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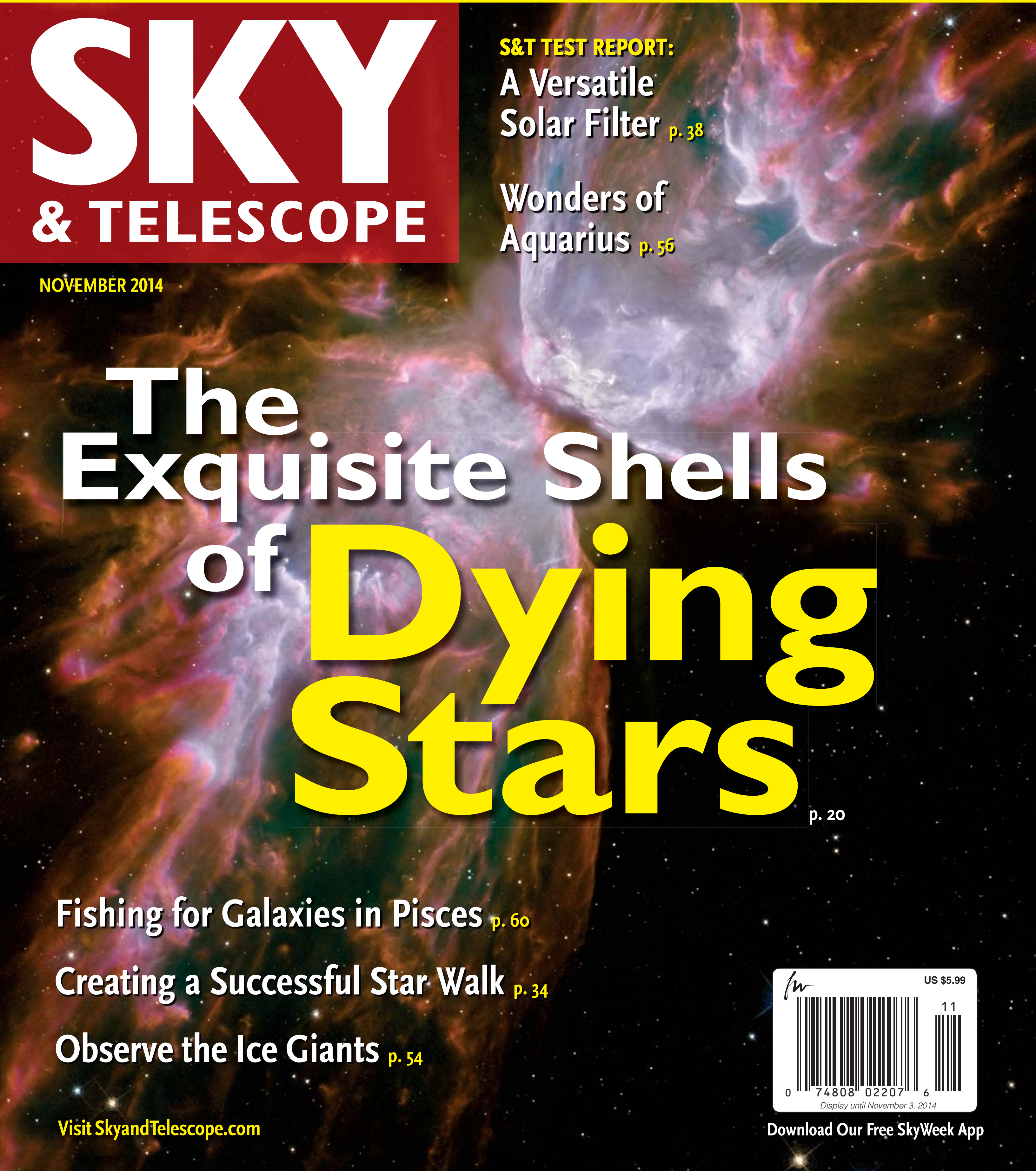

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This 4.3° F.o.V. image of Eta Carina (NGC3372) was imaged by Wolfgang Promper using the Tele Vue-NP127fli & FLI Proline 16803 camera.


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SKY & TELESCOPE
November 2014 VOL. 128, NO. 5

On the cover: NGC 6302's wings are one example of the mysterious shapes of planetary nebulae.

NASA / ESA / HUBBLE SM4 ERO TEAM

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OBSERVING NOVEMBER

S&T TEST REPORT

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November 2014 Digital Extra

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- **Dwarf Galaxies Packed a Punch**
  Watch a simulation video of reionization.

- **How to Orbit a Comet**
  Watch a video of the Rosetta spacecraft's planned orbit around its comet.

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Image by Anvar Ghadery

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Howard Trottier of South Okanagan, British Columbia, took and processed this image of the Cocoon Nebula.

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Two New Editors

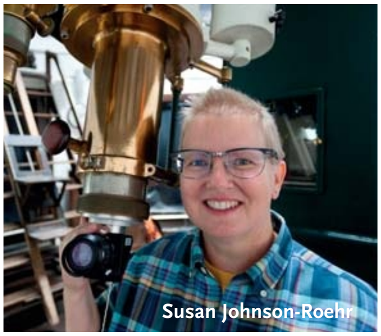
ON A WHITEBOARD in my office, I have written some of my favorite aphorisms. One, from inventor Charles Kettering, says, "The world hates change, yet it is the only thing that has brought progress."

S&T is going through changes that include the development of new products and services. Contributing editors Kelly Beatty and Dean Regas have recorded a series of videos about choosing and using telescopes, and they'll be available shortly. We have finished producing a beautiful and unique globe that showcases Earth's planetary nature, which will be available soon. And we've put together a gorgeous 2015 wall calendar that's full of useful observing information and is now for sale at **shopatsky.com**.

A big part of this change is bringing in new people with diverse skill sets, who can help us seize new opportunities. With that in mind, I'm extremely excited to introduce two new staffers: equipment editor John Gianforte and observing editor Susan Johnson-Roehr. Both are talented writers and communicators, and their work will start to appear in next month's issue.

John Gianforte

JAMES POULIOT / NHPR



Susan Johnson-Roehr

KEVIN O. MOONEY

An astronomy aficionado since age 7, John has taught astronomy and conducted research for years in the University of New Hampshire system, where he has operated a wide range of astronomical equipment. He has a master's degree in astronomy from Swinburne University and has experience in engineering and working for planetariums. "I'm most excited about continuing *S&T*'s great tradition of bringing the modern tools of astronomy into the hands of amateur astronomers and to help continue to close the gap between what professionals can achieve and what amateurs can do for the science of astronomy and for their own enjoyment." Check out his blog at **www.theskyguy.org**.

Susan, who goes by the initials J.R., has a Ph.D. in architecture from the University of Illinois. Her dissertation was about the history and design of astronomical observatories in South Asia. She has been a dedicated telescopic and naked-eye observer since childhood. "I'm thrilled to be joining *S&T* as the observing editor," she says. "I enjoy working with words and writing, and am looking forward to using my editing experience to share my love of amateur astronomy and observing with *S&T*'s readers."

On a final happy note, *S&T* web editor Monica Young recently gave birth to her second child, a boy named Rowan. Welcome to the world Rowan!

Robert Naeye
Editor in Chief

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A Forgotten Giant?

This April, my wife and I spent two weeks in France. While in Paris we saw many of the typical tourist sites, such as the Eiffel Tower and the Arc de Triomphe. One of the places we visited was a famous cemetery, Père Lachaise. Most people who come to this cemetery are looking for the burial places of famous musicians such as Frédéric Chopin or Jim Morrison. I, however, went there on a mission to find one of the most famous astronomers of all time, Charles Messier (1730–1817).

Near the entrance of the cemetery is a large map with the locations of all the famous people buried there. I searched and searched, but could not find Mr. Messier. I guess that outside of astronomy circles he isn't famous enough to warrant a mention on the cemetery map. Luckily, I knew from previous online research (Wikipedia) that Messier's final resting place is located in section 11. My wife and I spent almost an hour looking for the grave. We began to wonder, did Wikipedia steer us wrong?

It was my wife who finally found him. The gravestone is very plain and worn, so much so that we had difficulty reading it, but it was indeed the grave marker we were looking for. It is hard to describe what exactly I felt at that moment. My wife was shocked. She said to me, "But he owns the night sky, and there is nothing to commemorate that."

As an astronomer, I felt embarrassed that the final resting place of the man who gave us the Messier Catalog, and is still such a towering figure in astronomy, has been so neglected. I didn't have anything astronomy related with me to leave at the grave site, except my copy of *Sky & Telescope*. I took out the subscription card and placed it on the grave, under a stone to anchor it, just in case I wasn't the only astronomer looking for the site.

Does anyone have any information as to whether there are any plans to restore his gravestone?

Jason Todoroff
Horning's Mills, Ontario

Despite Charles Messier's renown in astronomy circles, his remains lie rather ignobly in Paris.

JASON TODOROFF

Fruits of Public Outreach

Gary Andreassen's Focal Point piece "Setting Expectations" (*S&T*: June 2014, page 86) set off a lovely recollection of the years I did a weekly sidewalk astronomy gig at the Palm Springs farmers' market. I would set up my Astroscan and Quantum 4-inch and, since it was a highly light-polluted area, restrict my targets to the Moon and whichever bright planets were available.

For the Moon gazers I had a short commentary on why Earth's surface doesn't look like the Moon's. If Saturn gleamed in the Quantum's eyepiece, I would lean in close and softly say, "Take your time; it's just you and the telescope. You should see a white blob kind of dancing around a bit." Then I'd encourage them to look for various features in the rings and on the planet itself.

Inevitably, there would after a few moments come a soft and lengthy, "Wow!" This would often be followed by a sudden pull-back from the eyepiece and the question, said with a cocked eyebrow, "Are you showing me a slide?"

Smiling indulgently, I would reply, "If I were showing you a slide, I'd be showing you something bigger, and in color, wouldn't I?" This always served to convince them and they would go back to the eyepiece in a deeply appreciative mood.

Two expressions of thanks stand out in particular. On one occasion, a boy of

about 10 remarked to his parents as they were leaving, "That was the best thing at this fair." On another occasion, two people seemed vaguely familiar. They told me that they'd been in Palm Springs the previous year. This year, they'd made a point of finding me, because their son (who had been with them the year before) had asked them to tell me something: "Our son had been saving up for a truck but he gave that up. Now he's saving for a telescope!" I changed a life!

Jim Sitton
Banning, California

Poetic Cosmology

What a marvelous article Alan MacRobert had in the July issue (page 18) on inflation cosmology, the latest discoveries in the field and their implications, and what further research may find — Hawking radiation, gravitational waves and quantized gravity, a multiverse, infinite atom-by-atom repetitions of Earth and its inhabitants, multiple Big Bangs, never-ending inflation, et cetera . . . it's such a wonderful and exciting time in which we live. William Shakespeare came to my mind. If only he had known how prescient his words mouthed by Hamlet were: "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."

Ron Adams
Rochester, New York

I read the news about the "proof" of cosmic inflation and wanted to offer something else that might help us ponder the origin of the universe: it's a poem I wrote in 2006 called "Cosmolo . . . Gee."

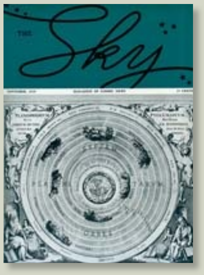
The universe began a long time ago.
How and when, we'll never know.
Did it begin with a great big bang?
Will it end in a tiny black hole?
Is it one continuous loop?
Again, we'll never know.
How does matter begin in a world without anything in it?
How does life begin and does it begin the first minute?
Do you think we will ever be able to go back to the beginning of time?
And will we find out the future there, too?
Is there reincarnation and déjà vu?
Is the speed of light the ultimate limit?
Does $E=mc^2$ hold true for antimatter, too?
And in the building blocks of the universe is $E=mc^2$ just one plus one equals two?
The answers to these might keep you up at night.
And how do you prove if you are wrong or right?
And imagine our surprise if we can someday go back to the beginning
of time and we hear someone say . . . Let there be light!

Robert Barrows
San Mateo, California

Write to Letters to the Editor, *Sky & Telescope*, 90 Sherman St., Cambridge, MA 02140-3264, or send e-mail to letters@SkyandTelescope.com. Please limit your comments to 250 words.

75, 50 & 25 Years Ago

Roger W. Sinnott



November 1939

A Comet Returns "It seems probable that Rigollet's comet, discovered in Taurus on July 27, 1939, is identical with a comet discovered by Caroline Herschel in 1788. Leland Cunningham of the Harvard Observatory has reported that the orbits of the two comets appear to check at practically every point. If the comets are not identical, they must then belong to the same family."

They are identical. Comet 35P/Herschel-Rigollet has a period of about 160 years and won't be back till the end of the 21st century.

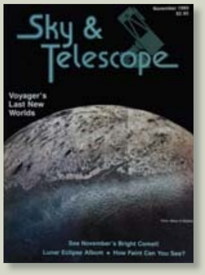
November 1964

Oval Globulars "Many of the globular star clusters show slightly elliptical outlines, and this flattening has long been interpreted by astronomers as due to rotation. Now a direct demonstration of the rotation of the southern cluster Omega Centauri has been announced by the Astronomer Royal, R. v. d. R. Woolley. . . .

"Omega Centauri as a whole is receding from Earth at about 230 kilometers per second. If this cluster is rotating around an axis that is more or less perpendicular to our line of sight, then all its member stars on one side of the axis should have radial velocities greater than 230, on the other side less than 230 kilometers per second. . . .

"That this is indeed the case for Omega Centauri was demonstrated from observations by G. A. Harding with the 74-inch reflector of Radcliffe Observatory. [Dr. Woolley] comments: '. . . the elliptical shape of the cluster is a consequence of a rotation considerably greater than galactic rotation. This latter result disposes of the view that the elliptical shape is a consequence of galactic tidal forces.'"

The shapes of globular clusters and the motions of their member stars are still being actively studied today. Recent studies confirm rotation is important in Omega Centauri, but other effects (including galactic tidal forces) might dominate in other clusters.



November 1989

Hipparcos Gloom "The star-mapping mission of the European Space Agency's (ESA) Hipparcos satellite may be severely curtailed even though technicians successfully raised the lowest point of its highly elliptical orbit. . . . ESA scientists are studying the damage inflicted on the solar cells by the Van Allen radiation belts. . . . By late October, ESA officials hope to be able to assess fully the condition of the spacecraft and plan a scaled-back mission or perhaps approve money for a replacement satellite."

The failure of a booster rocket on the launch vehicle had left the new satellite in an unintended orbit. But ESA scientists proved so successful in their software and control workarounds that the mission eventually met or surpassed all prelaunch expectations. Hipparcos measurements now define the astronomical reference frame in visible light. Its successor, Gaia (S&T: Apr. 2014, p. 10), also has had some startup problems (see page 14) but has now begun its science mission.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MISSIONS | Rosetta Catches Its Comet

ESA / ROSETTA / MPS FOR OSIRIS TEAM MPS / UPD / LAM / IAA / SSO / INTA / UPM / DASP / IDA (2)

Rosetta's OSIRIS narrow-angle camera took this image of Comet 67P/Churyumov-Gerasimenko on August 3rd, just a couple of days before the spacecraft's rendezvous with the nucleus. At the time the craft was 285 kilometers away, resolving features down to 5.3 meters (17 feet) wide.

At 10:30 Universal Time on August 6th, the European Space Agency reported that its Rosetta spacecraft had completed its decade-long voyage to Comet 67P/Churyumov-Gerasimenko (C-G) (*S&T*: Aug. 2014, p. 20) and reached the comet successfully.

The spacecraft had been gradually decelerating since May, so by the day of the rendezvous, it matched Comet C-G's speed (nearly 56,000 kilometers per hour or 35,000 mph) to within walking pace. To enter orbit, Rosetta commenced a 6-minute rocket firing that pushed it onto the first leg of a temporary triangular track around the comet, at a distance of roughly 100 km (60 miles).

When this issue went to press, the mission team planned to edge Rosetta into an elliptical orbit over the course of several weeks, before settling into a tighter circular orbit about 10 km above Comet C-G. This method of gradually transitioning into orbit conserves fuel and enables the team to estimate the nucleus's mass.

After reaching the comet, the craft began mapping the icy body to find a suitable location for its robotic lander, Philae. Mission planners aim to dispatch Philae on November 11th. This will put both Rosetta and Philae in position to accompany the comet as it swings around the Sun, reaching perihelion in August 2015. (Philae almost certainly won't survive the entire trek.)

The mission will be the first time that a spacecraft has so closely observed a comet transition from dormant to active. With such unprecedented data on the comet's physical properties and activity, Comet C-G promises to be what Mark McCaughrean (ESA Senior Science Advisor) calls a veritable "scientific Disneyland."

Prior to this mission, astronomers observed the comet using only ground-based telescopes. So when Rosetta closed in on the comet in mid-July, scientists were surprised to discover that it was a contact binary — a comet made up of two smaller components. Initial images showed what looked like a rubber ducky, but observations taken just prior to the rendezvous (above) show something more akin to a *Star Trek* phaser.

This discovery has a couple of important implications for the robotic lander. Philae runs on solar power, so the amount of sunlight that reaches the landing site is key. "With the irregular shape, there will be more shadowing and changes in illumination to consider," says mission team member Joel Parker (Southwest Research Institute). He also notes that the uniformity of the two components' makeup is a factor in choosing Philae's landing site — pre-landing measurements could reveal one to be more chemically and physically interesting than the other.

Once the lander reaches the surface, it will perform in situ measurements of the comet's nucleus as the icy body reacts to the Sun's warmth. The lander might only last a few days in the increasingly dangerous and dusty environment, but mission planners hope for months of data collection.

The shape of Comet C-G was just one of many surprises. Astronomers observed the nucleus "sweating" two glasses of water (about 300 grams) per second in June, when it was still 583 million km from the Sun. The comet was less active in July, an on-and-off pattern expected for a comet just waking up. Mission planners hope that the level of outgassing remains low for now, because outgassing can cause additional drag forces that make it difficult to fly the spacecraft and aim the lander.

■ **EMILY POORE & MARIA TEMMING**

This close-up from August 6th reveals boulders lying in a smooth region on the comet's nucleus. The area shown is about 2 km across.

X-RAY ASTRONOMY
Evidence that We Live in a (Local) Bubble

Astronomers have confirmed that a soft X-ray glow permeating the sky has two sources: one inside the solar system, one outside.

This background emission is an unexpectedly intense glow of soft X-rays blanketing the sky. X-rays at these low energies are easily absorbed by interstellar clouds, so astronomers previously concluded that they must originate within a few hundred light-years of the Sun.

To explain the X-ray background, scientists proposed the *local hot bubble* — a cavity in the interstellar medium spanning hundreds of light-years that's filled with million-degree, X-ray-emitting gas. Astronomers suspect that a nearby supernova explosion carved the bubble out hundreds of thousands or even millions of years ago.

But the local bubble paradigm was later challenged when astronomers observed X-rays emanating from a comet as it passed through the solar wind. After this discovery, many began to wonder whether the X-ray background might be produced by the solar wind interacting with other solar system material.

Massimiliano Galeazzi (University of Miami) and colleagues investigated the solar wind's X-ray production by examining the *helium focusing cone*, a "breeze" flowing into the solar system as our system passes through the Local Interstellar Cloud. The Sun's gravity focuses the helium into a cone shape. Neutral gas is relatively abundant in this cone, making it a good place to test the solar wind's X-ray-making prowess.

Galeazzi's team found that the X-ray emission created by the solar wind would only account for about 40% of the X-ray background. This confirms the existence of a local hot bubble in interstellar space that produces the bulk of the X-ray background, although the result suggests that the bubble's hot gas is slightly less dense than scientists earlier estimated, the team concludes July 27th in *Nature*.

The confirmation of the local hot bubble is a significant development in our understanding of the interstellar medium, which in turn is crucial for understanding star formation, our galaxy's structure, and galaxy evolution.

■ **MARIA TEMMING**

IN BRIEF

New Radio Burst Deepens Mystery. A newly detected fast radio burst (FRB) confirms that similar bizarre signals are of cosmic origin. Before now, astronomers had discovered the six known FRBs using the 64-meter Parkes radio telescope in Australia; four of these came to light last year (*S&T*: Oct. 2013, p. 10). The lack of findings by other facilities led to speculation that these signals might have originated on or near Earth. But Laura Spitler (Max Planck Institute for Radio Astronomy, Germany) and colleagues have found another burst in data from Arecibo Observatory, the team reports in the August 1st *Astrophysical Journal*. Astronomers continue to debate whether FRBs are from flaring stars inside the Milky Way or from other objects — e.g. neutron stars — lying billions of light-years away.

■ **SHANNON HALL**

Novae Surprise with Gamma Rays. Astronomers have detected gamma-ray emission from three classical novae — V959 Monocerotis 2012, V1324 Scorpii 2012, and V339 Delphini 2013 — and the unexpected discovery has left them perplexed. Gamma rays suggest that each nova's blast wave crashed into surrounding, slower-moving material, but there shouldn't be anything lying around these white dwarfs for the blast to smack into. The same process likely operated in all three novae, the Fermi-LAT Collaboration reports in the August 1st *Science*. That's puzzling, because the white dwarfs differ in mass, composition, and binary-system setup. Where and how the gamma rays originate remains unknown.

■ **CAMILLE M. CARLISLE**

Is Mercury a Hit-and-Run Survivor? Many astronomers think that Mercury ended up with its huge iron core after a smaller object crashed into it and tore off its outer layers. But Mercury likely wouldn't have its current volatile-rich exterior if it were an impactor's target (*S&T*: Apr. 2012, p. 26). A new computer model, detailed by Erik Asphaug (Arizona State University) and Andreas Reufer (University of Bern, Switzerland) in July 6th's *Nature Geoscience*, suggests that proto-Mercury itself threw the punches. If the body sideswiped much bigger objects one or more times, the encounters would have progressively stripped off most of its outer layers. This scenario works if the solar system's big rocky protoplanets had differentiated into iron-rich cores and silicate exteriors prior to these collisions. Afterwards, Mercury swept up the lighter elements that make up today's surface.

■ **J. KELLY BEATTY**

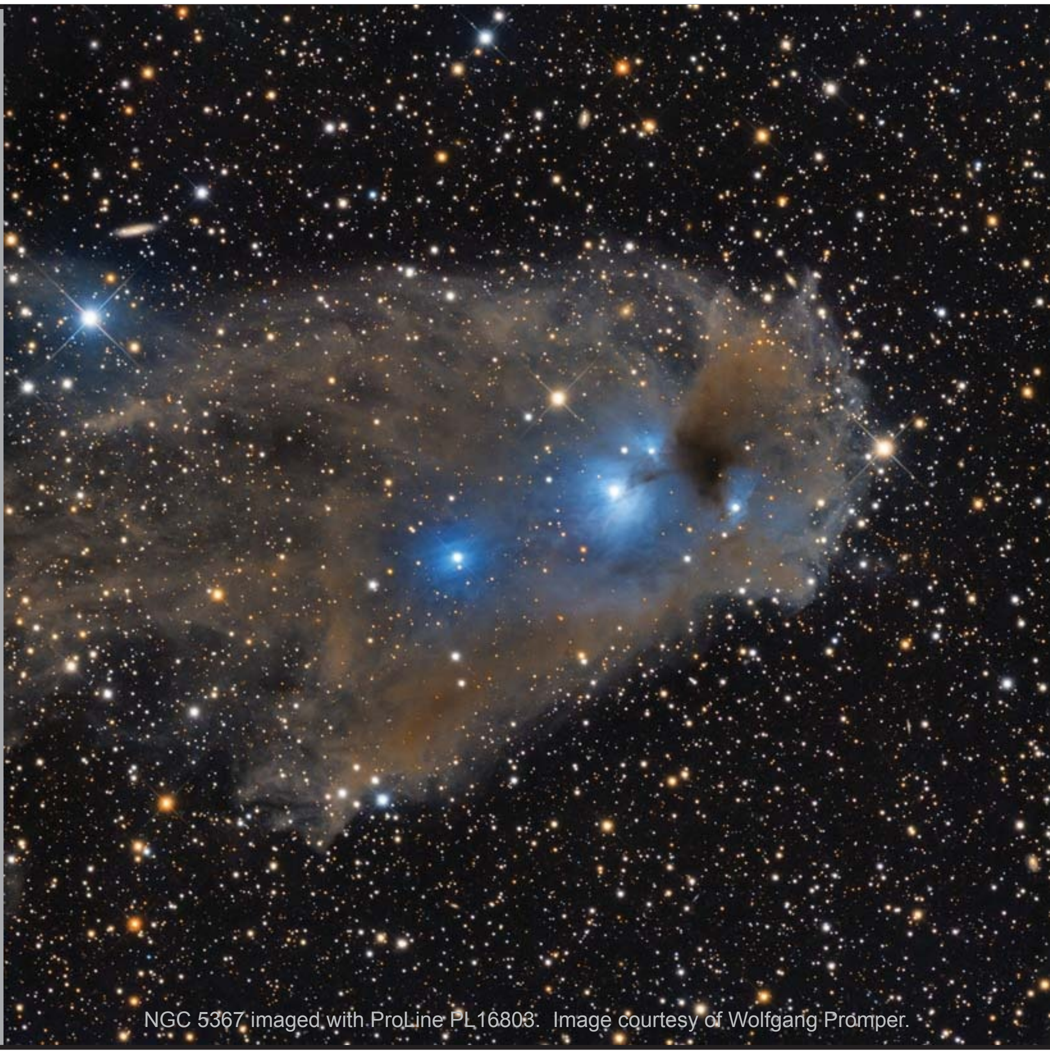
NASA Gears Up for Next Mars Rover. In a NASA press conference on July 31st, mission planners unveiled the seven scientific instruments that the agency's Mars 2020 rover will use to explore the Red Planet. These instruments will expand on Curiosity's research by not only searching for potential signatures of ancient life, but also studying the environmental factors that will affect a future human presence on the planet. One exciting feature is the Mars Oxygen ISRU Experiment (MOXIE), which will generate oxygen from atmospheric carbon dioxide. Other instruments will study the planet's chemical composition and mineralogy, as well as search for organic compounds that could hint at past life. The rover will also image the landscape and study the subsurface as deep as a half kilometer.

■ **MARIA TEMMING**

Gaia Belatedly Starts Work. ESA announced on July 29th that its Gaia star surveyor, launched in December 2013 (*S&T*: Apr. 2014, p. 10), is finally ready to begin its census of roughly 1 billion stars. Gaia faced a few unexpected problems after launch, such as a higher level of stray light invading the field of view than anticipated. Water also froze over some of the optics, requiring the mission team to heat them and melt the ice. However, the team now says the spacecraft is cleared for science duty. Mission planners anticipate they will be ready to release the first catalog of Gaia data in the summer of 2016.

■ **MARIA TEMMING**

The KAF-50100 has 3X more resolution than the KAF-16803



NGC 5367 imaged with ProLine PL16803. Image courtesy of Wolfgang Promper.

The KAF-50100 has 1/3 more area than the KAF-16803

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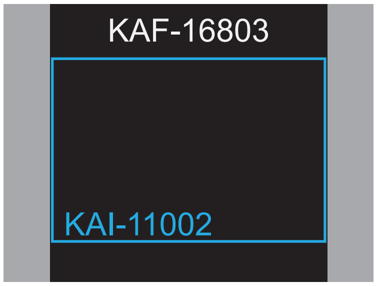

The gray box above is the actual size of the KAF-50100 imaging area. Compare to the KAF-16803 (black box) and KAI-11002 (blue box).

KAF-50100:
8136 x 6132
6 micron pixels

The world's first KAF-50100 sensor with microlenses is the result of a year-long collaborative effort between ON Semiconductor (formerly Truesense, formerly Kodak) and Finger Lakes Instrumentation. Our goal: to create a sensor with both high resolution and excellent quantum efficiency (QE). The significantly boosted QE of the new KAF-50100 sensor brings it in line with popular sensors such as the KAF-16803 and KAI-11002 but with much higher spatial resolution. Initial tests indicate that the microlensed KAF-50100 has more than double the quantum efficiency of the original sensor.

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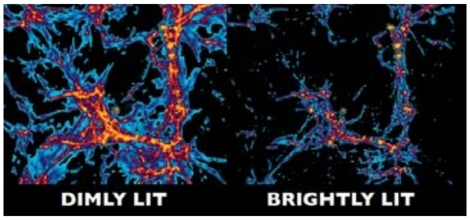
INTERSTELLAR SPACE | The Mystery of the Missing Light

The local universe appears to be missing a whole lot of ultraviolet photons. Juna Kollmeier (Carnegie Observatories) and colleagues report their discovery of this "photon underproduction crisis" in a study published in the July 10th *Astrophysical Journal Letters.*

The ultraviolet radiation permeating the universe has two main sources: quasars and young, hot stars. Their UV photons interact with the sparse gas pervading intergalactic space, converting neutral hydrogen atoms into electrically charged ions. Quasars probably account for most of the extragalactic UV background, because ultraviolet light from stars is usually absorbed by their host galaxies before it can reach the intergalactic hydrogen.



B. OPPENHEIMER / J. KOLLMEIER

A simulation of intergalactic hydrogen in a "dimly lit" universe compared with one of a "brightly lit" universe. Observations match the right-hand picture, but simulations using only the known cosmic ultraviolet sources produce the much thicker structures on the left.

Observations of the distant cosmos (i.e. stuff that existed about 12 billion years ago or earlier) show near-perfect agreement between the number of UV sources and the ionization rate of intergalactic hydrogen. But Kollmeier's team found that in the local universe, the amount of UV radiation produced by known sources was *one-fifth* the amount needed to account for observations of local intergalactic gas.

The crisis shows a significant discrepancy between our current models and our observations of the present-day universe, but none of the possible explanations is totally satisfactory. Astronomers might need to completely reevaluate how much UV radiation comes from quasars and young stars, as well as how much stellar radiation escapes the stars' host galaxies.

A more exciting alternative is that hitherto undiscovered sources dominate the local universe's UV background, such as decaying dark matter. "You know it's a crisis when you start seriously talking about decaying dark matter!" says study coauthor Neal Katz (University of Massachusetts, Amherst).

■ **MARIA TEMMING**

COSMOLOGY | Dwarf Galaxies Packed Mighty Punch

Light from the puniest galaxies played a bigger role in shaping the early universe than previously thought.

Right after its birth, the young universe was filled with a hot, dense fog of ionized gas. Over time it expanded and cooled, allowing electrons and protons to recombine into neutral atoms. Giant clouds of these primordial elements collapsed to form the first stars, whose ultraviolet rays heated the surrounding medium, once again stripping the hydrogen of its electrons in the *epoch of reionization*. This epoch marked the last major change in the early cosmos's makeup, because the universe remains largely ionized today.

Studies of distant quasars suggest the universe became fully reionized roughly 1 billion years after the Big Bang. On the other hand, studies from the cosmic microwave background (CMB) suggest the universe was 50% ionized around 400 million years after the Big Bang. Astronomers have had no luck in re-creating both in one coherent model.

John Wise (Georgia Institute of Technology) and colleagues attacked the mystery by using advanced computer simulations to re-create the conditions that likely occurred during the epoch of reionization. Contrary to conventional wisdom, they included dwarf galaxies, galaxies that are 1/1000 the mass and 1/30 the size of our Milky Way Galaxy.

Astronomers thought that the radiation from stars in nearby, larger galaxies was so strong that it would suppress their tiny neighbors, cutting off the formation of UV-producing stars. But the team found that researchers have wrongly overlooked the role played by dwarf galaxies. The simulations suggest that dwarf galaxies contributed nearly 30% of the ultraviolet light during the process of reionization. The dwarfs had such a big impact because a larger fraction of ionizing photons are able to escape dwarf galaxies (50%) as opposed to larger galaxies (a mere 5%).

Wise's team also found that the universe was fully ionized at 860 million years after the Big Bang, which fits with both the quasar and CMB results. The team's findings appear in the August 11th *Monthly Notices of the Royal Astronomical Society.*

The team's simulation naturally provides a gradual timeline that tracks the progress of reionization over hundreds of millions of years. "The smallest galaxies first dominate at early times; however, they basically kill themselves off by blowing out their gas through their own supernovae and heating their environment," says Wise. "Afterwards, larger galaxies (but still much smaller than the Milky Way by about 100 times in mass) take over the job of reionizing the universe." ✦

■ **SHANNON HALL**

Watch a simulation video of reionization at work at skypub.com/dwarfsreionize.

In the Days of the Comet

A comet's close passage to Mars reminds us of our own vulnerability.

I'M NEVER SURPRISED when Rob McNaught discovers a comet. As a postdoc, I spent an evening observing with him at Siding Spring Observatory in Eastern Australia. When night fell, I had my first really good look at the Southern sky. I could not have had a better guide, and with McNaught's deep-sky familiarity and encyclopedic knowledge, it was clear that he would instantly notice any faint intruders wandering into this territory.

