayer's atlas was also the first to include the Magellanic Clouds on a chart depicting the south polar regions, based on observations by Dutch navigators Pieter Dirkszoon Keyser and Frederick de Houtman. *Uranometria* employs a normal (Earth-based) view of the night sky.

Several more atlases appeared in the 17th and 18th centuries, following the invention of the telescope:

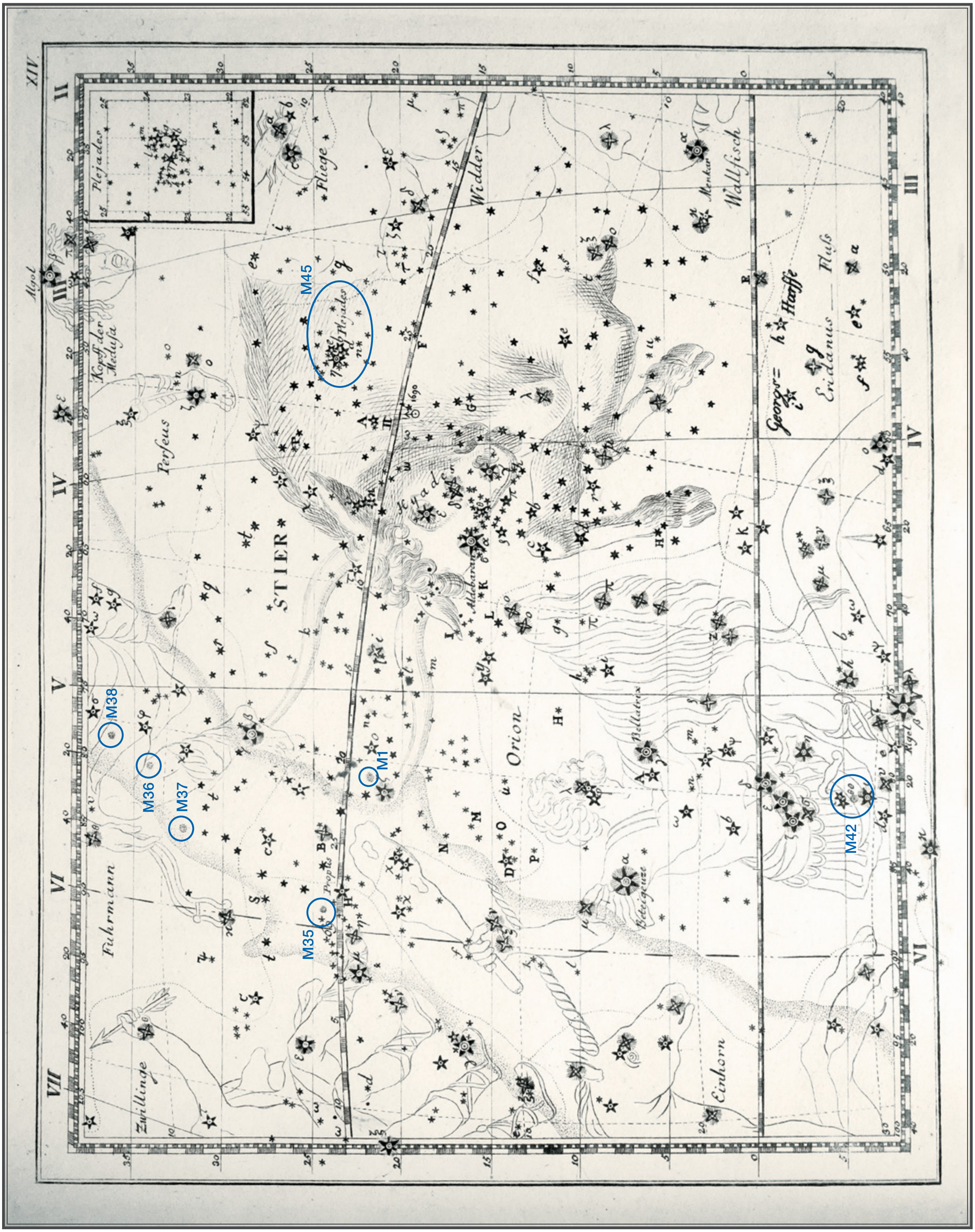
Coelum Stellatum Christianum by Julius Schiller (1627). As described by Michael Mendillo in the January 2021 issue of *Sky & Telescope* (page 64), Schiller replaced the pagan constellations with Christian figures. The atlas's 48 constellation charts (12 by 9.5 inches) have a sparse coordinate system, again based on the ecliptic. Schiller displayed a few deep-sky objects, including M7, M31, M44, the Double Cluster, M45 (the Pleiades, this time shown with 10 stars!), the Magellanic Clouds, as well as a number of false nebulae. These charts use an external view.

Firmamentum Sobiescianum by Johannes Hevelius (1687). For the first time, detailed maps of the southern sky appear. These are based on Edmund Halley's 1676–77 observations from the island of Saint Helena in the South Atlantic. Their addition brought the total number of constellation charts (14 by 11 inches) to 54. To M7, M31, M44, the Double Cluster, the Pleiades, the Magellanic Clouds, and a few false nebulae, Hevelius added two new southern deep-sky gems discovered by Halley: Omega Centauri and NGC 6231 in the tail of Scorpius. Hevelius didn't trust telescopes for star positions and relied on his own naked-eye observations for those stars observable from his home in Poland. He introduced 10 new constellations of his own design, seven of which have survived to modern times: Canes Venatici, Lacerta, Leo Minor, Lynx, Scutum, Sextans, and Vulpecula. *Firmamentum Sobiescianum* used an external view and a sparse coordinate system based on the ecliptic.

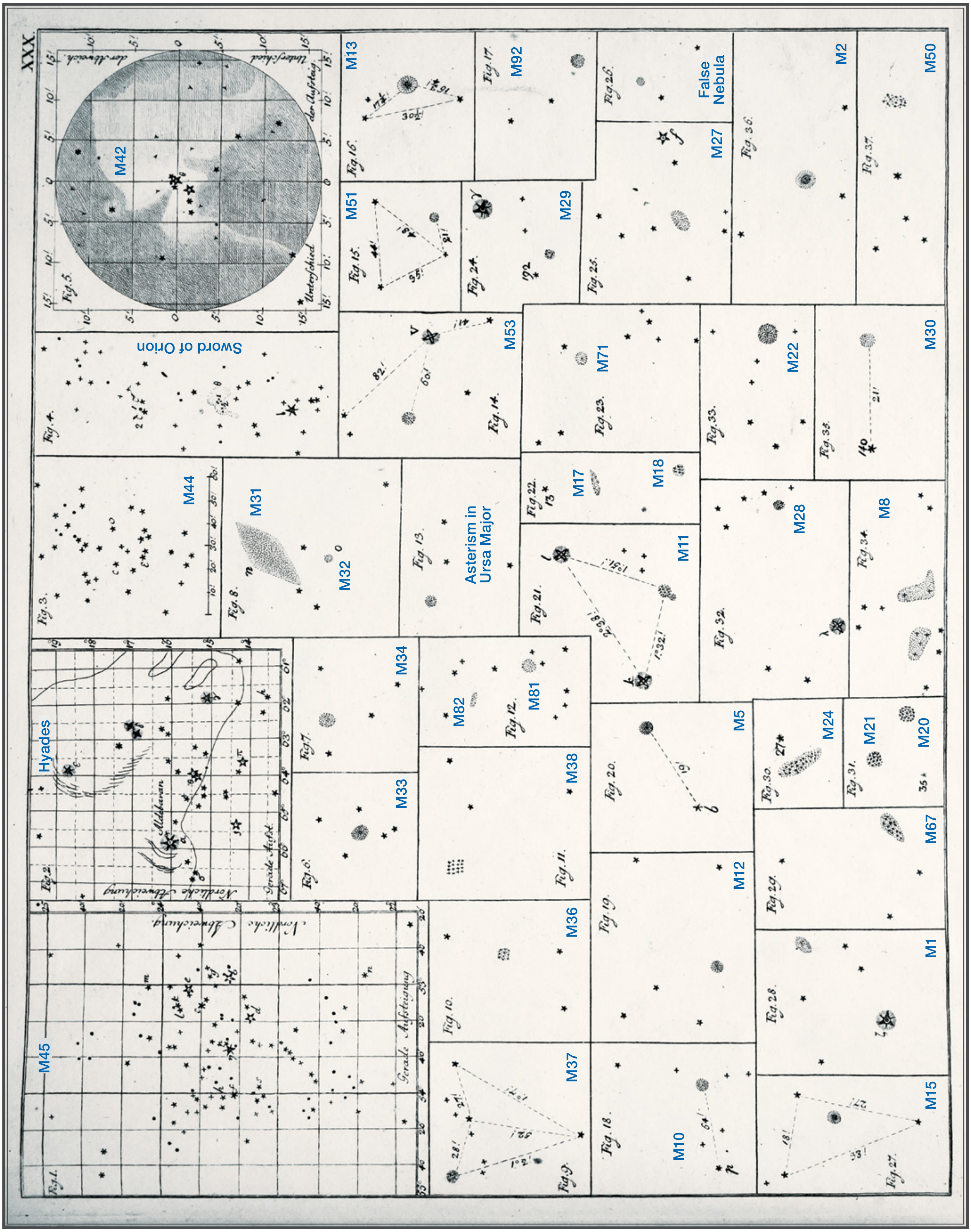
Atlas Coelestis by John Flamsteed (1729), the first Astronomer Royal. Flamsteed's opus represents a huge

▶ **TRY THIS AT HOME** See if you can use this chart from Bode's *Vorstellung Der Gestirne* to locate the deep-sky objects depicted. Note that M45 is shown as a cluster of stars on the main chart and also at a larger scale in the upper right corner. Bode's charts are plotted for epoch 1780. Due to precession, equatorial coordinates have changed a fair bit since then. (Object labels added by the author.)

COLLECTION OF RAY HARRIS EXCEPT FOR 1603 CHART: COLLECTION OF JAY AND NAOMI PASACHOFF; BODE'S CHART: COLLECTION OF RAY HARRIS



M45
M38
M36
M37
M1
M35
M42
STIER
Orion
Perseus
Fuhrmann
Zwillinge
Einhorn
Widder
Wallfisch
Fliege
Plejades
Hyades
Aldebaran
Beteigeuze
Bellatrix
Rigel
Algol
Kopf der Medusa
Menkar
Propus
Eridanus
Fluss


XXX
M42
Sword of Orion
M44
M31
M32
Hyades
M45
M13
M92
False Nebula
M2
M50
M27
M51
M29
M53
M71
M22
M30
M17
M18
M28
M8
Asterism in Ursa Major
M11
M34
M82
M81
M5
M24
M21
M20
M33
M38
M67
M12
M36
M1
M37
M10
M15

advance in atlases. The charts are very large (25 by 20 inches) and have an excellent equatorial coordinate system overlaid with the ecliptic system. *Atlas Coelestis* has 25 star maps, each covering several constellations and overlapping with each other. Flamsteed's focus was on aiding navigation, and so he included many more stars (2,919) than previous works. However, since nebulae are superfluous to navigation, the only deep-sky objects he plots are M31, M44, and M45, which are depicted as stars. A further limitation is that Flamsteed only mapped what he could observe from Greenwich, England. His atlas uses a normal view.

Atlas Celeste de Flamsteed by J. Fortin (1776). As suggested by the title, Fortin copied Flamsteed's *Atlas Coelestis* closely but with the addition of 15 deep-sky objects: M7, M9, M10, M11, M12, M13, M15, M22, M27, M28, M31, M32, M42, M55, and NGC 6242, with M44 and M45 shown as groups of stars. Fortin provided a key with different symbols for nebulae based on their appearance. Unfortunately, he also included a fair number of false nebulae. The 26 charts of this atlas are much smaller (9 by 7 inches) than Flamsteed's original.

Bode's Atlas of 1782

As most readers will have already gleaned, none of the atlases mentioned in the previous section would prove very useful to those hoping to find more than a handful of deep-sky objects. However, Bode's 1782 atlas, *Vorstellung Der Gestirne*, marks a significant departure.