In January 2013 he found a comet on a surprising path. Comet Siding Spring was apparently going to collide with Mars on October 19, 2014. Initial estimates suggested a nucleus up to 30 miles (50 km) across, substantially larger than the doomsday object that struck Earth 65 million years ago, leaving fire, darkness, and mass extinction in its wake. Such an event might spell big trouble for our spacecraft currently on Mars, but would also provide us with front-row seats to a phenomenal planet-altering collision.

But upon further observation and calculation, this comet only turned out to be half a mile across, and it will miss Mars by about 80,000 miles. That's probably still close enough to splatter the atmosphere with hydrogen gas and dust. A resulting meteor shower might be observable with spacecraft.

In a celestial coincidence, Comet Siding Spring will arrive near Mars less than a month after two spacecraft get there. NASA's MAVEN craft enters orbit on September 22nd, followed by India's Mars Orbiter Mission on September 27th. MAVEN is designed to study the Red Planet's upper atmosphere, so this should be a golden opportunity to learn more about the infrequent but inevitable interactions of planets and comets.

There's also an unsettling aspect to this. We hear a lot about the threat of near-Earth asteroids that could hit our planet. But a comet like this, plunging at a frightening pace from the near-interstellar darkness, would be a more formidable threat. In contrast to the many years or decades of warning we'd likely have for a menacing asteroid, a comet can appear with little notice. This Martian near-miss will occur less than two years after McNaught's discovery. If the wrong comet appeared, we might only have a similar interval between detection and Earth impact. The chances of this happening in any year are minuscule. But recent solar system history teaches us that if we watch for long enough, then seemingly unlikely objects and events will eventually materialize.

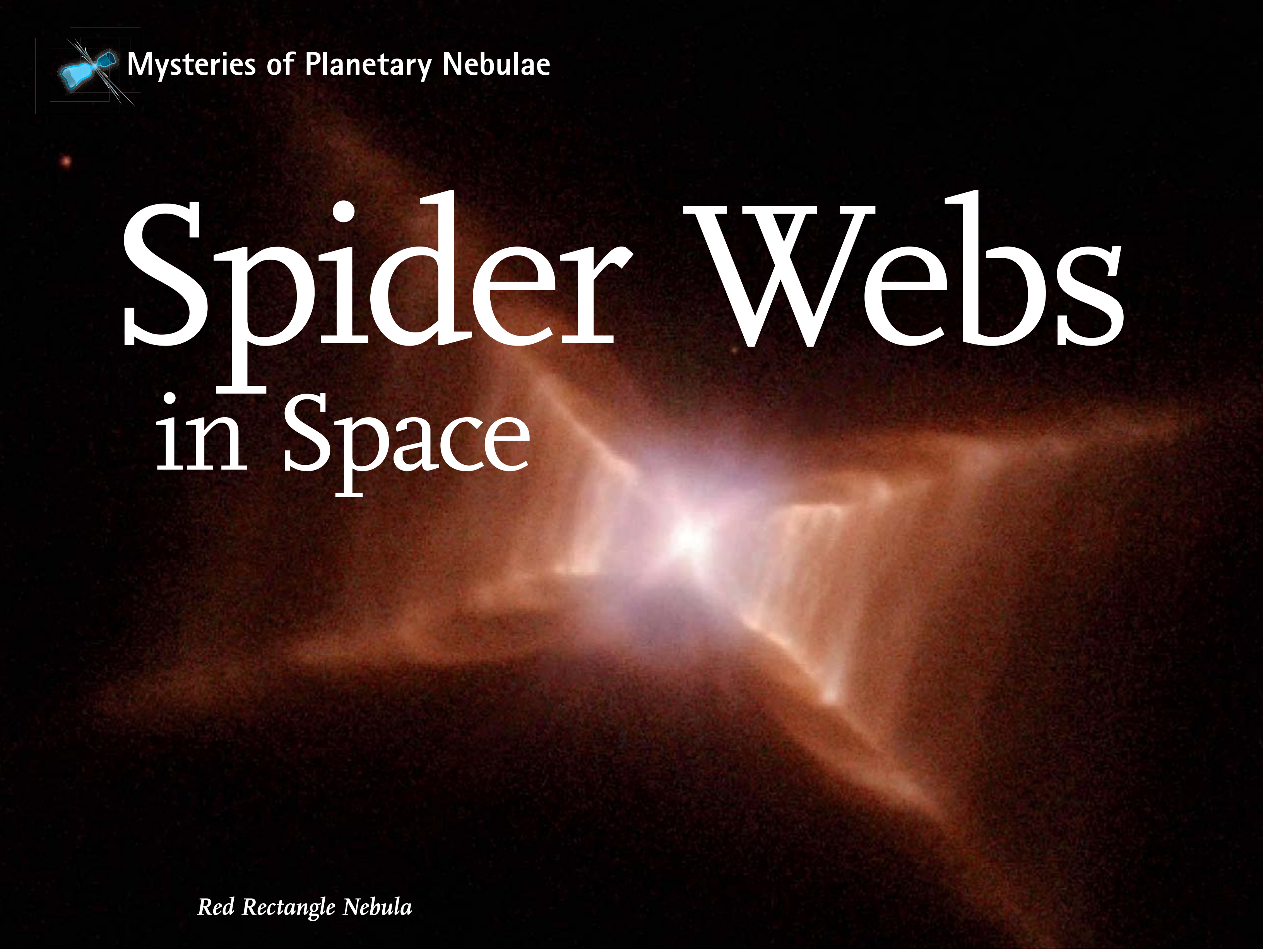
Comet Siding Spring presents more opportunity than risk. But the plausibility of a large Martian impact serves as a reminder that the apparent isolation of planetary distance can be abruptly shattered, and that given enough time, the constancy and safety of our world are illusory.

Meanwhile, the European Space Agency's Rosetta spacecraft has just pulled alongside Comet 67P/Churyumov-Gerasimenko for more than a year of close observation (page 12). The first pictures are riveting. Beyond the treasure trove of information about planetary origins, such missions are also valuable for the longer-term project of threat mitigation. Deepened understanding of cometary structure and evolution will sharpen our ideas about how to redirect or disrupt one, should that be necessary someday (*S&T:* Dec. 2010, p. 22).

Most likely, by the time a truly scary comet comes our way, we'll have systems in place to detect and deflect it. In the meantime, I'm glad — for many reasons — that the Rob McNaughts of this world are keeping watch. ✦

***David Grinspoon** is an astrobiologist and author at the U.S. Library of Congress. Follow his escapades on Twitter at @DrFunkySpoon.*

Spider Webs in Space



Red Rectangle Nebula

NASA / ESA / HANS VAN WINCKEL (CATHOLIC UNIVERSITY OF LEUVEN) / MARTIN COHEN (UNIVERSITY OF CALIFORNIA, BERKELEY)

Astronomers are still puzzled by how stars create the bizarre variety of planetary nebulae in our galaxy.

Robert Zimmerman

In October 1973, the 4-meter Mayall Telescope at Kitt Peak in Arizona was just starting operations. Ted Gull (now at NASA/Goddard Space Flight Center) was using the telescope to produce some spectacular test images.

Seeing the images, Martin Cohen (University of California, Berkeley) was impressed and asked Gull to use the telescope to photograph a particular star Cohen had spotted earlier that year using a U.S. Air Force sounding rocket. This star, HD 44179, was intriguing because of its unusual brightness in the infrared.

Gull's first images baffled him. In red wavelengths the star looked like a rectangle. "What in the world is going on with this system?" said Gull. To make sure the shape wasn't an artifact he took another image of a nearby star. It was a sharp point. HD 44179, however, remained "a crisp, rectangular object."

And thus the Red Rectangle was found.

Observations in the ensuing decades have not only produced even more amazing images of this strange angular object, they have added further mysteries. In 2003 a Hubble Space Telescope image revealed some inexplicable

STELLAR WEB The nebula surrounding HD 44719, known as the Red Rectangle, has baffled astronomers since its discovery in the 1970s. Explanations range from a bipolar flow seen at an odd angle to light leaking out through gaps in a dusty doughnut of material.

features, including four spokes on which were hung a series of "ladder rungs," or nested rectangles of increasing size. The structure almost looks as if a giant spider was weaving a web in space, stringing its thread from one beam of light to another.

What is really most astonishing about the Red Rectangle is that it is actually typical for a planetary nebula. In the past 20 years Hubble has given us our first high-resolution look at a large number of these weird and enigmatic objects and found that, more often than not, they are as complex, as astonishing, and as baffling as the Red Rectangle.

From this new data astronomers are beginning to put together a coherent outline of the origins and shapes of planetary nebulae. That picture is also giving astronomers a deeper understanding of the evolution of Sun-like stars. "By figuring out how these shapes transform we can learn to understand how stars really die," explains Raghvendra Sahai (NASA/JPL).

Even more exciting, scientists are beginning to suspect that the presence of exoplanets might explain the strange shapes of some planetary nebulae. "I like to say that we are putting the 'planet' back into 'planetary nebulae,'" adds Sahai.

The First Discoveries

Although the first planetary nebula, the Dumbbell Nebula (M27), was discovered by Charles Messier in 1764, it was William Herschel who gave these objects their name when he conducted his survey of the Northern sky in the late 1700s. They reminded him of Uranus, the planet he had just discovered — even though he knew that what he saw was absolutely not a planet. All told, Herschel found 33 planetary nebulae, though of these he mislabeled 13 as something else. (He also dubbed another 59 objects as planetary nebulae that turned out not to be.)

Since then, and especially since the repair of Hubble in 1993, scientists have found planetary nebulae in a bewildering variety of shapes. About a quarter or more have bipolar lobes extending out from their centers. About 20% have multiple lobes. Others appear oval, some look like barrels, and some resemble cylinders that have been squeezed in the center. A few even have spiral arms almost like galaxies. In a number of cases the central star is often offset from the center of the nebula, even when that nebula is highly symmetrical.

And then, like the Red Rectangle, there are some whose complex patterns and shapes are too difficult to describe in a mere sentence. You have to look at a high-resolution image of each to understand it.

Astronomers have so far identified approximately 3,500 planetary nebulae in the Milky Way. Based on a count of the planetary nebulae within 2 kiloparsecs (6,500 light-years) of the Sun, they extrapolate that the Milky Way's population includes anywhere from 11,000 to 28,000.

Stellar Evolution

Planetary nebulae form during a very short phase late in the life of Sun-like, low-mass stars. During this stage the star is known as an asymptotic giant branch (AGB) star, the name referring to the location of these stars on the Hertzsprung-Russell Diagram (*S&T*: June 2014, p. 32).

AGB stars are somewhat unstable. In this stage the star's core is mostly oxygen and carbon, surrounded by an inner shell of helium with an outer shell of hydrogen. Most of the fusion goes on in the outer hydrogen shell, which produces helium that rains down onto the helium shell below, increasing its density. Eventually this increased density ignites the helium in an explosive pulse called a helium flash, pushing against the hydrogen shell so that it expands, becomes less dense, and stops burning.

The helium shell burns for a while, then shuts down. The hydrogen shell then settles, becomes dense enough to again ignite, and kicks off the whole cycle again.

This helium-flash process repeats many times, and during this phase the star begins to send out a wind of high-density dust made of carbon and other heavy elements dredged up from the dying star's core. This dust drags gas from the star's fluffy outer envelope with it. The winds spew out anywhere from half to 90% of the star's mass and form a dense envelope surrounding the star.

As these low-mass stars burn off the last bits of their hydrogen and helium fuel while losing mass, their cores begin to evolve into a white dwarf, made up of the carbon and oxygen core that's not dense enough to burn. The wind changes from a slow high-density wind into a fast

NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA) low-density wind that collides with the older circumstellar cloud. At the same time the star's surface temperature increases to as high as 30,000 kelvin, and the intense radiation ionizes the surrounding gas clouds, causing them to glow.

Thus begins the planetary nebula phase of the star's life. The complex interaction between these two clouds, plus ultraviolet radiation from the star's hot surface, combine to shape the planetary nebula and make it visible.

The transition from an AGB star to a planetary nebula happens very quickly, no more than a few centuries and sometimes as short as a few decades. The planetary nebula phase that follows will then last a few tens of thousands of years. Lacking nuclear fuel, the star's winds eventually die off, the nebula steadily dissipates away, and we are left with nothing but a small and very compact white dwarf star that will slowly cool and fade away.

Shaping the Nebula

Very few planetary nebulae are round. Even those few that appear round might only look that way because we happen to be viewing them at a particular angle. Somehow, the shaping process turns the spherical AGB cloud into something much more complex. But astronomers lack a good theory to explain this change. Instead, they have many theories, none of which seems to fit all the observations. (See page 25 for three of the possibilities.)

For example, one theory posits that because the density of the older outer envelope might be different in different places, the later high-speed winds will tend to flow faster and farther into the more tenuous regions. In most cases, this means the inner wind will flow out the poles, producing a bipolar shape. In other cases, the inner wind punches through at different spots to produce a multipolar planetary nebula.

This theory is inadequate, however. For example, one feature seen in about half of all planetary nebulae is *point symmetry*, where each point on one side of the nebula matches a corresponding point on the other side. Point symmetry can produce some incredibly complex shapes, such as the Spirograph Nebula and the Cat's Eye Nebula. Both are point symmetric, but unlike bipolar objects, they look very different from each other.

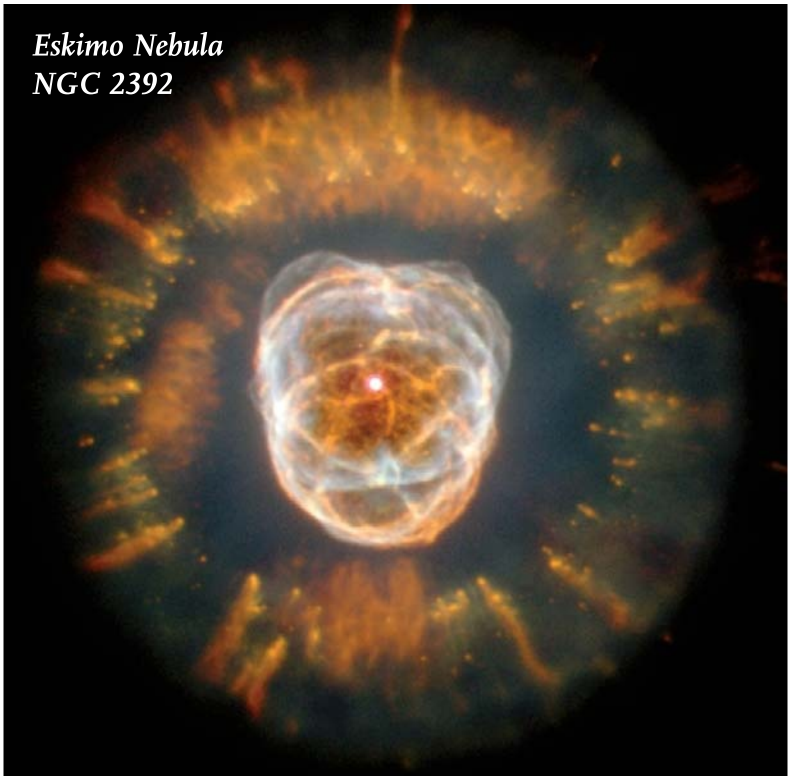
An inner fast wind impacting an outer older envelope

Boomerang Nebula
PGC 3074547

NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA) AND ESA / HUBBLE COLLABORATION

FACING PAGE: HUBBLE SPACE TELESCOPE / LARGE BINOCULAR TELESCOPE / SUBARU TELESCOPE / ROBERT GENDLER

Ring Nebula
M57



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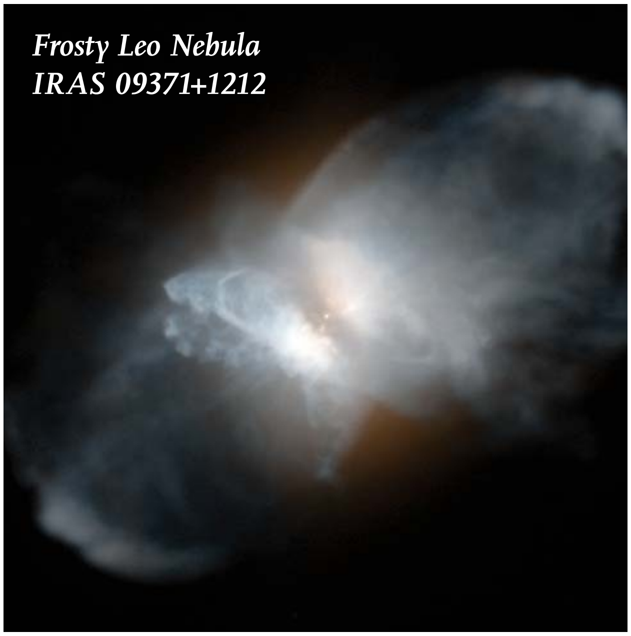

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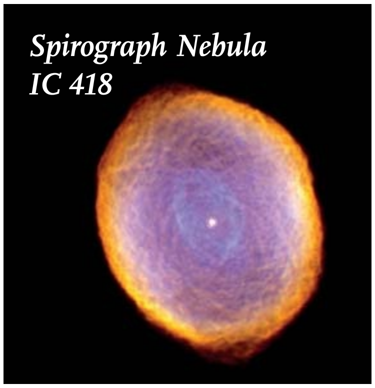


B. BALICK AND J. ALEXANDER (UNIV. OF WASH.) / A. HAJIAN (U.S. NAVAL OBS.) / Y. TERZIAN (CORNELL) / M. PERINOTTO (UNIV. OF FLORENCE) / P. PATRIARCHI (ARCETRI OBS.) / NASA

NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA)

NASA / ESA / HUBBLE HERITAGE TEAM (STSCI / AURA)

can't produce such complex point-symmetric shapes. If the AGB star was part of a binary system, however, the interaction between the two stars could do it. As the stars orbit each other they can churn the winds in many different ways to create point symmetry.

For example, what if the secondary star is close enough to the primary to accrete matter from it? The material would gather in an accretion disk around the secondary, spurring a fast bipolar wind that would blow out along the secondary's poles into the older circumstellar envelope surrounding both stars. This could further churn up the nebula and produce a wide variety of 3-dimensional patterns that the primary couldn't create on its own.

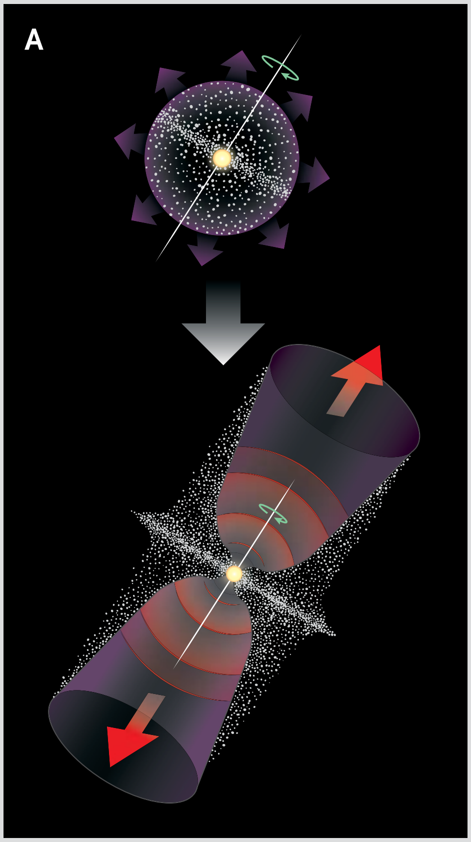
The problem is that, according to recent data, only about half of all planetary nebulae come from binaries in tight enough orbits to do the job. For the remainder, something else must produce the nebula's complicated shape.

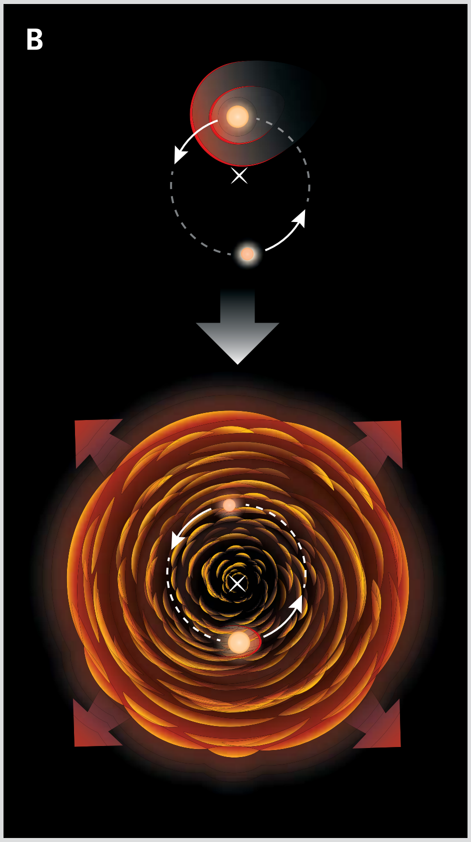
Some scientists have proposed that the star's magnetic field might help sculpt the nebula. The problem here is that the amount of magnetic energy used to fashion the cloud would suck the angular momentum from the star in only a few decades. Something else must replenish that energy.

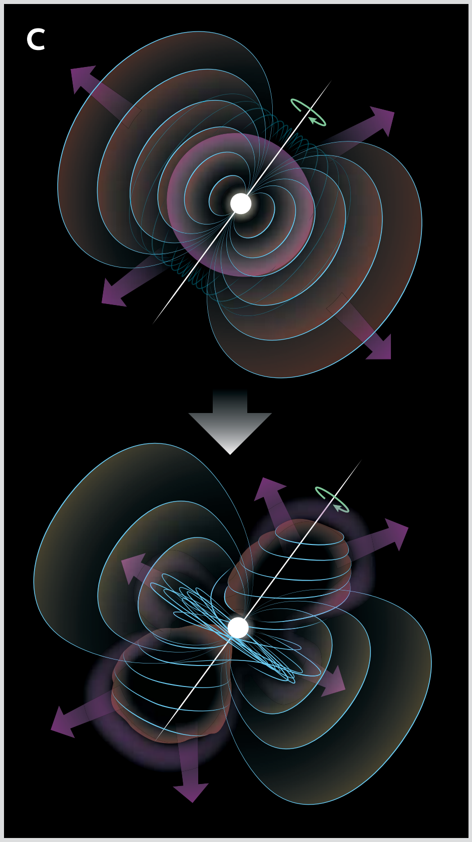
Most recently, some astronomers have begun considering the possibility that exoplanets might help solve this energy-loss problem. The angular momentum the star gains from swallowing a Jupiter-size exoplanet could be sufficient to replenish the energy of its magnetic field. As Wouter Vlemmings (Chalmers University of Technology, Sweden) said recently at a planetary nebula conference, "In principle a planet could handle it."

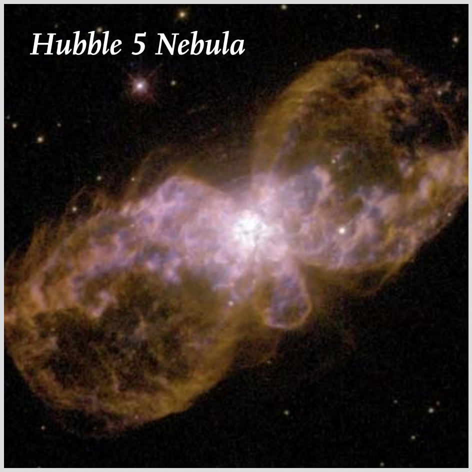
It's also quite possible that — instead of one single overarching theory of formation — each planetary nebula is formed in its own unique way. Some develop as they do because the stars are binaries, others because the

Three Ideas for Creating Planetary Nebulae









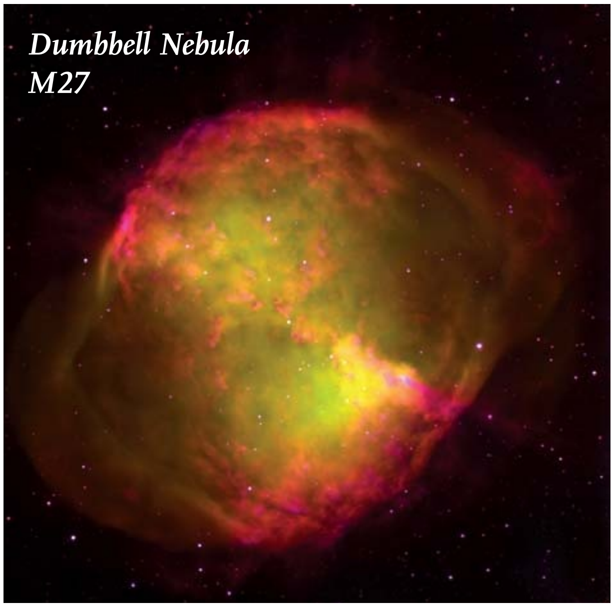
DIAGRAMS: *S&T*: GREGG DINDERMAN; CRL 2688: NASA / HUBBLE HERITAGE TEAM (STSCI / AURA) / RAGHVENDRA SAHAI (JPL) / WILLIAM SPARKS (STSCI); R SCULPTORIS: ALMA (ESO / NAOJ / NRAO) / MATTHIAS MAERCKER ET AL.; HUBBLE 5: BRUCE BALICK (UNIV. OF WASHINGTON) / VINCENT ICKE (LEIDEN UNIVERSITY)/ GARRELT MELLEMA (STOCKHOLM UNIVERSITY) / NASA

SHOWN HERE are three scenarios that might create planetary nebulae's strange shapes, with real examples that might (or might not) be the products of these scenarios.

In one version of the slow-then-fast wind (A), the spinning star puts out a dusty shell of gas that's denser around its equator. When the star later expels a fast wind, the wind rams into and is funneled by the older material, creating a bipolar outflow.

In a binary system (B), one of the two stars expels its shell as the stars orbit each other. The shell is squeezed in the direction the star travels, creating denser material in front of the leading side. As the stars orbit, the shell's expansion pushes the pattern of compression outward, creating a spiral pattern.

A third idea is that the star's magnetic field might play a role (C). After the star has thrown off its dusty gas layer, the exposed carbon-oxygen core is highly magnetized. One of several theories posits that, as the core spins, it twists up its magnetic field. Twisting the magnetic field makes the field want to expand. Because of the way the magnetic field reacts to the twisting, the expansion will be faster along the star's poles and along the equator, creating something that looks like a dumbbell wearing a tutu. This expansion shoves the surrounding gas envelope outward.



GEORGE JACOBY (WIYN / NSF)

star has a strong magnetic field and exoplanets. Many others might assume their complex forms because the outer cloud has its own unique shape, which helps guide the later fast winds coming from the evolving star. And finally, some planetary nebulae might form because of a combination of all of these factors.

The Red Rectangle

The Red Rectangle is an excellent example of why astronomers remain challenged by planetary nebulae. Computer simulations have suggested that the object's strange rectangular shape is merely a result of our viewing angle: we are looking directly at the side of a bipolar nebula made up of two cone-shaped lobes. From this angle the edges of the cones stand out so that instead of cones we see four spikes. The ladder rungs stretched between the two spikes on either side are merely evidence of repeated eruptions that over time burst out of the star and formed the two bipolar cones. From the side, these waves of debris appear as straight lines.

The Red Rectangle itself surrounds a binary system where the secondary star is ripping matter from the primary as it orbits it once every 318 days or so. It is from this secondary, thought to be a main-sequence star slightly less massive than our Sun, that the bipolar jets that form the Red Rectangle's X-shaped nebula are thought to come. The material pulled from the primary forms a thick rotating accretion disk around the secondary, which acts to direct as well as feed the cone-shaped bipolar jets flying outward above and below.

Sounds good, doesn't it? The problem is that this scenario leaves many questions unanswered. For example, why are the two bipolar lobes cone-shaped rather than wineglass-shaped, as with most bipolar planetary nebulae? Scientists aren't sure. One theory proposes that the X-shaped cones are really nothing more than light beams leaking through gaps in the inner torus, not two bipolar lobes seen from the side. Another theory says that the lobes are far older than estimated, and that what we're really seeing are not the full lobes, but the stems of the much larger wine glasses, most of which have now dissipated.

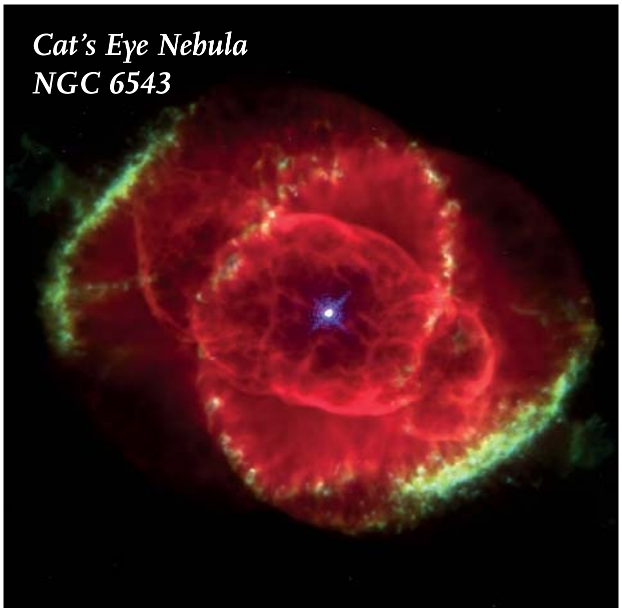
Then there is the speed of the Red Rectangle's expansion. Unlike most planetary nebulae, which expand quickly to form in only a few hundred years, the Red Rectangle's expansion rate is very slow, suggesting the object's formation took much longer, on the order of 14,000 years. Of this type of planetary nebulae, "We're not sure what's going to happen to them," explains Sahai. "We understand them poorly."

Then there are some of the Red Rectangle's smaller features. The ladder rungs suggest that they were produced by a series of eruptions spaced by a few centuries that are now expanding like smoke rings along the lobes. Unfortunately, as Nico Koning (University of Calgary, Canada) explains, "We know of no known process that produces these shells in the time sequence seen."

These questions are typical for all planetary nebulae. Although astronomers have developed good theories to explain their shape and origin, no theory as yet really manages to explain everything. "We have conferences every five years or so and seem to rehash the same questions each time," notes Koning. "Progress in this field seems very slow."

Which makes one wonder: maybe there are giant spiders weaving webs amidst the stars. ✦

__Robert Zimmerman__ is a contributing editor of S&T. *His webpage is* **http://behindtheblack.com**. *His classic history of the 1960s space race,* Genesis: The Story of Apollo 8*, is now available as an e-book.*



J. PATRICK HARRINGTON AND KAZIMIERZ J. BORKOWSKI (UNIVERSITY OF MARYLAND) / NASA

A Trio of Total Solar Eclipses

FRED ESPENAK & JAY ANDERSON

The next three years each offer a chance to view one of nature's greatest spectacles.

The Moon's dark umbral shadow will sweep across Earth's surface once every year from 2015 through 2017. This means that anyone lucky enough to find oneself in the lunar shadow's path, or who wants to travel, will witness that most spectacular of naked-eye astronomical phenomena: a total eclipse of the Sun. Although three total eclipses in three consecutive years is not unusual — it last happened in 2008–2010 — the eclipses forming this trio are remarkably different from one another.

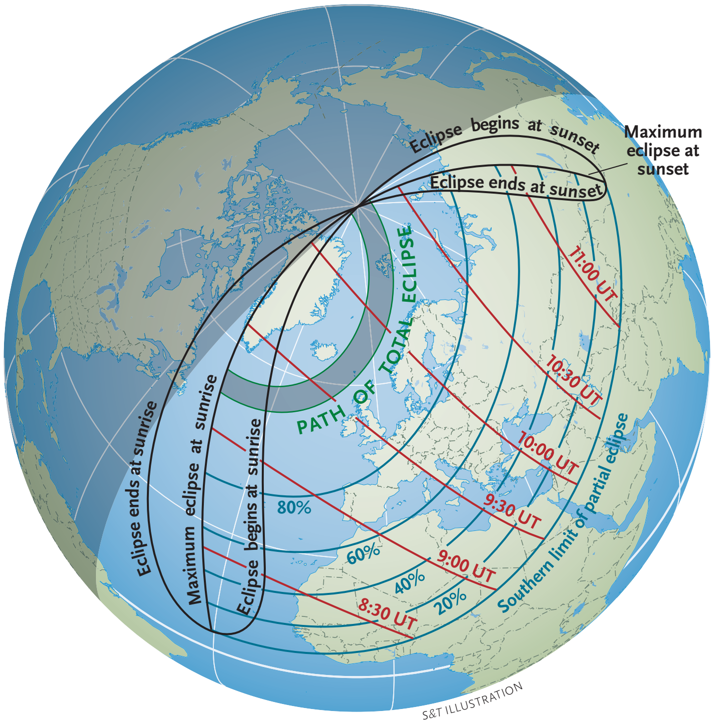
March 20, 2015

The stormy North Atlantic in late winter is hardly a popular tourist destination. Nevertheless, the track of the March 20, 2015 total eclipse passes right through the region and will likely draw many eclipse chasers. Although the path of totality is quite wide (about 287 miles, or 462 kilometers), the eclipse suffers from two important disadvantages: lack of land in the path and poor weather prospects.

As the map at right shows, the eclipse path forms a backward C-shaped curve beginning south of Greenland and ending at the North Pole. Unfortunately, Iceland lies just outside the broad path that counts the Faroe Islands and Svalbard as the only two land options. The surprisingly green Faroes are a small group of 18 islands northwest of Scotland. Svalbard is a Norwegian archipelago located midway between Norway and the North Pole. Both destinations offer two or more minutes of totality provided that the Sun is not obliterated behind thick clouds.

The Faroes are embedded in the main storm track across the North Atlantic and so have a well-deserved reputation for clouds. At Vágar Airport, on the west side of the islands, cloud cover averages 75%, and the average number of sunshine hours for March is a meager 24% of the maximum possible. Eclipse seekers will have to remain mobile, looking for openings in the clouds on eclipse day, or they'll need to head for high ground to surmount the fog that commonly envelops the archipelago in the morning.

The central line of the March 20, 2015 total solar eclipse crosses only a few points of land, all in the Faroe Islands and Svalbard.

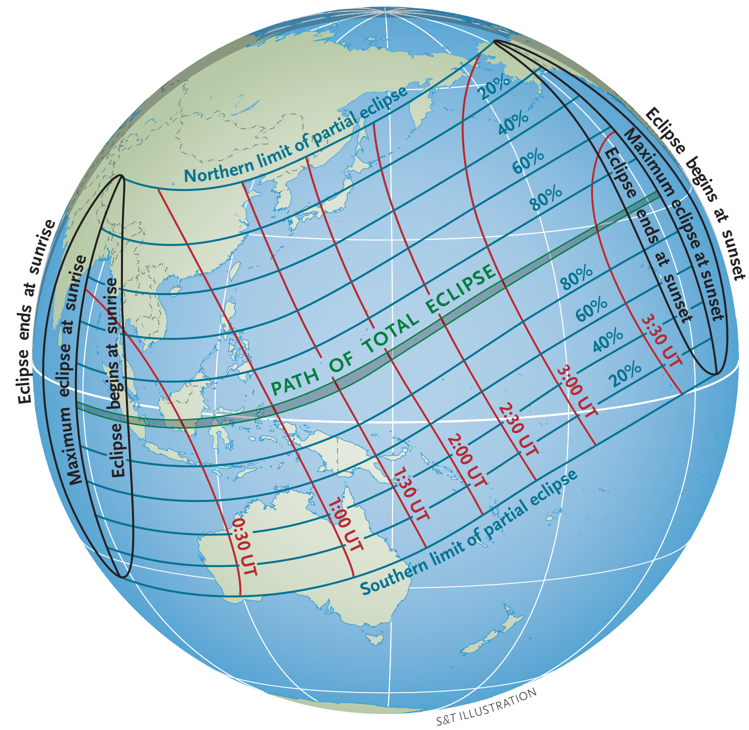


Bottom left: **Coauthor Fred Espenak and his wife Pat view totality from Libya on March 29, 2006.** ***Top:*** **A high-dynamic-range image of the eclipse reveals fine details in the corona.** ***Center:*** **A mosaic records the various eclipse phases.**

FRED ESPENAK (3)

SAYOGA / ©ISTOCKPHOTO.COM

Above: **A picturesque temple sits in Beratan Lake on the Indonesian island of Bali. The central path of the March 9, 2016 eclipse won't make landfall on Bali, but it's not far away for eclipse chasers. *Below*: The 2016 eclipse central line crosses mostly ocean, but makes landfall across several major islands in Indonesia.**



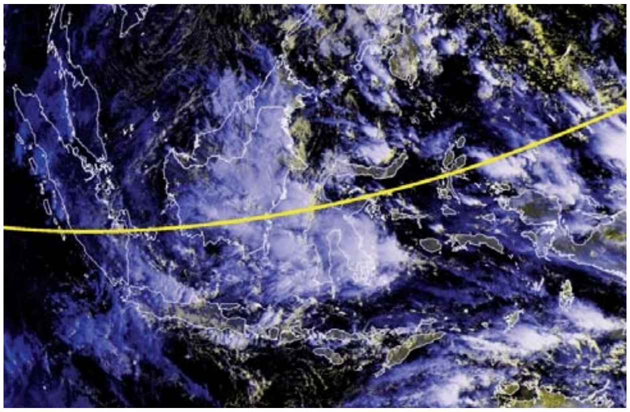
Longyearbyen, the leading community on Svalbard's Spitsbergen Island, offers better weather prospects, with an average cloudiness of 55%. Moisture is limited in the colder Svalbard climate and the terrain that dominates the community helps to break up and dissipate clouds. Eclipse sites within Longyearbyen must be chosen carefully so that the Sun is not blocked at the critical moment, but Spitsbergen scenery can provide spectacular settings for photographers.

If ever an eclipse begged for an aerial rendezvous, 2015 is it. Eclipse chaser Xavier Jubier is organizing one such flight, and he estimates at least a dozen more are being planned. Such flights are expensive, but airplanes can fly above most eclipse-obscuring clouds.

March 9, 2016

Nearly one year later and halfway around the planet, the central track of the 2016 eclipse crosses the equator, passing through a decidedly warmer climate. Although the shadow path is narrower than it was in 2015, it's more than twice as long and stretches ⅓ of the way around Earth. But nature's seeming perversity is at work again because most of the track crosses island-free ocean. The 2016 eclipse can only be seen on *terra firma* from Indonesia and a few tiny Pacific islands.

Nevertheless, the two to four minutes of totality coupled with the allure of Indonesia and the Pacific are factors in this eclipse's favor. The track begins 900 miles



NERC SATELLITE RECEIVING STATION / DUNDEE UNIV. / WWW.SAT.DUNDEE.AC.UK

This image from the Japanese MTSAT-2 weather satellite shows the cloud coverage over the Indonesian archipelago on March 9, 2013 at eclipse time. The infrared signal is shown in blue tones, the visible in yellows. White clouds are thick and high, yellow clouds are at low levels. High-level thin clouds are shades of blue.

west of Sumatra and quickly heads due east, where it crosses the island. Continuing onward, the central path traverses southern Borneo, Sulawesi, and the Moluccas, including Halmahera, as it slowly curves to the northeast. Stretching across the vast Pacific, the path passes near Wake and Midway Islands and ends about 1,100 miles northeast of the Hawaiian Islands.

The weather prospects are a major concern. Indonesia's humid and often cloudy climate offers daunting statistics for eclipse expeditions. The country lies beneath the Intertropical Convergence Zone (ITCZ), where trade winds from the Southern and Northern Hemispheres collide, serving up a daily menu of showers and thunderstorms. Western Indonesia in particular is one of the cloudiest places on Earth.

An observer in eastern Indonesia — Sulawesi or the Moluccas — will be on the edges of the ITCZ, where cloud coverages are about 20% less than the 75% to 85% in Borneo and Sumatra. Sulawesi and the Moluccas are rugged, so the best sites on these islands are in the mountain valleys, where the air is forced to descend, warming and drying in the process. Mountains can also shade the eclipse site for an hour or two after sunrise, slowing the daily rise in temperatures and delaying the start of convective buildups, an advantage that will be reinforced by the growing shade of the approaching lunar shadow.

Prospects on the ocean are much more promising, because a ship's mobility gives a much higher probability of success. Access to the eastern end of the path from the Hawaiian Islands is also generating eclipse-cruise and aerial-rendezvous possibilities.

August 21, 2017

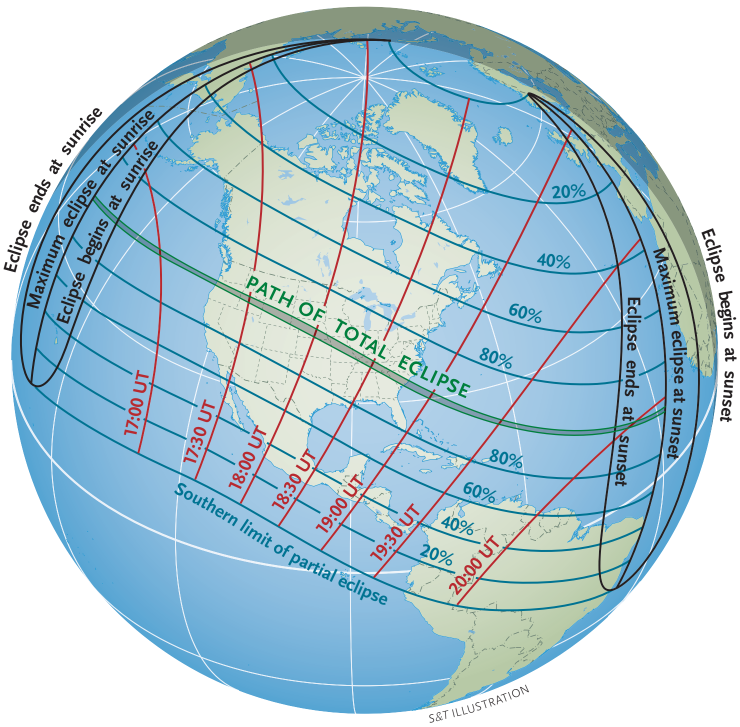
Although no dedicated eclipse chaser likes to pass up the opportunity to bask in the Sun's coronal glory during totality, many would consider the 2015 and 2016 eclipses to be warm-up acts for the main event: August 21, 2017. The path of totality returns to the continental United States for the first time since 1979 after a lapse of 38 years.

The eclipse track runs diagonally from the Pacific Northwest to the southern East Coast, spanning 2,500 miles and crossing significant portions of a dozen states. You'd have to go back nearly a century, to June 8, 1918, to find a total eclipse crossing a comparable swath of U.S. real estate. The central duration of totality is two or more minutes along the path, peaking at 2 min 40 sec near the Illinois-Kentucky border. Not only that, the eclipse takes place during the height of summer vacation season, giving millions of families the chance to witness totality.

As if that weren't enough good news, the weather prospects along the track are excellent. August is a notably sunny time of year, when the peak of the thunderstorm season has passed. A quick look at the cloud climatology reveals a fairly simple pattern: America is cloudy in the mountains and cloudy east of the Mississippi River. Within that broad-scale pattern, there are many local variations and attractive destinations to tempt eclipse chasers. The choice eclipse sites are in Oregon and Idaho followed closely by Wyoming and Nebraska. The Rocky Mountains are why those states have the best weather prospects.

Over Washington and Oregon, the up-and-down topography brings a cloudy climatology on windward slopes and sunny skies in the valleys. East of the Mississippi, the Appalachians do much the same, though the effect is

The central line of the great U.S. eclipse of August 21, 2017 will be within a one- or two-day drive of almost anyone living in the contiguous 48 states.



much smaller, because humid air can arrive from both east and west, courtesy of the Gulf of Mexico and Atlantic.

The eclipse central line comes ashore within spitting distance of a small park called Fishing Rock on the south edge of Lincoln Beach, Oregon — a scenic, rocky point accessed by a narrow forest trail. It's a fitting place to start the eclipse, because Lincoln Beach was also under the Moon's shadow for the February 26, 1979 total eclipse. The waterfront is noted for its fog, but it's not a serious problem because the mist usually only manages to reach a short distance inland on the narrow coastal plain.

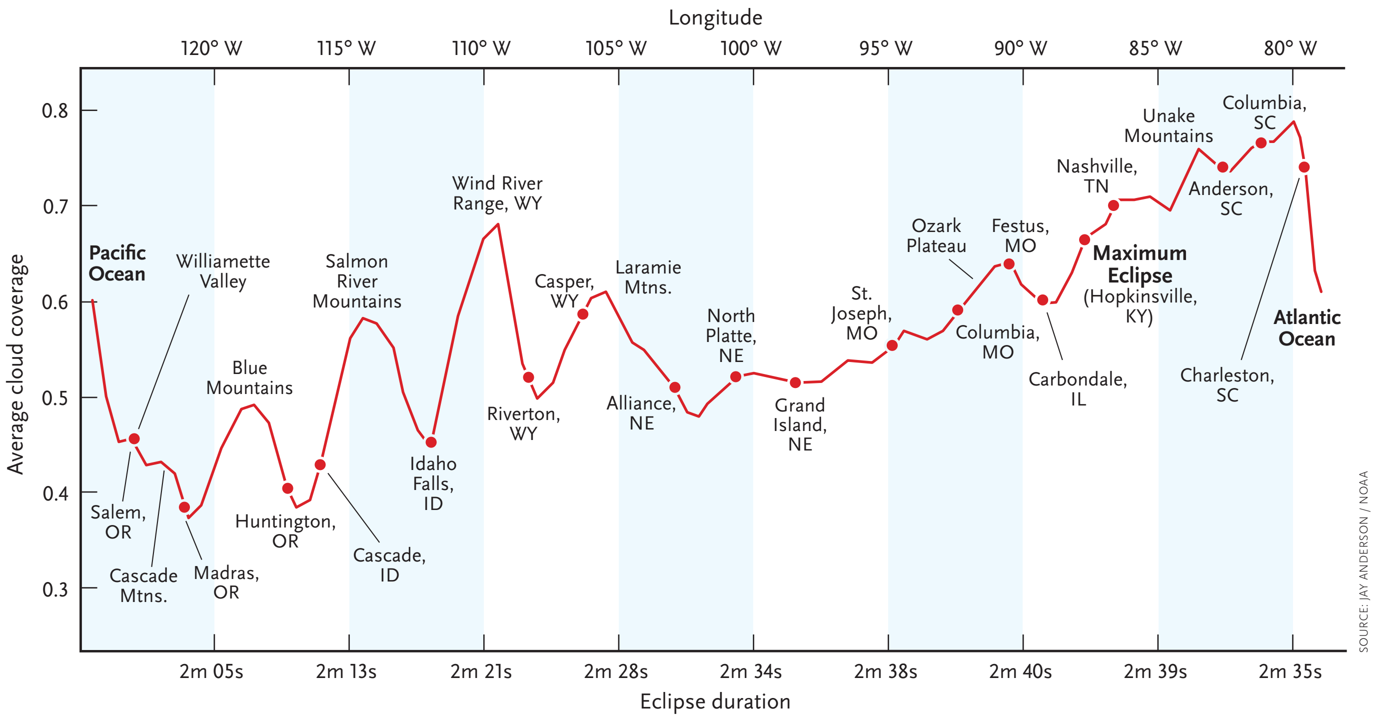
A winding highway out of Lincoln Beach takes the eclipse traveler across the Oregon Coast Range to Corvallis, Oregon, and the Willamette Valley. Located 10 miles north of the central line, Salem has an average cloud cover that is 20% lower than spots on the coast. Go a little farther east, across the much higher Cascade Range to the Columbia Plateau, and the weather gets even better. Madras, Oregon, lying only 6 miles south of the shadow axis, has the distinction of having the least August cloudiness along the eclipse track. At Redmond, Oregon, at the southern limit, 20 years of observations at the airport show an average August cloud cover of only 8%.

But Madras has competition — in the next valley, over the Blue Mountains. The highway goes to Interstate 84, the Snake River, and the Oregon-Idaho border, where satellite and surface observations reveal a cloud climatology nearly as good as Madras. A little farther along the track, however, you'll encounter the rugged peaks and valleys of the Rocky Mountains, where the topographic see-saw leads to even more pronounced cloud cover. Average cloud cover reaches 60% on the Salmon River Mountains of Idaho and more than 70% on the Wind River Range in Wyoming, but drops back to about 50% in the valley communities of Idaho Falls, Idaho, and Riverton, Wyoming.

To learn about the *Sky & Telescope* tours for the 2016 and 2017 eclipses, visit skypub.com/EclipseTours.

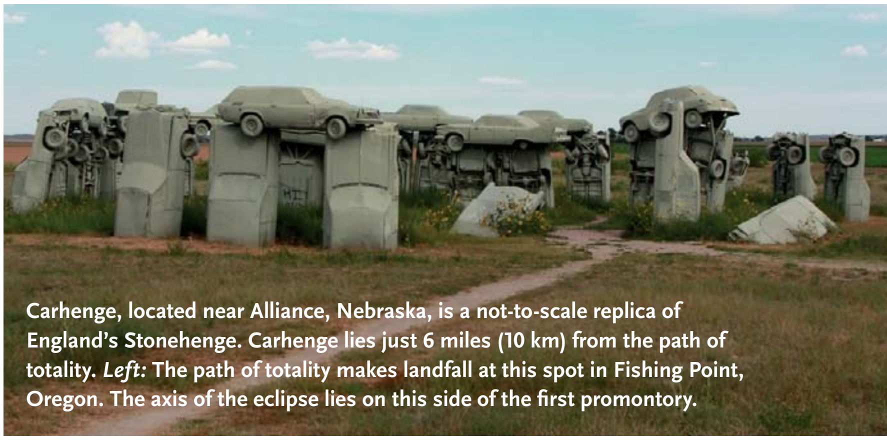
At Casper, Wyoming, the Rockies have been left behind and the Great Plains are in sight. Casper is the only sizeable city that lies smack on the central line, and it's a fine location — only about 10% cloud cover at eclipse time according to airport observations at lower elevations. Because of this, the Astronomical League has chosen Casper to host its national convention in the days just preceding the eclipse. The only fly in the ointment is the possibility of forest-fire smoke on eclipse day. The city often experiences a thin haze from fires elsewhere in the Western states. But smoke from forest fires could be a small problem just about anywhere in the West.

Nebraska and Kansas offer wide-open spaces and no cloud-making terrain to avoid, though the occasional August thunderstorm might present an avoidable problem. For the whimsical, check out Carhenge near Alliance, Nebraska, a short 6 miles north of the central line with a favorable dip in the average cloudiness to boot. A good highway network, unimpeded by mountain ranges,



This graph from satellite data plots the average cloud coverage along the path of totality for the 2017 eclipse. Use it to make relative comparison of sites, because satellite observations are typically 20% to 30% higher than what observers see from the ground.

Carbondale, Illinois is one of the luckiest towns for eclipse aficionados. This downtown location, on South Illinois Avenue, will see a 2 min 36 sec total eclipse on August 21, 2017 and a 4 min 09 sec total eclipse on April 8, 2024.



Carhenge, located near Alliance, Nebraska, is a not-to-scale replica of England's Stonehenge. Carhenge lies just 6 miles (10 km) from the path of totality. *Left:* The path of totality makes landfall at this spot in Fishing Point, Oregon. The axis of the eclipse lies on this side of the first promontory.

JAY ANDERSON (3)

allows for a quick eclipse-day escape if needed. Cloud cover generally averages between 20% and 40% on the Plains according to station observations, but more according to the satellites (which are typically about 20% to 30% higher than ground observations).

East of the Mississippi, cloud cover begins a steady climb, fed by moisture from the Gulf of Mexico and encouraged by Appalachian peaks. Surface observations show that cloudiness rises from around 25% in Missouri to more than 50% in Tennessee and the Carolinas. At Carbondale, Illinois, cloud coverage eases up a bit in the Big Muddy River watershed — a propitious omen, perhaps. Carbondale could be called America's Eclipse City, because it lies at the junction of the 2017 and 2024 eclipse paths. A little to the east, Hopkinsville, Kentucky is making plans for a big influx of visitors due to its proximity to the point of greatest eclipse, the instant when the axis of the Moon's shadow passes closest to Earth's center.

The lunar shadow leaves U.S. shores near Charleston, South Carolina, putting historic Fort Sumter 7 miles inside the south limit. The central line is a little farther north, close to Buck Hall Recreation Area, overlooking marshy islands and the Atlantic. The 2017 eclipse could not be better designed for the U.S.: coast-to-coast, north to south — and pretty decent summer weather to boot.

2017 Strategy: Mobility

Because of the convenient network of highways, the 2017 eclipse offers an excellent opportunity to hedge one's bets. Despite the favorable climatological outlook, clouds still occur some of the time everywhere along the path. The key to avoiding them is mobility. It's fine to choose a viewing location years in advance, but be prepared to abandon it if the forecast looks bad the day before the event. There's still time to pack the car and head for a location offering a better forecast. With an early start, you can cover 500 miles or more to reach a destination with clear skies. Mobility might increase your eclipse viewing odds by 10%, but it's still no guarantee, especially if August 21st hosts a major storm system covering much of the nation. Although this is unlikely, it might bring comfort to consider the backup plan — the next total solar eclipse in the U.S. is only seven years later, on April 8, 2024. ✦

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*Astronomer **Fred Espenak** (NASA/Goddard Space Flight Center) masters two eclipse websites (**eclipse.gsfc.nasa.gov** and **www.MrEclipse.com**) and is a coauthor of* Totality – Eclipses of the Sun. *Meteorologist **Jay Anderson** has written about eclipse climatology since 1979 and has journeyed to confirm his predictions in person. More detailed climate and weather information can be found at **www.eclipser.ca**.*

A Star Walk *for* Everyone

This project aims to protect the night sky by turning people's eyes to the stars.

PROJECT NIGHTFLIGHT

Karoline Mrazek & Erwin Matys

Light pollution is every astronomer's enemy. Professionals and amateurs alike suffer from the growing abundance of artificial light. To cut light pollution down or simply keep it from spreading further, public awareness is essential.

But people don't always respond well to cries of doom and gloom. Instead, we need to persuade them gently. In our experience, there is no better way to inspire public support than to lift people's gazes up toward the starry sky. Even those who are only marginally interested in astronomy are wowed when they see the Milky Way in all its splendor for the first time.

This is the awe our team seeks to harness. We are Project Nightflight, a small team of astrophotographers who have been working for years to present the marvels of the night sky to the public in our images. Our photographs of celestial objects always focus on the beauty of the universe, whether we shoot deep-sky fields or nightscapes. We like to draw people's attention to the natural wonders of the night sky, instead of raising the warning finger against light pollution.

Our latest approach to increasing public awareness was to design an astronomical "edutainment" venue near a major city. We came up with the idea of a permanent star walk: a nature trail with a focus on astronomy that introduces the splendor of the night sky at a beginner's level. With information panels posted along the route and located at an easily accessible distance from a major metro area, the star walk has proved to be a successful astronomy outreach program.

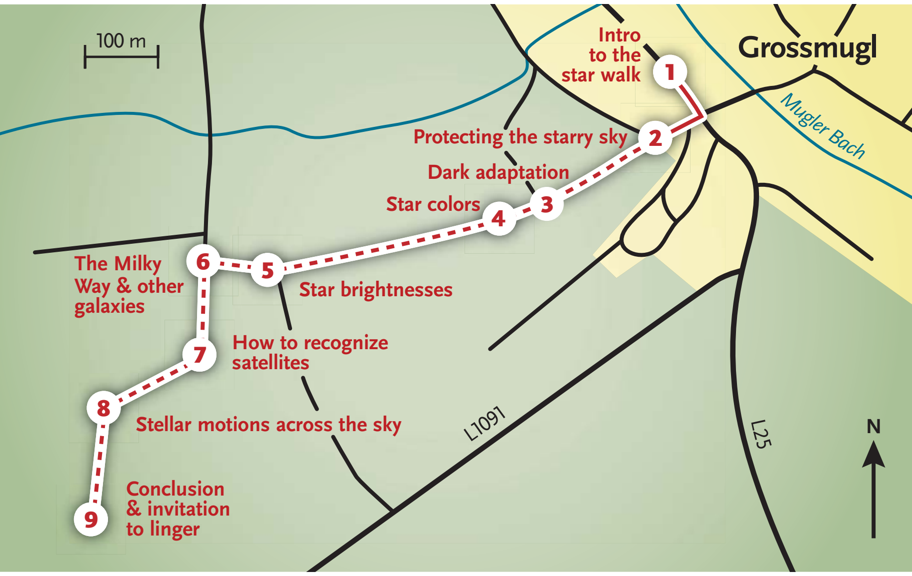
Step by Step

We chose to build this installation in Grossmugl, a small town of about 1,500 inhabitants that lies only a 30-minute drive north from Austria's capital, Vienna. Grossmugl was the ideal candidate for us because its night sky is still largely intact, frequently offering limiting magnitudes of 6 or better.

In May 2013 we presented our idea for a star walk and a detailed draft for its implementation to the mayor of this small town. He was enthusiastic about it and a few months later brought our plan before the town council, which approved it. During the winter months we were busy planning the details of the trail and designing the panels. We kept the topics on the displays deliberately simple to make them suitable for the general public and for children.

As soon as the snow melted the construction work began. The local construction team set up the signposts and mounted

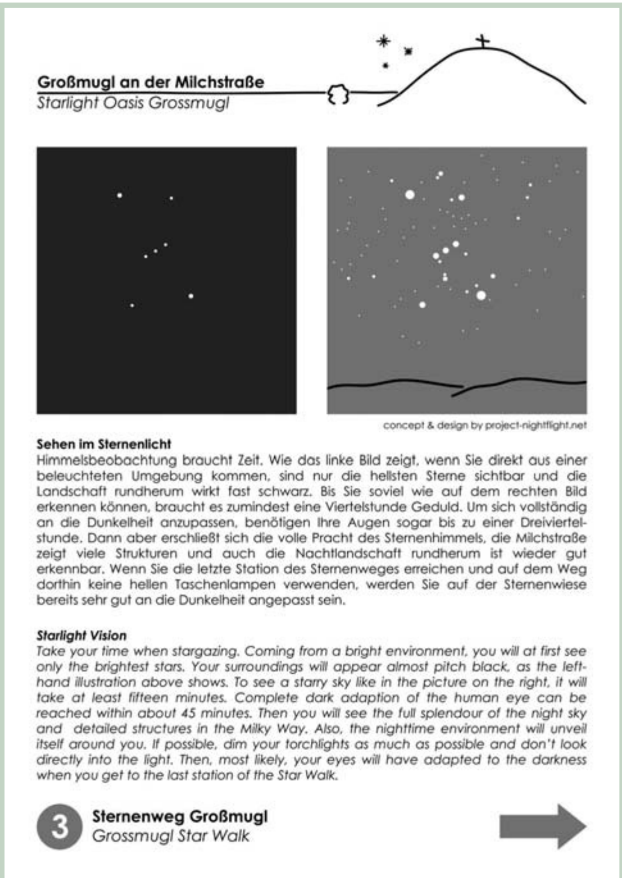
TWILIGHT WALK Despite looming clouds, the Grossmugl Star Walk's inauguration attracted a large group of curious skygazers. Above the scene, Jupiter, Castor, and Pollux shine brightly in the fading twilight.



THE STAR ROUTE Visitors encounter nine stations on their 1.5-kilometer walk from the village center to the ancient Leeberg burial mound. S&T: LEAH TISCIONE; SOURCE: GOOGLE MAPS

The Project Behind the Star Walk

The organization that spearheaded the Grossmugl star walk, Project Nightflight, is an association based in Austria known officially as *Verein zur Darstellung und Erhaltung des Sternenhimmels*, which translates as "Association for the Presentation and Conservation of the Starry Sky." The project is active worldwide and unites experienced, active astrophotographers in their endeavor to bring the unspoiled starry sky to others with their pictures and to promote the conservation of the dark sky as an environmental resource.



PROJECT NIGHTFLIGHT

SHORT AND SWEET Signposts along the star walk introduce visitors to various visual observing targets, from the Milky Way to satellites. The panels also discuss topics such as light pollution and dark adaptation (the latter appears above).

the displays. The signposts are simple wooden beams rammed into the ground, with the all-weather aluminum panels attached. These 2-mm-thick aluminum panels are reinforced with wooden multilayer boards to give them better stability. We designed everything to be maintenance-free, to keep upkeep efforts at a minimum.

One year later, on May 24, 2014, the star walk officially opened. Roughly 100 visitors came to participate in the inaugural walk, despite storm clouds looming on the horizon in all directions.

A Walk in the Dark

The Grossmugl Star Walk is a 1.5-kilometer-long nature trail that's open 24/7 all year round and doesn't require booking a reservation. It starts in the village center, where a trail of white stars painted on the pavement leads visitors into the surrounding fields and meadows. Along the trail stand nine panels that take visitors slowly on a journey into the night sky. The panels explain how easy it is to see constellations, star colors, and even galaxies with one's own eye, and each panel includes a simple illustration that shows the aspect of naked-eye observation covered in the text. The displays describe basic astronomy facts both in German and English. At each station a short audio in German is also available via QR code for download with smartphones.

The star walk is designed as a twilight walk. The large print on the panels is clearly readable without illumination even in nautical twilight, when stars of third magnitude are visible. The first station introduces the general idea of the walk. A set of pictograms encourages visitors to use red flashlights during the walk and to dim all lights so that their eyes can gradually adjust to the dark. The second display informs people that bright street lamps, illuminated shop signs, excessive parking-lot lighting, and other bright outdoor lights are the reason why they can no longer see faint stars and the Milky Way in densely populated areas. This display also explains that the right choice of lamps and lamp shielding can make the starry sky visible again. From the third display onward, the illustrations and the short texts describe celestial wonders that visitors can observe with the unaided eye.

Here and there we added discussions of some interesting facts that the nonstargazer might be unaware of: how long it takes the human eye to adapt to the dark, the different colors of stars, the range of star brightnesses (and the fact that bright stars are not necessarily close to Earth), the frequency of artificial satellites zipping across the sky, how the apparent motion of the stars across the sky works, and that some galaxies — including our home galaxy, the dazzling Milky Way — are visible to the naked eye. The panels explain all this in basic terms so that even visitors with no initial astronomical knowledge can enjoy their guided gaze up into the night sky.

The star walk ends at Star Meadow, a field of about one acre dedicated to skywatching all year round. It contains an Iron Age burial mound called the Leeberg tumulus, which was erected roughly 2,500 years ago. We chose this site as the walk's culmination to give visitors an Earth-based reminder of the ancient beauty of the sky. It's also a gathering point for astronomical events throughout the year.

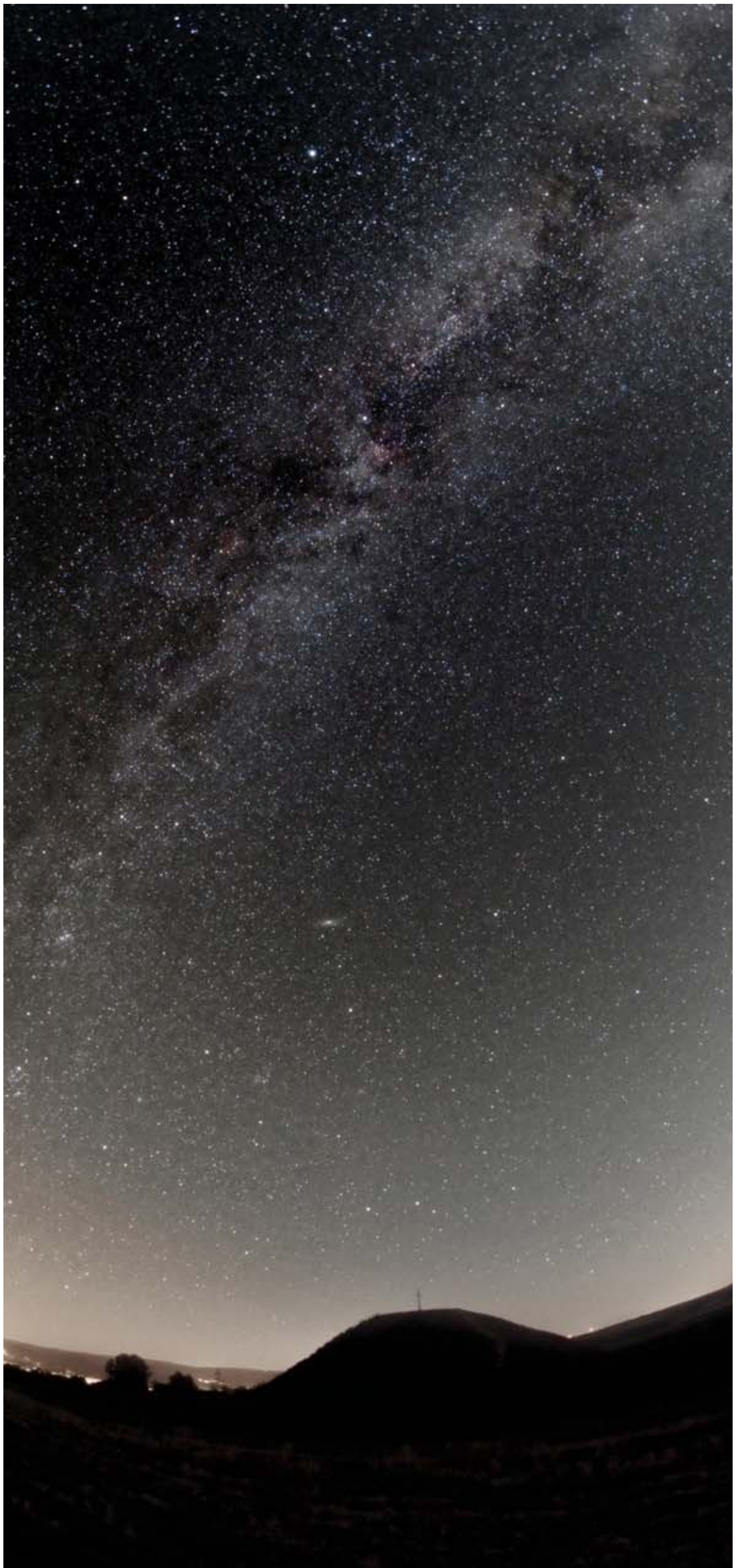
After finishing the walk, visitors can continue stargazing here with their dark-adapted eyes, perhaps sitting at a bench that locals call the Stars' Rest. Then they can return along the same path back to Grossmugl.