While the charts in *Vorstellung Der Gestirne* are very close copies of those in Fortin's atlas (but in German instead of French), Bode included 1,520 additional stars and 75 deep-sky objects, with only a handful of false nebulae. As in Fortin's atlas, Bode's work includes a key showing different symbols for the different types of nebulae.

In producing this atlas, it appears that Bode relied heavily on Messier's 1780 catalog and incorporated all 68 objects except for M40 (a pair of faint stars) and M43, which hardly requires a separate symbol due to its proximity to M42. The number of deep-sky objects plotted would seem to make *Vorstellung Der Gestirne* the first usable deep-sky atlas — but Bode went further by adding two special charts depicting nebulae and double stars in greater detail.

Chart XXX portrays deep-sky objects in 37 figures, and chart XXXI consists of 50 figures, mostly of double stars. Both extra charts are unique to Bode's atlas and are clearly designed to emphasize deep-sky observing. Bode also added pages of notes describing the objects depicted, but unfortunately he didn't provide coordinates, making it difficult to identify

◀ UP CLOSE Bode included 37 figures showing magnified views of deep-sky objects on chart XXX of his 1782 atlas. No coordinates were provided to identify these, but the author has labeled them based on Bode's written descriptions.

◀ CHART MASTER Johann Elert Bode (1747–1826) was not only a talented celestial cartographer but also a skilled observer credited with the discoveries of M53, M64, M81, M82, and M92. He also determined the orbit of the planet discovered by Herschel in 1781 and suggested Uranus as its name.

them. For example, his descriptions of the nebulae in Figures 9 and 10 on chart XXX are very similar. For Figure 9 Bode writes, "According to Messier, a nebulous star cluster in Auriga with a diameter of 9 minutes and very small stars. The position of the neighboring stars and their distance is recorded here per my observation." For Figure 10 he notes, "A star cluster in Auriga; according to Messier, it is also 9 minutes in diameter. One can hardly distinguish its stars through a small telescope. The stars around it are depicted according to Koehler's observation."

I was able to confirm the identity of each object on chart XXX only by comparing Bode's descriptions with those of Johann Gottfried Koehler (mentioned in the quote above) and Charles Messier. Messier's descriptions clarify that Bode's Figures 9 and 10 were in fact M37 and M36, respectively.

Only a few of the double stars on chart XXXI are labeled, and deciphering the descriptive text is even more problematic than it was for the nebulae. For example, for Figure 44 Bode wrote: "A small double star near the eighth and ninth brightest ones in Aquarius." I'm not a double-star buff, but I expect it wouldn't be easy for most observers to track down this pair.

And the Winner Is . . .

Following Bode's 1782 atlas, an updated edition of Fortin's atlas was published in 1795, and *Neuester Himmels-Atlas* by Christian Goldbach appeared in 1799, featuring white stars set against a black sky. Both works included many Messier objects; however, Bode was clearly the first to do so and certainly benefited from the timely release of Messier's second list of nebulae in 1780. Notwithstanding the difficulties deciphering *Vorstellung Der Gestirne*'s two bonus charts, Bode's emphasis on the deep sky makes his work stand out from the rest.

We can't know if astronomers of the late 18th century used this atlas to aid their own searches for nebulae, but today's amateurs could easily star-hop to most Messier objects with Bode's charts. *Vorstellung Der Gestirne* can justifiably be considered the first usable deep-sky atlas.

As good as Bode's star maps are, even a modestly equipped modern observer will quickly exhaust the atlas's supply of deep-sky targets. While we might lament the ever-worsening intrusion of light pollution in our 21st-century night skies, we can be thankful for the accuracy and detail of today's star atlases. Just imagine our hobby without them!

■ **RAY HARRIS** has been collecting and studying antique celestial charts and atlases since 1987, and has lectured widely on the art and science of early star atlases.

Star-Hop Maker

This program lets you generate custom star-hopping charts for use at the telescope.

Star-Hop Maker v1.1.0

Price: €21 (about US$25)
starhopmaker.com

What We Like

Unique program with many helpful features

Attractive and legible display

What We Don't Like

Program elements leave room for improvement

Cannot print maps

App only displays lists (not star-hop maps)

IF YOU WERE AN AMATEUR astronomer before the advent of computerized telescopes that point at celestial targets with the push of a few buttons, you've doubtlessly heard of star-hopping. If you haven't, it's a method of finding your way around the sky using stars as guideposts along a path to faint galaxies, nebulae, and star clusters. For example, "The cluster is halfway along a line between these two 5th-magnitude stars."

Star-hopping isn't just about finding objects. It also allows you to compose your own sky tours with efficient and easy-to-follow paths from object to object. That sort of star-hopping is as useful with a computerized telescope as it is with a manual one.

In days of yore, I spent long hours charting paths across the stars with a pencil and a printed star atlas. That isn't necessary anymore thanks to a program that creates star-hops for me — Paul Evangelopoulos' *Star-Hop Maker* for Windows PCs. The software is available as a download from the author's website and is offered in a 30-day trial version. A PDF document of instructions is also provided and is invaluable for learning the program, though it has plenty of room for improvement.

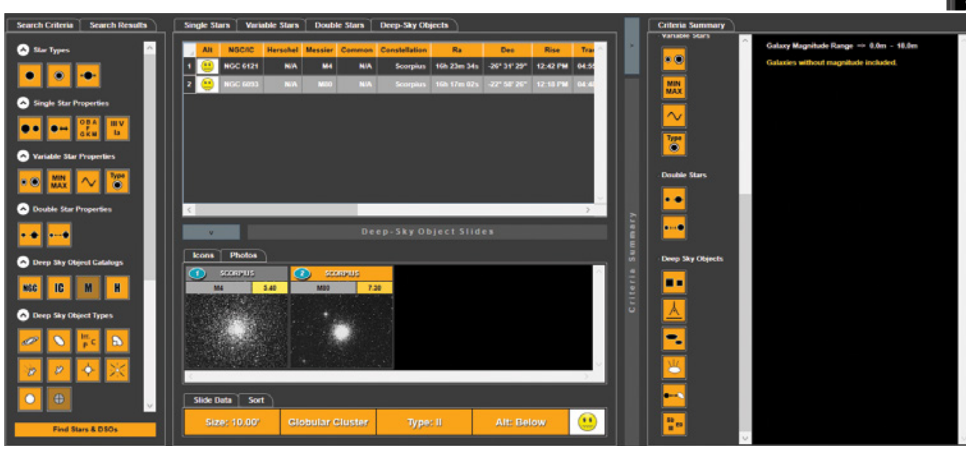
▲ Star-Hop Maker is a planetarium software program for PC computers that allows users to generate their own custom star-hop observing tours. Plan lists created in the program can be exported to an Android smart device for use at the telescope.

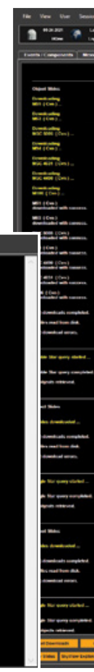
Getting Started

When opening the program for the first time, a busy screen appears containing a planetarium-style star chart and lots of controls along its periphery. A dropdown menu found along the top of the screen contains most of the program's controls. A toolbar with several icons is also located along the right of the display, and more commands are found along the left. In addition, there's a bar showing information about the observing site and sky just below the dropdown menu, and three small windows titled Star-Hop Gallery, Deep-Sky Object Filter, and Star-Hop Objects, respectively, along the bottom. That's a lot to take in for a new user.

After admiring the program's attractive, though complex, display, a good

▼▶ Creating a prepared star-hop involves searching the database for objects (below) and adding them to your star-hop in the Prepared Star-Hop Creator window (far right). Each object you add appears circled in the main star chart at right.





place to start is the Preferences menu found in the menu at the left of the screen. Clicking it opens a new window allowing you to customize some settings. First, scroll to the bottom and activate Tool Tips — the program's windows include numerous icons, many of which are difficult to identify without activating this important feature providing additional information when you hover your cursor over a button or other icon. It's curious that this feature isn't set to be on by default.

As with other planetarium-type software, it's important to set the geographic coordinates of your observing site. That's done by selecting User > Location in the dropdown menu and specifying your observing site by either entering latitude and longitude or zooming in and centering the map on your location. While this is explained in the instructions, it doesn't appear until the last page. While you're in the User section, you can also add your equipment you'll be observing with to better customize your maps.

Planning a Hopping Tour

Once you've input your information, it's time to compose a star-hop. *Star-Hop Maker* offers two types: "Prepared Star-Hops" and "Blind Star-Hops." I found the terminology confusing but came to understand a Prepared Star-Hop is one created by searching the program's database and selecting objects, while you create a Blind Star-Hop by choosing targets directly from the star chart.

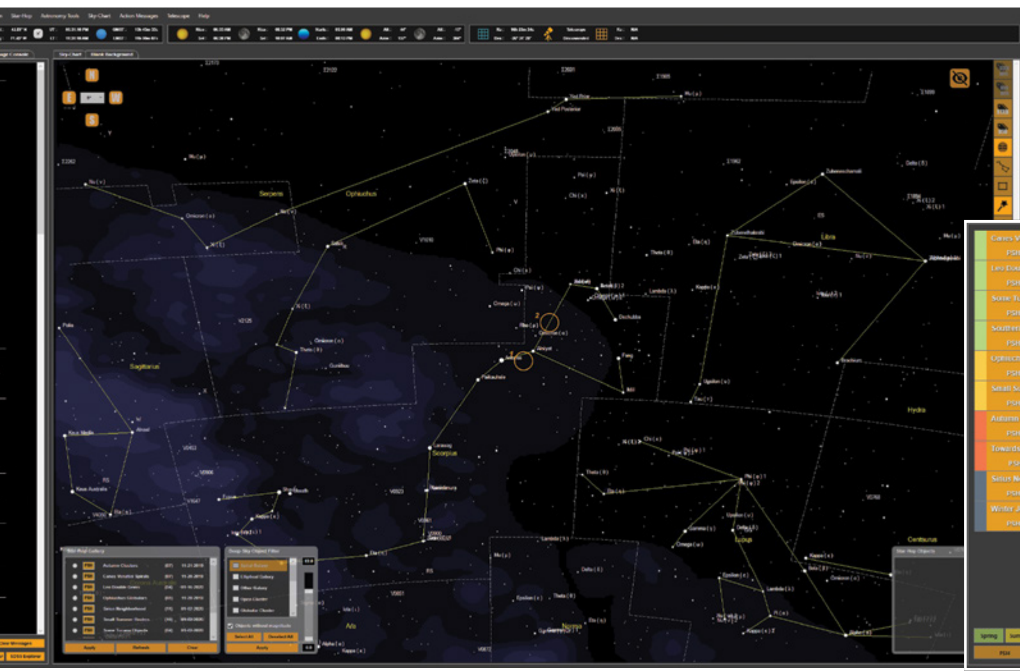
I began by making a Prepared Star-Hop. You access the *Star-Hop Maker*'s search engine by clicking Explore Database on the left command bar in the Events / Components tab. The Database Search window opens with the program's star and deep-sky catalogs. Users can add anything from the NGC and IC catalogs as well as the Messier and Herschel lists. In addition, it includes extensive double star and variable star listings. You can even make a tour of specific types of stars by spectral class, or double stars within a specified separation range.

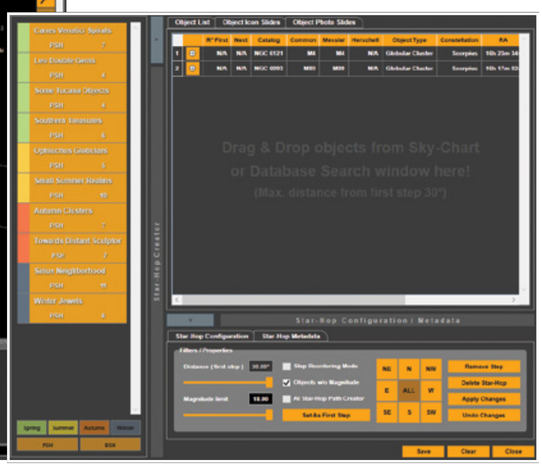
The Search Criteria section in the left tab of the Database Search window sets the object catalog, object type, constellation(s), and magnitude range to search. Clicking Find Stars & DSOs at the bottom of the tab returns a list of objects. As a test, I had the program search for Messier globular star clusters in Scorpius. On my computer, the search took about 15 seconds to find two clusters. Searches that produced a larger number of objects took about the same time, suggesting that my computer's processing speed was the limiting factor. In addition to the list, objects are displayed as either icons or images (if there is an Internet connection) at the bottom of the window.