Go Further

Already on the day of its opening the star walk showed its first positive effects: some village residents had improved their outdoor lights for the occasion. The municipality is also planning to change street lights to full cut-off lamps in the near future.

The Grossmugl Star Walk was a nonprofit project funded by a local corporate sponsor and carried by the enthusiasm of all involved, not least by the dedicated drive of the town's mayor. We hope that the star walk idea will inspire many amateur astronomers, stargazers, and perhaps even officials across the world to build similar venues dedicated to the night sky. For those who want to know more about the first permanent star walk installation, an illustrated and more detailed description is available for download in PDF format on our website in the Tests & Tools section. We intend the Grossmugl Star Walk to serve as a blueprint for similar projects and invite you to be creative: think of new and innovative ways to bring the night sky closer to the broader public's attention. ✦

__Karoline Mrazek__ and __Erwin Matys__ are founding members of Project Nightflight. Between them they have more than 40 years of astrophotography experience. Check out their images and learn more at __www.project-nightflight.net__.



STARRY SKY At Star Meadow, the star walk ends with an ancient burial mound and a fine view of the Milky Way. Only half an hour's drive away from Austria's capital, Vienna, the night sky is still largely intact here.

PROJECT NIGHTFLIGHT

Sean Wal

The Quark *from* DayStar Filters

A new approach to affordable solar hydrogen-alpha filters.

DayStar Instruments Quark Filter

U.S. price: from $995
www.daystarfilters.com

WHAT WE LIKE:

Compact and versatile

Easy to use visually and photographically

WHAT WE DON'T LIKE:

Requires fast refractor

Slow to adjust tuning

IN RECENT YEARS, specialized solar observing has spread through the amateur community like a proverbial wildfire. Much of this was due to the growing availability of affordable narrowband filters (primarily in the hydrogen-alpha line of 656.28 nanometers) using the Fabry-Perot etalon design. Suddenly, it became common to see solar prominences at star parties and other astronomical gatherings. Although many of these new filters eliminated the need for powered temperature regulation, they were often mounted in front of a telescope objective. This meant that to achieve higher resolution, you'd need a larger-aperture filter, which in turn quickly becomes quite expensive for the larger models. DayStar, a company long associated with narrowband solar filters, rolls out a slightly different approach to the focuser-mounted etalon that promises to be much more versatile and affordable.

The new DayStar Quark filter "H-alpha eyepiece" (a more apt name would be an "H-alpha Barlow") combines a telecentric Barlow with a small, power-regulated Fabry-Perot etalon used between your refractor's eyepiece and diagonal. Besides a power source, the company claims that's all you'll need for views of the Sun at the H-alpha line in refractors up to 80 mm for "brief observing sessions" of the Sun. With the addition of a 2-inch UV/IR blocking filter, the Quark is safe to use with telescopes up to about 120 mm before a full-aperture energy-rejection filter is recommended. As a longtime solar-telescope

***Above*: The Quark filter is as big as a large 2-inch eyepiece, and comes with end caps, a bolt case, and an AC adapter with international outlet adapters. All images are by the author.**

***Left:* The DayStar Quark Chromosphere filter provided a legitimate excuse for *S&T* staffers, including summer intern Maria Temming, to step outside the office on many mornings. Using the filter with a 70-mm f/6.8 Tele Vue Pronto and Up-Swing mount produced excellent views across the entire solar disk.**

owner with aperture fever, I wanted to find out more, and requested the Chromosphere unit for further evaluation.

The Quark filters are about the size of a very large eyepiece, 5¾ inches long by about 2¼ inches wide. Each weighs in at 0.88 pound (400 grams), so expect to have to rebalance your scope when installing the unit. The basic package comes with an AC adapter with various international plug attachments, end caps, and a large eyepiece bolt case. DayStar also included a 2-inch UV/IR blocking filter that it recommends installing on a 2-inch diagonal when tracking the Sun while using the Quark on telescopes larger than 80-mm aperture for extended periods.

The filter works by intercepting the light cone of your refractor before its focus point, allowing the use of a very small etalon while still taking advantage of your refractor's full aperture. DayStar recommends using achromats or apochomatic refractors without additional correcting elements near the focuser. Optical designs with rear elements, such as the Petzval, and any oil-spaced objectives, require a full-aperture energy-rejection filter for safe use. The unit incorporates both 1¼- and 2-inch nosepieces, and is threaded to accept 1¼-inch accessories. Its 1¼-inch eyepiece holder incorporates a non-marring brass compression ring (which can be upgraded to 2-inch format).

Within the nosepiece is a 12.5-mm broadband blocking filter that passes only a safe amount of light for viewing with small apertures. Immediately behind that is a 2-element telecentric Barlow-lens assembly that produces the 4.3× amplification necessary for the etalon to function properly. At the eyepiece end is the final 21-mm back filter.

The Quark in Action

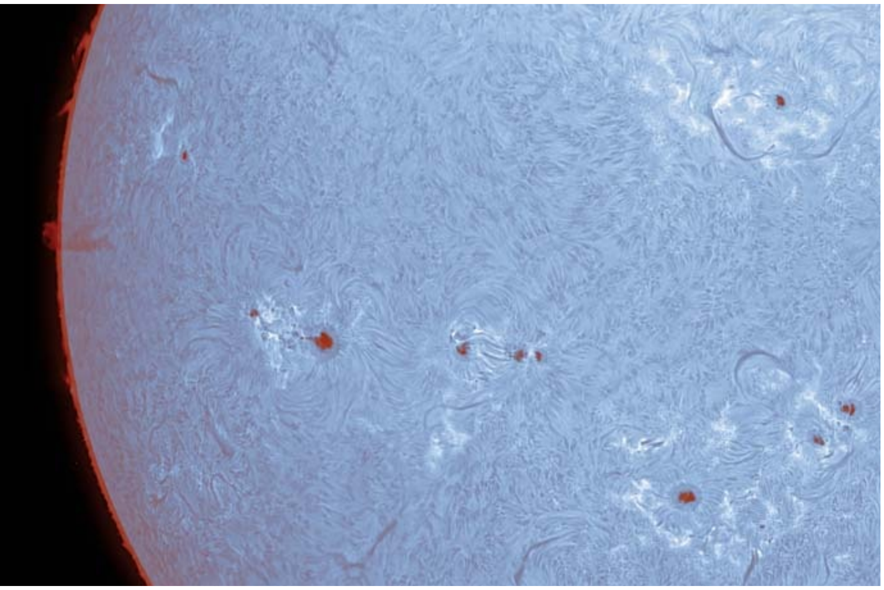
I initially tried out the Quark filter on a 4-inch f/9 achromat with a 20-mm eyepiece, using the supplied AC power adapter and the 2-inch UV/IR blocking filter mounted in the front of my diagonal. Literature provided with the unit advises waiting about 5 minutes to enable the temperature regulation to stabilize; the small indicator light located above the tuning knob should change from orange to green when ready. When everything was all set, I looked cautiously through the eyepiece and focused. Although the view was adequate, I quickly determined the magnification a bit too much for our usual conditions here in the Northeast U.S., particularly because it was later in the day when local seeing conditions deteriorate. In this configuration, I found that using a 32-mm Plössl eyepiece was comfortable enough to take in the entire field, but still only showed a portion of the Sun. This made it challenging to point the instrument to find prominences and active regions, particularly without an aiming device. Once I found an active region to focus on, the unit provided highly detailed views of filaments, light bridges within sunspots, and complex prominences.

As an avid solar observer, I prefer evaluating the entire solar disk, and then zooming in to active regions and prominences that warrant closer inspection. Because this wasn't possible with the f/9 scope, I next tried out the unit on a 70-mm f/6.8 Tele Vue Pronto. This proved to be an excellent match for the Quark; I was able to view the entire solar disk with a 32-mm Plössl, and the reduced magnification when using a 40-mm Plössl was even more comfortable before I switched to higher powers.

In this setup, the solar disk displayed filaments and active regions across the field; there was very little band shift as I approached the edge of the field, and this was only perceptible when I moved features to the very edge of the field. Prominences were easily visible along the limb.

The Quark filter uses a knob just above the power indicator to adjust the filter tuning in 0.1-angstrom increments, spanning an entire angstrom. This allows you to find the best tuning to see everything in the Sun's chromosphere, or see blue- and red-shifted features. This was probably the weakest feature of the Quark filters — each turn of the knob required a wait of 5 minutes or longer to really see a

Top: **The Quark's 1¼-inch nosepiece houses a 12.5-mm blocking filter that reduces the light entering the etalon to safe levels. Because the telescope's light path is converging, this filter doesn't constrict the light path at all.** ***Above:*** **the final 21-mm filter before the eyepiece provides an evenly illuminated view of the solar chromosphere. The 1¼-inch eyepiece holder is upgradable to a 2-inch version.**



Left: **Imaging through the DayStar Quark chromosphere filter was extremely easy and straightforward. Active regions around sunspots, filaments, and prominences were all easy to capture using a Celestron Skyris 274M video camera. The author recorded this mosaic on the morning of July 5th, when the Sun was riddled with activity.** *Right:* **The extensive instruction booklet included with the Quark filter explains proper use of the filter as well as some excellent tips on imaging through the unit. It goes into detail on how you should tip your video or CCD camera slightly to eliminate the distracting interference pattern known as "Newton's Rings" in the image above.**

change in the tuning of the filter. In fact, it was difficult to determine if there was any change at all unless I turned the knob 3 or 4 clicks. Users might have to spend some time finding the best settings for their particular setup.

Overall, the views were quite nice through the Quark chromosphere filter, though perhaps due to the long focal length of my scope/filter combination, I felt the contrast wasn't quite as strong as some other solar Hα filters I've used in the past. DayStar doesn't state the filter's exact bandpass range.

DayStar offers a 30-amp-hour battery pack with solar charger ($89) to power the Quark when observing where no AC power is available. The battery powered the Quark filter throughout the author's late July weekend visit to the annual Stellafane Telescope Makers Convention in Springfield, Vermont.

Photographic Performance

Imaging through the Quark was easy, and DayStar provides some excellent tips on how to do it in their well-written instruction booklet. I shot through the Quark Chromosphere filter using a Celestron Skyris 274 video camera. Initially, I had interference bands across the image, but tipping the camera in the compression ring, as suggested in the booklet, eliminated the issue. Images through the setup, particularly with the Tele Vue Pronto, were excellent. The filter produced no vignetting or passband shift across the entire image, which enabled me to stitch together seamless mosaics of the entire Sun.

The DayStar Quark Chromosphere filter performed admirably, but with some conditions — the filter functioned well in all the telescopes I used it with, and DayStar claims it will function safely with any size refractor with additional precautions. The caveat is that unless you enjoy good to excellent seeing conditions regularly, you'll need a relatively fast-focal-ratio refractor. So if you enjoy wide-field views of the Sun ringed with prominences, search for a really fast refractor with a focal ratio of about f/6 or better. That still gives you a large range of options. Since safety is always a concern when using solar filters, I consider the UV/IR-blocking filter to be an essential purchase. The modest power requirement is a small price to pay if you're looking to step up to extreme-close-up views of the nearest star. ✦

Imaging editor ***Sean Walker*** *is always excited to see what's going on in the solar atmosphere.*

New Product Showcase

▶ **COMPACT SPECTROGRAPH** JTW Astronomy announces the Spectra-L200 ($1,830), a slit spectrograph for amateur telescopes. Based on the Littrow spectrograph design, the Spectra-L200 allows users with modest telescopes to produce the high-resolution spectra needed to explore the structure and chemical makeup of stars and bright nebulae, or to see the redshift of distant quasars. A custom, multireflective entrance slit plate provides a unique arrangement of nine different slit gaps, ranging from 20 to 100 microns, and three pinholes that you can quickly select using a built-in thumbwheel. The unit attaches to your telescope using a female T-thread and weighs 2.7 pounds (1.2 kilograms). It performs best with telescopes having focal ratios of f/7 or greater. The heart of the instrument is a reflective grating positioned behind an oversized achromatic doublet. Its highly reflective chromium surface and transfer mirror enable you to directly track the target star through the guide port with your autoguiding camera. Additional gratings and accessories are available through the manufacturer's website.

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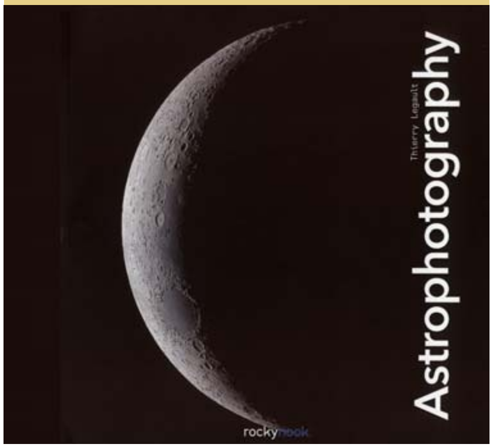
Noord-Holland, The Netherlands
www.jtwastronomy.com

▲ **PUSH-TO TWILIGHT II** Jim's Mobile Incorporated now offers encoders and hardware to mate its popular NGC-MAX positioning computer to the Explore Scientific Twilight II alt-az telescope mount (a complete kit with NGC-MAX computer sells for $729). Now you can have all the Messier, NGC, and IC catalog objects available at the push of a button for your dual-mounted telescopes. The kit's high-resolution encoders deliver 10,000-tics-per-revolution accuracy, virtually guaranteeing that your target lands in the field of your telescope every time. The kit comes complete with all mounting hardware and tools needed for installation and it works with the Twilight II, with or without the optional 8-inch extension pier. The mounting bracket, encoders, and NGC-MAX computer are each available separately.

JMI Telescopes
8550 W 14th Ave., Lakewood, CO 80215, 303-233-5353; www.jmitelescopes.com

▼ **IMAGING COMPENDIUM** Author and world-renowned astrophotographer Thierry Legault teaches you the art and techniques of astro-imaging in his book *Astrophotography* ($39.95, or $31.95 in eBook format). Legault's compendium walks readers through the hows and whys of astronomical imaging, from basic camera-on-tripod skyscape photography to the more complex and demanding processes that use specialized telescopes and cameras for a variety of astronomical subjects, including the Sun, Moon, planets, artificial satellites, and deep-sky targets such as nebulae and galaxies. Legault shares his experiences to help you obtain the best results from a variety of equipment while guiding you through the common steps used to capture and process astronomical imagery. Paperback, 225 pages. ISBN 978-1-937538-43-9.

Rocky Nook
802 E. Cota St., #3, Santa Barbara, CA 93103
805-687-8727; www.rockynook.com



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

In This Section

Additional Observing Articles:

The magnificent Helix Nebula is a visual treat (page 56) and one of the closest planetary nebulae to Earth (page 20).
NASA / NOAO / ESA / Margaret Meixner / Travis Rector

Sky at a Glance

NOVEMBER 2014

Oct 21 – Nov 4 **DAWN:** The zodiacal light is visible in the east 120 to 80 minutes before sunrise from dark locations at mid-northern latitudes. Look east for a huge, tall pyramid of light stretching from the eastern horizon up through Jupiter and tilted slightly to the right.

Oct 28 – Nov 7 **DAWN:** Mercury's best morning apparition of 2014 for northern observers. Mercury shines more than 5° above the eastern horizon an hour before sunrise as seen from latitude 40° north.

Nov 2 **DAYLIGHT-SAVING TIME ENDS** at 2 a.m. for most of the U.S. and Canada.

2 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 10:07 p.m. EST (7:07 p.m. PST); see page 51.

5 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 6:56 p.m. EST.

14 **DAWN:** Jupiter shines above the waning, slightly gibbous Moon.

17–18 **LATE NIGHT:** The Leonid meteor shower is likely to peak this night; it's best observed from midnight to the onset of morning twilight. The Leonids are usually weak; see page 50.

22 **EVENING:** Algol shines at minimum brightness for roughly two hours centered at 11:50 p.m. EST (8:50 p.m. PST).

25 **DUSK:** Mars glows well to the left of the waxing crescent Moon.

EVENING: Algol shines at minimum brightness for roughly two hours centered at 8:39 p.m. EST (6:39 p.m. MST).

Planet Visibility SHOWN FOR LATITUDE 40° NORTH AT MID-MONTH

◄SUNSET MIDNIGHT SUNRISE►

Mercury	Visible Oct 24 to Nov 19 — E
Venus	SW — Visible starting Nov 29
Mars	SW
Jupiter	E — S
Saturn	Hidden in the Sun's glare all month

Moon Phases

Full November 6 5:23 p.m. EST

New November 22 7:32 a.m. EST

Last Qtr November 14 10:16 a.m. EST

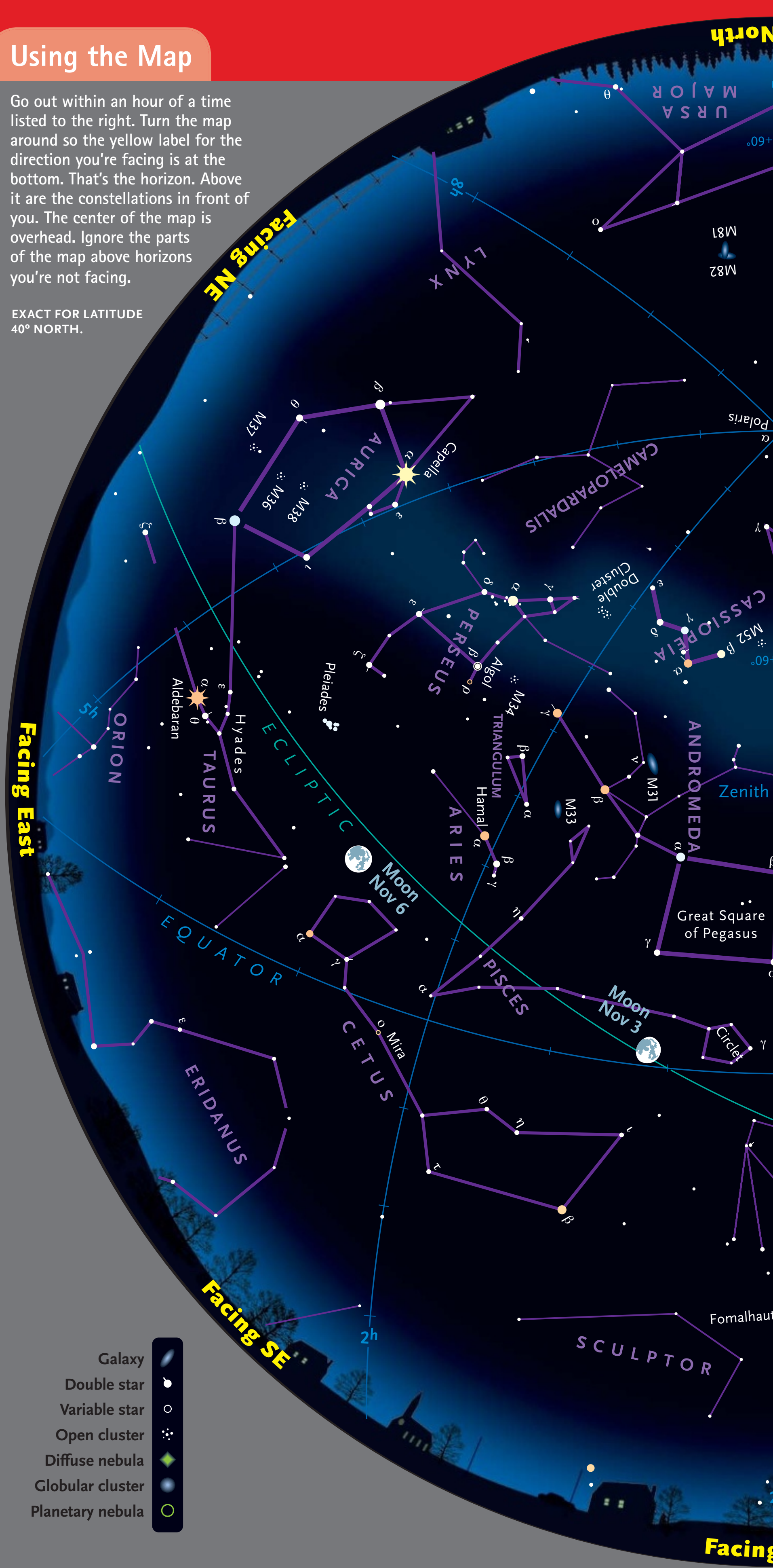
First Qtr November 29 5:06 a.m. EST

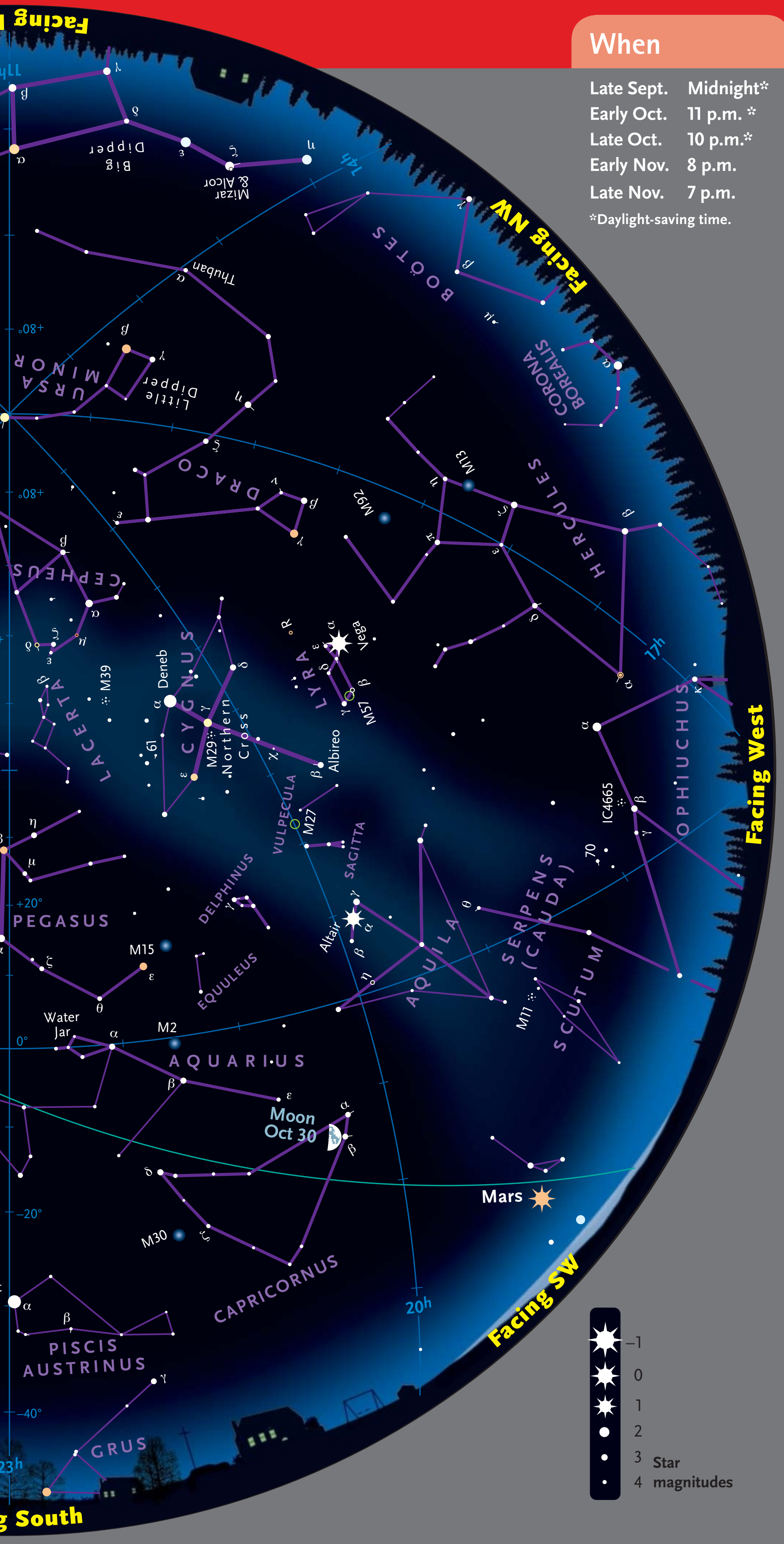
SUN	MON	TUE	WED	THU	FRI	SAT
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30	24	25	26	27	28	29

Using the 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. Above it are the constellations in front of you. The center of the map is overhead. Ignore the parts of the map above horizons you're not facing.

EXACT FOR LATITUDE 40° NORTH.





When

Late Sept.	Midnight*
Early Oct.	11 p.m. *
Late Oct.	10 p.m.*
Early Nov.	8 p.m.
Late Nov.	7 p.m.

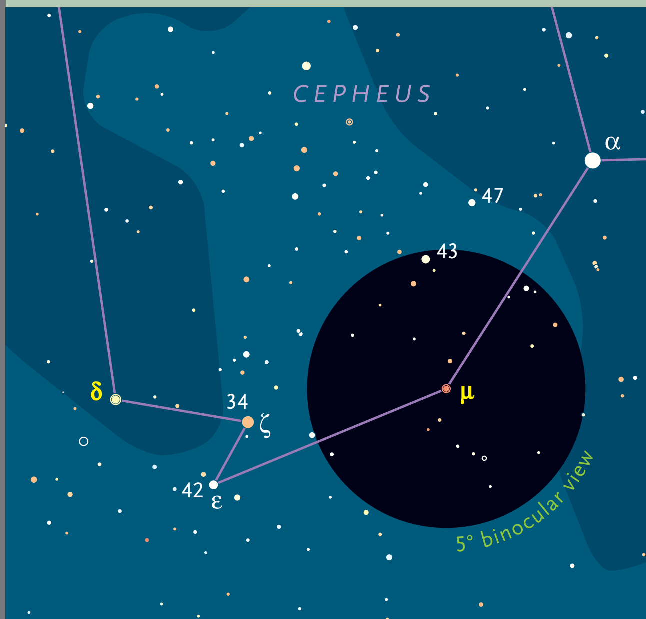
*Daylight-saving time.

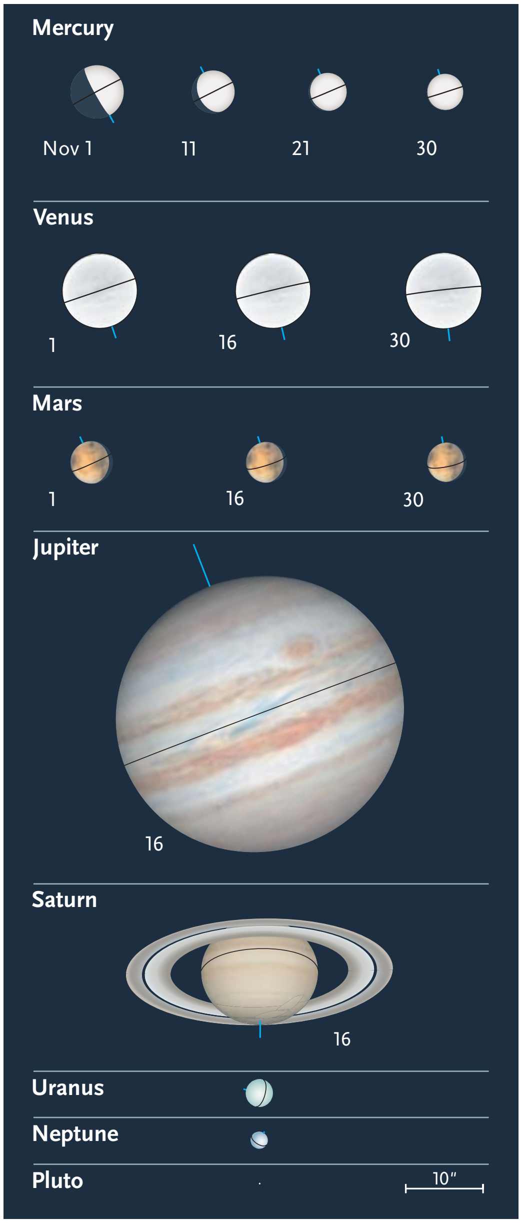
Two Cepheus Gems

Considering it's the celestial "King," the constellation Cepheus doesn't get a lot of attention. Possibly that's because it lacks the showpiece deep-sky treasures so numerous in neighboring Cassiopeia and Cygnus. But that's not to say that Cepheus is without interest for binocular observers. In fact, there's a pair of stellar jewels located along its southern reaches: Delta (δ) and Mu (μ) Cephei.

Delta is the prototypical Delta Cepheid — a class of stars that serves as an important rung on the cosmic distance ladder. It ranges between magnitude 3.5 and 4.4 and back every 5.366341 days. If you view under bright city skies, binoculars will help you see the star when it dips to the low end of its range. (Comparison-star magnitudes in the chart below have their decimal points omitted.) Delta is also a challenging binocular double star. Its companion shines at magnitude 6.3 and is positioned 41 arcseconds away. I can split the two readily with my 15×45 image-stabilized binoculars. If you initially don't succeed, try again when Delta is at the dim end of its range. This minimizes the brightness difference between components, which makes seeing the fainter star easier.

Lying about 6 degrees west of Delta is Cepheus's other stellar prize: Mu Cephei. Although it too is a variable star (magnitude 3.4 to 5.1, semiregular period), its chief claim to fame is its color. Mu, also known as Herschel's Garnet Star, is one of the reddest naked-eye stars in the sky. Sounds awesome, right? Keep in mind that, with rare exceptions, even strongly tinted stars have fairly subdued hues. Even in binoculars Mu is more a subtle yellowish-orange than stoplight red. Still, the stars's color is strong enough that it's easy to identify in its rich field. ✦



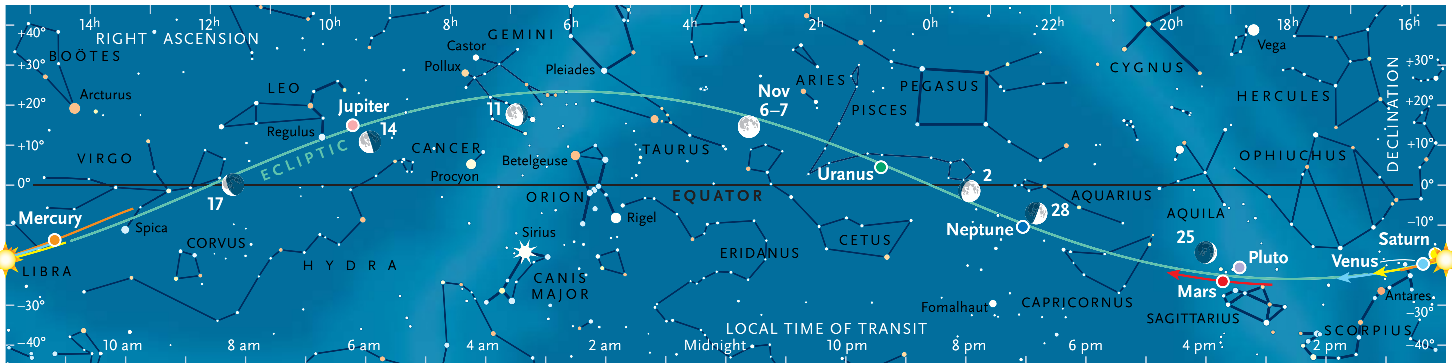


Sun and Planets, November 2014

	November	Right Ascension	Declination	Elongation	Magnitude	Diameter	Illumination	Distance
Sun	1	$14^h\ 23.6^m$	–14° 16′	—	–26.8	32′ 14″	—	0.993
	30	$16^h\ 22.7^m$	–21° 33′	—	–26.8	32′ 26″	—	0.986
Mercury	1	$13^h\ 16.1^m$	–5° 46′	19° Mo	–0.6	6.9″	55%	0.972
	11	$14^h\ 05.1^m$	–10° 41′	16° Mo	–0.8	5.5″	85%	1.211
	21	$15^h\ 05.3^m$	–16° 31′	10° Mo	–0.9	4.9″	96%	1.362
	30	$16^h\ 02.8^m$	–20° 53′	5° Mo	–1.1	4.7″	99%	1.432
Venus	1	$14^h\ 31.4^m$	–14° 03′	2° Ev	–4.0	9.7″	100%	1.715
	11	$15^h\ 21.0^m$	–17° 58′	4° Ev	–3.9	9.8″	100%	1.708
	21	$16^h\ 12.6^m$	–21° 05′	7° Ev	–3.9	9.8″	99%	1.698
	30	$17^h\ 00.7^m$	–23° 02′	9° Ev	–3.9	9.9″	99%	1.685
Mars	1	$18^h\ 17.3^m$	–24° 53′	56° Ev	+0.9	5.5″	90%	1.687
	16	$19^h\ 06.7^m$	–24° 01′	52° Ev	+1.0	5.3″	91%	1.758
	30	$19^h\ 52.8^m$	–22° 19′	48° Ev	+1.0	5.1″	92%	1.823
Jupiter	1	$9^h\ 31.3^m$	+15° 20′	78° Mo	–2.1	36.4″	99%	5.416
	30	$9^h\ 39.6^m$	+14° 46′	105° Mo	–2.2	39.7″	99%	4.966
Saturn	1	$15^h\ 27.2^m$	–16° 49′	16° Ev	+0.5	15.3″	100%	10.896
	30	$15^h\ 41.1^m$	–17° 39′	11° Mo	+0.5	15.2″	100%	10.917
Uranus	16	$0^h\ 48.5^m$	+4° 27′	140° Ev	+5.7	3.7″	100%	19.247
Neptune	16	$22^h\ 26.9^m$	–10° 31′	101° Ev	+7.9	2.3″	100%	29.761
Pluto	16	$18^h\ 49.2^m$	–20° 41′	48° Ev	+14.2	0.1″	100%	33.413

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

Planet disks at left have south up, to match the view in many telescopes. Blue ticks indicate the pole currently tilted toward Earth.