With the list on-screen, select Star-Hop > Create Prepared Star-Hop in the main window's toolbar. This opens the Prepared Star-Hop window, where I dragged my two globular clusters from the search list into the Prepared Star-Hop window. The two objects then appear circled on the star chart. Since this is creating a star-hop tour, I need to assign a bright star as the starting point. This is done by highlighting an object in the prepared list, so I went back to the Database Search page and clicked the Single Stars button and searched the constellation for bright stars. I dragged my choice into the Prepared Star-Hop Creator window. The last step is to highlight the star listing and click the Set As First Step button. Finally, click Save. The sky map immediately circles the starting point and destinations, and adds a bold line connecting each stop in the same order I chose them.

A Blind Star-Hop dispenses with the database search engine. After choosing Create Blind Star-Hop from the command bar at left, select a star for the starting point from the list that appears in the window. To add objects, use the Neighbors function in the Update section of the window, and be sure to increase the vertical slider value to its right, which lists objects within 15° of the chosen starting point. You can add anything that appears in the listing at the right side of the window to the hop.

ALL IMAGES COURTESY OF THE AUTHOR





▶ You can display objects in your star-hop as icons, or, with an internet connection, download Digitized Sky Survey images of the chosen targets.

Even easier is to select objects on the main screen by pressing the ALT key and dragging a box around a target with your mouse. A small window then opens where you click Select All, and then you hold the Ctrl key and your left mouse button to drag the contents of the small selection into the Creator window.

When it's observing time, choose Star-Hop > Run Star-Hop in the drop-down menu to retrieve your tour. The Star-Hop Runner window opens where you search for your custom hops by season and constellation. The main screen then displays each of your tour's stops in a numbered circle with a bold line leading from object to object. Clicking a photo in the window centers that target on the chart (and sends a paired Go To telescope to it). You can also add more destinations to the star-hop from the main screen the same way you add targets in a blind star-hop. All that's left to do is to activate night mode in the Preferences menu and use the chart to hop from deep-sky wonder to deep-sky wonder out at the telescope. Upload your tour lists to your Android smartphone running the free app *Star-Hop Maker Companion* via Google Drive to access additional information and photos of your targets on your smart device.

Additional Features

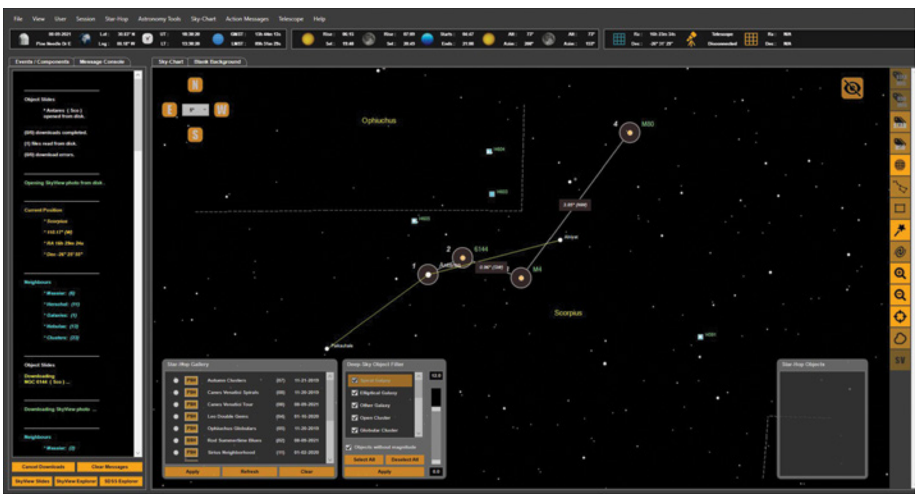
This is just a sampling of the many features *Star-Hop Maker* offers. It can apprise you of nightly events like when major objects rise and set and also includes a section to record your observations. Another interesting feature in the program is the Event Visualization tool found at Astronomy Tools > Event Visualization. This tool lets you visualize when your star-hop targets are best positioned for observing in the evening and is especially helpful when creating extensive tours.

In the course of learning to operate the software, I had to do a considerable amount of figuring out. In addition to telescope control, some other important things aren't discussed in the documentation. For example, minimizing the Runner window to get it out of the way of the star chart doesn't use typical Windows controls. It took a while before I noticed two small down arrows in the window that did the job.

There are a few program improvements and additions I'd like to see. Some type of visual feedback after a button is pressed would be helpful. When choosing Apply in a window, I wasn't always sure my selection had registered. And some of the names of commands and the windows they open are titled inconsistently. Finally, the program doesn't provide a method of printing the actual chart — File > Print Star-Hops only prints out the targets as a list, rather than the sky map tour you spent so much time creating. And while it includes a night mode, I'd still like to be able to print star-hops for use in the field without a computer.

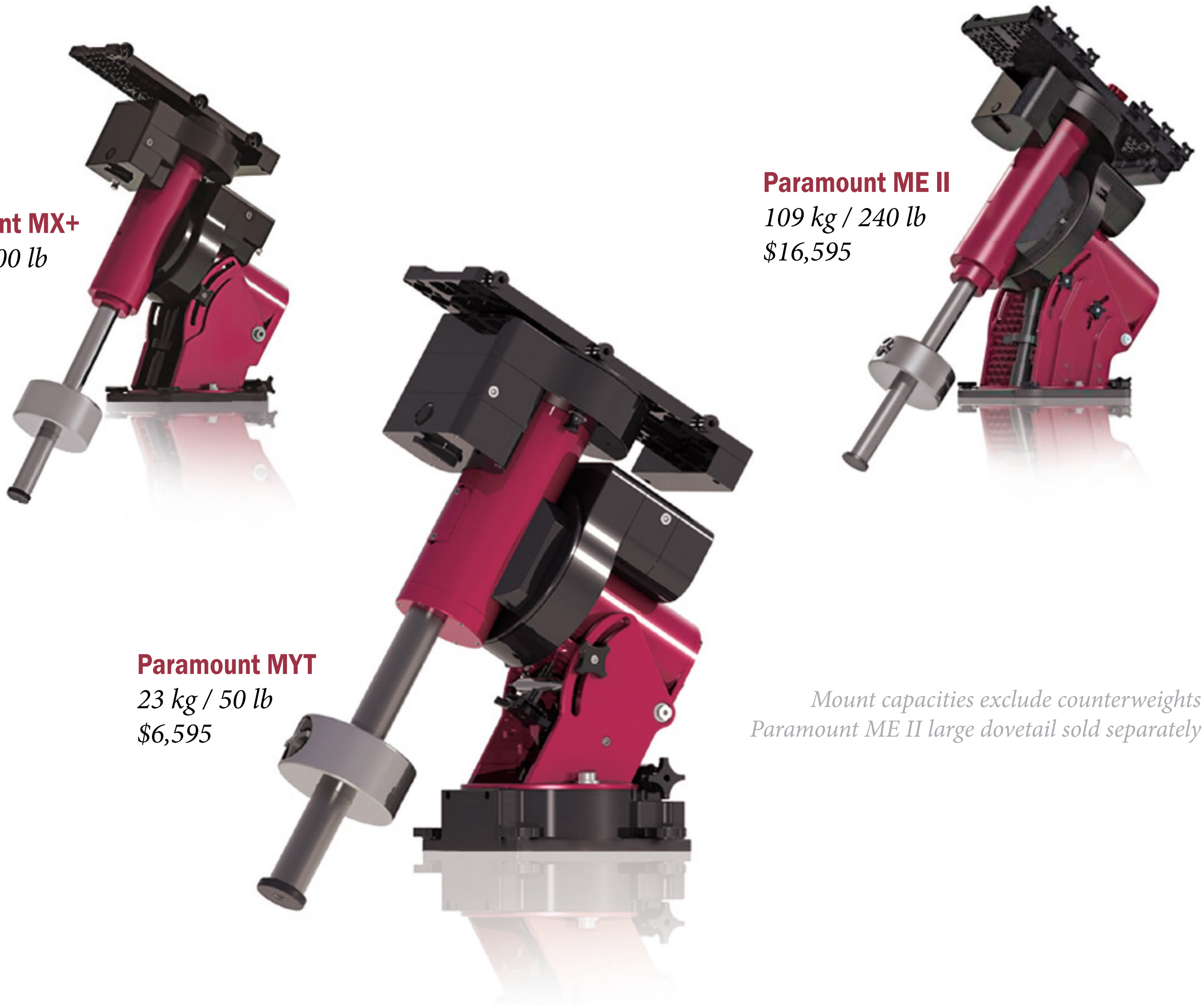
Despite these quibbles, *Star-Hop Maker* is quite impressive. Plotting star-hops is something that no other astronomy software has done before that I'm aware of. If this sounds interesting, begin planning an itinerary of your own with *Star-Hop Maker* and spend an evening touring the deep and starry sky.

■ Contributing Editor **ROD MOLLISE** still enjoys star-hopping from target to target in his backyard in Mobile, Alabama.



▲ Each stop on your star-hop appears circled and numbered on the main star chart, with a bold line connecting each step labeled with the precise distance between each field.

Omne Trium Perfectum



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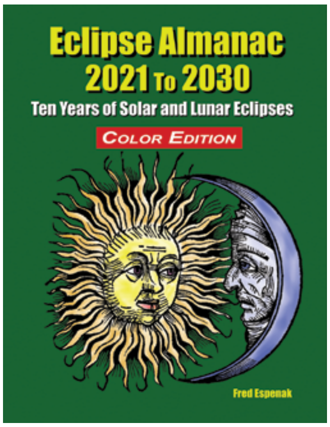

◀ ECLIPSE COMPENDIUM

Astrophysicist and *Sky & Telescope* contributor Fred Espenak releases *Eclipse Almanac*, a five-volume series that details every solar and lunar eclipse for the next 50 years ($11.99 per volume for the black-and-white edition, $16.99 per volume for color, and a Kindle edition is available for $7.99 per volume). Each volume is a concise reference for all eclipses over a 10-year period between 2021 and 2070, with detailed maps identifying the geographic regions of visibility. The volumes are arranged in three sections: The first concentrates on partial, total, and annular solar eclipses; section two details lunar eclipses; and the third section lists the dates and times of the Moon's phases throughout that volume's decade. *Eclipse Almanac* uses the new elliptical model for Earth's shadow, producing the most accurate predictions to date. 8½-by-11 inches, paperback.

AstroPixels Publishing
P.O. Box 16197, Portal, AZ 85632
astropixels.com

◀ OBSERVING STATION 2.0

Unistellar Optics unveils an updated version of its popular observing station, the eVscope 2 ($4,199). The system combines a 4½-inch f/4 reflector with a permanently mounted, 7.7-megapixel Sony IMX347 color CMOS detector, an enhanced-vision OLED screen "eyepiece," with Nikon optics, and a powerful alt-az Go To mount controlled by a smartphone. The system's patented Autonomous Field Detection feature automatically recognizes star fields, self-aligns, and is ready to observe within 10 seconds of powering up. Its track-and-accumulate imaging with automated intelligent image-processing produces colorful "live" images of more than 5,000 deep-sky targets from its internal database within minutes of pointing at a subject. Images are recorded to 64 gigabytes of internal storage and sent directly to your smartphone. The eVscope 2 weighs 19.8 lbs assembled and comes with a collapsible tripod, an internal rechargeable battery that powers the unit for up to 10 hours, a free control app requiring iOS 12 or Android 6 systems, and a hiking backpack.

Unistellar
unistellaroptics.com

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The Taming of the Slew

Big scopes offer many options for improvement.

◀ There's room inside the rocker box for magazine and chart storage.

A COUPLE OF YEARS AGO, Arkansas amateur Morgan Amos graduated from a 4-inch starter scope to a 12-inch Dobsonian. As he put it, "I fully expected a beautiful mail-order bride to arrive. Instead, I received a monstrous, difficult-to-handle mistress in a casket-sized box. I was nevertheless certain she was the one for me . . . with a little grooming."

Morgan has certainly done some excellent grooming. Let's have a look at what he's accomplished.

The first order of business was transport — the scope was simply too large and bulky to move in one piece, and even the mount alone was a hefty load. So Morgan decided to put it on a dolly. He could easily have bought a dolly, but he made his own from scratch using cherry wood and cedar milled from a tree in his yard, and he put hard urethane wheels underneath to roll smoothly on hard surfaces and not be too mushy. He set the wheels six inches in from the corners to avoid kicking them when standing close while observing and to accommodate leveling screws at the corners. To prevent the scope from swinging around in transit, he drilled a hole through both base plates and drops a wooden dowel pin into the hole to lock them together when necessary.

Then he added what he calls the "furniture." A Dobsonian rocker box has all that empty real estate on the sides; it seems a shame not to develop it. Many of us put an eyepiece rack on the focuser side, but that's usually about the extent of it. Morgan took that concept a bit further. He built storage compartments for all his accessories except for his eyepieces, which he keeps in a case on a portable folding table.

As with the dolly, you can buy ready-made storage boxes and attach them to the scope, or you can build them yourself. Morgan again made his own, using more cherry and cedar plus padauk with a few walnut, cocobolo, and myrtle burl accents. His storage boxes accommodate a Telrad and its custom 2-inch riser, two finder charts for Messier objects, a right-angle finder, four leveler foot pads, a 35-mm extension tube, a Howie Glatter Parallizer, a laser collimator, an AstroSystems LitePipe collimator, a Tele Vue in-travel adapter, AA batteries for the Telrad, and several hex wrenches. Another box has a sliding dovetail receptacle to store the red-dot finder when replaced with the Telrad.

The inside of the rocker box has enough space at the bottom for two slim book racks that hold a *Pocket Sky Atlas*, a Moon map, a planisphere, and an astronomical almanac.

Morgan recommends attaching the boxes to a back plate and then mounting the unit to the rocker box, rather than trying to fasten each box individually.

▲ *Left:* Morgan Amos's fully tricked-out 12-inch Dobsonian telescope. *Right:* Accessory compartments attached to the rocker box keep needed equipment close at hand.

ALL IMAGES COURTESY OF MORGAN AMOS

Something you won't find on Morgan's scope are counterweights. Rather than have to fiddle with weights each time he changes eyepieces or finders, he made a sliding dovetail control arm with a locking knob. The arm connects to the front of the rocker box where the handle used to be (no longer needed now that the scope rolls on a dolly), and it attaches to the top of the telescope tube with four rare-earth magnets. The magnets securely hold the head of the arm to the metal OTA and keep it snug against the front rim yet permit easy removal when necessary. Morgan adjusted the length of the arm's sliding parts to allow for motion all the way from the zenith down to about 11° above the horizon. When he moves the scope in altitude, he simply loosens the locking knob, makes his adjustment, and locks it down again. One additional benefit to this arrangement over counterweights is that the control arm dampens vibration almost instantly.

Morgan made one last major improvement: He put a big handle underneath the OTA's upper rim. He says, "I am fond of Rockler's 4½-inch jig handle that comfortably fills my whole hand rather than just a few fingers. It's the one thing I constantly hang onto throughout the night and use to slew the OTA with my left hand while operating the control arm locking knob with my right."

What's left to add? An azimuth setting circle between the base plates. Other than that, the only thing missing is the kitchen sink.

For more information, contact Morgan at **sagebully2@gmail.com**.

■ Contributing Editor **JERRY OLTION** says you don't truly own a scope until you've drilled holes in it.

SHARE YOUR INNOVATION
Do you have a telescope or ATM observing accessory that *S&T* readers would enjoy knowing about? Email your projects to Jerry Oltion at **j.oltion@gmail.com**.

NEBULOUS SWAN

Jeffrey Horne

Large swaths of bright nebulosity in Cygnus overshadow the usually prominent star Deneb (left). The bluish patch below Deneb is the North America Nebula, NGC 7000, with the fainter Pelican Nebula (IC 5070 and IC 5067) to its right. The Crescent Nebula (NGC 6888) stands out at the right, while the Cygnus Loop sits apart from the rest at lower right.

DETAILS: *ZWO ASI2600MC Pro camera with Canon EF 50-mm USM lens. Total exposure: 40¼ hours through Optolong L-eXtreme, L-Pro, and L-eNhance filters.*

◁ DUMBBELL NEBULA

Mathieu Guinot

Messier 27 in Vulpecula was the first planetary nebula discovered, but in this deep narrowband image it resembles neither a planet nor a dumbbell, its nickname. Faint waves of ionized gas form moth-like "wings" around its main shell.

DETAILS: *Lacerta FN25010c-flat reflector with ZWO ASI2600MM camera. Total exposure: 22 hours through Antlia Hα, O III, and RGB filters.*

▽ COCOONED IN STARS

Andy Nowlen

Dark streams of dust give IC 5146, the Cocoon Nebula, the appearance that it's burrowing through the star field. Hot, young stars inside the Cocoon excite the surrounding hydrogen gas, causing the nebula to glow a vibrant red.

DETAILS: *Sharpstar 76-mm ED Triplet APO refractor and Takahashi FSQ-106EDX4 Quadruplet refractor with ZWO ASI533 MC Pro camera. Mosaic of 9 panels totaling 14 hours through Optolong L-eNhance and L-eXtreme filters.*

▷ CASTILLO DE LUNA

Sergio Conceiçao

A rare Blue Moon, the third full Moon in a season with four, glides behind the thematically appropriate Castillo de Luna in Alburquerque, Spain, on August 22, 2021.

DETAILS: *Canon EOS R6 camera with 400-mm lens. Total exposure: 1⁄50 second at f/5.6.*

▽ VIBRANT NEBULOSITY

Emil Andronic

Ultraviolet radiation from hot stars within open cluster Berkeley 90 excites the gases of Sharpless 2-115 in Cygnus. Astronomers once thought smaller Abell 71 at the top left was a planetary nebula, later realizing that it's simply a round H II region.

DETAILS: *Astro-Tech AT106 ED Triplet refractor with ZWO ASI294MM Pro camera. Total exposure: 24¾ hours through narrowband filters.*

THE SPACE BUTTERFLY
Fernando Oliveira de Menezes
Messier 6, the Butterfly Cluster, is a bright open cluster in Scorpius full of hot, young, blue stars. The brightest star in the cluster is BM Scorpii (center left), an orange giant and a semiregular variable. The cluster's name stems from its outline resembling the outstretched wings of a butterfly.
DETAILS: *Sky-Watcher Esprit 150ED Triplet APO refractor with ZWO ASI6200MC Pro camera. Total exposure: 2.63 hours.*

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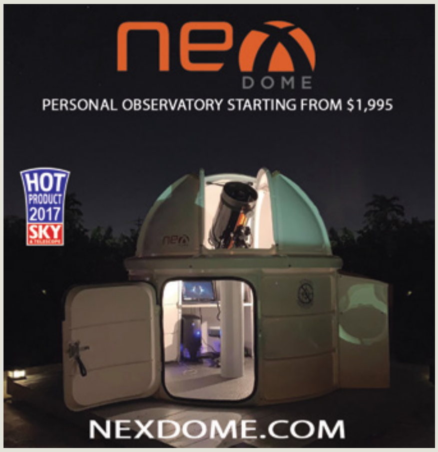
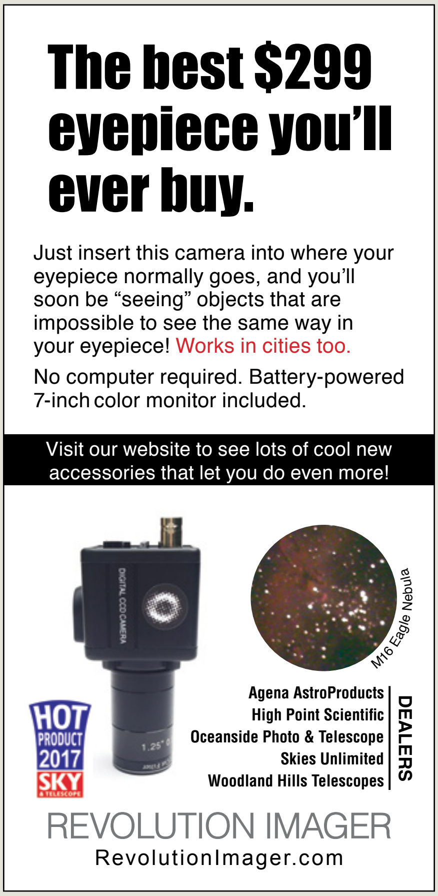


MISCELLANEOUS

CAMERAS



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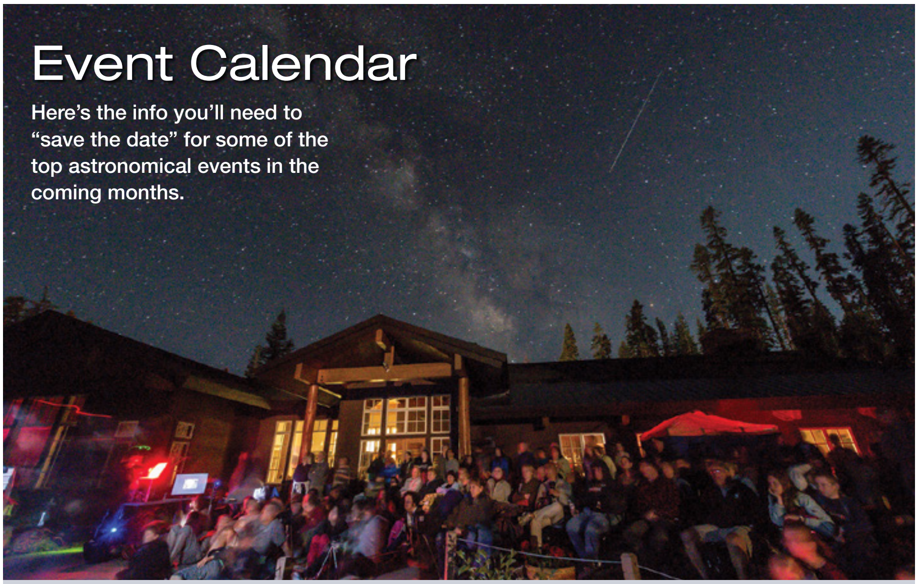
Event Calendar

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



ALISON TAGGERT-BARONE / LASSEN NPS / FLICKR

January 31–February 6
WINTER STAR PARTY
Scout Key, FL
scas.org/winter-star-party/?y=2022

April 9–10
NORTHEAST ASTRONOMY FORUM
Suffern, NY
neafexpo.com

April 24–May 1
TEXAS STAR PARTY
Fort Davis, TX
texasstarparty.org

April 27–30
MIDSOUTH STARGAZE
French Camp, MS
rainwaterobservatory.org

May 7
ASTRONOMY DAY
Everywhere!
https://is.gd/AstronomyDay

June 2–5
CHERRY SPRINGS STAR PARTY
Cherry Springs State Park, PA
cherrysprings.org

June 18–25
GRAND CANYON STAR PARTY
Grand Canyon, AZ
https://is.gd/GrandCanyonStarParty

June 22–26
ROCKY MOUNTAIN STAR STARE
Gardner, CO
rmss.org

July (date not yet determined)
OREGON STAR PARTY
Indian Trail Spring, OR
oregonstarparty.org

July 22–31
SUMMER STAR PARTY
Plainfield, MA
rocklandastronomy.com/ssp.html

July 24–29
NEBRASKA STAR PARTY
Valentine, NE
nebraskastarparty.org

July 26–31
TABLE MOUNTAIN STAR PARTY
Oroville, WA
tmspa.com

July 28–31
STELLAFANE CONVENTION
Springfield, VT
stellafane.org/convention

October 1
ASTRONOMY DAY
Everywhere!
https://is.gd/AstronomyDay

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

Savoring Space and Time

Despite its ravages, the pandemic gave many of us a pair of precious gifts.