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

Fred Schaaf welcomes your comments at fschaaf@aol.com.

Fred Schaaf

The Harvest of the Autumn Sky

November nights offer several succulent star patterns.

"They find me walking
With my lady at my side,
Like Beatrice my guide.
Together traveling far,
We're harvesting the stars,
We're harvesting the stars."
"God bless you, jester,
You've come through love and hate
And now love is your fate.
The dying people wait.
We'll nourish them with stars."
— Bob Schaaf, *The Wind Gem*

My brother, who composed the song from which these lines come, isn't the only person who has conceived of a harvest of heavenly objects. Veteran deep-sky observer and astronomy writer James Mullaney, for one, has a fine book titled *Celestial Harvest*. And as far back as 1779, the French astronomer Joseph-Jérôme de Lalande introduced on a celestial globe a far-northern constellation (now defunct) called Custos Messium, the "Keeper of the Harvest." Lalande confessed that this name was in punning tribute to none other than Charles Messier himself.

Is there in fact a harvest of celestial objects we can reap in autumn's evening skies? November is a little late for most Earthly harvesting, though many of you readers will be first seeing this article in late September, when the Northern Hemisphere harvest is in full swing. But November has always seemed to me one of the best months for finding and gathering choice asterisms and star clusters that are visible to the naked eye.

Harvesting asterisms. Most of the traditional autumn constellations are notoriously dim. Perhaps that's why little patterns of stars stand out more now and are sought-after on autumn evenings. You'll need rather dark skies to find these asterisms; binoculars may help.

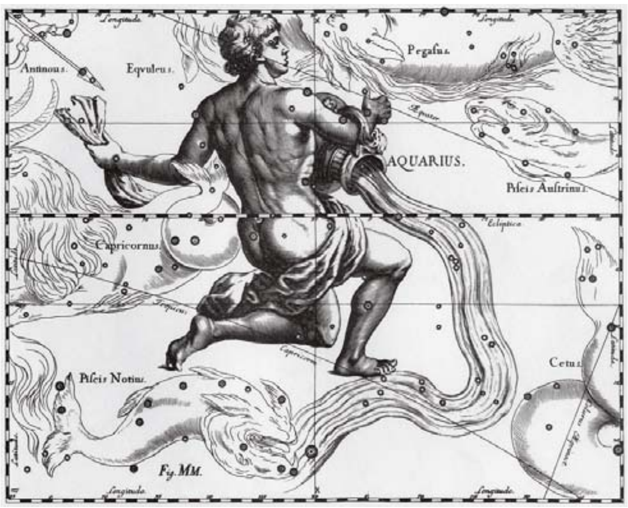
In Aquarius there is the sideways Y of stars called the Urn or Water Jar. It's being tipped and poured by this constellation of the Water Bearer. The Water Jar is located right on the celestial equator and is composed of 4th-magnitude stars, though many people also include 2.9-magnitude Alpha (α) Aquarii, also known as Sadalmelik, in the asterism. The brightest star of the Y is Sadachbia, Gamma (γ) Aquarii. The names Sadalmelik and Sadachbia may respectively mean "the lucky stars of the king" and "the lucky stars of the tents," though no one is really sure if the "lucky" part of the translation is right.

Eta (η) Aquarii marks the bottom or tail of the Y. A line from Eta through Alpha, then continued for the same distance, reaches the delectable 6th-magnitude globular cluster Messier 2.

The Water Jar fits within the field of view of most binoculars, and so does an asterism not far to its northeast: the Circlet, a roundish loop of 4th- and 5th-magnitude stars that depicts the head of the western fish of Pisces. Other autumn star patterns that could be considered asterisms, even though they form the main patterns of constellations, are those of Aries the Ram and Triangulum the Triangle.

All these asterisms — and some naked-eye clusters I'll discuss next month — really do remind me of fruits or vegetables to be harvested.

Stars as sustenance. I've pondered writing a fantasy novel in which there are Star Wolves that gain part of their sustenance by licking the starlight off snow in far-northern lands. Richard Hinckley Allen says that in one version of the great East Asian star myth of the Weaving Maiden (Vega) and Cowherd or Prince (Altair), the two are separated because the Prince blows money on "a very promising scheme to tap the Milky Way and divert the fluid to nourish distant stars." But my brother writes of nourishing the "dying people" with stars. All lovers of the stars should be able to understand what he means. ✦



SOURCE: HEVELIUS

Aquarius, the Water Bearer, tilts his jar toward Pisces and Cetus in this mirror-reversed chart from Johannes Hevelius's 1690 star atlas.

A Three-Planet Month

Mercury, Mars, and Jupiter are in good view this November.

Mars is the only bright planet visible at dusk for most of November. It appears fairly low in the southwest as the sky darkens and keeps setting about 3½ hours after the Sun all month. Jupiter rises in the middle of the night and shines very high in the south by sunrise or earlier. And Mercury puts on a fine dawn display in the first half of November.

The other two bright planets are harder. Toward the end of November, Venus can be glimpsed very low in the west-southwest shortly after sunset. And just before month's end, binoculars may show Saturn low in the morning twilight.

DUSK

Mars comes into view at dusk around the same spot in the southwest throughout November. It dims marginally, from magnitude 0.9 to 1.0, and telescopes show that its tiny, slightly gibbous disk shrinks a bit, from 5.5″ to 5.1″ wide.

Mars glides across most of Sagittarius during the month. It passes less than 4° south of very dim **Pluto** from November 9th through 12th. To see Pluto through a medium or large backyard telescope, start immediately after dark, before the 14.2-magnitude world sinks too low, and pinpoint its location with the finder chart on page 50 of the June issue.

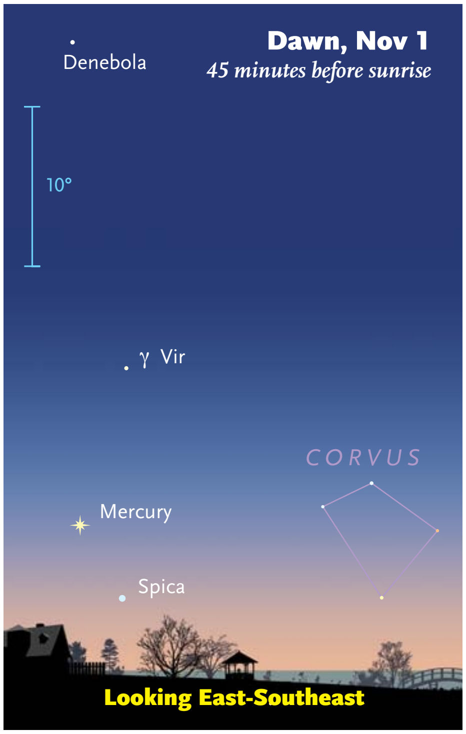
As evening advances, first **Neptune** and then **Uranus** cross the meridian. Neptune is a 7.9-magnitude speck more than two hours west of 5.7-magnitude Uranus. Consult the finder charts on page 50 of the September issue, or at **skypub.com/urnep**, to find them in Aquarius (Neptune) and Pisces (Uranus).

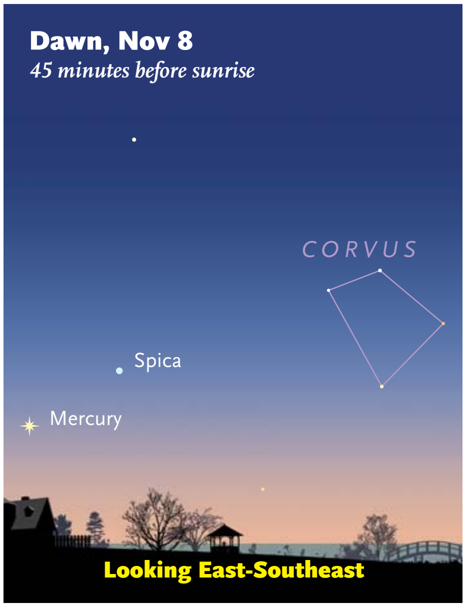
Venus passed through superior conjunction with the Sun on October 25th and begins November setting less than 10 minutes after sunset at mid-northern latitudes. If you point binoculars just above the west-southwest horizon shortly after sunset each week, you'll eventually catch Venus emerging into view. It shines at magnitude –3.9 but appears much fainter in the bright twilight. A naked-eye observation will be much harder. Even by the end of November, Venus is less than 5° high at sunset as seen from latitude 40° north.

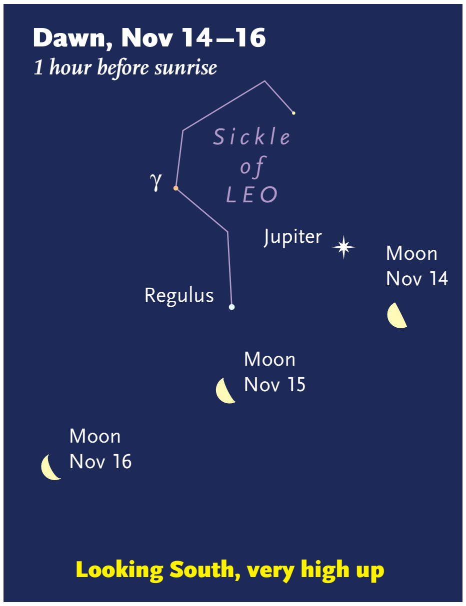
Saturn sets less than an hour after the Sun as November starts, and it's already too low in the Sun's afterglow for mid-northern observers to spot without optical aid. Venus passes just 1.5° south of Saturn on the American evening of November 12th. Venus may be visible through a telescope, but at magnitude 0.5, the ringed planet is much too dim to see so close to the Sun. Saturn goes through conjunction with the Sun on November 18th and pops up in the sunrise glow toward month's end, as described below.

LATE NIGHT TO DAWN

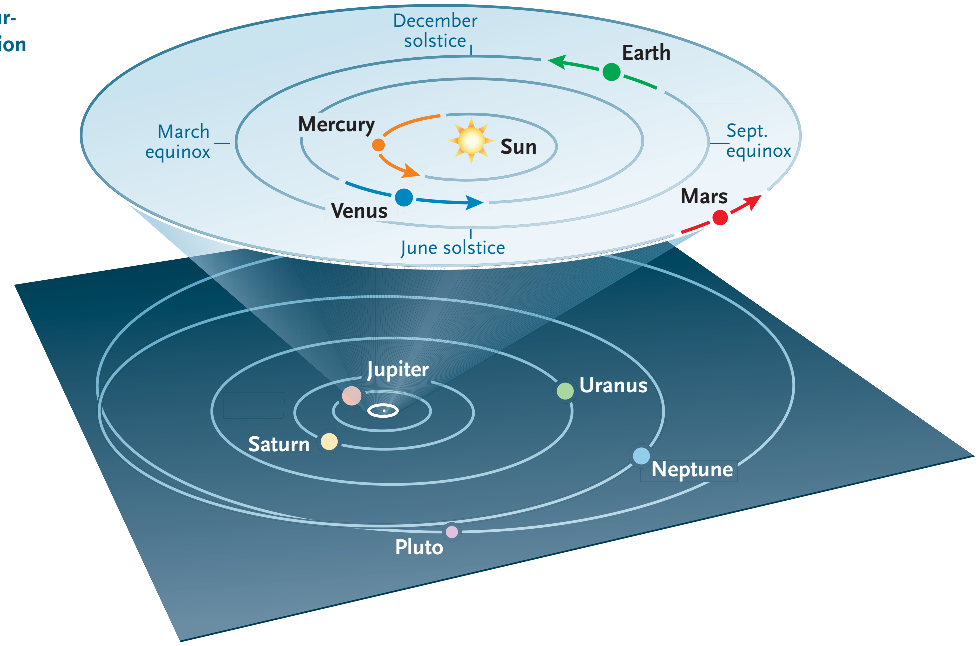
Jupiter rises around 1 a.m. daylight-saving time at the start of November. But by the end of the month the giant planet comes







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



above the horizon around 10 p.m. standard time. Jupiter brightens slightly in the interval — from magnitude –2.1 to –2.2 — and it grows larger as seen through a telescope, from 36″ to 40″ wide. Jupiter is at quadrature, 90° west of the Sun, on November 14th. So this is the month when shading is most visible on Jupiter's western edge, and it's when the Galilean satellites appear farthest east of their shadows as they traverse Jupiter's giant face. This is also when the huge world is highest in the south around the time of morning twilight.

In November, Jupiter is slowing its direct (eastward) motion in western Leo. Regulus shines about a fist-width at arm's length to Jupiter's left at dawn all month.

DAWN

Mercury is at greatest elongation on November 1st. Its angular separation from the Sun is only 18.7°, because it's just a week after Mercury's perihelion. But mid-northern observers see Mercury almost directly above the point where the Sun will rise. That's because the ecliptic is close to vertical at dawn, and in addition Mercury is 2° north of the ecliptic.

So the first few mornings of November are the climax of Mercury's best dawn apparition of 2014. The speedy little planet starts the month rising about 90 minutes before the Sun and stands almost 10° high in the east-southeast 45 minutes before sunup. Mercury then shines at magnitude –0.6, and telescopes show its disk 7″ wide and about half lit.

On the morning of November 4th, Mercury is closest to much dimmer Spica, which lies about 4° south (lower right) of the planet. Three days later, Spica is distinctly higher than Mercury.

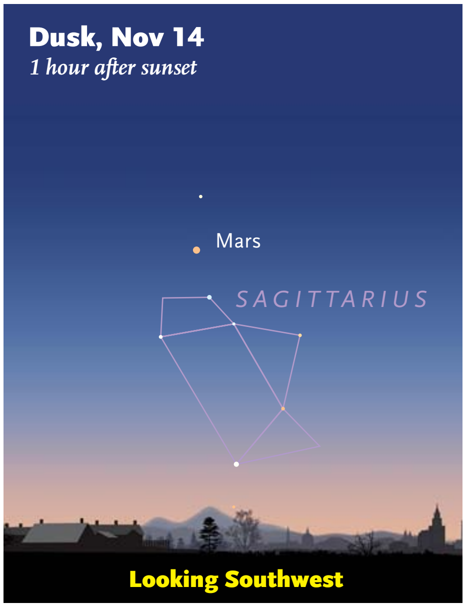
Although Mercury brightens throughout November, it keeps appearing lower in the dawn. It's lost to naked-eye view during the third week of November and becomes invisible through binoculars not long after.

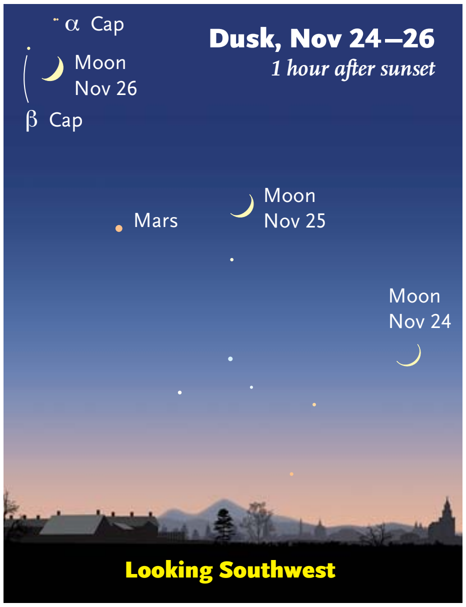
Saturn lifts into the dawn after its conjunction with the Sun on November 18th. Saturn is only 1.7° north of much brighter Mercury on November 26th, but they're probably both unviewable, just 7° from the Sun. Yet by November 30th Saturn is rising an hour before the Sun and should be visible through binoculars and telescopes a half hour before sunrise.

MOON PASSAGES

The **Moon** is full on the American evening of November 6th. The Moon is waning gibbous, just shy of last quarter, when it shines lower right of Jupiter before dawn on November 14th. A modest lunar crescent is only a slight hindrance for viewing the Leonid meteor shower in the small hours of the morning on November 17th and 18th (see page 50).

Around nightfall on November 25th, the waxing crescent Moon floats well to the right of Mars. The next evening it's even farther to Mars's upper left. ✦





November Meteors Slow & Fast

Two very different showers dominate the November meteor calendar.

ROBERT MIKAELYAN

At dusk on October 13, 2009, this dazzling fireball awed untold thousands in the Netherlands and northern Germany. Some called it as bright as the full Moon. It broke into several bright fragments before disappearing, and sonic booms followed. It may or may not have been a Taurid fireball, but its date and evening appearance were about right.

Skywatchers are coming to realize that mid-autumn tends to be fireball season. At least in some years. The reason is the strange Taurid meteor shower, active all the way from early October through late November. The Taurids rank as a rather minor shower in terms of numbers, with only a dozen or fewer meteors visible per hour even under ideal conditions during the peak weeks. But something about the origin of the Taurid meteoroid stream endowed it with an unusual proportion of large chunks compared to the usual little pebbles and bits of coarse sand.

The Taurids are debris from the periodic comet 2P/Encke. They have orbital periods of only about 3.3 years and never venture farther from the Sun than the asteroid belt. So when they cross Earth's distance from the Sun, they're traveling slower than most shower meteors, which have fallen sunward from farther out.

Moreover, the Taurids catch up to Earth somewhat from behind: in roughly the same direction Earth is moving. For these reasons, they arrive in our skies at the unusually slow velocity of 30 km per second (67,000 mph).

Their direction of arrival also means that the shower's radiant rises high in the evening, not just the morning as with most showers. So Taurids appear from dusk to dawn.

Between October 10th and November 25th the radiant moves all the way from north of the head of Cetus to north of the Hyades cluster. Even though the Taurid radiant "point" is unusually large and diffuse, meteor observers have identified two overlapping sub-radiants, the Southern and Northern Taurids. The shower transitions from the former to the latter during late October and early November.

Taurid fireballs have come to be called "the Halloween fireballs," but that refers to the broad Halloween season. If you see a slow fireball in October or November, check whether the direction of its path, traced far backward, leads to the area above Cetus's head in October or the vicinity of the Pleiades and Hyades later in November.

Swift Leonids

A very different beast is the more famous Leonid shower. It lasts just a couple of days, covering the mornings of November 17th and 18th this year. The Leonids are among the swiftest possible meteors, hitting Earth head-on at 71 km per second. But this shower is also weak; it's now down to maybe a dozen visible per hour under good conditions. That's a pale shadow of the grand Leonid displays of 1998 to 2002, when the shower's parent comet, 55P/Tempel-Tuttle, was passing through the inner solar system.

The Leonids are at their best from midnight to dawn. The Moon won't be much trouble; it doesn't rise until about 2 or 3 a.m. on those mornings and even then it's a fairly dim waning crescent.

Action at Jupiter: Moons

November finds Jupiter still rising late at night and showing itself highest and sharpest at the beginning of dawn. This month Jupiter grows encouragingly from 36″ to 40″ in equatorial diameter. I think of any Jupiter diameter in the 30s as "small" and any in the 40s as "good." Jupiter will be only slightly wider, 45″, when it comes to opposition next February 6th.

Any telescope shows Jupiter's four big Galilean moons. Binoculars usually show at least two or three, and occasionally all four. Identify them using the diagram on page 52. Also tabulated there are all the interactions between Jupiter and its satellites in November. Jupiter and its environs are a busy place!

The Great Red Spot, becoming shorter and rounder with

The Moons of Uranus & Neptune

The twin outermost planets are invitingly high in the south these evenings, shining at magnitude 5.7 and 7.9 in Pisces and Aquarius, respectively. Find them with the charts on page 50 of the September issue or at **skypub.com/urnep**, and see page 54 for Richard Jakiel's article on observing them telescopically.

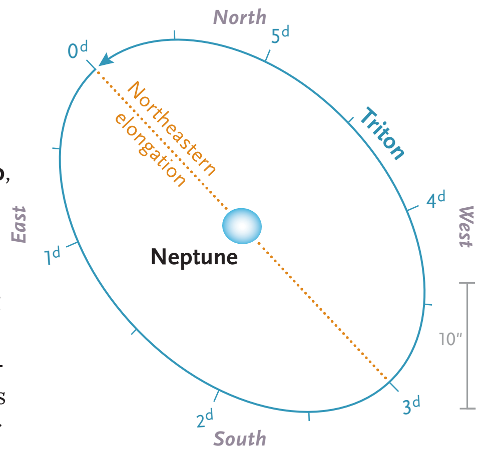
Much more challenging are their faint satellites. Triton, Neptune's one big moon, is magnitude 13.1. But if you've ever found Pluto (physically similar), Triton is easier — not only because Triton is brighter and higher, but because it never strays more than 17″ from its host planet.

The brightest moons of Uranus — Ariel, Umbriel, Titania, and Oberon — are about as bright as Triton except for Titania, magnitude 14.0. But Uranus's brighter glare makes them tougher to see. In all cases, use your highest power.

The trick to finding any faint, difficult target is knowing *exactly* where to look. To get finder charts for the moons customized to the date and time when you plan to observe, go to **skypub.com/triton** and **skypub.com/uranusmoons**.

Or for Triton, the least difficult one, you can use the diagram above with a calculator as follows:

Convert the time and date you'll observe into a decimal date in Universal Time (for example, 12:00 UT November 9th is "November 9.50"). Next, find how long this has been, in days, since the most recent of these selected dates of Triton's northeastern elongation: September 23.06, October 4.82, November 3.22, December 2.60.



Divide this difference by 5.877 (Triton's orbital period in days). Drop anything to the left of the decimal point. Multiply what remains by 5.877. The result tells how many days (^{d}) Triton has moved counterclockwise around its orbit in the diagram since northeastern elongation.

For instance, at 5:00 UT October 20th (October 20.21), Triton turns out to be 3.6 days past northeastern elongation — putting it west-southwest of the planet. That's where to look.

Algol, the prototype eclipsing variable star, fades every 2.87 days from its usual magnitude 2.1 down to 3.4. It stays near minimum light for two hours, and it takes several more hours to fade and to rebrighten. Shown above are magnitudes of comparison stars with decimal points omitted. The geocentric predictions below are from the heliocentric elements Min. = JD 2452253.559 + 2.867362*E*, where *E* is any integer. Courtesy Gerry Samolyk, AAVSO.

Minima of Algol

Oct.	UT	Nov.	UT
2	14:10	3	3:07
5	10:59	5	23:56
8	7:47	8	20:45
11	4:36	11	17:34
14	1:25	14	14:22
16	22:14	17	11:11
19	19:02	20	8:00
22	15:51	23	4:50
25	12:40	26	1:39
28	9:29	28	22:28
31	6:18		

and Red Spot

each passing decade (July issue, page 16), is becoming easier to spot as Jupiter shines higher in steadier air. Here are the times, in Universal Time, when the Great Red Spot should cross the planet's central meridian. The dates, also in UT, are in bold. (Eastern Daylight Time is UT minus 4 hours; Eastern Standard Time is UT minus 5 hours.)

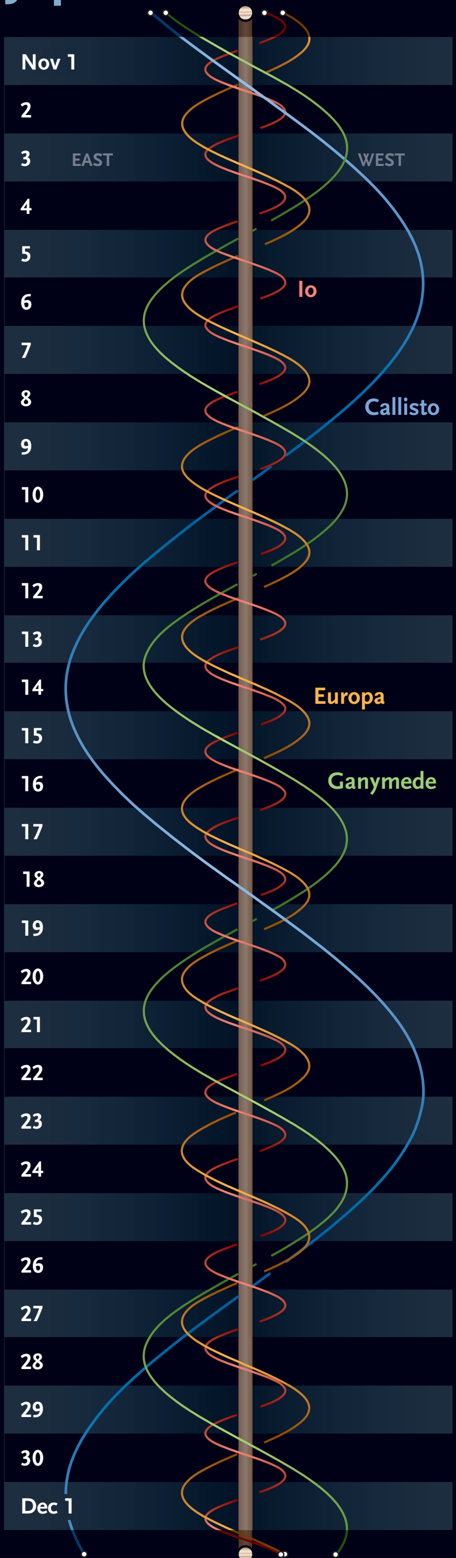
October 1, 0:31, 10:27, 20:22; **2,** 6:18, 16:14; **3,** 2:10, 12:05, 22:01; **4,** 7:57, 17:53; **5,** 3:48, 13:44, 23:40; **6,** 9:36, 19:31; **7,** 5:27, 15:23; **8,** 1:19, 11:14, 21:10; **9,** 7:06, 17:01; **10,** 2:57, 12:53, 22:49; **11,** 8:44, 18:40; **12,** 4:36, 14:32; **13,** 0:27, 10:23, 20:19; **14,** 6:15, 16:10; **15,** 2:06, 12:02, 21:58; **16,** 7:53, 17:49; **17,** 3:45, 13:40, 23:36; **18,** 9:32, 19:28; **19,** 5:23, 15:19; **20,** 1:15, 11:10, 21:06; **21,** 7:02, 16:58; **22,** 2:53, 12:49, 22:45; **23,** 8:40, 18:36; **24,** 4:32, 14:28; **25,** 0:23, 10:19, 20:15; **26,** 6:10, 16:06; **27,** 2:02, 11:58, 21:53; **28,** 7:49, 17:45; **29,** 3:40, 13:36, 23:32; **30,** 9:28, 19:23; **31,** 5:19, 15:15.

November 1, 1:14, 11:09, 21:05; **2,** 7:01, 16:56; **3,** 2:52, 12:48, 22:44; **4,** 8:39, 18:35; **5,** 4:31, 14:26; **6,** 0:22, 10:18, 20:13; **7,** 6:09, 16:05; **8,** 2:00, 11:56, 21:52; **9,** 7:48, 17:43; **10,** 3:39, 13:35, 23:30; **11,** 9:26, 19:22; **12,** 5:17, 15:13; **13,** 1:09, 11:04, 21:00; **14,** 6:56, 16:51; **15,** 2:47, 12:43, 22:38; **16,** 8:34, 18:30; **17,** 4:25, 14:21; **18,** 0:17, 10:12, 20:08; **19,** 6:04, 15:59; **20,** 1:55, 11:51, 21:46; **21,** 7:42, 17:38; **22,** 3:33, 13:29, 23:25; **23,** 9:20, 19:16; **24,** 5:12, 15:07; **25,** 1:03, 10:59, 20:54; **26,** 6:50, 16:46; **27,** 2:41, 12:37, 22:33; **28,** 8:28, 18:24; **29,** 4:19, 14:15; **30,** 0:11, 10:06, 20:02.

These times assume the spot is centered at System II longitude 227°. If it's not following predictions, it will transit 1⅔ minutes early for every degree of longitude less than 227°, or 1⅔ minutes later for every degree more.

Features on Jupiter appear closer to the central meridian than to the limb for 50 minutes before and after transiting. A light blue or green filter slightly boosts the contrast of Jupiter's reddish, orange, and tan markings.

Jupiter's Moons

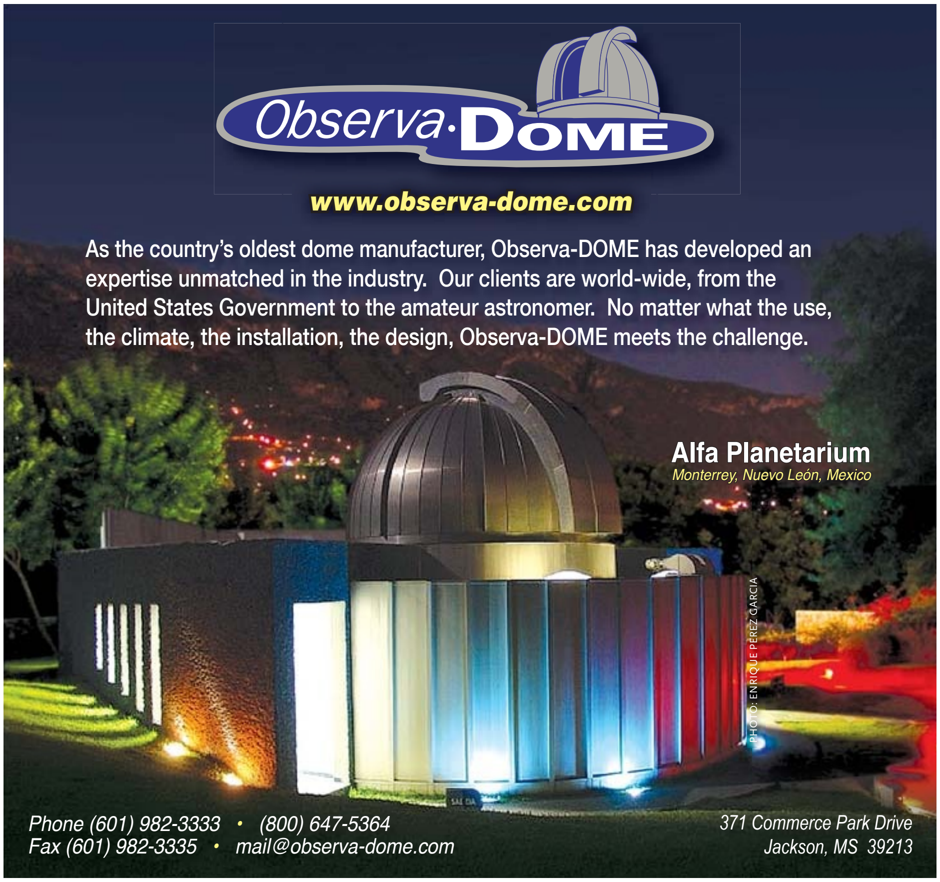


The wavy lines represent Jupiter's four big satellites. The central vertical band is Jupiter itself. Each gray or black horizontal band is one day, from 0h (upper edge of band) to 24h UT (GMT). UT dates are at left. Slide a paper's edge down to your date and time, and read across to see the satellites'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

Phenomena of Jupiter's Moons, November 2014

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

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



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Realm of the Ice Giants

Track down the outermost planets this month.

The cool nights of mid-autumn are perfect for hunting down the most distant planets of the solar system. Both Uranus and Neptune are well placed in the evening sky now, and with the large, high-quality telescopes many of you own, you may be able to make real contributions to the study and understanding of these remote worlds.

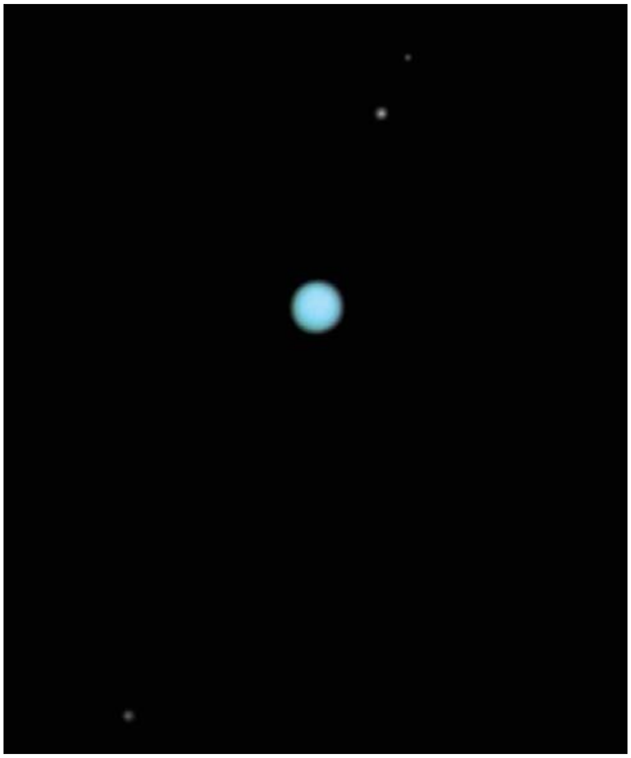
Uranus and Neptune share a remarkable number of characteristics. Their sizes, masses, and compositions are similar. They both have a few faint rings and a retinue of satellites. Their internal compositions aren't nearly as hydrogen- and helium-rich as larger Jupiter and Saturn; each consists instead of a small, rocky core surrounded by a massive mantle of water, ammonia, and methane ("ices" to planetary scientists, even when they're hot fluids). The part we see is the top of a deep atmosphere rich in hydrogen, helium, and methane. The early evolution of Uranus in particular must have been dramatic, judging by its axial tilt. Although Neptune has a roughly Earth-like tilt of 28°, Uranus rotates on its side, with its axis inclined 98° from its orbit. This hints at an immense collision and merger when the solar system was young.

Neptune reached opposition on August 29th this year, Uranus on the night of October 7th. However, this hardly matters because of their great distances; their apparent sizes change little throughout the year. Both are now easier to find than usual, because they are located close to naked-eye stars. Use the finder charts in the September issue, page 50, or online at **skypub.com/urnep**.

Uranus has a slightly blue-green tint. Visual observers tend to describe Neptune as more gray-blue. The colors are fairly subtle, however, and any color difference between them is controversial (*S&T:* September 2010, p. 56).

Uranus during October and November is about magnitude 5.7, near the threshold of naked-eye visibility. It's slightly more than a degree east of the equally bright, reddish-orange star HD 4628; their contrasting colors make for an interesting study in a small telescope or binoculars. The planet's tiny disk (3.7″) requires moderately high magnification to resolve. Details such as limb darkening and a slightly brighter polar region may be detectable in large scopes under good seeing. Faint, low-contrast cloud belts have been reported intermittently in past years, though they are extremely difficult to spot at best.

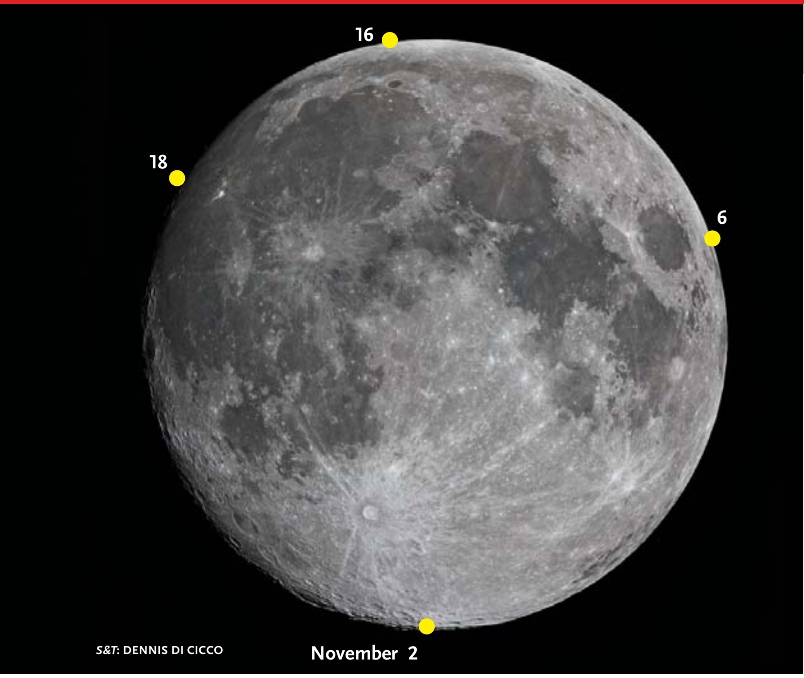
Although the distant planets Neptune and Uranus (*left* and *right*, respectively) taunt amateurs with their tiny disks, imagers with mid-sized telescopes can capture decent photos of these colorful worlds as well as their brighter satellites.



JOHN BOUDREAU (2)

***Richard Jakiel** observes the solar system and deep space from his home "Mars House" in the wilds of suburban Atlanta, Georgia.*

Richard Jakiel



S&T: DENNIS DI CICCO

The Moon • November 2014

Phases

FULL MOON
November 6, 22:23 UT

LAST QUARTER
November 14, 15:16 UT

NEW MOON
November 22, 12:32 UT

FIRST QUARTER
November 29, 10:06 UT

For key dates, yellow dots indicate which part of the Moon's limb is tipped the most toward Earth by libration under favorable illumination.

Distances

Perigee 228,589 miles	November 3, 0^h UT diam. 32′ 29″
Apogee 251,243 miles	November 15, 2^h UT diam. 29′ 33″
Perigee 229,800 miles	November 27, 23^h UT diam. 32′ 19″

Librations

Malapert (crater)	November 2
Hubble (crater)	November 6
Desargues (crater)	November 16
Voskresenskiy (crater)	November 18

Unlike Uranus, Neptune requires optical aid to see at all. It's about two magnitudes fainter at 7.8 or 7.9 this fall, and its tiny disk is only 2.3″ across. Currently, Neptune is about ½° west of σ Aquarii (4.8). Other than perhaps limb darkening, there isn't much to see on this diminutive orb. Any traces of cloud markings require very large telescopes, sensitive cameras, and superb seeing conditions.

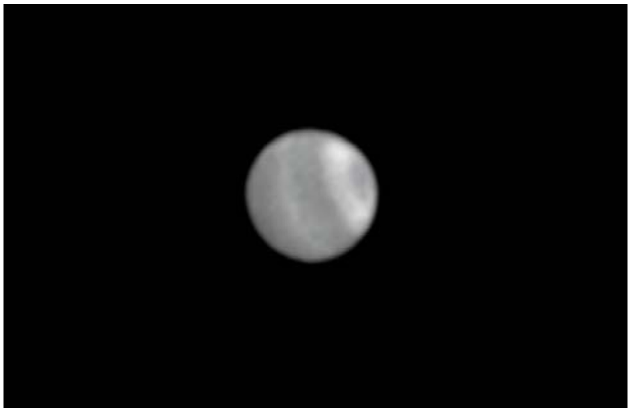
The real fun for visual observers is to spot these distant worlds' brighter moons, as told on page 51. Uranus has five satellites within range of large amateur instruments. The outermost moons — Titania (magnitude 13.0) and Oberon (13.2) — are the least difficult and can been spotted with 10- to 12-inch scopes. Closer-in Umbriel (14.0) and Ariel (13.2) require larger apertures. If you have access to a 20-inch scope, and if the seeing is good, try spotting Miranda (15.8) near Uranus's pale disk.

Neptune has one moon within range of amateur instruments: Triton. It has the distinction of being the only large moon that orbits its planet backward, hinting at its likely origin as a captured Kuiper Belt object. Using an 8-inch or larger scope at high power in a dark sky, Triton (13.0) is detectable 12 to 17 arcseconds from Neptune.

By adding a high-speed digital video camera and popular image-stacking software, you can photograph all of these moons with an 8-inch scope. Any hope of recording Uranus and Neptune themselves as anything more than tiny disks requires a 10-inch scope. In the last few years, planetary imagers working at near-infrared wavelengths have recorded subtle atmospheric belts and a brighter polar region on Uranus, and a bright spot on Neptune.

You can contribute to our growing body of knowledge about these distant worlds. A small telescope with a CCD camera or photometer is enough for a long-term brightness-monitoring project, highly desired by the scientific community. Amateur organizations including the Association of Lunar & Planetary Observers (**www.alpo-astronomy.org**) and the British Astronomical Association (**www.britastro.org**) always welcome data submitted by amateurs. Additionally, the professional Planetary Virtual Observatory & Laboratory (**www.pvol.ehu.es/pvol**) is a public database where amateurs can upload their images to contribute to the study of the atmospheres of the outer planets. In recent years, amateur images shared here have been cited in papers published in professional journals.

As the nights grow longer through year's end, spending time with the ice giants can add a new level of enjoyment to your evening. ✦



DAMIAN PEACH

Uranus is generally featureless in visible wavelengths, but images such as this, which was recorded at near-infrared wavelengths with a 14-inch telescope, have revealed atmospheric banding.

A Meeting of the Waters

Aquarius hosts one great planetary nebula and some fascinating galaxies.

The zodiacal constellation of Aquarius aptly hosts the planet Neptune from 2012 through 2021. Aquarius is the Water Carrier, and Neptune is named for the mythic Roman god who governs Earth's waters. This November we find Neptune's pale blue dot less than a degree west and a bit north of the star Sigma (σ) Aquarii.

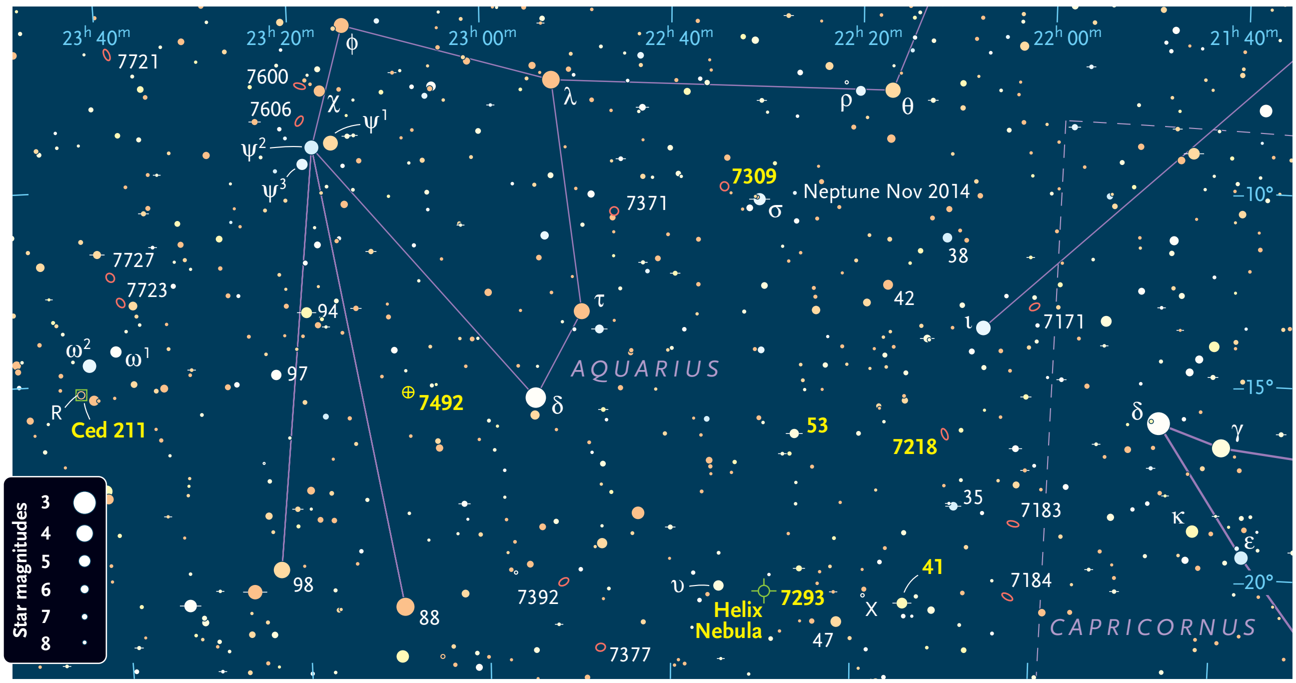
The surrounding sky also harbors many deep-sky wonders, mostly the teeming star cities called galaxies. The closest galaxy to Sigma that's listed in the *New General Catalogue of Nebulae and Clusters of Stars* is **NGC 7309**, which dwells 58′ east-northeast of the star. A pretty little thing in photographs, NGC 7309 is quite faint through my 105-mm refractor at 122×. It appears roundish with uniformly low surface brightness. In my 10-inch reflector at 213×, NGC 7309 spans about 55″ and displays a broadly but only slightly brighter middle. A dim star sits 1.6′ east of the galaxy's center. My 15-inch scope at 245× reveals very subtle brightness variations that indicate two spiral arms unwinding clockwise, one starting in the north and the other opposed.

Images show that NGC 7309 is actually a three-armed spiral, which is relatively rare. Can you spot a third arm? Seen nearly face-on to our line of sight, this complex galaxy also sports a weak bar and a broken, inner pseudo-ring. NGC 7309 is about 160 million light-years distant.

Let's now dive southward to the charming visual binary **53 Aquarii**, a nearby couple only 66 light-years away from us. My 130-mm refractor at 164× just barely pries apart a matched set of yellow suns, currently aligned east-northeast to west-southwest.

According to a 2010 study by Zorica Cvetković and Slobodan Ninković in the *Serbian Astronomical Journal*, these stars are true twins of our Sun, each weighing in at 1.0 solar mass. The orbital period of the pair is a lengthy 3,500 years. Author and astronomer Jim Kaler states that at closest approach in their highly elliptical orbit, these stars are only 30 astronomical units apart — the distance between the Sun and Neptune. If our solar system had a second Sun in place of Neptune, it would outshine 400 full Moons as seen from Earth.

West of 53 Aquarii and north of 35 Aquarii, we find **NGC 7218**, a spiral galaxy with multiple arms that's otherwise similar to NGC 7309 in structure. This galaxy is tilted to our line of sight, so it looks oval through my



Minnesota astrophotographer Rick Johnson imaged the exotic three-armed galaxy NGC 7309 with a 14-inch SCT. The field of view is 31′ wide.

105-mm scope at 36×, and it leans north-northeast. At 87× NGC 7218 covers about 2′ × ¾′ and brightens slightly toward the center. With my 10-inch scope at 115×, the galaxy is closely guarded by a faint star at the eastern side of its northern tip, while a brighter one rests 1′ east of the galaxy's center. At 213× a large, brighter interior dominates the galaxy, and there seems to be a somewhat brighter region nested within it that's askew with respect to the galaxy's long axis. Checking this in my 15-inch reflector at 192×, the out-of-kilter feature tilts east-north-east, pointing between the two faint stars.

The tilted patch within NGC 7218 turns out to be its bar, which is short but more pronounced than NGC 7309's bar. NGC 7218 is about half as far away as NGC 7309.

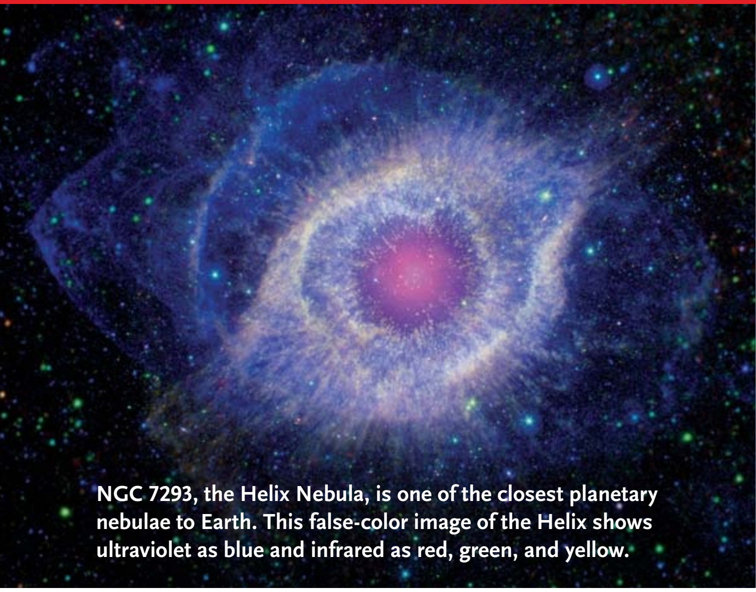
Plunging father south we come to another colorful double star, **41 Aquarii**. This fetching duo is comfortably split through my 130-mm scope at 63×. The bright golden primary is attended by a moderately bright yellow-white companion to the east-southeast. The companion is a normal star heated by hydrogen fusion in its core, as is our Sun. The brighter star is a giant. It has used up the hydrogen in its core, which is now furiously burning helium instead. The pair is roughly four times as distant as 53 Aquarii.

The **Helix Nebula** (NGC 7293) is an Aquarius must-see for tourists of the night sky. Lying east of 41 Aquarii and 1.2° west of Upsilon (υ) Aquarii, this remarkable planetary nebula appears almost half as big across as the full Moon. Even from my moderately light-polluted yard, 12×36 image-stabilized binoculars show a large, roundish, low-surface-brightness glow with a faint star at its west-northwestern edge. The nebula looks as though it would just fit between two field stars that have a separation of 13′.

Through my 105-mm scope at 17×, the Helix is easily visible in the same field of view with Upsilon. It's oblong, a bit darker in the center, and neatly inscribed in a triangle defined by two widely spaced stars at each corner. At 47×, the long ends appear fainter than the rest of the wide annulus, and several stars decorate the nebula and the area around it. A narrowband nebula filter nicely enhances the view, while an O III filter makes the nebula stand out well against the background sky but hides most of the stars. The Helix is gorgeous at 87×. The extent of the nebula and the variations in its brightness are clearer, and I even get a vague sense of the double-ring structure that gives the Helix its name. The planetary's central star is faintly visible, and the closer star of the pair marking the triangle's south-southwestern point is double.

At 700 light-years, the Helix is one of the closest planetary nebulae. Its 19′ length, as projected on the sky, is nearly 4 light-years across, which could almost fill the distance between our Sun and the next nearest star, Proxima Centauri. Visible chiefly on infrared and ultraviolet images, the nebula's outer halo is twice as large.

The discovery of the Helix Nebula by German Astronomer Karl Ludwig Harding was first reported in Berlin's



NGC 7293, the Helix Nebula, is one of the closest planetary nebulae to Earth. This false-color image of the Helix shows ultraviolet as blue and infrared as red, green, and yellow.

NASA / JPL-CALTECH

Deep-Sky Gems in Aquarius

Object	Type	Mag(v)	Size/Sep	RA	Dec.
NGC 7309	Spiral galaxy	12.5	1.9′ × 1.8′	22^h 34.3^m	−10° 21′
53 Aquarii	Double star	6.3, 6.4	1.3″	22^h 26.6^m	−16° 45′
NGC 7218	Spiral galaxy	12.0	2.5′ × 1.1′	22^h 10.2^m	−16° 40′
41 Aquarii	Double star	5.6, 6.7	5.2″	22^h 14.3^m	−21° 04′
Helix Nebula	Planetary nebula	7.3	16′ × 12′	22^h 29.6^m	−20° 50′
NGC 7492	Globular cluster	11.2	4.2′	23^h 08.4^m	−15° 37′
Ced 211	Emission nebula	variable	2.0′ × 1.0′	23^h 43.8^m	−15° 17′

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.

Astronomisches Jahrbuch for 1827, published in 1824. Harding also discovered the asteroid Juno and has a lunar crater named after him.

Another non-galaxy object in this region is **NGC 7492**, which is considerably fainter than Messier 2 and Messier 72, the other two globular cluster residents of Aquarius. In fact, I can barely tell that NGC 7492 is there through my 105-mm refractor at 28×, but a small magnification boost to 47× shows a mottled ashen haze about 3′ across. At 87× the globular cluster appears sandwiched between two very faint stars — one close to its eastern side and the other a bit farther from its west-northwestern edge. It displays irregularities in brightness and holds a slightly brighter core. In my 10-inch reflector at 187×, it looks a little larger, and a few extremely faint stars intermittently glint within the haze.

NGC 7492's brightest stars meagerly shine at about 15th magnitude due to their great distance of 86,000 light-years. The cluster dangles 77,000 light-years below the plane of our galaxy.

The last object on our tour is **Cederblad 211**, parked 47′ south-southeast of Omega^2 (ω^2) Aquarii. I observed it merely because it was plotted on my chart, yet it turned out to be a very unusual nebula. My 130-mm refractor at 48× offered only a star in a tiny fuzzspot. At 91× the nebula became a little ribbon of light tipped north-northeast, but I suspected dimmer nebulosity as well. Turning to my 15-inch scope at 133×, the slender band is fairly bright, and the star within glows orange. Ghostly wings of uneven brightness are now unfurled to its east and west, spanning about 1½′ and transforming the nebula into a diaphanous longwing butterfly.

The peculiar shape of Cederblad 211 is fashioned by R Aquarii, the symbiotic binary star at its heart. It consists of a red giant paired with a white dwarf. In the most likely scenario, the giant slowly loses mass to its companion via stellar winds. The process triggers sporadic outbursts that eject material from the system. The red giant is a pulsating variable with a period of 387 days and a range of 5th to 12th magnitude. It's currently near minimum. ✦

POSS-II / CALTECH / PALOMAR OBSERVATORY

Above: **The tiny nebula Cederblad 211 floats 22′ east-northeast of 5th-magnitude HD 222643. It's powered by the star R Aquarii, whose variability was first detected by Karl Ludwig Harding, discoverer of the Helix Nebula.**

Right: **German stargazer Uwe Glahn sketched Cederblad 211 as seen through his 27-inch Newtonian at 586×. He saw only the bright north-south axis, not the faint east-west extension.**

Fuzzy Duos Inside the Circlet

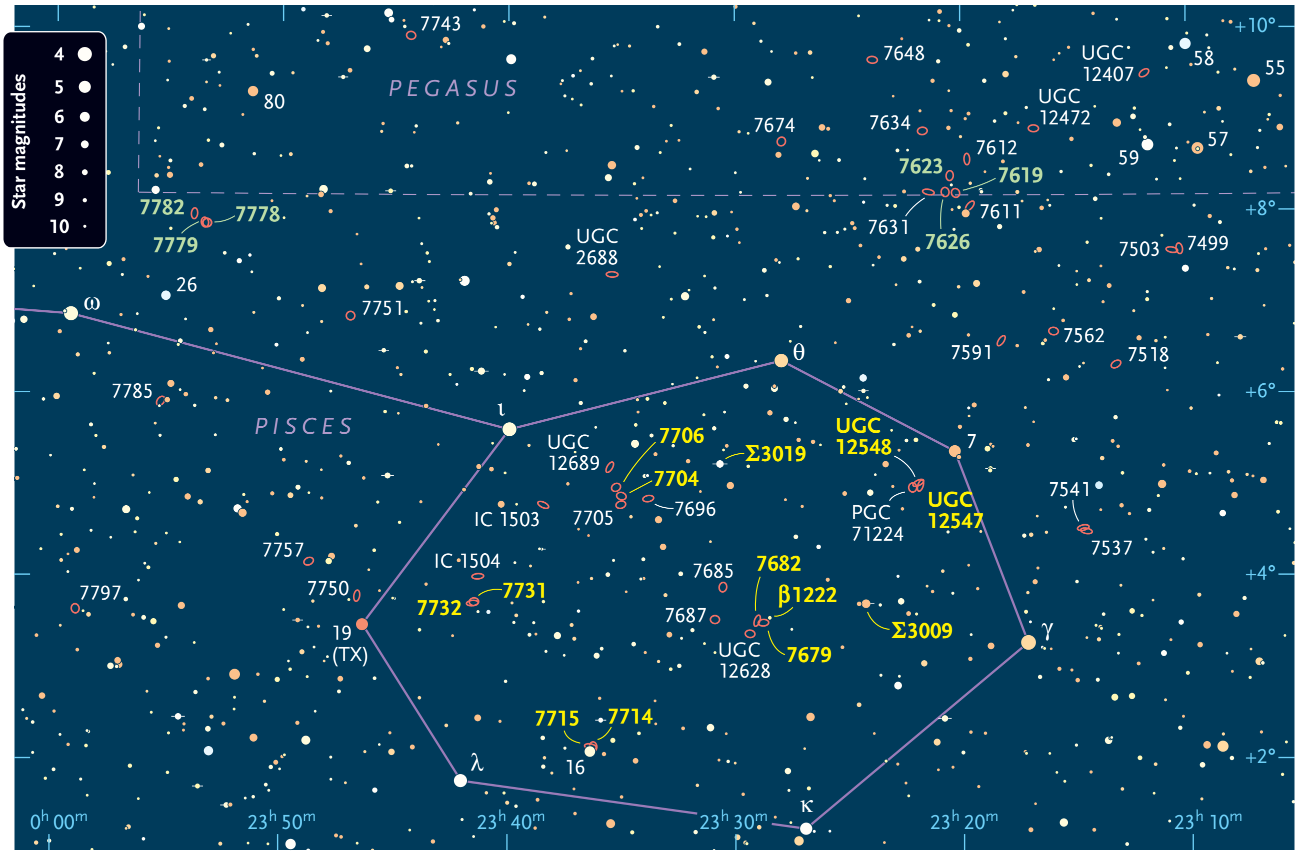
Five galaxy pairs inhabit this well-known asterism in Pisces.

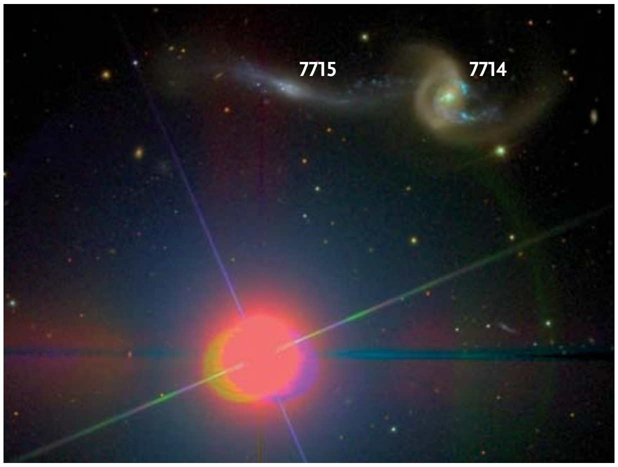
THE CIRCLET OF PISCES, as plotted on the all-sky map on page 44, is outlined by Lambda (λ), Iota (ι), Theta (θ), Gamma (γ), and Kappa (κ) Piscium. To that quintet of 4th- and 5th-magnitude stars I like to add similarly bright 7 and 19 Piscium on the west and east sides, respectively, to form the 7°-wide figure outlined on the chart below. The star 19 Piscium is interesting in its own right; it's a carbon star (deep red) and an irregular, low-amplitude variable — hence its alternate name TX Piscium.

The extended Circlet contains perhaps two dozen galaxies within range of my 17.5-inch f/4.5 Dobsonian on a moonless country night. The targets are all small, but some of them form close pairs that display considerable character at around 300×. Let's assess these fuzzy duos in a clockwise tour around the asterism, beginning with a challenging pair just north of 5.7-magnitude 16 Piscium, which lies 1.5° west of Lambda.

The glare from 16 Psc nearly swamps **NGC 7714** and **NGC 7715** just 4′ north-northwest of the star. Images show that these spiral galaxies are gravitationally interacting to produce distorted arms and prominent starburst regions. In my scope, 12.5-magnitude NGC 7714 is a dim patch accompanied by a 14th-magnitude star less than 1′ southwest. A closer look reveals another star so near the galaxy's center that it masquerades as a brilliant nucleus. (The Sloan Digital Sky Survey image on the facing page

The galaxy pairs and double stars described in this article are labeled in yellow. Galaxies with green labels are discussed in the article that starts on page 62.





The interacting spiral galaxies NGC 7714 and 7715, collectively known as Arp 284, are almost overwhelmed by the glare of the foreground star 16 Piscium. The field of view is 7.3′ wide.

shows the actual nucleus beside the star.) My averted vision detects extended nebulosity southeast of the bright center, giving the object a cometlike appearance. Averted vision also helps me locate severely deformed, 14.2-magnitude NGC 7715 barely 2′ eastward. Telescopically, it's a narrow haze, elongated east-northeast by west-southwest, that points slightly south of its brighter neighbor.

From 19 Psc it's a 1¼° sweep west-northwestward to **NGC 7731** and **NGC 7732**, only 1.4′ apart. A face-on spiral, 12.8-magnitude NGC 7731 is a somewhat ragged oval blob, slanted northeast-southwest, with a bright, almost starlike middle. An 11.6-magnitude star lies about 1′ east of it. A similar distance south of the star is a celestial ghost: the nearly edge-on, 13.8-magnitude galaxy NGC 7732. Even with the star to guide me, I consider this tenuous wisp, elongated east-west, surprisingly hard to spot. A less challenging edge-on lies ¼° north-northwest. Like NGC 7732, **IC 5014** is a cigar-shaped mass oriented east-west, but it brightens gently toward the middle and presents a sharp edge along its southern flank. A 15th-magnitude star flickers alongside that flank, south-southwest of the midpoint, while a pair of brighter stars shine northeast of center.

At Iota Piscium, we drop southwestward 1.3° to a scatter of faint fuzzies dominated by the nondescript S0 galaxies **NGC 7704** and **NGC 7706**, magnitude 13.4 and 13.2, respectively. NGC 7706 appears diffusely oval with a faint star on its southwest periphery. NGC 7704, 5′ southwest, is similar, with a dim star near its southeast edge. In the space between that galaxy and the 12th-magnitude star 3′ west of it, I can usually confirm ultra-tiny **PGC 214966**.

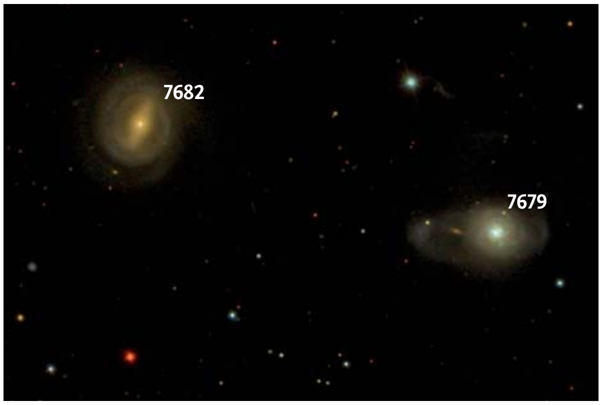
Nudging ¼° farther west nets little 13.9-magnitude **NGC 7696**. And 6′ south of NGC 7704 is the pale glow of 14.4-magnitude **NGC 7705**. From NGC 7706, a ¼° shift north-northeast sweeps up the edge-on, 14th-magnitude galaxy **UGC 12689** (PGC 71831). This strongly elongated object, oriented northwest-southeast, is broadly brighter across the middle and fades at the ends. Two 14th-magnitude stars lie almost parallel to the galaxy's eastern flank.

Next, we hop over Theta at the top of the Circlet and head southwest to 7 Psc. From there we turn south-southeastward for 20′ to a 10th-magnitude star, then push a similar distance eastward until we encounter **UGC 12547** and **UGC 12548** (PGC 71204 and PGC 71209, respectively). These little fellows, a mere 2.5′ apart, are totally unalike. UGC 12548 is a 14th-magnitude edge-on specimen that yields to averted vision as a subtly mottled streak with a broad central bulge. Southwest of it, fainter UGC 12547 is a face-on, two-arm spiral that at best registers as a vaguely oval patch. I can also detect minute 16th-magnitude **PGC 71224** less than 6′ east-southeast of the pair.