LIKE MANY IN THE UNITED KINGDOM, I was furloughed for six months as a result of COVID-19. As a judge in the horseracing industry, I determine race winners in a high-octane environment in which errors with split-second decisions can cost millions. Governed by deadlines, schedules, and endless thinking ahead, I frequently disappear up my own tailpipe! But lockdown changed all that, and two priceless gifts emerged: space and time.

Instantly, "empty" days and nights stretched ahead. Freed from work, I had space and time to think about . . . space and time. Untethered from early morning starts and relentless pressure to be at the top of my game, my foot eased off the proverbial pedal. I stayed out late observing, occasionally all night, for when would such freedom arise again?

Night after glorious night I gazed into contrail-free, relatively unpolluted skies with tack-sharp stars. The Milky Way seemed more luminous and voluminous, its rarely visible dust lanes now clearly threaded through its star-spangled length. When the Moon emerged, she was brighter, her mare and craters wondrously defined. I delighted in the phase transitions, and in earthshine that was stunningly incandescent. I even pulled out my "trusty but dusty" TAL-1 telescope, cleaned it, and aimed it skyward to track the travelling planets, which, as with all else, stood out so much sharper than pre-pandemic.

There I stood in magnificent isolation in the field near our house, present in a way never permitted before, enjoying all the space and time in the world, in the universe even, following my own mantra, which is to "look up, live it, and love it." It was magical.

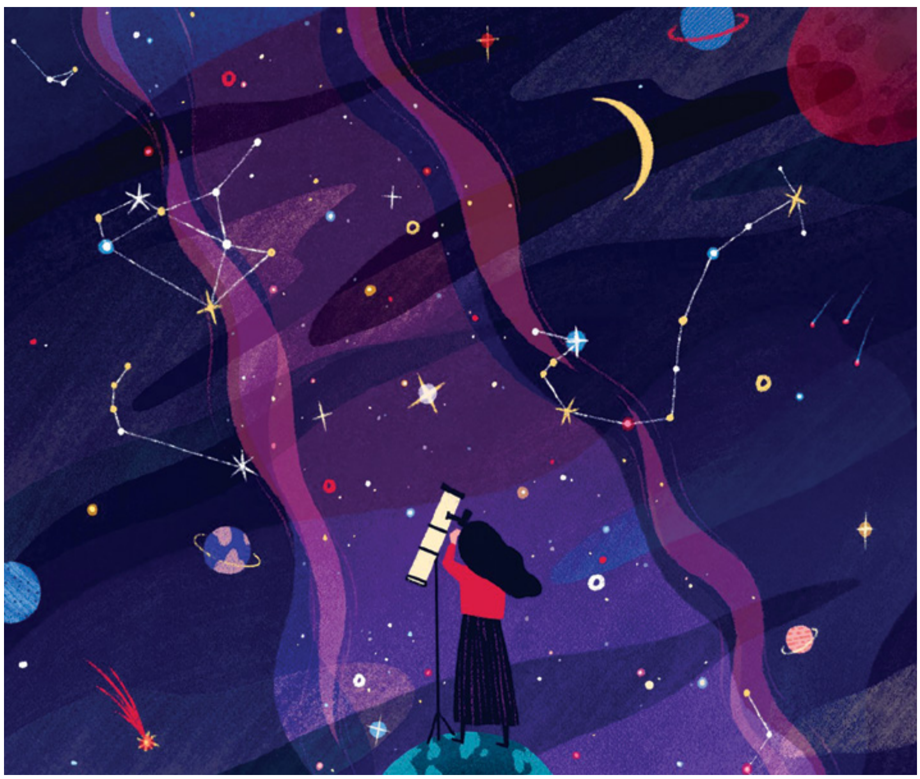
But I couldn't totally disconnect from the company's "cyber hive," and I monitored horseracing matters on the workplace social media site. Here I read such comments as: "I'm bored out of my tiny mind" — "I've got loads of time and nothing to do with it" — "I just can't walk the darn dog anymore." Reading them, I grew more saddened by the day. *At last you have the space and time you've long lamented not having,* I inwardly screamed. *Look up!*

So, taking action, I began posting photos of the planets. I received instant feedback and questions: Where are they? Can I spot them now? How did they get there? Soon I was overwhelmed. My equine-absorbed colleagues, many immersed in homeschooling, fired questions from their kids, some of whom were working on science projects but had no idea about astronomy.

I moved from the Moon, planets, and constellations to how the stars came to be, suggesting that my colleagues spare a thought for how small and transient their space and time are compared to the size and age of the cosmos itself! Families soon confessed to staying out late to watch the Moon rise or to seek out the planets. They posted their own images in a bid to share their awe and joy. The site became a much-followed hub for everyone to showcase their newfound time and space.

I'm now back at work and bemoan the loss of these two treasured gifts. Once again, schedules, deadlines, and constant low-level stress are the order of the day. But a glance at the night sky is a reminder for all of us that we should make the space and time.

■ **JANE GREEN** is a Racing Judge for the British Horseracing Authority in England but also finds time to write, lecture, and broadcast on astronomy.



JESSIE LIN

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Skygazer's Almanac 30°S 2022

FOR LATITUDES NEAR 30° SOUTH

A SUPPLEMENT TO SKY & TELESCOPE

EVENING SKY

Jan 4 Earth is 147,105,053 km from the Sun (perihelion) at 4:55 p.m. AEST; latest twilight of the year at latitude 30° south

Jan 7 Mercury attains greatest elongation, 19° east of the Sun

Jan 9 Latest sunset

Apr 29 Mercury stands 21° east of the Sun

Apr 30 A partial eclipse of the Sun is visible mainly from Chile and Argentina

Jun 8 Earliest end of evening twilight

Jun 10 Earliest sunset

Jun 21 Shortest day, $10^h\ 13^m$ at latitude 30° south; winter begins at the solstice, 7:14 p.m. AEST

Jul 4 Earth is 152,098,455 km from the Sun (aphelion) at 5:11 p.m. AEST

Aug 14 Saturn is at opposition tonight

Aug 27 Mercury is 27° east of the Sun

Sep 16 Neptune is at opposition tonight

Sep 26 Jupiter comes to opposition

Nov 8 A total eclipse of the Moon can be seen from Australia, 8:16 to 9:42 p.m. AEST; the early partial stage is visible from South America before dawn

Nov 9 Uranus is at opposition

Dec 1 Mars is nearest Earth and appears 17.2 arcseconds across in a telescope

Dec 8 Mars is at opposition

Dec 21 Mercury is 20° east of the Sun

Dec 22 Longest day, $14^h\ 05^m$ at latitude 30° south

Dec 29 Mercury is 1.4° to lower right of Venus

MORNING SKY

Feb 17 Mercury reaches greatest elongation, 26° west of the Sun

Mar 3 Mercury is 0.7° to the right of Saturn

Mar 21 Fall begins at the equinox, 1:33 a.m. AEST; Mercury is 1.3° to upper right of Jupiter; Venus is at greatest elongation, 47° west of the Sun

Mar 29 Saturn is 2.1° to the right of Venus

Apr 5 Saturn is 0.4° to lower left of Mars

Apr 13 In a telescope, Neptune is 0.1° to upper right of Jupiter

Apr 28 Venus and Neptune are just ½ arcminute apart this morning near 5:11 a.m. AEST!

May 1 Jupiter is 0.2° to the left of Venus

May 16 A total lunar eclipse occurs for South America, with the early partial stage visible from Africa

May 19 Neptune is 0.6° to lower left of Mars

May 30 Mars is 0.6° to the right of Jupiter

Jun 12 Uranus is 1.5° to lower left of Venus

Jun 17 Mercury is at greatest elongation, 23° west of the Sun

Jul 2 Latest sunrise

Jul 4 Latest onset of morning twilight

Aug 2 Uranus is 1.3° below Mars

Sep 23 Spring begins at the equinox, 11:04 a.m. AEST

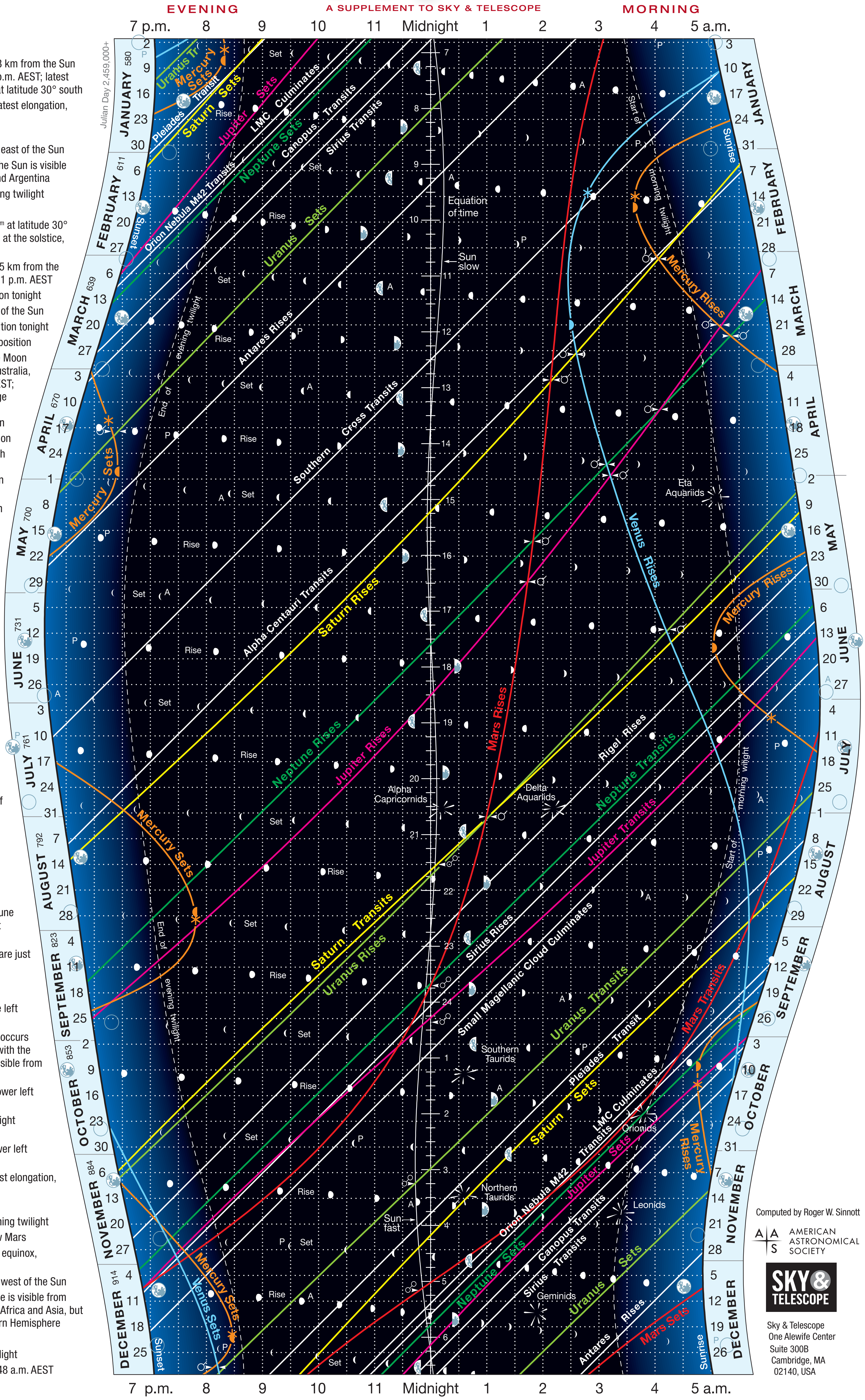
Oct 9 Mercury stands 18° west of the Sun

Oct 25 A partial solar eclipse is visible from Europe and parts of Africa and Asia, but not from the Southern Hemisphere

Dec 4 Earliest sunrise

Dec 9 Earliest morning twilight

Dec 22 Summer solstice, 7:48 a.m. AEST



Conjunction (appulse) · Greatest elongation · Greatest illuminated extent · Opposition · New Moon · First Quarter · Full Moon · Last Quarter · A Apogee · P Perigee · Waxing (moonset) · Waning (moonrise)

Computed by Roger W. Sinnott

AMERICAN ASTRONOMICAL SOCIETY

SKY & TELESCOPE

Sky & Telescope
One Alewife Center
Suite 300B
Cambridge, MA
02140, USA

Skygazer's Almanac 30°S 2022

FOR LATITUDES NEAR 30° SOUTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time is moonrise?