Our final waypoint is Gamma, the brightest star in the Circlet. From Gamma we hike 3° eastward to the middle of the asterism, where the face-on spirals **NGC 7679** and **NGC 7682** (magnitude 12.6 and 13.2, respectively) lie 4.3′ apart. NGC 7682 is round and diffuse, while its partner is condensed with a bright center. These galaxies exhibit some evidence of mutual attraction; images show an arm of NGC 7679 swelling in the direction of NGC 7682. East and northeast of the pair are two more NGC galaxies: 13.2-magnitude **NGC 7685** and 13.4-magnitude **NGC 7687**, while to the southeast is 15th-magnitude **PGC 71578**. This roundish glow is attended 3′ westward by a 1′-long row of three stars — a miniature Orion's Belt!

Finally, double star enthusiasts should take a crack at **Burnham 1222** (β1222) only 6′ northwest of NGC 7679. Its 10th-magnitude components, just 1.4″ apart, resolve between 222× and 285×, depending on the seeing. Much easier is colorful **Struve 3009** (Σ3009, magnitude 6.9 and 8.8, 7.1″ separation) located 1.9° east-northeast of Gamma Psc. Another fine catch, **Struve 3019** (Σ3019, 7.8, 8.4, 10.9″), is 1.3° south-southeast of Theta Piscium. ✦

S&T *contributing editor* ***Ken Hewitt-White*** *observes faint fuzzies under the dark skies of British Columbia, Canada.*



SLOAN DIGITAL SKY SURVEY (2)

The asymmetric spiral NGC 7679 and the striking barred spiral NGC 7682 constitute entry number 216 in the *Arp Atlas of Peculiar Galaxies.*

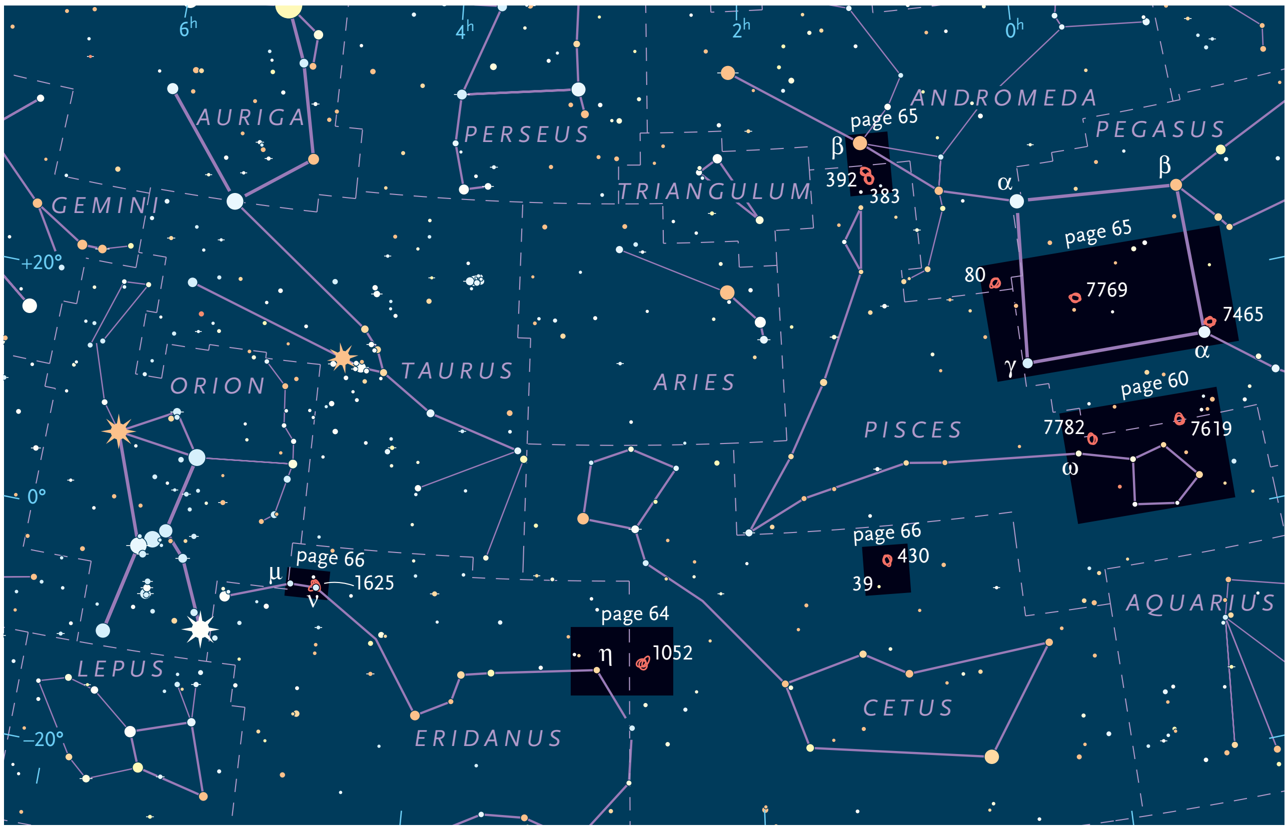
Observing Autumn

Good things often come in threes.

Galaxies are gregarious as a rule: they're usually found in close association with other galaxies. Only about 5% of galaxies surveyed so far are truly isolated. Still, finding small groups of interesting galaxies that fit pleasingly into a single eyepiece field of view is rare enough to be a special experience. Three-galaxy groupings have a particular appeal. They have enough variety to thrill the senses but not so much that it to overwhelms them. Unlike galaxy groups and clusters, galaxy trios aren't always true physical structures — some are just whimsical associations that connect the three objects in the viewer's imagination.

The November sky is replete with rich galaxy fields, and many of these contain triplets that just seem to belong to one another. In this tour we'll visit threesomes that should be detectable in telescopes with 10 inches of aperture from a transitional rural/suburban sky (Bortle Class 4, *S&T* February 2001, p. 126). In the accompanying table, I have assigned a difficulty score to each galaxy. It's based on a seven-point scale, where 1 is easy in a 10-inch scope and 7 would be undetectable. Your own results are likely to vary depending on your telescope, skies, and experience level. I have also provided a recommended magnification that might optimize your chances of visual detection — similarly based on a 10-inch telescope. Consider this as a reasonable starting point and adjust your magnification to suit your own tastes and conditions.

The galaxy trios described in this article span a wide swath of the autumn sky, which also includes the galaxy pairs discussed in the *Going Deep* column on page 60. For clarity, each trio is labeled with the NGC number of its brightest member. See the pages listed below for detailed charts of the highlighted regions.



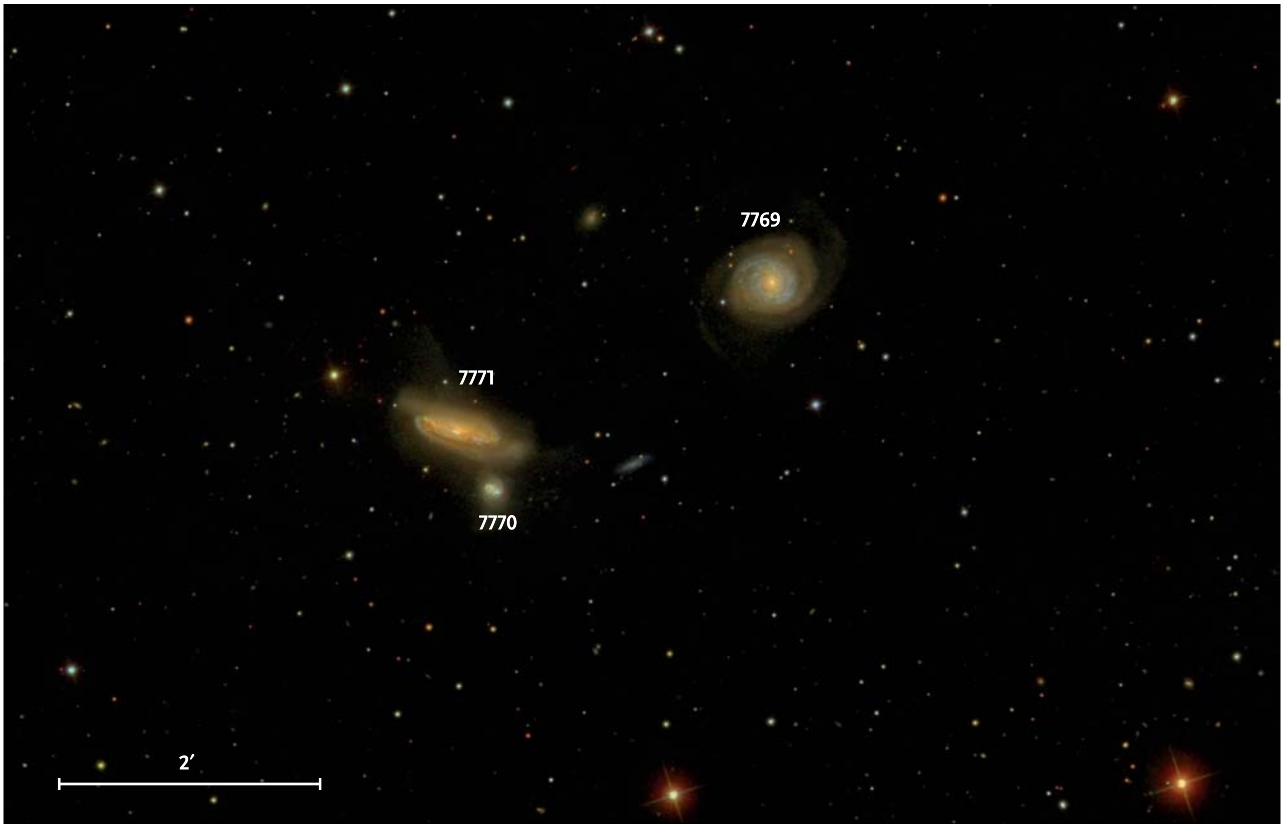
Galaxy Trios

Ted Forte

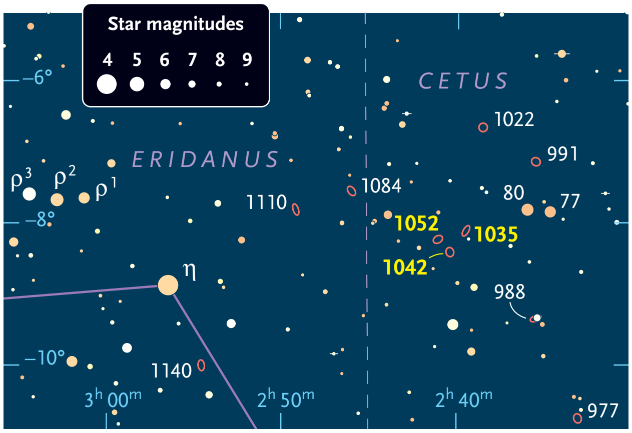
Let's start with one of the easiest groups. Imagine a diagonal line bisecting the Great Square of Pegasus from Gamma (γ) to Beta (β) Pegasi. Our trio lies one-third of the way along that line. **NGC 7769** is the brightest in the group and appears mostly round, with a brighter core and a tiny stellar nucleus. **NGC 7771**, about 5′ to the east-southeast, is nearly as bright as its sibling. It's elongated east-northeast and has a slightly brighter, bar-shaped core. Close alongside it to the south is the tiny round smudge of the third and dimmest member of the trio, **NGC 7770**. All three have similar redshifts, making it possible — but by no means certain — that they're physically associated.

Our next target is the brightest group on our tour, though its low declination might make it challenging for some northern observers. **NGC 1035**, **NGC 1042**, and **NGC 1052** form an isosceles triangle near the eastern border of Cetus, about 4° west of Eta (η) Eridani. NGC 1052 is the eastern corner of the triangle and the brightest of the group. It's a bright oval with a very much brighter center. About 15′ to the southwest is NGC 1042, which is larger but has much lower surface brightness; its diffuse glow is smooth and rather evenly illuminated. The apex of the triangle is occupied by NGC 1035, a spindle-shaped object about 2′ in length that shows up rather easily. It's a peculiar spiral, seen nearly edge-on, that lies about 7′ north of a 9.2-magnitude field star.

Now let's move on to some more challenging fare. The ability to detect small, dim galaxies is an observing skill well worth developing. Like any skill, it improves with practice and is enhanced by the employment of certain effective techniques. If you're new to this pursuit, the NGC 7769 and 1052 groups are good places to hone your



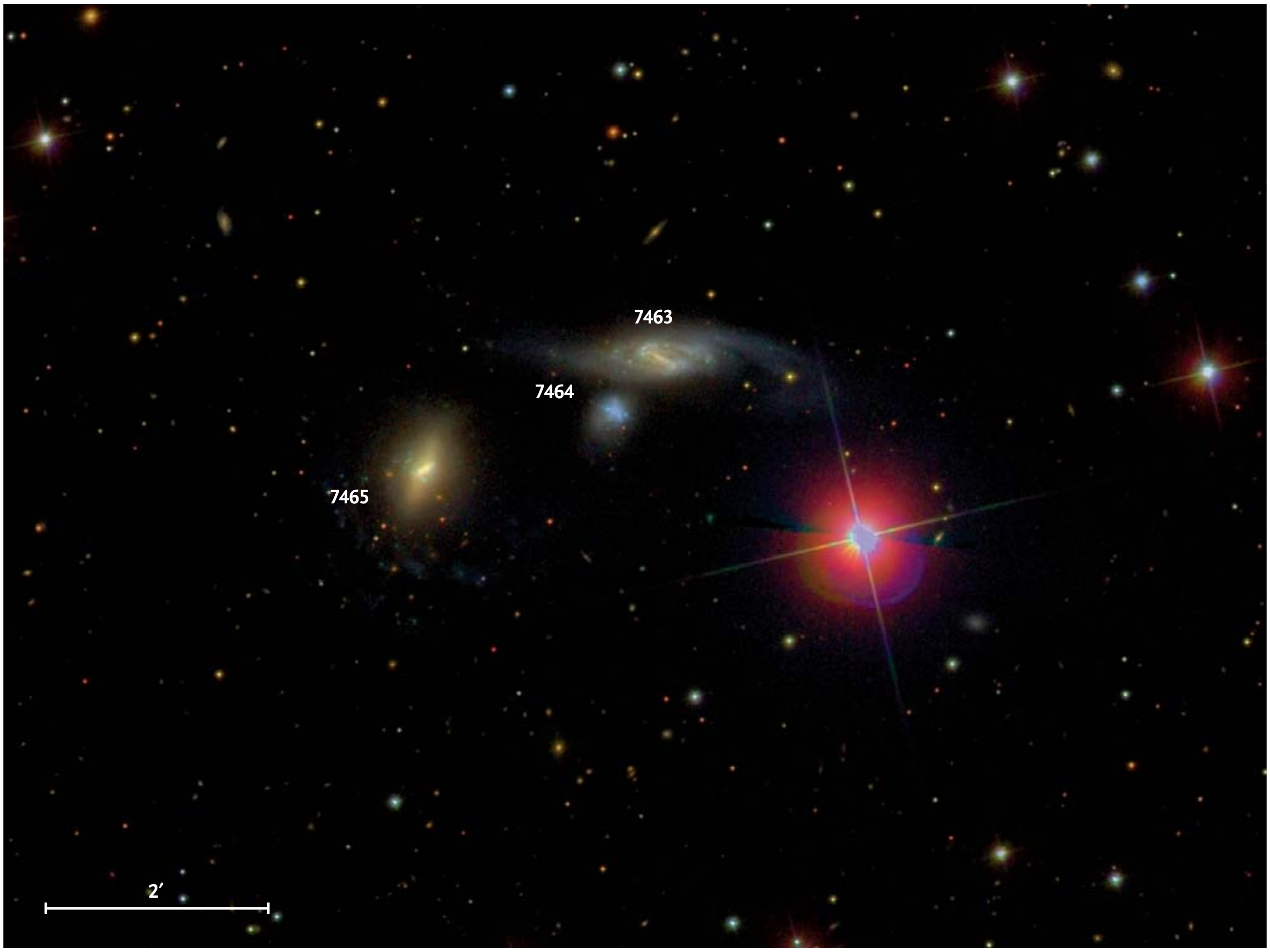
ALL PHOTOS: SLOAN DIGITAL SKY SURVEY

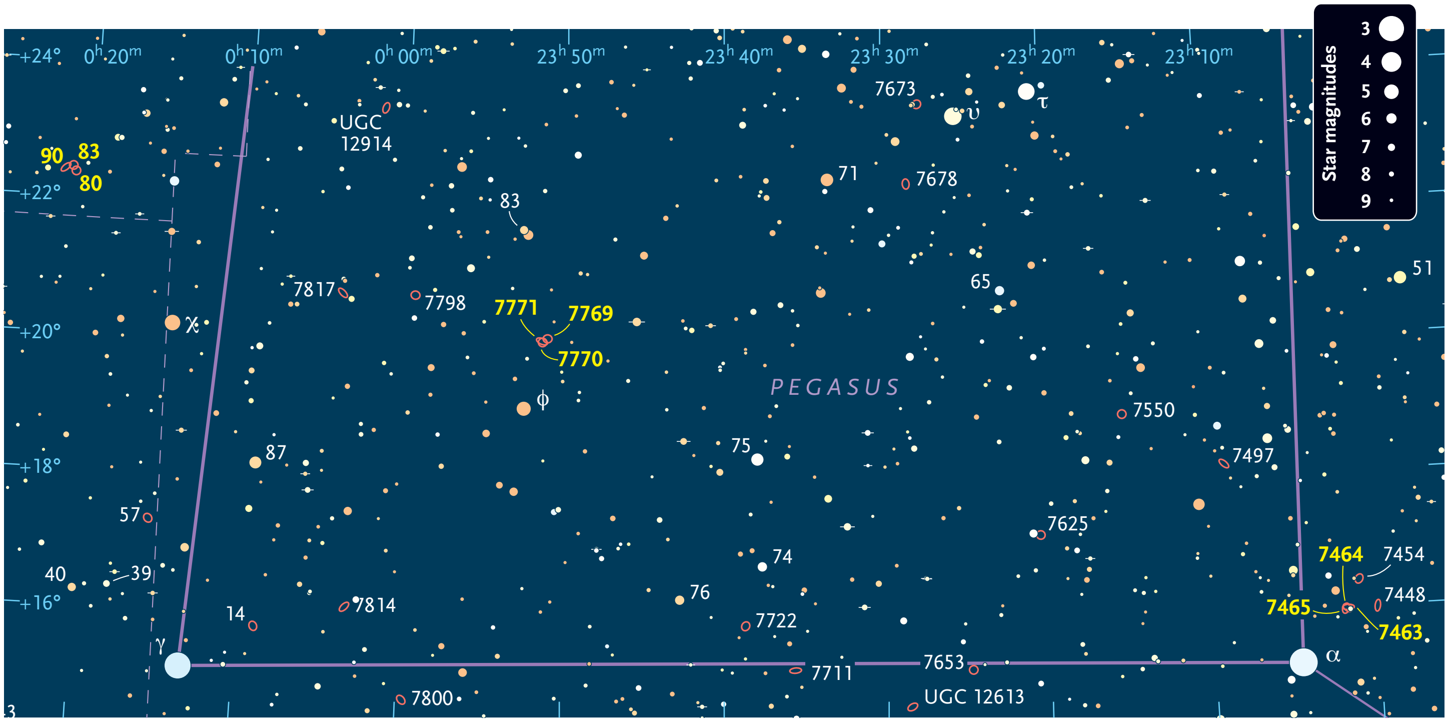


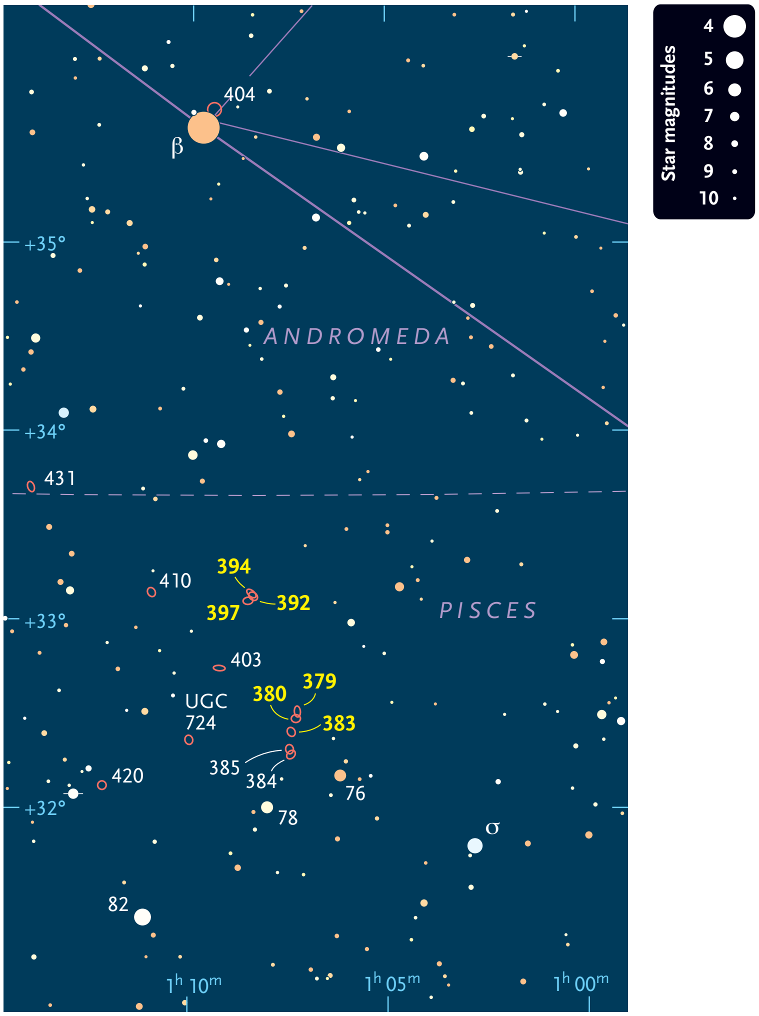
expertise before moving on. For a novice, expectation may be the highest hurdle. Knowing what to expect comes with experience, and there's no substitute for persevering until that first flash of recognition is achieved. Observing at the limit of your scope's capability requires both patience and good conditions, and you shouldn't be discouraged if you have to come back another night to try again.

Be sure to achieve good dark adaptation. If, like me, you use a computer in the field, you will have to readapt after every check of the screen. Even a dim red screen will degrade your night vision somewhat, as will a red light bright enough to read a chart. It will take several minutes of adjustment to regain maximum sensitivity. A dark cloth to block any extraneous light can be a great help. Relax. Straining to see is counterproductive. Jiggle the scope. Movement can help your brain detect faint objects. Vary the magnification. Detecting faint objects is a matter of contrast between object and background, and the proper magnification will optimize it. Finally, learn to use averted vision — looking slightly to the side of your target. With practice it will become second nature.

About 1° northwest of Alpha (α) Pegasi is our next triplet. **NGC 7465** is the brightest and most easterly of the group. It appears oval, is elongated nearly north-south, and has a bright core. The northernmost member of the group, **NGC 7463**, is very elongated east-west and about 2′ long. Its bright central region is bar-shaped. The third member of the group, **NGC 7464**, is a tiny round spot southeast of 7463 that might be quite challenging in smaller scopes. The three reside in an area barely 3′ across and they share the field with an 8th-magnitude star about 3′ to their west-southwest.



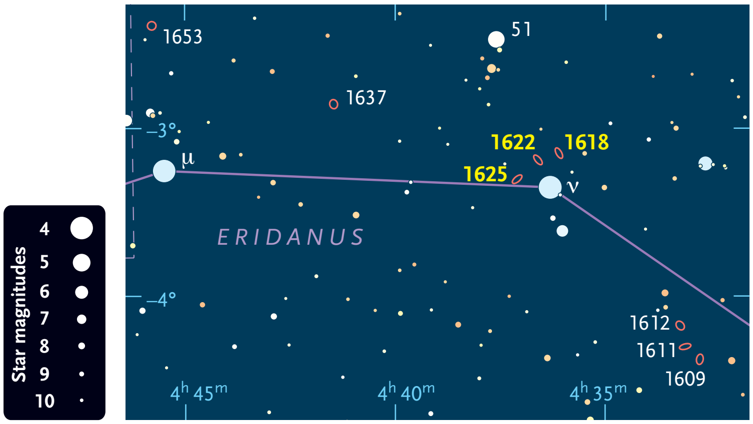


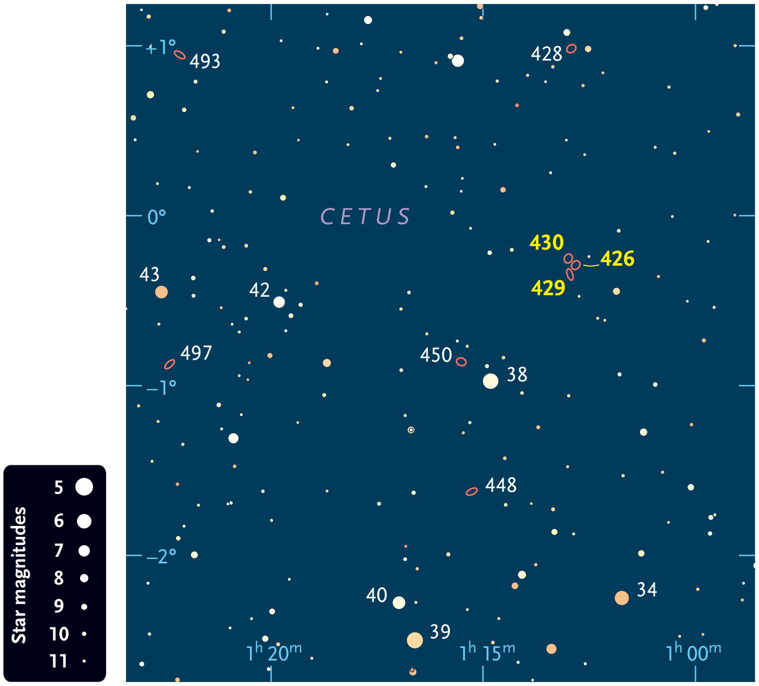


NGC 7778, **NGC 7779**, and **NGC 7782** lie 1¾° northwest of 4th-magnitude Omega (ω) Piscium, near the Circlet of Pisces (see page 60). At less than 2′ separation, NGC 7778 and 7779 make an obvious pair. NGC 7779 is a tiny bit elongated, whereas NGC 7778 is absolutely round, but the two are similar in size and brightness, and both have bright, round cores. **NGC 7782**, the brightest and largest of the trio, is more than 8′ to the northeast. It's a bright oval, elongated nearly north-south, with a very much brighter core. The three form a dogleg pattern and share the field with a couple of fainter galaxies.

The Pisces Cloud is a small group of galaxies in northern Pisces, about 3° south of Beta Andromedae and 45′ west of a line connecting that star and 4.5-magnitude Tau (τ) Piscium. The three brightest galaxies in this group form a pleasing triplet that fits well within the field of a medium-power eyepiece. The brightest in the trio — in fact in the whole group — is **NGC 383**. This 2.0′ × 1.7′ oval has a much brighter circular core that overshadows the tiny companion galaxy NGC 382. To the north is round **NGC 380** and beyond it, the more elongated **NGC 379**. The three elliptical galaxies seem attached, as if strung on a string. The trio, together with a few other members in this chain of galaxies, is designated Arp 331. They lie probably about 200 million light-years away. All the NGC galaxies in the chain are shown and labeled on the final page of this article.

NGC 7619 and **NGC 7626** are visual twins in the heart of the Pegasus I Galaxy Cluster, which straddles the border between Pegasus and Pisces just north of the Circlet of Pisces. The twin galaxies are about 7′ from each other and 2.6° northwest of Theta (θ) Piscium. Both have





bright, roundish, nearly stellar cores surrounded by diffuse halos about 2′ across. The third member of the trio, **NGC 7623**, lies about 11′ north of the pair. An oval with a bright core, it's smaller and fainter than its two siblings and a bit elongated along its north-south axis. These are the three brightest members of the galaxy cluster, which lies about 250 million light-years from Earth and is a visual treat through large telescopes. Two dozen galaxies 14th magnitude or brighter reside in this area, which is just about the size of a typical binocular field.

My 10-inch scope shows about ten galaxies in a single eyepiece field centered on **NGC 80** in Andromeda. It's the brightest member of a trio that also includes **NGC 83** and **NGC 90**. NGC 80 is small and round with a stellar nucleus; NGC 83 is also small and round but its center is more gradually brighter. NGC 90 (sometimes misidentified as NGC 91) is a small, faint galaxy that will challenge owners of smaller scopes. The triplet is located 2½° east of the Great Square of Pegasus, about equidistant from Alpha Andromedae and Gamma Pegasi. This may be more of a quadruplet than a triplet, because **NGC 93** also seems to fit with the group.

Center a scope on 4th-magnitude Nu (ν) Eridani, and the northern half of your field of view will contain three 12th- or 13th-magnitude, elongated galaxies aligned in a gentle arc spanning about 17′. **NGC 1625**, the brightest of the three, anchors the eastern end of the arc about 12′ from the bright star. An edge-on spiral, it's faint, elongated northwest-southeast, and has a mottled center. Another edge-on galaxy, **NGC 1622**, lies 10′ northwest of NGC 1625. This barred spiral is about 3′ in length and angled as if pointing toward Nu Eridani. It has a bright, elongated core and a dense knot southwest of the core. **NGC 1618** appears as a diffuse oval with a slightly brighter center about 8′ west-northwest of NGC 1622. The three make an interesting trio, but you may have to position Nu Eridani beyond the edge of the field to acquire them. Once located, they should be easy enough to see even with the star in the field.

A very challenging trio lies in Cetus about 50′ northeast of 5.7-magnitude 38 Ceti. **NGC 430**, **NGC 426**, and **NGC 429** will fit in the field of view of a high-power eyepiece. You'll probably need relatively high magnification to detect NGC 429, a faint edge-on sliver 1.4′ × 0.3′ in size. Reducing the power may improve your chances of picking out its two siblings. Both NGC 430 and 426 are round, pretty small, and pretty faint.

Our tour's last and most difficult group lies in Pisces about 2½° south of Beta Andromedae. **NGC 392** has a brighter circular core with a faint oval halo. Its close companion **NGC 394** is just 1′ to the northeast. NGC 394 is quite small, very faint, and appears like a circular smudge around a stellar core. The third member, **NGC 397**, is a tiny circular spot 2′ southeast of NGC 392. A ghostly, faint, averted-vision object in a 10-inch scope, it will require patience and concentration to detect.

Galaxies are a favorite of backyard observers for a variety of reasons. Not the least of these, perhaps, is the realization of just what that fuzzy spot represents: a vast island universe of stars, planets, and nebulae as diverse and mysterious as our own Milky Way. Maybe there are planets teaming with life, even civilizations of intelligent beings, but certainly within these galaxies there are unimaginable worlds and strange environments too numerous to contemplate. It delights the imagination.

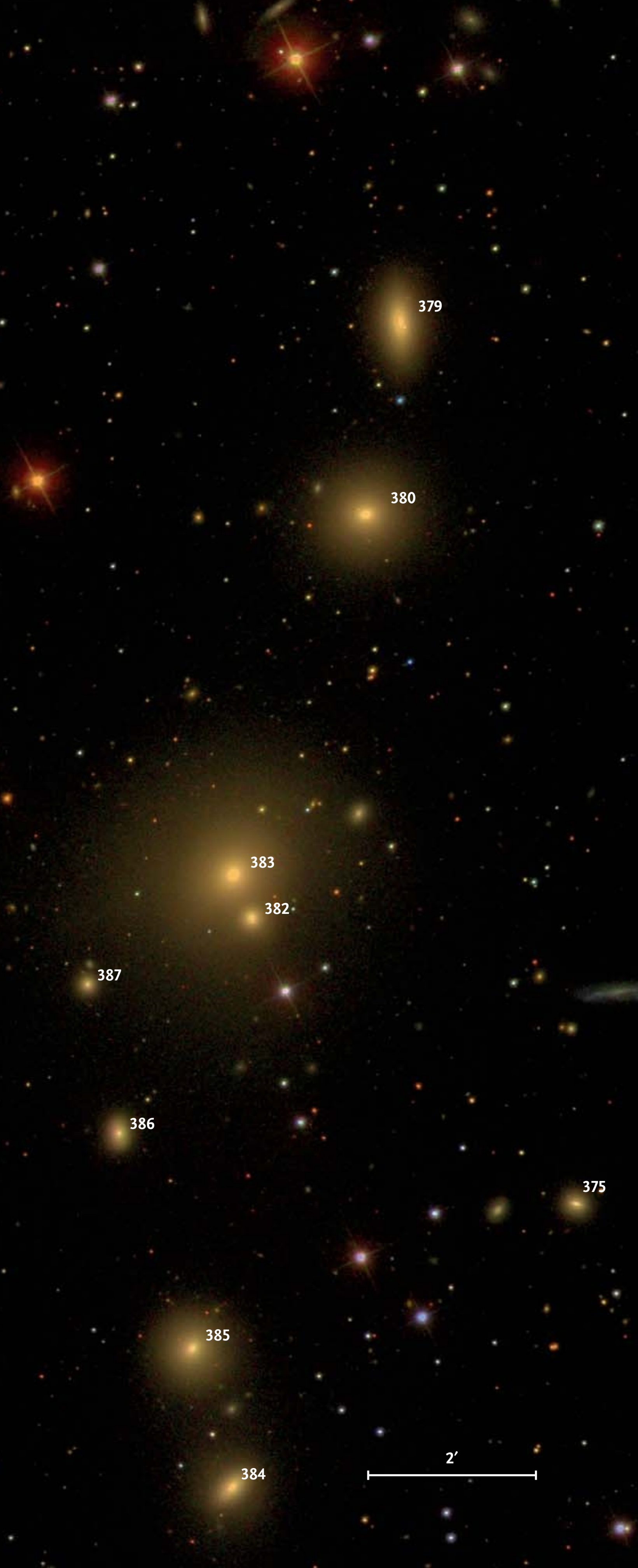
Groups of galaxies, such as the trios described here, multiply the possibilities. There are many more examples of galaxy triplets to be found this month and throughout the year. I hope this sampling will inspire you to seek them out. ✦

*Contributing editor **Ted Forte** observes from his home near Sierra Vista, Arizona. He pens a monthly astronomy column for his local newspaper, the* Sierra Vista Herald.