Welcome to the *Skygazer's Almanac 2022,* a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 30° south — in Australia, southern Africa, and the southern cone of South America.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart, you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 9, 2022.

First find "January" and "9" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 9–10 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 9–10 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 9th occurs at 7:06 p.m. *Local Mean Time*. (All times read from the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Mercury sets at 8:15 p.m., long enough after the Sun that we might have been able to spot it in the southwestern sky. Moving to the right, we see that Saturn sets at 8:32, so it will be off tonight's observing list. But the Pleiades transit the meridian at 8:33, meaning the famous star cluster is at its highest in the sky.

Twilight ends at 8:40, marking the moment when the Sun is 18° below the horizon and the sky is fully dark. The bright planet Jupiter sets at 9:32.

At about 10:07 the Large Magellanic Cloud culminates (another way of saying it transits). Then the two brightest nighttime stars, Canopus and Sirius, transit at 11:08 and 11:30, respectively. Transit times of such celestial landmarks help us follow the march of constellations during the night.

A large Moon symbol is centered on the dotted line at 11:45, and the legend at the bottom of the chart tells us it is at first-quarter phase, setting.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 9–10 this is $7^h\ 17^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due north. On January 9th the Sun runs slow, transiting at 12:07 p.m. This deviation, important for reading a sundial, is caused by the tilt of the Earth's axis and the ellipticity of its orbit.

At 12:46 a.m. the dim planet Uranus sets. Then at 2:04 Antares, a star we usually associate with later seasons, climbs above the southeastern horizon. Mars also rises, at 2:56.

The first hint of dawn — the start of morning twilight — comes at 3:34. The Sun finally peeks above the southeastern horizon at 5:09 a.m. on Monday morning, January 10th.

Other Charted Information

Many of the year's most important astronomical events are listed in the chart's left-hand margin. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are marked by a ☌ symbol on the

Local Mean Time Corrections

Adelaide	+16	Melbourne	+20
Brisbane	−13	Perth	+18
Canberra	+4	Sydney	−4
Cape Town	+46	Johannesburg	+8
Durban	−3	Port Elizabeth	+18
Harare	−4	Pretoria	+8
Asunción	−10	Rio de Janeiro	−7
Buenos Aires	+54	Santiago	+43
Montevideo	+45	São Paulo	+6

planets' event lines. Here, the symbol indicates the night when the planets appear closest in the sky (at appulse), not just when they have the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol. For instance, Saturn reaches opposition on the night of August 14–15 this year.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces left (waxing Moon sets) or right (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark when their telescopic disks have the greatest illuminated extent in square arcseconds. For example, this occurs for Venus on February 13th and for Mercury the very next morning.

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant (point of origin) is highest in the night sky. This often occurs just as morning twilight begins. (Note that our predicted peak of the Southern Taurids, a sparse and ill-defined shower, falls a few weeks earlier than in recent years.)

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2459, as indicated just off the chart's upper left margin. To find the last three digits for days in January, add 580 to the date. For instance, on January 9th we have 580 + 9 = 589, so the Julian Day is 2,459,589.

Rising or Setting Corrections

South Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
10°	0	8	16	24	33	43
15°	0	6	12	19	26	33
20°	0	4	8	13	18	23
25°	0	2	4	7	9	12
30°	0	0	0	0	0	0
35°	0	2	5	7	10	13
40°	0	5	10	16	22	29
45°	1	8	17	26	37	49
50°	1	12	25	39	54	72

Note that the Julian Day does not change to this value until 12:00 Universal Time (UT). In Australia, 12:00 UT falls during the evening of the same day (at 10 p.m. Australian Eastern Standard Time, AEST). Before that time, subtract 1 from the Julian day number just obtained.

Time Corrections

All events on this southern version of the *Skygazer's Almanac* are plotted for an observer at longitude 135° east and latitude 30° south. However, you need not live near McDouall Peak, South Australia, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's south temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in order of decreasing importance.

• **DAYLIGHT-SAVING TIME ("SUMMER TIME").** When this is in effect, add one hour to any time read from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by many minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Australia are 150°E for the eastern states (which use Australian Eastern Standard Time, AEST), and 142.5°E for the central state and territory (an odd value that puts the minute hands of their clocks 30 minutes out of joint with most of the rest of the world).

If your longitude is very close to your standard time-zone meridian, luck is with you and your LMT correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Melbourne, Australia (longitude 145°), is 5° west of its time-zone meridian (150°). So at Melbourne, add 20 minutes to any time obtained from the chart. The result is standard time.

Find your Local Mean Time correction and memorize it; you will use it always. The table below at left has the corrections, in minutes, for some major cities.

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 30° south. This effect depends strongly on a star or planet's declination. The declinations of the Sun and planets are listed each month in *Sky & Telescope*.

If your site is *south* of latitude 30°S, an object with a south declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), while one with a north declination spends less time above the horizon. If you are *north* of 30°S, the effect is just the reverse. With these rules in mind, you can gauge the number of minutes for correcting a rise or set time using the table above left.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 135°E. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of central Australia, and two minutes later for each time zone west of there. Observers in southern Africa can simply shift the Moon symbol a third of the way to that for the following date. Those who live in South America can shift the symbol about halfway there.

For reprints (item SGA22S, $5.95 each) or to order a similar chart for latitude 40° north or 50° north, go to: shopatsky.com/collections/calendars-almanacs

Skygazer's Almanac 2022 is a supplement to *Sky & Telescope* Magazine, One Alewife Center, Suite 300B, Cambridge, MA 02140, USA, skyandtelescope.org.

SKY & TELESCOPE

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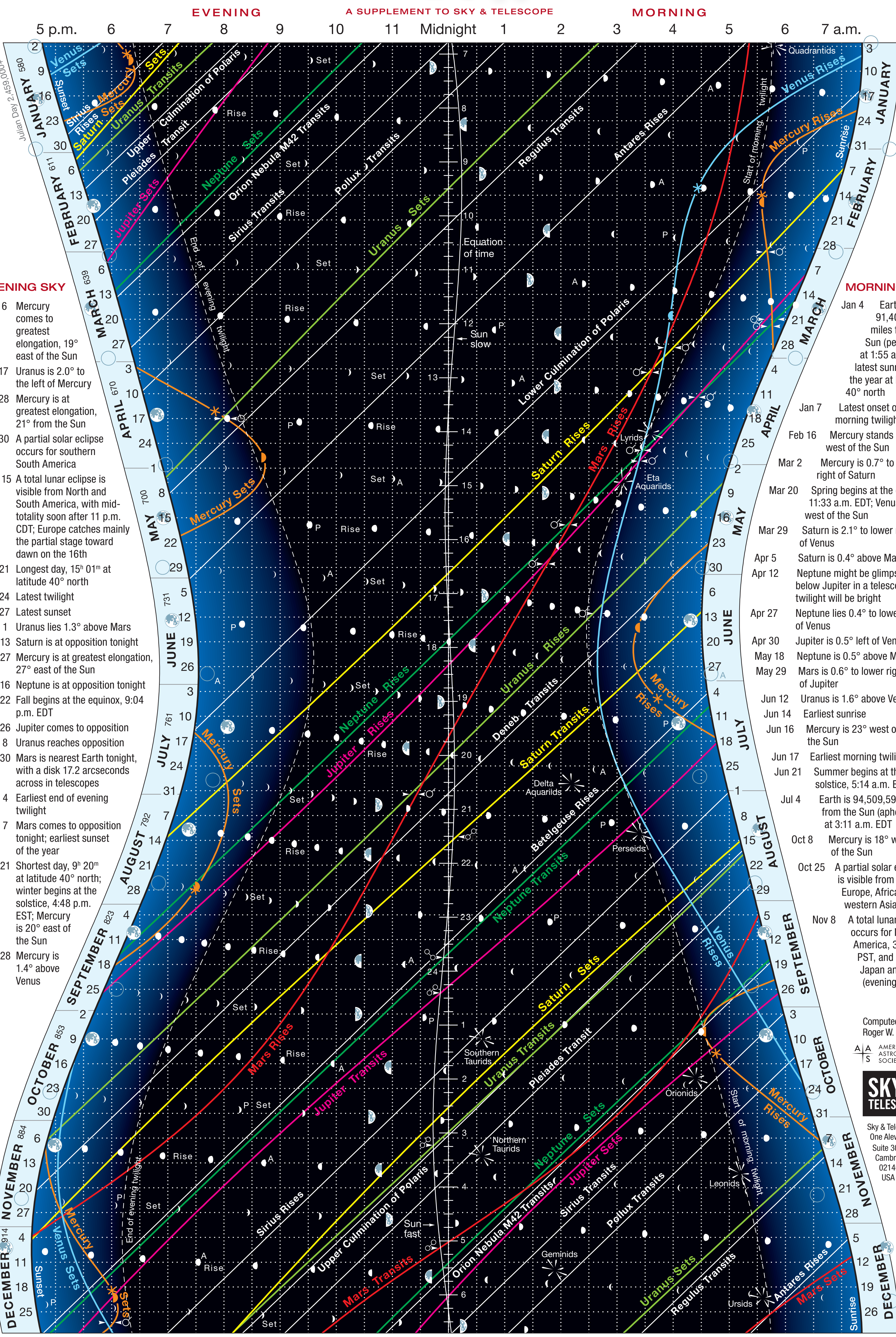
Skygazer's Almanac 40°N 2022

FOR LATITUDES NEAR 40° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



Conjunction (appulse) · Greatest elongation · Greatest illuminated extent · Opposition · New Moon · First Quarter · Full Moon · Last Quarter · A Apogee · P Perigee · Waxing (moonset) · Waning (moonrise)

EVENING SKY

- Jan 6 — Mercury comes to greatest elongation, 19° east of the Sun
- Apr 17 — Uranus is 2.0° to the left of Mercury
- Apr 28 — Mercury is at greatest elongation, 21° from the Sun
- Apr 30 — A partial solar eclipse occurs for southern South America
- May 15 — A total lunar eclipse is visible from North and South America, with mid-totality soon after 11 p.m. CDT; Europe catches mainly the partial stage toward dawn on the 16th
- Jun 21 — Longest day, $15^h 01^m$ at latitude 40° north
- Jun 24 — Latest twilight
- Jun 27 — Latest sunset
- Aug 1 — Uranus lies 1.3° above Mars
- Aug 13 — Saturn is at opposition tonight
- Aug 27 — Mercury is at greatest elongation, 27° east of the Sun
- Sep 16 — Neptune is at opposition tonight
- Sep 22 — Fall begins at the equinox, 9:04 p.m. EDT
- Sep 26 — Jupiter comes to opposition
- Nov 8 — Uranus reaches opposition
- Nov 30 — Mars is nearest Earth tonight, with a disk 17.2 arcseconds across in telescopes
- Dec 4 — Earliest end of evening twilight
- Dec 7 — Mars comes to opposition tonight; earliest sunset of the year
- Dec 21 — Shortest day, $9^h 20^m$ at latitude 40° north; winter begins at the solstice, 4:48 p.m. EST; Mercury is 20° east of the Sun
- Dec 28 — Mercury is 1.4° above Venus

MORNING SKY

- Jan 4 — Earth is 91,406,842 miles from the Sun (perihelion) at 1:55 a.m. EST; latest sunrise of the year at latitude 40° north
- Jan 7 — Latest onset of morning twilight
- Feb 16 — Mercury stands 26° west of the Sun
- Mar 2 — Mercury is 0.7° to lower right of Saturn
- Mar 20 — Spring begins at the equinox, 11:33 a.m. EDT; Venus is 47° west of the Sun
- Mar 29 — Saturn is 2.1° to lower right of Venus
- Apr 5 — Saturn is 0.4° above Mars
- Apr 12 — Neptune might be glimpsed 0.1° below Jupiter in a telescope, but twilight will be bright
- Apr 27 — Neptune lies 0.4° to lower left of Venus
- Apr 30 — Jupiter is 0.5° left of Venus
- May 18 — Neptune is 0.5° above Mars
- May 29 — Mars is 0.6° to lower right of Jupiter
- Jun 12 — Uranus is 1.6° above Venus
- Jun 14 — Earliest sunrise
- Jun 16 — Mercury is 23° west of the Sun
- Jun 17 — Earliest morning twilight
- Jun 21 — Summer begins at the solstice, 5:14 a.m. EDT
- Jul 4 — Earth is 94,509,598 miles from the Sun (aphelion) at 3:11 a.m. EDT
- Oct 8 — Mercury is 18° west of the Sun
- Oct 25 — A partial solar eclipse is visible from parts of Europe, Africa, and western Asia
- Nov 8 — A total lunar eclipse occurs for North America, 3 a.m. PST, and for Japan and China (evening of 8th)

Computed by Roger W. Sinnott

American Astronomical Society

Sky & Telescope
One Alewife Center
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Cambridge, MA 02140
USA

Skygazer's Almanac 40°N 2022

FOR LATITUDES NEAR 40° NORTH

What's in the sky tonight?

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Welcome to the *Skygazer's Almanac 2022,* a handy chart that answers these and many other questions for every night of the year. It is plotted for skywatchers near latitude 40° north — in the United States, the Mediterranean countries, Japan, and much of China.

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A sweep of the eye shows that the line for the night of January 9–10 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 9–10 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 9th occurs at 4:53 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your clock time. More on this later.)

We see that Venus sets at 5:01 p.m., so soon after the Sun that we won't see it at all. But Mercury sets in near darkness at 6:25, so it is well worth looking for until that time. It is far from the Sun during this current apparition, as described in the column of text left of the chart.

At 6:29 a dashed line shows that twilight technically ends. This is when the Sun is 18° below the horizon and the sky is fully dark.

The ringed planet Saturn sets at 6:45, so we can cross it off tonight's observing agenda. But dim Uranus transits the meridian at 7:16, meaning it is due south and "riding high," an excellent time to look for it in binoculars.

At 7:42 Polaris, the North Star, has its upper culmination. It then stands directly above the north celestial pole (by 38′ or 39′ this year), a good time to check the alignment of an equatorial telescope. The bright planet Jupiter sets at 8:24.

The famous Pleiades star cluster transits at 8:30 p.m., followed by the Orion Nebula (10:18) and Sirius (11:27). Transit times of such celestial landmarks help us keep track of the march of constellations across the night sky.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 9–10 this is $7^h\ 19^m$. To find the sidereal time at any other time and date on the chart, locate that point and draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 9th the Sun runs slow, transiting at 12:07 p.m. This deviation, important for reading a sundial, is caused by the tilt of the Earth's axis and the ellipticity of its orbit.

At 12:45 a.m. a small Moon symbol appears on the dotted line, and we can tell from the legend at the bottom of the chart that it is at waxing gibbous phase, setting. The wee hours continue, and at 4:46 Antares rises. This is a star we usually associate with a much later season.

The first hint of dawn — start of morning twilight — comes at 5:45 a.m. Then the brilliant planet Venus rises at 6:51. The Sun finally peeks above the horizon at 7:21 a.m. on January 10th.

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are indicated by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest in the sky, not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and thus visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is marked there by a ☍ symbol, as for Saturn on the night of August 13–14.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark their dates of greatest illuminated extent in square arcseconds. For example, this occurs for Venus on the morning of February 12th this year.

Meteor showers are marked by a starburst symbol on the date of peak activity and at the time when the shower's radiant is highest in the night sky. This is often just as morning twilight begins.

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2459, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 580 to the date. For instance, on the evening of January 9th we have 580 + 9 = 589, so the Julian Day is 2,459,589. For North American observers this number applies all night, because the next Julian Day always begins at 12:00 Universal Time (6:00 a.m. Central Standard Time).

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at longitude 90° west and latitude 40° north, near the population center of North America. However, you need not live near Peoria, Illinois, to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
50°	0	7	14	23	32	43
45°	0	3	7	10	14	19
40°	0	0	0	0	0	0
35°	0	3	6	9	12	16
30°	0	5	11	16	23	30
25°	0	8	16	24	32	42

To convert the charted time of an event to your civil (clock) time, the following corrections must be made. They are mentioned in order of decreasing importance:

• **DAYLIGHT-SAVING TIME.** When this is in effect, add one hour to any time obtained from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in North America are Eastern Time, 75°W; Central, 90°; Mountain, 105°; and Pacific, 120°. If your longitude is very close to one of these (as is true for New Orleans and Denver), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

Local Mean Time Corrections

Atlanta	+38	Los Angeles	–7
Boise	+45	Memphis	0
Boston	–16	Miami	+21
Buffalo	+15	Minneapolis	+13
Chicago	–10	New Orleans	0
Cleveland	+27	New York	–4
Dallas	+27	Philadelphia	+1
Denver	0	Phoenix	+28
Detroit	+32	Pittsburgh	+20
El Paso	+6	St. Louis	+1
Helena	+28	Salt Lake City	+28
Honolulu	+31	San Francisco	+10
Houston	+21	Santa Fe	+4
Indianapolis	+44	Seattle	+9
Jacksonville	+27	Tulsa	+24
Kansas City	+18	Washington	+8
Athens	+25	Lisbon	+36
Baghdad	+3	Madrid	+75
Beijing	+14	New Delhi	+21
Belgrade	–22	Rome	+10
Cairo	–8	Seoul	+32
Istanbul	+4	Tehran	+4
Jerusalem	–21	Tokyo	–19

For instance, Washington, DC (longitude 77°), is 2° west of the Eastern Time meridian. So at Washington, add 8 minutes to any time obtained from the chart. The result is Eastern Standard Time.

Find your time adjustment and memorize it. The table below left shows the corrections from local to standard time, in minutes, for some major cities.

• **RISING AND SETTING.** These times need correction if your latitude differs from 40° north. This effect depends strongly on a star or planet's declination. (The declinations of the Sun and planets are listed monthly in *Sky & Telescope*.)

If your site is *north* of latitude 40°, then an object with a north declination stays above the horizon *longer* than the chart shows (it rises earlier and sets later), whereas one with a south declination spends less time above the horizon. At a site *south* of 40°, the effect is just the reverse. Keeping these rules in mind, you can gauge the approximate number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion affects lunar rising and setting times if your longitude differs from 90° west. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Central Time, and two minutes later for each time zone west of it. European observers can simply shift each rising or setting Moon symbol leftward a quarter of the way toward the one for the previous night.

Skygazer's Almanac 2022 is a supplement to *Sky & Telescope* Magazine, One Alewife Center, Suite 300B, Cambridge, MA 02140, USA, skyandtelescope.org.

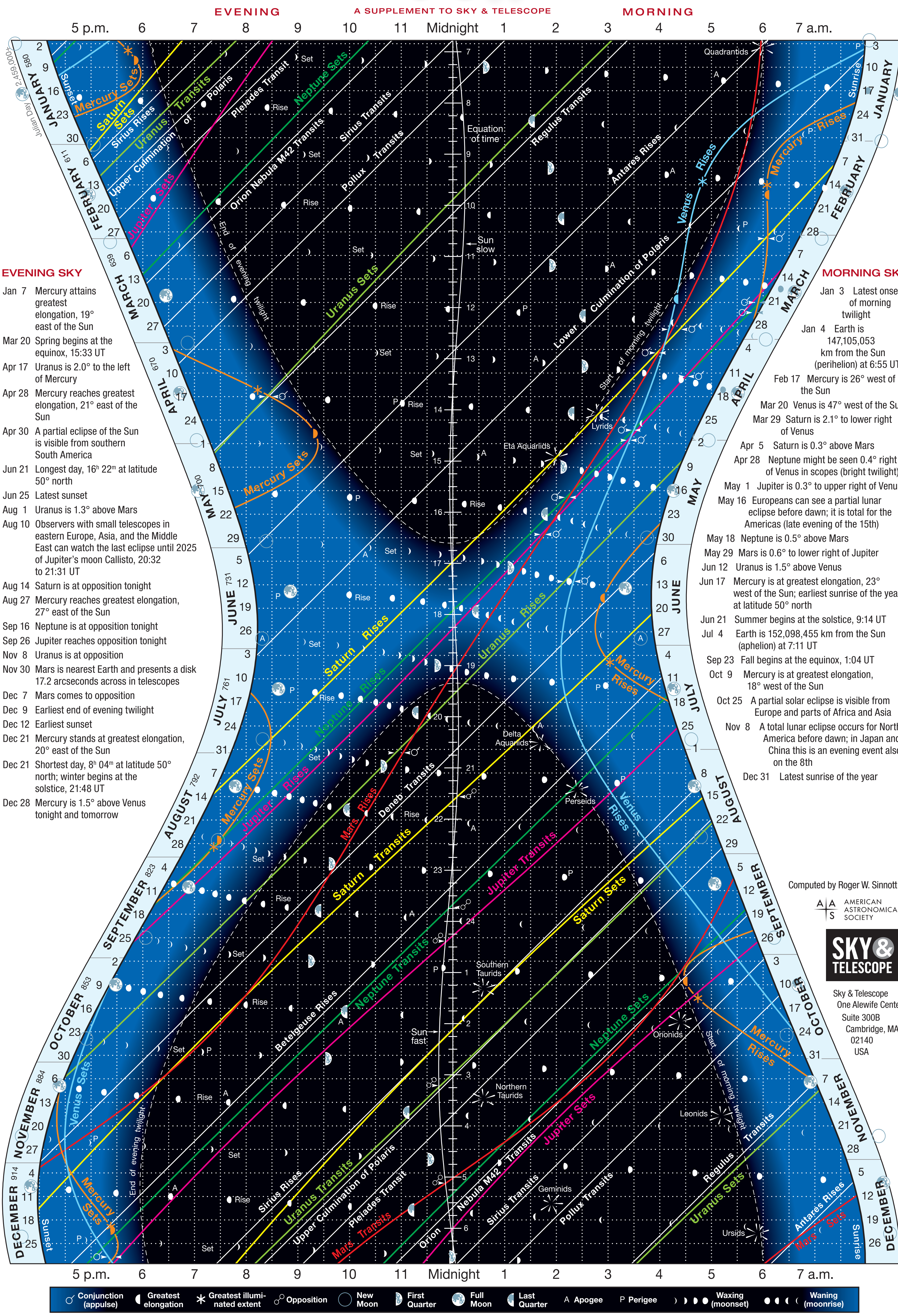
SKY & TELESCOPE

AMERICAN ASTRONOMICAL SOCIETY

Skygazer's Almanac 50°N 2022

FOR LATITUDES NEAR 50° NORTH

A SUPPLEMENT TO SKY & TELESCOPE



EVENING SKY

- Jan 7 Mercury attains greatest elongation, 19° east of the Sun
- Mar 20 Spring begins at the equinox, 15:33 UT
- Apr 17 Uranus is 2.0° to the left of Mercury
- Apr 28 Mercury reaches greatest elongation, 21° east of the Sun
- Apr 30 A partial eclipse of the Sun is visible from southern South America
- Jun 21 Longest day, 16ʰ 22ᵐ at latitude 50° north
- Jun 25 Latest sunset
- Aug 1 Uranus is 1.3° above Mars
- Aug 10 Observers with small telescopes in eastern Europe, Asia, and the Middle East can watch the last eclipse until 2025 of Jupiter's moon Callisto, 20:32 to 21:31 UT
- Aug 14 Saturn is at opposition tonight
- Aug 27 Mercury reaches greatest elongation, 27° east of the Sun
- Sep 16 Neptune is at opposition tonight
- Sep 26 Jupiter reaches opposition tonight
- Nov 8 Uranus is at opposition
- Nov 30 Mars is nearest Earth and presents a disk 17.2 arcseconds across in telescopes
- Dec 7 Mars comes to opposition
- Dec 9 Earliest end of evening twilight
- Dec 12 Earliest sunset
- Dec 21 Mercury stands at greatest elongation, 20° east of the Sun
- Dec 21 Shortest day, 8ʰ 04ᵐ at latitude 50° north; winter begins at the solstice, 21:48 UT
- Dec 28 Mercury is 1.5° above Venus tonight and tomorrow