Selected Galaxy Trios in the Autumn Sky

Galaxy	Const	RA	Dec	Mag(v)	Size	Score	Power
NGC 7769	Peg	$23^h\ 51.1^m$	+20° 09′	12.0	3. 2′ × 2.7′	3	100×
NGC 7771	Peg	$23^h\ 51.4^m$	+20° 07′	12.3	2.4′ × 1.1′	4	100×
NGC 7770	Peg	$23^h\ 51.4^m$	+20° 06′	13.8	0.7′ × 0.4′	4	100×
NGC 1052	Cet	$2^h\ 41.1^m$	–8° 15′	10.5	2.8′ × 2.0′	3	40×
NGC 1042	Cet	$2^h\ 40.4^m$	–8° 26′	11.0	4.3′ × 3.6′	3	60×
NGC 1035	Cet	$2^h\ 39.5^m$	–8° 08′	12.2	2.2′ × 0.6′	3	130×
NGC 7465	Peg	$23^h\ 02.0^m$	+15° 58′	12.6	2.2′ × 1.8′	3	100×
NGC 7463	Peg	$23^h\ 01.9^m$	+15° 59′	13.2	2.6′ × 0.6′	5	150×
NGC 7464	Peg	$23^h\ 01.9^m$	+15° 58′	13.3	0.5′ × 0.5′	3	150×
NGC 7782	Psc	$23^h\ 53.9^m$	+7° 58′	12.2	2.2′ × 1.3′	4	100×
NGC 7778	Psc	$23^h\ 53.3^m$	+7° 52′	12.7	1.0′ × 1.0′	3	120×
NGC 7779	Psc	$23^h\ 53.4^m$	+7° 53′	12.7	1.4′ × 1.1′	4	120×
NGC 383	Psc	$1^h\ 07.4^m$	+32° 25′	12.2	2.0′ × 1.7′	4	80×
NGC 380	Psc	$1^h\ 07.3^m$	+32° 29′	12.5	1.3′ × 1.3′	4	120×
NGC 379	Psc	$1^h\ 07.3^m$	+32° 31′	12.8	1.4′ × 0.7′	4	120×
NGC 7619	Peg	$23^h\ 20.2^m$	+8° 12′	11.1	2.5′ × 2.3′	3	80×
NGC 7626	Peg	$23^h\ 20.7^m$	+8° 13′	11.1	2.6′ × 2.3′	4	40×
NGC 7623	Peg	$23^h\ 20.5^m$	+8° 24′	12.9	1.3′ × 0.9′	6	120×
NGC 80	And	$0^h\ 21.2^m$	+22° 21′	12.1	1.6′ × 1.6′	4	85×
NGC 83	And	$0^h\ 21.4^m$	+22° 26′	12.5	1.5′ × 1.5′	4	100×
NGC 90	And	$0^h\ 21.9^m$	+22° 24′	13.7	1.9′ × 0.8′	5	100×
NGC 1625	Eri	$4^h\ 37.1^m$	–3° 18′	12.3	2.1′ × 0.5′	4	120×
NGC 1622	Eri	$4^h\ 36.6^m$	–3° 11′	12.5	3.7′ × 0.7′	5	130×
NGC 1618	Eri	$4^h\ 36.1^m$	–3° 09′	12.7	2.4′ × 0.8′	5	120×
NGC 430	Cet	$1^h\ 13.0^m$	–0° 15′	12.5	1.3′ × 1.1′	4	120×
NGC 426	Cet	$1^h\ 12.8^m$	–0° 17′	12.9	1.4′ × 1.0′	4	120×
NGC 429	Cet	$1^h\ 13.0^m$	–0° 21′	13.4	1.4′ × 0.3′	6	150×
NGC 392	Psc	$1^h\ 08.4^m$	+33° 08′	12.7	1.2′ × 0.9′	4	100×
NGC 394	Psc	$1^h\ 08.4^m$	+33° 09′	13.8	0.6′ × 0.3′	4	200×
NGC 397	Psc	$1^h\ 08.5^m$	+33° 07′	14.8	0.7′ × 0.5′	6	150×

Positions, sizes, and magnitudes are from Wolfgang Steinicke's website, www.klima-luft.de/steinicke/index_e.htm. The difficulty score ranges from 1 (easy) to 7 (undetectable) as described in the main text. Galaxies within each trio are listed in order of brightness.



S. Harris's Cartoon

The science cartoonist **Sidney Harris** describes his sources of inspiration.

Born in Brooklyn, New York, Sidney Harris had no science background when he began drawing cartoons. Yet soon after he began illustrating science themes around 1955, his cartoons achieved widespread attention. His ability to find and connect incongruities within subjects ranging from aliens to the Big Bang has created some of the most recognizable cartoons pertaining to science. To learn more about his sources of inspiration, Harris answered these questions from S&T.

What made you decide to start drawing science cartoons for a living?

I still can't figure out why most people try to freelance as a cartoonist, but in my case it was obvious — I had nothing else to do. I was planning to try my hand at writing humor. But as I was starting out in my early 20s, I was surprised to see long lists of magazines that published cartoons in *Writer's Digest*. Even though I could barely draw, it seemed easier and faster to make a little drawing than to write an article. Maybe it was, but it took many drawings, perhaps

ALL CARTOONS COURTESY OF SIDNEY HARRIS

Creator


Including you.
I'm working on that.
S. Harris


S. Harris
"IF THAT'S THE CORRECT TIME, THEN WE'RE THREE WEEKS LATE."

thousands, to reach some proficiency.

Around 1970, after I had been freelancing for a few years, I came across *American Scientist* magazine. I was somewhat surprised when the editor, Jane Olson, invited me to submit material, and it quickly occurred to me that I didn't have much to send — a few talking animals, a rocket ship, and a room-size computer. But Olson's response made me think this was a magazine worth pursuing. I've since published hundreds of cartoons in *American Scientist*.

Because I had been reading *Scientific American* for some time, I scoured their back issues for subject matter. It didn't take me long to realize that science, with its enormous range of subjects, was a gold mine for cartoons. Soon I was producing enough drawings to contribute to *Science 80* (later *81*, *82*, etc.), *Science*, *Physics Today*, *Scientific American*, *Today's Chemist*, numerous medical periodicals, and, on a few occasions, *Sky & Telescope*.

Science (and the math behind it) is endlessly astounding and informative, each week delivering a ton of new topics that I could put into a cartoon.

Have your methods changed since we entered the internet age?

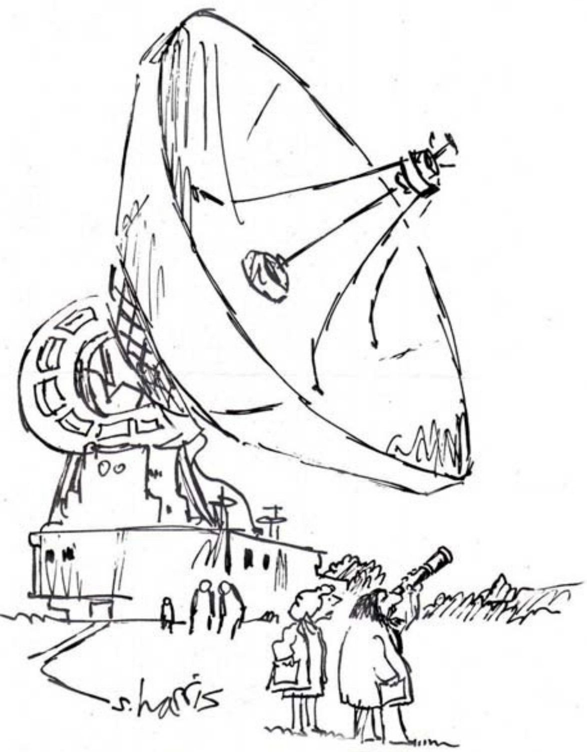
Today, many magazines are either gone, or they no longer publish cartoons. As some of my colleagues say, everyone loves cartoons except editors. But I still draw my weekly quota, put some on my website (**www.ScienceCartoonsPlus.com**), and wait for someone to tell me one or more is just right for their textbook or newsletter.

I've moved from magazines to books over the years, and now I've had more than 20 books of my cartoons put out by various publishers, including the most recent, *Aside From the Cockroach, How Was Everything?* This was my first attempt at self-publishing.

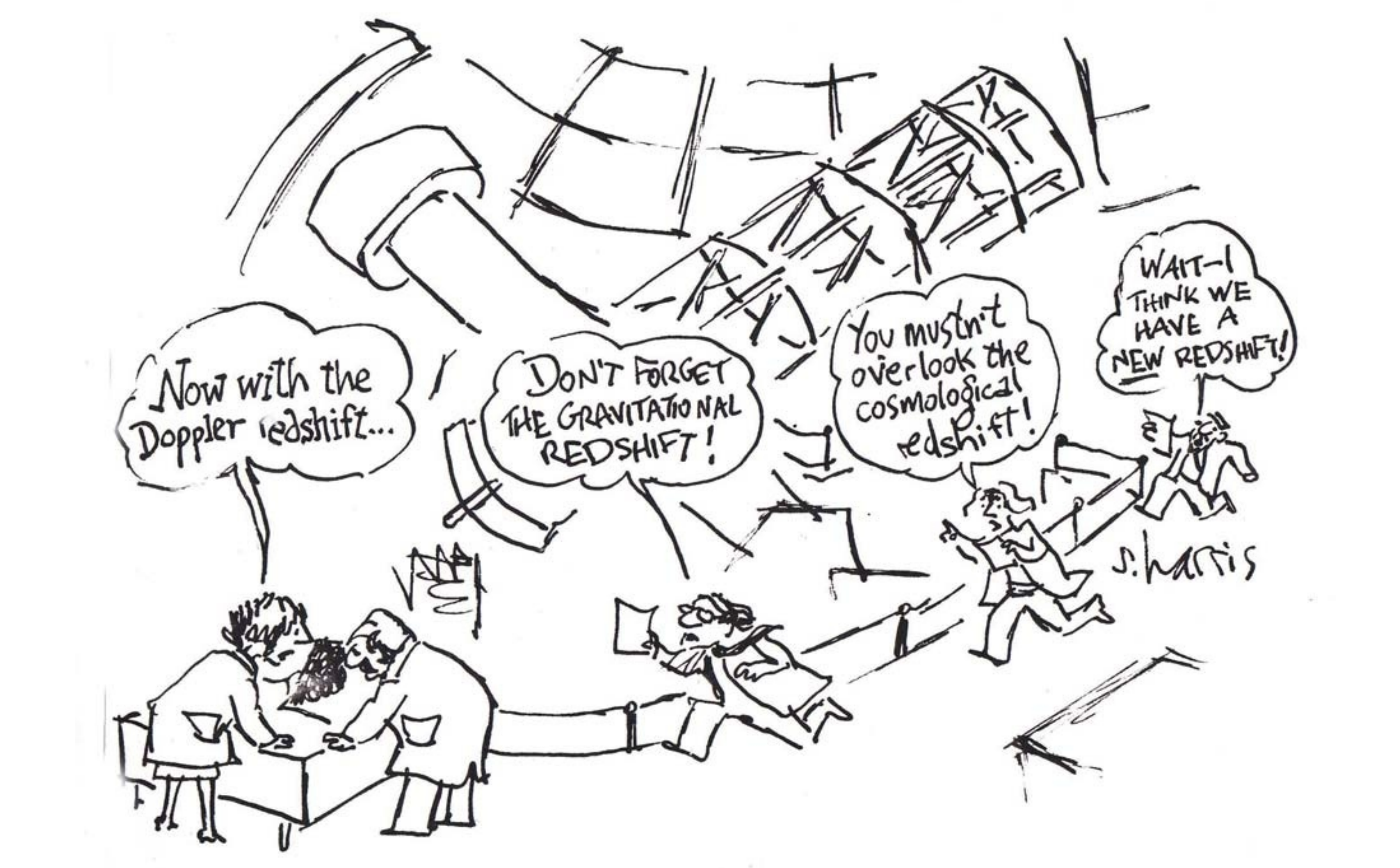
Do scientists ever contribute ideas for your cartoons?

Over the years scientists have sent me what they refer to as "an idea for a cartoon." Their ideas generally contain some technical description that everyone at the lab or observatory thought was hilarious, such as, "If the R particle seems to stop spinning again, then 14% of that exoplanet is made of brass." These "ideas" probably make sense to them, but they're almost always unintelligible to me, and probably would be equally unintelligible to a large percentage of the people not in their group. My surprise at discovering what a distant planet is made of is equal to my amazement that it's possible to discover such a thing. I'd be satisfied just to find out that there is a distant planet. Little do these scientists know, my knowledge of particles doesn't go beyond the belief that they probably exist.

"DR. RENLY BELIEVES HE'S CLOSE TO THE ANSWER. HE DISCOVERED THAT THE CLUSTERS OF GALAXIES SPELL OUT SOMETHING, BUT HE'S STILL MISSING A FEW LETTERS."



"JUST CHECKING."



Where do you get your ideas from then?

I instinctively know, or at least I believe, that the majority of cartoon readers rarely want to deal with much inside information. If I have a vague idea that people may have been able to tell time — day or week or even year — by looking at Stonehenge, that's all the information I need to come up with an idea for a cartoon: there definitely is a Stonehenge, it likely was a device of some kind for measuring time, and from there, I extrapolate. Having a timepiece of any sort to measure weeks strikes me as taking the concept into the realm of the ridiculous, so I just had to draw a few actors and a horse and wagon, put them all together, and there's the cartoon.

Not only do I find astronomy astounding, astronomers seem equally remarkable. Very often my cartoons are about astronomers, not astronomy, since they're easier to speculate about.

Which of your cartoons has achieved the most fame?

The drawing depicting the universe before the Big Bang (right) has been one of my most widely reprinted, and often misprinted, cartoons. Not surprisingly, the drawing took the least time to create. After all, how long does it take to make a dot, even a large dot? But more than once it was published with the caption intact, and the dot missing. The first instance appeared on the last page of my 1989 book *Einstein Simplified* (which is still in print). The dot was not there, since the printer evidently thought it was an imperfection. The publisher had to recall several thousand books, and the dot was added, one by one, by way of a rubber stamp made for the occasion.

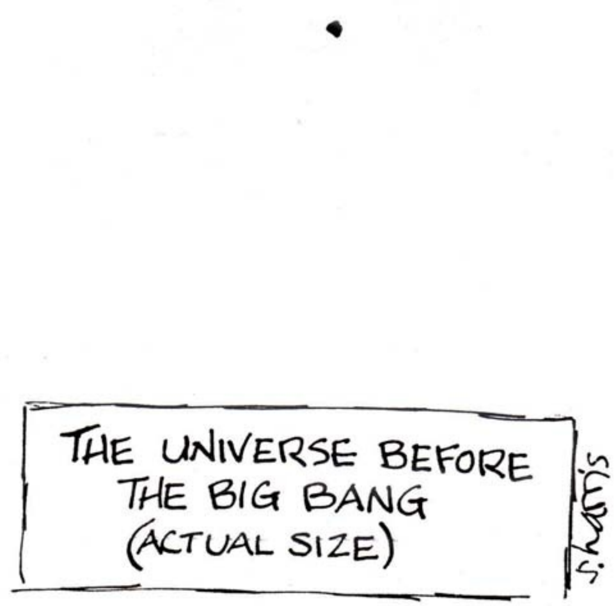
At an American Association for the Advancement of Science convention a few years later, I showed the cartoon on one of my slides. After my presentation, an astronomer came up to me and, referring to his notebook, told me the exact size of the universe as was known at that time. He was very precise. As he walked away, another astronomer pointed out that the first fellow didn't know what he was talking about.

Do you feel your cartoons must reflect accurate science?

If I had started creating cartoons while working in science, I probably would have come up with entirely different ideas for my drawings. Instead, I fell into creating science cartoons after creating them on other subjects first. I don't create these cartoons as someone with any expertise in astronomy, but rather as someone who knows some basic ideas (not including the math) about the subject. I talk to myself about it for a while and come up with an observation.

As I said at a talk to a group of scientists some time ago, "I have a great advantage over you. Even though my drawings have appeared in several highly regarded science periodicals, I don't have to get it right." ✦

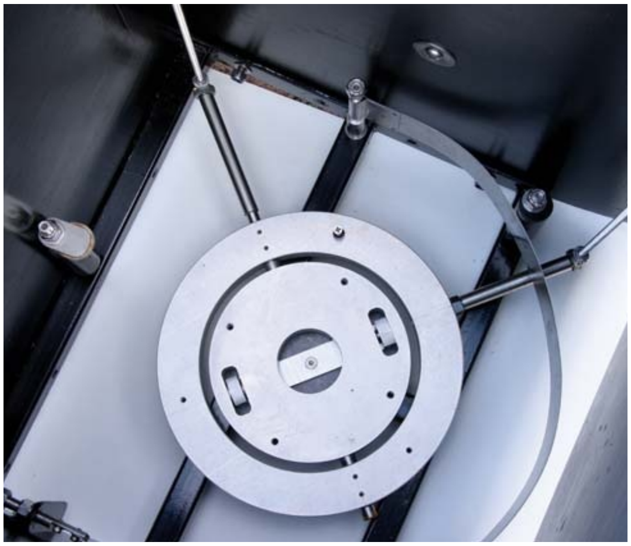
Sidney Harris's cartoons have been published in many dozens of books and hundreds of magazine issues. In 1997 Harris was elected an honorary member of Sigma Xi, a nonprofit society for scientists and engineers founded at Cornell University. He currently resides in Connecticut.



A Gimbaled Mirror Cell

Aligning your Newtonian's optics is a snap with well-designed components.

IT'S REMARKABLE HOW certain designs persist despite having obvious shortcomings. Take the collimation adjustments found on 99.99% of all reflectors, both commercially made and home built. Rare is the scope that doesn't use three evenly spaced adjustment screws both for collimating the primary mirror and setting the tilt of the secondary. And yet, the motions produced by this arrangement are unintuitive and difficult to remember. Wouldn't it be much better to have two adjustments that produce perpendicular motions, one that moves the collimation target up and down and another that shifts it left and right? I have made a few scopes with this X-Y-axis-adjustment scheme and find it makes collimation much, much easier. Australian Doug Parkes is another ATM who shares this preference.



DOUG PARKES (2)

***Below*: Sydney, Australia, telescope maker Doug Parkes utilizes gimbal mounts for both the primary and secondary mirrors in his 15-inch Dobsonian. *Right*: The primary mirror's gimbal mount is shown here with the three 3-point support triangles removed. The outer ring pivots along one axis, and the pair of rings move as a single unit along a second, perpendicular axis. This X-Y motion greatly simplifies collimation.**

Being a retired aircraft mechanic, Doug has taken this X-Y concept to a very high level with his 15-inch Dob. "The advantages of this design are obvious: movement can only occur in one of two planes (at 90° to each other) and only one axis moves at a time," says Doug. "Best of all, only two adjustment screws are required to achieve collimation."

The primary mirror is mounted on a conventional 9-point flotation system. But the rest of the cell is unconventional. The main components are two beautifully machined aluminum rings that are gimbaled together. The outer ring's diameter is dictated by the location of the three mirror-support triangles attached to it. This ring (along with the support triangles) pivots on two pins affixed to an inner ring. As Doug explains, "The inner ring tilts on a pair of bearing blocks, while the outer ring tips on ball bearings set into the periphery of the inner ring." In other words, when the mirror is adjusted on the X axis, both rings move in unison, but when the mirror is tilted along the Y axis, only the outer ring moves.

The result is a cell that tilts the primary mirror in two perpendicular directions — one adjustment for the X axis, another independent one for the Y axis. This design necessarily has a limited range of motion, but as Doug notes, "For correct collimation in a well-constructed telescope, the maximum travel for each ring only needs to be about 5 millimeters at the periphery of the rings."

The implementation elevates this arrangement to a level beyond being a clever design. "I fitted the adjustment shafts with large, knurled knobs that allow me to collimate the primary mirror while I'm standing at the eyepiece," says Doug. Each adjuster consists of a length of threaded rod, which is captured at the top end in the mirror box. At the mirror-cell end, the threaded rod is fitted with a spherical ball-rod end, which mates to a pin in the outer circumference of the mirror cell's outer ring.

The same principles can be applied to different designs utilizing other materials. For example, some of my scopes have a plywood double-plate design with a central pivot that provides the same X-Y adjustments, albeit without the outstanding ease of Doug's setup. Other clever ATMs will find even more ingenious ways to utilize these concepts to create new mirror cells.

Readers wishing to know more about Doug's telescope can contact him at doug_parkes@yahoo.com. ✦

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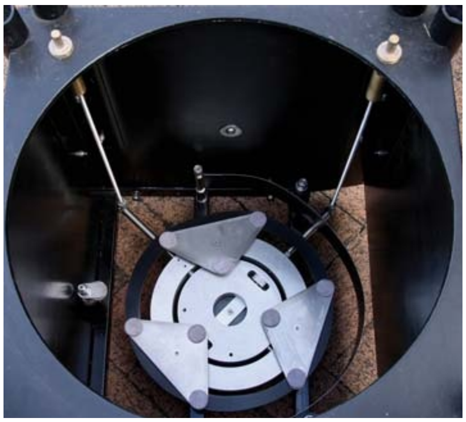
*Contributing editor **Gary Seronik** is an experienced telescope maker and observer. You can read about his double-plate mirror cell at his website, **www.garyseronik.com**.*



DOUG PARKES

Two knobs on the top of the scope's mirror box enable easy collimation of the primary mirror. The adjustments can be made while looking in the collimation eyepiece.

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LIGHT PLAY
Hubert Dróždž
Vivid electric-blue noctilucent clouds silently shimmer over the rooftops of Radomsko, Poland, on the night of July 3rd.
Details: *Canon EOS 450D DSLR camera with 18-to-55-mm zoom lens at 40 mm. Composite of two 30-second exposures at ISO 200.*

◀ **RISING SUPERMOON**
Jamie Cooper
The closest perigee Moon of the year, dubbed the Supermoon, rises above the London skyline on the evening of August 10th.
Details: *Canon EOS 6D DSLR camera with 70-to-200-mm zoom lens at 70 mm. Total exposure was ¼ second at ISO 1000.*

▼ **ELEPHANT'S TRUNK**
Andre van Zegveld
The dark cometary globule IC 1396A in Cepheus appears silhouetted by the glowing emission nebula IC 1396.
Details: *TEC APO140ED refractor with SBIG STL-11000M CCD camera. Total exposure was 30 hours through Astrodon narrowband filters.*

▼ **SPIRAL NEIGHBOR**
André van der Hoeven
The largest nearby spiral galaxy, M31, appears riddled with pinkish star-forming regions and complex dust lanes in deep images with small telescopes.
Details: *TMB-92mm refractor with QSI 583ws CCD camera. Total exposure was 5.6 hours through color and Hα filters.*

▲ **CLOSER SUPERMOON**
Jerry Lodriguss
The rising full Moon of August 10th presents its dark maria through thin, wispy clouds over the outskirts of Philadelphia, Pennsylvania.
Details: *Astro-Tech AT65EDQ refractor with modified Canon EOS Rebel XS. 10-image HDR composite.*

▶ **DEEP ANTENNAE**
Rolf Wahl Olsen
Colliding galaxies NGC 4038/4039 in Corvus present pinkish star-forming regions within the merging galactic nuclei and long, bluish star streams from tidal interactions.
Details: *Homebuilt 12½-inch Newtonian relflector with QSI 683wsg CCD camera. Total exposure was 75 hours through Astrodon color filters.* ✦

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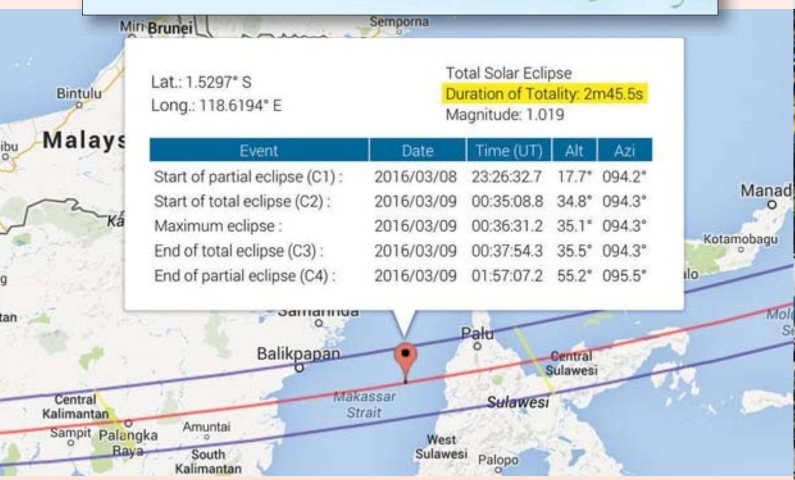

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Long.: 118.6194° E

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Duration of Totality: 2m45.5s
Magnitude: 1.019

Event	Date	Time (UT)	Alt	Azi
Start of partial eclipse (C1) :	2016/03/08	23:26:32.7	17.7°	094.2°
Start of total eclipse (C2) :	2016/03/09	00:35:08.8	34.8°	094.3°
Maximum eclipse :	2016/03/09	00:36:31.2	35.1°	094.3°
End of total eclipse (C3) :	2016/03/09	00:37:54.3	35.5°	094.3°
End of partial eclipse (C4) :	2016/03/09	01:57:07.2	55.2°	095.5°

Add eight (8) hours to UT time for local time. I.e., the start of the total eclipse (C2) will be 8:35am.

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Dr. E.C. Krupp is an astronomer and Director of Griffith Observatory in Los Angeles. He received his M.A. and Ph.D. in astronomy at UCLA, where he studied the properties of rich clusters of galaxies as a student of Professor George O. Abell. He started his career at Griffith Observatory in 1970. Dr. Krupp has personally visited, studied, and photographed more than 2,000 ancient, historic, and prehistoric sites throughout the world and has led or supported 13 total solar eclipse expeditions and four annular eclipse efforts.

For more info: 650-644-5812 or Info@InsightCruises.com

Robert Naeye has been *Sky & Telescope's* Editor in Chief since 2008. Previously he was Senior Editor at *Sky & Telescope* and Senior Science Writer for the Astrophysics Science Division of NASA's Goddard Space Flight Center. Robert is the author of two books: *Through the Eyes of Hubble: The Birth, Life, and Violent Death of Stars* and *Signals from Space: The Chandra X-ray Observatory.*

Greg Bryant has been Editor of *Australian Sky & Telescope* since 2006 and a Contributing Editor to *Sky & Telescope* since 2001. He has also been involved with the publication of an Australian annual astronomy yearbook since the early '90s and science writing for the Australian Research Council's Centre of Excellence for All-Sky Astrophysics. A keen amateur astronomer for more than 30 years, Greg most recently teamed up with Insight Cruises for their successful 2012 Total Solar Eclipse tour in Australia. In 2000, the International Astronomical Union named asteroid 9984 Gregbryant in his honor.

David Tholen, Ph.D. is an astronomer at the Institute for Astronomy of the University of Hawaii (IfA), who specializes in planetary and solar system astronomy. Winner of the American Astronomical Society Division for Planetary Science's Urey Prize in 1990, Dr. Tholen and his students have discovered many near-Earth asteroids, the most famous being Apophis, which will make an extremely close approach to the Earth on April 13, 2029.

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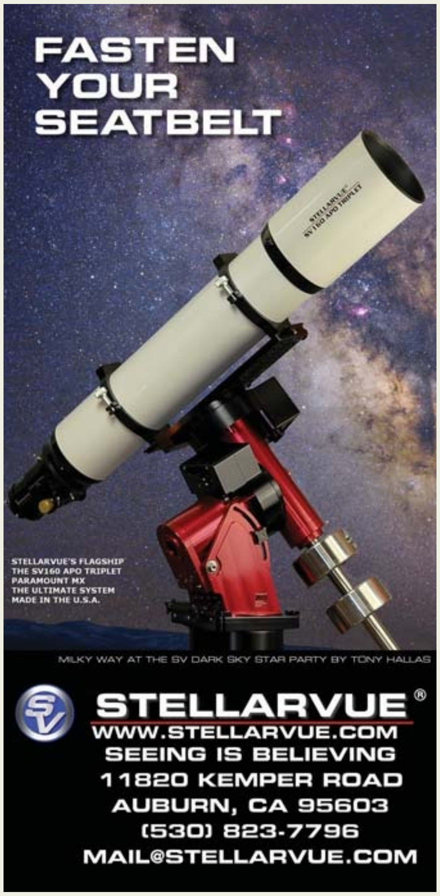

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Off the Rails

The author discovers that horseracing and astronomy can actually mix.

Although I'm known as an author, speaker, and broadcaster, my daily reality is in the nerve center of race days, the Stewards Rooms of English racecourses. This is where British Horseracing Authority (BHA) officials conduct inquiries, levy fines for errant jockeys and trainers, and broadcast the results around the world.

I love horses. I love astronomy too, often talking it up to anyone who will listen and to many who won't. When, on wet winter days, my racing colleagues moan about missing the sunshine, I'll ask if they know the whereabouts of our star. They'll smile blankly and change the subject. When a starter excitedly tells me he's off with his wife to see Norway's Northern Lights, I'll politely ask if he knows what they are. "Haven't a clue," he'll say, before adding, "but there's a horse, Aurora Borealis, running in the final race!"

Clearly, horses and astronomy are an impossible mix. Mention anything astronomical and I suddenly find myself sitting alone or discussing the merits of one zodiacal sign over another. My comrades read racing publications, but would rather extract their own teeth than touch *S&T*. They know racing, but they resembled blinkered racehorses, tracking life's running rail but oblivious to all around. They never looked up, never once turned their racing binoculars toward the Moon or stars, but I had a hunch they wanted to . . . they just didn't know it yet.

The Chairman of the BHA's Disciplinary Panel one day asked for a presentation at an important charity fundraiser. "About horseracing?" I asked. "No!" she vehemently replied, "Astronomy!" By her own admission she was clueless. Moreover, she had to convince an equally unenlightened charity committee. It was a giant leap of faith, but there was no stopping this particular lady. The local planetarium was booked and tickets were selling fast.

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After a reception, and with the warnings "You will mention horseracing, won't you?" and "It won't be too technical, will it?" ringing in my ears, I embarked on an illustrated astronomical journey, beginning with the size, activity, and location of our Sun, before losing it in the immensity of 200 to 400 billion other suns in our Milky Way Galaxy. My audience of racing dignitaries, gentry, and business professionals was uncharacteristically quiet. Were they bored, blown away, or indulging in a champagne-induced nap? I took them onward from our Galaxy to the Local Group, to clusters and superclusters, to the immense structuring filaments and sheets of the observable universe. Still my audience was quiet.

But I need not have worried. It was shock. On this new cosmic racecourse, their imaginations were suddenly unbridled and their thoughts were running free. Soon questions galloped forth. Folk were smiling and laughing, shuffling excitedly in their seats.

The target funds were raised and my race days are now peppered with talk of lunar cycles and light-years, of the location of Jupiter or the Andromeda Galaxy. They train their binoculars on the Orion Nebula and watch Venus rise in the east. The barrier between the subjects of horses and astronomy has gone, as it does for all subjects when myopic blinkers and restrictive rails are removed. ✦

***Jane A. Green** is the author of* The Astronomy Manual *and* Celestial Extra Texture, *the latter about horses and astronomy. She lives in East Sussex, UK, and can be reached at **www.whatalotofpollux.blogspot.co.uk**.*