MORNING SKY

- Jan 3 Latest onset of morning twilight
- Jan 4 Earth is 147,105,053 km from the Sun (perihelion) at 6:55 UT
- Feb 17 Mercury is 26° west of the Sun
- Mar 20 Venus is 47° west of the Sun
- Mar 29 Saturn is 2.1° to lower right of Venus
- Apr 5 Saturn is 0.3° above Mars
- Apr 28 Neptune might be seen 0.4° right of Venus in scopes (bright twilight)
- May 1 Jupiter is 0.3° to upper right of Venus
- May 16 Europeans can see a partial lunar eclipse before dawn; it is total for the Americas (late evening of the 15th)
- May 18 Neptune is 0.5° above Mars
- May 29 Mars is 0.6° to lower right of Jupiter
- Jun 12 Uranus is 1.5° above Venus
- Jun 17 Mercury is at greatest elongation, 23° west of the Sun; earliest sunrise of the year at latitude 50° north
- Jun 21 Summer begins at the solstice, 9:14 UT
- Jul 4 Earth is 152,098,455 km from the Sun (aphelion) at 7:11 UT
- Sep 23 Fall begins at the equinox, 1:04 UT
- Oct 9 Mercury is at greatest elongation, 18° west of the Sun
- Oct 25 A partial solar eclipse is visible from Europe and parts of Africa and Asia
- Nov 8 A total lunar eclipse occurs for North America before dawn; in Japan and China this is an evening event also on the 8th
- Dec 31 Latest sunrise of the year

Computed by Roger W. Sinnott

AMERICAN ASTRONOMICAL SOCIETY

SKY & TELESCOPE

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Skygazer's Almanac 50°N 2022

FOR LATITUDES NEAR 50° NORTH

What's in the sky tonight?

When does the Sun set, and when does twilight end? Which planets are visible? What time does the Moon rise?

Welcome to the *Skygazer's Almanac 2022,* a handy chart that answers these and many other questions for every night of the year. This version is plotted for skywatchers near latitude 50° north — in the United Kingdom, northern Europe, Canada, and Russia.

For any date, the chart tells the times when astronomical events occur during the night. Dates on the chart run vertically from top to bottom. The time of night runs horizontally, from sunset at left to sunrise at right. Find the date you want on the left side of the chart, and read across toward the right to find the times of events. Times are labeled along the chart's top and bottom.

In exploring the chart you'll find that its night-to-night patterns offer many insights into the rhythms of the heavens.

The Events of a Single Night

To learn how to use the chart, consider some of the events of one night. We'll pick January 9, 2022.

First find "January" and "9" at the left edge. This is one of the dates for which a string of fine dots crosses the chart horizontally. Each horizontal dotted line represents the night from a Sunday evening to Monday morning. The individual dots are five minutes apart.

Every half hour (six dots), there is a vertical dotted line to aid in reading the hours of night at the chart's top or bottom. On the vertical lines, one dot is equal to one day.

A sweep of the eye shows that the line for the night of January 9–10 crosses many slanting *event lines*. Each event line tells when something happens.

The dotted line for January 9–10 begins at the heavy black curve at left, which represents the time of sunset. Reading up to the top of the chart, we find that sunset on January 9th occurs at 4:18 p.m. *Local Mean Time*. (All times on the chart are Local Mean Time, which can differ from your civil clock time by many minutes. More on this later.)

Note that Mercury sets at 5:56 p.m., long enough after the Sun that we might have spotted it, low in the southwestern sky. Moving to the right, we see a dashed line marking the end of evening twilight at 6:16 p.m. This is the time when the Sun is 18° below the horizon and the sky is fully dark.

The ringed planet Saturn sets at 6:20, so we can cross it off tonight's observing agenda. But dim Uranus transits the meridian at 7:17, meaning it is due south at its high point in the sky — a good time to look for it in binoculars.

Polaris, the North Star, reaches upper culmination near 7:43. This is when Polaris stands directly above the north celestial pole (by 39′ or 38′ this year), a good opportunity to check the alignment of an equatorial telescope.

The Pleiades star cluster in Taurus transits the meridian at 8:31, followed by the Orion Nebula (Messier 42) at 10:19 and Sirius at 11:28. Transits of such celestial landmarks help remind us where the constellations are during the night.

Running vertically down the midnight line is a scale of hours. This shows the sidereal time (the right ascension of objects on the meridian) at midnight. On January 9–10 this is $7^h\ 18^m$. To find the sidereal time at any other time and date on the chart, locate the point for the time and date you want, then draw a line through it parallel to the white event lines of stars. See where your line intersects the sidereal-time scale at midnight. (A star's event line enters the top of the chart at the same time of night it leaves the bottom. Sometimes one of these segments is left out to avoid crowding.)

Near the midnight line is a white curve labeled *Equation of time* weaving narrowly right and left down the chart. If you regard the midnight line as the previous noon for a moment, this curve shows when the Sun crosses the meridian and is due south. On January 9th the Sun runs slow, transiting at 12:07 p.m. This deviation, important for reading a sundial, is caused by the tilt of the Earth's axis and the ellipticity of its orbit.

A large Moon symbol appears centered on the dotted line at 12:39 a.m., and the legend at the bottom of the chart tells us it is at first-quarter phase, setting. As the wee hours continue, Antares, a star we usually associate with a later season of the year, rises at 5:33.

The first hint of dawn — the start of morning twilight — comes at 5:59. Then brilliant Venus rises at around 7:18. The Sun finally peeks above the eastern horizon at 7:56 a.m. on Monday morning, January 10th.

Local Mean Time Corrections

Amsterdam	+40	Manchester	+8
Belfast	+24	Montreal	–6
Berlin	+6	Moscow	+26
Bordeaux	+62	Munich	+14
Bremen	+24	Oslo	+17
Brussels	+44	Ottawa	+3
Bucharest	+16	Paris	+51
Budapest	–16	Prague	+2
Calgary	+36	Quebec	–15
Copenhagen	+10	Regina	+58
Dublin	+25	Reykjavík	+88
Geneva	+35	St. John's	+1
Glasgow	+16	Stockholm	–12
Halifax	+14	Toronto	+18
Hamburg	+20	Vancouver	+12
Helsinki	+20	Vienna	–5
Kiev	–2	Warsaw	–24
London	0	Winnipeg	+29
Lyons	+41	Zurich	+24

Other Charted Information

Many of the year's chief astronomical events are listed in the chart's evening and morning margins. Some are marked on the chart itself.

Conjunctions (close pairings) of two planets are marked on the chart by a ☌ symbol on the planets' event lines. Here, conjunctions are considered to occur when the planets actually appear closest together in the sky (at appulse), not merely when they share the same ecliptic longitude or right ascension.

Opposition of a planet, the date when it is opposite the Sun in the sky and visible all night, occurs roughly when its transit line crosses the Equation-of-time line (*not* the line for midnight). Opposition is indicated there by a ☍ symbol. For instance, Saturn reaches opposition on the night of August 14–15 this year.

Moonrise and *moonset* can be told apart by whether the round limb — the outside edge — of the Moon symbol faces right (waxing Moon sets) or left (waning Moon rises). Or follow the nearly horizontal row of daily Moon symbols across the chart to find the word *Rise* or *Set*. Quarter Moons are indicated by a larger symbol. Full Moon is always a large bright disk whether rising or setting; the circle for new Moon is open. *P* and *A* mark dates when the Moon is at perigee and apogee (nearest and farthest from Earth, respectively).

Mercury and *Venus* never stray far from the twilight bands. Their dates of greatest elongation from the Sun are shown by ◗ symbols on their rising or setting curves. Asterisks mark the dates when their disks in telescopes show the greatest illuminated extent in square arcseconds. For example, Venus does so on the morning of February 13th this year.

Meteor showers are marked by a starburst symbol at the date of peak activity and the time when the shower's radiant is highest in the night sky. This is often just as twilight begins before dawn. (Note that we've adjusted the predicted peak of the Southern Taurids, a sparse, ill-defined shower, to fall somewhat earlier than in recent years.)

Julian dates can be found from the numbers just after the month names on the chart's left. The Julian Day, a seven-digit number, is a running count of days beginning with January 1, 4713 BC. Its first four digits this year are 2459, as indicated just off the chart's upper left margin. To find the last three digits for evenings in January, add 580 to the date. For instance, on the evening of January 9th we have 580 + 9 = 589, so the Julian Day is 2,459,589. For European observers this number applies all night, because the next Julian Day always begins at 12:00 Universal Time (noon Greenwich Mean Time).

Rising or Setting Corrections

North Latitude	Declination (North or South) 0°	5°	10°	15°	20°	25°
60°	1	11	23	36	53	80
55°	0	5	10	16	23	32
50°	0	0	0	0	0	0
45°	0	4	8	13	18	24
40°	1	8	15	23	32	43
35°	1	10	20	31	44	68
30°	1	12	25	39	54	72
25°	1	15	30	46	64	84

Time Corrections

All events on this *Skygazer's Almanac* are plotted for an observer at longitude 0° and latitude 50° north, a reasonable compromise for the countries of northern and central Europe. However, you need not be on a boat in the English Channel to use the chart. Simple corrections will allow you to get times accurate to a couple of minutes anywhere in the world's north temperate latitudes.

To convert the charted time of an event into your civil (clock) time, the following corrections must be made. They are given in decreasing importance:

• **DAYLIGHT-SAVING TIME (OR "SUMMER TIME").** When this is in effect, add one hour to any time that you obtain from the chart.

• **YOUR LONGITUDE.** The chart gives the *Local Mean Time* (LMT) of events, which differs from ordinary clock time by a number of minutes at most locations. Our civil time zones are standardized on particular longitudes. Examples in Europe are Greenwich Mean Time (or Universal Time), 0°; Central European Time, 15°E; and Eastern European Time, 30°E. If your longitude is very close to one of these (as is true for London), luck is with you and this correction is zero. Otherwise, to get standard time *add 4 minutes* to times obtained from the chart for each degree of longitude that you are *west* of your time-zone meridian. Or *subtract 4 minutes* for each degree you are *east* of it.

For instance, Copenhagen (longitude 12.5° east) is 2.5° west of the Central European Time meridian. So at Copenhagen, add 10 minutes to any time obtained from the chart. The result is Central European Standard Time.

Find your local-time correction and memorize it. In the table below at left are the corrections from local to standard time, in minutes, for some major cities.

• **RISING AND SETTING.** Times of rising and setting need correction if your latitude differs from 50° north. This effect depends strongly on a star or planet's declination. (The declinations of the Sun and planets are listed in *Sky & Telescope*.)

If your site is north of latitude 50°, then an object with a north declination stays above the horizon longer than the chart shows (it rises earlier and sets later), while one with a south declination spends less time above the horizon. At a site south of 50°, the effect is just the reverse. Keeping these rules in mind, you can gauge roughly the number of minutes by which to correct a rising or setting time from the table above.

Finally, the Moon's rapid orbital motion alters lunar rising and setting times slightly if your longitude differs from 0°. The Moon rises and sets about two minutes earlier than the chart shows for each time zone east of Greenwich Mean Time, and two minutes later for each time zone west.

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